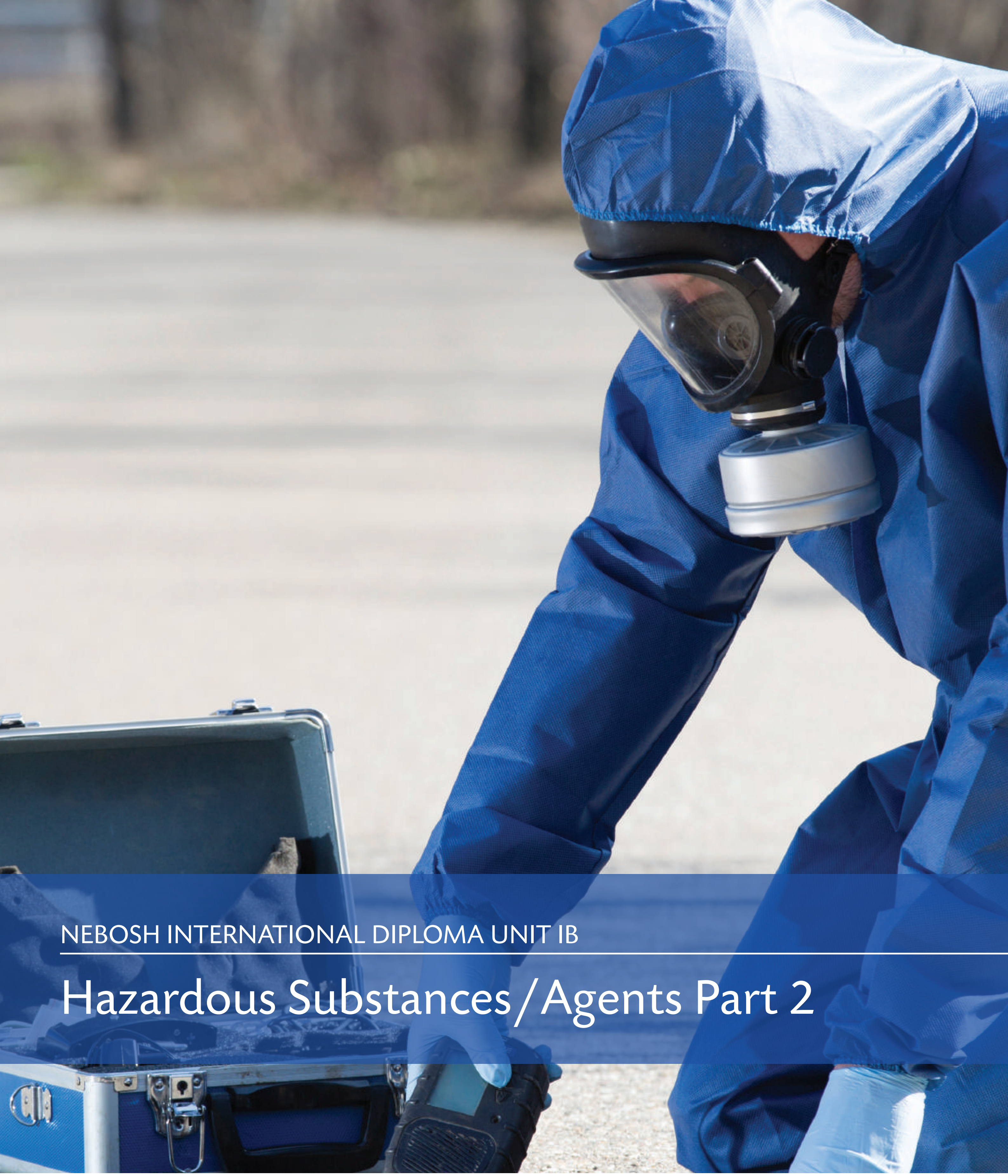

NEBOSH INTERNATIONAL DIPLOMA UNIT IB

# Hazardous Substances/Agents Part 2

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RRC INTERNATIONAL

# NEBOSH INTERNATIONAL DIPLOMA

## UNIT IB: HAZARDOUS SUBSTANCES/AGENTS - PART 2

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## Course Structure

This textbook has been designed to provide the reader with the core knowledge needed to successfully complete the NEBOSH International Diploma in Occupational Health and Safety, as well as providing a useful overview of health and safety management. It follows the structure and content of the NEBOSH syllabus.

The NEBOSH International Diploma consists of four units of study. When you successfully complete any of the units you will receive a Unit Certificate, but to achieve a complete NEBOSH Diploma qualification you need to pass the three units within a five-year period. For more detailed information about how the syllabus is structured, visit the NEBOSH website (www.nebosh.org.uk).

## Assessment

Unit IB is assessed by a three-hour exam that is set out in two sections. Section A consists of six 10-mark compulsory questions, and Section B consists of five 20-mark questions, of which you must choose three.

NEBOSH set and mark this exam paper.

## More Information

As you work your way through this book, always remember to relate your own experiences in the workplace to the topics you study. An appreciation of the practical application and significance of health and safety will help you understand the topics.

## Keeping Yourself Up to Date

The field of health and safety is constantly evolving and, as such, it will be necessary for you to keep up to date with changing legislation and best practice.

RRC International publishes updates to all its course materials via a quarterly e-newsletter (issued in February, May, August and November), which alerts students to key changes in legislation, best practice and other information pertinent to current courses.

Please visit www.rrc.co.uk/news/newsletters.aspx to access these updates.

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**UNIT IA**
Managing Health and Safety

**UNIT IB**
Hazardous Substances/Agents

**UNIT IC**
Workplace and Work Equipment Safety

**UNIT DNI**
Application of Health and Safety Management in the Workplace

**NEBOSH International Diploma in Occupational Health and Safety**

Element IB6

# Noise and Vibration

## Learning Outcomes

Once you've read this element, you'll understand how to:

1. Explain the basic physical concepts relevant to noise.
2. Explain the effects of noise on the individual and the use of audiometry.
3. Explain the measurement and assessment of noise exposure.
4. Explain the principles and methods of controlling noise and noise exposure.
5. Explain the basic physical concepts relevant to vibration.
6. Explain the effects of vibration on the individual.
7. Explain the measurement and assessment of vibration exposure.
8. Explain the principles and methods of controlling vibration and vibration exposure.

# Contents

# Basic Concepts of Noise

### IN THIS SECTION...

- Noise is defined as 'all sound which can result in hearing impairment or be harmful to health or otherwise dangerous'.
- A noise source generates pressure waves in air. Two characteristics of these pressure waves, their amplitude and frequency, are important in understanding their nature:
  - The amplitude determines the intensity of the noise - measured using the decibel scale (dB).
  - The frequency determines the pitch of the noise - measured in hertz (Hz).
- The decibel scale is a logarithmic scale. The addition of 3dB is a doubling of noise intensity.
- The human ear is not equally sensitive to all frequencies, consequently the A-weighting matrix (represented by dB(A)) is used to correct for this frequency bias when calculating the amount of energy that has been delivered into the inner ear.
- The amount of damage done to the inner ear is determined by the dose of noise received. Dose is determined by two factors; the intensity of the noise (dB(A)) and the duration of exposure.

## Definitions

According to the ILO, noise is defined as:

> *"all sound which can result in hearing impairment or be harmful to health or otherwise dangerous."*

**Source: C148 – Working Environment (Air Pollution, Noise and Vibration) Convention, 1977 Copyright © International Labour Organisation 1977**

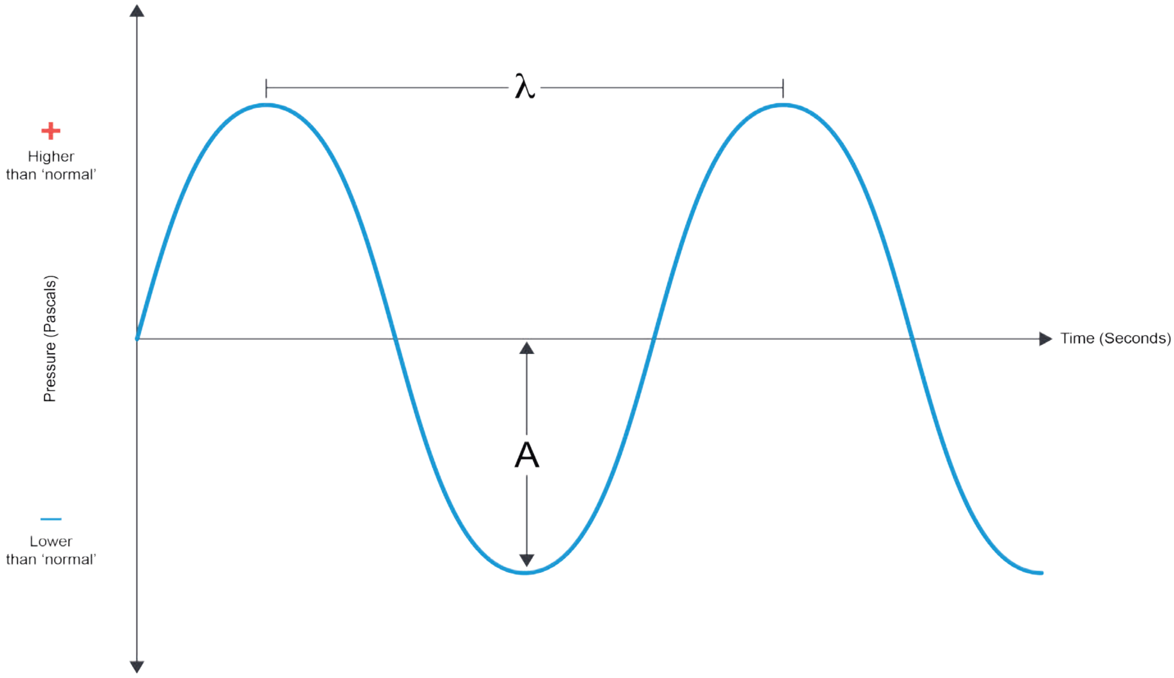
It is worth noting that noise is commonly defined as 'unwanted sound' and, indeed, this definition can be found on the European Agency for Safety and Health at Work (EU OSHA) website. From a health and safety perspective, this definition is incorrect and misleading. It makes no difference whether a sound is wanted or unwanted; if exposure is significant then risk of hearing damage exists. To protect workers' hearing it is important to consider the risk to hearing created by the noise of an orchestra in the same way as that of a diesel engine.

A significant occupational noise source – chainsaw use

## Basic Concepts

A source of noise (e.g. chainsaw or hi-fi system) emits pressure waves into the air. These pressure waves are longitudinal waves, meaning that they exist as compression waves in the medium through which the sound is travelling. Sound will only travel through a medium (such as air or water). It cannot travel through a vacuum (and so the strap-line 'In space, no-one can hear you scream' is true). Sound pressure waves then move away from the noise source at the speed of sound (343 metres per second in air at sea level).

The characteristics of a sound pressure wave can be visualised by plotting a graph of pressure (measured in Pascals) against time, as in the following figure.




Graph of pressure against time for a sound of one single frequency, as might be generated by a tuning fork

There are several characteristics of this sound wave that are of interest:

- Amplitude

  This is the maximum displacement of pressure. In the graph it is represented by A and can be thought of as the height of the peak or depth of the trough of the sound wave. This equates to the 'loudness' or 'volume' of the noise; the bigger the amplitude the greater the pressure difference and the louder the noise sounds.

- Intensity

  The intensity of sound is the power transmitted per unit area (measured in $W/m^2$); it is proportional to the square of the amplitude.

- Frequency

  This is the number of sound pressure waves generated per second (the unit of frequency is the hertz (Hz)). The frequency of a sound wave relates directly to its pitch. Sounds with a low frequency will sound very low-pitched and sounds with a high frequency will sound high-pitched. Frequency is inversely proportional to the wavelength of the sound wave; the distance (in metres) between one peak and the next (shown in the graph above by the symbol λ). This means that, as wavelength increases, frequency decreases.

## The Decibel Scale

One consequence of the fact that sound intensity is proportional to the square of the amplitude is that, as amplitude increases, intensity increases exponentially. To explain; an increase in amplitude from 2 to 3 and then 4 is matched by an increase in intensity from $2^2$ (4) to $3^2$ (9) and then $4^2$ (16).

The human ear can hear sounds across an enormous range of intensities; from the **threshold of hearing** up to the **threshold of pain**. The intensity of the pressure wave at the threshold of pain is 10,000,000,000,000 times greater than the intensity of the pressure wave at the threshold of hearing.

To allow for easy measurement of sound intensity across such a huge range, the **decibel scale** is used, where 0 decibels (dB) is the threshold of hearing and 130dB is at the threshold of pain. The decibel scale is a logarithmic scale meaning that an increase in dB value of ten represents a ten-fold increase in intensity. So, 10dB is ten times the intensity of 0dB, 20dB is a hundred times the intensity of 0dB, 30dB is a thousand times the intensity of 0dB, and so on. See below for some typical decibel levels associated with different noise sources.


Examples of typical noise levels
Source: INDG362 (rev1) Noise at Work – Guidance for Employers on the Control of Noise at Work Regulations 2005, HSE, 2005

## A-Weighting and C-Weighting

The human ear is not equally sensitive to sounds across all frequencies. Humans cannot hear very low- or very high-frequency sounds. The human hearing frequency range is from 20Hz to 20,000Hz (20KHz). Even within this frequency range the human ear is more efficient at detecting the mid-range frequencies. Because the human ear is not equally sensitive to sounds at all frequencies, sound level meters have weighted scales to account for a variable sensitivity to frequency. The **A-weighted scale (dB(A))** electronically assimilates the sound pressure and mimics the human ear's response across the range of frequencies. The measurement of noise in dB(A) is a good indication of the physical harm caused to hearing.

Other weighting scales are also used, such as **C-weighting (dB(C))** for peak sound pressure.

## Addition of Decibels

Because the decibel scale is a logarithmic scale it is not possible simply to combine two separate sound levels together by adding them. For example, if you were to stand mid-way between two identical diesel engines, each of which individually produced a sound pressure level of 90dB(A), you would not be exposed to 90 + 90 = 180dB(A). Such a noise level would rupture your eardrums and cause instant deafness.

However, an estimate of the combined noise intensity can be made provided the two noise sources are of equal value (i.e. same decibel value). In that case, a 3dB increase represents a doubling of sound intensity. In practice, the introduction of another source of equal value will double the sound intensity and hence increase the dB reading by 3. So, for the example above, two noise sources of 90dB(A) will give a total of 93dB(A).

So, 83dB + 83dB = 86dB

and

105dB + 105dB = 108db

## Noise Dose

The damaging effects of noise are related to the total dose of energy that the ear receives. The dose is determined by two factors: the **level of noise** and the **duration of exposure**. A large dose of noise presents the same risk of hearing damage irrespective of how that large dose is achieved; so, a dose of noise achieved by exposure to a very loud noise for a short period of time presents the same risk of hearing damage as the same dose of noise achieved by exposure to a lower level of noise over a much longer period of time. The two doses of noise are said to be **equivalent**.

MORE...

www.

Useful resources can be found on the EU OSHA website at:

http://osha.europa.eu/en/topics/noise/index_html/what_is_noise_html

The concept of equivalent noise dose has been used in legislation. The ILO Convention C148 covering air pollution, noise and vibration does not establish limits but determines that these should be established by the appropriate national competent authority. In the UK, the **Control of Noise at Work Regulations 2005 (CNAW)** refer to a worker's daily noise dose as the "equivalent continuous **daily personal noise exposure** level" or $L_{EP,d}$ and use the concept of noise dose to average out worker exposure over an 8 hour working shift.

For example, if a worker's noise exposure is calculated to be an "equivalent continuous daily personal noise exposure level" ($L_{EP,d}$) of 85dB(A) then this is equivalent to exposure to a continuous noise, at an unvarying level of 85dB(A), occurring for eight hours. Exposures with different combinations of sound level and duration can produce a daily personal noise exposure ($L_{EP,d}$) of 85dB(A). This is illustrated in the following table:

Equivalent Noise Exposures

| Sound Level dB(A) | Exposure Equivalent to 85 dB(A) $L_{EP,d}$ |
|---|---|
| 85 | 8 hours |
| 88 | 4 hours |
| 91 | 2 hours |
| 94 | 1 hour |
| 97 | 30 mins |
| 100 | 15 mins |
| 103 | 7.5 mins |

To explain; you will remember that a doubling of sound intensity is achieved by adding 3dB. Thus the same dose of noise is achieved by doubling sound intensity but halving the time of exposure (85 + 3dB = 88dB(A); 8 hours / 2 = 4 hours). So what the table shows is that 85dB(A) for 8 hours is the same dose of noise as 88dB(A) for 4 hours, which is the same dose of noise as 103dB(A) for 7.5 minutes, etc. The above noise exposures are all equivalent to 85dB(A) $L_{EP,d}$. Each of these exposures will therefore deliver the same amount of energy into the ear and so present the same degree of risk to hearing.

The following noise exposures will have to be directly measured or calculated during a noise assessment:

- **$L_{Aeq}$** – this represents the **equivalent continuous** A-weighted noise dose over the measurement period (alternatively written as $L_{eq}$dB(A)). $L_{Aeq}$ is, in effect, a time-weighted average dose of noise over any time period chosen, e.g. 5 seconds, 7 minutes or 3 hours.
- **$L_{EP,d}$** – this represents the equivalent continuous **daily personal noise exposure** level. $L_{EP,d}$ is, in effect, the time-weighted average dose of noise calculated for a notional eight-hour day.
- **$L_{EP,w}$** – this represents the equivalent continuous **weekly personal noise exposure** level. Where very changeable exposures occur from day to day, the regulations allow for a weekly personal noise exposure ($L_{EP,w}$) to be estimated and used for comparison to the standards.

- **$L_{CPeak}$** – maximum C-weighted peak sound pressure level(s) to which a person is exposed. This is the peak sound pressure level recorded during a noise survey using a sound level meter set to the C-weighted decibel scale. This is not a time-weighted average exposure (and so not a dose) but represents the 'spike' in sound pressure level achieved by exposure to a single **impulse** noise, such as a loud bang. A metal-cutting guillotine or a large metal object dropped on a concrete floor would produce such a pressure spike.

### MORE...

www.

The UK HSE website has a microsite dedicated to noise which has a range of publications, tools, etc. to use:

www.hse.gov.uk/noise

## STUDY QUESTIONS

1. How does the ILO define "noise"?
2. Explain the terms "amplitude" and "frequency" as applied to a simple noise wave.
3. Explain the term "pitch".
4. What is the A-weighted scale and what is its purpose?
5. Why can't decibel values be added together directly?

(Suggested Answers are at the end.)

# Health Effects of Noise Exposure

## IN THIS SECTION...

- The human ear detects noise by mechanically transmitting sound pressure waves from the outer ear through to the inner ear. There, fine sensory hairs respond to the pressure waves in fluid, sending nerve signals to the brain.
- Exposure to excessively loud noise can physically damage the transmission structures of the ear and can also cause deterioration of the sensory hairs in the inner ear.
- Tinnitus, Temporary Threshold Shift (TTS), Permanent Threshold Shift (PTS) and Noise-Induced Hearing Loss (NIHL) are all health effects associated with exposure to loud noise.
- Audiometry can be used as a form of health surveillance to determine the sensitivity of a person's hearing. The graphs produced (audiograms) can be used to differentiate between age-related hearing loss (presbycusis) and NIHL.
- As a result of audiometry a worker's hearing can be categorised and appropriate action taken to manage their health.
- There are various advantages and disadvantages to audiometry, which may be required by national legislation.

## Physiology of the Ear

In order to explain how hearing is affected by exposure to noise, it is important to first consider the biology of our ears.

The main parts of the ear are shown in the following figure.

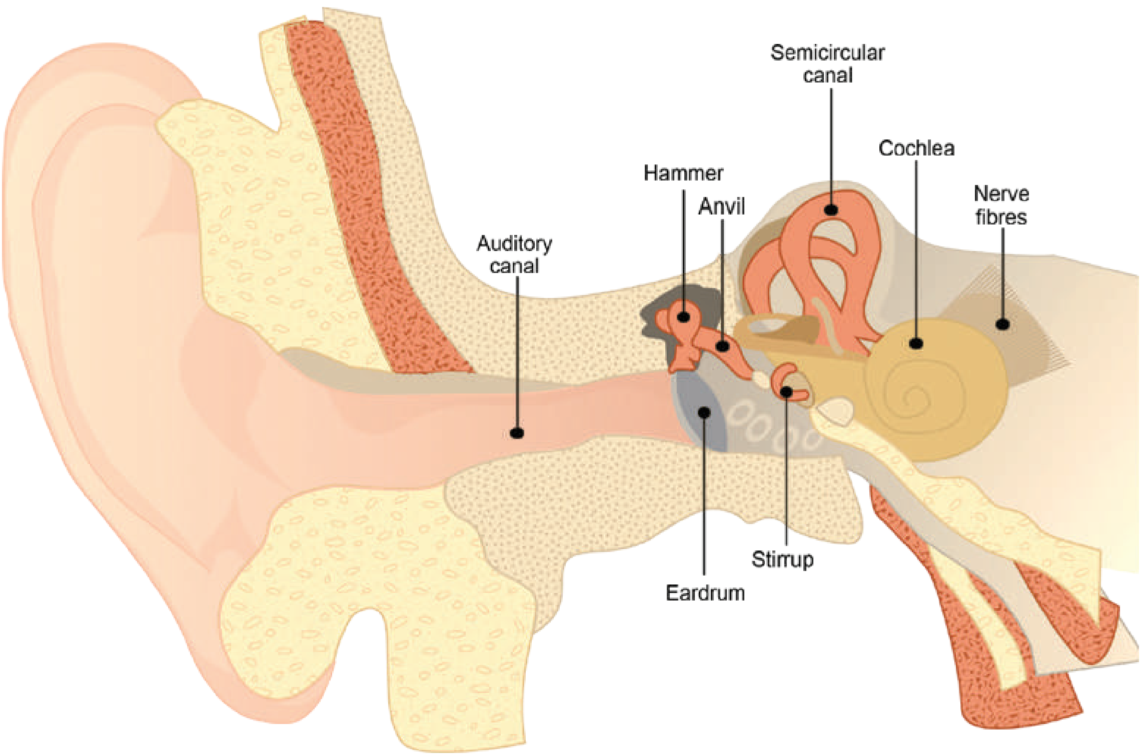



Diagram showing the internal parts of the ear

The three main parts of the ear are the:

- Outer ear with auditory canal.
- Middle ear.
- Inner ear.

The outer ear reflects and focuses incoming sound waves into the auditory canal. Sound waves then pass down the canal and set the eardrum vibrating. Between the eardrum and the fluid-filled inner ear are three small bones (ossicles) of the middle ear, known respectively as the hammer, the anvil and the stirrup. The hammer is attached to the eardrum and together with the anvil it forms a lever that acts on the stirrup. The stirrup is attached to the oval window in the wall separating the middle and inner ears. The middle ear transmits sound energy into the fluid of the inner ear.

The inner ear is made up of a complex set of small tubes and chambers embedded in solid bone. The part concerned with hearing is the **cochlea**, a spiral cavity that resembles a snail shell. The cochlea consists of about 30,000 highly sensitive hair cells. Pressure waves, transmitted into the fluid in the cochlea by the middle ear, bend the 'tufts' on top of these hair cells, stimulating the nerve endings at their base. Thus, sound energy is transmitted from the outer ear, through the middle, to the inner ear where it is converted to nerve impulses which are transmitted to the auditory centres of the brain.

# Effects of Noise Exposure

## Hearing Loss

Hearing loss (the process of losing auditory sensitivity) occurs to a degree naturally with age, but it may occur to a greater degree as the result of external causes. It can be classified under two broad headings:

- **Conductive hearing loss** occurs due to a physical breakdown of the conducting mechanism of the ear resulting from an acute acoustic trauma, e.g. an explosion or gunfire. The eardrum, ossicles or the cochlea can be damaged, often beyond repair. There is no cure, although surgery may reduce the damage to the eardrum.

  This form of hearing loss is rarely caused by occupational noise exposures.

- **Sensorineural hearing loss** occurs when the hair cells in the cochlea are damaged. Harm may result from natural causes, such as infection, or by physical injury.

  In an occupational setting, sensorineural hearing loss occurs from long-term exposure to excessive noise, and so this is the type of hearing loss most commonly found by the safety practitioner.

## Tinnitus

Tinnitus is a condition where the sufferer hears "ringing in the ear" or other types of noise in their head without there being any external noise source. There are no observable external symptoms.

Tinnitus can occur after exposure to excessive noise levels as an acute condition which recedes with time (e.g. after attending a rock concert). The recovery period could be 12 or more hours where very high exposure levels occur. People who have chronic noise-induced hearing impairment can suffer from chronic tinnitus. The symptoms of tinnitus suggest that damage to the nerve structure of the cochlea or the auditory nerve has occurred, or possibly both.

## Threshold Shift

Threshold shift is a reduction in a person's ability to hear, i.e. they need more sound intensity to stimulate their hearing. The condition can be permanent or temporary.

- Temporary Threshold Shift (TTS)

  Temporary Threshold Shift (TTS) occurs after exposure to high noise levels where hearing acuity returns with time. The condition has been described as a fatigue of the hair cells in the cochlea. The level of threshold shift is expressed in terms of the raising of sound intensity required to hear a given sound level, e.g. a 20dB shift means the sound level has been increased by a value of 20dB before the individual concerned could detect the sound.

If a person is subjected to a high noise level, say 90dB for a few hours, and then has a hearing test (audiometry), a loss of hearing acuity will be detected, with the most pronounced dip occurring at a frequency of 4000Hz (4kHz). This is often described as the '4kHz dip' for acoustic trauma. The amount of dip from the 0dB average level is used to specify the amount of threshold shift. The development of a TTS is a function of time and noise level; the longer the exposure and the higher the noise, the greater the hearing loss.

Recovery from TTS occurs over a period of several hours to several days; it is rapid at first and then proceeds at a reduced rate. The higher the noise exposure, the longer the recovery time.

- Permanent Threshold Shift (PTS)

  Permanent Threshold Shift (PTS) is the condition where there is a permanent reduction in hearing acuity, with the most pronounced reduction occurring at 4kHz. This reduction is irreversible, with no recovery of hearing acuity with time away from exposure. The condition follows from repeated TTS exposures, as might occur in a workplace where noise levels are high day after day and hearing protection is not worn (or not sufficient).

  When PTS first begins to occur the dip may be detectable using a hearing test (audiometry) but may not interfere with the individual's ability to hear human speech. Unfortunately, if further high noise exposures take place, the shift worsens until the condition described as "noise-induced hearing loss" occurs, where the ability to hear human speech is disrupted.

### Noise-Induced Hearing Loss (NIHL)

Noise-Induced Hearing Loss (NIHL) is permanent threshold shift caused by exposure to excessive noise. NIHL is a condition that results from failure of the hair cells in the cochlea to respond fully to sound intensities having frequencies within the human speech range. The person does not necessarily lose the ability to hear all sounds, but is not able to distinguish the spoken word clearly, even if it is presented with a raised voice.

### Presbycusis

Presbycusis is the term used to describe a reduction in hearing acuity that occurs naturally with age. This age-related hearing loss affects the individual's ability to hear high frequency (high-pitched) noise most markedly. This type of hearing loss might start at the age of 30 and become more significant from the age of 60 onwards. Presbycusis accounts for the fact that young people may be sensitive to high frequency noise that an older person cannot hear and has been put to use in 'youth repellent devices' to disperse teenagers.

### Other Effects of Noise on Health

In addition to the short- and long-term effects of exposure to noise on hearing, there can also be other health effects:

- Neuro-psychological disturbances such as headache, fatigue, insomnia (sleeplessness) and irritability.
- Cardiovascular system disturbances such as hypertension and cardiac disease.
- Digestive disorders such as peptic ulcers and colitis.

## Health Surveillance

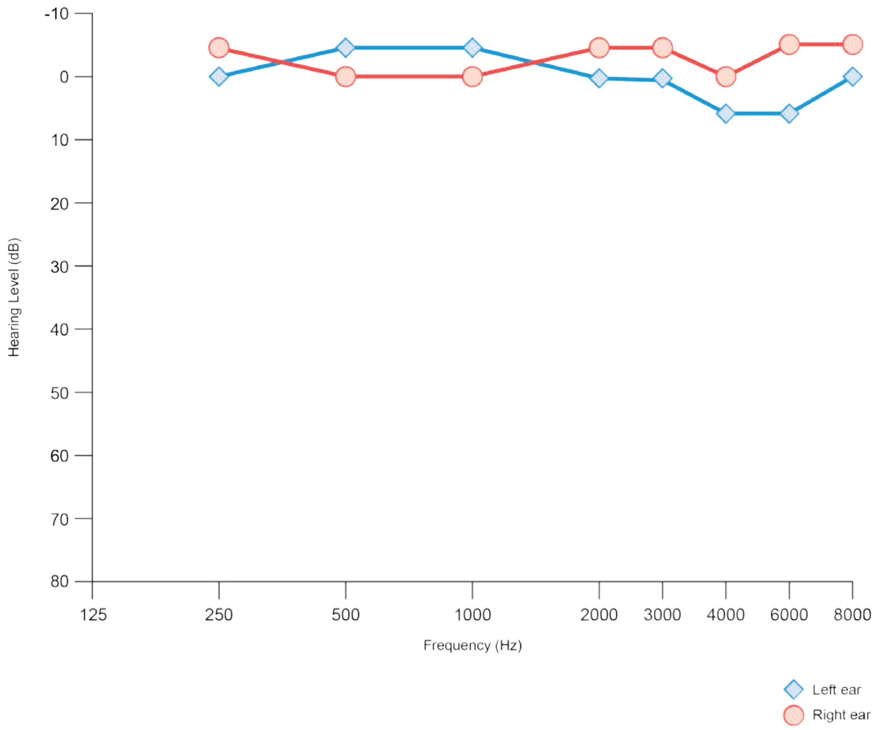
**ILO Code of Practice – Ambient Factors in the Workplace** (Section 9.4) specifies the conditions under which health surveillance may be required. The CoP states that health surveillance (audiometry) may be required when a worker's noise exposure reaches levels prescribed in national law or in international standards. The records of health surveillance should be retained in a confidential medical file and shared with the worker.

Health surveillance may include:

- Pre-employment or pre-assignment examinations, in order to:
  - Determine whether the worker should not be exposed to noise.
  - Determine any existing sensitivity to noise.
  - Establish a baseline record for use in further medicals.
- Medical examinations, which should be carried out:
  - Periodically, to detect early signs of occupational disease or any sensitivity to occupational noise or stress due to noise exposure.
  - Upon return to work after prolonged absence.
  - At the end of employment, in order to establish a picture of the effects of noise during employment.
  - When abnormalities are detected.

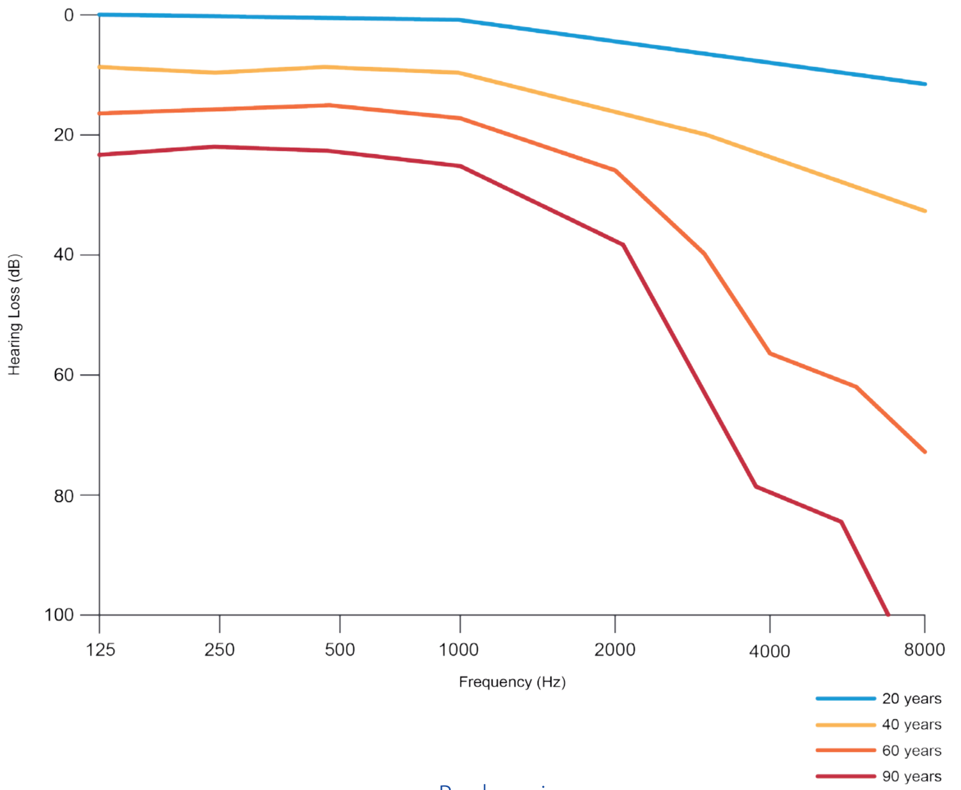
**Audiometry** is the process of scientifically quantifying hearing performance in order to detect problems with hearing, such as noise-induced hearing loss. The most commonly used form of audiometry is **Pure Tone Audiometry** where the threshold of audibility (i.e. the level of sound required to be just audible) at pre-determined frequencies allows the plotting of a graph (**audiogram**) to visualise hearing acuity.

The following figure shows an audiogram for a person with normal hearing.



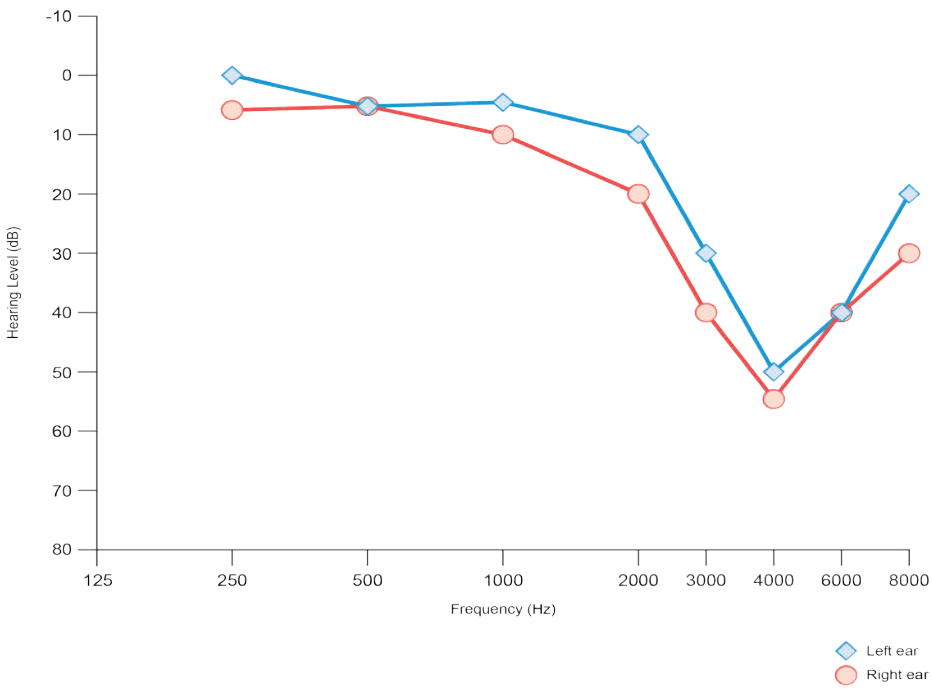

Normal hearing

The graph above shows the sound pressure level (dB) that was just detectable by an individual during a hearing test in a sound-proof chamber when pure tones at eight different frequencies were played through headphones. The frequencies used were 0.25kHz, 0.5kHz, 1kHz, 2kHz, 3kHz, 4kHz, 6kHz and 8kHz. The audiogram shows the person has normal hearing acuity in both their right and left ears.




Presbycusis

The figure above shows typical audiograms for individuals of various ages. This clearly shows the effects of **presbycusis** (age-related hearing loss), with a small amount of hearing loss (20dB) at low frequencies (125Hz-1kHz) but very marked hearing loss at high frequencies with age. For a typical 60-year-old a pure tone at 8kHz can only be heard at over 70dB. At 90 years this same 8kHz frequency cannot be heard even at levels over 100dB.




Noise-induced hearing loss

The audiogram above is typical for an individual suffering from noise-induced hearing loss. The graph shows little or no reduction in hearing levels at low frequencies (0.25-1kHz), but then marked reduction in hearing levels from 2-8kHz with the most significant dip at 4kHz. This 4kHz dip is very indicative of noise-induced hearing loss, rather than presbycusis (where the reduction in hearing level continues as frequency increases). Note that both ears are affected to a similar degree.

## Audiometry Technique

Audiometry should be carried out for all workers frequently exposed to significant noise levels. Base-line audiometry should be conducted on employment or pre-employment. Repeat tests should be conducted annually for the first two years and then every three years subsequently (unless problems arise or noise exposure changes significantly). Audiometry can also be carried out following the results of workplace noise assessments or following complaints to satisfy both the employer and employees that workers' hearing is being adequately protected.

Audiometry should only be carried out by a suitably qualified person using a standard method and calibrated equipment. Various international standards exist that govern the method and equipment used. This is important to ensure scientific accuracy and repeatability of results.

Audiometry is usually carried out in a sound-proof booth to remove unwanted background noise. It is important that the test subject is protected from any significant noise exposure before the test takes place, as this might cause temporary threshold shift that will lead to an invalid test. Ideally, individuals who might suffer significant noise exposure at work would be tested before they start work, but this is often not possible in a large workplace where lots of workers require testing. In these circumstances, individuals should wear hearing protection prior to testing to ensure no significant noise exposure occurs.

Before carrying out a hearing test, information is obtained about the person's past medical history, not only concerning the ears but also other conditions that may have a bearing on possible hearing loss.

The ears should then be examined to ensure that there is not an excessive build-up of wax and to determine if the eardrum has suffered any damage which may have an impact on hearing.

The audiometric test can be carried out using automatic or manual audiometers, but the essential test procedure is the same:

- The subject is asked to remove anything that might upset the test results, e.g. spectacles, earrings, hearing aids and chewing gum.
- Instructions are given about the test procedure and the subject is required to indicate whether they can just hear or cannot hear a certain sound (usually by pressing or releasing a button).
- Earphones are fitted carefully over the ears and the test is then carried out on each ear.
- Firstly, a threshold test is undertaken in which each ear is subjected to sound at a frequency of 1kHz at varying levels of intensity, ranging from low to high and high to low.
- Following this pre-check, both of the subject's ears are tested through a range of frequencies (usually 0.5, 1, 2, 3, 4, 6 and 8kHz) and the hearing level is recorded for each frequency.
- When the test is completed, a second threshold check should be carried out to see that no errors have crept in during the test.

The results of the test are normally displayed as an audiogram that is then explained to the individual. The individual is often given a copy of their audiogram. A letter is then sent to the individual confirming the results of the test and any further action required.

The **accuracy** of audiometry can be affected by several factors:

- Technical limitations – how accurately can the hearing level be determined?

- Learning effect – the first ear tested sometimes appears worse than the second one since the individual becomes more proficient at detecting the threshold.
- Headphone fit – some of the variation in threshold measurement has been attributed to differences in the location of the headphones.

A further complication of audiometric testing is that it is subjective and relies on the co-operation of the subject. If the subject is unable or unwilling to co-operate with the test then unrepresentative results will be obtained.

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## Use of Results

As seen in the previous audiogram, noise-induced hearing loss gives a fairly distinctive pattern of hearing loss, with a characteristic dip at 4KHz. This dip is not temporary (so a repeat test several days after the first test would reveal the same pattern).

The results of audiometry should only be interpreted by a suitably qualified person, such as an occupational health physician, occupational health nurse or audiologist, as there are many reasons why hearing level may be affected of which over-exposure to noise is only one.

It is not usually necessary to remove a worker from a noisy environment, even if they are classified as suffering from noise-induced hearing loss, provided it is possible for them to wear adequate hearing protection.

Records of the results of hearing tests and any letters sent to the individual form part of that person’s medical records. As such, they must be kept secure and separate from other personnel records. Medical ethics dictate that records and results of hearing tests are medically confidential and should not be shared with anyone without the consent of the individual concerned. Group results of hearing tests can be shared with the employer, provided they have been anonymised so that the employer cannot identify the individuals’ results.

A common use of audiometric testing is at the pre-employment stage. This serves two purposes:

- It enables an initial assessment of hearing ability to be made in order to establish a baseline, which can be used as a standard against which any deterioration due to poor noise control arrangements can be measured by future audiometric tests.
- The other use is to detect any signs of noise-induced hearing loss arising from previous employments. If this is detected and documented, it can serve to safeguard the employer against any false accusations (and civil law liability) that hearing loss might have been due to this employment rather than previous ones.

## TOPIC FOCUS

**Advantages and Disadvantages of Audiometry**

The **advantages** of audiometry are:

- Early detection of individuals with hearing loss that will allow those individuals to be further protected to prevent deterioration.
- Early detection of poorly controlled noise exposure in the workplace that will allow other workers to be further protected before hearing loss occurs.
- Negative test results (i.e. no hearing loss) will confirm that the hearing conservation programme in place in the workplace is working effectively.
- Establishment of a pre-employment baseline that will protect the employer in the event of a claim for compensation.
- Compliance with legal requirements.

Some **disadvantages** of audiometry are:

- As a form of health surveillance it is inherently reactive in that it simply confirms hearing loss after it has occurred (rather than preventing that hearing loss).
- It can be inaccurate for technical reasons or due to an uncooperative test subject.
- It can be difficult to operate in practice when large numbers of workers have to be tested.
- Classification of a worker as suffering from noise-induced hearing loss may act as the trigger for a claim for compensation.

In many legal systems, noise-induced hearing loss can form the basis of a claim for compensation. The results of audiometry can be used both by the claimant to substantiate their claim and by the employer to defend such a claim. Pre-employment testing establishes a baseline which may allow the employer to show that hearing loss was a pre-existing condition rather than the result of exposure during employment.

## STUDY QUESTIONS

6. Describe how the ear converts sound waves into nerve stimulation to the auditory centres of the brain.
7. Explain how the damaging effects of noise are related to the dose that the ear receives.
8. Which of the two types of hearing loss – conductive and sensorineural – is more relevant to the health and safety practitioner?
9. Explain the term 'threshold shift'.
10. Identify three factors that can affect the accuracy of audiometric testing.

(Suggested Answers are at the end.)

# Measurement and Assessment of Noise Exposure

## IN THIS SECTION...

- Noise surveys must be carefully planned to ensure that representative measurements are taken to give a true reflection of real noise exposures occurring at work.
- Several different instruments are available for measuring noise; simple sound level meters, Integrating Sound Level Meters (ISLM), dosimeters and octave band analysers.
- ISLMs used for noise surveys must be calibrated before use and must be tested and certificated for results to be valid.
- Key information recorded during a survey is the equivalent continuous A-weighted sound pressure level ($L_{Aeq}$), maximum C-weighted peak sound pressure level ($L_{CPeak}$) and the duration of exposure.
- $L_{Aeq}$, in combination with duration of exposure, is then used to calculate a daily personal noise exposure ($L_{EP,d}$). This can be done using formulae, the UK's HSE web-based calculator or the HSE ready reckoner.
- Calculated personal exposures ($L_{EP,d}$) can then be compared to the legal standards.

## The Principles of Noise Assessment

Section 9.2 of **ILO Code of Practice – Ambient Factors in the Workplace** outlines the requirements for carrying out a workplace noise risk assessment.

Workplace risk assessments should consider risk of hearing impairment

The CoP states that the level of noise and/or duration of exposure should not exceed the limits established by the competent authority or other internationally recognised standards. The assessment should consider the:

- Risk of hearing impairment.
- Degree of interference with speech communications essential for safety purposes.
- Risk of nervous fatigue, with due consideration to the mental and physical workload and other, non-auditory hazards or effects.

The CoP requires that, for the prevention of adverse effects of noise on workers, employers should:

- Identify the sources of noise and the tasks that give rise to noise exposure.
- Seek the advice of the competent authority or occupational health service about exposure limits and other standards to be applied.
- Seek the advice of the suppliers of processes and equipment about the expected noise emission.
- If necessary, arrange for noise measurements to be taken by competent persons to nationally or internationally recognised standards.

The employer might make use of an external consultant to undertake a noise assessment. Or, it might be undertaken by an internal person. In either case, the person must be competent. Qualifications such as the UK's Institute of Acoustics Certificate of Competence in Workplace Noise Risk Assessment can be used as proof of competence as can experience and membership of organisations such as the UK's Association of Noise Consultants (ANC), British Occupational Hygiene Society (BOHS), etc.

Note there is often confusion between noise surveys and noise risk assessments. A **noise survey** is a measurement and record of noise levels in a noisy area. The data is used in **noise assessments**, which is far more than a noise survey.

## Planning the Survey

The noise survey forms an important part of the noise risk assessment and should cover the following points:

- Who Should Be Assessed?

  All workers likely to be exposed at or above a lower exposure action value, for example:

  – Workers who spend most of their day next to noisy machines.

  – Those who enter noisy areas for short periods.

  – Those whose exposure varies from day to day (maintenance, etc.).

- Where?

  At every location that the person works in or walks through during the day:

  – Note the time spent in each location.

  – It is not generally necessary to record exposures below 75dB(A) or so, because it is not significant in relation to the action value.

- How?

  – Take measurements at the position occupied by the operator's head and preferably with the person not present. If the operator needs to be present (e.g. to control the machine), then measure close enough to the head to get a reliable measurement, but far enough away to avoid sound reflections (>15cm).

  – In order to avoid taking lots of measurements, you can assume a worst case and measure the noisiest location (or during the loudest periods).

  – You can take more detailed measurements if this approach shows that the lower exposure action value is likely to be exceeded.

  – If using a dosimeter, place the microphone on the person's shoulder (to prevent it touching the neck, etc.).

**DEFINITION**

**EXPOSURE ACTION VALUE**

A noise exposure level at which employers are required to take certain steps to reduce the harmful effects of noise on hearing.

In UK legislation, for example:

- The lower exposure action value is a daily or weekly average noise exposure level of 80dB, at which the employer has to provide information and training and make hearing protection available.
- The upper exposure action value is set at a daily or weekly average noise exposure of 85dB, above which the employer has to take measures to reduce noise exposure and require the use of hearing protection if the noise cannot be controlled by these measures.

- For How Long?

  Measurements need to be sufficient to account for variations in the day.
  With integrating sound level meters, measurements should be long enough to obtain an indication of the average level of exposure. You may need to measure the A-weighted $L_{eq}$ for the entire exposure period, but you can often do it for a shorter period if noise is steady or cyclic.

  Dosimeters are designed to operate for long periods (an entire shift) and for workers who have highly variable exposure.

- Group Sampling

  If several workers work in the same area, you may be able to assess the exposure for all by doing measurements in selected locations. Choose the locations and durations so as to determine the highest exposure someone is likely to receive.

- Mobile Workers and Highly Variable Daily Exposures

  This includes, for example, maintenance. There is no typical daily exposure here. Measure a range of different activities likely to be encountered – estimate the worst likely exposure from these.

- Very Short Duration Noise

  This includes, for example, gunfire, explosions, cartridge-operated tools.

  This may already be included in the overall noise measurements of $L_{Aeq}$ for the exposure period. There are methods to assess this separately if it has been excluded from other measurements, or if the meter does not have sufficient dynamic range.

- Second, More Detailed, Noise Survey

  This may be needed where exposure is at, or exceeds, an upper exposure action value. You may need to use frequency (octave band) analysis to enable proper selection of noise-attenuating materials and hearing protection.

# Taking Measurements

## Instrumentation

The sound level meter used must be a Class 2 integrating sound level meter (or better), with an in-date certificate of test and a suitably tested calibrator. Dosimeters might be used where workers move around in the workplace, preventing the measurement of exposure at static locations.

Several different categories of instrument are available.

- Simple Sound Level Meters (SSLMs)

  This gives a read-out of the sound level at that moment in time, usually with the facility to switch between A-weighting and C-weighting – they are basic meters that are suitable for the measurement of continuous or intermittent periods of steady noise. They can also be used where the noise fluctuates moderately. If the noise is non-impulsive and fluctuates through a range less than five dB(A), the average reading of the meter can be estimated by eye if the response of the meter is set to slow.

A simple Sound Level Meter (SLM)

  Simple sound level meters are convenient for making routine **spot checks**, but are not considered adequate for establishing compliance with legal standards in most instances.

- Integrating Sound Level Meters (ISLMs)

  These are general-purpose meters that are capable of measuring the noise levels over a period of time and adding them together (integration) to give an average value for the measurement period. This value is called the $L_{eq}$.

  For use in compliance with **legal standards**, such a meter must be, at least, a:

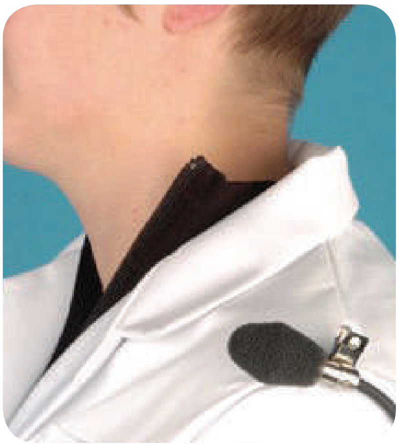
  – Class 2 instrument (BS EN **ISO 61672-1:2013**).
  – Equivalent, continuous A-weighted sound pressure level ($L_{Aeq}$ or $L_{eqd}$B(A)), which is used to calculate the daily personal noise exposure ($L_{EP,d}$).
  – Maximum C-weighted peak sound pressure level ($L_{CPeak}$).

  An **octave band analyser** is a type of ISLM that allows frequency analysis of the noise to be carried out. Many ISLMs have a built-in octave band analysis function. Frequency analysis is described on the next page.

An Integrating Sound Level Meter (ISLM)

- Personal Sound Exposure Meters (Dosimeters)

  These devices are worn by the person whose exposure is being determined, to measure the total noise dose over the whole working period. The equipment consists of a small, portable amplification and recording unit that can be worn in a pocket or on a belt by the operative, and a flexible microphone unit that can be attached to a collar or supported from a helmet. The important point is to ensure that the microphone is positioned close enough to the operator's head to obtain a reliable assessment of the noise to which they are exposed. However, if the microphone is mounted too close to the person's body, reflections from the person will reduce the accuracy of the measurement. These meters are also susceptible to abuse by the wearer (e.g. tapping the microphone). For use in compliance with **legal standards**, it must, at least, comply with BS EN 61252.



Recommended position for a dosimeter microphone
Source: L108 Controlling noise at work (2nd ed.), HSE, 2005 (www.hse.gov.uk/pubns/priced/l108.pdf)

## The Importance of Calibration

The meter should be calibrated before and after use to ensure the noise measurements accurately reflect the actual noise intensities. A separate calibrator is used for this purpose; this produces a pure tone of a set intensity against which the meter can adjusted.

For use in compliance with legal standards, calibrators should be at least Class 2, BS EN 60942.

Both calibrator and sound level meter must be tested and certificated every two years to ensure scientific accuracy.

### Measurements to be Taken

There are no established international limits for noise exposure, therefore we will use the limits and measurements established in the UK's **CNAW** regulations as an example.

For **each** significant noise exposure (which might occur at different locations or for different tasks performed at the same location):

- $L_{Aeq}$ - equivalent continuous A-weighted sound pressure level.
- $L_{CPeak}$ - maximum C-weighted peak sound pressure level(s) to which the person is exposed.
- Duration of exposure.

These will enable calculation of the daily (or weekly) noise exposure ($L_{EP,d}$).

## Interpretation and Evaluation of Results

### Calculating Noise Exposure

It is important to appreciate the two terms '$L_{Aeq}$' and '$L_{EP,d}$':

- $L_{Aeq}$ represents the equivalent continuous A-weighted noise dose over the measurement period (alternatively written as '$L_{eqdB}$(A)'). $L_{Aeq}$ is, in effect, a time-weighted average dose of noise over any time period chosen: 5 seconds, 7 minutes or 3 hours.
- $L_{EP,d}$ represents the equivalent daily (eight-hour) personal noise exposure. $L_{EP,d}$ is, in effect, the time-weighted average dose of noise calculated for a notional eight-hour day.

  In the UK regime, the **Control of Noise at Work Regulations 2005** use $L_{EP,d}$ (daily dose) as one standard for noise exposure. Therefore, using an ISLM to measure $L_{Aeq}$ does not allow direct comparison with the legal standards. First, the measurements must be used to calculate $L_{EP,d}$. If a single noise exposure occurs during the working day and the working day lasts for eight hours exactly, then this is simple, since $L_{EP,d}$ will be the same as the measured $L_{Aeq}$.

But, where the duration of exposure is less, or greater than, exactly eight hours, or where multiple exposures occur, then $L_{EP,d}$ will have to be calculated.

**Three different methods** can be used to calculate $L_{EP,d}$:

- Use the Equations

  As presented in **Schedule 1** to **CNAW**.

  For multiple exposures:

$$L_{EP,d} = 10\log_{10}\left[\frac{1}{T_0}\sum_{i=1}^{n} T_i 10^{0.1(L_{Aeq,T})_i}\right]$$

  Where $T_0$ = 28,800 seconds (eight hours)

  $T_i$ = duration of period $_i$ (in seconds), n = number of individual periods in the working day.

  $(L_{Aeq,T})i$ = equivalent continuous A-weighted sound pressure level that represents the sound the person is exposed to during period *i*.

  In simple cases of single exposures, this simplifies to:

$$L_{EP,d} = L_{Aeq,T_e} + 10\log_{10}\left(\frac{T_e}{T_0}\right)$$

  Where $T_e$ = duration of the person's working day, in seconds.

- Use the HSE Calculator

  A simple spreadsheet calculator is provided by the UK's HSE on their noise website for this purpose. This allows for multiple exposures and exposure duration to be entered and outputs a figure for $L_{EP,d}$.

- Use the HSE Ready Reckoner

  The UK's HSE has also published a ready reckoner, which uses a points system to calculate the daily noise exposure. This ready reckoner is also available from the HSE website.

**MORE...** www.

The useful daily and weekly spreadsheet calculators and ready reckoners are available from the UK HSE website at:

www.hse.gov.uk/noise/calculator.htm

## Comparison with Legal Limits

Once an individual worker's or group of workers' daily personal noise exposure ($L_{EP,d}$) has been reliably estimated, it must then be compared to the limits contained in national and international legislation or standards.

Examples of national limits:

- The noise exposure limits in Europe were established from the **Physical Agents (Noise) Directive 2003/10/EC**. In the UK this was implemented as the **Control of Noise at Work Regulations 2005 (CNAW)**, which establish the following exposure limits:
  - Lower daily action limit of 80 dB(A) $L_{EP,d}$ with a peak sound pressure limit of 135dB(C) $L_{CPeak}$.
  - Upper daily action limit of 85 dB(A) $L_{EP,d}$ with a peak sound pressure limit of 137dB(C) $L_{CPeak}$.
  - In addition, no worker should be exposed to levels of noise exceeding 87 dB(A) $L_{EP,d}$ or 140dB(C) $L_{CPeak}$. These are known as 'exposure limit values'.

It should be noted that where very changeable exposures occur from day to day the Regulations allow for a weekly personal noise exposure ($L_{EP,w}$) to be estimated and used for comparison to the standards.

In many cases, measurements of $L_{CPeak}$ taken from sound level meters during the survey can be directly compared to the $L_{CPeak}$ values given in the Regulations.

Comparison of the measured $L_{EP,d}$, $L_{EP,w}$ and $L_{CPeak}$ values in the workplace with the standards in CNAW will allow the correct actions to be identified to achieve legal compliance. These will be described in the next section.

- In Australia, similar limits have been established in the **National Standard for Occupational Noise (NOHSC: 1007(2000))**:
  - An eight-hour equivalent continuous A-weighted sound pressure level, $L_{Aeq,8h}$, of 85dB(A).
  - Peak sound pressure level, $L_{C,peak}$, of 140dB(C).

  These measurements are to be taken at the ear of the worker and do not take into account the effect of any hearing protection which may be worn. Note also that the Australian standard uses the $L_{Aeq}$ measurement rather than the $L_{EP,d}$ limit adopted by the UK.
- In the US there are similar legal limits published in OSHA Standard 1910.95, which stipulates:
  - The employer shall implement a hearing protection programme when employee noise exposures equal or exceed an eight-hour TWA of 85dB(A) or equivalently a dose of 50%. This is without regard to any attenuation provided by hearing protection.

**MORE...** www.

General information on noise and more specific information about measuring noise at work is available from the UK HSE website at:

www.hse.gov.uk/noise/index.htm

Information on the Australian limits can be found at:

www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/ns2000occupationalnoise

Information on the US OSHA standard can be found at:

www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735

## STUDY QUESTION

11. What are the main types of equipment available for measuring noise levels and noise exposure?

(Suggested Answer is at the end.)

# Controlling Noise and Noise Exposure

### IN THIS SECTION...

- Noise control can be achieved by applying a hierarchy of controls:
  - Reduce noise at source by eliminating hazardous noise at source, changing the source, re-locating the source, re-designing the source and maintenance.
  - Attenuate noise transmission by isolating the source, damping, using acoustic barriers or using an acoustic enclosure for the source.
  - Control noise exposure at the receiver using acoustic havens, hearing protection zones and the use of passive and active hearing protection, limiting exposure time and health surveillance.
- Hearing protection must be carefully selected by reference to its attenuation data and the noise profile of the workplace. Three different methods exist to determine the attenuation achieved: octave band analysis; High, Medium, Low (HML) and Single Number Rating (SNR).

## Hierarchy of Noise Control

Wherever noise is a problem, there are three orders of priority for dealing with it. Within each of these there are various options available that form a simple hierarchy of control:

Noise can be controlled using a hierarchy

- Reduce Noise at Source

  Eliminate hazardous noise at source – remove the noise source entirely. Where this is not reasonably practicable, then:
  - Change the source to one that generates less noise.
  - Re-locate the noise source.
  - Re-design the source.
  - Carry out maintenance.
  - Implement a purchasing policy so that only low-noise equipment is purchased.
- Attenuate Noise Transmission

  Reduce the transmission of noise before it reaches the worker, through:
  - Isolating the source to prevent transmission, e.g. using anti-vibration mounts.
  - Acoustic barriers that interrupt the movement of sound waves through the air.
  - Acoustic enclosure of the noise source.
- Control Noise Exposure at the Receiver

  This can be controlled by:
  - Acoustic havens.
  - Hearing protection zones and the use of passive and active hearing protection.
  - Limiting exposure time.
  - Health surveillance (audiometry).

Practical examples of the application of the noise control hierarchy are given in the next section.

## Noise Control at Source

Noise exposure control is best done by elimination of the source of the noise problem. This might be done by avoiding noisy activities or avoiding plant and equipment that produce excessive noise. This can be done at the planning stage by adopting a noise-avoidance purchasing policy, where noise emissions are taken into consideration as a part of the purchasing process for plant and equipment.

Noise can often be reduced by **substituting** plant or equipment.

Suggested substitution of plant or equipment

| Noisy Equipment or Process | Substituted By |
|---|---|
| Diesel/petrol engines | Electric motors |
| Pneumatic tools | Electric tools |
| Riveting | Welding |
| Solid wheels | Pneumatic rubber tyres |
| Metal gears and bearings | Plastic gears and fibre bearings |
| Metal chutes, buckets and boxes | Rubber or plastic ones |

Alternatively, it may be possible to reduce the noise level within the workplace by **re-locating** the source of noise.

In "open air" conditions, sound decreases by 6dB for every doubling of the distance away from the source:

Table showing reduction in dB level as a result of increasing distance from source to receiver

| Distance | Noise Level |
|---|---|
| 1m | 112dB |
| 2m | 106dB |
| 4m | 100dB |
| 8m | 94dB |

This is because noise (like many other forms of radiated energy) obeys the inverse square law; the energy intensity per unit area decreases inversely proportionally to the square of the distance from source to receiver.

A typical example is the use of compressor rooms where the compressor is removed from the main workplace and re-located in an isolated location. Whilst this does not reduce the noise being generated by the machine, it does reduce the noise exposure in the main workplace.

Rather than replace a complete machine or process, it may be possible to carry out a **modification**. For example, plastic or rubber-coated rollers and guides on a conveyor belt may be used for handling glass or metal components.

Many machines become noisy because of worn parts, poor maintenance, inadequate lubrication, or because they are 'out of balance'. **Planned preventive maintenance or condition-based maintenance**, involving the replacement of parts and lubrication, will reduce noise (and increase efficiency). Balancing rotating parts (to minimise vibration) can achieve significant noise reduction.

# Attenuating Transmission Pathways

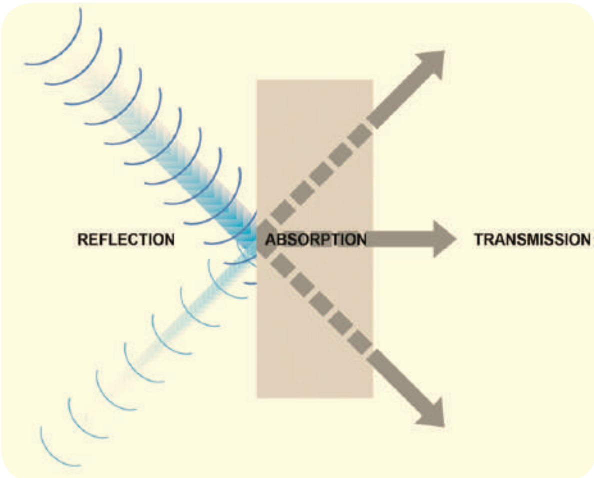
## Noise Pathways

Before looking at practical examples of noise exposure control it is perhaps useful to consider how noise travels from its source to an exposed individual in the workplace. A worker who is exposed to noise from a noise source will receive the noise from one or more different pathways:

- **Directly** – the noise moves directly from the source to the individual through the air.
- **Reflected** – some noise is reflected off surfaces before it hits the receiver, e.g. off hard surfaces such as walls, ceiling or desk top.
- **Transmitted** – some of the noise from the source will move into the floor and other structures, will be transmitted through the structure in the form of mechanical vibration and will then be re-emitted into the air.

When sound strikes a surface (such as a wall), several things can happen. Depending on the properties of the material (the material of which the wall is made) and the characteristics of the noise, a proportion will be **reflected** from the surface, some will be **absorbed** by the surface and some **transmitted** through the surface.

The following figure illustrates the interaction of a sound wave front with a slab of material and its reflection, absorption and transmission.




Interaction of sound waves with a slab of material

Materials can be classified according to how well they reflect, absorb and transmit sound. These properties can be quantified under laboratory conditions in various different ways and therefore used to design acoustic controls. Two particularly useful qualities of a building material are the **sound absorption coefficient** and the **sound reduction index**.

- Sound Absorption Coefficient

  This is defined as:

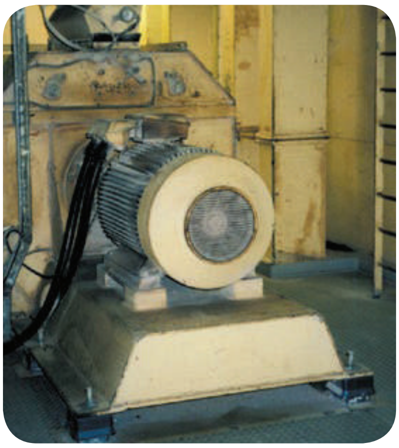
$$\frac{\text{intensity of sound absorbed by material}}{\text{intensity of sound incident on same area of material}}$$

  This gives a measure of how well a material absorbs sound falling onto it and can be derived for sounds of different frequencies. The higher the coefficient, the more sound is absorbed and the less is reflected or transmitted through. For example, glass fibre (75mm thick) has an absorption coefficient of 0.99 at 500Hz. In other words, 99% of sound falling onto the glass fibre is absorbed and only 1% is reflected back or transmitted through the material.

- Sound Reduction Index (SRI)

  This is the difference, in decibels (dB), between the sound level incident on a material and the sound level transmitted through the material, i.e. the level of attenuation (sound reduction) of noise. It is an idealised laboratory measurement of sound insulation (i.e. sound reduction) properties; real world measurements can differ (transmission through floor, etc.). SRI is also known as **transmission loss**. For example, a wall made of eight-inch hollow concrete blocks has a transmission loss of 58dB at 2kHz. In other words, the sound intensity at the 2kHz frequency is reduced by 58dB by passage through the wall. In general, the denser the barrier material, the higher the transmission loss.



Anti-vibration mounts isolate grinder from supporting surface

Source: L108 Controlling noise at work (2nd ed.), HSE, 2005 (www.hse.gov.uk/pubns/priced/l108.pdf)

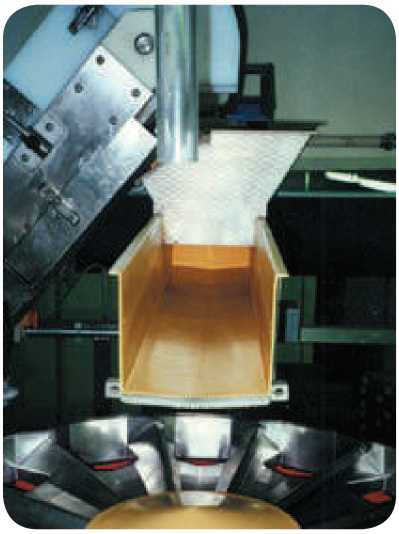
## Isolation

Noise is not only transmitted from a source directly into air. It is also transmitted mechanically from the source to adjacent structures by direct physical transmission of vibration. This transmission route can be interrupted by isolating the noise source from adjacent structures. This is often achieved by mounting the whole machine on steel springs or high-density rubber matting. The principle here is that though the machine itself vibrates, that mechanical vibration is absorbed by the isolating material and is not transmitted through.

## Damping

**Damping** is one modification technique that can be very effective at reducing the noise radiated from steel panels and any structure that can 'ring' due to vibration. The principle is the same as for a musical cymbal that radiates sound when struck. If the instrumentalist touches the cymbal with their hand then the sound is 'damped' and reduces immediately. In industry, damping may be achieved by:

- Using materials that have a higher damping capacity, e.g. cast iron causes less 'ring' than steel.
- Attaching stiffening ribs to the structure.
- Applying a commercial damping treatment, such as a plastic layer.
- Applying a sandwich layer between two vibrating structures.



Damping material applied to transport chutes in the food industry

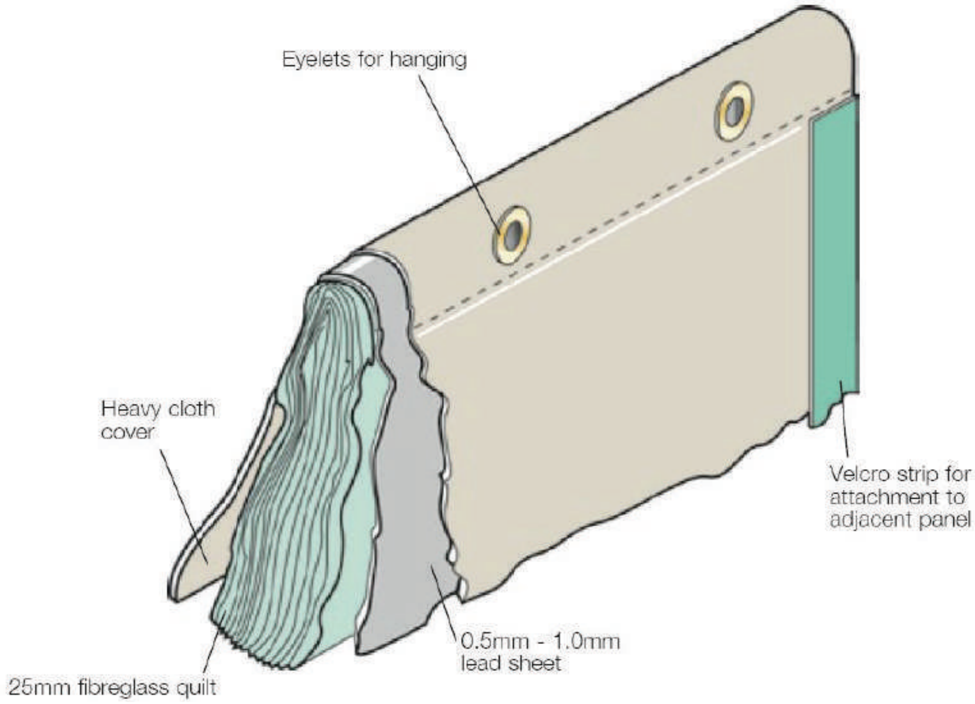
Source: L108 Controlling noise at work (2nd ed.), HSE, 2005 (www.hse.gov.uk/pubns/priced/l108.pdf)

## Diffusion

This involves reflecting sound waves off convex or uneven surfaces. It helps evenly distribute sound and so blends it. It can eliminate sharp echoes.

## Acoustic Barriers

This involves installing an acoustic screen between the noise source and the receiver. It therefore stops the direct noise but may allow reflective noise to reach the receiver. The screen is most effective against high frequencies and when close to the source. Barriers can be hard structures placed close to the noise source or can be flexible, matting-type materials suspended in the workplace adjacent to the noise source.




Example of construction of a hanging, flexible acoustic barrier
Source: L108 Controlling noise at work (2nd ed.), HSE, 2005 (www.hse.gov.uk/pubns/priced/l108.pdf)

## Acoustic Enclosure

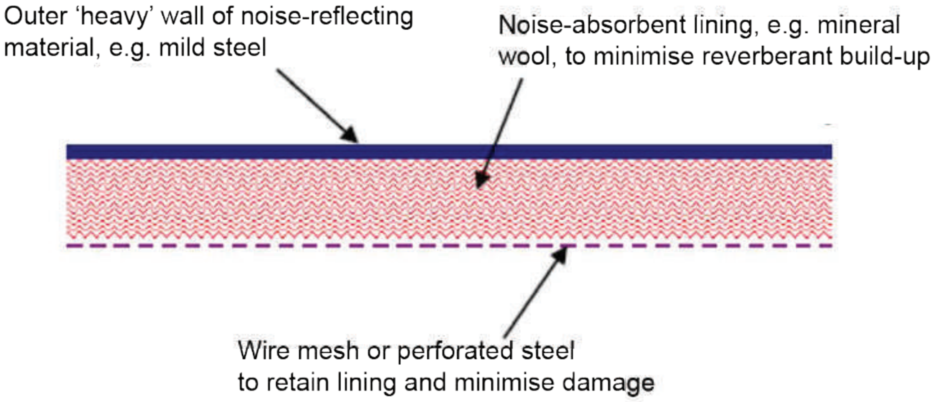
In many cases, the best method of noise control is to enclose the noise source.

To be effective, enclosures must be airtight; the smallest gap allows sound to escape and reduces the attenuation of the noise inside the enclosure. This is a particular problem with, for example, woodwork machines, such as saws and planes, where timber is fed in at one end and comes out at the other. However, such equipment can be fitted with noise-reducing feed, and delivery tunnels fitted with windows to allow clear viewing and with adequate lighting.

Machinery enclosures should be mounted so that they do not transmit noise and vibrations to the floor.

Dense high-mass materials are good sound insulators. They include brick, concrete, heavy-gauge steel and plaster. However, in order to absorb noise and reduce reflections from walls, low-density porous materials are required, such as mineral fibre and acoustic tiles.

Acoustic enclosures, therefore, have a heavy noise-reflecting outer skin and a noise-absorbent lining, such as mineral fibre. A typical enclosure wall is shown in the following figure:



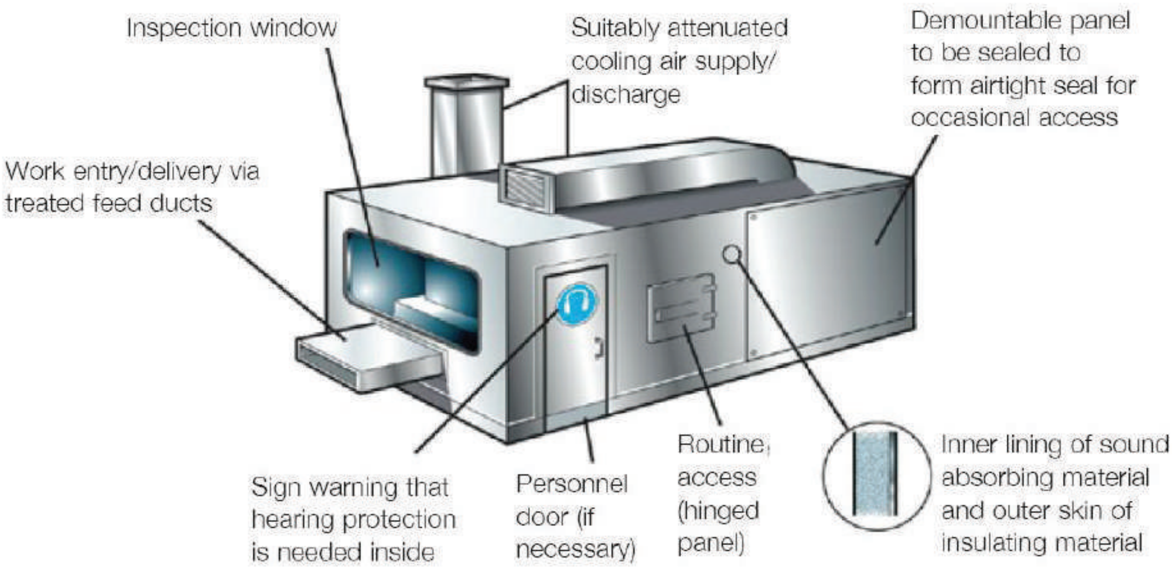

Structure of the wall of a noise enclosure

The amount of noise reduction or attenuation offered by the enclosure is measured by the difference in sound levels before and after the enclosure (or any other form of control) is fitted. A good enclosure will reduce noise levels by between 10dB(A) and 30dB(A).

There are also design and operational issues to consider. These include maintenance and access considerations which, if ignored, will result in doors being left open or panels permanently removed. Key design features include:

- Sound reduction index of the panelling of the enclosure.
- Protection of the internal absorbent lining.
- Robust construction.
- Sealing between panel and floor, and around penetrating ducts and pipes.
- Access for operation and maintenance.
- Robust locks to doors and hatches.
- Observation windows.
- Adequate internal space.
- Adequate lighting and ventilation.




Features required of a typical machine enclosure
Source: L108 Controlling noise at work (2nd ed.), HSE, 2005 (www.hse.gov.uk/pubns/priced/l108.pdf)

## Active Noise Cancellation

Active noise cancellation, or Active Noise Reduction (ANR), is a method of reducing the noise emitted by a piece of equipment or machinery. The principle relies on electronic equipment detecting the sound pressure waves being created by the machine and then generating the exact opposite (180° out of phase) sound pressure waves so that the two pressure waves counteract or cancel one another. ANR equipment usually consists of one or several microphones mounted in or on the machinery, an electronic control unit and one or several speakers to generate the 'anti-noise'.

This technology is not generally widespread but is being used in car design (to reduce occupants' exposure to low-frequency engine noise) and some industrial machinery.

The one application where this technology is very widespread is in anti-noise headphones and hearing protection that will be outlined in the next section.

## Control at the Receiver

There are two main ways of controlling exposure by protecting the receiver. These are by the use of an acoustic haven (noise haven or refuge) and by the use of hearing protection. Hearing protection, in common with other types of PPE, should only be used when other methods are not reasonably practicable.

## Acoustic Havens

An alternative to enclosing the machine is to enclose the worker. In facilities where a range of noisy plant is operated from a central control room, it is easier and cheaper to provide an acoustically insulated control room, or haven, than it is to enclose all the plant. Since the haven is a workplace for the operatives that use it, in addition to the acoustic performance of the enclosure, it is also necessary to consider environmental issues to ensure that workers are able to use the haven without risk or discomfort.

Key design considerations include:

- Noise reduction properties of the haven.
- Similar construction considerations as for the noise enclosure discussed earlier, except that the noise-absorbent lining is not required (since the purpose is now to keep the noise out rather than to keep the noise in).
- Observation windows.
- Adequate internal space.
- Adequate lighting and ventilation.
- Adequate seating.
- Inclusion of as many controls as possible to reduce the time needed to be spent wearing ear protection in the noisy environment outside the haven.

## Hearing Protection Zones

Areas in the workplace where noise levels are likely to give rise to exposures at, or above, the limits (as identified in the noise assessment), will usually be designated as mandatory hearing protection zones, with signs to inform workers and visitors to the area. Signs must be displayed. Workers entering such zones must be provided with suitable hearing protection. They must also be provided with information, instruction and training on the hazards and risks presented by noise; the control measures in place; and the correct fitting, maintenance and cleaning of the hearing protection. The employer must enforce the use of the hearing protection issued.

A noise refuge and control room
Source: L108 Controlling noise at work (2nd ed.), HSE, 2005 (www.hse.gov.uk/pubns/priced/l108.pdf)

# Hearing Protection

Hearing protection comes in a wide variety of types suitable for different applications. It is important that the correct type of hearing protection is selected and that it is used and maintained correctly. This section provides an overview of some of the different types of hearing protection available and the issues that must be considered in selection, care and use.

## Earplugs and Earmuffs

**Earplugs** are small-shaped bungs that are inserted into the external auditory canal. Many are designed to be **disposable**, and some **re-usable**. The disposable types are usually made from polyurethane foam; and the re-usable type from flexible plastic or rubber. They often come with a cord or neck-band to prevent loss.

There are many **advantages** to earplugs, such as:

- Universal fit.
- They are relatively cheap.
- They require little or no maintenance.
- Minimal training is required for effective use.
- They are compatible with spectacles and any other items of PPE that have to be worn.
- There is generally good user acceptance.

Some of the **disadvantages** include:

- Supervision is more difficult (to ensure that plugs are being worn correctly, or at all) especially from a distance.
- They can be difficult to fit correctly*.
- They can work loose during use.
- They are not appropriate when hearing protection has to be removed and re-fitted frequently, in an environment where contamination to the fingers is likely.
- They are not suitable for some individuals due to medical conditions.
- They do not reduce sound transmission through bone to the inner ear.

* A note on fitting earplugs. Most earplugs have to be inserted into the ear canal to be effective. This cannot be achieved simply by pushing the plug into the ear canal, as the canal has a kink in it. To straighten this kink the ear lobe has to be pulled back as the earplug is fitted. This is best achieved by reaching around the back of the head with the opposite arm.

Earplugs with neck bands

Earplugs with neck cords

**Custom moulded earplugs** are another option. This type of earplug is custom-made to fit each ear of the individual and fits into the ear canal and the external folds of the outer ear. These are more expensive than other types of plug but share most of the benefits and disadvantages.

Custom moulded earplugs

Source: L108 Controlling noise at work (2nd ed.), HSE, 2005 (www.hse.gov.uk/pubns/priced/l108.pdf)

**Earmuffs** (ear defenders) are designed to cover the ears externally with large cups held in position by a headband. The cups are designed with an annular cushion made of a plastic material, filled with polyurethane foam, gel or liquid to provide a seal between the cups and the side of the head.

Some of the **advantages** of earmuffs are:

- They are easy to fit and use.
- Supervision of use is easy, even at a distance.
- They are more suitable for situations where they have to be frequently removed and re-fitted and where there is risk of finger contamination.
- They are more effective at reducing bone transmission.

Some of the **disadvantages** include:

- They are more expensive than most earplugs.
- They may be incompatible with other items of PPE, such as hard hats, breathing apparatus, etc.

- Protection is reduced when worn by people with spectacles, earrings or a lot of hair around the ears.
- They require more training, cleaning and maintenance than most types of earplug.

## Special Types of Protector

Several different types of special hearing protection are available for use in special circumstances. These include:

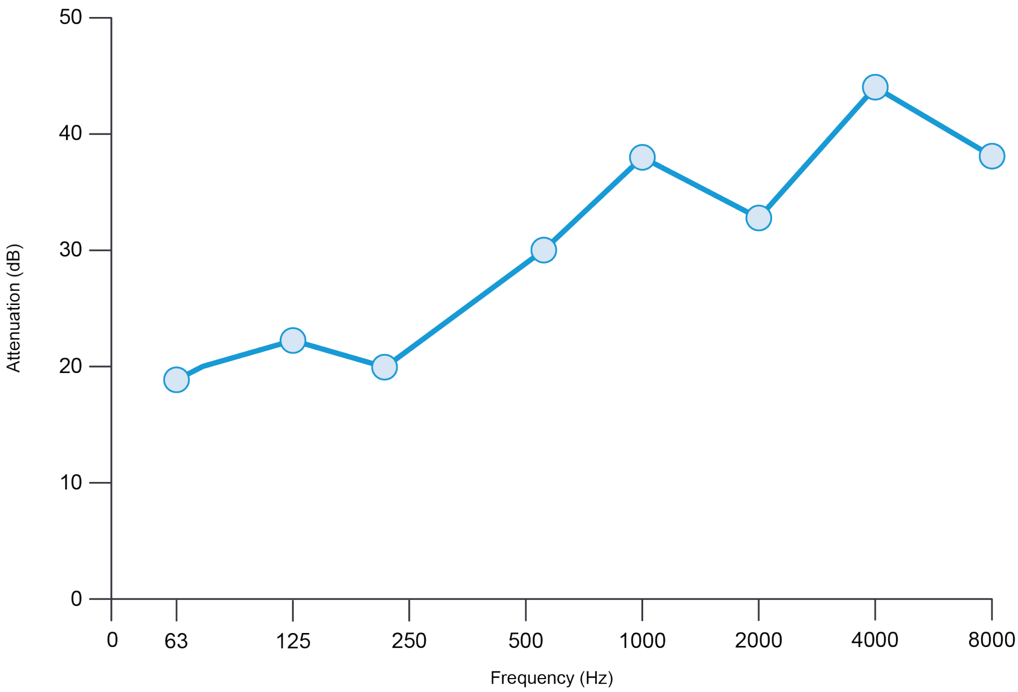
- **Level-dependent protectors** – where the degree of attenuation increases as noise level increases, so allowing easy communication at low noise levels, but offering full protection at high noise levels.
- **Flat response protectors** – where the amount of noise attenuation is the same across all frequencies. This is unlike most ordinary hearing protectors where the degree of attenuation increases as frequency increases (i.e. they reduce the high-pitch noise more than low-pitch noise). This is of particular use to musicians who need to be able to hear the 'true' sound of their instrument but at reduced intensity.
- **Active noise-reduction protectors** – where electronic circuitry detects and then cancels out some of the background noise. This is done by generating the exact opposite sound pressure waves to the background sound pressure waves, so that the peaks and troughs of the pressure waves are out of phase and cancel each other out.
- **Communication protectors** – where the protectors have a speaker (and perhaps microphone) built in so that the wearer can hear (e.g. for entertainment) and perhaps talk (e.g. two-way radio).

Types of earmuff
Source: L108 Controlling noise at work (2nd ed.), HSE, 2005 (www.hse.gov.uk/pubns/priced/l108.pdf)

## Significance of Attenuation Data

Hearing protection should be chosen to reduce noise exposure at the user's ear to below the relevant action value. However, the degree to which a particular type of hearing protection reduces sound intensity varies with frequency.

The attenuation curve for one model of earmuff is given in the following figure.




Attenuation curve for one model of earmuff

As can be seen from the graph, the earmuffs cut out more decibels at higher frequencies than they do at lower frequencies.

There is great variation in the **attenuation characteristics** of different makes and models of hearing protection. It is therefore essential that the attenuation characteristics of the hearing protection selected are suitable for use in the particular noise environment in which they are to be worn. These attenuation characteristics are supplied by the manufacturer in the form of a data table, as shown in the following example.

Example of Manufacturer's Data Table for a Pair of Earmuffs

| | Octave band centre frequency (Hz) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| Mean attenuation (dB) | 11.5 | 11.8 | 11 | 20.4 | 22.9 | 29.8 | 39.5 | 39.6 |
| Standard deviation (dB) | 4.4 | 3.2 | 1.9 | 3.6 | 2.2 | 2.5 | 2.7 | 4.9 |
| APV = mean attenuation - std. dev. (dB) | 7.1 | 8.6 | 9.1 | 16.8 | 20.7 | 27.3 | 36.8 | 34.7 |
| Single number values | H | 27 | M | 19 | L | 13 | SNR | 22 |

(Based on an original in L108 Controlling noise at work (2nd ed.), HSE, 2005 (www.hse.gov.uk/pubns/priced/l108.pdf))

APV is the **Assumed Protection Value** at each octave band centre frequency. It is calculated as the mean attenuation minus one standard deviation. Note that three different sets of data are presented in the table, three rows of octave band data, three High, Medium, Low (HML) numbers and one Single Number Rating (SNR) number.

These characteristics have to be compared with the characteristics of the noise in the workplace. This requires data about the workplace noise, which will come from a noise survey using an octave band analyser or integrating sound level meter.

There are three methods for predicting the effects of hearing protection so that its suitability can be assessed:

- The **octave band method** is the most accurate but requires a full octave band spectrum of the noise in the workplace, as derived from octave band analysis.
- The **HML method** is less accurate if noise is dominated by single frequencies but only requires two bits of information about the workplace noise - A-weighted and C-weighted average sound pressure levels.
- The **SNR method** is the simplest but least accurate (but still suitable for most general applications). One piece of information is required about the workplace noise - C-weighted average sound pressure level.

Calculating the predicted level of protection offered by an item of hearing protection can be done using the formulae presented in the UK HSE publication L108 *Controlling noise at work* (Appendix 3). Alternatively, a calculator is available on the HSE website. This spreadsheet allows any of the three methods described to be used and the result can be saved for reference.

Whichever method is used, a 4dB addition is always made to the predicted noise exposure at the ear to take account of '**real world**' factors. This reflects the fact that the attenuation data for hearing protection is collected in idealised laboratory conditions by the manufacturer and so a margin of error has to be included to allow for imperfect use.

Using the methods described above, the level of noise that will be experienced by an individual **at the ear** when wearing a certain type of hearing protection can be reliably estimated. If predicted noise levels are less than 70dB(A) then the hearing protection is unsuitable because it 'over-protects' the ear. **Over-protection** causes difficulties with communication and hearing warning signals. Users become isolated from their environment, leading to safety risks, and may be inclined to remove the hearing protection and risk damage to their hearing.

## TOPIC FOCUS

### Example Use of the SNR Method

A noise survey and assessment has shown that hearing protection must be worn in a workroom. One type of hearing protection has been selected for use, but it must be checked to ensure that it gives the correct level of protection.

The noise survey has indicated that the C-weighted average sound pressure level in the workroom is 92dB(C). The manufacturer's data sheet for the hearing protection gives the SNR number as 30.

To calculate the estimated sound pressure level at the ear take the SNR number away from the C-weighted average:

$$92 - 30 = 62\text{dB(A)}$$

We must then make a 4 dB additional to take account of 'real-world' factors:

$$62 + 4 = 66 \text{ dB(A)}$$

So, a worker wearing the selected hearing protection in the workroom would receive 66dB(A) at their ear.

We must then evaluate this predicted exposure against the relevant legal standards. If we use the UK/EU standards, we find that we may be below the UEAV (85dB(A)) and the LEAV (80dB(A)) but, unfortunately, we are also below the guideline 70dB(A), which shows that we are 'over-protecting' the worker's hearing. This hearing protection is therefore not suitable for use in the workroom, so another type, offering a lower level of protection, should be found.

## MORE...

www.hse.gov.uk/noise/index.htm

The hearing protection spreadsheet calculator is available from:

www.hse.gov.uk/noise/calculator.htm

Schedule 1 of the Control of Noise at Work Regulations can be found at:

www.legislation.gov.uk/uksi/2005/1643/schedule/1/made

ACoP and Guidance - L108 - Controlling Noise at Work is also relevant here (available as before).

## STUDY QUESTIONS

12. What are the three ways in which a sound wave front may interact with a slab of material?
13. List the three priorities of noise control.
14. Describe the principal design features of an acoustic enclosure.
15. What is the difference between a noise enclosure and a noise haven?
16. What are the various types of ear protection available?

(Suggested Answers are at the end.)

# Basic Concepts of Vibration

### IN THIS SECTION...

- Hazardous vibration can be divided into two types: Hand-Arm Vibration (HAV) and Whole-Body Vibration (WBV).
- Vibration can be characterised using several factors, notably the magnitude (measured in $m.s^{-2}$), frequency (hertz, Hz) and direction (in three dimensions x, y and z).
- The harm caused by vibration is determined by dose, in turn determined by the vibration magnitude and duration of exposure. The eight-hour energy-equivalent vibration magnitude is used as the standard daily exposure.

## Definitions

Vibration is the term given to an oscillatory motion involving an object moving back and forth.

Under **ILO Convention C148**, article 3, vibration is defined as:

> *"any vibration which is transmitted to the human body through solid structures and is harmful to health or otherwise dangerous."*

**Copyright © International Labour Organisation 1977**

Occupational exposure to vibration can result in two distinct effects – Hand-Arm Vibration Syndrome (HAVS) and Whole-Body Vibration (WBV). Under the UK's **Control of Vibration at Work Regulations 2005**:

- **Hand-arm vibration** is defined as:

  *"Mechanical vibration which is transmitted into the hands and arms during a work activity."*

- **Whole-body vibration** is defined as:

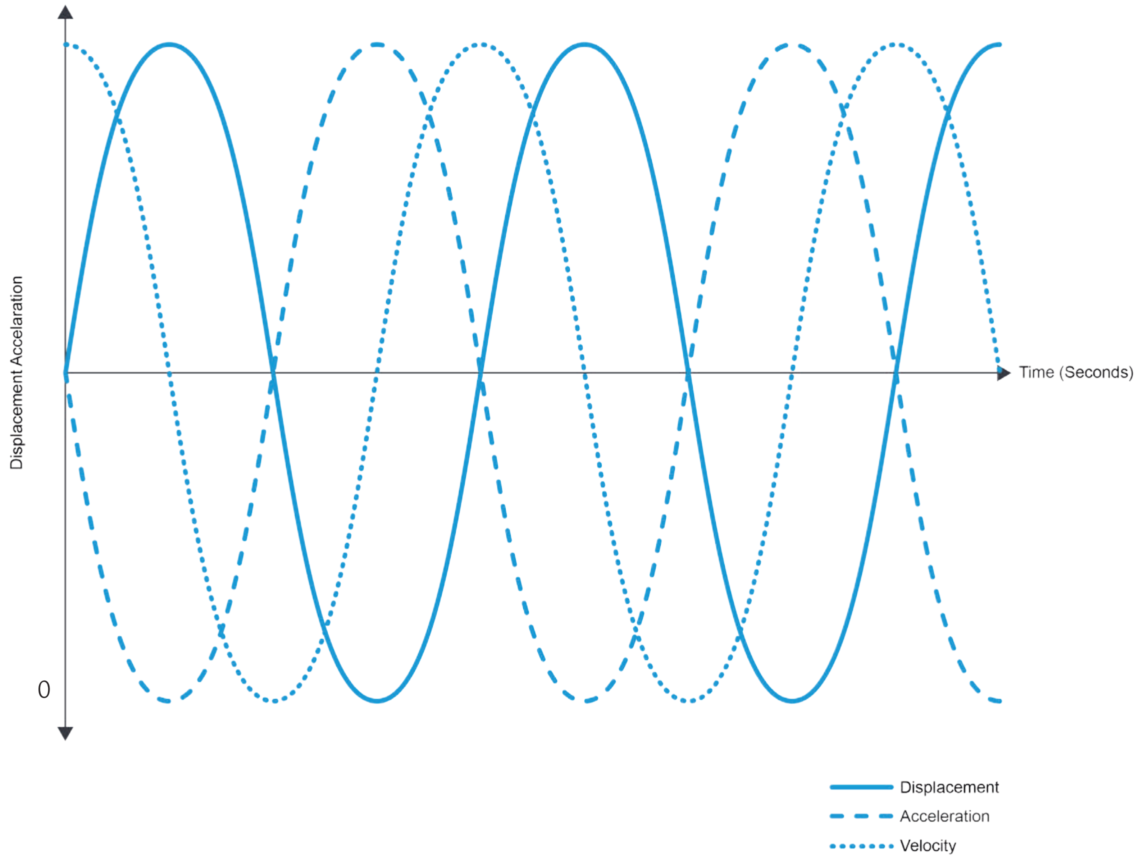
  *"Mechanical vibration which is transmitted into the body, when seated or standing, through the supporting surface, during a work activity."*

Compactors and other tools can generate a lot of vibration, which is then delivered into the hands and arms of the worker

## Basic Concepts

When an object (such as the end of a ruler clamped over the edge of a desk) vibrates, it starts from a position of maximum displacement, accelerates towards the equilibrium position from which it has been displaced, overshoots this equilibrium position at its maximum velocity, and begins to decelerate due to a restraining force, until it comes to rest (temporarily) at maximum displacement in the opposite direction. The restraining force then begins to propel the object towards the equilibrium position and the process is repeated.

The following figure shows the relationship between **acceleration**, **velocity** and **displacement** over time.




Sinusoidal vibration – the relationship between displacement, acceleration and velocity

The key terms to consider are:

- **Amplitude**

  Amplitude is the distance (in metres) from the point of rest (0 above) to the point of maximum displacement in either direction.

- **Frequency**

  The frequency of vibration is expressed in cycles per second or hertz (Hz), as used for noise measurement.

- **Acceleration**

  Acceleration is a measure of the rate of change of velocity of a vibrating object (in units of metres per second per second, $m/s^2$). This is used as the basis for measuring vibration magnitude.

- **Vibration Magnitude**

  Vibration magnitude is expressed in terms of acceleration. Since the acceleration of a vibrating object changes in a sinusoidal manner with time (see graph), the magnitude of the vibration is taken as an average measure of the acceleration. For sinusoidal motion, the average value used is the root-mean-square value (RMS acceleration).

- **Vibration Direction**

  With complex vibrating objects there may be displacement in all three dimensions (x, y and z). Vibration in all three dimensions will contribute to the overall vibration received by the hand or body, so the amount of vibration in each dimension may have to be considered.

## Occupational Vibration Exposure

There is a wide range of occupations who are at risk from exposure to hand-arm vibration in the workplace. Examples include:

- Construction workers – using concrete breakers, cut-off saws and hammer drills.
- Estates workers – using powered lawnmowers and brush cutters (strimmers).
- Mechanics and bodyshop workers – using powered tools such as orbital sanders and torque wrenches.

Sources of whole-body vibration include forklift trucks, dumper trucks and other vehicles used while standing or sitting.

The following table shows examples of the typical vibration levels that might be experienced when working with common tools:


Axes of vibration for hand-transmitted and whole-body vibration

| Tool type | Lowest | Typical | Highest |
|---|---|---|---|
| Road breakers | 5 m/s$^2$ | 12 m/s$^2$ | 20 m/s$^2$ |
| Demolition hammers | 8 m/s$^2$ | 15 m/s$^2$ | 25 m/s$^2$ |
| Hammer drills/combi hammers | 6 m/s$^2$ | 9 m/s$^2$ | 25 m/s$^2$ |
| Needle scalers | 5 m/s$^2$ | - | 18 m/s$^2$ |
| Scabblers (hammer type) | - | - | 40 m/s$^2$ |
| Angle grinders | 4 m/s$^2$ | - | 8 m/s$^2$ |
| Clay spades/jigger picks | - | 16 m/s$^2$ | - |
| Chipping hammers (metal) | - | 18 m/s$^2$ | - |
| Stone-working hammers | 10 m/s$^2$ | - | 30 m/s$^2$ |
| Chainsaws | - | 6 m/s$^2$ | - |
| Brushcutters | 2 m/s$^2$ | 4 m/s$^2$ | - |
| Sanders (random orbital) | - | 7-10 m/s$^2$ | - |

Typical vibration levels for common tools
Source: INDG175(rev2) Control the risks from hand-arm vibration, HSE, 2005

## Comfort Levels

Lower frequency vibrations tend to cause physical discomfort. Here are a few examples of some discomfort effects at different frequencies:

- 3 – 6 Hz:
  - For example, next to large, slow-speed diesel engines:
    - Chest diaphragm resonates, i.e. vibrates in sympathy.
    - Gives a feeling of nausea.
- 20 – 30 Hz:
  - Head, neck and shoulders resonate.
- 60 – 90 Hz:
  - Eyeballs resonate.

## Vibration Dose

Legislation, such as the UK's **Control of Vibration at Work Regulations 2005**, works on the basis that the amount of harm done by exposure to vibration is dependent on the **dose** of vibration energy received – the principle being that a given dose of vibration energy, however delivered, will cause an equivalent degree of harm.

This dose is determined by the **magnitude** of the vibration (RMS acceleration) and the **duration** of exposure.

The daily dose of vibration received by a worker can therefore be expressed as the **eight-hour energy-equivalent vibration magnitude.** In the **EU Directive 2002/44/EC**, this is described as being 'standardised to an eight-hour reference period'. This idea is very similar to the idea that a person's noise exposure can be expressed as a daily personal noise exposure, $L_{EP,d}$.

All of the exposure values in the regulations are expressed using this standard dose. So, if a worker's personal vibration exposure is to be compared to the standards, their personal **eight-hour equivalent vibration magnitude exposure** will have to be reliably estimated (either by reference to available data or by direct measurement).

It must be remembered that the regulations cover both Hand-Arm Vibration (HAV) and Whole-Body Vibration (WBV). In both instances, the same concept of personal daily dose still applies. However, different exposure values exist for the two different sorts of vibration exposure and two different sets of formulae are used to determine the dose.

### MORE...

www.

The main Vibration page of the HSE website links to lots of relevant pages and downloads:

www.hse.gov.uk/vibration/index.htm

ACoP and Guidance on the Control of **Vibration at Work Regulations 2005** is also available from the HSE in the form of two guides, L140 - Hand-Arm Vibration and L141 - *Whole-Body Vibration* available from:

www.hse.gov.uk/pubns

The pocket card INDG296(rev2) Hand-arm vibration – A guide for employees provides concise information on HAVS, the symptoms and how to reduce the risks of developing the disease, available at:

www.hse.gov.uk/pubns/indg296.htm?ebul=hsegen&cr=17/23-jun-14

The **Control of Vibration at Work Regulations 2005** can also be viewed in full online at:

www.legislation.gov.uk

### STUDY QUESTION

17. What is meant by "vibration dose"?

(Suggested Answer is at the end.)

# Health Effects of Vibration Exposure

### IN THIS SECTION...

- Workers at risk of HAVS include those using cutting and grinding tools and pneumatic hand tools.
- Those at risk of WBV are principally vehicle and plant driver/operators, especially when moving over rough terrain.
- The main health effect of WBV is back pain.
- The main health effect of HAV exposure is Hand-Arm Vibration Syndrome (HAVS), often characterised by blanching of the fingers on exposure to cold (often called 'vibration-induced white finger').
- The severity of HAVS can be quantified using the Stockholm scale.

## Workers at Risk

### Hand-Arm Vibration

Typical work activities associated with hand-arm vibration exposure include:

- **Percussive metalwork tools**, including:
  - Riveting.
  - Chipping hammers.
  - Fettling tools (used to remove excess metal from castings).
  - Impact wrenches (used to tighten nuts and bolts).
  - Hammer drills.
  - Percussive chisels.
- **Rotary tools and grinders**, including:
  - Rotating abrasive wheels (hand-held angle grinders).
  - Disc cutters.
  - Workpieces held against pedestal grinders.
  - Dental tools.
- **Percussive hammers and drills**, which are used to break up rocks, concrete and masonry.
- **Chainsaws**, brush-cutters and other horticultural and arboricultural equipment.

A petrol driven disc cutter is used to cut concrete. Vibration is delivered into both hands during use. Noise and dust will also be major health hazards

Certain workers may be more vulnerable to continued vibration exposure. These include persons suffering from:

- Existing hand-arm vibration syndrome.
- Raynaud's phenomenon.
- Peripheral vascular disease.
- Trapped nerves in the hand or arm.
- Neurological disorders.
- Past history of injuries or malformation of the hand-arm system.
- Exposure to toxic agents or medication that affects peripheral blood circulation.

### Whole-Body Vibration

Typical work activities involving risk of whole-body vibration exposure include:

- Drivers of heavy vehicles, e.g. tractors and earth-moving vehicles.
- Drivers of forklift trucks.
- Operators of heavy machines, e.g. power presses.
- Aircraft personnel.

WBV exposure is particularly associated with drivers and operators of plant and vehicles that have to move over rough terrain, such as forestry tracks.

Especially vulnerable workers would include those with pre-existing back injuries, pregnant women, young people and those who have undergone back surgery.

## Health Effects

### Whole-Body Vibration

Exposure to Whole-Body Vibration (WBV) can cause great discomfort. However, the principal health risk associated with WBV is back pain.

There are many causes of back pain, such as poor manual handling technique and poor posture. But back pain is also caused or exacerbated by WBV exposure.

WBV has been anecdotally linked to many other ill-health conditions, such as vertigo, but as yet no proven link exists between WBV and any other specific condition. The focus of the HSE guidance relating to WBV is back pain.

### Hand-Arm Vibration

Exposure of the fingers or hands to regular and prolonged vibration can result in a range of disorders:

- Circulatory disorders (blanching of the fingers).
- Neurological disorders (numbness and tingling).
- Muscular effects (difficulty with grip and reduced dexterity).
- Articular effects (bone and joint problems).

Collectively, these are known as **Hand-Arm Vibration Syndrome (HAVS)**.

**Carpal tunnel syndrome** (compression of the median nerve in the wrist) can also be caused by exposure.

### Hand-Arm Vibration Syndrome (HAVS)

The symptoms of HAVS include:

- Numbness and tingling in the fingers, and a reduced sense of touch and temperature, due to damage to nerves in the hand. This damage can make it difficult to feel and handle small objects.
- Periodic **blanching** attacks during which the blood circulation in the fingers is impaired and parts of the fingers become white. This is usually known as **Vibration-Induced White Finger** (VWF). During these attacks the fingers feel numb. As blood circulation returns to the fingers they are throbbing, red and painful. The main trigger for these symptoms is exposure to the cold (rather than exposure to vibration). In rare advanced cases, blood circulation may be permanently affected.
- Joint pain and stiffness in the hand and arm. Grip strength can be reduced due to nerve and muscle damage.

An individual employee with HAVS may not experience the complete range of symptoms, e.g. there may be nerve damage symptoms without there being blood circulation problems and vice versa. The symptoms of HAVS are usually progressive as exposure to vibration continues, e.g. the effects on blood circulation are seen initially in the tips of the affected fingers, with changes spreading up the finger.

There is little evidence to indicate that recovery from VWF occurs when exposure to vibration ceases. Reports indicate recovery is only slight and very slow.

As an attack can be brought on by cold and damp conditions, those affected often have to give up outdoor activities in an effort to reduce the painful blanching attacks that occur.

Finger blanching
Source: L140 Hand-arm vibration, HSE, 2005 (www.hse.gov.uk/pubns/priced/l140.pdf)

## Standardised Diagnostic Tests for HAVS

Several tests are available for quantifying the severity of HAVS in an individual. They can be used in conjunction with reported symptoms in clinical diagnosis by a physician, and to track the progression of the condition.

One in common use is the **Stockholm Workshop Scale**.

The Stockholm Scale is subdivided into two components (the grading is made separately for each hand):

- Vascular (Blood Flow) Tests

  These use a cold challenge to the hands (immersion in cold water):

  – Time taken for the finger to return to full circulation after Cold Provocation Test (CPT).

  – Finger Systolic Blood Pressure (FSBP) test.

- Sensorineural Tests (for Assessing Nerve Damage)

  – Vibrotactile Perception Threshold (VPT) – based on perception of vibrations applied to the finger.

  – Thermal (temperature) Perception Threshold (TPT) – based on subjective judgments on perception of 'hot' and 'cold' with the finger.

Stockholm workshop scale: vascular component

| Stage | Grade | Description |
|---|---|---|
| 0 | - | No attacks |
| 1 | Mild | Occasional attacks affecting only the tips of one or more fingers |
| 2 | Moderate | Occasional attacks affecting tips and middle (rarely, but also parts closest to palm) of one or more fingers |
| 3 | Severe | Frequent attacks affecting all parts of most fingers |
| 4 | Very severe | As in Stage 3, with degenerate skin changes in the fingertips |

Stockholm workshop scale: sensorineural component

| Stage | Symptoms |
|---|---|
| 0SN | Exposed to vibration, but no symptoms |
| 1SN | Intermittent numbness, with or without tingling |
| 2SN | Intermittent or persistent numbness, reduced sensory perception |
| 3SN | Intermittent or persistent numbness, reduced tactile discrimination and/or manipulative dexterity |

## Aggravating Factors

- Exposure to low temperatures not only brings on blanching attacks in those already suffering from HAVS, but would appear to speed up the development of the condition. Workers exposed to hand-arm vibration in cold, wet conditions are therefore at greater risk.
- Worker lifestyle also has an effect, with smokers being more at risk of the condition.
- Individuals with pre-existing circulatory disorders such as Raynaud's phenomenon (sometimes known as Raynaud's disease or syndrome), will also be more at risk.

### STUDY QUESTIONS

18. List the range of work activities associated with hand-arm vibration.

19. Which workers might be exposed to whole-body vibration hazards?

20. Describe the range of effects that vibration can have on the human body.

21. Describe the condition 'vibration-induced white finger'.

(Suggested Answers are at the end.)

# Measurement and Assessment of Vibration Exposure

## IN THIS SECTION...

- Vibration risk assessments should be carried out which consider:
  - The potential sources of vibration and tasks carried out.
  - Any exposure limits that apply.
  - Expected vibration emission levels from equipment.
  - The need for measurements to quantify and characterise vibration and assess effectiveness of
  - existing controls.
  - The potential for elimination of vibration and other controls, such as training.
  - The possibility of exposure to cold environments and the nature of the vibration (HAV or WBV).
- Vibration magnitude can be measured directly using an accelerometer, or taken from manufacturer's data. This data, in combination with duration of contact, can then be used to reliably estimate personal exposures.
- These personal exposures can then be compared to the standards established in national legislation.
- The action values require the employer to act to control exposure. The limit values must not be exceeded.

# Planning a Vibration Survey

## The Principles of Vibration Assessment

The **ILO Code of Practice – Ambient Factors in the Workplace** (Section 10.2) recommends that an assessment of risk from vibration is carried out if workers or others are frequently exposed to hand-arm vibration or whole-body vibration. The aim should be to eliminate vibration at source or reduce it to the lowest practicable level by all appropriate means.

The employer might make use of an external consultant to undertake a vibration assessment. Or, it might be undertaken by an internal person. In either case, the person must be competent. Qualifications from recognised training providers can be used as proof of competence as can experience and membership of organisations such as the British Occupational Hygiene Society (BOHS), etc.

Vibration exposure may lead to risk assessment

## TOPIC FOCUS

**Vibration Risk Assessment**

In the risk assessment, employers should:

- Identify the source of vibration in the workplace and the tasks which are carried out that are likely to result in exposure.
- Consider the exposure limits which may apply (seeking advice from the relevant competent authority).
- Seek advice from the suppliers of equipment and vehicles about their expected vibration emissions.
- If necessary, arrange for a competent person to carry out measurements of vibration.

Consideration should be given to:

- Identifying if there is potential to eliminate the sources of vibration.
- Determining if additional controls, such as training or the use of supports, may be effective in reducing the risk.
- Whether there is a risk of exposure to the cold which could contribute to symptoms of VWF.
- Whether there is a risk of exposure to vibration to the head, eyes or any displays used which could affect the perception of such displays and result in errors.
- Whether there is any potential for body or limb vibration which could affect manipulation of controls.

If the risk assessment determines that they are required, vibration measurements should be used to:

- Quantify the level and duration of worker exposure to vibration.
- Allow comparison to national standards.
- Identify and characterise the sources of vibration.
- Assess the need for engineering controls and other appropriate measures and their effective implementation.
- Evaluate the effectiveness of control measures.

We will consider the measurement and calculation of vibration later in the element.

## Planning the Survey

- ### Who Should Be Assessed?

  All workers likely to be exposed at, or above, a daily exposure action value, e.g. workers who spend some of their day using vibrating hand-held equipment (such as a chainsaw operator) or sit behind the wheel of equipment likely to cause a significant WBV exposure (e.g. dumper truck drivers on a construction site).

  Health surveillance results, such as base line health surveillance when workers first join an organisation and ongoing health surveillance carried out periodically, may identify vulnerable individuals whose vibration exposure needs to be assessed. Examples would include workers exposed to HAV who have Reynaud's syndrome or a pre-existing diagnosis of HAVS and workers exposed to WBV who are recovering from back surgery.

- ### Where?

  For hand-arm vibration, the vibration passing into the hands and arms is of interest and therefore measurements are taken at the hand-grips of the hand-held equipment. For whole-body vibration exposure, it is the vibration passing into the feet (if stood) or seat (if sat) that is of interest and therefore measurements are taken at the surface that is being stood or sat on.

- How?

  If using a vibration transducer (accelerometer) to take actual readings, then the instrument is firmly attached to the vibrating surface or handle. Alternatively, published vibration magnitude data might be used, provided that data give a reliable estimate of actual vibration magnitude exposures.

- For How Long?

  Measurements need to be sufficient to account for variations in the vibration magnitude that would naturally occur during the working day.

  As with integrating sound level meters, measurements should be long enough to obtain an indication of the average level of exposure.

- Group Sampling

  If several workers work on the same task, it would be possible to assess the exposure for all by doing measurements on one, provided the work is genuinely of the same type. Choose the work tasks and durations so as to determine the highest exposure someone is likely to receive.

### Using Published Data

There are many sources of information on vibration magnitudes that can be used to estimate exposures. These include:

- Manufacturers of the tools, machinery, plant or vehicle under investigation.
- Trade associations who have experience with the equipment and work processes in use.
- Peer organisations that are involved in the same industry or process.
- Authorities such as the UK's HSE, who publishes guidance on the typical vibration magnitudes associated with various work activities and items of equipment.

Whatever the source of vibration exposure data, it is essential that it is used appropriately in any evaluation of vibration exposure. The information used must reflect the real situation occurring in the workplace and allowances must be made to take account of 'real world' factors (such as the wear-and-tear that occurs as equipment ages). Provided the margin of error is taken into account and caution is applied during the evaluation process, these data sources can be used to allow a meaningful assessment.

## Taking Measurements

### Instrumentation

Vibration is measured using a vibration meter or accelerometer that has three electronic sensors that measure the acceleration caused by the vibration in each of the three dimensions x, y and z. This meter must comply with the appropriate BS EN ISO standards in terms of design, construction, use, calibration, maintenance and testing.

The monitoring device is attached to the surface, handle or workpiece in contact with the worker. Measurements have to be taken over a long enough period of time to ensure that truly representative average readings have been collected.

During measurement, frequency-weighting is applied to the vibration magnitudes to account for the fact that certain frequencies increase health risk (this is similar to the A-weighting applied during noise measurement).

Once representative measurements of vibration magnitude in all three of the dimensions (x, y and z) have been taken, the treatment varies depending on whether the assessment is for HAV or WBV. In either instance, the vibration magnitude data are combined to give an overall vibration magnitude figure that can then be used to calculate personal daily exposure.

Calculation of vibration dose can be done using the three methods described below. Calculations by any method will require information about the duration of exposure to the vibration. This can be derived by observation or by reference to work schedules, worker interview, etc.

Note that, for HAV, the total time taken to carry out a task is not important; what is important is the amount of contact time, or **trigger time**, when the worker is in contact with the vibrating surface.

# The Importance of Calibration

As for sound level meters, the accelerometer should be calibrated before and after use to ensure the vibration measurements accurately reflect the actual vibration magnitudes. A separate calibrator is used for this purpose; this produces a vibration of a set intensity against which the meter can adjusted.

Both calibrator and accelerometer must be tested and certificated every two years to ensure scientific accuracy.

# Interpretation and Evaluation of Results

## Calculating Vibration Exposure

**Three different methods** can be used to calculate a workers personal exposure:

- Using Equations

  For single exposures to **hand-arm vibration**:

$$A(8) = a_{hv}\sqrt{\frac{T}{T_0}}$$

where: $a_{hv}$ is the vibration magnitude in metres per second squared (m/s$^2$).

$T$ is the duration of exposure to the vibration magnitude $a_{hv}$.

$T_0$ is the reference duration of eight hours (28,800 seconds).

For multiple exposures in the same working period:

$$A(8) = \sqrt{A_1(8)^2 + A_2(8)^2 + A_3(8)^2 + \ldots}$$

where $A_1(8)$, $A_2(8)$, $A_3(8)$, etc. are the partial vibration exposure values for the different vibration sources, each calculated as above.

For single exposures to **whole-body vibration**:

$$A(8) = K.a_w\sqrt{\frac{T}{T_0}}$$

where: $a_w$ is the vibration magnitude (root-mean-squared frequency-weighted acceleration magnitude) in one of three orthogonal directions, **x**, **y** and **z**, at the supporting surface.

$T$ is the duration of exposure to the vibration magnitude $a_w$.

$T_0$ is the reference duration of eight hours (28,800 seconds).

$k$ is a multiplying factor.

For multiple exposures in the same working period:

$$A(8) = \sqrt{\frac{1}{T_0}\sum_{i=1}^{n} a_{wi}^2 T_i}$$

where: $n$ is the number of individual operations within the working day.

$a_{wi}$ is the vibration magnitude for operation $i$.

$T_i$ is the duration of operation $i$.

> **MORE...** www.
>
> The HSE calculators and ready reckoner are available from the main vibration page of the HSE website:
>
> www.hse.gov.uk/vibration/index.htm
>
> From there, you can browse the specific HAV and WBV pages.

- **Use the UK's HSE Calculators**

  Two simple spreadsheet calculators are provided by HSE on their vibration website, one for HAV and one for WBV. These allow for multiple exposures and exposure durations to be entered and output a figure for A(8).

  For each calculator, the measured or estimated vibration magnitudes and the respective durations of exposure are entered. The spreadsheet then calculates the A(8) exposures and indicates where this lies with regards to the legal standards.

- **Use the UK's HSE Ready Reckoner for HAV**

  The guidance to the UK's **Control of Vibration at Work Regulations 2005** (L140 - Hand-Arm Vibration) contains a ready reckoner, which uses a points system to calculate the daily vibration exposure. This ready reckoner is also available on the HSE website.

| Vibration magnitude m/s² | 15 m | 30 m | 1 h | 2 h | 3 h | 4 h | 5 h | 6 h | 8 h | 10 h |
|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 800 | | | | | | | | | |
| 30 | 450 | 900 | | | | | | | | |
| 25 | 315 | 625 | 1250 | | | | | | | |
| 20 | 200 | 400 | 800 | | | | | | | |
| 19 | 180 | 360 | 720 | 1450 | | | | | | |
| 18 | 160 | 325 | 650 | 1300 | | | | | | |
| 17 | 145 | 290 | 580 | 1150 | | | | | | |
| 16 | 130 | 255 | 510 | 1000 | | | | | | |
| 15 | 115 | 225 | 450 | 900 | 1350 | | | | | |
| 14 | 98 | 195 | 390 | 785 | 1200 | | | | | |
| 13 | 85 | 170 | 340 | 675 | 1000 | 1350 | | | | |
| 12 | 72 | 145 | 290 | 575 | 865 | 1150 | 1450 | | | |
| 11 | 61 | 120 | 240 | 485 | 725 | 970 | 1200 | 1450 | | |
| 10 | 50 | 100 | 200 | 400 | 600 | 800 | 1000 | 1200 | | |
| 9 | 41 | 81 | 160 | 325 | 485 | 650 | 810 | 970 | 1300 | |
| 8 | 32 | 64 | 130 | 255 | 385 | 510 | 640 | 770 | 1000 | 1200 |
| 7 | 25 | 49 | 98 | 195 | 295 | 390 | 490 | 590 | 785 | 865 |
| 6 | 18 | 36 | 72 | 145 | 215 | 290 | 360 | 430 | 575 | 720 |
| 5.5 | 15 | 30 | 61 | 120 | 180 | 240 | 305 | 365 | 485 | 605 |
| 5 | 13 | 25 | 50 | 100 | 150 | 200 | 250 | 300 | 400 | 500 |
| 4.5 | 10 | 20 | 41 | 81 | 120 | 160 | 205 | 245 | 325 | 405 |
| 4 | 8 | 16 | 32 | 64 | 96 | 130 | 160 | 190 | 255 | 320 |
| 3.5 | 6 | 12 | 25 | 49 | 74 | 98 | 125 | 145 | 195 | 245 |
| 3 | 5 | 9 | 18 | 36 | 54 | 72 | 90 | 110 | 145 | 180 |
| 2.5 | 3 | 6 | 13 | 25 | 38 | 50 | 63 | 75 | 100 | 125 |
| 2 | 2 | 4 | 8 | 16 | 24 | 32 | 40 | 48 | 64 | 80 |
| 1.5 | 1 | 2 | 5 | 9 | 14 | 18 | 23 | 27 | 36 | 45 |
| 1 | 1 | 1 | 2 | 4 | 6 | 8 | 10 | 12 | 16 | 20 |

Daily exposure time

The ready reckoner - available from the HSE website
Source: L140 Hand-arm vibration, HSE, 2005 (www.hse.gov.uk/pubns/priced/l140.pdf)

# Comparison with Legal Limits

There are no internationally recognised standards or exposure limits for the control of vibration. We will consider some national and regional examples in this section.

## Europe and the UK

In Europe, the directive **2002/44/EC** (known as the Physical Agents (Vibration) Directive) established limits that were to be implemented. In the UK this was achieved through the **Control of Vibration at Work Regulations 2005**, which specify exposure limit values and action values for both hand-arm and whole-body vibration.

- Hand-arm vibration:
  - The daily exposure limit value is 5m/s² A(8).
  - The daily exposure action value is 2.5m/s² A(8).
- Whole-body vibration:
  - The daily exposure limit value is 1.15m/s² A(8).
  - The daily exposure action value is 0.5m/s² A(8).

Where an **Exposure Action Value (EAV)** is likely to be reached or exceeded, the employer must:

- Reduce exposure to as low a level as is reasonably practicable by introducing appropriate organisational and technical measures.
- Provide appropriate health surveillance.
- Provide information, instruction and training to employees.

> **MORE...** www.
>
> The UK legal limits can be found in the **Control of Vibration at Work Regulations 2005** (as before) and further information and explanation is available from the HSE:
>
> www.hse.gov.uk/vibration/index.htm
>
> The EU directive **2002/44/EC** is available from:
>
> http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0044

The employer must ensure that his employees are not exposed to vibration above the **Exposure Limit Value (ELV)**.

If exposure above the limit value does occur then the employer must:

- Immediately reduce exposure to below the limit value.
- Identify the reason for that limit being exceeded.
- Prevent the limit from being exceeded again.

The directive and corresponding UK regulations also require that health surveillance and information, instruction and training are provided where there may be a health risk to individuals exposed below the EAV. This would be appropriate for workers who are particularly vulnerable to the effects of HAV or WBV, for example those who are:

- Identified as suffering from HAVS.
- Known to suffer from Raynaud's phenomenon or other circulatory disorders.
- Known to have a pre-existing back injury.
- Recovering from back surgery.

## Australia

Australia has developed standards for:

- Whole-body vibration – AS 2670.1-2001 – *Evaluation of human exposure to whole-body vibration*, which is identical to **ISO 2631-1:1997**, *Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration*.
- Hand-arm vibration – AS 2763-1988 – *Vibration and shock – Hand-transmitted vibration – Guidelines for measurement and assessment of human exposure,* which is aligned with **ISO 5349:2001**, *Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration.*

These Australian Standards do not define what the safe limits of exposure to vibration are, but provide guidance on how to evaluate exposure to vibration.

In Australia, there are no specific vibration regulations, but the **Commonwealth Occupational Health and Safety Code of Practice 2008** has a specific section on vibration and prescribes a process for controlling the risks of vibration exposure in accordance with the hierarchy of controls. It also states that where hazardous vibration has been identified, employers must measure the vibration levels and recommends that employers should regularly monitor and review the exposure levels of workers, assess the control measures in place and undertake regular medical checks of workers.

## USA

In the USA, the **Occupational Safety and Health Administration (OSHA)** has not developed standards for occupational exposure to vibration, but the American Conference of Governmental Industrial Hygienists (ACGIH) has developed Threshold Limit Values (TLVs) for vibration exposure (see the following table). These represent acceleration levels and exposure durations to which most workers may be exposed repeatedly without severe damage to the fingers. The ACGIH advises that these guidelines be applied in conjunction with other protective measures including vibration control.

The ACGIH is not a policy-making organisation and the TLVs they recommend are not enforceable or a form of regulation in America.

| ACGIH Threshold Limit Values | |
|---|---|
| **Total Daily Exposure Duration (hours)** | **Maximum value of frequency-weighted acceleration ($m/s^2$) in any direction** |
| Between four and eight hours | $4m/s^2$ |
| Between two and four hours | $6m/s^2$ |
| Between one and two hours | $8m/s^2$ |
| Less than one hour | $12m/s^2$ |

### STUDY QUESTIONS

22. Outline a strategy to implement a risk assessment for hand-arm vibration.

23. State three methods for reliably estimating the daily exposure of a worker to hand-arm vibration if the vibration magnitude and duration of exposure are known.

(Suggested Answers are at the end.)

# Controlling Vibration and Vibration Exposure

- Control of vibration exposure can be achieved by applying controls in a priority order:
  - Elimination of exposure.
  - Purchase of equipment with low vibration performance.
  - Equipment maintenance.
  - Reduction in the time of exposure.
  - Providing information, instruction and training.
  - Providing PPE (not an option for WBV).
- Health surveillance must be provided for workers exposed to HAV above the EAV and those diagnosed with HAVS.

## Practical Control Measures

Practical control measures for reducing occupational exposure to **hand-arm vibration** include:

Equipment must be selected appropriately

- Elimination

  It is sometimes possible to eliminate vibration exposure from a task completely. Where the ELV is exceeded, this may be the only way of reducing exposure. Elimination might be achieved by changing work methods entirely or by changing items of plant and equipment. For example:

  - Changing fabrication methods, e.g. using adhesives or welding to avoid using pneumatic riveting hammers.
  - Replacing pneumatic 'buzz' saws with laser profilers for cutting thin steel sheet.
  - Using prefabricated components to reduce the need for 'cutting and patching' to fit on site.
  - Mechanising or automating processes that use hand-held machines.
  - Using machine-mounted breakers, mobile road-cutting machines and/or trenching machines instead of hand-operated road breakers for trench-work.
  - Splitting large blocks using hydraulic expanding devices inserted into pre-drilled holes ('bursting').

- Equipment Selection

  If the use of vibrating hand-tools cannot be avoided by elimination, then exposure can be reduced by appropriate equipment selection. Many manufacturers include low vibration or anti-vibration features in their equipment design, e.g. anti-vibration handles on hand-held power tools. Manufacturers are also required by law to make vibration data available to purchasers. It is, therefore, possible to make informed choices about what equipment to buy:

  - Establish a purchasing policy that specifies vibration as one criteria of selection and vet new equipment on
  - this basis.
  - Use manufacturer's data to select low-vibration magnitude equipment.
  - Choose equipment that will be efficient in use; the less time the equipment is in use, the lower the exposure time and the lower the dose.

- Choose equipment that is lighter to hold, so requiring less grip-strength.
- Look at the ergonomics of use and choose equipment that is comfortable to use, as this usually indicates less force is required in use.

MORE...

www.

Again, the UK HSE website has lots of useful information and links on this topic at:

www.hse.gov.uk/vibration/index.htm

- Care and Maintenance

  Tools and equipment suffer wear and tear during normal use. This inevitably increases the vibration magnitude generated:

  - Replace worn parts and correct unbalanced equipment.
  - Maintain any anti-vibration devices or features on equipment (such as anti-vibration handles).
  - Sharpen tools to reduce both the vibration generated and the duration of the job (exposure time).

- Job Rotation

  Job rotation and rest breaks can reduce exposure time:

  - It is relatively easy to identify the amount of contact or trigger time that a worker can use a tool for before they approach the relevant action or limit values, provided the vibration magnitude of the equipment is known. The UK's HSE HAV ready reckoner or online calculator can be used for this. In this way, a maximum permitted exposure time can be identified for individual items of equipment.
  - Alternatively, where multiple exposures are likely to take place during a work period, the vibration exposure
  - can be tracked for each individual to ensure that personal exposure does not exceed the relevant action or limit values.

- Information, Instruction and Training
  - Information on the risks of the use of vibrating equipment and the associated health conditions should be provided.
  - Instruction on the control measures to minimise the risk should be given. Some of this will relate to equipment use, but it should also include advice on keeping hands warm and dry to maintain good blood circulation.

- PPE
  - Anti-vibration gloves are available on the market. Their use as a control measure is questionable however, as they may be ineffective at reducing vibration at the most damaging frequencies and may even increase vibration at some frequencies. Guidance does not recommend their use as a control measure.
  - Gloves and other items of PPE should be used however to keep the hands warm and dry.

Practical control measures for reducing occupational exposure to **whole-body vibration** include:

- Elimination

  Since most WBV exposure is to vehicle drivers and operators, elimination and automation are unlikely to be an option in many instances. However, it may be possible to reduce the risk of WBV by using automated guided vehicles in a warehouse.

- Equipment Selection

  Vehicle and plant manufacturers include low-vibration or anti-vibration features in their design, for example anti-vibration cab and seat suspension systems. Manufacturers are also required by law to make vibration data available to purchasers. The following points should be considered when selecting equipment:

  - Establish a purchasing policy that specifies vibration as one criterion of selection and vet new equipment on this basis.
  - Use manufacturers' data to select low-vibration magnitude equipment.

- Choose equipment that is going to be suitable for the job and environment of use (e.g. adequate load capacity, right size wheels for the terrain, capable of required speeds, etc.).
- In particular, focus on the suspension systems for seats, cabs and vehicle body, all of which isolate the driver from the movement of the tyres over rough ground.

- Care and Maintenance
  - Balance wheels to eliminate judder.
  - Maintain any anti-vibration devices or features (such as seat or cab suspension systems).
  - Maintain traffic routes by grading surfaces and filling potholes to keep surfaces as smooth as practical.
- Reduced Time Exposure
  - Job rotation and rest breaks can reduce exposure time.
  - Maximum duration of use can be applied to vehicle and plant provided reliable vibration magnitude data is available. The HSE online calculator can be used for this purpose.
- Information, Instruction and Training
  - Information on the risks of exposure to WBV and the associated health conditions should be provided.
  - Instruction and training on the control measures to minimise the risk should be given. This will relate to vehicle use, care and maintenance.
  - PPE is not available to control against WBV.

## Health Surveillance

**ILO Code of Practice – Ambient Factors in the Workplace** (Section 10.4) recommends that health surveillance is carried out for all workers potentially exposed to vibration in the workplace. This could take the form of the following checks:

- A pre-employment medical to identify symptoms of HAVS and other non-occupational diseases such as Raynaud's phenomenon.
- Periodic medical examinations for those workers exposed to hand-arm vibration, including the identification of possible symptoms of HAVS such as numbness and loss of sensation.

In the event that symptoms are detected, the employer should be informed that there may be a weakness in the controls.

### STUDY QUESTION

24. Discuss the control options available to reduce the risk from hand-arm vibration.

(Suggested Answer is at the end.)

# Summary

## Basic Concepts of Noise

We have described how:

- Noise is defined as 'all sound which can result in hearing impairment or be harmful to health or otherwise dangerous'.
- A noise source generates pressure waves in air. Two characteristics of these pressure waves, their amplitude and frequency, are important in understanding their nature:
- The amplitude determines the intensity of the noise - measured using the decibel scale (dB).
- The frequency - determines the pitch of the noise - measured in hertz (Hz).
- The decibel scale is a logarithmic scale. The addition of 3dB is a doubling of noise intensity.
- The human ear is not equally sensitive to all frequencies; consequently, the A-weighting matrix (represented by dB(A)) is used to correct for this frequency bias when calculating the amount of energy that has been delivered into the inner ear.
- The amount of damage done to the inner ear is determined by the dose of noise received. Dose is determined by two factors: the intensity of the noise (dB(A)) and the duration of exposure.

## Health Effects of Noise Exposure

We have described how:

- The human ear detects noise by mechanically transmitting sound pressure waves from the outer ear through to the inner ear. There, fine sensory hairs respond to the pressure waves in fluid, sending nerve signals to the brain.
- Exposure to excessively loud noise can physically damage the transmission structures of the ear and can also cause deterioration of the sensory hairs in the inner ear.
- Tinnitus, Temporary Threshold Shift (TTS), Permanent Threshold Shift (PTS) and Noise-Induced Hearing Loss (NIHL) are all health effects associated with exposure to loud noise.
- Audiometry can be used as a form of health surveillance to determine the sensitivity of a person's hearing. The graphs produced (audiograms) can be used to differentiate between age-related hearing-loss (presbycusis) and NIHL.
- As a result of audiometry, a worker's hearing can be categorised and appropriate action taken to manage their health.
- There are various advantages and disadvantages to audiometry, which may be required by national legislation.

## Measurement and Assessment of Noise Exposure

We have described how:

- Noise surveys must be carefully planned to ensure that representative measurements are taken to give a true reflection of real noise exposures occurring at work.
- Several different instruments are available for measuring noise; simple sound level meters, Integrating Sound Level Meters (ISLM), dosimeters and octave band analysers.
- ISLMs used for noise surveys must be calibrated before use and must be tested and certificated for results to be valid.
- Key information recorded during a survey is the equivalent continuous A-weighted sound pressure level ($L_{Aeq}$), maximum C-weighted peak sound pressure level ($L_{CPeak}$) and the duration of exposure.

- $L_{Aeq}$, in combination with duration of exposure, is then used to calculate a daily personal noise exposure ($L_{EP,d}$). This can be done using formulae, the UK's HSE web-based calculator or the HSE ready reckoner.
- Calculated personal exposures ($L_{EP,d}$) can then be compared to the legal standards.

## Controlling Noise and Noise Exposure

We have described how:

- Noise control can be achieved by applying a hierarchy of controls:
  - Reduce noise at source by eliminating hazardous noise at source, changing the source, re-locating the source, re-designing the source and maintenance.
  - Attenuate noise transmission by isolating the source, damping, using acoustic barriers or using an acoustic enclosure for the source.
  - Control noise exposure at the receiver using acoustic havens, hearing protection zones and the use of passive and active hearing protection, limiting exposure time and health surveillance.
- Hearing protection must be carefully selected by reference to its attenuation data and the noise profile of the workplace. Three different methods exist to determine the attenuation achieved: octave band analysis, HML and SNR.

## Basic Concepts of Vibration

We have described how:

- Hazardous vibration can be divided into two types: Hand-Arm Vibration (HAV) and Whole-Body Vibration (WBV).
- Vibration can be characterised using several factors, notably the magnitude (measured in $m.s^{-2}$), frequency (hertz, Hz) and direction (in three dimensions x, y and z).
- The harm caused by vibration is determined by dose, in turn determined by the vibration magnitude and duration of exposure. The eight-hour energy-equivalent vibration magnitude is used as the standard daily exposure.

## Health Effects of Vibration Exposure

We have described how:

- Workers at risk of HAVS include those using cutting and grinding tools and pneumatic hand tools. Those at risk of WBV are principally vehicle and plant driver/operators, especially when moving over rough terrain.
- The main health effect of WBV is back pain.
- The main health effect of HAV exposure is HAVS, often characterised by blanching of the fingers on exposure to cold (often called 'vibration-induced white finger').
- The severity of HAVS can be quantified using the Stockholm scale.

## Measurement and Assessment of Vibration Exposure

We have described how:

- Vibration risk assessments should be carried out which consider:
  - The potential sources of vibration and tasks carried out.
  - Any exposure limits which apply.
  - Expected vibration emission levels from equipment.
  - The need for measurements to quantify and characterise vibration and assess effectiveness of existing controls.
  - The potential for elimination of vibration and other controls, such as training.
  - The possibility of exposure to cold environments and the nature of the vibration (HAV or WBV).

- Vibration magnitude can be measured directly using an accelerometer, or taken from manufacturer's data. This data, in combination with duration of contact, can then be used to reliably estimate personal exposures.
- These personal exposures can then be compared to the standards established in national legislation.
- The action values require the employer to act to control exposure. The limit values must not be exceeded.

## Controlling Vibration and Vibration Exposure

We have described how:

- Control of vibration exposure can be achieved by applying controls in a priority order:
  - Elimination of exposure.
  - Purchase of equipment with low vibration performance.
  - Equipment maintenance.
  - Reduction in the time of exposure.
  - Providing information, instruction and training.
  - Providing PPE (not an option for WBV).
- Health surveillance must be provided for workers exposed to HAV above legal standards and those diagnosed with HAVS.

# Exam Skills

## QUESTION

By now you should be getting the hang of exam-style questions. This one is a good example of a 10-mark question on the topic of whole-body vibration. Remember, you should aim to spend around 15 minutes on a 10-mark question in the exam, so time yourself as you complete this activity and see if you can provide a full answer in that time.

Bulldozer drivers at a large construction site have reported incidences of back pain which they believe are caused by exposure to whole-body vibration.

(a) **Outline** a range of control measures that could be used to minimise the risk of the drivers experiencing back pain caused by exposure to whole-body vibration. **(7)**

(b) **Identify THREE** other possible work-related causes of the back pain being experienced by the bulldozer drivers. **(3)**

## Suggested Answer Outline

(a) The examiner would expect an outline including seven points from the following:

Vehicle selection (size, power suited for task); keep individual exposure at least below exposure limit value (try to reduce below exposure action value, too); suspension seats (vibration damped, adjustable for individual weights); work patterns (breaks, job rotations); instruction (minimising WBV, avoidance of jolts/shocks).

(b) Your answer could include any three of the following:

Poor posture; prolonged sitting; poor control layout (stretching/twisting/over-reaching); lack of adjustability of seating; repeated mounting of and jumping down from high cab; manual handling.

## Example of How the Question Could be Answered

*(a) In order to minimise the risk of drivers experiencing back pain caused by exposure to whole-body vibration, initial controls would include fitting suspension seats with vibration damping and improving suspension on vehicles.*

*Maintenance of vehicles and daily checks on conditions such as tyre pressure and suspension would also reduce vibration levels.*

*Job rotation would reduce the exposure time of drivers and heated seats and back support might reduce the actual risk of harm. Selecting seating to suit operators (taking into account their shape, size and weight) is also an important control measure and provision of information to drivers on hazards and controls should assist compliance with the control measures in place. In the longer term, selection of low-vibration vehicles would minimise the overall risk.*

*(b) Three possible reasons for back pain could be:*

- *Poor posture of the driver caused by seat design or cab layout.*
- *The need to sit for extended periods without rest or movement.*
- *Lack of seat adjustment to accommodate the different range of drivers who may be required to use the equipment.*

## Reasons For Poor Marks Achieved By Candidate in Exam

- They did not discuss vibration attenuation in relation to tracked vehicles.
- They confused whole-body and hand-arm vibration.
- They referenced the **Control of Vibration at Work Regulations 2005**, or other national legislation and, particularly, the exposure limit and action values.
- They did not relate causes of the back pain to the scenario in the question.

Element IB7

# Radiation

## Learning Outcomes

Once you've read this element, you'll understand how to:

1. Outline the nature of the different types of ionising and non-ionising radiation.
2. Explain the effects of exposure to non-ionising radiation, its measurement and control.
3. Outline the effects of exposure to ionising radiation, its measurement and control.
4. Outline the different sources of lasers found in the workplace, the classification of lasers and the control measures.

# Contents

# Types of Ionising and Non-Ionising Radiation

### IN THIS SECTION...

- Radiation can be grouped into two main types: ionising and non-ionising.
- Ionising radiation causes ionisation in the material that absorbs it – this delivers energy into the material and promotes unusual chemical reactions that would otherwise not occur.
- The electromagnetic spectrum is the full range of frequencies that electromagnetic radiation can be found at, from high-frequency gamma-rays to low-frequency long wave radiowaves.
- All types of non-ionising radiation are electromagnetic waves and can be broadly categorised as optical (ultraviolet, visible and infrared radiation) and electromagnetic fields (or radiofrequencies: microwaves and radiowaves).
- Ionising radiation can be grouped into five different types: alpha and beta particles, neutrons, x-rays and gamma-rays. These vary in their properties and characteristics, particularly in their ability to penetrate matter. Three of these types of ionising radiation are particulate in nature – alpha particles, beta particles and neutrons. The two others, gamma- and x-ray, are forms of high-energy electromagnetic radiation.
- Two international agencies set standards with regards to radiation safety: the International Commission for Radiological Protection (ICRP) and the International Commission for Non-Ionising Radiological Protection (ICNIRP).

## Introduction

Radiation is energy that is emitted by a source.

There are two basic kinds - known as electromagnetic and particulate radiation, respectively. Electromagnetic radiation is made up of energy waves (these are often described as being 'pure energy'). Particulate radiation is made up of particles (these particles carry energy, just as waves do, but they also have mass). Some radiation can cause ionisation when it strikes matter and so you will also find that radiation may be referred to as ionising or non-ionising. Particulate radiation considered in this section is all ionising radiation. Some forms of electromagnetic radiation can also be ionising, but some forms are not. We'll look at these terms (ionising, non-ionising, electromagnetic, particulate) in more detail below.

Radiation can be ionising or non-ionising

## Distinction Between Ionising and Non-Ionising Radiation

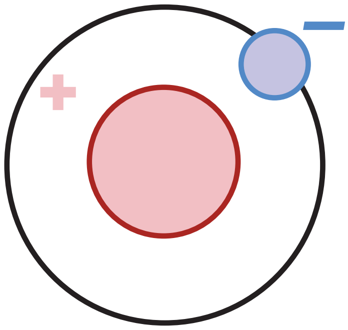
Simply put, ionising radiation is radiation that causes ionisation in the material that absorbs it and non-ionising radiation is radiation that does not cause ionisation in the material that absorbs it.

In order to understand ionisation it is first necessary to explain basic atomic structure.

## Sub-Atomic Physics

Unfortunately, sub-atomic physics is unavoidable when trying to properly understand radiation, so let's look at a simple way of thinking about atomic structure:

- All matter is made up of atoms.
- Atoms have a structure rather like an onion: a central core surrounded by layers or shells.
- The shells of the atom contain one or more electrons moving around at high speed.
- The core of the atom contains the atomic nucleus which is made up of two types of sub-atomic particle; protons and neutrons.
- Electrons are relatively small and light with a negative (-ve) electrical charge (-1).
- Protons are relatively big and heavy with a positive (+ve) electrical charge (+1).
- Neutrons are relatively big and heavy with no overall electrical charge (neutral).
- The number of protons in the nucleus of an atom determines which chemical element that atom is. For example, hydrogen has one proton in its nucleus, carbon has six and uranium has 92.
- The number of electrons in the shells around the nucleus normally matches the number of protons in the nucleus. This means that the positive electrical charge of the protons is exactly balanced by the negative electrical charge of the electrons (e.g. for hydrogen, one proton in the nucleus plus one electron in orbit around the nucleus = +1 + -1 = 0 charge). In this way, a hydrogen atom has a net neutral electrical charge.



Hydrogen atom
One proton in the nucleus at the core One electron orbiting in a shell around the nucleus

Having set the scene, we can now move on to define ionisation.

## Ionisation

**Ionisation** occurs when one or more electrons are removed from its shell around the nucleus of an atom:

- Removal of an electron means that the number of protons in the nucleus is no longer balanced by the number of electrons. The result is that the atom has a net **positive charge**. It is referred to as an **ion**.
- Ions take part in chemical reactions very readily. For example, hydrochloric acid has a large number of hydrogen ions available for chemical reaction. That is why the acid reacts easily with other substances and why it is corrosive.

If an atom is joined to other atoms to form a molecule, ionisation of that atom will often mean that the molecule falls apart.

As we noted earlier, ionising radiation **causes** ionisation in the material that absorbs it:

- So, if ionising radiation is absorbed by living tissue, then atoms inside that living tissue will be converted to ions by the radiation. In effect, the radiation kicks electrons out of their shells.
- This is why ionising radiation is damaging to living tissue. The radiation causes the destruction of molecules making up the cell and, in particular, it causes the destruction of DNA.
- Simply put, the ionising radiation delivers energy into the living tissue, causing high-energy chemical reactions to take place.

(The health effects of ionising radiation will be described in more detail later in this element.)

Note that if you are unfamiliar with the principles being discussed here, it is easy to confuse ionisation and radioactivity. Just because an atom has been ionised does not mean that it is radioactive.

Radioactivity is often a **source** of ionising radiation. Ionisation is the **effect** of that radiation.

If it helps, you can think of a radioactive material as acting as a source of energy supplying power in the form of ionisation in the same way that a battery acts as a source of energy supplying power to a light bulb. When you flick the switch, the battery does not turn the light bulb into another battery. It simply puts energy into the bulb which then lights up.

(Radioactivity will be introduced later in this section.)

## The Electromagnetic Spectrum

The electromagnetic spectrum is the spectrum made up of all possible frequencies or wavelengths of electromagnetic radiation (see the following diagram.

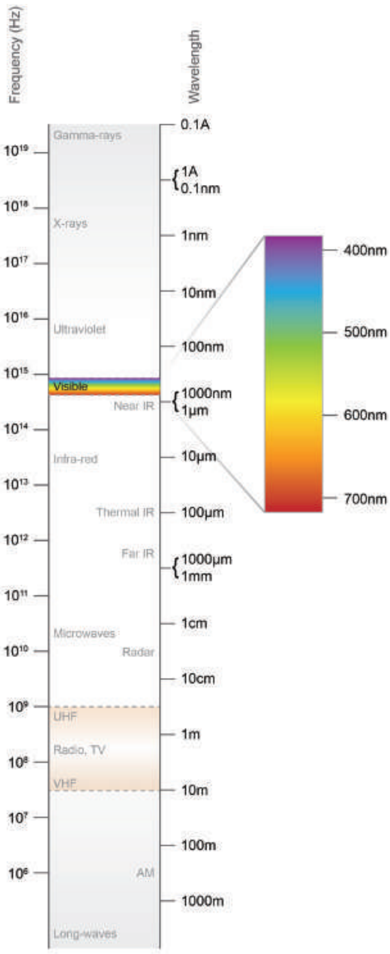
You may remember from previous elements that the wavelength of a waveform is the distance (in metres) from one peak to the next and that frequency is the number of waves per second (in hertz). Since the speed of electromagnetic radiation is fixed (at the speed of light) as wavelength increases, frequency decreases. The two parameters are therefore inversely proportional to one another.

**Visible light** is a form of electromagnetic radiation.

The human eye is sensitive to a very narrow part of the electromagnetic spectrum, between wavelengths of 400 to 700 nanometres.

As the wavelength gets shorter (and frequency increases), the light becomes invisible to the human eye and we enter the **ultraviolet** (**UV**) frequencies. Continue to shorten the wavelength and increase frequency and we move up through the **x-ray** frequencies and **gamma-ray** frequencies. This is the very high-energy end of the spectrum.

If, however, we return to the visible part of the spectrum and then increase wavelength (decrease frequency) we drop out of the bottom of the visible light spectrum and into the **infrared** (**IR**) frequencies. Again, these frequencies cannot be seen by the human eye but they can be felt (in the form of radiant heat). Carry on increasing wavelength and decreasing frequency and we move down into the **microwave** and then the **radiowave** frequencies. All TV and radio signals, from Ultra-High Frequency (UHF) to long wave are broadcast in this part of the spectrum. This is the low-energy end of the spectrum.



The electromagnetic spectrum

All electromagnetic radiation has some features in common; it moves at the speed of light ($3 \times 10^8$ m/s) and in straight lines (unless interfered with in some way). Beyond these similarities, electromagnetic radiation at different frequencies has very different characteristics. These can best be understood by looking at the way the spectrum can be broken up into sections:

- Ionising Electromagnetic Radiation

  This is the high-energy end of the spectrum, up to 100 nanometres wavelength. **Gamma-rays** and **x-rays** form this part of the spectrum. These rays are so high-energy that they can kick electrons out of their atomic shells and cause ionisation, as described previously.

  – **Gamma-rays** are emitted from the nucleus of many radionuclides during radioactive decay (see later). A typical occupational source of gamma-rays would be the radionuclide Cobalt 60 used for industrial radiography (a form of non-destructive testing).

- **X-rays** are emitted from the electron shells around the nucleus. X-rays are generated artificially by bombarding a metal target with electrons inside a vacuum tube - a typical occupational source of x-rays would be an x-ray generator used for medical radiography.

Both gamma rays and x-rays, like light, 'shine' in straight lines at the speed of light. They are very penetrating and can shine through many types of material, such as paper, aluminium and human tissues. They are unlikely to penetrate through 50mm-thick lead. They will shine for kilometres through the atmosphere.

- Non-Ionising Electromagnetic Radiation

This is lower energy end of the spectrum, which includes optical radiation and radio frequencies:

- **Optical Radiation**

  This section of the spectrum is made up of UV, visible and IR light. These wavelengths do not cause ionisation, but they can still cause damage to the skin and, in particular, to the eye. Typical occupational exposures would include:

  - Ultraviolet – naturally occurring in sunlight, emitted from sunlamps, arc welding, etc.
  - Visible – naturally occurring in sunlight, emitted from visible lasers, arc welding, etc.
  - Infrared – emitted from any hot object but, particularly, things glowing red, yellow or white hot, such as metal casting, molten glass, furnaces, etc.

- **Radiofrequencies (RF)**

  This section of the spectrum is made up of microwaves and radiowaves. These wavelengths do not cause ionisation. They can, however, be absorbed by the body to cause internal heating. Typical occupational exposures would include:

  - Microwave – emitted by communications equipment, microwave cookers.
  - Radiowaves – emitted from satellite communications, TV and radio broadcasts, radar, Magnetic Resonance Imaging (MRI) in medical diagnosis.

You will notice from the above that the electromagnetic spectrum is made up of two types of ionising radiation (x-rays and gamma-rays) and various types of non-ionising radiation (UV, visible, IR, microwaves and radio-frequencies). In fact, **all types** of non-ionising radiation are electromagnetic waves. The same cannot be said for ionising radiation, however.

## Particulate Radiation

Earlier in this element, we saw how the electromagnetic spectrum comprises a wide range of types of radiation, some of which (like x-rays) are ionising and some of which (like IR) are not. In this section, we look at **particulate** radiation - alpha particles, beta particles and neutrons - all of which are forms of ionising radiation. These are made of sub-atomic particles rather than electromagnetic rays. They are emitted by radioactive substances. Later in this element, we will return to examine the topics of radioactivity and how radioactive decay produces different forms of ionising radiation. For now, we just need to be concerned with the three principal types of particulate ionising radiation (see Topic Focus).


Image displayed by an infrared camera sensitive to IR radiation given off by the human body

TOPIC FOCUS

### Types of Particulate Radiation

- **Alpha particles** are particles made up of two protons and two neutrons. They are emitted from the nucleus during radioactive decay. Alpha particles are far less penetrating than gamma-rays. They can only move through a few centimetres of air and are unable to penetrate even thin material, such as paper or aluminium foil. Alpha particles striking the skin are unlikely to be absorbed by living skin tissue as the dead layer of cells at the top of the epidermis (horny layer) will block their entrance. A typical occupational source of alpha particles is smoke detectors.

Alpha particles released from a source radionuclide (central white blob) make ionisation trails (fuzzy white streaks) in a cloud chamber

- **Beta particles** are particles made up of one electron. They are emitted from the nucleus during radioactive decay (and in case you were wondering what an electron is doing in the nucleus, it is created when one of the neutrons in the nucleus spontaneously splits apart to become one proton and one electron. The proton stays in the nucleus but the electron is spat out). Beta particles are more penetrating than alpha particles but far less penetrating than gamma-rays. They can pass through metres of air, through paper and through the horny layer at the top of the epidermis. They cannot pass through thicker material, such as several centimetres of aluminium or 1mm-thick lead. A typical occupational source of beta particles is thickness gauges.
- **Neutrons** are particles from the nucleus emitted during certain types of radioactive event, usually fission reactions inside nuclear reactors. Neutrons are the most penetrating form of all. They can pass through tissue and even relatively thick dense materials, such as 50mm of lead. Neutron-absorbing shields are often made of concrete. Water is an excellent neutron shield, which is why spent nuclear fuel is stored in pools. A typical occupational source would be a nuclear reactor at a nuclear power plant.

# Radiation Protection Agencies

The two main international radiation protection agencies are the International Commission on Radiological Protection (ICRP) and International Commission on Non-Ionising Radiation Protection (ICNIRP). Many countries have formed regulatory and advisory bodies responsible for radiological protection at national level.

## International Commission on Radiological Protection

This is an independent, registered charity based in Sweden. It was established to advance the science of radiological protection. The ICRP provides guidance and recommendations on protection from ionising radiation. Their guidance and recommendations are used as the basis for European Directives (and therefore also for national legislation). The ICRP established the key principle of justification in radiation protection, namely:

> *"no practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes."*

## International Commission on Non-Ionising Radiation Protection

This is an independent, non-profit organisation based in Germany and comprised of scientific experts. It was established to examine possible adverse effects on human health of exposure to non-ionising radiation. The ICNIRP's stated principal aim is to "disseminate information and advice on the potential health hazards of exposure to non-ionising radiation to everyone with an interest in the subject". The ICNIRP publishes guidance (such as exposure guidelines), consulting with organisations such as the World Health Organisation, the ICRP and professional organisations, such as the Institute of Electrical and Electronics Engineers (IEEE).

**MORE...** www.

General information on radiation is available from the ICRP and the ICNIRP at the following websites:

www.icrp.org

www.icnirp.de

Information on radiation is also available from the HSE and Public Health England at:

www.hse.gov.uk/radiation

www.gov.uk/government/organisations/public-health-england

www.onr.org.uk/index.htm

**STUDY QUESTIONS**

1. State the two main categories of non-ionising radiation.
2. Suggest five broad regions of the electromagnetic spectrum that can be used to classify non-ionising radiation.
3. What is the source of beta radiation and what is it used for?
4. What is the difference between gamma radiation and x-rays?

(Suggested Answers are at the end.)

# Non-Ionising Radiation

## IN THIS SECTION...

- Non-ionising radiation is produced by the sun (both UV and visible light from the sun are significant health hazards) and artificially by various types of equipment, such as sunbeds (UV), arc-welding (UV, visible and IR), furnaces (IR), ovens (microwaves) and radio transmitters (microwaves and radiowaves).
- Each type of non-ionising radiation has specific health effects:
  - UV can cause sunburn, arc-eye, premature ageing of the skin and increased risk of skin cancer.
  - Visible light can cause damage to the retina and permanent blindness.
  - IR can cause skin burns and cataracts.
  - Radiofrequencies can cause burns and internal heating.
- Exposure Limit Values (ELV) for non-ionising radiation are set out in national and regional standards, e.g.in the EU, the EU Physical Agents (Electromagnetic Fields) Directive (2013/35/EU).
- Control of exposure to non-ionising radiation is achieved by risk assessment and application of a standard control framework.
- Protection from harmful UV, visible and IR radiation can often be achieved by eye protection and skin protection.
- Protection from EMF radiation is achieved by isolation, interlocks, safe systems or work (including permit systems) and maintaining distance from source.

## Sources of Non-Ionising Radiation

Non-ionising radiation comprises electromagnetic radiation from the UV, visible, IR, microwave and radiowave wavelengths. Sources of non-ionising radiation can be both natural and man-made.

The sun emits non-ionising radiation at all wavelengths

### Natural Sources

A very significant source of many of these forms of non-ionising radiation is the sun. The sun emits non-ionising radiation at all wavelengths, but the wavelengths that are most important from an occupational health point of view are visible and UV light. Any worker required to spend significant periods of time outdoors is exposed to these forms of non-ionising radiation.

### Artificial Sources

Different man-made sources will emit different forms of non-ionising radiation. Typical examples of sources for each form include:

- **UV** – sunlamps in tanning salons, arc-welding, science lab equipment, ink and adhesive curing.
- **Visible** – general lighting, cutting and welding, theatre and photographic lights, visible light lasers used in various applications.
- **IR** – metal furnaces, glass furnaces, fire, heat lamps.
- **Microwave** – microwave ovens, mobile phone masts, mobile phone antennae.
- **Radiowaves** – communications equipment.

In some instances, the wavelength of the radiation emitted can be closely controlled and emission of one form of non-ionising radiation occurs (e.g. a microwave oven does not emit IR or other radiowaves). In other instances, a source can emit across a wide band of wavelengths and, consequently, may emit several different forms of radiation at once (e.g. arc welding results in the emission of intense UV, visible and IR light – all of which are unwanted by-products of the welding process).

White-hot flame emits intense UV, visible and IR light

## Routes of Exposure and Effects of Non-Ionising Radiation

The routes of exposure to non-ionising radiation will vary to a degree, depending on the type of radiation. The main exposure route for optical radiation (UV, visible and IR) is direct or indirect exposure of the eyes and skin. These are the two parts of the body prone to damage from these forms on non-ionising radiation. Direct exposure can result from directly looking at the source of the radiation, or being adjacent to the source without protection. For example, an arc-welder might glance at their workpiece without putting their face-shield on; this would result in direct UV exposure of the eyes and the skin of their face. Indirect exposure might occur as a result of reflected light rays. For example, a lab technician might receive a visible laser light strike to their eye as a result of the laser light reflecting off a shiny surface, accidentally introduced into the beam of the laser.

For microwave and radiofrequencies, since these forms of non-ionising radiation can penetrate into the body, the routes of exposure will be as a result of being within the beam of, or close to, the source of the radiation. Any part of the body, whether covered or not, is likely to absorb the radiation if it is within the radiation pathway.

The health effects of non-ionising radiation depend on the form of radiation.

### Ultraviolet

Health effects resulting from an excessive exposure to ultraviolet radiation depend mainly on the wavelengths of the radiation. As penetration into dense material is limited, its effect on the human body will be mainly confined to the outer skin and the eyes.

**Acute effects** of exposure to ultraviolet radiation include:

- **Skin** – sunburn (reddening of the skin or **erythema**) as a result of exposure to wavelengths below 315nm. The severity depends on the duration and intensity of the exposure; people with a dark skin have a higher threshold than those with fair skin.
- **Eye** – arc-eye (inflammation and temporary blindness, also known as ‘snow-blindness’ or ‘photokeratitis’), as a result of exposure to wavelengths below 315nm. This is essentially sunburn to the outer layers of the eye; the conjunctiva and cornea. Symptoms normally start several hours after exposure and will last for 36 hours.

Erythema on the surface layers of the eye

**Chronic effects** of exposure to ultraviolet radiation include:

- **Premature ageing of the skin** – as a result of destruction of the long collagen molecules in the skin that give it elasticity.
- **Skin cancer** (melanoma) – as a direct result of UV damage to DNA molecules in skin cells and as an indirect result of the production of free radicals (atoms, molecules or ions with unpaired electrons) by UV in skin tissue.
- **Cataracts** – yellowing of the lens of the eye.

Other health effects associated with UV exposure include:

- **Photosensitisation** – sensitisation of the skin caused by UV exposure of chemicals in, or on, the skin, such as tar compounds, synthetic dyes, antibiotics and tranquillisers, which can build up in the skin during medication.
- **Formation of toxic contaminants** – ultraviolet radiation of wavelengths below 250nm has the ability to produce ozone and oxides of nitrogen. These gases have an irritant or corrosive effect on the respiratory system, causing inflammatory conditions similar to bronchitis. Both ozone and oxides of nitrogen form hazardous gaseous environments where arc welding is carried out and must be removed from the breathing zone by exhaust ventilation systems.

## Visible

The most obvious effect is nuisance or disability glare as a result of being dazzled by the intense visible light:

- **Nuisance glare** – being dazzled by intense light that causes the pupil of the eye to contract, so making less intense areas more difficult to see (e.g. trying to look at a computer screen when facing a sunlit window).
- **Disability glare** – being dazzled by intense light that causes the retina to become unresponsive to light, resulting in temporary blindness (e.g. staring at a light bulb and then trying to look at an image).

These effects directly affect safety. Other health effects resulting from an excessive exposure to visible light radiation depend on wavelength, intensity and duration of exposure:

- **Blue light hazard** – retinal damage as a result of exposure to short wavelength visible light (at the blue end of the spectrum). This is thought to lead to permanent damage to retina cells and has been implicated in age-related macular degeneration (a form of blindness).
- **Permanent blindness** – as a result of exposure of the retina to intense light, as might be encountered when using a laser (especially Class 3B or 4, e.g. for laser surgery or metal cutting – the classification of lasers will be covered later) or when using optical instruments such as a telescope and accidentally looking at the sun.

## Infrared Radiation

Infrared radiation is produced by hot bodies and covers the wavelength region of about 700nm to 106nm. Wavelengths between 750nm and 1,300nm are able to penetrate the skin and cornea. A maximum penetration of about 5mm into the skin occurs at about 1,100nm, while maximum absorption in the liquid humour and the lens of the eye occurs at 1,300nm.

- **Acute effects** – reddening of the skin (erythema) and surface layers of the eye.
- **Chronic effects** – cataracts can occur from occupational exposure to white-hot surfaces over a period of about 15 years through the absorption of infrared radiation in the lens of the eye.

Infrared radiation emitted by fire

## Microwaves

Microwave radiation covers the wavelength region between about 1mm and 1m. Biological harm is caused by the process of internal heating, the heat being generated by the vibration or rotation of water molecules. This is the way that a microwave oven works; it heats food by causing excitation of water molecules in the food.

While the body as a whole has effective temperature-regulating systems, certain tissues, such as the lens of the eye, have poor or non-existent blood supplies and hence a poor capacity for temperature control by heat transfer.

It is such tissues that are most at risk from microwave exposure, since only a relatively small temperature increase is needed to damage cell proteins.

Health effects are only seen at significant exposures, such as accidental exposure to intense microwave radiation inside an industrial oven or microwave transmitter.

Chronic health effects associated with low level exposure (such as the use of mobile phones) are unproven.

Health effects caused by mobile phone radiation exposure is unproven

## Radiowaves

Radiofrequency wavelengths cause a similar internal heating effect to microwaves. Contact with an active transmitter is likely to result in skin and tissue burns. A significant exposure to intense radiowaves would be required to cause internal heating at a distance. So, those in the immediate vicinity of an active powerful radar or radiowave transmitter are at risk.

Chronic health effects from low level exposure are unproven. (**Lasers** are dealt with in a separate section towards the end of this element.)

# Quantifying Exposure

Optical radiation can be measured using a light meter or lux meter. These measure the amount of light falling onto a surface. Specific meters are required for measuring UV, visible or IR radiation. Radiofrequency radiation can be measured using an electromagnetic field (EMF) meter.

There is a number of terms that are commonly used in specifying exposure to radiofrequency and optical radiations:

- Irradiance or Power Density

  This is a measure of power per unit area, typically given in watts per square metre or centimetre ($W/m^2$ or $W/cm^2$).

- Specific (Energy) Absorption Rate (SAR)

  This is a measure of the amount of power deposited in the body by radiation (and so the biological effects) – typically given in W/kg. It varies from point to point in the body, as different parts have different conductivities and different resonant frequencies for maximum absorption, etc. In the case of radiofrequency radiation, which includes microwaves, energy deposition chiefly results in heat. Different SAR limits have been developed worldwide, e.g. the limits established for the sale of mobile telephones in the US by the Federal Communications Commission may differ from those established in the EU by CENELEC.

- Radiant Exposure (Incident Energy per Unit Area) or 'Dose'

  Typically given in Joules per square metre or centimetre ($J/m^2$ or $J/cm^2$).

## Exposure Limit Values

At national level, established competent authorities develop standards based on guidance from the International Commission on Non-Ionising Radiation Protection (ICNIRP). For electromagnetic fields in the frequency range 100kHz to 10GHz, the ICNIRP has issued whole-body average exposure guidelines of a Specific Absorption Rate (SAR) of $0.4W/kg^{-1}$ for people at work averaged over any six-minute period. Other values have been published for localised effects (head, trunk, limbs, etc.).

Exposure limit values vary depending on the frequency of the radiation and the part of the body exposed, with the current occupational exposure SAR for head and trunk exposure given as $10\ W/kg^{-3}$. It is also accepted that people not at work (members of the public) should have a lower exposure and, hence, the SARs are set at lower values, e.g. at $0.08\ W/kg^{-3}$ for whole-body exposure and $2W/kg^{-3}$ for head and trunk exposure. Common head and trunk exposure will result from mobile phone usage, therefore national limits have been established to limit the SAR value of phones.

Though ICNIRP has set guidance values, these are not always the values that appear in regional or national legislation. So, for example, there are differences between EU legislation as set out in EU Directives and transposed into national legislation and the standards that apply in USA.

## Risk Assessment

The **ILO Code of Practice – Ambient Factors in the Workplace** (Section 7.2) provides guidance on the assessment of risk posed by optical radiation (ultraviolet, visible light and infrared radiation). It states that employers should assess equipment and activities likely to give rise to hazardous levels of radiation, including work outdoors exposed to the sun. The risk assessment should consider:

- Any equipment that is likely to give rise to a risk of exposure. Information should be sought from suppliers about the potential emissions and any controls required during installation and use.
- Any activities that are likely to give rise to a risk of exposure.
- Comparison of measured exposure levels with exposure limits obtained from the competent authority (established in national or international law or national standards).
- The potential for the misuse or misunderstanding of safety precautions. Examples of misuse would include violations of safety rules such as access restrictions.

## Control Measures for Non-Ionising Radiation

A common framework for control can be applied to both optical (UV, visible and IR) and electromagnetic field (EMF) radiation:

Signs are an example of control measure of non-ionising radiation

- Eliminate as far as possible – explore alternative technologies.
- Other working methods may reduce the risk – administrative controls for routine operation and maintenance, permits, etc.
- Choose equipment emitting less radiation.
- Technical measures to reduce unwanted emission of radiation – interlocks, shielding, enclosures, screens, etc.
- Maintenance.
- Design, siting and layout of workplaces and workstations – control over direction, stray fields/reflections (e.g. painting surfaces matt black), etc.
- Limit the duration and level or intensity of exposure, e.g. time, distance (except in the case of lasers, where increasing the distance doesn't work!).
- PPE, e.g. eye protection.
- Follow manufacturer instructions.
- Develop and implement safe systems of work.
- Provide information, instruction and training.
- Signs.

A range of commercial instruments are available for monitoring and measuring non-ionising radiation over the whole of the electromagnetic spectrum. Monitoring should be in relation to the standards to ensure that exposure levels are adequately controlled.

We shall now take a look at specific controls used for each type of non-ionising radiation covered earlier.

## Protection from Ultraviolet Radiation

In occupational settings, ultraviolet radiation often demands the establishment of **safe-person strategies** and personal protection, e.g. where electric arc welding is carried out. Simple shielding of the skin by keeping it covered forms adequate protection. Body areas at risk are the backs of the hands, the forearms and the neck, which can be protected by wearing long-sleeved overalls with high collars and gloves. The face can be protected by the use of a face-shield which cannot be penetrated by ultraviolet radiation.

The eyes must be protected with the use of eye protection that absorbs ultraviolet radiation. Special optical filters have been developed for this. Injury to the retina from intense visible light in welding operations must also be reduced with the use of filters. Mobile or temporary screen may be necessary to protect passers-by from welding flash.

Where ultraviolet radiation is produced in a discharge system and forms part of a process, safe-place strategies can be used. The radiation can be contained in screened areas, interlock systems can be fitted to lamp-housing, and all surfaces can be made dull or matt black to prevent reflections. An important point to note is that many cases of 'arc eye' have been caused in people not involved in welding processes, but as a result of reflected radiation.

With a large number of systems using ultraviolet radiation as part of the process, administrative controls involving limitation of access to the radiation area, use of warning signs, limitation of exposure and the use of distance protection are methods that must be adopted.

## Protection from Infrared Radiation

Protection from infrared radiation can be achieved by good engineering design, by enclosing, insulating and shielding IR sources where possible. As with all forms of radiation, maintaining distance from the source will significantly reduce exposure. PPE in the form of IR-absorbing or reflecting eye protection and skin protection is also an effective safe person approach. This method of protection is used by fire-fighting personnel.

## Protection from Microwave and Radiofrequency Radiation

To control exposure of persons working in the vicinity of equipment that generates microwave radiation or other forms of radiofrequency radiation, the whole system should be enclosed in a metal structure to attenuate the level of radiation outside the enclosure to less than the maximum permissible exposure limit. Isolation and lock-off of equipment should be carried out before transmitters are worked on or near. Any access doors, gates or hatches should be interlocked to prevent activation of the transmitter when access is being gained. Additional administrative controls may also be needed, such as a permit-to-work system to control access to transmitter arrays.

Maintaining distance from the source of EMF is also an effective control and is the primary method of ensuring safety for non-workers. For example, mobile phone transmitters are built on masts to keep them at a distance from members of the public.

An alternative approach is to limit the power output of the transmitter and/or limit the duration of exposure.

### STUDY QUESTIONS

5. What are the hazards of exposure to ultraviolet radiation?
6. What are the hazards of microwave radiation and how can harmful exposure be controlled?
7. Describe the framework or approach for control of exposure to non-ionising radiation.

(Suggested Answers are at the end.)

# Ionising Radiation

## IN THIS SECTION...

- Ionising radiation is produced by the spontaneous radioactive decay of radioactive substances in rocks, soils, water and air. This is natural background ionising radiation.
- Ionising radiation is also produced and used in many workplace applications, from smoke detectors to industrial and medical radiography equipment, such as x-ray sets.
- Ionising radiation sources can be hazardous outside the body, depending on the radiation's ability to penetrate into body tissues. Sources can also be extremely hazardous inside the body. Radioactive substances can get into the body by the normal routes - inhalation, ingestion, skin absorption and injection. The physical form of a radioactive substance affects its available routes of entry.
- The acute effects of exposure to ionising radiation (radiation sickness) include nausea, vomiting, diarrhoea, fever and death. These effects are non-stochastic; they do not occur below a particular dose threshold.
- The chronic effects of exposure to ionising radiation are an increased risk of cancer and genetic damage.These effects are stochastic; there is no known threshold below which the effects cannot occur and the greater the dose, the greater the risk.
- Several different terms and units are used to quantify ionising radiation: activity (becquerel), absorbed dose (gray), equivalent dose (sievert) and effective dose (sievert).
- Activity and dose can be measured using equipment such as thermo-luminescent dosimeters. Dose assessments can only be carried out by Approved Dosimetry Services (ADSs).
- Control of exposure to external radiation sources is achieved using three principles: time, distance and shielding.
- Control of exposure to internal radiation sources is achieved by preventing the inhalation, ingestion, absorption or injection of the radioactive substance in the first place.
- The annual dose limit set in the **ILO Code of Practice – Radiation Protection of Workers (Ionising Radiations)** for employees over 18 is an effective dose of 50mSv. Dose limits are also set for trainees, pregnant women and members of the public. Lower dose limits may be imposed by national legislation.
- The primary dose limits apply to workers engaged in radiation work. Workers not engaged in radiation work are treated as if they were members of the public in terms of restricting radiation exposure.
- Work areas where workers are likely to receive certain specified doses have to be designated as controlled or supervised areas. These areas must be demarked, signed, monitored for radioactivity and made subject to local rules.
- The employer may have to designate a competent Radiation Protection Officer (RPO) to survey the application of radiation protection regulations, standards and rules and to provide advice on all relevant aspects of radiation protection.

## Sources of Ionising Radiation

As outlined in the first section of this element, ionising radiation comprises x-ray and gamma-ray electromagnetic radiation and alpha particles, beta particles and neutrons. Sources of ionising radiation can be both natural and man-made.

Nuclear power stations are a source of man-made radiation

## Natural Sources

A very significant source of most of these forms of ionising radiation is the earth itself. The rocks that make up planet Earth are radioactive, containing dozens of radionuclides. A typical example is uranium 238, found at low concentrations in all rocks, soil and water. The radioactive decay of uranium has 14 steps (this will be explained later in this section). Each uranium atom emits eight alpha particles and six beta particles as it decays through these steps. The half-life of uranium is extremely long, hence this radiation is emitted slowly from the uranium (again, the principle of half-life will be explained later in this section).

Significantly, one of the elements formed by the slow radioactive decay of uranium in the ground is radon 222. Radon is a gas at normal temperature and pressure so, once formed, it escapes from the rock and diffuses into the atmosphere.

The Earth - a significant source of ionising radiation

Once in the atmosphere, it may be inhaled. The sun also emits ionising radiation but most of this is filtered out by the earth's atmosphere, and very high energy gamma-rays, called 'cosmic rays', bombard the earth from space.

As a result of these naturally occurring radiation sources, our bodies are being exposed to all of the forms of ionising radiation all of the time. This is referred to as background radiation. This background radiation cannot be described as safe, since all ionising radiation carries some inherent health risk (see later). What we do know, however, is that our bodies have very efficient mechanisms to repair the damage caused by this low-level background radiation. So, the background radiation levels give us an idea of the kind of radiation level that might be considered tolerable as a result of occupational exposure.

## Artificial Sources

Artificial sources of ionising radiation can consist of naturally occurring radionuclides that have been mined, extracted and concentrated. Alternatively, artificial sources may contain radionuclides that have been made in nuclear reactors. Many of the radionuclides used for cancer radiotherapy are manufactured in this way.

Typical examples of sources for each form include:

- **Alpha particles** – emitted by radionuclides and used in smoke detectors, anti-static devices and certain types of cancer tumour radiotherapy.
- **Beta particles** – emitted by radionuclides and used in thickness gauges, medical and science lab work as tracers and cancer tumour therapy.
- **Neutrons** – emitted by fissile material, such as uranium 235 and plutonium 239 inside nuclear power plants, and generated by high-energy particle beam collisions in nuclear physics research facilities.
- **X-rays** – generated by bombarding a metal target with high-energy electrons in a vacuum tube. They are used for medical radiography, industrial radiography, security scanning of objects and people, quality control during manufacturing and laboratory analysis, such as x-ray crystallography.
- **Gamma-rays** – emitted by radionuclides, such as caesium 137 and used in industrial radiography, some medical radiography, cancer tumour radiotherapy and in medical and science lab work.

# Concepts in Radioactivity and Radiation Exposure

## Radioactivity Explained

### RECAP

Just a reminder of where we were with a simple model of atomic structure:

- Electrons (-ve charged particles) are found whizzing around in shells around the nucleus.
- Protons (+ve charged particles) and neutrons are found in the nucleus at the core.
- The number of protons in the nucleus of an atom determines which chemical element that atom is. This is an important point to remember for the next section.
- The number of electrons in the shells around the nucleus normally match the number of protons in the nucleus, resulting in an overall neutral electrical charge.

So, now to move on to account for radioactivity in this model:

- The number of neutrons in the nucleus of an atom can vary; this gives rise to the existence of different types of the same element that have the same number of protons and electrons but different number of neutrons. These are called 'isotopes' or 'nuclides'.
- For example, hydrogen normally has one proton, one electron and no neutrons. It can, however, have one proton, one electron and one neutron. This is a nuclide of hydrogen called deuterium. Alternatively, it can have one proton, one electron and two neutrons. This is the nuclide tritium. All three atoms are hydrogen because they all have one proton.
- Most atoms have a stable structure in that the number of protons and neutrons in the nucleus does not change.
- Some atoms, however, have an unstable nucleus that cannot maintain its structure over time. When this occurs, the nucleus will, at some stage, spontaneously fall apart. This is the process of radioactive decay. An atom with an unstable structure is called a 'radionuclide'.

Smoke detector
Contains an encapsulated radionuclide - americium 241

- In the hydrogen example given above, deuterium is stable (not a radionuclide) but tritium is an unstable radionuclide; it is radioactive.
- When an atom undergoes radioactive decay, it will emit ionising radiation. There are several different forms of ionising radiation that might be emitted and the exact form emitted will depend on the radionuclide involved. The radiation emitted is predictable; any given radionuclide always gives off the same type of ionising radiation.

This leads us to the topics of half-life and decay chains.

## Half-Life and Decay Chains

One other factor that is predictable about a radioactive material is how quickly a particular radionuclide will undergo spontaneous radioactive decay. Some radionuclides decay very quickly, others very slowly. The rate at which radioactive decay occurs is known as the 'half-life'. This is the length of time that it would take for half of the atoms of any given radionuclide to undergo radioactive decay.

For example, the radionuclide uranium 238 has a half life of approximately 4.5 billion years. This means that if you take a 1kg block of pure uranium 238 and wait 4.5 billion years, then analyse the same block of material, you will find only 500g of uranium 238. Half of the uranium 238 atoms have undergone spontaneous decay and are no longer present.

One thing to note about radioactive elements is that, when a radionuclide atom undergoes radioactive decay, it is not all converted to radiation. Some small part of each atom is emitted as radiation, but the rest remains. Importantly, the number of protons in the atom's nucleus is changed. This means that the atom is converted from one element to another element. Often, this new element is itself a radionuclide. In other words, when a substance undergoes radioactive decay it often produces a new substance that is also radioactive. This new radioactive substance will then decay, emit ionising radiation and might produce another radioactive substance in turn.

For example, when an atom of uranium 238 undergoes radioactive decay, it gives off ionising radiation (an alpha particle) and the atom is converted to thorium 234. This is a radionuclide, so it decays to form protactinium 234 and emits ionising radiation (a beta particle). There then follow another 12 radioactive decay events, making a grand total of 14 steps in the decay chain! Finally, we end up with a lead 206 atom. This is stable (not radioactive). See the diagram below for the full decay chain (note this is an example and does not have to be memorised!)

| Type of Radiation | Nuclide | Half-Life |
|---|---|---|
| α | uranium-238 | $4.5\times10^{9}$ years |
| β | thorium-234 | 24.5 days |
| β | protactinum-234 | 1.14 minutes |
| α | uranium-234 | $2.33\times10^{5}$ years |
| α | throium-230 | $8.3\times10^{4}$ years |
| α | radium 226 | 1590 years |
| α | radon-222 | 3.825 days |
| α | polonium-218 | 3.05 minutes |
| β | lead-214 | 26.8 minutes |
| β | bismuth-214 | 19.7 minutes |
| α | polonium-214 | $1.5\times10^{-4}$ seconds |
| α | lead-210 | 22 years |
| β | bismuth-210 | 5 days |
| β | polonium-210 | 140 days |
| α | lead-206 | stable |

Uranium 238 radioactive decay chain

Note how each step in the chain is accompanied by an alpha particle (α) or beta particle (β) emission.

## Quantifying Exposure

Several different units are used to quantify the activity of a radioactive source and the dose of radiation that an exposed individual might receive (note that these are the standard SI units and are not universally adopted; other units for quantifying radiation and dose exist):

- Radioactivity and the Becquerel (Bq)

  A measure of the rate at which a radionuclide is decaying to produce ionising radiation. In other words, a measure of how **hot** a radioactive source is. One Becquerel is one disintegration per second. This is used to indicate the amount of radiation produced and/or the amount of a radioactive material present.

  One limitation of the becquerel is that it does not indicate how much of this radiation is actually being absorbed. For this we turn to:

- Absorbed Radiation Dose and the Gray (Gy)

  This is a measure of the amount of energy deposited into matter by the radiation. One gray is equivalent to one joule per kilogram.

  Acute radiation sickness will occur with whole-body doses of 1 gray or less (in other words, 1 gray per kg of bodyweight; equivalent to 75 joules of energy for a 75kg person) and could prove fatal. Whole-body doses of 8 gray or more are always fatal.

  One limitation of the gray is that it does not take into account the fact that different types of ionising radiation cause more or less biological damage. To account for this, we turn to:

- Equivalent Dose and the Sievert (Sv)

  This is a measure of the likely biological damage resulting from radiation exposure. The equivalent dose relates to the dose received by a tissue or part of the body, weighted to take account of the different biological effects of different types of radiation.

  A 'radiation weighting factor' is used so that doses from different sources can be compared in terms of the harm they cause. The unit of dose equivalence is the Sievert (Sv).

  Equivalent dose (Sv) = Absorbed dose (Gy) × Radiation Weighting Factor

  The following table identifies the weighting factor for different types of radiation:

Weighting Factors for Radiation

| Type of Radiation | Radiation Weighting Factor |
|---|---|
| Gamma-rays, x-rays, beta particles | 1 |
| Slow neutrons | 5 |
| Fast neutrons | 20 |
| Alpha particles | 20 |

One limitation with this is that different body tissues respond to radiation exposure in different ways. For example, one sievert of radiation to the skin does not carry the same health risk as one sievert delivered to lung tissue. For this, we turn to:

- **Effective Dose and the Sievert (Sv)**

This is a measure of the whole-body dose of radiation received. This is the weighted sum of all the equivalent doses. To calculate effective dose, the equivalent dose, for each tissue is multiplied by its respective **tissue-weighting factor.** These products are then added together to arrive at the effective dose for the whole body.

For example, the tissue-weighting factor for gonads (testes or ovaries) is 0.2, compared to 0.01 for the skin.

Effective dose (Sv) = Sum of (equivalent dose × tissue-weighting factor)

- **Dose Rate**

This is the dose absorbed in unit time and indicates the amount of radioactive dose received by a person within a certain period of time.

## AN ANALOGY

These four different characteristics can be confusing, so try this analogy.

Imagine standing in front of a wall of shotguns, each of which is firing lead pellets at you. The shotguns vary in the rate at which they fire and the size of pellet that they fire:

- The activity (becquerel) gives an indication of the rate at which the shotguns fire. The larger the number, the more guns fire each second.
- The absorbed dose (gray) gives an indication of the number of pellets that hit you; the larger the number, the more pellets go in.
- The equivalent dose (sievert) gives an indication of how much damage each pellet does to a body part – this varies depending on pellet size. Bigger pellets do more damage so are given a larger weighting factor to account for their larger size (equivalent dose = absorbed dose × pellet weighting factor).
- The effective dose (sievert) gives an indication of how much damage your body suffers **as a whole**, since being shot in the finger is nasty, but being shot in the head will kill you. This is accounted for by giving different body parts a tissue weighting factor. The effective dose is the sum of all of the individual body part equivalent doses multiplied by their respective tissue-weighting factors.

So, if someone hangs around in front of this wall for a minute, they might be hit five times, twice in the arms (one small pellet one medium-sized), twice in the legs (two large pellets) and once in the torso (medium-sized).

Their absorbed dose is 5Gy.

But their equivalent dose to different body parts is:

Arms (1 × 1) + (1 × 5) = 6Sv

Legs (2 × 20) = 40Sv

Torso (1 × 5) = 5Sv

Their whole-body effective dose is:

(6 × arm weighting factor (0.1)) + (40 × leg weighting factor (0.2)) + (5 × torso weighting factor (0.5)) = 0.6 + 8.0 + 2.5 = 11.1Sv

Obviously, this analogy breaks down pretty quickly if you stop to think about it seriously, but it can be useful as a way of trying to understand why several different characteristics and units have to be used.

## Routes of Exposure to Ionising Radiation

The routes of exposure to ionising radiation will depend largely on the type of ionising radiation in question and the nature of its sources.

One critical factor in determining the possible routes of exposure is the penetrating power of the radiation:

- **Alpha particles** have little penetrating power, can be stopped by a few centimetres of air, a sheet of paper or the horny layer of dead cells at the surface of the epidermis.
- **Beta particles** have more penetrating power, can move through several tens of centimetres of air and can penetrate through the horny layer and into living tissue beneath.
- **Neutrons, x-rays and gamma-rays** are extremely penetrating and can pass through kilometres of air and right through the human body (longer wavelength x-rays are less penetrating and are absorbed by hard tissue, such as bone and teeth).

The conclusion to draw here is that alpha particle sources present little risk to health, provided they are kept **outside** the body because the radiation cannot penetrate the skin to cause harm. Beta particle sources do present a health risk when **outside the body**, but that risk can be relatively easily controlled by separation from the source. Neutrons, x-rays and gamma-ray sources present a significant health risk when outside the body because the radiation can shine though objects, through air and into the body to cause harm.

Another critical factor in determining the possible routes of exposure is the nature of the radiation source and its physical form. The influence of physical forms are familiar from previous elements:

- **Solids** – in their massive form are unlikely to get into the body and therefore may be harmful on contact with the skin during handling, but otherwise may present little health risk.
- **Dusts** – can become airborne and may be inhaled. Once in the lungs, the dust may be deposited or may even be absorbed into the bloodstream.
- **Liquids** – can be ingested with relative ease, put into contact with skin or may be able to permeate through the skin (especially if mixed with solvents).
- **Mists** – can be inhaled into the lungs and absorbed into the bloodstream.
- **Gas and vapours** – can be inhaled into the lungs and then absorbed into the bloodstream.

The routes of entry are also familiar; inhalation, ingestion, absorption through the skin and injection through the skin (by penetration or at region of skin damage).

These factors have to be looked at together in order to determine the most significant routes of entry. For example:

- Uranium 238 is an alpha particle emitter. A solid chunk of uranium can be handled safely with only a pair of gloves for protection. It cannot be inhaled, ingested or pass through the skin. The alpha particles produced have little penetrating power.
- Americium 241 used in smoke detectors is an alpha particle and low-energy gamma-ray emitter. In its metal capsule inside the smoke detector, this material presents little risk to people. But if it were burnt to form a dust and then inhaled, then significant exposure might occur.
- Caesium 137 is an alpha particle emitter that also produces high-energy gamma-rays. This radionuclide cannot be handled safely at all outside of its heavy lead enclosure. Gamma-ray exposure could happen even with the caesium 137 in another room or part of a site.

## Health Effects of Ionising Radiation

Ionising radiation can cause ionisation in the cells that make up body tissues. The part of the cell that is most readily damaged by ionising radiation is its DNA. To explain this health effect it is necessary to set the scene with a little biology revision.

## BIOLOGY REVISION

The human body is made up of trillions of cells. Almost every cell (with the notable exception of red blood cells) contains a nucleus (no, this is different; no protons or neutrons in this one). The nucleus contains the genetic material of the cell, in the form of 23 pairs of chromosomes. Each chromosome consists of one very long single molecule of deoxyribonucleic acid (DNA). Spaced out along each chromosome are genes, sections of the DNA molecule that contain the instructions that tell the cell how to work. Not all of these genes are active all of the time; they are only switched on where and when needed. They are, however, critical in controlling the proper functioning of the cell.

If a chemical change is introduced into a strand of DNA, then that molecule is said to be mutated. Mutations occur all of the time in human body cells; they are a fact of life. Most mutations do not occur in genes, they occur in sections of DNA that do not contain genes. Even if a mutation does occur in a gene, it may be in a gene that is inactive or it may not introduce any change in the way that an active gene functions. There will be times, however, when a mutation occurs that alters the way that a gene works; a damaging mutation. If the gene plays a part in the control of cell division, then it is possible that uncontrolled cell division might occur. This is the basis for cancer cell formation. Uncontrolled cell divisions lead to the growth of a tumour and the potential for tumour cells to spread and invade other tissues. Cells have defence mechanisms to prevent this kind of damaging mutation leading to uncontrolled cell division. These defence mechanisms lead to programmed cell death (apoptosis).

# Acute and Chronic Effects of Ionising Radiation

## Acute Effects

There are no immediate **acute** ill-health effects of exposure to very low levels of ionising radiation. We are all exposed to background radiation all of the time and no acute symptoms or ill health are detected.

At low doses, ionising radiation causes ionisation in cells. This ionisation damages the DNA that makes up the cell chromosomes. This damage is either:

- repaired, in which case the cell continues to function, or
- cannot be repaired, causing the cell to undergo programmed cell death, or
- cannot be repaired, leading to a mutation that may have an influence in the future, but has no immediate health effect.

Damage to DNA is a chronic ill-health effect of exposure to ionising radiation

Above a particular threshold dose, however, acute effects will be detected. These effects become more marked as the dose of radiation increases. The effects are the result of massive cell death caused by direct damage to the DNA of cells (the DNA is literally shredded by the radiation) or by indirect programmed cell death as a result of damage. This is **acute radiation sickness** (or 'acute radiation syndrome'). Typical symptoms include:

- Nausea and vomiting.
- Hair loss.
- Diarrhoea.
- Headache.
- Fever.
- Central nervous system impairment.
- Skin burns and ulceration.
- Death.

At low doses, symptoms may not start to become apparent for 24-48 hours. At very high doses, symptoms will appear within minutes of exposure and death will be certain even with medical attention.

For example, 31 people died of acute radiation sickness within three months of the Chernobyl nuclear disaster in 1986. Several of these deaths occurred with a few minutes of exposure.

Certain cells in the body are more prone to damage by ionising radiation, most especially:

- White blood cells – leading to low white blood cell count and a suppressed immune system.
- Lining of the intestines – leading to destruction of the gut wall and invasion of the body cavities by gut bacteria.
- Bone marrow cells responsible for red blood cell production – leading to anaemia.

The acute effects of ionising radiation can be described as **deterministic** (or **non-stochastic**), meaning that they are predictable and will not occur below a particular threshold level. Above the threshold, there is a clear relationship between the severity of the effect (response) and the dose of radiation received. This is the same dose/response relationship that was seen for many toxic substances.

## Chronic Effects

The **chronic** ill-health effects of exposure to ionising radiation are an increased risk of cancer and genetic damage. Exactly the same damage and repair mechanisms described above will occur, but the person may not suffer any symptoms of acute radiation exposure because the dose of radiation received is too low to cause any significant cell death:

- Damage to the DNA in the cell nucleus leads to mutation of genes.
- These mutations cause the cell to divide in an uncontrolled manner, forming a tumour.
- The cells' self-repair mechanisms fail to detect the error and so programmed cell death does not occur.
- This may happen because the genes responsible for the repair mechanism and apoptosis are themselves damaged or mutated by the radiation. Simply put, if the radiation damages or mutates the right combination of genes, cell division goes out of control and the cell doesn't recognise this and does not kill itself.

The doses of radiation capable of causing the kind of genetic change leading to cancer are known to be very small. There is no known threshold below which this effect does not occur. So, we can say that there is **no known safe level** of exposure to ionising radiation where there is no risk of cancer. As the dose of ionising radiation increases, the risk of cancer increases. At high doses the risk is greater, but cancer is not a determined outcome. Thus, the chronic effects of exposure to ionising radiation are **stochastic** or chaotic effects; involving the **probability** of an ill-health effect.

The damaging effects of ionising radiation may occur in the **somatic cells**; these are the normal cells of the body, such as bone marrow cells, brain cells, liver cells, white blood cells, etc. Mutation or DNA damage to these cells will result in the **somatic effects**, either the cell repairing the damage, dying or carrying the mutation forward in time to a point where it starts the cell down the route of carcinogenesis.

Alternatively, the damaging effects of ionising radiation may occur in **germline cells**; these are the cells of the body responsible for passing genetic material on from parent to offspring (specifically, the eggs in the ovaries of a woman and the sperm-producing cells in the testes of a man).

Such damage and mutation to germline DNA results in the **genetic effects** of ionising radiation:

- Sterility.
- Heritable genetic defects in children.

# Measurement of Radiation and Exposure

The detection and measurements of radiation can be achieved using various instruments. These can be used to establish the:

- Type of radiation present.
- Quantity of radioactivity present.

- Type of radiation that a worker has been exposed to.
- Dose of radiation that a worker has been exposed to.

## Passive Dosimeters

The primary means of determining personal radiation exposure is by means of a dosimeter. Passive dosimeters do not provide a direct (i.e. immediate) display of the radiation dose. Instead, they have to be treated or analysed in some way to extract the result. It is issued and worn by persons who may be exposed to radiation during the course of their work. After a given period, quarterly or monthly depending on the potential level of exposure, the dosimeter is removed and analysed. Results can be used to estimate the personal exposure to different types of ionising radiation, i.e. radiation dose.

Dosimeter

Assessments from the dosimeter are recorded in personal radiation dose records. Running totals are kept to ensure that permissible levels are not exceeded.

### Thermo-Luminescent Dosimeters (TLDs)

The Thermo-Luminescent Dosimeter (TLD) is the commonly used passive dosimeter which can be worn as a badge on work clothing (to estimate dose to the abdomen) or in a ring form on the fingers (to estimate dose to the hands). The principle of operation is that the material of the dosimeter emits light following heat treatment which is proportional to the degree of exposure to radiation.

## Active Dosimeters

Active dosimeters provide a direct reading of the radiation dose. A common type is the personal alarm dosimeter

### Personal Alarm Dosimeter

This is an an electronic device (typically battery-operated) worn by the worker that records exposure during the work period. Unlike passive devices, it gives a direct visual readout of the exposure. The device also incorporates an audible alarm. This can be set to alarm at specific thresholds (dose or dose rate) - so giving early warning of potential overexposure.

## Dosimetry Services

Employers are often required by law or best practice to designate certain workers whose radiation exposure is likely to exceed a specified dose as 'classified persons'.

Employers must then make suitable arrangements with a dosimetry service for the estimation of that classified person's radiation exposure. This is usually done with the use of TLD dosimeters, etc.

Records of worker radiation dose (as calculated by the dosimetry service) must be reported to the employee, as must the results of medical surveillance. Records must be kept by the employer for a period of time that will usually be dictated in national legislation. For example, in the UK, records must be kept for a minimum of 50 years, or until the worker reaches the age of 75 (whichever is the sooner).

# Control Measure Principles for Ionising Radiation

The practical control of ionising radiation can, in some instances, be highly technical and, in other instances, very simple and straightforward. Control measures used must be chosen to match the specific circumstances of the work. Often, generic control measures can be applied; in other instances, a specific set of controls have to be designed specifically to meet a particular application. These controls are always based on some basic principles.

## External Radiation

External radiation arises from outside the body and may irradiate skin, tissues or internal organs, depending on the type of radiation and its ability to penetrate the body. Protection from external ionising radiation is based on three principles:

- **Time** – by reducing the time of exposure to the radiation, the accumulated dose is reduced. This follows the same principles as for toxic chemicals, noise and vibration:

  Dose = Intensity × Time

- **Distance** – by increasing the distance from the source to the person, the dose of radiation is reduced (or eliminated):
  - Alpha and beta particles do not travel long distances through air (they collide with the air molecules and lose their energy). Therefore, separation by a few centimetres or metres is sufficient to eliminate all exposure.
  - Neutrons, x- and gamma-rays travel much greater distances through air (kms), but in doing so they obey the inverse square law: the dose of radiation decreases as a function of the square of the distance from source to person.

  So,
  - if the dose at 1m distance is x,
  - the dose at 2m distance will be ¼ x,
  - and the dose at 4m distance will be $^1/_{16}$ x.
- **Shielding** – using materials to absorb the radiation so that it cannot pass through. This is the best method of control, since it applies a safe place approach and relies less on human behaviour (safe person approach). Different types and thicknesses of shielding material are used for different radiation sources:
  - Alpha particles are easily shielded with virtually any material since they have very low penetration power.
  - Beta particles can be stopped with a few millimetres of aluminium or thin brass.
  - X- and gamma-rays require thicker, denser materials, such as lead.
  - Neutron sources are often enclosed in thick concrete enclosure or hydrogen-rich materials, such as paraffin wax or water (neutrons are not stopped by dense materials, such as lead).

In some instances where the shielding needs to be removed for maintenance or other access (e.g. on an x-ray generator), an interlocked shielded enclosure will be required.

The **ICIRP** requires, firstly, the restriction of exposure by means of engineering controls, such as shielding, ventilation and containment. Once these measures have been implemented, procedural controls, involving systems of work and the provision of personal protective equipment, may need to be employed.

## Practical Control of Internal Radiation

Internal radiation stems from radioactive materials that have been deposited in the body (by inhalation, ingestion, injection or absorption through the skin) and are continually irradiating internal organs and tissues from within.

Once a radionuclide has entered the body, it is difficult, if not impossible, to limit personal exposure. If the substance is taken up by the body, then it will pass into the bloodstream and, from there, all parts of the body will receive a dose.

The substance may then accumulate in specific target organs as it is metabolised, delivering a greater dose to these organs (e.g. polonium 210 accumulates in the liver and kidneys).

Even if the substance is not taken up by the body but is simply deposited in the lungs or gut, these organs do not posses thick epidermal cell structures; they are made of delicate epithelial tissue that will receive the radiation dose. Thus, even an alpha particle emitter that would be virtually non-hazardous outside the body becomes extremely hazardous if swallowed or inhaled.

The control of exposure to internal radiation sources is therefore based entirely on keeping the radioactive material out of the body.

This is done using standard methods appropriate for toxic substances and biological agents, such as:

- Containment of unsealed radioactive material within ventilated glove boxes.
- Partial containment in fume hoods under negative pressure.
- Respiratory protective equipment.
- Other PPE to prevent skin contamination.
- Prohibition of eating, drinking and smoking.
- Good hygiene practices, such as routine hand-washing after source handling.

One control measure that is relevant to both types of radiation exposure is the use of **sealed sources**. A sealed source is a source of radiation where the radioactive material is embedded or encased in a solid container that prevents the radioactive material itself from forming a dust, vapour, gas, fume or any other form that might become airborne or liquefied.

Sealed source

(Source: The International Atomic Energy Agency, www.iaea.org/OurWork/ST/NE/NEFW/Technical-Areas/WTS/sealedsources-sealedsources.html)

## Radiation Protection Code of Practice

The **ILO Code of Practice – Radiation Protection of Workers (Ionising Radiations)** outlines some suggested control measures that should be taken to control exposure to radiation. These standards may be exceeded by national or regional legislation.

### Notification, Registration and Licensing of Radiation Work

Chapter 3 of the CoP calls for a system of notification or registration of radiation sources to a competent authority.

The requirement to notify radiation work would depend on the nature of the radiation; some processes may be exempted, whilst other processes may be required to submit detailed safety reports in order to demonstrate the safety and integrity of the design. The operator would be granted a licence to use radiation sources in the prescribed manner.

### Classification of Workers and Areas

Section 4 of the CoP establishes two categories of workers:

- Workers engaged in radiation work – these people are subject to certain dose limits, which we will consider in a later Topic Focus.
- Workers not engaged in radiation work – these workers should be treated (as far as restricting exposure is concerned) as members of the general public.

The CoP also distinguishes between two working conditions for classified workers:

- Working Condition A – persons whose annual exposure might be in excess of three-tenths of the relevant dose limit.
- Working Condition B – persons whose annual exposure is most unlikely to be in excess of three-tenths of the relevant dose limit.

**MORE...** www.

The **ILO Code of Practice – Radiation Protection of Workers (Ionising Radiations)** is available from: www.ilo.org/safework/info/standards-and-instruments/codes/WCMS_107833/lang--en/index.htm

The UK HSE also provides a range of useful information and sources about radiation: www.hse.gov.uk/radiation

www.hse.gov.uk/radiation/ionising/radon.htm

Public Health England in the UK also has a range of information, including useful information on radon gas, available from: www.gov.uk/healthprotection/radiation

Additional information is also available from the UK Building Research Establishment: www.bre.co.uk

Persons under 16 years of age should not be classified as radiation workers, whilst pregnant workers and persons under 18 years of age should not carry out work under Working Condition A.

## TOPIC FOCUS

**Radiological Dose Limits**

Setting radiation dose limits is a common approach to the control of exposure to ionising radiation, for the protection of both radiation workers and others. Though there are some differences in the exact approach adopted in different countries, and though the actual dose limits can vary from country to country, the **ILO Code of Practice – Radiation Protection of Workers (Ionising Radiations)** establishes some limits. The limits are specified in terms of effective dose (dose to the whole body) and equivalent dose (for various parts of the body) in any calendar year and are expressed in units of mSv:

| Category | Annual Effective Dose | Annual Dose Equivalent | |
|---|---|---|---|
| | | Any organ or tissue (except lens of the eye) | Lens of the eye |
| Workers over 18 | 50mSv | 500mSv | 150mSv |
| Members of the public and those not engaged in radiation work | 1mSv | 50mSv | 50mSv |

**Note:**

- The dose equivalents indicated above are the mean dose equivalent over the organ or tissue.
- In the case of skin, the dose equivalent resulting from skin contamination is averaged over $100cm^2$, but if the contamination is very uneven, and is suspected to arise from an unplanned exposure, the dose equivalent should be averaged over $1cm^2$.

A dose limit of 5mSv may be used for members of the public and others not working with radiation in certain years, providing that their lifetime exposure average is less than 1mSv.

It should be noted that many countries will have adopted more stringent limits than those contained in the ILO Code of Practice. For example, in the EU, the annual effective dose limit for workers over 18 years old is 20mSv.

## Competent Advice

In the **ILO Code of Practice - Radiation Protection of Workers (Ionising Radiations)**, Radiation Protection Officers (RPOs) are technically competent persons designated by the employer to:

- Survey the application of radiation protection regulations, standards and rules.
- Provide advice on all relevant aspects of radiation protection.

## Radiation Surveillance

Chapter 7 of the CoP outlines the requirement for radiation surveillance. This simply calls for a programme of radiation surveillance to be established to determine the precautions that are required in order to comply with the dose limits established. We have already considered the use of surveillance techniques, such as Approved Dosimetry Services (ADSs).

## Health Surveillance

Chapter 7 of the CoP also outlines the health surveillance requirements for workers engaged in radiation work. This should be carried out by an occupational physician. Workers classified under Working Condition A should undergo surveillance by an approved medical practitioner (who has been approved by the competent authority).

Health surveillance under normal conditions should include:

- Health assessment appropriate to the work to be undertaken before assignment.
- Periodic health surveillance during the assignment.
- Special health surveillance required by the competent authority for workers under Working Condition A.
- Assessment when pregnancy is reported.
- Other assessments required by the competent authority.

Health surveillance for workers who have had an abnormal exposure to radiation should include special assessment at the following times:

- When the results of radiological surveillance indicate that the person has received radiation dose equivalents in excess of twice the relevant dose limits.
- Before the radiation worker returns to work after restriction on medical grounds following a radiation accident.

# Controls

In broad terms, the control measures for ionising radiation aim to minimise:

- Exposure to external radiation arising from outside the body.
- Exposure to internal radiation arising from radioactive substances that could enter the body.

So, control measures will principally involve:

- Shielding of external radiation.
- Strict containment of radioactive chemicals, particularly dusts, vapours and gases that might enter the body.

How these might be incorporated into the design features of workplaces where radioactive materials are used is discussed below.

## Design Features

The actual design of facilities that handle radioactive materials will vary considerably, depending on the nature of the work. So, for example, the design features of a nuclear power station will look very different from those employed in a hospital radioactive tracer laboratory. However, the general principles are common to both.

Easily cleanable surfaces helps prevent radioactive contamination build-up

External radiation (from bulk storage and handling of radioactive materials) will be minimised by controls, such as:

- Shielding.
- Remote operation.
- Excluding unauthorised persons.
- Siting facilities away from generally accessible areas.

Internal radiation (from radioactive substances that might enter the body) will be prevented by:

- Sealed storage.
- Handling in ventilated facilities (glove boxes and fume cupboards).

- Provision of easily cleanable surfaces (floors, walls, benches, ceilings) to prevent accumulation of radioactive contamination.
- Provision of facilities for hand-washing (and possibly full change of clothing).

## Ventilation and Building Design

Ventilation is an important control for radioactive contamination and the principles are very similar to those used for the control of airborne contaminants that we have previously considered in Elements IB3 and IB5.

A general principle of building design is to ensure a negative pressure gradient from the external environment of

the workplace to the area where the radioactive materials are stored and used. So, for example, we ensure that we handle radioactive materials in ventilated facilities, such as glove boxes or fume cupboards at a negative pressure (i.e. less than atmospheric pressure). In the event of any loss of containment of the glove box (e.g. a torn glove), the direction of airflow will be from the workroom into the facility, minimising the amount of radioactive material likely to escape. Similarly, the corridor outside the workroom will be at slightly higher pressure than the workroom, but still less than the external environment. This ensures that the airflow is always into the building, then into the workroom and then into the glove box, maximising the containment of the radioactive materials and minimising any possible release and spread of radioactive contamination.

Some more specific design fundamentals for facilities handling radioactive materials are as follows:

- **Siting** – facilities should be located away from areas where security cannot be guaranteed. Entry to the working area should be through a lobby, via an overshoe barrier (this may be a simple step-over barrier or a more substantial one allowing persons to sit while putting on overshoes; it may also provide areas for shoe/overshoe storage), personal monitoring for contamination and a washing area.
- **Space requirements** – layout should be planned to avoid unnecessary movement of radioactive materials.
- **Ventilation and containment** – general dilution ventilation should be provided in the workroom and local exhaust ventilation facilities (fume cupboards and glove boxes) used where radioactive materials are handled. Air movement should be maintained from less contaminated areas (e.g. corridor, lobby, workroom) towards potentially more contaminated areas (e.g. fume cupboard, glove box), with extraction through the facility to a discharge stack.
- **Surfaces** – walls and ceilings should be coated with a smooth, hard gloss finish to ensure ease of cleaning. Floors should be covered with an impervious surface, such as PVC, with joints and edges to walls smooth and sealed. Bench working surfaces should be smooth, hard and non-absorbent, with all gaps and joints sealed to avoid contamination traps.
- **Radioactive waste disposal sinks** should be dedicated for radioactive materials to ensure that radioactive liquids can be safely disposed of, without contaminating other equipment. These should be sealed to the back wall and provided with splash backs and drains connected directly to the main sewage system.
- **Hand wash sinks** should be provided in the lobby area before entry into the workroom with elbow- or knee-operated taps.
- **Monitoring facilities** for hand and feet contamination should be provided on both sides of an overshoe barrier (to prevent contamination spreading by foot).
- **Storage of radioactive materials** – secure storage for both stocks and waste material is required.

## STUDY QUESTIONS

8. Explain the meaning of the following terms:
    (a) Half-life.
    (b) Activity.
    (c) Absorbed dose.
    (d) Equivalent dose.
9. What is the difference between stochastic and non-stochastic effects?
10. For each type of ionising radiation, give an example of its use or application in the workplace.
11. What is the principal instrument used to detect and quantify radiation?
12. What is the difference between exposure to external radiation and exposure to internal radiation?
13. Outline the three principles of radiation protection.

(Suggested Answers are at the end.)

# Lasers

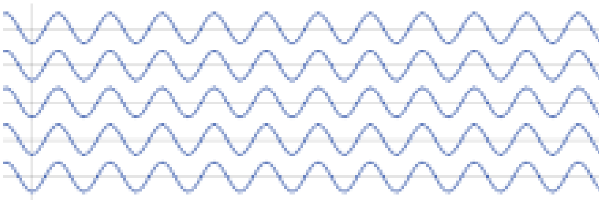
## IN THIS SECTION...

- Laser light is normally a highly coherent, non-divergent beam of electromagnetic radiation in the UV, visible or IR wavelengths.
- Lasers are used for thousands of different domestic and industrial applications, from CD and DVD players to industrial metal cutters and medical instruments.
- The main health risk from laser light is damage to the eyes; from temporary discomfort to permanent blindness, with different parts of the eye being affected by different wavelengths of light. Skin damage can also occur with high power lasers.
- Laser products are classified (according to the power of the laser beam that can be accessed) into four main classes, from Class 1 (intrinsically safe) to Class 4 (high power >0.5 Watt), with some sub-classes.
- Classification also defines the health risks associated with the laser product, from no health risk for Class 1, to high risk of permanent eye damage by direct and indirect beam strike and risk of skin burns for Class 4.
- Control measures for lasers follow the standard approach of engineering controls, administrative controls and, lastly, PPE.

## Typical Laser Sources

Laser light is electromagnetic radiation that has been produced in such as way that the light waves are all of one wavelength and all in phase (in step with each other, i.e. the peaks and the troughs are all aligned). Laser light is therefore very coherent and usually non-divergent (the beam does not spread out as it travels through air or materials).

> **DEFINITION**
>
> **LASER**
>
> Is an acronym that stands for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.



Laser light waves

To give an example of this coherent, non-divergent nature, a laser beam is routinely shone from the earth onto a mirror target, placed on the surface of the moon (by an Apollo mission) and then captured back on earth so that the exact distance from earth to moon can be calculated – a round trip distance of half a million miles.

Different types of laser emit laser light at different wavelengths. Some of these wavelengths fall within the visible light part of the electromagnetic spectrum, giving a laser beam that can be seen with the eye. But other lasers produce light in the UV and IR parts of the spectrum; these are invisible to the human eye. Microwave and radiowave lasers also exist, though these are usually called 'masers'.

Lasers are used for many different purposes and have been incorporated into a surprising number of items of equipment. Typical occupational sources of laser light would include:

- Barcode scanners used to identify and track items in retail, wholesale, warehousing, transport and delivery sectors.
- CD and DVD readers and burners in players and computers.

- Distance measuring devices, such as range finders, theodolytes and speed guns.
- Marking devices, such as gun sights, laser pointers and laser spirit levels.
- Medical devices, such as dental drills, laser scalpels and those used for eye surgery.
- Lasers used in nightclubs and outdoor light shows.
- Metal-working cutters and welders.

## Routes and Effects of Exposure to Lasers

The main health risk associated with exposure to laser light is eye damage. Even a very low power (<1mW) laser

beam can cause temporary or permanent damage to the retina of the eye. This is because the eye may focus the laser beam through the cornea and lens to a very small spot on the retina, so concentrating the light intensity. This will happen for all visible light wavelengths and some IR wavelengths as well. Other IR wavelengths and UV lasers can cause damage to the tissues at the front of the eye, such as the cornea and lens. High power laser beams can cause permanent blindness in very short exposure times.

The other health risk associated with high power lasers is skin damage; laser light falling on the skin can cause surface burns. If the beam is powerful enough, these burns will extend through the skin and into other body tissues. This is only a significant health risk for high power lasers.

The obvious exposure route for laser light is direct exposure where the light beam hits the eye (either as a result of pointing the laser at the face or by putting the face into the path of the beam).

The less obvious exposure route is indirect exposure where the laser light reflects off shiny surfaces and then strikes the eye. For high power lasers, this exposure route can present a very significant hazard since even momentary exposure to a beam that has been reflected off several surfaces can cause blindness.

Intense Pulsed Light (IPL) sources used for medical and cosmetic skin treatments (such as the removal of skin pigmentation) can also present a risk to the eye and skin. These light sources are not laser sources (the light produced is broad spectrum rather than of fixed wavelength) but the health risks are similar to those associated with laser light.

## Hazard Classification of Lasers

The CENELEC European Standard **EN 60825-1** classifies **laser products** into eight classes, based on Accessible Emission Levels (AELs), i.e. the level of radiation to which human access is possible. The use of this classification system precludes the need for the user to make an assessment since the classification of the laser product is the responsibility of the manufacturer. The classifications are:

- **Class 1** laser products are considered safe in foreseeable use. The maximum permissible exposure level cannot be exceeded because the laser is of such low power, or is totally enclosed, so that no laser radiation in excess of the specified AEL leaves the enclosure, e.g. CD and DVD players/burners and laser printers. It is worth noting that a typical CD burner contains a laser that is powerful enough to burn skin, start fires and cause permanent eye injury, yet it is classified as Class 1 because the interlocked enclosure render the beam inaccessible.
- **Class 1M** is similar to Class 1, but the beam is not safe if viewed with the aid of magnifying optical instruments, such as binoculars or a magnifying glass, e.g. some fibre optic communication beams.
- **Class 1C** lasers are designed specifically for contact application to skin (or non-ocular tissue), such as cosmetic skin treatments - however, depending on the needs of the treatment, skin exposure may exceed Maximum Permissible Exposure (MPE). Eye hazards are prevented by engineering means.
- **Class 2** is for lasers emitting in the visible range only, i.e. 400-700nm. Class 2 lasers are low power devices up to 1mW maximum. They are not considered to be particularly hazardous in normal use. They will not burn skin but could cause eye damage. However, the blink response (i.e. the natural aversion to having a dazzling bright light shone in your eye) is enough to make them relatively safe. Many laser pointers and barcode scanners are Class 2.

It is worth noting that though a Class 2 laser is unlikely to do permanent damage unless shone into the eye deliberately for a few seconds, they can cause momentary dazzle which can prove dangerous. They are often misused in this way by members of the public (e.g. police, fire-fighters and pilots are targeted).

- **Class 2M** is similar to Class 2, but the beam is not safe if viewed with the aid of magnifying optical instruments, such as a surveying telescope, e.g. some laser level instruments used in civil engineering.
- **Class 3R** laser products are limited to a maximum output power of 5mW. These can potentially cause eye injury even on short exposure times. Examples include some laser pointers and some laser levels used in home improvement work.

Laser hazard warning sign

- **Class 3B** laser products are limited to a maximum output power of 500mW. These are hazardous to the eye – both directly and indirectly by reflection. Eye protection should therefore be worn. Typical examples include physiotherapy and research lasers.
- **Class 4** lasers are high power devices (> 500mW). They are hazardous to eyes and skin and can cause fires; the higher the power, the greater the risks. Examples include display lasers (used in laser light shows), laser metal cutters and surgical lasers. Class 4 lasers are usually mains powered, but the others can all be battery powered and therefore portable.

## Control Measures for Lasers

All laser products should be correctly labelled with their class and appropriate warning signs. The main methods of control for lasers are:

- Engineered controls:
  - Screening/enclosures to prevent the escape of hazardous beams.
  - Interlocks on equipment and rooms so that power to the laser is isolated when hazardous areas are entered.
  - Non-reflective surfaces. Many high-power laser enclosures and rooms are painted matt black to prevent reflection.
- Administrative controls:
  - Warning lights (to indicate 'in operation').
  - Signs warning of the laser hazard inside a particular enclosure or in a room/area.
  - Training for users of Classes 3R, 3B and 4 lasers (and possibly even for lower classes, such as 1M and 2M, because of the risks associated with magnifying lenses).
  - Safe systems of work and emergency procedures. Permit systems might be employed to control high-risk activities with high-power lasers, such as guard removal during use.
- PPE:
  - Laser safety eyewear. This will often be in the form of goggles to completely encase the eye and prevent access to the eye from the sides. Eyewear must be selected to give protection from the particular wavelengths of light produced.
  - Skin protection may be necessary for high-power lasers.

**MORE...** www.

Guidance from the EU contains information about the application of **AOR** to lasers, and worked examples of high power laser exposure risk assessment, further detail can be found at:

www.hse.gov.uk/radiation/nonionising/opticalintro.htm

www.hse.gov.uk/radiation/nonionising

A Non-Binding Guide to the Artificial Optical Radiation Directive 2006/25/EC is also available to download from:

www.hse.gov.uk/pubns

Public Health England also provides useful information on lasers at:

www.gov.uk/government/publications/laser-radiation-safety-advice

## STUDY QUESTIONS

14. Describe the classification system for lasers based on relative hazard potential.

15. Explain the types of control measures that can be employed to prevent harmful exposure to laser radiation.

(Suggested Answers are at the end.)

# Summary

## Types of Ionising and Non-Ionising Radiation

We have examined how:

- Radiation can be grouped into two main types: ionising and non-ionising.
- Ionising radiation causes ionisation in the material that absorbs it – this delivers energy into the material and promotes unusual chemical reactions that would otherwise not occur.
- The electromagnetic spectrum is the full range of frequencies that electromagnetic radiation can be found at, from high frequency gamma-rays to low frequency long wave radiowaves.
- All types of non-ionising radiation are electromagnetic waves and can be broadly categorised as optical (ultraviolet, visible and infrared radiation) and electromagnetic fields (or radiofrequency: microwaves and radiowaves.
- Ionising radiation can be grouped into five different types: alpha and beta particles, neutrons, x-rays and gamma-rays. These vary in their properties and characteristics, particularly in their ability to penetrate matter.
- Three of these types of ionising radiation are particulate in nature – alpha particles, beta particles and neutrons. The two others, gamma and x-ray, are forms of high-energy electromagnetic radiation.
- Two international agencies set standards with regards to radiation safety: the International Commission for Radiological Protection (ICRP) and International Commission for Non-Ionising Radiological Protection (ICNIRP).

## Non-Ionising Radiation

We have examined how:

- Non-ionising radiation is produced by the sun (both UV and visible light from the sun are significant health hazards) and artificially by various types of equipment, such as sunbeds (UV), arc-welding (UV, visible and IR), furnaces (IR), ovens (microwaves) and radio transmitters (microwaves and radiowaves).
- Each type of non-ionising radiation has specific health effects: UV can cause sunburn, arc-eye, premature ageing of the skin and increased risk of skin cancer; visible light can cause damage to the retina and permanent blindness; IR can cause skin burns and cataracts; radio frequencies can cause burns and internal heating.
- Exposure limit values for non-ionising radiation are set out in international standards and national and regional law, such as the **EU Physical Agents (Electromagnetic Fields) Directive (2013/35/EU)**.
- Control of exposure to non-ionising radiation is achieved by risk assessment and application of a standard control framework.
- Protection from harmful UV, visible and IR radiation can often be achieved by eye protection and skin protection.
- Protection from EMF radiation is achieved by isolation, interlocks, safe systems or work (including permit systems) and maintaining distance from source.

## Ionising Radiation

We have examined how:

- Ionising radiation is produced by the spontaneous radioactive decay of radioactive substances in rocks, soils, water and air. This is natural background ionising radiation.
- Ionising radiation is also produced and used in many workplace applications, from smoke detectors to industrial and medical radiography equipment, such as x-ray sets.
- Ionising radiation sources can be hazardous outside the body, depending on the radiation's ability to penetrate into body tissues. Sources can also be extremely hazardous inside the body. Radioactive substances can get into

the body by the normal routes - inhalation, ingestion, skin absorption and injection. The physical form of a radioactive substance affects its available routes of entry.

- The acute effects of exposure to ionising radiation (radiation sickness) include nausea, vomiting, diarrhoea, fever and death. These effects are non-stochastic; they do not occur below a particular dose threshold.
- The chronic effects of exposure to ionising radiation are an increased risk of cancer and genetic damage. These effects are stochastic; there is no known threshold below which the effects cannot occur and the greater the 1 dose, the greater the risk.
- Several different terms and units are used to quantify ionising radiation: activity (becquerel), absorbed dose (gray), equivalent dose (sievert) and effective dose (sievert).
- Activity and dose can be measured using equipment, such as thermo-luminescent dosimeters. Dose assessments can only be carried out by Approved Dosimetry Services (ADSs).
- Control of exposure to external radiation sources is achieved using three principles: time, distance and shielding.
- Control of exposure to internal radiation sources is achieved by preventing the inhalation, ingestion, absorption or injection of the radioactive substance in the first place.
- The annual dose limit set in the **ILO Code of Practice – Radiation Protection of Workers (Ionising Radiations)** for employees over 18 is an effective dose of 50mSv. Dose limits are also set for trainees, pregnant women and members of the public. Lower dose limits may be imposed by national legislation.
- The primary dose limits apply to workers engaged in radiation work. Workers not engaged in radiation work are treated as if they were members of the public in terms of restricting radiation exposure.
- Work areas where workers are likely to receive certain specified doses have to be designated as Controlled or Supervised Areas. These areas must be demarked, signed, monitored for radioactivity and made subject to local rules.
- The employer must designate a competent Radiation Protection Officer to survey the application of radiation protection regulations, standards and rules and to provide advice on all relevant aspects of radiation protection.

## Lasers

We have examined how:

- Laser light is normally a highly coherent, non-divergent beam of electromagnetic radiation in the UV, visible or IR wavelengths.
- Lasers are used for thousands of different domestic and industrial applications, from CD and DVD players to industrial metal cutters and medical instruments.
- The main health risk from laser light is damage to the eyes; from temporary discomfort to permanent blindness, with different parts of the eye being affected by different wavelengths of light. Skin damage can also occur with high power lasers.
- Laser products are classified (according to the power of the laser beam that can be accessed) into four main classes, from Class 1 (intrinsically safe) to Class 4 (high power >0.5 Watt), with some sub-classes. Classification also defines the health risks associated with the laser product, from no health risk for Class 1 to high risk of permanent eye damage by direct and indirect beam strike and risk of skin burns for Class 4.
- Control measures for lasers follow the standard approach of engineering controls, administrative controls and, lastly, PPE.

# Exam Skills

## QUESTION

Staff working in a dental practice are exposed to x-rays.

(a) **Outline** the properties of x-rays. **(4)**

(b) **Outline** how the dental practice can monitor the staff exposure. **(6)**

## Approaching the Question

This is a question on a specific form of ionising radiation: x-rays. Most people will be aware of the use of x-rays for medical radiography and so can at least visualise their operation in a dental practice.

1. In part (a), you are asked to outline the properties of x-rays and the examiner is looking for you to show how x-rays differ from other types of ionising radiation (alpha and beta particles or gamma radiation, for example).

   Part (b) is concerned with how exposure to x-rays might be monitored so you need to apply your knowledge of methods of measuring ionising radiation to this specific example of x-ray exposure in a dental practice.
2. You may determine from the marks allocated that you are required to provide at least four different properties of x-rays for part (a) and at least six issues relating to exposure monitoring for part (b). This should help you with your time allocation.
3. Now highlight the key words. In this case, they might look like this:

   Staff working in a dental practice are exposed to x-rays.

   (a) **Outline** the properties of x-rays. **(4)**

   (b) **Outline** how the dental practice can monitor the staff exposure. **(6)**
4. Now have a go at the question. What can you remember about x-rays? How do they differ from other types of ionising radiation? What methods of measuring ionising radiation can you recall from your notes? Which ones could be used to monitor x-ray exposure? Remember that your answer is an outline, so it needs to include a reasonable degree of detail.

## Example of How the Question Could be Answered

*(a)* *X-rays are a form of electromagnetic radiation artificially produced when an x-ray machine is switched on. They are generated by bombarding a metal target with high energy electrons and are very penetrating. They can shine through many types of material such as paper, aluminium and human tissues. Consequently, they present an external radiation hazard but can be shielded by lead.*

*(b)* *Thermo-Luminescent Dosimeters (TLDs) can be used to monitor radiation exposure. They are personal dosimeters which can be worn on the body to monitor exposure over a fixed period of time and give a measurement of dose. Following exposure to x-rays, the dosimeters are processed to determine the level of exposure. The TLD is heated and the amount of light emitted indicates the degree of exposure. An approved dosimetry service should be used to determine the radiation dose from the TLDs.*

## Reasons For Poor Marks Achieved By Candidate in Exam

An exam candidate would achieve **poor marks** for an answer if they:

- Confused electromagnetic x-radiation with particulate radiation.
- Did not include an outline of how x-rays are produced.
- Failed to specify the use of thermo-luminescent dosimeters to monitor staff exposure.
- Did not demonstrate understanding of how the dosimeters are actually used to measure radiation exposure.

Element IB8

# Mental Ill Health and Dealing with Violence and Aggression at Work

## Learning Outcomes

Once you've read this element, you'll understand how to:

1. Explain the effects and causes of common types of mental ill health within the workplace.
2. Explain the identification and control of workplace mental ill health with reference to relevant standards.
3. Explain the scope, effects and causes of work-related violence/aggression.
4. Explain the identification and control of work-related violence/aggression with reference to relevant standards.

# Contents



# Mental Ill Health at Work

### IN THIS SECTION...

- According to the European Agency for Safety and Health at Work, stress is the second most reported work-related ill-health complaint, affecting almost a quarter of workers in the 27 EU member states. Stress, anxiety and depression are the single biggest causes of lost time in the UK.
- Work-related stress can be defined as the adverse reaction that people have to excessive pressure or other demands placed on them at work.
- Though not a disease, chronic stress can cause ill health and may act as a trigger for mental health problems, such as anxiety and depression.
- Stress causes a range of physical and behavioural symptoms in the short term which can go on to become serious ill health, such as anxiety and depression, high blood pressure (hypertension) and heart disease.
- The causes of work-related stress can be characterised as organisational factors (such as how work is organised and the workplace culture), job factors (such as role, content and control) and individual factors (such as working relationships and work-life balance).

## The Prevalence of Mental Ill Health Within the Workplace

Obtaining reliable data on the incidence and prevalence of work-related stress, anxiety and depression is notoriously difficult, especially on a global or regional scale. So, in the following section, we will look at data gathered in Great Britain, which has a population size of c63 million and a working population size of c37 million.

The 2015 report from the HSE on work-related stress, anxiety and depression in Great Britain contains the following headline figures:

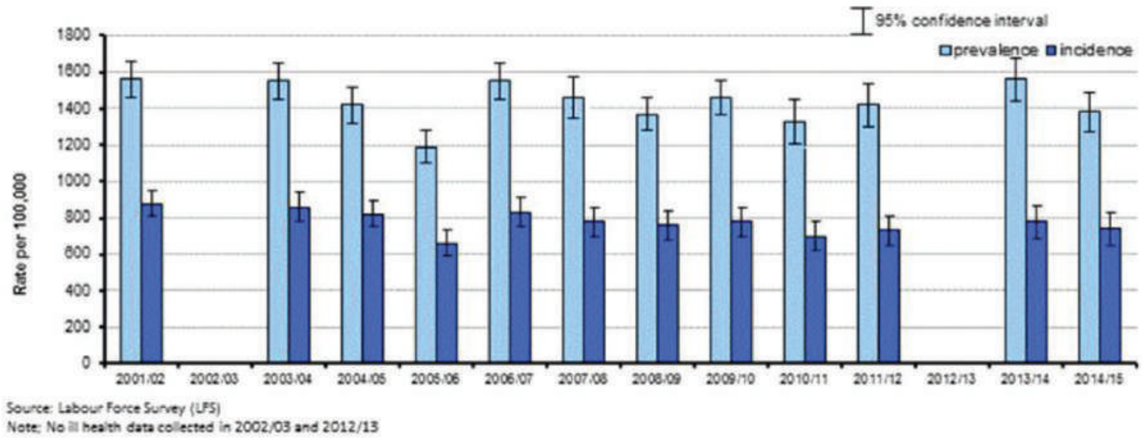
- The total number of cases of work-related stress, depression or anxiety in 2014/15 was 440,000 cases, a prevalence rate of 1,380 per 100,000 workers.
- The number of new cases was 234,000, an incidence rate of 740 er 100,000 workers. The estimated number and rate have remained broadly flat for more than a decade.
- The total number of working days lost due to this condition in 2014/15 was 9.9 million days. This equated to an average of 23 days lost per case.
- In 2014/15, stress accounted for 35% of all work-related ill health cases and 43% of all working days lost due to ill health.
- Stress is more prevalent in public service industries, such as education, health and social care, and public administration and defence.
- By occupation, jobs that are common across public service industries (such as health, teaching, business, media and public service professionals) show higher levels of stress as compared to all jobs.

### DEFINITION

**WORK-RELATED STRESS**

The HSE in the UK defines work-related stress as "the **adverse reaction** people have to **excessive pressures** or other types of demand placed on them at work".

The European Agency for Safety and Health at Work expands upon this by stating that "people experience stress when they perceive that there is an imbalance between the demands made of them and the resources they have available to cope with those demands".



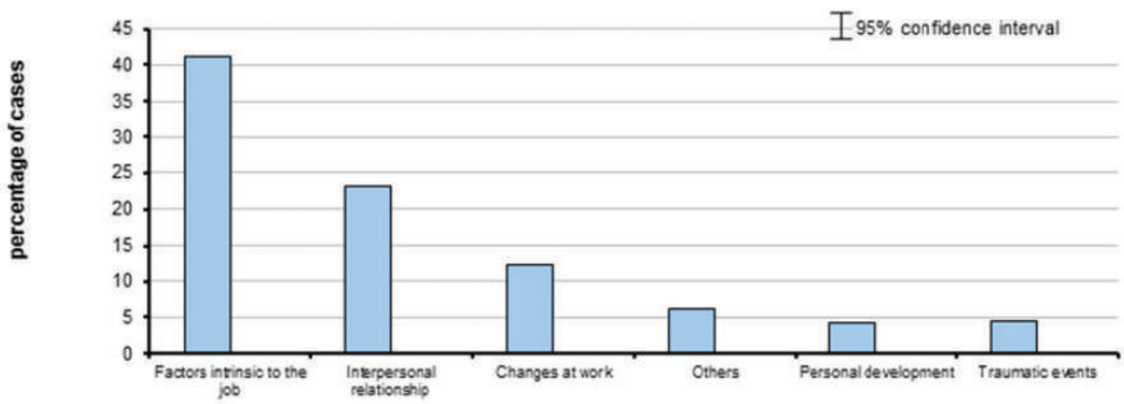

Estimated prevalence and incidence rates of stress, depression or anxiety caused or made worse by work, for people working in the last 12 months
Source: The HSE's report, Work-related Stress, Anxiety and Depression Statistics 2015 (www.hse.gov.uk/statistics/causdis/stress/stress.pdf)

These statistics come from the LFS. The LFS is a household survey, conducted by the Office for National Statistics, consisting of around 41,000 households each quarter across Great Britain which provides information about the labour market. HSE commissions a module of questions in the LFS to gain a view of work-related illness based on individuals' perceptions.

The LFS provides national estimates of the overall prevalence (total cases) of self-reported work-related illness during the previous 12 months, as well as estimates of the incidence (new cases) of work-related illness in the same period. It is important to recognise that this survey collect self-reported data (i.e. data not requiring any form of formal diagnosis or filtering).

The HSE also collects data on work-related stress through The Health and Occupation Research network for General Practitioners (THOR-GP) across Great Britain. This network asks reporting general practitioners to assess whether new cases of mental ill health presented in their surgeries are work-related and, if so, what was the work-related cause of this disorder. The two data sources may reflect different perceptions of work-related attribution to individual cases.

The THOR-GP network report for 2012-2014 identifies a breakdown of work-related mental ill-health cases by precipitating events and diagnosis. It concludes that workload pressures were the predominant factor, in agreement with the LFS, with interpersonal relationships at work and changes at work significant factors also.




Breakdown of mental ill-health cases reported to THOR-GP according to precipitating event THOR-GP, three-year aggregate total 2012 to 2014

Source: The HSE's report, Work-related Stress, Anxiety and Depression Statistics 2015 (www.hse.gov.uk/statistics/causdis/stress/stress.pdf)

## Anxiety and Depression

The main work factors cited by respondents as causing work-related stress, depression or anxiety (Labour Force Survey (LFS), 2009/10-2011/12) were workload pressures, including tight deadlines and too much responsibility and a lack of managerial support.

Anxiety can have both psychological and physical symptoms.

Psychological symptoms can include:

- Feeling worried or uneasy a lot of the time.
- Having difficulty sleeping.
- Inability to concentrate.
- Irritability.
- Being extra alert (hypervigilance).
- Feeling on edge or not being able to relax.

Physical symptoms can include:

- Pounding heartbeat.
- Breathing faster.
- Palpitations (irregular heartbeat).
- Nausea.
- Chest pain.
- Headaches.
- Loss of appetite.

**MORE...** www.

There are many other sources of statistics on the prevalence and incidence of work-related stress, available at:

www.hse.gov.uk/statistics/causdis/stress/index.htm

**DEFINITIONS**

**ANXIETY**

*"A feeling of unease, such as worry or fear, that can be mild or severe."*

**DEPRESSION**

*"Is when you have feelings of extreme sadness, despair or inadequacy that last for a long time."*

Long-term anxiety can lead to serious ill-health conditions, such as hypertension (chronic high blood pressure).

Anxiety is sometimes linked to panic disorder (having panic attacks) and Post-Traumatic Stress Disorder (PTSD), caused by exposure to a traumatic event. It is also frequently linked to depression.

The severity of the symptoms of depression can vary. At its mildest, depression involves being persistently low in spirit (low mood) while, at its most severe, depression makes sufferers feel suicidal and that life is no longer worth living.

Symptoms of depression can include the following:

- Continuous low mood.
- Feelings of hopelessness and helplessness.
- Low self-esteem.
- Guilt.
- Irritability and intolerance.
- Lacking motivation or interest.
- Difficulty with decision-making.
- Suicidal thoughts.
- Thoughts of self-harm.

At the more severe end of the scale, depression may lead to a diagnosis of clinical depression that can be categorised as mild, moderate or severe. At the sever end of the scale, clinical depression can involve psychosis characterised by hallucinations, delusions and disturbed thoughts.

## Work-Related Stress

**Stress** is not a disease, but a natural reaction to pressure. Unrelieved stress can cause disease. It certainly contributes to poor work performance and absence.

**Pressure** is an inherent part of work, whether it is a deadline that must not be missed, a rate of output that must be maintained, multiple demands that must all be met simultaneously or simply the risk of massive financial loss if work does not go well.

Pressure does not necessarily lead to stress. In many circumstances, people are able to cope with the pressure they are under. In fact, in many situations, pressure is a good thing. It results in a positive performance, maintains motivation and interest and improves health.

However, in some instances, a person finds themselves **unable to cope** with the pressure that they are under. This leads to a negative reaction, rather than a positive one. This reaction is psychological in origin, i.e. the negative reaction is in the mind.

If the pressure is short term, then the person may show some of the signs and symptoms of stress, but it is unlikely that there will be any significant health consequences. It is a common experience to suffer a few sleepless nights worrying about an exam or an interview, you prepare yourself as best you are able, then afterwards the pressure is relieved and the worry goes away.

> **DEFINITION**
>
> **WORK-RELATED STRESS**
>
> *"The adverse reaction that people have to excessive pressure or other demands placed on them at work".* (HSE)
>
> The European Agency for Safety and Health at Work expands upon this by stating that *"people experience stress when they perceive that there is an imbalance between the demands made of them and the resources they have available to cope with those demands".*

But if the pressure continues or increases, then the relatively minor symptoms of stress can escalate into **physical and/or mental ill health**.

Work-related stress should not be confused with anxiety or depression. These are common mental health problems that can and do exist entirely independently of work-related stress. It is estimated that a quarter of the population will suffer some form of mental illness at some stage in their lives. The two most common forms of mental illness are anxiety and depression. Many of the signs and symptoms of anxiety and depression are the same as those for stress. It is possible to suffer from these mental health problems without being stressed or under any pressure (work-related or not). However, it must be recognised that there is strong relationship between these mental health problems and work-related stress. The one can trigger or contribute to the other, and vice-versa.

## Physical and Psychological Effects of Stress

The physical effects of stress in the workplace can involve a range of symptoms, which include:

- Raised heart rate.
- Increased sweating.
- Headaches.
- Dizziness.
- Blurred vision.
- Aching neck and shoulders.
- Skin rashes.
- Lowered resistance to infection.

These symptoms are usually short-lived, depending on the nature of the stressful condition.

As well as physical effects, stress can also cause psychological and behavioural changes, such as:

- Increased worrying and irritability.
- Increased alcohol consumption. Increased smoking.
- Difficulty sleeping.
- Poor concentration.
- Loss of appetite or overeating.
- Inability to cope with everyday tasks and situations.

Again, these symptoms may be short term in response to an isolated, finite period of excessive pressure.

If excessive pressure remains and the individual cannot cope in the long term, then chronic symptoms and disease may occur. Examples of these are:

- Anxiety and depression.
- High blood pressure (hypertension).
- Heart disease.
- Eczema and psoriasis.
- Irritable bowel syndrome.
- Susceptibility to ulcers.
- Loss of libido, erectile dysfunction (in men) and irregular menstrual cycle (in women).

We can see, therefore, that chronic stress may lead to a range of serious ill-health conditions and diseases, and should be treated seriously as a workplace hazard.

**MORE...** www.

There are many useful and interesting resources available for work-related stress. Try the following:

www.hse.gov.uk/stress

osha.europa.eu/en/topics/stress

www.nhs.uk/Conditions/Stress/Pages/Introduction.aspx

www.osha.gov/SLTC/etools/hospital/hazards/stress/stress.html

# Causes of Work-Related Mental Ill Health

One of the problems with dealing with stress, anxiety and depression as an occupational health matter is that different people have different abilities to cope with pressure at work. These abilities vary massively between people and are influenced by many factors, such as personality, cultural background, experience, education, motivation, etc.

Also, the coping abilities of an individual are not set, but vary over time. Indeed, many people find that the trigger that sets off an inability to cope with work-related stress does not come from within work at all; it comes from outside. Personal bereavement, separation, divorce, family ill health and other stressors outside of work render the individual unable to deal with work pressures that they would ordinarily cope with.

Therefore, it is not easy to identify one, or even several different causes responsible for stress - there is a range.

With regards to the range of work-related factors that cause stress, the UK's HSE has developed a framework that can be adopted by organisations. This framework is called the 'management standards approach'. The management standards approach examines the causes of work-related stress under six headings:

- **Demands** – excessive demands of the job in terms of workload (too much or too little), targets (e.g. unachievable sales targets for sales staff), speed of work and deadlines, as well as working hours (e.g. excessively long) and work patterns (e.g. changing shift patterns). Also, the nature of the job itself: some jobs are inherently difficult (e.g. air-traffic control) and some expose workers to highly emotional situations (e.g. dealing with child-protection issues for a social worker).

Poor working relationships are often a cause of stress

- **Control** – lack of control over work, especially where the work is demanding. Control means personal control by the worker over what work is to be done, how it is to be done, the priorities involved (e.g. realistic deadlines) and even simple things like control over the working environment (e.g. light levels, temperature, background noise, etc.).
- **Support** – lack of support in terms of information, instruction and training to do the work and having no-one to turn to when pressure increases (e.g. no advice/counselling service).
- **Relationships** – poor workplace relationships and, in particular, bullying and harassment whether by managers, peers or subordinates (e.g. social isolation and exclusion of a worker by their peer group as a result of prejudice).
- **Role** – lack of clarity about an individual's role, what responsibilities and authority they have, and how they fit in to the larger organisational structure (e.g. lack of any form of job description, or role clarity for a worker used to working in a highly bureaucratic organisation). Conflicting demands can also create stress under this heading (e.g. having to increase productivity while at the same time decreasing headcount).
- **Change** – the threat of change and the change process itself, whether it is a change that affects just one worker (e.g. demotion, re-assignment), or the whole organisation (e.g. redundancies, management take-over). This can create huge anxiety and insecurity.

(More on the management standards approach later in this element.)

It is important to recognise that, though this framework provides a range of factors that can be used to identify and assess the potential causes of stress (these can be considered as the stress risk factors), the specific risk factors that are actually present in the workplace will vary depending on the nature of the work being undertaken and the actual circumstances relating to that work. For example, staff working in a call centre may not be undergoing any kind of organisational change, so this risk factor will be irrelevant. But they may be subject to **demanding** call targets on a daily basis and they may work in a call centre where high staff turnover means that workplace **relationships** cannot form, or be maintained.

## Work-Related and Non-Work-Related Factors

Most cases of stress and mental ill health found within the workplace are rarely caused by work-related factors alone. As was previously highlighted, the coping abilities of an individual are not set, but vary over time. Stressors from the individual's personal (non-work-related) life may act as a significant cause or contribution to the pressure that they are under. Personal bereavement, separation, divorce, family ill health and other stressors outside of work render the individual unable to deal with work pressures that they would ordinarily cope with. Or these non-work-related stressors may act as triggers for mental ill health. Just as there is an interaction between a person's physical fitness and their ability to deal with the physical demands of their work, so there is an interaction between their mental fitness and the mental demands of their job. Physical injury or illness acquired outside of work can have consequences within work. And so it is for mental health.

### STUDY QUESTIONS

1. What are the short-term symptoms that might arise in staff who are suffering high levels of stress?
2. Which organisational factors could be responsible for creating avoidable workplace stress?
3. Define anxiety and depression.

(Suggested Answers are at the end.)

# Identification and Control of Work-Related Mental Ill Health

## IN THIS SECTION...

- The management of work-related stress and mental ill health can be achieved by applying a standard risk assessment methodology (five-step approach).
- The UK's HSE management standards approach to risk assessment establishes six standards to be achieved by the organisation under the headings: demands, control, support, relationships, role and change.
- Organisations can benchmark their performance against these six standards in a variety of ways, e.g. by using the HSE staff survey.
- Risk-reduction measures have to be tailored to meet the specific needs of the organisation.

## Facilitating Work

Most people who experience stress or mental health problems recover fully or are able to live with and manage them, and continue to work effectively.

"*If more people knew about the nature of mental illness, they would understand that it doesn't mean people are unable to contribute to society. The mentally ill are the most keen to work out of all those with disabilities, and yet it is a common experience for people to be discriminated against at work after being diagnosed, to be passed over for promotion, to lose their job or not even be considered when applying for one.*" (www.rethink.org)

Employers should have policies and procedures in place to help employees get back into work

However, for many years, mental health has been stigmatised and those suffering from it, discriminated against. Consequently, those suffering from stress and mental ill health are excluded from work.

At the same time, it must be recognised that prolonged absence from work can have a negative impact on a person's physical and mental health. Studies have shown that individuals off work for long periods of time can become less active, which may result in their being unable to maintain social contacts, possibly leading to feelings of social exclusion. They may subsequently suffer from feelings of isolation, lose their confidence and have low self-esteem. All these effects could lead to poor mental health and the person suffering from anxiety and depression.

So, here we have an example of a vicious cycle; people who suffer from stress and mental ill health are excluded from work and long-term absence from work can cause mental ill health.

The solution: the employer must adopt policies and procedures that enable those suffering from stress and mental ill health to remain in work.

It is important to remember that disability and equality legislation may make it unlawful to discriminate against people with mental health problems.

## Identification and Assessment of Risk of Stress and Mental Ill Health

There is unlikely to be specific national legislation relating to the management of work-related stress or mental ill health. Employers may have implied duties under general health and safety legislation, e.g. the requirement to carry out suitable and sufficient risk assessment. Aside from any legal duties, employers will often want to effectively manage stress, anxiety and depression as a matter of good practice and to reduce the impact of worker absence on the organisation. Though management practices will vary by region, the UK's HSE approach will be used as a good example.

A standard five-step approach to risk assessment can be adapted for both work-related stress and mental ill health:

- Identify the risk factors.
- Identify the people who might be harmed.
- Evaluate the risks: explore problems and identify solutions.
- Record findings and implement them.
- Monitor and review to assess effectiveness.

In practice, many different tools are used as part of the risk assessment to identify and evaluate risk, at either the individual and/or organisational level and also develop workable solutions, for example:

- Discussions and focus groups.
- The use of sickness absence data.
- Interviews.
- Surveys/questionnaires.

We look at some examples of this later in the element.

As work-related stress, anxiety and depression are a widespread problem, some regulators (such as the UK HSE) have developed a framework that can be adopted by organisations for this risk assessment. This framework is called the 'management standards approach' and will be explained in more detail later, as an example of one approach.

It is important to point out that prevention is better than cure; the risk assessment-based approach for both work-related stress and mental ill health is designed to minimise the incidence of these in the workplace. This can only be done by taking a strategic organisational view and adopting organisation-wide control measures. In this way, the various factors that lead to stress are removed or moderated across the whole organisation and the varying personal susceptibilities to their influence become of secondary importance.

Some organisations have taken a different approach to stress risk assessment in that they have applied an individual approach (rather than an overall organisational approach), focusing on the specific factors that might lead to stress for individual workers, taking into account personal factors, etc. But this approach may prove ineffective in operation.

The strategic risk assessment-based approach designed to prevent stress (discussed next) does not discharge an employer of their duty of care, should individual cases of work-related stress or mental ill health occur. When individual cases come to light (and even with management arrangements in place they can and do still happen), the employer will have to respond appropriately. In both cases, the immediate and long-term response of the employer is critical in ensuring the minimisation of harm. In many cases, the employer's response when at-risk individuals are identified can 'make or break' the individual concerned.

## Practical Control Measures

Developing control measures is often the most difficult part of tackling stress, anxiety and depression in the workplace. It is recognised that there is rarely a single standard 'one size fits all' solution. It is best to develop solutions locally, taking account of the issues discovered in the specific workplace context. Some of the tools mentioned earlier are also very useful for both identifying problems and helping develop solutions, e.g. focus groups of around 8-10 people have been found to work quite well for this. The basic approach to developing practical control measures is:

- First, take time to fully identify and clarify the problem (try to be as specific as possible).
- Ask how this became a problem (for example, was it always a problem? If not, what changed to cause it?).
- Determine whether this is a one-off problem (so, will it naturally go away in the short-term or is it something that is likely to be a long-term issue? If it's very short-term, you may not need to take any action at all).
- Suggest solutions to identified problems.
- Ask how your suggested solutions would actually solve the problems.
- How would the solutions be practically implemented? Who would do it and when? How would you check the solutions are effective?
- Prioritise your actions - don't do too much in one go.

The practical control measures needed to effectively manage stress must be targeted to the needs of the organisation. Implementing control measures when the matter that those control measures address is not a stress risk factor in the workplace is a waste of time, money and effort. Consequently, any control measure introduced has to address a real need.

As might be expected, the starting point for this approach will be establishing an organisational **policy on stress management** setting out the aims and objectives of the organisation and responsibilities for implementation.

Some examples of practical solutions to address some of the causes of stress, anxiety and depression include:

- Involving staff in the review of working hours and shift systems.
- Considering flexible working and changes to start and finish times.
- Developing a system to notify employees of unplanned tight deadlines and the need to work long hours.
- Holding team meetings and individual meetings to discuss anticipated workload and challenges.
- Agreeing fair work patterns to cope with peaks and staff absences.
- Counselling – offering access to counselling services.
- Return to work policy – phased return after long absence.

In the next section, we'll look at the stress management standards approach which is recommended by the UK HSE.

## The Management Standards Approach

The HSE's management standards define the culture of an organisation where the risks from work-related stress are being effectively managed and controlled. In other words they represent goals or targets to be achieved by the organisation.

### TOPIC FOCUS

There are six management standards to aim for, which effectively cover the primary sources of stress at work:

- **Demands** – this includes issues such as workload, work patterns and the work environment.
- **Control** – how much say the person has in the way they do their work.
- **Support** – this includes the encouragement, sponsorship and resources provided by the organisation, line management and colleagues.
- **Relationships** – this includes promoting positive working to avoid conflict and dealing with unacceptable behaviour.

(Continued)

## TOPIC FOCUS

- **Role** – whether people understand their role within the organisation and whether the organisation ensures they do not have conflicting roles.
- **Change** – how organisational change (large or small) is managed and communicated in the organisation.

These six management standards represent a framework against which an organisation can benchmark its performance through the risk assessment process. For each standard, the HSE has set out a description of the **standard** to be met, along with a description of some of the actions that would be observable within the organisation if the standard were being achieved (**indicators** that the standard is being met).

For example, under the management standard entitled 'demands', the standard is that:

- employees indicate that they are able to cope with the demands of their jobs; and
- systems are in place locally to respond to any individual concerns.

What should be happening/states to be achieved:

- the organisation provides employees with adequate and achievable demands in relation to the agreed hours of work;
- people's skills and abilities are matched to the job demands;
- jobs are designed to be within the capabilities of employees; and
- employees' concerns about their work environment are addressed.

Organisations can, therefore, use various methods to benchmark their performance against each of these management standards and then use the result of that benchmarking exercise to prioritise which standards are being achieved already, which are being approached and which are being missed. This then allows for the correct identification of priorities and action planning to address those priorities.

Benchmarking might be done by analysing data that already exists within the organisation, such as:

- Sickness and absence data.
- Productivity data.
- Staff turnover.
- Performance appraisals.
- Exit interviews.
- Team meetings.
- Informal talks to staff.

Alternatively, the HSE has designed a survey questionnaire and survey analysis software that can be used to analyse the results from that survey. This is a sensible approach as it takes the benchmarking exercise out of management hands (where management perceptions may bias the results) and relies on direct feedback from employees on **their perception** of the cultural standards. Since it is the personal opinions of employees that matter in the context of stress management, this is a very useful way of gathering data on perceived standards.

Informal talks to staff

The questionnaire **management standards indicator tool** contains 35 questions and is two pages' long. The intention is that it will be completed anonymously by all, or a very significant sample of, staff and used to give an indication of the level of compliance with each of the six management standards. It is not intended as a personal stress indicator tool and does not necessarily give any indication of the ability of any one individual to cope with their work pressures.

The indicator tool does not have to be used. Organisations are free to adapt the survey questionnaire to suit their own purposes or use other questionnaires instead.

> **MORE...** www.
>
> The UK HSE's management standards indicator tool is available at:
>
> www.hse.gov.uk/stress/standards/downloads.htm

Analysis of the indicator tool allows the organisation to identify their current level of performance against each of the six management standards and highlight areas for improvement. The organisation then has to act on these results and has to design a series of actions to address each. The HSE has indicated that larger organisations might take six months to carry out their risk assessment, involving use of the survey tool and analysis and evaluation for results, followed by a further 12 months to put action plans into effect and monitor results. Consequently, the risk assessment might be reviewed after a period of 18 months by completion of a second staff survey to view areas of improvement and areas of future concern.

Using the management standards as a framework, the HSE gives various examples of possible control measures, such as:

- Demands
  - Involve staff in the review of working hours and shift systems.
  - Consider flexible working and changes to start and finish times.
  - Develop a system to notify employees of unplanned tight deadlines and the need to work long hours.
  - Hold team meetings and individual meetings to discuss anticipated workload and challenges.
  - Agree fair work patterns to cope with peaks and staff absences.
  - Ensure sufficient resources are available for staff to be able to do their jobs (time, equipment, etc.).
  - Provide training (formal or informal) to help staff prioritise, and information on how they can seek help if they have conflicting priorities.
  - Include training and personal development plans in the appraisal process to allow staff to achieve development.
  - Deal with risk of violence in consultation with employees.
- Control
  - Allow staff to have a say over the way their work is organised and done.
  - Consult staff during the planning stage of projects to talk about the anticipated output and methods of working.
  - Allocate responsibility to teams rather than individuals to take work forwards.
  - Talk about the skills people have and how they would like to use their skills.
  - Talk about the way decisions are made and possible scope for staff involvement.
- Support
  - Hold regular one-to-one meetings to talk about any emerging issues or pressures.
  - Include 'work-related stress/emerging pressures' as a standing item for staff meetings and/or performance reviews.

> **MORE...** www.
>
> As always, useful information and further resources are available from the UK HSE:
>
> www.hse.gov.uk/stress/standards

- Seek examples of best practice where people received good support from managers or colleagues.
- Adopt 'open door' policies or agreed times when managers are available.
- Support staff experiencing problems outside work.
- Disseminate information on other areas of support (human resources department, occupational health, trained counsellors, charities).
- Offer access to counselling, either internally or externally.

Support staff seeking to return to work following long-term absence caused, or made worse, by stress. This should be done in line with organisational return to work policies as detailed in Element IB1.

- Relationships
  - Develop a written policy for dealing with unacceptable behaviour at work and communicate this to staff.
  - Implement procedures to resolve conflict at work.
  - Introduce a confidential reporting system for unacceptable behaviour.
  - Establish grievance and disciplinary procedures.
  - Select or build teams that have the right blend of expertise and experience for new projects.
  - Provide training to help staff deal with difficult situations.
  - Celebrate success.
- Role
  - Enable staff to clarify their role and to discuss any possible role conflict.
  - Display team/department targets and objectives to help clarify unit and individual role.
  - Agree specific standards of performance for jobs and individual tasks and review periodically.
  - Introduce personal work plans that are aligned to the outputs of the unit.
  - Introduce or revise job descriptions to help ensure the core functions and priorities of the post are clear.
  - Hold regular one-to-one meetings to ensure individuals are clear about their role and know what is planned for the coming months.

Staff should be aware of why change is happening

- Change
  - Ensure all staff are aware of why the change is happening.
  - Define and explain the key steps of the change.
  - Ensure employee consultation and support is a key element of the programme.
  - Establish a system to communicate new developments quickly.
  - Ensure staff are aware of the impact of the change on their jobs.
  - Provide a system to enable staff to comment and ask questions before, during and after the change.

## STUDY QUESTIONS

4. What are the headings of the HSE six management standards?
5. Discuss examples of good management practice that can serve to reduce stress levels in an organisation that is undergoing change.
6. Describe measures that can be taken to reduce individual stress by improving work relationships.

(Suggested Answers are at the end.)

# Work-Related Violence

## IN THIS SECTION...

- Work-related violence is defined as any incident in which a person is assaulted, threatened, harmed or injured in the course of their work.
- Violent incidents cause physical and psychological harm and are a significant contributor to work-related stress.
- Various factors contribute to the risk of work-related violence. These all relate to the job that the worker is carrying out, such as: dealing with members of the public, handling cash, lone working and conducting home visits.

## Definitions

Violence at work is recognised by many organisations (such as employers, health and safety authorities and various charities) as a significant workplace hazard.

The **ILO Code of Practice – Workplace Violence in Services Sectors and Measures to Combat this Phenomenon** defines workplace violence as:

> *"Any action, incident or behaviour that departs from reasonable conduct in which a person is assaulted, threatened, harmed, injured in the course of, or as a direct result of, his or her work."*

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Violence is characterised by aggressiveness, either repeated or unexpected

The CoP goes on to further clarify the definition by stating that:

> *"Internal workplace violence is that which takes place between workers (including managers and supervisors).*
>
> *External workplace violence is that which takes place between workers (and managers and supervisors) and any other person present at the workplace."*

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In the **ILO Framework Guidelines for Addressing Workplace Violence in the Health Sector - The Training Manual** the following definition is given:

> *"Violence can be defined as a form of negative behaviour or action in the relations between two or more people. It is characterised by aggressiveness which is sometimes repeated and sometimes unexpected.*
>
> *It includes incidents where employees are abused, threatened, assaulted or subject to other offensive acts or behaviours in circumstances related to their work.*
>
> *Violence manifests itself both in the form of physical and psychological violence. It ranges from physical attacks to verbal insults, bullying, mobbing, and harassment, including sexual and racial harassment."*

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It is important to recognise that this definition goes well beyond the immediate and obvious association of violence with physical assault (being punched, kicked, stabbed or shot, etc.). Inclusion of the words "abused" and "threatened" broadens the range of events that fall within the scope of the definition significantly. Verbal threats, gestures and personal abuse are clearly brought within the meaning of the term. It is also important, however, to recognise that this definition has no basis in statute law (it does not come from a set of regulations) and that an organisation is therefore free to use a definition of violence as they see fit. This would be particularly important when creating and implementing an organisational policy on work-related violence.


Call centre operative

Using the ILO definition of work-related violence, the following incidents might fall within its scope:

- A member of the public hits a shop assistant during a customer query.
- A security guard is threatened with a gun during a robbery.
- A social services worker is verbally threatened with assault during a home visit.
- A train driver is spat at by a customer on a station platform.
- A call centre operative is verbally abused during a credit control call.

## Physical and Psychological Effects

Clearly, a very wide range of physical injuries can result from physical assault, from a fatal wound to bruising and grazing (the most common reported injury). Most incidents, however, do not involve physical assault and so never result in physical injury. This can belie the fact that perhaps the most serious effect of many violent incidents is not the physical injury; it is the psychological effect of the incident. Violent incidents of any type, whether physical or verbal, can be **traumatic**, may leave the victim suffering from traumatic stress and can result in Post-Traumatic Stress Disorder (PTSD).

The effect that an incident has will depend on many factors, such as the nature of the incident itself and, very significantly, the personal characteristics of the victim. For example, some individuals may be 'thick skinned' enough to shrug off verbal abuse as simply 'part of the job' (see note). Other individuals would find a single incident of verbal abuse very distressing and would show the typical symptoms of traumatic stress (tearfulness, anxiety, etc.). This can lead to PTSD. It may also be a trigger for any mental health condition (such as anxiety and depression) that an individual may be susceptible to.

(Note: it is worth pointing out that whilst individual workers are fully entitled to their opinion that abuse is simply 'part of the job', it should never be the policy of their employer that this is the case. Workers are entitled to enjoy safe working conditions and that includes freedom from violence.)

Victims of violence can often suffer psychological harm in this way. Typical reactions include:

- Withdrawal.
- Hyper-vigilance.
- Loss of confidence.
- Loss of self-esteem.
- Mood swings.
- Breakdown of working and personal relationships.
- Anxiety and depression.
- Suicide attempts.

The other way that violent incidents may cause harm is by contributing to work-related stress. This is less to do with the fact that being spat at was traumatic and has left you with PTSD. It is more to do with the fact that when you know that your job exposes you to the risk of being spat at by complete strangers, it makes you more anxious and vigilant than you might otherwise be. It increases stress. It is the **feeling of being at risk** (feeling vulnerable) that is important here, rather than an incident that has already happened.

# Risk Factors

## Workers at Risk

The single biggest risk factor for work-related violence is the **nature of the job** being carried out by the worker. Workers whose jobs require them to deal with the public are most at risk from violence. In fact, **working with the public** might be identified as the single biggest risk factor for work-related violence.

There are certain workplaces, however, where this is not the case; workers are not dealing with the general public but are still at risk of violence, e.g. prison service and psychiatric hospital staff.

Particularly at risk are those who are engaged in:

- Giving a service – such as social services, infrastructure maintenance engineers, retail staff, etc.
- Caring – such as nurses, doctors, care assistants, etc.
- Education – teachers and support staff.
- Cash transactions – bus drivers, taxi drivers, bank staff, post office staff, etc.
- Delivery/collection – postal workers, lorry drivers, security van drivers, etc.
- Controlling – stewards, security staff, etc.
- Representing authority – police, traffic wardens, bailiffs, various enforcement officers and inspectors, etc.

Another very significant risk factor is **lone working**. Staff working alone are more at risk of violence than they might otherwise be if they were accompanied by a colleague. For example, social working conducting home visits, service engineers working in a local community, and night-shift security.

One final risk factor worth drawing attention to is **conducting home visits**. Workers making home visits, such as care workers, social workers, doctors, engineers and enforcement officers are at greater risk. The reason for the home visit is significant here; an enforcement officer following up a noise complaint is more at risk of violence during a home visit than a satellite TV installation engineer (provided the TV works).

Though there is some relationship between the sex of victim and risk of violence and the age of victim and risk of violence, these effects are relatively minor and probably result from the age and sex correlation for particular jobs and sectors (e.g. there are more female nurses than male ones).

It can be misleading to make general assumptions about at-risk workers. For example, the assumption that women are more at risk than men (which seems to be based on the view that men are more muscular and therefore better able to defend themselves). This assumption is often erroneous as, in many sectors, men are more frequently the victim of violence than women.

## Assailants

The majority of incidents involve assailants who were strangers to the victim. Where the assailant was already known to the victim, it was almost always work that has made them known to the victim.

Whilst it might be easy to stereotype assailants as white, male with low IQ, it is the case that the typical assailant (if there is such a thing) will depend largely on the nature of the job and sector under scrutiny. For example, whilst it is true that nurses are assaulted by drunk males in hospital Emergency departments, it is also the case that they are assaulted by sober elderly female patients in Care of the Elderly wards. Most at-risk sectors and organisations have access to statistics that allow for some definition of the typical assailant. It will, however, always be the case that some assailants will not fit this typical mould.

What is the case, however, is that the circumstances of violent incidents often involve risk factors, such as when the assailant:

- Is under the influence of drink or drugs.
- Is in pain or distress.
- Is under significant stress.
- Is being forced or coerced.
- Is committing theft.
- Is committing sexual assault.
- Has a mental health condition.

In many instances, violent incidents do not occur without warning or without some build-up of tensions. There are often tell-tale signs that reveal the build-up of tension, anger and aggression in the assailant. In the minority of cases, there will be no warning; e.g. theft and sexual assault are usually premeditated and therefore the tell-tales are concealed by the assailant.

## STUDY QUESTIONS

7. Explain what is meant by 'violence at work'.
8. Outline the principal activities, and examples of, associated staff, where it is possible that there might be a risk from workplace violence.

(Suggested Answers are at the end.)

# Identification and Control of Workplace Violence

### IN THIS SECTION...

- The assessment of risk of work-related violence can be based around a four-stage approach:
  - Find out if there is a problem.
  - Decide what action to take.
  - Take action.
  - Check what you have done.
- Identifying the extent of the problem usually involves use of incident reporting systems and/or formal or informal staff surveys.
- The control measures for minimising risk of violence can be categorised as organisational (such as zero-tolerance policies, cashless systems and customer vetting), physical controls (such as security screens, alarms and CCTV cameras) and behavioural controls (such as recognising and defusing potential violent incidents prior to escalation).

## Assessment of Risk of Violence

The Health and Safety Executive, in their guidance publication *Violence at Work – A Guide for Employers (INDG69(rev))*, sets out a structured action plan for the assessment and control of risk of violence. The key elements of the action plan are:

- Find out if there is a problem.
- Decide what action to take.
- Take action.
- Check what you have done.

> **MORE...** www.
>
> More information is available from the UK HSE at:
>
> www.hse.gov.uk/violence
>
> You can also download INDG69 *Violence at Work - A Guide for Employers* from:
>
> www.hse.gov.uk/pubns

### Find Out if There Is a Problem

The first stage must be to identify whether a problem actually exists. In some workplaces, there may be a perceived threat of violence at work, but no supporting evidence. In other workplaces, there will be real evidence of violent incidents taking place.

There are two common ways of investigating this question:

- **Staff surveys** – informal or formal surveys of the workforce. This might be done for all workers or it might be targeted at groups of workers who are at risk, such as those who deal with the public (rather than back-room staff). This type of survey might involve managers or worker representatives and enables the collection of a wide range of work-based experiences described by employees themselves to give their personal views.
- **Incident reporting** – through the introduction of a formal reporting system. Existing accident reporting systems may already provide adequate information. In some instances, existing reporting systems can be adapted to suit; in other instances, a separate reporting system has to be designed and implemented.

It is important that data collection provides adequate information to enable proper evaluation of the risks so that the correct preventive measures can be formulated. The following basic information will need to be reported:

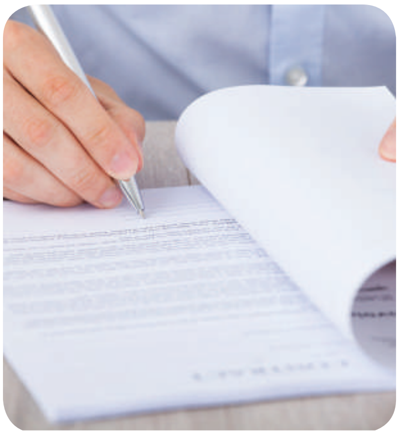
- Type of incident (physical, verbal abuse, etc.).
- Details of the incident (before and during).

- Information about the assailant.
- Information about the victim.
- Details of the outcome (injury, emotional shock, stress).

## Decide What Action to Take

The action above is the first step of the risk assessment process. The remaining five steps of risk assessment can then be applied:

- Identify who might be harmed, and how.
- Are the existing arrangements adequate or does more need to be done?
- Develop any necessary preventive measures. (Examples of preventive measures are considered later in this element.)
- Record the significant findings of the risk assessment.
- Review it regularly.



Significant findings of the risk assessment are recorded

## Take Action

Involvement of staff in introducing measures to combat violence, and inclusion of the measures in the safety policy, will ensure that staff are aware of what is going on. It is important to seek the co-operation of staff, and ensure that they follow procedures properly and report any further incidents.

## Check What You Have Done

As with any programme designed to manage an occupational health and safety risk, it is important to check that control measures are working. Reviews on the effectiveness of implemented controls can be done by management, or by the health and safety committee.

# Control Measures

Control measures will be considered under three headings: organisational, physical and behavioural.

## Organisational Controls

Some of the control measures designed to eliminate or reduce risk of violence have to be designed and implemented at an organisational level. For example:

- Clear organisational policy on work-related violence.
- A zero-tolerance policy towards violence by customers, clients, members of the public and staff. This is agreed at senior level and then broadcast through signs and notices.
- Prosecution of offenders who commit criminal assault.
- Changes to give staff less face-to-face contact with the public, e.g. by means of automatic ticket dispensers/collectors and cash machines.
- Use of cash-free systems such as cheques, credit cards or tokens to make robbery less likely (e.g. the London Underground 'Oyster Card' system).
- Use of work activity risk assessment protocols to identify and address potential problem activities.
- Vetting of clients and customers and identification of potentially violent individuals, where the organisation has records relating to the individual prior to any face-to-face meetings. For example, agencies such as the Department of Work and Pensions (DWP) have personal records relating to many clients that can be used to vet individuals based on past history.
- Use of work/visit scheduling where staff working in the community follow a known schedule and periodically report in to base, so that their route and last known contact point are known.

- Development of emergency procedures, including methods for raising an alarm and the subsequent emergency response. Some organisations use code words to raise the alarm (e.g. used in a mobile phone conversation with base during a home visit where a worker feels anxious but no assault has actually taken place).
- Prohibition of lone working for certain high-risk jobs or when visiting high-risk areas.
- Policies and procedures to ensure minimum staffing numbers are maintained.
- Post-incident handling and the support and counselling services made available to staff after an event.

Less contact with the public can reduce risk of violence

## Physical Controls

Physical controls can be used to both reduce the risk of violent incidents occurring and also to reduce the severity of such incidents, should they occur.

Examples include:

- Changing the layout of public waiting areas. Better seating, lighting, décor and more regular information about delays can stop tension building up in hospital waiting rooms, housing departments and benefit offices.
- Re-designing counters to increase width or height to give staff protection from physical contact.
- Securing loose objects, such as display stands and chairs, so that they cannot be used as weapons in the event of an incident.
- Using panic buttons, personal alarms, mobile phones, etc. to enable rapid contact for assistance. Technology has developed rapidly in this area and low-profile devices exist that can send an alarm, give GPS co-ordinates and transmit real-time audio in the event of activation.
- Using security measures, such as cameras, protective screens and security-coded doors to monitor staff and prevent unauthorised access.
- Employing security staff to act as a deterrent and to control assailants in the event of an incident.

## Behavioural Controls

It is, of course, essential that workers make use of all of the organisational and physical control measures that exist within a workplace. For example, if security doors exist between public and staff areas, then those doors must be kept securely closed at all times except when in use. Similarly, if staff conduct lone-working home visits in areas where such visits are prohibited, or without making use of client vetting procedures, or without informing control staff of their whereabouts, then obviously control breaks down. Individual staff behaviour is, therefore, essential in ensuring effective use of available control measures.

It is also the case though, that in many instances, despite attempts to engineer risk reduction, there will be some element of staff/public or staff/client interaction. In some instances, virtually none of the controls mentioned above can be applied. Heavy reliance then falls on behavioural controls in ensuring that staff **show the right behaviours** in an attempt to reduce the risk of incidents occurring and the severity of outcome should they occur. Typical behavioural controls include:

- Quick and courteous handling of complaints and queries.
- Demonstrating assertive authority without becoming aggressive.
- Reading verbal and body language clues that indicate a person is becoming tense and that an incident may escalate.
- Using appropriate verbal and body language to diffuse a potentially escalating situation.
- Using appropriate self-defence or restraint techniques in the event of an incident.

Even simple and specific behaviours can make a difference in this context. Things such as:

- Wearing non-grab-able clothing (such as clip-on tie and trousers rather than long skirt).
- Not wearing flamboyant or expensive clothing that attracts attention.
- Not conducting home visit during hours of darkness.
- Not carrying obvious valuables (such as laptop or mobile phone).
- Not displaying obvious ID when out in the community (it must be carried but can be concealed except when in use).
- Parking to allow a quick getaway.
- Not accepting food or drink during a home visit.

Of course, these behaviours have to be tailored to suit individual circumstances.

Organisations should consider documenting these behavioural controls in the form of guidelines for staff.

## TOPIC FOCUS

**Staff Training**

Various types and levels of training should be provided to staff, depending on circumstances. Typical training would include:

- Awareness training to enable staff to understand the causes of violence relevant to their workplace and the general measures in place to reduce risks, such as incident reporting procedures and security controls.
- Specific training on safe systems of work that minimise the risk of violence, such as lone-worker procedures and client/customer vetting.
- Personal behaviour training that focuses on the verbal and body language associated with aggression and violence, early recognition of such signs in others and appropriate responses to defuse escalating incidents (often referred to as 'defusion training').
- Self-defence training, including restraint techniques and the use of reasonable force.

## STUDY QUESTIONS

9. Outline the principal elements of a strategy for management of violence at work.

10. State the range of measures commonly used to combat violence at work.

(Suggested Answers are at the end.)

# Summary

## Mental Ill Health at Work

We have:

- Examined the prevalence and incidence of work-related stress, anxiety and depression.
- Defined anxiety and depression.
- Defined work-related stress as the adverse reaction that people have to excessive pressure or other demands placed on them at work.
- Outlined the range of physical and behavioural symptoms caused by stress, which can go on to become serious ill health.
- Described the causes of work-related stress as organisational factors, job factors and individual factors.

## Identification and Control of Work-related Mental Ill Health

We have:

- Explained the UK HSE's management standards approach to stress risk assessment that establishes six standards to be achieved by the organisation, under the headings 'demands', 'control', 'support', 'relationships', 'role' and 'change' and how organisations can benchmark their performance against these standards using the HSE staff survey tool.

## Work-Related Violence

We have:

- Defined work-related violence as any incident in which a person is abused, threatened or assaulted in circumstances relating to their work.
- Outlined the incidence of work-related violence.
- Outlined the physical and psychological harm caused by violence.
- Considered the risk factors, such as dealing with members of the public, handling cash, lone working and conducting home visits.

## Identification and Control of Work-Related Violence

We have:

- Outlined a four-stage approach to risk assessment for violence that usually involves identifying the extent ofthe problem using incident reporting systems and/or formal or informal staff surveys.
- Categorised control measures for minimising risk of violence as organisational, physical and behavioural and emphasised the need for staff training.

# Exam Skills

## QUESTION

**Identify** a range of information sources an employer could use to determine the extent of work-related stress for workers within an organisation. **(10)**

### Approaching the Question

1. This is a relatively straightforward question, but the potential danger is that there are no sub-sections to keep you on track. Therefore, if you head in the wrong direction at the start, it is possible to lose all 10 marks, so it is very important to focus and be certain to answer the question that you were asked.
2. In this question, the examiner is looking for "information sources" that could indicate the extent of work-related stress, so be sure to focus on these. You are only required to "identify" them, however, which in terms of the NEBOSH command words means "provide without explanation".
3. Now, highlight the key words in the question:

   **Identify** a range of information sources an employer could use to determine the extent of work-related stress for workers within an organisation. **(10)**
4. Now have a go at the question.

### Example of How the Question Could be Answered

*There is a number of information sources that could be considered:*

- *Productivity (such as volume or quality of work).*
- *Company data on accidents/incidents.*
- *Levels of sickness absence (some of which may be attributed directly to stress; others may appear as minor absences).*
- *Health surveillance data from company medicals, etc.*
- *Information obtained from return-to-work interviews or medicals for those returning from illness.*
- *Details of staff turnover, as high turnover may indicate dissatisfaction.*
- *Exit interview reports from those leaving the company who may cite stress as an issue.*
- *Time-keeping/clock-card data which indicate poor or erratic timekeeping.*
- *Number of complaints received, grievances or discipline issues.*
- *Feedback from staff surveys.*
- *Feedback from performance appraisals.*
- *The results of an assessment of performance carried out against published stress management standards.*

### Reasons For Poor Marks Achieved By Candidate in Exam

An exam candidate would achieve poor marks for an answer which:

- Failed to identify a wide enough range of information sources.
- Outlined a narrow range of obvious sources, such as absence and medical information, in too much detail.
- Did not appreciate that assessment against published management standards is a valid source.
- Concentrated only on medical information and did not consider feedback from the workforce.

Element IB9

# Musculoskeletal Risks and Controls

## Learning Outcomes

Once you've read this element, you'll understand how to:

1. Outline types, causes and relevant workplace examples of injuries and ill-health conditions associated with repetitive physical activities, manual handling and poor posture.
2. Explain the assessment and control of risks from repetitive activities, manual handling and poor posture.

# Contents



# Musculoskeletal Injuries and Ill Health

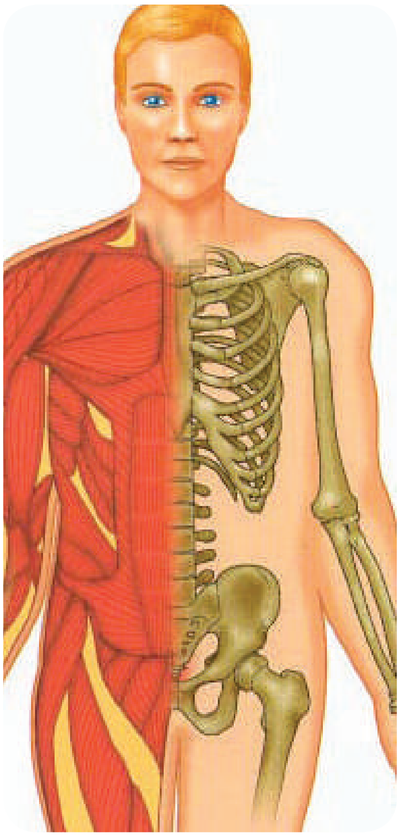
## IN THIS SECTION...

- The human skeletal system is made up of the skeleton with its associated muscles, cartilage, tendons and ligaments.
- Musculoskeletal Disorders (MSDs) include back injury and back pain; upper limb disorders; and muscle, tendon and ligaments injures.
- Certain work activities, such as production line work, DSE use and manual handling have a high risk of MSDs.

## The Human Musculoskeletal System

The human musculoskeletal system is made up of the skeleton and associated soft tissues, such as muscles, tendons and ligaments.

- The **skeleton** – forms the bone frame of the body upon which everything else is supported.
- **Cartilage** – is joined to the bone in certain areas either to support anatomical structures (such as the nose and ear) or to form articulating surfaces in joints (such as in the spine or knee).
- **Skeletal muscles** – are able to contract (shorten) and relax (extend) so as to achieve movement.
- **Tendons** – tough connective tissue that joins muscle to bone so that when a muscle contracts, the bone it is joined to moves.
- **Ligaments** – tough connective tissue that joins bone to bone to form the joints, such as knee, hip, spine and shoulder joints.
- **Nerves** – the central nervous system is made up of the brain and spinal cord. This is connected to a network of peripheral nerves that carry sensory information from the body to the brain and nerve signals from the brain to muscles to control movement.



Human musculoskeletal system showing the skeleton with muscle tissues overlaid
Source: HSG60 Upper limb disorders in the workplace (2nd ed.), HSE, 2002 (www.hse.gov.uk/pubns/priced/hsg60.pdf)

## Types of Injury and Ill Health

The specific injuries and ill health associated with poor ergonomic design of work will depend on the nature of the work activity and the individual concerned. Manual handling, use of Display Screen Equipment (DSE), repetitive activities and poor posture whilst sitting or standing for long periods of time are all significant causes of Musculoskeletal Disorders (MSDs) and other associated conditions.

Typical forms of ill health associated with poor work design are:

- **Back Injury and Back Pain**

  The spine is made up of individual bones (vertebrae) separated by tough pads (intervertebral discs). Wear and tear can occur to these discs so that they become distorted (prolapsed disc). This causes extreme pain and discomfort and is often accompanied by nerve pain because the distorted disc traps nerves where they enter the spinal cord. This type of injury is perhaps the most serious of all manual handling injuries since recovery is often slow, incomplete and, in some instances, the casualty will have to undergo surgery to repair the defect or may end up permanently disabled.

- **Work-Related Upper Limb Disorders (WRULDs)**

  A collection of conditions that affect the arms, wrists and hands (collectively known as upper limbs). Examples include carpal tunnel syndrome (inflammation of a nerve in the wrist that causes tingling sensations, pins and needles, numbness in the fingers and arm pain) and tenosynovitis (inflammation of the tendons in the forearm that makes finger movement difficult and painful). Early symptoms of WRULDs often include tingling sensations, numbness and discomfort but then progress to more severe pain and immobility. These conditions sometimes require corrective surgery (which is not always successful) and can lead to disability. They are sometimes referred to as 'Repetitive Strain Injuries' (RSIs).

- **Tendon and Ligament Injuries**

  When tendons and ligaments are overloaded, they tear causing painful injuries that can take a long time to heal. In some instances, recovery is incomplete and an operation may be required. Though tendons and ligaments are tough, they are prone to overuse injury (from repetitive use) or overload injury. They do not repair well because they have a fairly poor blood supply. Many WRULDs are, in fact, tendon and ligament injuries.

- **Muscle Injuries**

  Overloaded muscle tissue can tear. This is painful and likely to lead to short-term impairment. Skeletal muscle does, however, have a rich blood supply so will tend to repair quickly and effectively in most instances. Sheet muscle, such as the muscle surrounding the intestines in the abdominal cavity, does not repair so well, which is why hernias (bulges or splits) in this sheet muscle can last for a long time, can be extremely painful and may require corrective surgery.

- **Cuts, Burns and Broken Bones**

  These are straightforward physical injuries as a result of dropping a load, picking up a load that is hot, sharp or otherwise hazardous.

- **Other Chronic Soft-Tissue Injuries**

  These are associated with sitting, standing or kneeling for long periods of time at work, e.g. painful knee joints as a result of having to kneel down for long periods of time. This can lead to a condition known as 'beat knee' where a thick callus of skin develops under the knee as a result of pressure.

**DEFINITIONS**

**ERGONOMICS**

The study of the relationship between the worker, the work that they are doing and the environment in which they are doing it.

**MANUAL HANDLING**

The lifting, carrying, pushing and pulling of a load by bodily force.

An uncomfortable static posture leads to musculoskeletal disorders such as neck pain and knee pain. long duration work of this nature is almost certain to lead to MSDs of one sort or another

## Associated Conditions

Non-musculoskeletal conditions include:

- Eye Strain

  This is often associated with the use of Display Screen Equipment (DSE) or assembly line work where a high degree of visual acuity is required (such as soldering circuit boards or handling small components). Temporary eye fatigue is commonly associated with prolonged use of DSE screens. There is no evidence to suggest that long-term eye damage results.

- Fatigue and Stress

  These are often associated with some types of DSE work (e.g. call centre staff) and manual or repetitive handling where a high level of output has to be maintained.

## High-Risk Activities

**MSD** risk is associated with:

- Sitting for a long period of time.
- Standing for long periods of time, particularly in a static position.
- Any repetitive movement of the body.
- Any repetitive use of force.
- Any form of manual handling, irrespective of the weight being manipulated.
- Work in restricted work spaces where body posture is constrained by the available space.

Many jobs and work activities have an associated risk of MSDs. In fact, most people's jobs will have an element of MSD risk since one or more of the risk factors are likely to be present some, or most, of the time. Certain types of work involve one or several of the above risk factors and so might be characterised as high-risk. For example, bricklaying on a construction site involves several of the risk factors noted above: the work is repetitive; awkward posture and twisting is necessary; rest periods may be infrequent; and the work area may be extremely cold and windy or hot, humid and airless. Below is a few other high-risk types of work with their associated MSDs.

### Production/Assembly Line Work

Assembling small components and/or repetitive handling on a factory production line will have many of the same health effects listed above:

- **WRULDs** – associated with repetitive handling of parts for long periods of time.
- **Eye strain** – temporary eye fatigue associated with having to focus on small parts.
- **Back pain** – and other MSDs associated with sitting or standing in a fixed position for long periods of time, perhaps in association with over-reaching, twisting and stooping to reach parts.
- **Fatigue and stress** – associated with infrequent rest breaks and a demanding work rate.

The portability of laptops allows them to be used in a casual manner that is inappropriate for long-duration use

### Display Screen Equipment (DSE) Use

Use of Display Screen Equipment (DSE) or computers and keyboards (including laptop computers) is a common workplace activity that has several associated ill-health issues:

- **WRULDs** – associated with repetitive use of the keyboard and mouse for long periods of time.

- **Eye strain** – temporary eye fatigue associated with prolonged use of the screen.
- **Back pain** – and other MSDs associated with sitting in a fixed position, perhaps with poor posture, for long periods of time.
- **Fatigue and stress** – associated with the type of work being done, e.g. call centre staff may be subjected to verbal abuse during telephone calls.

These health effects can occur when using desktop computers but are becoming increasingly common in association with the use of laptops when they are used for long-duration work.

## Manual Handling

Manual handling is a very common workplace activity and may involve very repetitive handling or one-off movements of very large and heavy items (e.g. handling structural steels into position in an inaccessible location, transferring patients from wheelchair to toilet or bed). It has several associated ill-health issues:

- **Back injury and back pain** – associated with repetition, heavy lifting or poor posture, such as twisting, stooping or over-reaching.
- **Tendon and ligament injuries** – associated with repetitive handling and heavy lifting.
- **Muscle injuries** – associated with overloaded muscle tissue.
- **Hernias** – of the sheet muscle that surrounds the gut.
- **Work-Related Upper Limb Disorders (WRULDs)** – as a result of repetitive movements.
- **Cuts, burns and broken bones** – through direct physical injury.

### MORE...

www.

There are several useful sources of information on musculoskeletal risk and injury, including:

www.hse.gov.uk/msd

www.hse.gov.uk/msd/uld/whatareulds.htm

www.backcare.org.uk

The HSE publication, INDG171 *Managing upper limb disorders in the workplace – A brief guide*, is aimed at employers and managers in small businesses and is available at:

www.hse.gov.uk/pubns/indg171.pdf

### STUDY QUESTIONS

1. What is a WRULD and how might it be brought about?
2. What are the main types of injury associated with manual handling operations?

(Suggested Answers are at the end.)

# Assessing and Controlling Musculoskeletal Risk

## IN THIS SECTION...

- Many risk factors influence the risk of MSDs associated with a particular activity. These include repetition, force, posture, twisting, rest, equipment design, equipment adjustability, lighting, other environmental parameters and individual capabilities.
- MSD risk assessments often follow a format established by relevant legislation. For example, a manual handling risk assessment considers the load, task, environment and individual capabilities.
- Assessment tools are available to assist with the risk assessment of both manual handling and repetitive activities. The HSE has published four such tools: the MAC, VMAC, ART and RAPP tools. Other tools are available, such as the RULA.
- The control measures introduced following such risk assessments will vary, depending on the nature of the activity in question. Manual handling control measures are very different to those employed for DSE use. Generally, hazard elimination by automation or mechanisation are preferred solutions. Where this is not possible, the provision of equipment and aids, task re-design and alterations to the work environment might be used. Ultimately, control may rely on good practices with regards to posture and technique. This will necessitate training.

## Risk Factors

The specifics of manual handling risk assessment and DSE workstation assessment will be discussed in the next section. There are, however, some general risk factors that contribute to ergonomic risk:


Manual handling strain

- **Repetition** – the need for repetitive movements when carrying out the task (e.g. typing for several hours).
- **Force** – the physical force required to perform the task and the strain this puts on the body (e.g. closing stiff catches on a machine).
- **Posture** – any requirement to adopt an awkward posture (e.g. stooping over into a bin to pick out contents).
- **Twisting** – any twisting action required by the task (e.g. twisting the wrist when using a screwdriver).
- **Rest** – the potential for the worker to rest and recover from any fatigue (e.g. a worker on a production line cannot stop the line; they have to keep working even when fatigued).
- **Equipment design** – the shape of the equipment and how this affects ease of use (e.g. a large, shaped handle on a scraper makes it easier to hold and use).
- **Equipment adjustability** – the scope there is for the user to adjust the equipment to suit their personal preferences (e.g. the height of the seat for a computer user).
- **Lighting** – the availability of natural and artificial light and the effect on the worker's ability to see the work clearly.
- **Other environment parameters** – in particular, temperature, humidity and ventilation will directly affect the worker's ability to perform the task and their comfort.
- **Individual capabilities** – of the person doing the work. In particular, young persons and new and expectant mothers should be given additional protection. Other vulnerable groups might include disabled people and those with a known existing injury or ill-health condition (such as recovering from surgery).

# Risk Assessment Methods

The ergonomic risk assessment method applied to a work activity will depend, to a large degree, on the nature of the work activity. In particular, manual handling and the use of DSE each have their own risk assessment methods.

## Assessing Manual Handling Risk

When a hazardous manual handling activity cannot be completely eliminated, then it must be assessed. This risk assessment will be slightly different from the general risk assessment you are already familiar with because it focuses exclusively on the hazard of manual handling and ignores all other hazards.

Manual handling risk assessment focuses on four main factors:

- The task.
- The load.
- The environment.
- Individual capabilities.

Holding a load away from your torso when lifting increases the risk of injury

### The Task

The focus here is on the movements required of the worker as they handle the load. The **task** can be assessed by asking questions, such as:

- At what height is the load being picked up, carried or put down?
- Is the task very repetitive?
- Is a long carrying distance involved?
- Does the task involve stooping (worker has to keep their legs straight and bend their back) to move the load? Does the task involve twisting (turning the shoulders while the feet stay still)?
- Can rest breaks be taken as the worker requires them?
- Does the task involve lifting the load through a vertical distance?
- Does the task involve reaching above shoulder height? Does the task involve the worker holding the load away from their trunk (torso)?

### The Load

Here, the focus is the load that is being handled. Though the load is usually an inanimate object, in some workplaces it may be an animal or a person, e.g. in a hospital, patients have to be moved from bed to gurney (a wheeled stretcher/trolley), from wheelchair to bath, etc.

The **load** can be assessed by asking questions, such as:

- How heavy is the load?
- How large and bulky is the load?
- How stable is the load?
- Where is the Centre of Gravity (C of G) of the load?
- Is the load difficult to grip?
- Is the load hot, sharp or otherwise hazardous?

Uneven load

## The Environment

The focus here is the environment in which the handling takes place.

The **environment** can be assessed by asking questions such as:

- Are there restrictions on the space available?
- Is the floor surface slippery or uneven?
- Are there changes in floor level (steps, stairs, etc.)?
- What are the light levels like?
- What is the temperature and humidity?

## Individual Capabilities

The focus here is on the **worker** carrying out the handling activity.

**Individual capabilities** can be assessed by asking questions, such as:

- Does the activity require unusual ability? Some handling activities require unusual strength, stamina, size or technique.
- Does the activity present significant risk to vulnerable individuals, such as pregnant women or people with pre-existing back injuries?

Guidance note L23 *Manual Handling* includes an appendix that explains how to choose the right level of detail for manual handling risk assessments.

There are three levels of detail:

- Simple filters to distinguish low-risk tasks from the tasks which need a more detailed assessment.
- The *Manual handling assessment charts (the MAC tool)* or the *Risk assessment of pushing and pulling (RAPP) tool*, which are HSE's tools for assessing the most common manual handling risk factors of these tasks. They help to prioritise action to control the risks.
- A full risk assessment:
  - If an assessment with the HSE tools (MAC or RAPP) has been carried out then any necessary information can be added to ensure adequate coverage of the factors required by the Regulations.
  - A stand-alone full risk assessment can be carried out using online checklists.

The flowchart in Figure 19 of L23 describes this process.

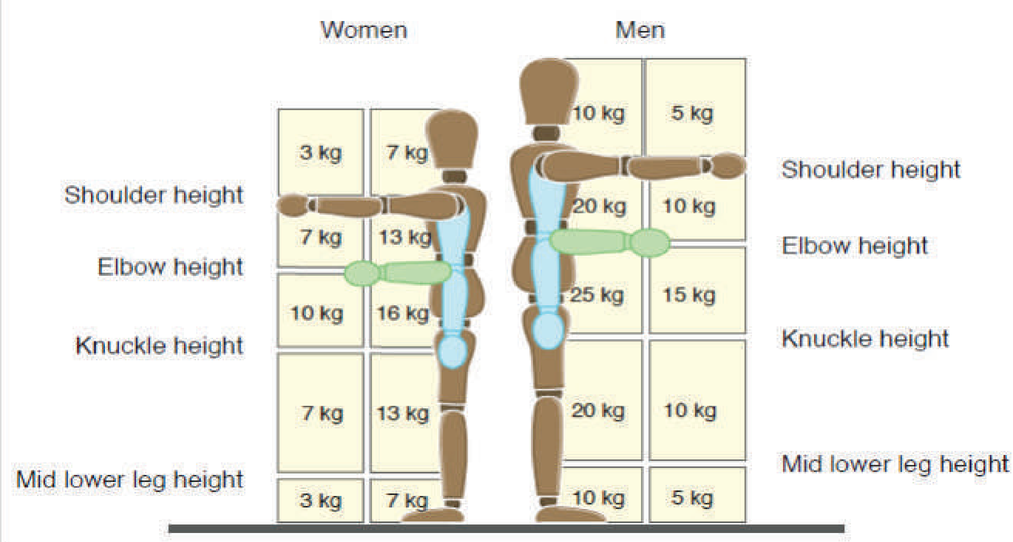
## The Simple Filters

There are different filters for four types of manual handling operations:

- Lifting and lowering.
- Carrying for up to 10 m.
- Pushing and pulling for up to 20 m.
- Handling while seated.

Details of these filters are contained in the guidance on the **Manual Handling Operations Regulations 1992**, L23, available at http://www.hse.gov.uk/pubns/priced/l23.pdf.

The diagram for the lifting and lowering risk filter is reproduced below.




The lifting and lowering filter (Source: www.hse.gov.uk/pubns/priced/l23.pdf)

Each box in the diagram contains a filter value for lifting and lowering in that zone. The filter values are reduced if handling is done with arms extended, or at high or low levels, as that is where injuries are most likely to happen. If the maximum weight being handled is less than the value given in the boxes where the lifter's hands pass through when moving the load, then the operation is within the guidelines. If the weight lifted exceeds the filter weight then the MAC tool can be used to do a more detailed assessment, or a full risk assessment can be carried out using the online checklists.

## DSE Workstation Assessment

Employers must carry out a DSE assessment of the user's workstation to ensure that the equipment and environment meets minimum standards and that the workstation can be adjusted to suit the user.

During the DSE assessment it will be necessary to check the:

- Screen.
- Keyboard.
- Chair (including foot rest – if required).
- Desk.
- Other associated equipment such as telephone.
- Environment, such as lighting, space, noise and temperature.

The UK's HSE has published a guidance note on DSE workstation assessment (*L26: Work with Display Screen Equipment*) that contains a checklist that can be used to facilitate and record the workstation assessments. The checklist is included as Appendix 5 to the guidance.

The checklist prompts the assessor to examine a range of characteristics to determine if the equipment provided at the workstation is of an acceptable standard and well set up. Key characteristics the assessor should examine include the:

- Display screen.
- Keyboard.
- Mouse.
- Furniture.
- Environment.

An example of part of the checklist is included below for illustration.

| RISK FACTORS | Tick answer YES | Tick answer NO | THINGS TO CONSIDER | ACTION TO TAKE |
|---|---|---|---|---|
| **3 Mouse, trackball etc** | | | | |
| Is the device suitable for the tasks it is used for? | | | If the user is having problems, try a different device. The mouse and trackball are general-purpose devices suitable for many tasks, and available in a variety of shapes and sizes. Alternative devices such as touchscreens may be better for some tasks (but can be worse for others). | |
| Is the device positioned close to the user?  ✔  ✘ | | | Most devices are best placed as close as possible, eg right beside the keyboard.<br>Training may be needed to:<br>■ prevent arm overreaching;<br>■ tell users not to leave their hand on the device when it is not being used;<br>■ encourage a relaxed arm and straight wrist. | |
| Is there support for the device user's wrist and forearm? | | | Support can be gained from, for ex desk surface or arm of a chair. If no supporting device may help.<br>The user should be able to find a c working position with the device. | |
| Does the device work smoothly at a speed that suits the user? | | | See if cleaning is required (eg of mo rollers).<br>Check the work surface is suitable. may be needed. | |
| Can the user easily adjust software settings for speed and accuracy of pointer? | | | Users may need training in how to settings. | |

Part of the DSE assessment checklist; Appendix 5 of L26: Work with display scre uk/pubns/priced/l26.pdf)

Risk assessment of DSE workstations may be required by national legislation

## Use of Assessment Tools

A variety of assessment tool have been developed to assist in the assessment of manual handling and repetitive activities. The detail of these tools varies, but the general approach is similar: they examine individual risk factors associated with the task and allocate a numerical score accordingly. The numerical score for risk factors is then summed and the total score is used to:

- Give a general indication of MSD risk level and acceptability/tolerability.
- Prioritise tasks according to MSD risk.
- Highlight individual risk factors that make the most significant contributions to total score so that those risk factors can be addressed.

It should be noted that these assessment tools do not themselves constitute a detailed risk assessment that would achieve legal compliance, but are simply aids in the assessment process.

**MORE...** www.

Guidance note *L26: Work with Display Screen Equipment* is available as a free download from www.hse.gov.uk/pubns

It is also available in an updated form as an independent document (series code ck1).

## Manual Handling Assessment Charts (MAC) Tool

The Manual Handling Assessment Charts (MAC) tool was developed by the UK's HSE primarily for inspectors to use during inspection visits as a quick tool to identify and quantify the level of risk associated with manual handling operations. The tool has since been published by the HSE as a tool for assisting in the management of manual handling risk.

The MAC tool uses a numerical score and a traffic light approach to indicate the level of risk. Three types of manual handling operation can be assessed:

- Single lifting operations.
- Single carrying operations.
- Team handling operations.

Each operation is divided into the different manual handling risk factors and presented as a flow chart. During use, an operation has to be observed and the flow chart used to guide the user through each factor of the manual handling operation to grade the degree of risk.

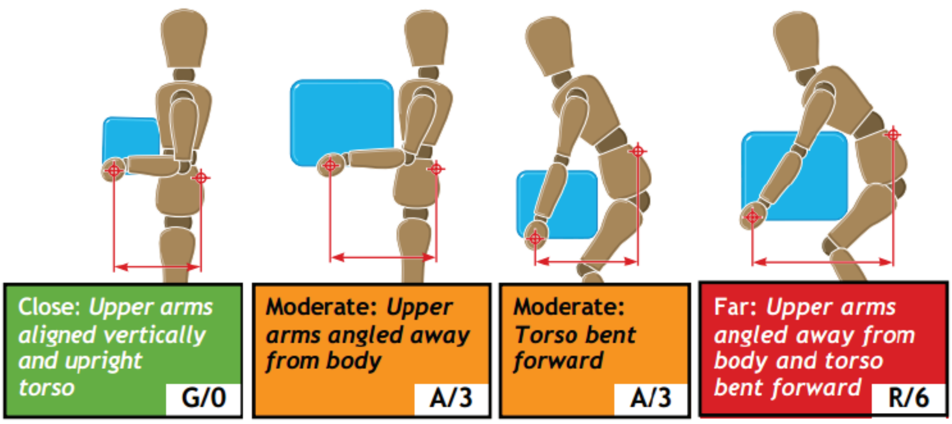
The risk factors assessed include:

| | |
|---|---|
| A | Load weight/frequency |
| B | Hand distance from the lower back |
| C | Vertical lift region |
| D | Torso twisting and sideways bending |
| E | Postural constraints |
| F | Grip on the load |
| G | Floor surface |
| H | Other environmental factors |

An example of one risk factor and the possible scores allocated is shown in the following figure:

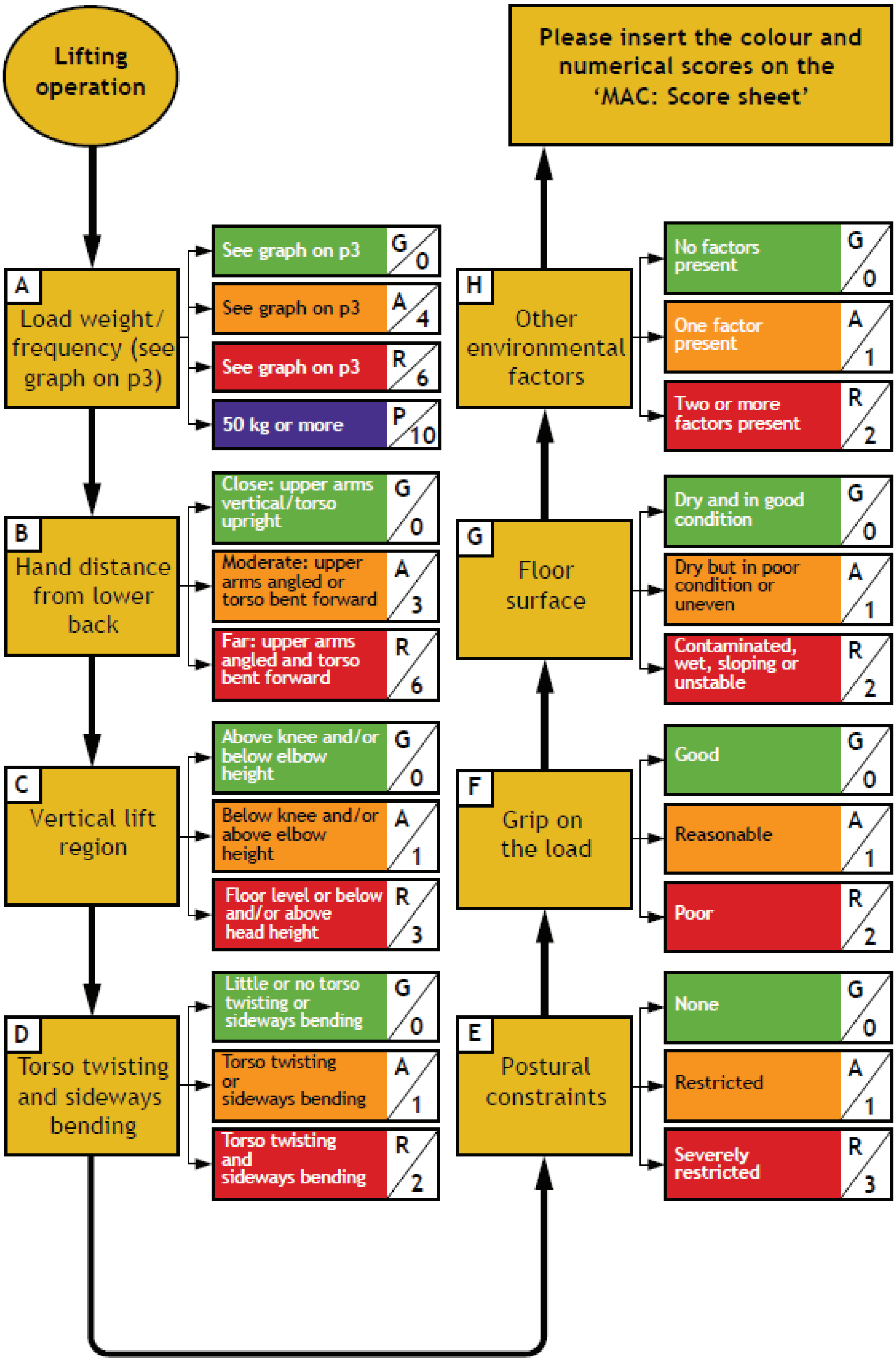
## B Hand distance from the lower back

Observe the task and examine the horizontal distance between the operative's hands and their lower back. Always assess the 'worst case scenario'. Use the following to guide your assessment:




Example risk assessment
Source: INDG383(rev1) Manual handling assessment charts (the MAC tool), HSE, 2014 (www.hse.gov.uk/pubns/indg383.pdf)

Colour coding for each of the risk factors allows for easy identification of the significant contributing risk factors. The MAC flow diagram for a lifting operation is illustrated in the following diagram.




MAC flow diagram
Source: INDG383(rev1) Manual handling assessment charts (the MAC tool), HSE, 2014 (www.hse.gov.uk/pubns/indg383.pdf)

## Variable Manual Handling Assessment Chart (VMAC) Tool

The MAC tool was designed for assessing handling operations where the operative handles the same weight throughout the working day. However, in practice, load weights are often variable. For example, with order picking, parcel sorting, trailer loading/unloading and parts delivery in manufacturing, the actual weight of the load may vary considerably. In response to this, the HSE developed the VMAC tool.

The VMAC tool is designed for assessing manual handling operations where the weight of the load varies. It is an online tool to be used with the MAC tool to highlight high-risk tasks. However, it is more complex than is needed for assessing many manual handling operations and it can be difficult or time-consuming to obtain weights of each item that a person handles during a shift. Like the MAC tool, it incorporates a numerical and colour-coding score system. It can be used to assess jobs where the weights handled change during the working day. It's based on the same data as the MAC tool and it uses the same colour bands. The additional data needed to use it are the weights of the items and the distance carried.

**MORE...** www.

The VMAC tool is available online at www.hse.gov.uk/msd/mac/vmac/index.htm and can be downloaded in spreadsheet form.

## Assessment of Repetitive Tasks (ART) Tool

The Assessment of Repetitive Tasks (ART) tool was developed by the UK's HSE to assist in the assessment of tasks that require repetitive moving of the upper limbs (arms and hands). It examines some of the common risk factors in repetitive work that contribute to the development of upper limb disorders.

In general approach, the ART tool is similar to the MAC tool. A specific activity is observed for a period of time, a description of the activity is made, then a series of specific risk factors are examined and scored, using a traffic light colour coding system to indicate significant risk factors.

Risk factors include:

| | |
|---|---|
| A | Frequency and repetition |
| A1 | Arm movements |
| A2 | Repetition |
| B | Force |
| C | Awkward postures |
| C1 | Head/neck posture |
| C2 | Back posture |
| C3 | Arm posture |
| C4 | Wrist posture |
| C5 | Hand/finger grip |
| D | Additional factors |
| D1 | Breaks |
| D2 | Work pace |
| D3 | Other factors |
| D4 | Duration |
| D5 | Psycho-social factors |

**MORE...** www.

Information on the ART tool, including a downloadable version of the tool is available from the following websites:

www.hse.gov.uk/msd/uld/art/index.htm

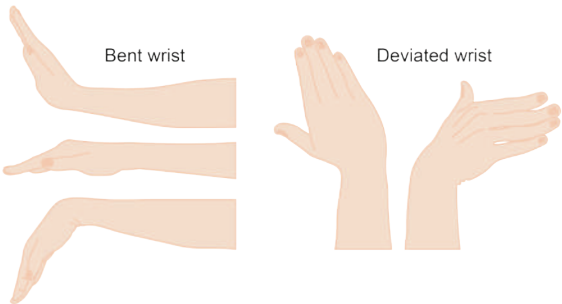
www.hse.gov.uk/pubns/indg438.pdf

An example of one risk factor and the possible scores allocated is given in the following figure:

## C4 Wrist posture

The wrist is considered to be bent or deviated if an obvious wrist angle can be observed.

***The wrist is:***




| The wrist is: | L | R |
|---|---|---|
| Almost straight/in a neutral position | 0 | 0 |
| Bent or deviated part of the time | 1 | 1 |
| Bent or deviated more than half of the time | 2 | 2 |

Based on: INDG438 Assessment of repetitive tasks of the upper limbs (the ART tool), HSE, 2010 (www.hse.gov.uk/pubns/indg438.pdf)

The overall risk score is calculated by summing the score for factors A1-D3. The sum is then multiplied by a duration multiplier (D4) which is derived from the length of time that a worker performs the activity during a day (this multiplier ranges from 0.5x to 1.5x). D5 is not assigned a score, but identifies additional factors to be considered.

Overall exposure scores can be used to prioritise repetitive tasks on the basis of ULD risk and can also be used to give an indication of acceptability/tolerability.

| Exposure Score | Risk | Action |
|---|---|---|
| 0-11 | Low | Consider individual circumstances |
| 12-21 | Medium | Further investigation required |
| 22 or more | High | Further investigation required urgently |

### Risk Assessment of Pushing and Pulling (RAPP)

The *Risk Assessment of Pushing and Pulling (RAPP) tool* has been developed by the HSE and is designed to help assess the key risks in manual pushing and pulling operations involving whole-body effort, e.g. moving loaded trolleys or roll cages, or dragging, hauling, sliding or rolling loads. It is intended to be used alongside the *Manual handling assessment charts (MAC tool)*, discussed earlier, which helps assess lifting and carrying operations, and it follows a similar approach.

## Other Assessment Tools

In addition to these four HSE published tools, other assessment tools are available from alternative sources:

- **The Manual Material Handling (MMH) checklist** - the National Institute of Occupational Safety and Health (NIOSH), a reputable American source, publishes this tool on their website. It is similar to, but less well developed and supported than, the MAC tool.

**MORE...** www.

The Risk Assessment of Pushing and Pulling (RAPP) tool (INDG478) is available online at http://www.hse.gov.uk/pubns/indg478.pdf.

To download a copy of the MMH checklist, visit: www.cdc.gov/niosh

and search for 'Ergonomic Guidelines for Manual Material Handling'.

An online version of the RULA tool is available at: www.rula.co.uk

- **The Rapid Upper Limb Assessment (RULA) tool** - this has been developed by ergonomists at the University of Nottingham. A RULA gives a quick and systematic assessment of the postural risks to workers. One benefit of RULA over ART is that more detailed examination of left and right arm, wrist and hand position and movement is inherent in the tool, along with consideration of head, back and leg position and movement. Similar to the ART tool, the results of the test is a RULA score that can be used to prioritise comparative risk and indicate the urgency of the need for change.

Similar to the ART tool, the result of the test is a RULA score that can be used to prioritise comparative risk and indicate the urgency of the need for change.

| Action Level | RULA score | Action |
|---|---|---|
| 1 | 1-2 | Working in the best posture with no risk of injury from their work posture. |
| 2 | 3-4 | Working in a posture that could present some risk of injury from their work posture, and this score most likely is the result of one part of the body being in a deviated and awkward position, so this should be investigated and corrected. |
| 3 | 5-6 | Working in a poor posture with a risk of injury from their work posture, and the reasons for this need to be investigated and changed in the near future to prevent an injury. |
| 4 | 7-8 | Working in the worst posture with an immediate risk of injury from their work posture, and the reasons for this need to be investigated and changed immediately to prevent an injury. |

# Practical Control Measures

In general terms, the **control** of ergonomic risk can be achieved by introducing changes to the:

- task and the way that it is done,
- tools, equipment and machinery, and
- workplace environment,

so as to suit the individuals carrying out the work.

In some cases, it may be appropriate to put restrictions on the individuals doing the work (i.e. restricting those people who have a known WRULD to light duties to avoid further injury).

The first step in achieving controls is to undertake a **risk assessment**. This risk assessment may follow a standard format as indicated by the relevant guidance and it might make use of an assessment tool such as the ART tool, RULA or some other aid.

The controls identified by the risk assessment will inevitably vary, depending on the nature of the task being assessed. Several examples of control options are discussed below, classified according to work activity.

## Display Screen Equipment Control Measures

The following control measures are appropriate for DSE use include:

- Carrying out a **workstation assessment** to ensure that the equipment and environment meet minimum standards and that the workstation can be adjusted to suit the user.
- Providing basic DSE workstation **equipment** that meets minimum standards in terms of good ergonomic design.
- Planning the user's **work routine** so that they can take short, frequent breaks from screen and keyboard use.
- Providing DSE users with a **free eye test** and, if required, **spectacles** for screen use.
- Providing **information** and **training** to users on the potential health risks of DSE use and the preventive measures; in particular, ergonomic use of the workstation.

In the UK, these measures are incorporated into the **Health and Safety (Display Screen Equipment) Regulations 1992**, which follow the approach identified in the relevant EU directive.

Some of the minimum standards for workstation equipment and the good practices with regards to posture and workstation use are illustrated in the following figure:


Good ergonomics at a DSE workstation
(Based on original source L26 Work with display screen equipment (2nd ed.), HSE, 2003 (www.hse.gov.uk/pubns/priced/l26.pdf))

The numbered issues are as follows:

1. Adjustable height and angle to seat back.
2. Good lumbar support.
3. Adjustable height seat to bring the hands to a comfortable position on the keyboard. The seat also has a stable 5-star base.
4. Correct seat height adjustment and keeping the feet supported prevents excess pressure on underside of thighs and backs of knees.
5. Foot support if the user cannot get their feet on the floor.
6. Space for postural change, no obstacles under desk; this allows the user to fidget and change position as they work.
7. Forearms approximately horizontal when hands are on the keyboard.
8. Minimal extension, flexion or deviation of wrists; wrists should be straight and flat when on the keyboard, indicating proper seat height adjustment.
9. Screen height and tilt should be adjustable so as to allow comfortable head position.
10. Space in front of the keyboard to support hands/wrists during pauses in typing; a wrist-rest can provide further support if required.

Additional points:

- The desk should be laid out to minimise the need for twisting or over-reaching (e.g. when reaching for a telephone).
- A document holder may be required.
- If frequent telephone use is necessary when using the keyboard then a headset may be necessary.
- Workplace lighting should be provided so as to avoid reflections on the screen and glare.
- Unfortunately, some of these good ergonomic principles cannot be applied to use of a laptop computer. If laptops are going to be used in the workplace, then:
  - Allow short- but not long-duration use.
  - When laptops are going to be used for long durations, apply the same management approach of workstation assessment, frequent breaks, eyesight tests for users, information and training.
  - Provide a docking station and/or separate screen, keyboard and mouse as required to allow the user to convert the laptop to a more adjustable configuration.

## Factory Assembly Line Control Measures

The control measures appropriate for the factory assembly line are very similar to those applied in the case of DSE use:

- Carry out an **ergonomic assessment** of the workstation to ensure that it is appropriate and can be adjusted to suit the worker's needs.
- Plan the worker's **work routine** so that they can take recovery breaks.
- Provide **information** and **training** to workers on the potential MSD health risks and the preventive measures; in particular, ergonomic use of the workstation.

Specific controls might include:

- **Automating** the process to eliminate the MSD risk entirely.
- **Re-layout of the workstation** to allow comfortable posture and to minimise overreaching, stooping, twisting, etc.
- Providing **seating** if not already available.
- Providing **comfortable shoes** and floor mats to relieve foot pressure if sitting is not possible.
- Allowing short, **frequent breaks** from the production line or introduce job rotation to prevent long duration on one task.
- Ensuring **lighting** is appropriate to the task (brightness or lux levels should be relatively high for fine-detail work).
- Introducing ergonomically-designed **hand tools**.

### TOPIC FOCUS

**Good ergonomic design of tools and equipment**

**Force** – choose tools and equipment that require minimal force to hold, use or operate. Choose smaller, lighter tools in preference to larger, heavier ones, where possible. Make use of powered tools/equipment rather than hand tools/equipment where excessive force has to be used (e.g. air-powered wrench rather than a hand wrench). Also, provide support for tools and equipment that must be held during use, where weight is excessive.

(Continued.)

## TOPIC FOCUS

**Posture** – select tools and equipment that allow the operator to adopt a comfortable posture during use rather than requiring them to bend, twist, stoop or overreach (e.g. long-handled scrapper for cleaning inside a container rather than short-handled scrapper, which requires stooping over the container to reach the bottom).

**Twisting** – select tools that minimise the need to twist the arm/wrist during use (e.g. a battery-powered screwdriver).

**Rest** – select tools and equipment that allow the user to rest during use, and provide a rest for the tool so that the user can put it down during rest periods.

**Shape** – select tools and equipment that are shaped for ease of use and comfort. Special attention should be paid to the handles of hand-held tools (e.g. a large soft handle on a hand-grip will be more comfortable for long-term use than a narrow, unpadded handle).

**Adjustability** – the more adjustability the tools and equipment have, the better able users will be to adjust them to suit their personal comfort (e.g. an adjustable-height work-piece platform will be easier to use for a taller or shorter worker than one fixed at standard height).

## Manual Handling Control Measures

Control of manual handling risk can be achieved by using a simple hierarchy of controls:

- Eliminate the manual handling.
- Assess the manual handling that cannot be eliminated.
- Use handling aids.
- Modify the task, load or environment.
- Ensure individual capabilities are matched to the activity.

### Eliminate the Manual Handling

This can be done by automation or mechanisation of the handling activity. Conveyor belt systems, forklift trucks, electric pallet trucks, cranes, hoists and other types of mechanical moving or lifting equipment provide a way of moving loads without the need for workers to use bodily force.

Electric hoist moving load

### Assess Manual Handling that Cannot Be Eliminated

This can be done by looking at the four factors of: task, load, environment, and individual capabilities (see below).

### Use Handling Aids

Consider the use of a piece of equipment that does not completely eliminate the manual handling but does make it much easier. For example, a sack truck does not eliminate the need to push the load, but it does eliminate the need to carry it.

There are many handling aids available, such as trolleys, barrel lifts, gin wheels, trucks, hoists and lifts that require some manual effort to lift or support the load, but give the worker mechanical advantage.

### Modify the Task, Load or Environment

When the appropriate questions we listed earlier are answered, there are usually some simple solutions that present themselves.

Modifications may be possible to reduce the significant risk factors, such as the:

- Task:
  - Control repetitive handling by introducing frequent rest breaks or job rotation to minimise the length of time that an individual worker has to perform the task.
  - Eliminate stooping and twisting by changing the layout of the workstation.
  - Use a table or lift to bring the load to waist height to eliminate picking up from floor level.
- Load:
  - Break down a heavy load into smaller parts.
  - Use several workers to handle a large, bulky load.
  - Stabilise an unstable load by securing it or putting it into a container.
  - Mark up a load with an off-centre C of G so that workers can see where the C of G is.
  - Attach handles to a load that is difficult to grasp.
- Environment:
  - Re-arrange the workspace to allow more space for the handling activity.
  - Level an uneven floor.
  - Supply additional lighting in a poorly lit location.

> **MORE...** www.
>
> General guidance is available from:
>
> www.hse.gov.uk/msd/index.htm
>
> There is also an associated workstation checklist to aid in risk assessment.
>
> The publications can be accessed at:
>
> www.hse.gov.uk/pubns/indg36.pdf
>
> www.hse.gov.uk/pubns/ck1.pdf

### Ensure Individual Capabilities are Matched to the Activity

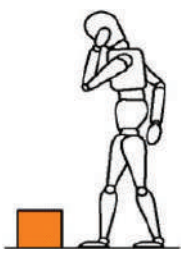
If the activity requires unusual ability then workers must have that ability. For example, if unusual strength and size are required, then the worker must have those characteristics; if a particular technique is required then the worker must be trained so that they develop that technique.

If the activity presents significant risk to vulnerable individuals such as pregnant women or people with pre-existing back injuries, then those people will have to be prohibited from carrying out the activity.

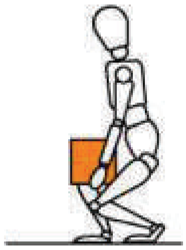
## Safe Lifting Technique

Employees should be trained in basic safe lifting technique. This technique minimises the risk of musculoskeletal disorders:

- Before Lifting
  - Check the weight, C of G and stability of the load.
  - Plan the route of the carry.
  - Establish a firm grip.



- The Lift
  - Bend the knees and use the leg muscles to lift.
  - Keep the back upright.
  - Keep the load close to the body.
  - Avoid twisting, over-reaching, jerking.



- Setting Down
  - Use the same principles as when lifting.
  - Maintain good balance.
  - Set the load down and then adjust its position using body weight.

## STUDY QUESTIONS

3. What risk-reduction measures can be introduced to avoid the development of WRULDs?
4. Summarise the requirements relating to the following elements of DSE workstations:

   (a) Work surface/desk.

   (b) Keyboard.

   (c) Chair.

   (d) Space.
5. What alterations could you suggest to the organisation of a display screen operator's tasks in order to reduce the physical stress that he/she may be exposed to?
6. What are the characteristics of the load which present a hazard during manual handling operations?
7. Identify the main hazards presented by the working environment in respect of manual handling operations.
8. What is the primary means of minimising the hazards of manual handling?
9. How can manual handling tasks be re-designed to make them less hazardous?

(Suggested Answers are at the end.)

# Summary

## Musculoskeletal Injuries and Ill Health

We have:

- Outlined the human skeletal system made up of the skeleton with its associated muscles, cartilage, tendons and ligaments.
- Outlined various Musculoskeletal Disorders (MSDs), including back injury and back pain; upper limb disorders; and muscle, tendon and ligaments injures.
- Described various work activities, such as production line work, DSE use and manual handling that have a high risk of MSDs.

## Assessing and Controlling Musculoskeletal Risk

We have:

- Explained the risk factors that influence the risk of MSDs associated with a particular activity, such as repetition, force, posture, twisting, rest, equipment design and adjustability, lighting, environment parameters and individual capabilities.
- Outlined how MSD risk assessments often follow a format established by relevant legislation, such as manual handling risk assessments that must consider the load, task, environment and individual capabilities.
- Explained the use of various assessment tools to assist with the risk assessment of both manual handling and repetitive activities, such as the HSE's MAC and ART tools.
- Explained the variety of control measures available to combat MSDs risk, such as hazard elimination (by automation or mechanisation), the provision of equipment and aids, task redesign, alterations to the work environment and the use of good practices with regards to posture and technique.

# Exam Skills

This is a traditional exam-style musculoskeletal question for you to try; NEBOSH could ask about any section so you need to understand everything in your material.

## QUESTION

Work-Related Upper Limb Disorders (WRULDs) can develop if ergonomic principles are not followed when designing work tools and work equipment.

(a) **Outline** what is meant by the term 'ergonomic principles'. **(2)**

(b) **Outline** how the design of work tools and work equipment can help to minimise the risk of a person developing a WRULD. **(8)**

## Approaching the Question

Remember, this is a 10-mark question so in the exam you would need to spend no more than 15 minutes answering it. Look at both parts carefully to decide how much detail you need to include in each.

Visualise a tool and how you would design it to minimise ergonomic issues.

## Suggested Answer Outline

(a) The examiner would require you to define the term "ergonomic principles" – 'designing the workplace, work methods and work equipment to suit the worker, or ensuring a good fit between the person and their work as far as tools, equipment and workstation are concerned'.

(b) Remember this is about design factors.

The examiner would expect you to include eight points from the following: design tool specifically for the job; availability of range of sizes or making them adjustable; left-handed variants; weight (light-weight as far as possible); handles/supports designed in at appropriate points, taking account of weight distribution (i.e. weight-balanced while holding); easy to maintain/clean; require minimum (or appropriate) force; avoidance of posture extremes or repetitive movement; avoidance of excessive noise/vibration; conformity with appropriate standards (e.g. EN 614).

## Example of How the Question Could be Answered

(a) *'Ergonomic principles' refers to the design of the workplace or task so that it takes into account the person(s) doing the task or activity. This ensures that there is a good fit between them and the tools, equipment, and workstation.*

(b) *When designing work tools and equipment to minimise the risk of WRULD, there is a number of requirements to take into account.*

*Where possible, the grip strength required should be minimised, and the size of the hands of the workers and how they will hold the tool or equipment should be taken into account, including the needs of left-handed workers.*

*Handles should be shaped to facilitate a neutral wrist position and include a variety of sizes to accommodate all workers.*

*The balance of the tool should reduce undue stress on the forearm and wrist and the force required to manipulate the tool and equipment should be minimised. In general, the need for repetitive movements or awkward postures should be avoided and the tool or item of equipment will need maintenance to keep it in good condition.*

*Finally, it is always important to involve users at the design stage and any proposed designs should meet appropriate BS EN standards.*

## Reasons For Poor Marks Achieved By Candidate in Exam

- They suggest that the term meant fitting the person to the work.
- They miss the reference to design in the question and includes information about selection and maintenance issues.
- They concentrate solely on the components of a DSE workstation rather than dealing with tools and equipment in general.

Element IB10

# Work Environment Risks and Controls

## Learning Outcomes

Once you've read this element, you'll understand how to:

1. Explain the need for, and factors involved in, the provision and maintenance of temperature in both moderate and extreme thermal environments.
2. Explain the need for suitable and sufficient lighting in the workplace, units of measurement of light and the assessment of lighting levels in the workplace.
3. Explain the need for welfare facilities and arrangements in fixed and temporary workplaces.
4. Explain the requirements and provision for first aid in the workplace.

# Contents

# Temperature and Thermal Environment

## IN THIS SECTION...

- Thermal comfort is a person's subject opinion as to whether they feel comfortable with their thermal environment.
- Thermal balance is achieved when the rate of metabolic heat production is balanced by the rate of heat gain or loss by conduction, convection, radiation and evaporative heat loss. If this balance is upset, then heat stress or hypothermia result.
- Exposure to extreme thermal environments can lead to heat stress and heat stroke or cold injuries and hypothermia. These conditions can be life-threatening.
- Extreme thermal environments are encountered in many indoor industrial workplaces and in outdoor working.
- The environmental parameters that affect thermal comfort are air temperature, radiant temperature, humidity and wind speed. These can be measured using various types of thermometer, hygrometer and anemometer.
- Other parameters that affect thermal comfort are work rate, clothing and duration of exposure.
- The Wet Bulb Globe Temperature (WBGT) Index is used as a tool to assess the likely heat stress on workers if carrying out work in any given thermal environment. It can be used to predict the degree of heat stress and the duration of exposure that is likely to prove acceptable.
- The control measures available for maintaining thermal comfort and a safe thermal environment employ engineering, administrative and behavioural options.

## Thermal Comfort

When looking at the issue of temperature and the thermal environment, it is important to distinguish between working in **extreme thermal environments**, where **significant risk** may arise in relatively short periods of time (such as dehydration and hypothermia) and working in **non-extreme thermal environments**, where no comparable risk is created, but workers experience **discomfort**. For example, fire-fighters have to work in hot environments wearing full protective clothing and breathing apparatus. It is not hard to imagine that even a very fit person might become heat stressed and suffer heat exhaustion that might prove life-threatening in a relatively short period of time. On the other hand, office workers might have to sit for long periods of time in a relatively benign environment where the air temperature is 17°C.

No-one is going to suffer hypothermia, but most people will feel cold and uncomfortable carrying out sedentary work in such an environment and the levels of discomfort will increase over time.

### DEFINITION

**THERMAL COMFORT**

The term describes a person's psychological state of mind and is usually referred to in terms of whether someone is feeling too hot or too cold.

It is defined in British Standard BS EN ISO 7730 as:

*"that condition of mind which expresses satisfaction with the thermal environment.'"*

In between these extremes, there is, of course, a sliding scale where discomfort (psychological in origin) turns into health risk (physical in origin). The degree of discomfort and the degree of health risk have both been the subject of scientific study over time. However, since they are both subject to many variables, it is difficult to make definitive statements about what is/is not acceptable as we move along that sliding scale. This is particularly the case for discomfort which is inherently a subjective opinion.

**Thermal comfort** is defined in British Standard **BS EN ISO 7730** as:

*" that condition of mind which expresses satisfaction with the thermal environment."*

The term describes a person's psychological state of mind and is usually referred to in terms of whether someone is feeling too hot or too cold.

Thermal comfort is difficult to objectively determine because allowances have to be made for a range of environmental and personal factors when deciding what will make people feel comfortable. We all know from personal experience what room temperatures will make us feel most comfortable and we know that this will vary depending on a range of factors, such as the activity that we are performing. For example, as I sit writing these words the air temperature is 18°C and I am feeling a little cold. If I were stood up lecturing that would be a perfect temperature for me, but probably rather cold for those sat listening (metabolic work rate is higher if you are stood than when you are seated). If I were playing five-a-side football it would be unbearably hot in an indoor sports hall with no cooling breeze (running makes metabolic work rate soar). We also know from personal experience that what suits us does not suit other people. People have very different opinions about what constitutes thermal comfort. Some people would happily sit in an office heated to 25°C, a temperature that others would find sleep-inducing. You all have your own opinions on the matter.

The best that an employer can realistically hope to achieve is a thermal environment that satisfies the majority of people in the workplace, or put more simply, 'reasonable comfort'. The UK's HSE considers 80% of occupants as a reasonable limit for the minimum number of people who should be thermally comfortable in an environment.

Thermal comfort is not measured by air temperature, but by the number of employees complaining of thermal discomfort.

# Heat Balance

The body can be considered to be a chemical factory which carries out myriad complex chemical reactions at a temperature of about 37°C and a pressure of one atmosphere. Normal pressure variations do not affect the metabolic processes unduly, but the body temperature is critical and does not vary in general outside the range 36-38°C.

Many body reactions involve oxidation where heat will be generated. In order to maintain a stable temperature required for the efficient functioning of the central nervous system and body organs, the metabolic heat loss must be carefully controlled. The body has developed a very sensitive heat control system which is able to react to the considerable variations in environmental temperatures to which the body is exposed and can activate mechanisms which will oppose or allow heat loss in an effort to keep the body temperature stable. There are, however, limits.

## Thermo-Regulatory Mechanisms

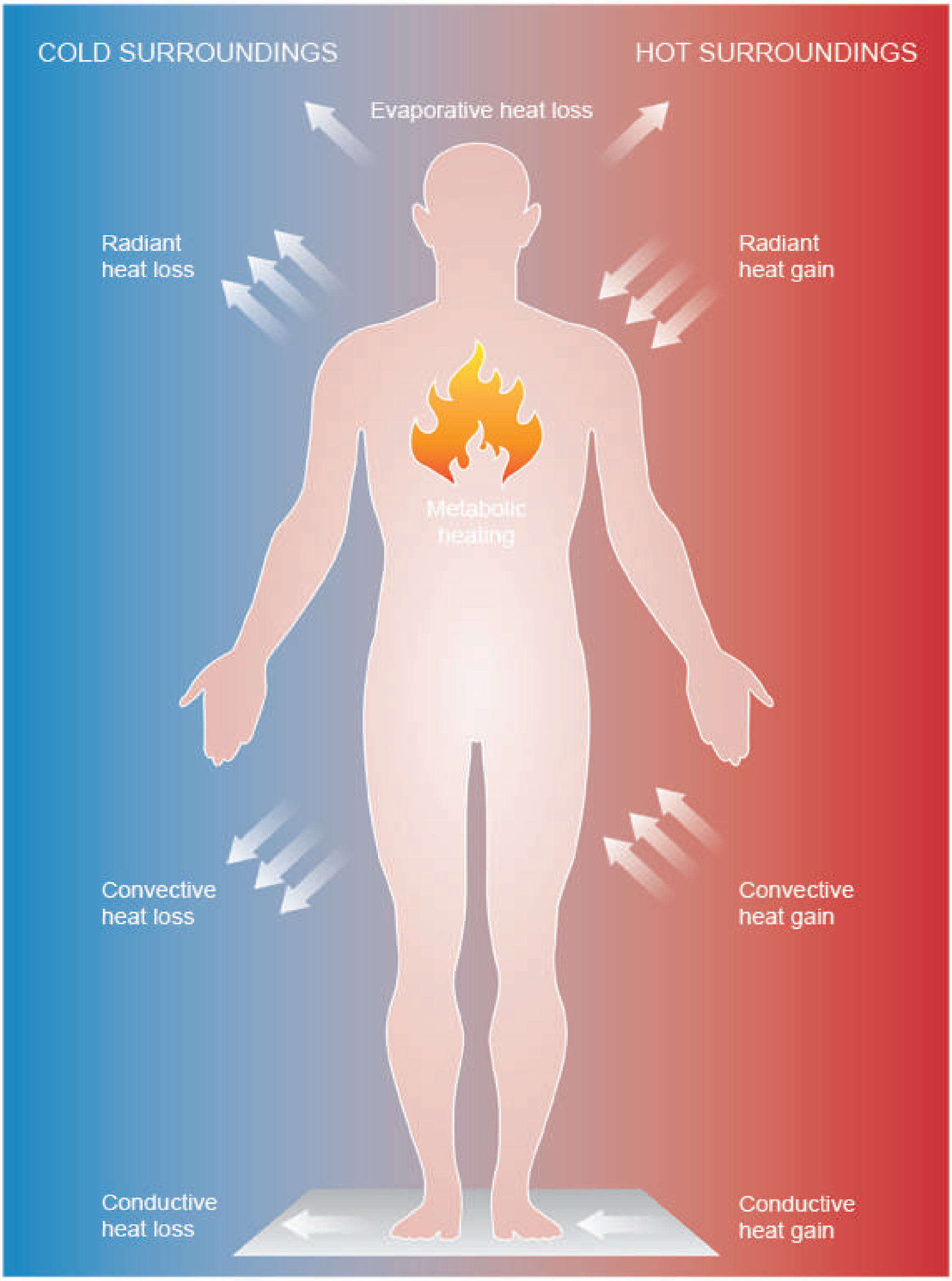
As core temperature increases, the body responds by trying to lose heat to the external environment. This is done by transporting heat from the core to the surface of the body (the skin). Blood vessels in the dermal layer of the skin dilate (vaso-dilation) so that blood can flow close to the surface of the skin. The increase in temperature at the skin leads to heat loss by radiation (infrared radiation) and direct conduction into colder air. At the same time, sweat (a mixture of water and salts extracted from the blood by the sweat glands in the dermal layer of the skin) is excreted up the sweat ducts and onto the surface of the skin. This liquid spreads over the surface of the skin and evaporates. As it does so, it takes heat from the surface of the skin (this is the heat required to change the state of the water from a liquid to a vapour). This lost heat cools the skin, which, in turn, cools the blood. The cooled blood is returned to the core where it picks up more heat; and so the cycle is repeated.

As core temperature decreases, the opposite reaction takes place. Blood supply to the skin is reduced by restricting the size of the blood vessels (vaso-constriction). The excretion of sweat onto the surface of the skin stops. Blood is kept in the core of the body and blood supply to the extremities will be reduced to a minimum. Hair on the skin is brought upright. This is done by small erectile muscles in the dermal layer of the skin attached to each hair follicle – this is what creates the puckered skin effect of 'goose-bumps'. If core temperature cannot be maintained, then the body may respond by trying to create additional heat through muscle activity in the form of uncontrollable shivering.

In both instances, these mechanisms are entirely automatic and are not under conscious control. There is, of course, a range of actions that the individual can take that will affect heat loss or heat gain, e.g. stopping work, seeking shade, removing clothing, splashing water onto the skin, standing in a breeze, etc., or increasing work rate, putting on additional clothing, seeking warmth, getting out of moving air, removing wet clothing, etc.

Heat transfer mechanisms are illustrated in the following figure:




Modes of heat exchange between the body and the environment

The important heat transfer mechanisms are:

- Radiation.
- Evaporative cooling.
- Convection.

Conduction is of limited importance except where there is considerable body contact with a heating or cooling source, e.g. motor fitters lying on concrete floors.

Convection is very important as heat transfer from the body depends on convection currents in the air: convection currents are also an integral part of evaporative cooling.

Radiation becomes progressively more important as temperature rises, since the radiant heat from a source is proportional to $K^4$ (K is absolute temperature in degrees Kelvin: K = °C + 273).

A worker on an oil platform works in a range of extreme environments

The body's thermal balance can be represented by the equation:

$M = K + C + R + E$

where M is the rate of metabolic heat production.

K is the loss or gain of heat by conduction.

C is the loss or gain of heat by convection.

R is the loss or gain of heat by radiation.

E is the heat loss from skin or respiratory tract due to evaporation of moisture (so this is never +ve).

When both sides of the equation balance, thermal balance exists (i.e. the metabolic heat production rate is balanced by the amount of heat being gained or lost through the various mechanisms).

When the equation does not balance, core temperature cannot be maintained and rises or falls to cause heat stress or cold stress, respectively.

# Health Effects of Working in Extreme Thermal Environments

## Exposure to Hot Conditions

When air temperature is high, or significant radiant heat is falling on a person, or they are doing heavy work perhaps whilst wearing protective clothing, then core temperature may increase faster than the body can loose heat. If the body is not able to lose heat quickly enough and core temperature rises, this leads to **heat stress**.

Since one of the major ways that heat is lost by the body is by evaporative heat loss (sweating), the amount of water vapour in the air (humidity level) has a significant effect on rate of heat loss. When the air temperature reaches 35°C or more, the body loses heat by sweating alone. If relative humidity levels are 80% or more then evaporation of sweat virtually stops. This is why tropical climates can be exhausting,; the combination of high air temperature and high humidity means you sweat but do not enjoy any cooling effect; - you simply get wet and dehydrate but it does not cool you down.

The extent of the effects depends on: the individual (in particular, whether they are acclimatised); environmental conditions, such as temperature, humidity and air movement; clothing; work rate, etc.

Typical symptoms of heat stress include:

- Inability to concentrate.
- Muscle cramps (due to salt loss through sweating).
- Heat rash (sometimes called 'prickly heat').
- Severe thirst (due to dehydration) – a late symptom.
- Fainting (sometimes called 'heat syncope').
- Heat exhaustion – fatigue, giddiness, nausea, headache, moist skin.
- Heat stroke – hot dry skin, confusion, convulsions, loss of consciousness. This is the most serious effect as it can lead to coma and death.

Fire-fighters work in an extremely hot environment

These symptoms are caused by a combination of dehydration (loss of water and salts from the blood through sweating), loss of blood pressure (caused by the blood vessels vaso-dilating to bring the blood closer to the surface of the body) and the increased core temperature (which takes metabolic processes away from their optimal rate).

Depending on circumstances, mild heat stress can develop into heat exhaustion and heat stroke over several days, hours or minutes.

### Exposure to Cold Conditions

Exposure to extreme cold conditions may lead to **cold injuries**:

- Non-freezing injuries, such as chilblains (painful lumps, often on feet) and trench foot (swollen, infected feet as a result of cold and damp).
- Freezing injuries, such as frostnip (freezing of the surface layers of skin) and frostbite (freezing of skin and deeper tissues), usually to the extremities (fingers and toes).

Exposure to cold conditions may also lead to **cold stress**. This is the exact opposite of heat stress, where the body is unable to maintain core temperature at 37°C and consequently the core temperature starts to fall. Once core temperature falls below 35°C, then hypothermia has occurred.

Symptoms of hypothermia include:

- Feeling cold, followed by pain, then numbness.
- Shivering (automatic muscle contractions in an attempt to generate metabolic heat).
- Uncharacteristic mood and behaviour changes.
- Confusion.
- Muscular weakness.
- Drowsiness.

The condition can lead to coma and death. Like heat stroke, hypothermia may take hours to progress, or may take minutes if the conditions are right.

## Typical Work Situations

**Thermal discomfort** can occur in any work situation since it is a personal, subjective state of mind. A number of factors might be indicative of typical work situations where it is likely to arise:

- Large areas of glazing may cause overheating through solar gain (greenhouse effect).
- Air movement is necessary to provide air changes for fresh air requirements, but if the velocity rises above 0.15 m/s, there may be complaints about draughts.

- People, artificial lighting and computers can add considerably to the heat generated in a particular area, creating overheating problems.
- Lack of control by individuals over their environment. The absence of adjustable heating controls, opening windows and controllable ventilation systems leads to high levels of dissatisfaction.


Glass blowing furnace

**Heat stress and cold stress** occur in more extreme thermal environments. Typical work situations causing heat stress include:

- Furnace work, handling molten metal.
- Glass-making.
- Welding, brazing.
- Boiler and furnace maintenance, boiler-room work.
- Deep-mining work.
- Laundries.
- Kitchens.
- Fire-fighting.

Typical work situations causing cold stress include:

- Outdoor work (agriculture, maintenance, etc.).
- Sea fishing, shipping.
- Oil rigs.
- Deep freeze stores, cold rooms.
- Diving.

# Environmental Parameters that Affect Comfort

## Air Temperature (Surrounding Temperature)

In terms of temperature, **heat will always flow from a high temperature to a low temperature**. It therefore follows that, as the temperature of the surroundings increases, the body will find it increasingly difficult to **lose** heat. There will come a point where the body will begin to overheat. Similarly, as air temperature falls, the heat gradient between the body and the surrounding air becomes steeper; this causes heat to flow from the body more rapidly, making it difficult for the body to maintain temperature.

## Radiant Temperature

Thermal radiation is the heat that radiates from a warm object. Radiant heat may be present if there are heat sources in an environment.

Radiant temperature has a **greater** influence than air temperature on how we lose/gain heat to/from the environment. Our skin absorbs almost as much radiant energy as a matt black object, although this may be reduced by wearing reflective clothing.

Examples of radiant heat sources include: the sun; fire; electric fires; furnaces; steam rollers; ovens; walls in kilns; cookers; dryers; hot surfaces and machinery, molten metals, etc.

## Humidity

The amount of water vapour in the air has a bearing on the ability to lose water vapour from sweat on the surface of the skin, so humidity becomes an important factor in determining the amount of evaporative cooling.

Humidity is a measure of the concentration of water vapour in the atmosphere. The amount of water vapour is dependent on two main factors, the:

- Presence of liquid water to supply the water vapour; air over water will have a higher concentration than air over a desert.
- Temperature of the air; the higher the air temperature, the greater the capacity of the air to hold water vapour.

At any given temperature, the air can only hold a certain amount of water vapour. Where conditions of maximum water vapour occur, the air is said to be saturated. Cold air can hold a lot less water vapour than warm or hot air. So, it becomes saturated at much lower water vapour concentrations. This is why arctic winds always feel 'dry' (they contain little water vapour), but hot summer breezes can be 'dry' (low water vapour concentration) or 'muggy' (high water vapour concentration or even saturated).

Because of the interplay of temperature and water vapour concentration, humidity is expressed in terms of **relative humidity**.

Relative Humidity (RH) is a ratio; it has no units (though it is sometimes expressed as %) and is defined by the following formula:

$$RH = \frac{\text{Mass of water vapour present in a given volume of air at a given temperature}}{\text{Mass of water required to saturate that volume of air at the same temperature}} \times 100$$

## Air Velocity or Wind Speed

The rate of evaporative cooling depends on the air velocity – or air-change rate. With low air-change rates, the evaporation zone (the layer of air near the skin that sweat is evaporating into) soon becomes saturated with water vapour and the evaporation rate will decrease, hence the cooling effect stops. When air velocity is high, water vapour leaves the sweat freely and so sweating has a far greater effect on heat loss rate.

In situations where air is moving over exposed skin but that skin is dry (not sweating), the air will draw heat from the skin by conduction (heat flows from hot to cold). Thus, on a cold day, exposed dry skin is cooled by air movement. The rate of heat transfer increases as air speed increases, giving rise to the wind-chill effect.

# Measuring Environmental Parameters

## Thermometers

Thermometers are the main instruments for measuring temperature. There are three main types:

- ### Liquid Thermometers

  The operating mechanism depends on the fact that liquids expand in a regular manner with temperature change. Liquid expands into a graduated capillary tube.

  The two main liquids used are mercury and alcohol. Mercury has a wide liquid range but, as it freezes, at about -39°C, it is more useful for higher temperature measurements up to about 350°C. Alcohol is useful for low temperature measurements because it freezes at about -130°C.

Various types of thermometer are used to measure temperature

  Use of mercury (toxic) thermometers is becoming rarer and many countries have completely banned their use in health care environments. Some manufacturers have introduced other liquid alloys as a suitable replacement.

- Thermocouples

  Thermocouples or thermo-electric thermometers depend on the variation of current with temperature produced by two different metals in contact with each other and incorporated in an electric circuit.

- Resistance Thermometers

  Resistance thermometers depend on the variation in resistance with temperature, and hence current flow, within materials when incorporated in an electrical circuit.

Thermometers are used to measure three important temperature parameters – dry bulb air temperature, wet bulb air temperature and radiant temperature.

The **dry bulb air temperature** can be measured using mercury/alcohol in glass thermometers, thermocouples or resistance thermometers. The sensing head has to be protected from radiant heat exchange by placing either a polished silver or aluminium shield around it. A current of air may be drawn across the sensing head to increase the speed of response and minimise the influence of radiation.

The **wet bulb air temperature** is obtained with the sensing head covered with a muslin sock wetted with distilled water and protected from radiant heat. Air has to flow past the wet bulb at a minimum velocity of about 4m/s, which can be achieved by drawing air over it using a clockwork or electrically-driven fan.

Readings should be taken successively until the last two agree. Drying or contamination of the sock must be prevented and humid air from the observer's body must not be allowed to pass over the thermometer.

Measurements of **radiant temperature** are usually made with a black globe thermometer. It is made of a 150mm-diameter hollow copper sphere painted matt black, into which a thermometer is inserted with its bulb at the centre of the globe. The instrument has a slow response, taking about 20-30 minutes to reach equilibrium. It is easy to use but because it is subject to convective cooling, corrections have to be made for air velocity and dry bulb temperature.

## Hygrometers

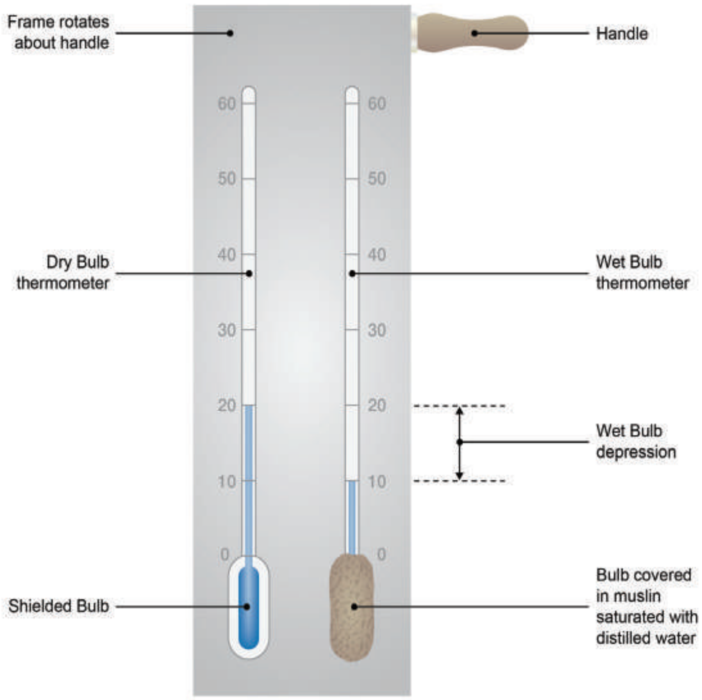
Hygrometers are used to measure atmospheric humidity. Many different types exist, such as the whirling hygrometer and electronic versions.

### Whirling Hygrometer (Sling Psychrometer)

The whirling hygrometer (illustrated in the following figure) is used in conjunction with tables (psychrometric charts) which can relate the variation between two thermometer readings to relative humidity.

The principle of operation depends on the rate of evaporative cooling which occurs on the wet bulb thermometer. It is often referred to as 'wet bulb depression'.

The cooling effect depends on the amount of water vapour in the air. For low amounts, the cooling will be considerable, so there will be a large temperature drop. Higher levels of water vapour will reduce the evaporation rate and, hence, the cooling effect. The dry bulb thermometer enables the general air temperature to be measured so the relative wet bulb depression can be deduced.




Whirling hygrometer

The general procedure for using a whirling hygrometer is as follows:

- Fill the compartment under the wet bulb thermometer with distilled water. Impure water causes inaccuracies owing to variable evaporation and deposition of dissolved salts.
- Allow the muslin cover over the bulb to become totally saturated with water.
- Whirl the hygrometer at arm's length to reduce contamination by body moisture, for about one minute. The rate of rotation must be sufficient to exceed a minimum air flow velocity over the wet bulb of 4 m/s.
- Stop whirling and read the wet bulb temperature immediately, then read the dry bulb temperature.
- Note the temperatures and, from their values or difference, read off the relative humidity from an appropriate chart.

### Anemometer

Anemometers measure wind speed (and usually direction) and come in a range of types. One type is simply a freely rotating propeller blade. The air causes the blades to rotate and the wind speed can be determined by direct reading of the calibrated instrument. Another type is the heated head of hot wire anemometer, consisted of a heated wire whose cooling rate depends on the surrounding air speed.

A range of electronic instruments is available that can measure one or several of the above environmental parameters at once. These instruments are able to integrate the results to give an indication of thermal stress using recognised indexes, e.g. heat stress monitors.

## Other Parameters that Affect Comfort

### Metabolic Rate

The body's metabolic rate can be expressed in watts (joules of energy per second) or watts per square metre (of body surface area). The metabolic rate in a completely resting body is approximately 45W/$m^2$ of body surface. If the surface area of a typical male is taken as 1.8 $m^2$ this amounts to a total heat output of about 80W.

As the level of activity or physical work increases, so does the metabolic rate. The following table gives approximate metabolic heat production rates for different levels of activity, ranging from 75W during sleep to 1,600W during intense athletic activity. A notable occupational figure is that for heavy work, which is around 450W.

Metabolic rates for different activities

| Activity | Metabolic Heart Production Rate M(W) |
|---|---|
| Sleeping | 75 |
| Resting | 90 |
| Sitting | 105 |
| Standing | 125 |
| Light work | 160 |
| Walking | 280 |
| Heavy work | 450 |
| Running | 1,000 |
| Intense athletics | 1,600 |

## Clothing

Clothing, as you might expect, has a significant effect on the ability of the body to lose heat to the external environment. In considering conduction of heat at the body surface through clothing, it is the resistance (or insulation) to heat flow across a given thickness of material that we are concerned about. This parameter is given an arbitrary unit, the 'clo', to express the insulation value of clothing; 1.0 clo is defined as the insulation provided by clothing which allows comfort in still air at a uniform temperature of 21°C. Thermally insulating polar clothing provides clo values as high as 3 or 4. Examples of clo values for typical workplace outfits are given in the following table.

'Clo' values for typical workplace outfits

| Clothing | Clo Value |
|---|---|
| Shorts | 0.1 |
| Light summer clothing | 0.5 |
| Typical indoor clothing | 1.0 |
| Heavy suit | 1.5 |
| Polar clothing | 3-4 |

## Sweat Rate

Sweat rate needs to be within certain narrow limits for us to feel comfortable (put simply, sweating helps us cool down but excessive moisture makes us feel uncomfortable – we like to be largely free of sweat).

## Duration of Exposure

It may seem an obvious point, but the longer someone is exposed to thermal discomfort, the more severe the effects are likely to be.

# Assessing Heat Stress and the Wet Bulb Globe Temperature (WBGT) Index

The purpose of heat stress indices is to estimate the physiological responses of an individual to their environment. The end result is to provide a value that allows a comparison between environments, different working situations and different types of clothing to be made.

Various types of heat stress index have been developed that summarise environmental, and other, parameters into a single number which can be used to quantify the severity of the thermal environment. The most widely used is the **WBGT Index**.

The Wet Bulb Globe Temperature (WBGT) heat stress index is the most widely accepted heat stress index and forms the basis of many standards. It has been published as British Standard **BS EN 27243**.

WBGT is calculated from:

WBGT = 0.7 WB + 0.3 GT   indoors

or

WBGT = 0.7 WB + 0.2 GT + 0.1 DB   outdoors

where   WB is the wet bulb temperature.
GT is the globe thermometer temperature.
DB is the dry bulb temperature.

The outdoor formula reduces the influence of the globe contribution from direct sun.

The index takes account of radiant and air temperatures, humidity and low air velocities. The index value must be used in conjunction with empirical recommendations (set out in **ISO 27243**) to indicate a level that is safe for most people who are physically fit and in good health. Different values are quoted to distinguish persons acclimatised or unacclimatised to heat. If conditions of exposure fluctuate, a time-weighted average exposure can be derived and used.

| Metabolic rate M (W/m²) | Reference value of WBGT | | | |
|---|---|---|---|---|
| | Person acclimatised to heat (°C) | | Person not acclimatised to heat (°C) | |
| 0. Resting M ≤ 65 | 33 | | 32 | |
| 1. 65 ≤ M ≤ 130 | 30 | | 29 | |
| 2. 130 ≤ M ≤ 200 | 28 | | 26 | |
| | No sensible air movement | Sensible air movement | No sensible air movement | Sensible air movement |
| 3. 200 < M < 260 | 25 | 26 | 22 | 23 |
| 4. M > 260 | 23 | 25 | 18 | 20 |

## Example of WBGT in Use

If the following workplace parameters are measured in an indoor workplace:

- Air temperature = 26°C.
- Globe temperature = 26.5°C.
- Wet-bulb temperature = 18°C.
- Little air movement.
- Acclimatised workers are estimated to be working at 250W/m².

The WBGT = 0.7 WB + 0.3 GT = (0.7 × 18) + (0.3 × 26.5) = 12.6 + 7.95 = **20.6°C**

Looking in the table, the WBGT reference value for 'Metabolic Rate Class 3' when the 'person acclimatised to heat', and 'no sensible air movement' is a WBGT of = 25°C.

The measured value of 20.5°C is **below** the WBGT reference value of 25°C and so it can be concluded that heat stress is **not** a risk in this environment.

If the workplace **environment changed** so that:

- globe temperature = 33°C, and
- wet-bulb temperature = 28°C

then WBGT = 29.5°C, which is above the WBGT reference value of 25°C. Therefore, risk of heat stress exists.

Metabolic work rate can be estimated by reference to tables of typical work rates associated with particular activities, trades and even use of PPE.

## Practical Control Measures

Control measures that can be used to improve unsatisfactory thermal environmental parameters include the following:

### Hot/Humid Environments

- Control Heat Sources

  It may be possible to enclose heat sources and provide lagging/insulation to prevent the escape of heat into the wider workplace environment. For example, a large oven or steam pipes passing through a workspace can be lagged/insulated. It may also be practical to separate areas within the workplace where excess heat and/or humidity are going to occur from other areas where such extremes are not needed, effectively segregating extreme areas from other workspaces.

- Circulation of Air and Ventilation
  - Ventilation can be used to remove or dilute hot/humid air and replace it with cool/dry air. Air conditioning can be used for internal workspaces.
  - Increased air velocity can aid bodily cooling through heat loss due to increased sweat evaporation. Air handling units and fans can be used for internal workspaces.

- Workplace Design

  Radiation barriers placed between the source of heat and the worker can reduce the level of radiant heat exposure. (Barriers should be good insulators and high-heat reflectors to prevent them heating up and becoming radiant heat sources themselves.)

  In outdoor workplaces, shade from the heat of the sun can be supplied. If this is not practical then shade and fans might be supplied in external rest areas to help workers cool down between work rotations.

  Cool refuges can be incorporated into very hot and humid environments so that workers can temporarily seek relief from the extreme environment to cool down.

- Job Design and Job Rotation

  For outdoor workers, restrict work to the cooler parts of the day or work at night. Avoid work during the hottest parts of the day:

  - Control the duration of each work period and ensure that sufficient rest breaks are incorporated into work routines so that workers can cool down. Heat stress indices, such as the WBGT index, can be used to make calculations of the maximum allowable work period and the rest period required to achieve heat balance.

- Supervision is necessary to ensure that the work regimes are followed and that potential heat stress is detected at an early stage.
- Acclimatisation is important to enable workers to become used to the more extreme thermal environments. Acclimatisation allows the worker's body to adjust physiologically and it also allows workers to adjust mentally how they plan and manage their work.
- Easy access to drinking water or other cold drinks is important for workers in hot environments, as is access to electrolytes (salt) so that salts lost by sweating can be replaced.

- **Personal Protective Equipment**

  Personal protective equipment insulates the body and reduces evaporative heat loss which increases the risk of heat stress if physically demanding work is carried out. If protection is needed against radiant heat, heat-resistant clothing gives limited protection with ice-cooled jackets and air-cooled or water-cooled suits needed for longer periods of exposure. However, the use of such personal protective equipment is likely to increase the metabolic rate and possibly lead to thermal strain.

- **Information, Instruction, Training and Supervision**

  Workers need to understand the hazards and risk associated with heat stress, dehydration and heat stroke. They must be trained to understand the uses and limitations of the control measures necessary and how to recognise the signs and symptoms of heat stress in themselves and their fellow workers, so that they can react appropriately.

- **Health Surveillance**

  The regular monitoring of workers is important for those who work in extreme temperatures. The testing of kidney, respiratory and cardiovascular functions, together with general health, are relevant.

## Cold Environments

- **Enclose/Segregate Cold Areas**

  Indoor workplaces that present a cold environment will often be refrigerated (such as food industry workrooms, store rooms, freezers and blast chills) and, consequently, are usually heavily segregated and insulated for energy efficiency purposes. It may be possible to enclose processing equipment and provide lagging/insulation so that the wider workplace environment can be maintained at a reasonable temperature.

- **Provide Heating**

  If the indoor workspace is simply cold because of ambient outdoor temperatures and there is no operational reasons for the low temperature, then the workplace should be heated to achieve the minimum temperatures set out in the **ACoP** to **WHSWR** and **CDM**.

  Heating may be provided by fixed installations or using portable heaters, such as LPG-fuelled space heaters or electrically powered IR radiant heaters. This heating might be applied to the entire workplace or it might be localised to the workstations where workers spend much of their time.

- **Workplace Design**

  Protection from moving draughts is important when workers are in a cold environment. Controlling airflow into workroom and placing barriers between works and air in-feeds will make a significant difference to cooling effects and thermal comfort.

  In outdoor workplaces, protection from the wind might be supplied. Weather protected rest areas, such as a heated porta-cabin, must be provided to help workers warm up between work rotations.

  Warm refuges can be incorporated into very cold internal environments (such as a sub-zero frozen foods warehouse) so that workers can temporarily seek relief from the extreme environment to warm up.

- **Job Design and Job Rotation**

  For outdoor workers, keep track of weather forecasts and avoid or restrict work during the coldest periods:

  - Control the duration of each work period and ensure that sufficient rest breaks are incorporated into work routines so that workers can warm up.
  - Supervision is necessary to ensure that the work regimes are followed and that hypothermia is detected at an early stage.
  - Acclimatisation is important to enable workers to become used to the more extreme thermal environments. Acclimatisation allows the worker's body to adjust physiologically and it also allows workers to adjust mentally how they plan and manage their work.
  - Easy access to hot food and hot drinks is important for workers in extreme cold environments. In such environments, workers may burn far more calories than 'normal' simply to keep warm.

Restrict work during the coldest periods

- **Personal Protective Equipment**

  Protective clothing is an important control measure against cold stress and may need to incorporate the following features:

  - Thermal insulation provided by a fibrous structure that traps air.
  - An outer, tightly woven layer that is windproof.
  - Waterproofing for cold, wet environments. However, this type of clothing may be impermeable to water vapour escaping from the skin and condensation within the clothing may reduce its effectiveness. This can be a significant issue for physically active workers in an extremely cold environment. They sweat as a result of intense physical activity and then become hypothermic once the physical activity stops as a result of wearing damp or frozen clothing.
  - Semi-permeable ('breathable') fabrics may be needed for active personnel where clothing must be waterproof and windproof but also allow perspiration to escape.

- **Information, Instruction, Training and Supervision**

  Similar to the very hot environment, workers need to understand the hazards and risk associated with hypothermia; the uses and limitations of the control measures necessary, and how to recognise the signs and symptoms of hypothermia in themselves and their fellow workers so that they can react appropriately.

- **Health Surveillance**

  The regular monitoring of workers is important for those who work in extreme temperatures. The testing of kidney, respiratory and cardiovascular functions, together with general health, are relevant.

## STUDY QUESTIONS

1. What are the forms of heat transfer relevant to a person in a workplace environment?
2. Define the term 'relative humidity'.
3. State the three types of thermometer and the principles of their operation.
4. Explain the difference between measuring the dry bulb air temperature and the wet bulb air temperature.
5. Define the WBGT heat stress index.
6. State the principal categories of control for hot conditions.

(Suggested Answers are at the end.)

# Lighting

### IN THIS SECTION...

- Employers must provide adequate and appropriate workplace lighting.
- Inadequate lighting has many associated health and safety implications, such as poor visual perception, stroboscopic effects, poor colour assessment, glare, tissue damage and eye fatigue.
- Light levels can be measured with a light meter. Various standards exist for the levels of illuminance that should be provided in different types of work situation.

## The Need for Workplace Lighting

Workplace lighting is required to:

- Permit safe movement around the workplace (both on foot and in vehicles).
- Permit the safe and efficient performance of tasks and activities.
- Reveal the structure and contents of a room or space.
- Allow safety in the event of emergencies.
- Prevent eye fatigue during close work.
- Maintain alertness and reduce fatigue, etc.

Adequate and appropriate lighting is required in the workplace

The way that the need for workplace lighting is met is a subject of scientific and engineering study in its own right that (as with most health and safety topics) has a wealth of technical detail.

When providing adequate and appropriate lighting, note should be taken of the following points:

- Lighting should be sufficient to enable people to work, use facilities and move from place to place safely and without experiencing eye strain.
- Stairs should be well lit in such a way that shadows are not cast over the main part of the treads.
- Where necessary, local lighting should be provided at individual workstations, and at places of particular risk, such as pedestrian crossing points on vehicular traffic routes.
- Outdoor traffic routes used by pedestrians should be adequately lit after dark.
- Dazzling lights and annoying glare should be avoided.
- Lights and light fittings should be of a type, and so positioned, that they do not cause a hazard (including electrical, fire, radiation or collision hazards).
- Light switches should be positioned so that they may be found and used easily and without risk.
- Lights should not be allowed to become obscured, e.g. by stacked goods, in such a way that the level of light becomes insufficient.
- Lights should be replaced, repaired or cleaned, as necessary, before the level of lighting becomes insufficient.
- Fittings or lights should be replaced immediately if they become dangerous, electrically or otherwise.
- Appropriate emergency lighting must be supplied.

Note that reference to emergency lighting above does not relate specifically to fire escape route emergency lighting, since that is covered by fire safety legislation. Emergency lighting in this context is additional emergency lighting so that in the event of a 'normal' workplace lighting failure (such as during a power outage) there is sufficient emergency lighting to allow workers and others to remain safe and healthy. So, for example, emergency lighting would have to be provided to a hospital operating theatre to act as a back-up in the event of a mains power failure.

# Health and Safety Aspects of Lighting

## Incorrect Perception/Failure to Perceive

Insufficient or unsuitable lighting can affect perception by casting shadows that leave hazards in semi or total darkness. When moving from areas of very different light intensities, it can take the eye a little while to adapt to the lower or higher light levels. Moving from a very dark area to a bright area (or vice versa) very quickly can cause a temporary loss of vision. Lighting should be sufficient to enable people to see in order to move about without walking into, or falling over, objects. Some types of work require the ability to see in fine detail, e.g. to read gauges or displays or to see a workpiece or tool. The level of lighting necessary will depend on the type of work being carried out and the hazards associated with it. The finer the detail of the work, the higher the illuminance (light level) required. The illuminance in areas adjacent to the work location must be considered if movement occurs within these areas.

## Stroboscopic Effects

Strobe effects have been a problem with certain lights that operate from AC power. The oscillations in the power levels cause oscillations in the light level. When light level fluctuations are large and at a frequency which synchronises with some multiple of the frequency of a rotating or vibrating machine part, the part appears stationary. (This is the principle of the stroboscopic light used when checking the ignition timing of an engine). This effect is also achieved at nightclubs where 'strobe lights' are used. To reduce this potentially dangerous illusion, it is customary to use 'out-of-phase' light bulbs and minimal-flicker fluorescent lighting tubes in machine shops. Flicker is a related issue but where the oscillation frequency is much lower (up to around 50Hz); flicker is then visible to most people and causes discomfort and fatigue. It has also been associated with triggering epileptic seizures in a small number of susceptible individuals with the pre-existing condition.

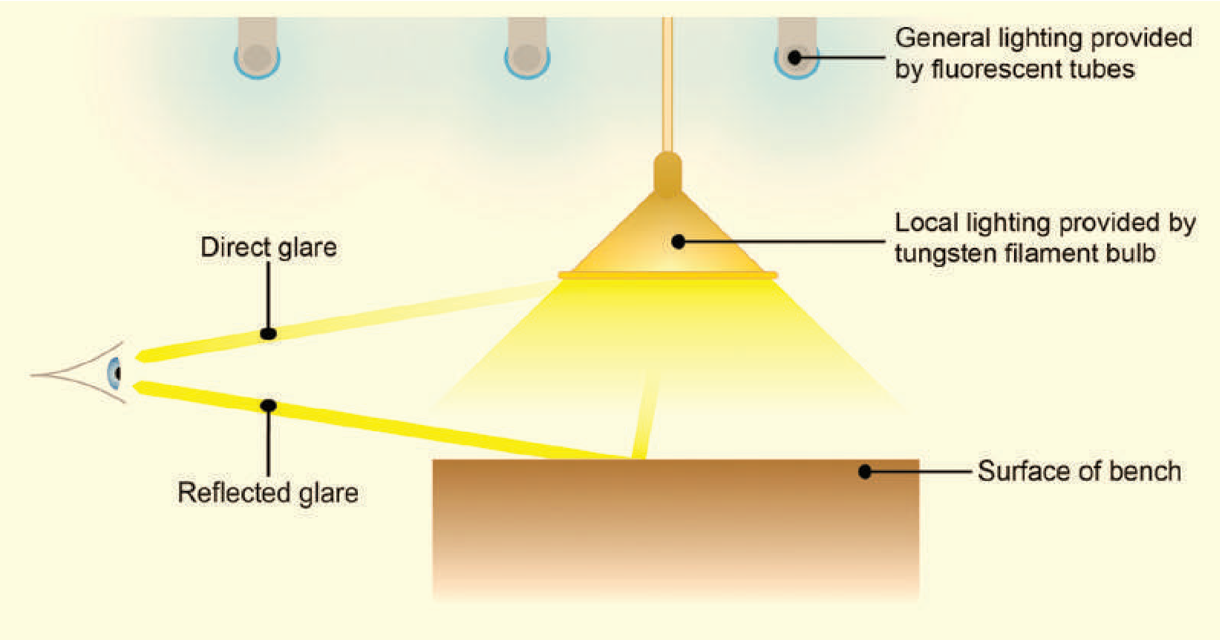
## Colour Assessment

The ability of the human eye to discern colour is greatly hampered under low light conditions. This is because the colour-sensing cells in our eyes are less sensitive than those which simply detect black or white. Colours that appear strikingly different under bright light can appear almost indistinguishable under dim lights. This can clearly have serious implications where colour is a critical indicator (such as in electrical wiring).

Different types of artificial lighting can also have a marked impact on colour perception compared to natural lighting conditions. This is because the colour spectrum of the light can enhance or conceal the colour of surfaces.

## Disabling and Discomfort Glare

Glare may occur when windows or other light sources are too bright compared with the general brightness of the scene being viewed (anybody who has driven a car at night will be familiar with the approaching car that has the headlights on main beam). If glare impairs perception then it is known as 'disability glare'. If it simply causes a nuisance then it is known as 'discomfort glare'. For example, shining a bright hand torch into a person's eyes at night when the person has been outside under very low light levels for a period of time (so their eyes are dark-adapted) will cause disability glare.




Sources of glare

To overcome glare:

- Displace the source of glare outside the line of vision.
- Position lights correctly, for example:
  - Illuminate desks and worktops from the side.
  - Run fluorescent tubes parallel to side edge, not front edge.
- Worktops should be light in colour.
- Avoid gloom in roof areas, especially with high ceilings.
- Choose the recommended surface reflectance.
- Screen fluorescent tubes or bulbs with the appropriate diffuser or shade.
- Use matt finishes on worktops and machines.

## Eye Tissue Damage from Light Exposure

Even for non-laser light sources, it is the nature of visible radiation that it is focused on the retina by the lens giving increased irradiance, so an intense light source viewed directly by the eye can lead to retinal damage through local burning. You will be aware of the warnings given during partial eclipses of the sun for observers not to view the sun directly through telescopes or binoculars due to the likelihood of intensification of the sun's rays and retinal burning occurring. Under normal conditions where optical instruments are not in use, the blink response should be adequate to protect the eye from inadvertent exposure to an intense light source.

Further information on the health risks of optical radiation, the law and control measures is given in Element IB7.

## Visual Fatigue

Poor lighting and glare can cause visual fatigue (or eye strain) by making the visual system work harder. The symptoms of fatigue vary according to the task being carried out and the lighting conditions. It is most common when the visual system has to act at the limit of its capabilities for any length of time.

Symptoms of visual fatigue include irritation of the eyes (inflammation, itchiness), breakdown of vision (blurred or double vision) and referred symptoms (headaches, giddiness, fatigue). Strain injuries, such as neck and backache, can also occur and are usually due to the person bending to get closer to the task due to poor lighting.

Visual fatigue can be caused by the following factors, which should be taken into account when planning lighting installations:

- Low or high illuminance on a task.
- Veiling reflections (i.e. high luminance reflections which can overlay/mask your view of the task, such as reflection from a window overlaying information on a computer screen).
- Disability glare caused by high brightness.
- Illuminance differences between task and adjacent areas.

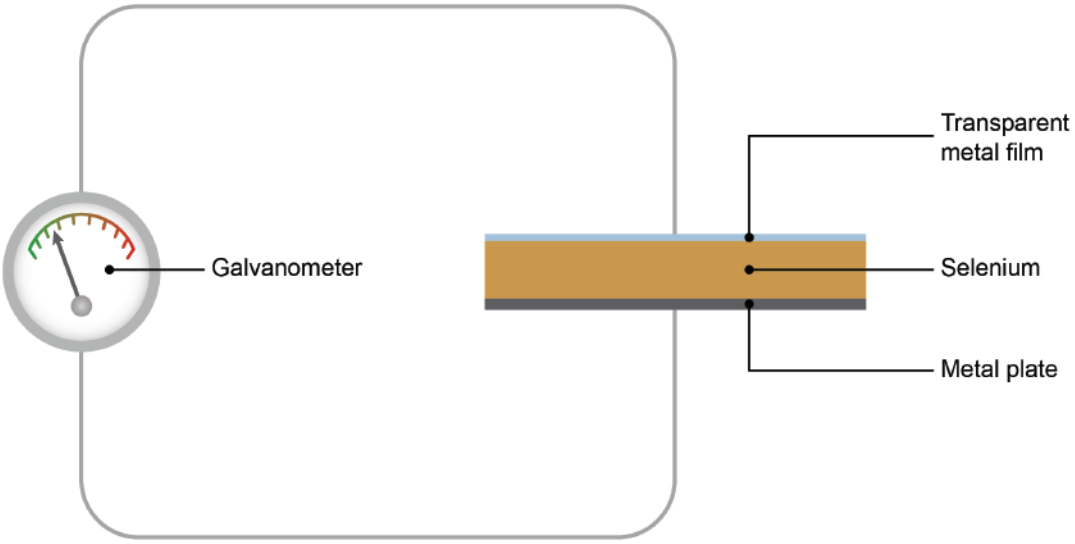
### Effect on Attitudes

There is evidence to suggest that the body is aroused and the brain made more alert when the eye is stimulated by natural sunlight. If the body is starved of light of sufficient intensity, symptoms of drowsiness and fatigue may develop. Seasonal Affective Disorder (SAD) is a recognised form of depression induced by the shorter days of winter. It seems to be triggered by a lack of bright light penetrating the retina of the eye to the pineal gland in the brain. Darkness produces increasing amounts of the sleep-inducing hormone melatonin, which makes people feel lethargic, oversleep, crave carbohydrates and feel generally depressed.

## Measurement and Assessment of Light Levels

### Instrumentation

Light levels are measured using a light meter. A light meter is simply a photocell which, when light falls on it, generates a current to move a pointer over a graduated scale.



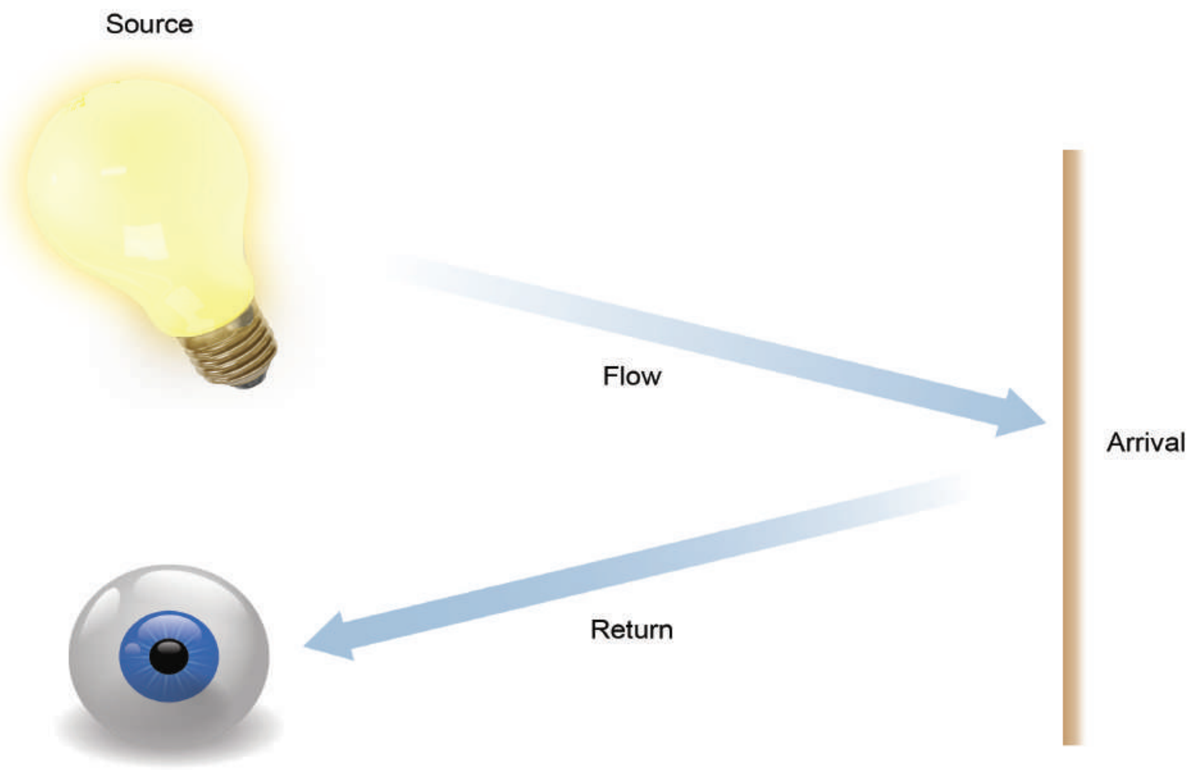

Light meter

A photocell of the barrier type is made with a layer of selenium on a metal plate. On top of the selenium is deposited a thin semi-transparent film of gold or other metal.

Usually, a switch is fitted to make it a double-range instrument, say 0 to 500 and 0 to 2,500 lux, or the equivalent in imperial units. Most modern instruments have a filter which matches cell response to eye response at all relevant wavelengths.

## Units

It is convenient to distinguish four stages as being involved in light by which to see: source, flow, arrival and return. They are illustrated in the following figure.




Four stages of light

The power of a light source to emit light is luminous intensity, which is measured in units of candela (cd). The quantity of light emitted by a source or received by a surface is the luminous flux, which is measured in units of lumen (lm).

The most important unit of illumination is the **lux**, which is the amount of light incident per unit area of surface. One lux is produced by a luminous flux of one lumen (the quantity of light emitted by a source or received by a surface) falling on one square metre of surface.

1 lux = 1 lumen/$m^2$

## Measurement

In practice, the illuminance over an area is never uniform; the brightest point at any time should never be more than 15% above the average and the darkest point never less than 20% below the average. The following procedure is recommended:

- Divide the interior into a number of equal areas, each as nearly square as possible.
- Take an illuminance reading at the centre of each area.
- The mean of the readings gives an estimate of the average illuminance value, the accuracy depending on the number of measurement points and the uniformity of the illuminance.

Illuminance measurement points

| Room Index* | No. of Points |
|---|---|
| Below 1 | 4 |
| 1 and below 2 | 9 |
| 2 and below 3 | 16 |
| 3 and above | 25 |

***Room index** is a parameter determined by the dimensions of the room and the mounting height of the light fittings.

The table gives an accuracy of better than 10% for space/height ratios up to 1.5:1.

Doubling the number of assessment points gives an accuracy of 5%.

If work is performed in a room partially lit by daylight and partly by artificial light, it will be necessary to take three surveys:

- In daylight with all artificial lights turned off.
- In daylight with all artificial lights turned on.
- At night with all artificial lights turned on.

Measurement of the artificial light can be obtained by subtracting the first from the second, but the two readings are often large and almost equal. Therefore, it will often be necessary to resort to the last, i.e. after dark.

## Assessment of Lighting Levels and Standards

The starting point of much interior lighting is the **illuminance** the installation is designed to produce. Normally, a decision is based on the recommendations for illuminance for a wide range of visual tasks given in national or regional codes, such as the UK's Code of the Society of Light and Lighting (SLL) (part of the UK Chartered Institution of Building Services Engineers). The recommendations are summarised as follows:

Recommendations for illuminance of certain tasks

| Class of Visual Task | Examples | Illuminance Measured in Lux |
|---|---|---|
| Casual seeing. | Locker rooms. | 100 |
| Rough task, large detail. | Stores, heavy engineering. | 200 |
| Ordinary task, medium detail. | Offices, woodworking. | 400 |
| Severe task, small detail. | Food-can inspection, tailoring, drawing office. | 600 |
| Severe prolonged task with small detail. | Fine assembly and machining, hand sewing. | 900 |
| Very severe prolonged task with very small detail. | Mending hosiery, gem-cutting, fine gauging. | 1,300-2,000 |
| Exceptionally severe task with minute detail. | Watch-making and inspection of very small parts. | 2,000-3,000 |

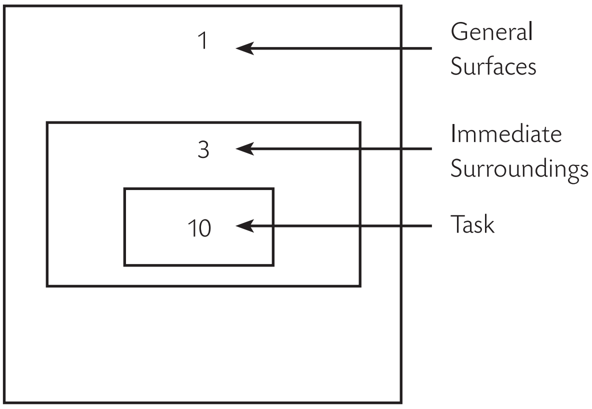
Lower values than those given in the table above are described in the UK's HSE Publication *HSG38 Lighting at Work*. The HSE recommendations are based entirely on health and safety considerations, whereas the SLL recommendations also take account of cost-effectiveness, productivity and amenity. Their recommendations cover a wide range of tasks and activities related to visual performance and visual preference.

They also take into account:

- Practical experience.
- Improvements in lamp design and efficiency.
- Modern techniques and equipment.
- The influence of daylight on the interior.
- The decreasing cost of light relative to the increasing cost of labour.

The recommended levels are neither maxima nor optima, but they do represent current good practice in developed countries. The visual performance of people of any age should be satisfactory, provided they have normal or corrected sight, and they should feel they are working in a well-lit interior.

Illuminance is a measure of the amount of light falling on a surface; vision depends on the amount of light reflected from a surface, i.e. its reflectance or brightness. Reflectance (and colour) is important in the control of contrasts within the observer's field of vision. The ability to see a task clearly depends not only on the level of incident light, but also on the contrast with its surroundings and the amount of light reflected from them. The latter can be increased by increasing the incident light falling on the surface and it is a consequence that higher illumination levels allow objects to be seen with greater ease. Ideally, the contrast ratio between the task and its surroundings should be 10:3:1 (see the following figure).




Contrast ratio

**MORE...**

www.

*HSG38 Lighting at Work* is available from the UK HSE at:

www.hse.gov.uk/pubns/priced/hsg38.pdf

The Society of Light and Lighting provides a range of information and resources available from:

www.cibse.org/societyof-light-and-lighting-sll/publications

Reflectance of the immediate surroundings, e.g. the bench or desk top, should be between 40-50%. Other parts of the workroom should have the following characteristics:

Reflectance

| Area | Reflectance % | Colour/Finish |
|---|---|---|
| Ceilings | 70 | Matt white or near white |
| Walls | 40-70 | Light pastel colours |
| Floors | 30 | Darker than the walls - a high gloss is undesirable |
| Furniture | 20-50 | Light, natural wood, bench finishes |

**STUDY QUESTION**

7. Identify the symptoms of visual fatigue.

(Suggested Answer is at the end.)

# Welfare Facilities

## IN THIS SECTION...

- The employer has to provide adequate sanitary conveniences, washing facilities, drinking water, changing facilities, and facilities to rest and eat meals.
- Special circumstances apply with regards to the welfare arrangements for new and expectant mothers, smoking and people with disabilities.

## Sanitary Conveniences

In the UK, there is an Approved Code of Practice (ACoP) to the **Workplace (Health, Safety and Welfare) Regulations 1992** which details the recommended minimum number of sanitary conveniences that should be provided. Whilst this is not directly applicable worldwide, it can provide good guidance in the absence of an international standard.

Separate sanitary accommodation should be provided for men and women

The number of people at work refers to the maximum number likely to be in the workplace at any one time. Where separate sanitary accommodation is provided for a group of workers, e.g. men, women, office workers or manual workers, a separate calculation should be made for each group. The room containing the facilities should be adequately ventilated and lit and kept clean and in an orderly state. Separate rooms for men and women should be provided except where the water closet is in a separate room and can be locked from the inside.

The following table shows the recommended number of water closets and wash stations per number of people at work.

Water closets and wash stations per numbers at work

| Number of people at work | Number of water closets | Number of wash stations |
|---|---|---|
| 1 to 5 | 1 | 1 |
| 6 to 25 | 2 | 2 |
| 26 to 50 | 3 | 3 |
| 51 to 75 | 4 | 4 |
| 76 to 100 | 5 | 5 |

In the case of sanitary accommodation used only by men, the following table may be followed, if desired, as an alternative to the second column of the previous table. A urinal may either be an individual urinal or a section of urinal space which is at least 600mm long.

Water closets and urinals per number of men

| Number of men at work | Number of water closets | Number of urinals |
|---|---|---|
| 1 to 15 | 1 | 1 |
| 16 to 30 | 2 | 1 |
| 31 to 45 | 2 | 2 |
| 46 to 60 | 3 | 2 |
| 61 to 75 | 3 | 3 |
| 76 to 90 | 4 | 3 |
| 91 to 100 | 4 | 4 |

## Washing Facilities

The same UK ACoP requires that suitable and sufficient washing facilities are provided. This includes showers if required by the nature of the work or for health reasons.

Washing facilities should:

- Be provided in the immediate vicinity of sanitary conveniences.
- Be provided in the vicinity of changing rooms.
- Be supplied with hot and cold (or warm) water.
- Include soap or other means of cleaning.
- Include towels or other means of drying.
- Be sufficiently ventilated and lit.
- Be kept in a clean and orderly condition.

Separate facilities for men and women should be provided (except where they are intended to be used by only one person at a time and can be locked from inside).

Hand-wash facilities must be supplied with soap or some other means of cleaning the hands

## Drinking Water

It is clear that an adequate supply of drinking water should be provided for all workers.

The UK ACoP to the regulations specifies that drinking water should be supplied direct from a tap or pipe rather than a storage tank or cistern (unless appropriately covered, cleaned and tested). Drinking water sources should not be provided in work areas where contamination is likely to occur. Where sources of non-drinking water exist, these must be marked to clearly distinguish drinking water from non-drinking water.

## Accommodation for Clothing

The UK ACoP lays down requirements for suitable and sufficient accommodation (storage) to be provided for clothing. It requires that the accommodation be provided for:

- Clothing that is not worn during working hours.
- Special clothing that is worn for work but not taken home.

Special work clothing includes all clothing that is only worn at work, such as overalls, uniforms, thermal clothing and hats worn for food hygiene purposes.

Accommodation for work clothing and workers' own personal clothing should enable it to hang in a clean, warm, well ventilated place where it can dry out during the course of a working day if necessary. If the workroom is unsuitable for this purpose, then accommodation should be provided in another convenient place. The accommodation should consist of, as a minimum, a separate hook or peg for each worker.

Where work clothing (including personal protective equipment) which is not taken home becomes dirty, damp or contaminated due to the work, it should be accommodated separately from the worker's own clothing. Where work clothing becomes wet, the facilities should enable it to be dried by the beginning of the following work period unless other dry clothing is provided.

## Changing Facilities

The UK ACoP requires that, for a person who has to wear special clothing for work, suitable and sufficient facilities shall be provided to change the clothing.

Changing rooms are not regarded as suitable unless they are separate for men and women.

Changing facilities should be readily accessible from workrooms and eating facilities, if provided. They should be provided with adequate seating and should contain, or connect directly with, clothing accommodation and showers or baths, if provided. They should be constructed and arranged to ensure the privacy of the user.

The facilities should be large enough to enable the maximum number of persons at work expected to use them at any one time, to do so without overcrowding or delay. Account should be taken of starting and finishing times of work and the time available to use the facilities.

## Rest and Eating Facilities

Many pieces of national legislation include the requirement for the provision of welfare facilities. However, there is also an international requirement in the form of **ILO Recommendation R102: Welfare Facilities Recommendation 1956**. This recommendation includes consideration of the requirement for:

Food preparation and eating areas must be adequately clean to prevent cross-contamination of food

- Feeding facilities in, or near, the undertaking (workplace) – this includes the provision of canteens, buffets/trolley services or mess rooms, especially where other appropriate facilities are unavailable. Special consideration should be given to the provision of facilities for shift workers.
- Rest facilities in, or near, the workplace. The recommendation states that, where possible, seats should be provided for use during work, with a footrest where necessary. Where alternative facilities are not available, a rest room should be provided for workers to take rest breaks during working hours. The rest room should have a suitable temperature, adequate ventilation and lighting and an adequate number of seats for those using it.
- Recreation facilities (excluding holiday facilities). The recommendation also calls for the workplace to encourage the provision and development of recreation facilities in the area. Whilst many larger organisations do choose to provide such facilities, this requirement has not been enacted in law in many countries!
- Transportation facilities to and from work where ordinary public transport is inadequate or impractical. The recommendation states that where private cars are used, adequate parking should be provided – unfortunately, this requirement has been somewhat outdated since its conception in 1956 and many workplaces (especially in city centre or high-population-density locations) are finding it increasingly difficult to provide parking for workers. The recommendation also calls for the provision of transport (such as works buses) where there is inadequate public transport. Again, in many countries, it is the custom and practice to rely on private vehicles, although this is not always the case.

The recommendation excludes workers in the agricultural and sea-transport sectors.

We can see how some of these requirements have been adopted in the UK by, again, returning to the ACoP to the regulations, which requires the following:

- Suitable seats should be provided for workers to use during breaks. These should be in a suitable place where PPE need not be worn. In offices and other reasonably clean workplaces, work seats will be sufficient, provided workers are not subject to excessive disturbance during breaks.
- Rest areas or rooms should be large enough, and have sufficient seats with backrests and tables, for the number of workers likely to use them at any one time.
- Where workers regularly eat meals at work, suitable facilities should be provided for the purpose. Such facilities should also be provided where food would otherwise be likely to be contaminated.
- Seats in work areas can be counted as eating facilities, provided they are in a sufficiently clean place and there is a suitable surface on which to place food. Eating facilities should include a facility for preparing or obtaining a hot drink, such as an electric kettle, a vending machine or a canteen. Workers who work during hours or at places where hot food cannot be obtained in, or reasonably near to, the workplace should be provided with the means for heating their own food.
- Eating facilities should be kept clean. Responsibility for cleaning should be clearly allocated. Steps should be taken where necessary to ensure that the facilities do not become contaminated by substances brought in on footwear or clothing. If necessary, adequate washing and changing facilities should be provided.
- Canteens or restaurants may be used as rest facilities, provided there is no obligation to purchase food in order to use them.
- Rest facilities for pregnant women and nursing mothers should be located close to toilets/washrooms. Rest facilities should also include somewhere to lie down if necessary.

# Special Circumstances

## Welfare Facilities for Pregnant Women and Nursing Mothers

It is a requirement in some national legislation that suitable facilities be provided for pregnant women and nursing mothers to rest, and this may include the provision of somewhere for the woman to lie down.

It is good practice to provide a private, healthy and safe environment for nursing mothers to express and store milk. It is not suitable to use toilets for this purpose.

## Smoking at Work

The control of smoking in the workplace is often considered a public health issue and is handled very differently across the globe.

In the UK, most workplaces are now required to be smoke-free, and most business vehicles are included in the smoking ban. However, smoking is permitted in private residences, private cars or open-air public areas. This is largely mirrored across the rest of Europe, with smoking bans common in most enclosed workplaces, although estimates based on ILO data suggest that as many as 10,000 workers could die annually in the EU due to exposure to tobacco smoke at work.

In the US, the Centre for Disease Control (CDC) has stated that approximately half of all US states have enacted comprehensive smoking bans in private workplaces, restaurants and bars, though these bans are controlled through state, commonwealth or local laws rather than federal laws.

**MORE...** www.

Though it is not an authoritative source, Wikipedia contains a list of countries that have imposed smoking bans at:

http://en.wikipedia.org/wiki/List_of_smoking_bans

The UK HSE provides further information about smoking in the workplace at:

www.hse.gov.uk/contact/faqs/smoking.htm

There may be exemptions in law for workplaces that are also a person's residence – this includes prisons and care homes. It is good practice (if not a legal requirement) to designate smoking areas in order to dissuade secretive smoking, which can result in fires if smoking materials are not extinguished.

## Disabled Persons

When determining the welfare requirements of the workplace, it is necessary to consider the needs of persons with disabilities. In Europe, **Directive 89/654/EEC** covers the minimum health and safety requirements of workplaces, but also stipulates that workplaces must take into account the needs of disabled workers. This directive will be enacted slightly differently in all member states, but practically this means that when assessing the suitability of welfare facilities at the workplace, consideration should be given to:

- People who may have, amongst other things, mobility or access difficulties.
- The needs of disabled workers whilst carrying out their job, but also their escape requirements in an emergency, such as a fire.

**European Directive 2000/78/EC** was also established to protect disabled workers (and those associated with disabled workers) from discrimination (although it also covers other factors, such as religion, age, gender or sexual orientation). Again, this was required to be enacted in national legislation by member states. In essence, the legislation calls for reasonable adjustments to be made to accommodate the needs of disabled workers. Note that these do not simply consist of the provision of wheelchair access ramps and lifts, but may include:

- Additional training.
- Rest breaks.
- Adjusted working hours.
- Additional equipment such as vibrating pagers for those with hearing impairment, etc.

> **MORE...** www.
>
> For answers to frequently asked questions on disability, see the EU OSHA website at:
>
> http://osha.europa.eu/en/priority_groups/disability/faq.php
>
> http://osha.europa.eu/en/topics/accident_prevention/risks
>
> A guide to US disability rights law can be found at:
>
> www.ada.gov/cguide.htm

There may be some circumstances where discrimination on the grounds of health and safety is permitted in order to ensure the safety of the individual. For example, in the event that the worker wears a full beard for religious reasons but is also required as an integral part of their job to wear full-face breathing apparatus, that person may not be permitted to work in that area if the apparatus can't be fitted correctly to achieve a safe seal.

In the US, the Americans with Disabilities Act (ADA) prohibits discrimination on the basis of disability in employment. Again, workers with disabilities or those associated with people with disabilities (such as those who care for family members) are protected in law. An individual with a disability is defined by the ADA as "a person who has a physical or mental impairment that substantially limits one or more major life activities, a person who has a history or record of such an impairment, or a person who is perceived by others as having such an impairment". The ADA does not specifically name all of the impairments that are covered.

Many of the controls required for persons with disabilities may also help prevent accidents to other employees, such as:

- Good lighting.
- Safe access and exit points.
- Well maintained pedestrian and traffic routes.
- Clear communication and indication of hazards.

## STUDY QUESTION

8. If a person has to wear special clothing for work, what type of facilities needs to be provided by the employer?

(Suggested Answer is at the end.)

# First-Aid Provision

## IN THIS SECTION...

- There are no detailed international requirements for the provision of first aid in the workplace. The UK **Health and Safety (First Aid) Regulations 1981** are an example of typical national legislation. Under these regulations:
  - In undertaking their assessment of first-aid need, the employer should consider several key factors, such as the size and nature of the organisation, its geographic spread and location and work patterns.
  - Trained first aiders have to undertake first aid at work or emergency first aid at work training courses and have to be re-certificated every three years.
  - Alternatively, an appointed person can be put in charge of contacting the emergency services and maintaining first-aid equipment, for which they need no training.

## Legal Framework

Although there is a brief mention of the need to consider first-aid provision in **ILO Convention C161**, there are no detailed international requirements for the provision of first aid in the workplace. We will therefore look to the UK's **Health and Safety (First Aid) Regulations 1981** as an example of national legislation.

Eye-wash stations may form a part of the employers basic first-aid provision

The legislation is supported by an ACoP and Guidance Notes, of which the current version (coded L74) is dated 2013. The aim of the regulations is to ensure that all people at work are adequately covered and their flexibility is designed to ensure that people in similar work situations are covered to a similar standard.

The regulations require the employer to:

- Assess the first-aid need.
- Provide first-aid materials, equipment and facilities.
- Provide first-aid personnel.
- Inform employees of the first-aid arrangements.

The self-employed have to provide first-aid equipment for their own use.

### First-Aid Needs Assessment

The employer must carry out an assessment to determine his first-aid needs. It is **not** sufficient just to rely on the number of employees to determine appropriate first-aid cover.

It is recognised in the ACoP and Guidance that an employer may wish to tailor their first-aid provision to target the specific hazards and risks associated with their workplace. For example, an employer placing work groups into remote locations where adverse weather conditions will be one of the most significant hazards, may want to tailor first-aid provision to tackling the hazards of hypothermia and heat stroke.

The regulations only require an employer to address the first-aid needs of his employees. They do not require him to assess and provide for the needs of members of the public or visitors (such as school children). The HSE, however, recommends that such provision is included in the assessment of needs as a matter of good practice.

## TOPIC FOCUS

The ACoP and guidance to the **Health and Safety (First Aid) Regulations 1981** (L74) outlines the factors to be considered in assessing first-aid provision, namely:

- Size of the organisation (e.g. number of employees).
- Nature of the work and workplace hazards and risks, e.g. hazardous substances, dangerous machines, tools or animals. (NB: remember that there may be different levels of risk in different parts of one workplace (office vs production line).)
- Nature of the workforce, e.g. experience, young workers, pregnancy, disabilities.
- The organisation's accident history.
- The needs of travelling, remote and lone workers, e.g. they may need a travel first-aid kit.
- Work patterns, e.g. coverage for shift work or out-of-hours work.
- The distribution of the workforce, e.g. a large site with multiple buildings which are far apart.
- The remoteness of the site from emergency medical services.
- Employees working on shared or multi-occupied sites.
- Annual leave and other absences of first aiders and appointed persons – adequate coverage.
- First-aid provision for non-employees (not a legal requirement, but recommended).

Where the employer provides a full-time occupational health service which is under the charge of a registered medical practitioner or qualified occupational health nurse, the first-aid arrangements for the establishment should be made by them. The arrangements may differ from those set out in the ACoP, provided they are of at least equivalent standard.


First-aid training using a resuscitation dummy

In certain circumstances, additional specialised training may be required by a first aider, i.e. where specific hazards or risks exist within a workplace, such as:

- Danger of poisoning by cyanides and related compounds.
- Danger of burns from hydrofluoric acid.
- Need for oxygen as an adjunct to resuscitation.

If the employer has assessed the first-aid need and decided that it is not necessary to have a first aider, then it is acceptable for the employer to nominate an appointed person to take charge of:

- The first-aid equipment and facilities.
- Contacting the emergency services.

Such appointed persons are not approved to render any treatment unless they have been trained.

# Typical First-Aid Arrangements

## First Aiders/Appointed Persons

The employer must provide an adequate and appropriate number of suitable persons to render first aid to ill or injured employees at work. A suitable person is someone who holds a current **First Aid at Work** (FAW) or **Emergency First Aid at Work** (EFAW) certificate.

FAW training courses are normally three days' duration and EFAW two days' duration. Certificates last for three years, after which a refresher course and re-assessment are required before re-certification. The HSE recommends that annual refresher training is provided for all first aiders.

## First-Aid Equipment and Facilities

All first aiders should have access to any equipment provided and all employees should have reasonable access to first aid. Although equipment will vary, all establishments without exception, should provide at least one first-aid box. The ACoP contains a suggested list of contents for first-aid boxes but this is purely a suggested list; it is not mandatory.

An employer whose establishment presents a high risk from hazards should provide a suitably equipped and staffed first-aid room. A note should be placed on the door showing the names and locations of first aiders. Adequate records must be kept of all treatments.

In situations where specialised first-aid equipment is required at the workplace, it may be kept in the first-aid room as appropriate.

Travelling workers can be supplied with a travelling first-aid kit. This is usually a smaller first-aid kit than the standard. A list of typical contents is given in the ACoP and guidance.

Tablets and medicines should not be kept in first-aid kits. Though first aiders may be trained to administer aspirin in the case of heart attack, they are not trained to administer any other drugs or tablets. The HSE recommends that aspirin is not kept in first-aid boxes.

**MORE...** www.

First-aid information is available from the UK HSE at:

www.hse.gov.uk/firstaid/index.htm

L74: ACoP and Guidance on the **Health and Safety (First Aid) Regulations 1981** is also available from:

www.hse.gov.uk/pubns

**STUDY QUESTION**

9. What factors should an employer consider when assessing their first-aid needs?

(Suggested Answer is at the end.)

# Summary

## Temperature and Thermal Environment

We have:

- Identified the legal requirements for an employer to regulate indoor workplace temperatures.
- Defined thermal comfort as a person's subject opinion as to whether they feel comfortable with their thermal environment.
- Outlined the range of health conditions associated with exposure to extreme thermal environments and the typical workplaces where these might be encountered.
- Explained the environmental parameters that affect thermal comfort and how these can be measured using various types of meter.
- Explained how thermal balance is achieved when the rate of metabolic heat production is balanced by the rate of heat gain or loss by conduction, convection, radiation and evaporative heat loss.
- Explained the use of the Wet Bulb Globe Temperature (WBGT) Index to assess heat stress.
- Outlined the control measures available for maintaining thermal comfort and a safe thermal environment by engineering, administrative and behavioural options.

## Lighting

We have:

- Identified the legal requirements for an employer to provide suitable and sufficient workplace lighting.
- Outlined the health and safety implications associated with inadequate lighting.
- Outlined the use of light meters to measure light levels and the standards that exist for the levels of illuminance that should be provided in different types of work situation.

## Welfare Facilities

We have:

- Identified the regulatory requirements for an employer to provide adequate welfare facilities for workers.
- Outlined the requirements for the provision of sanitary conveniences, washing facilities, drinking water, changing facilities, and facilities to rest and eat meals.
- Identified special circumstances that may apply with regards to the welfare arrangements for new and expectant mothers, smoking and people with disabilities.

## First-Aid Provision

We have:

- Outlined the requirements for an employer to assess their first-aid need and provide first-aid equipment, facilities and trained personnel.
- Explained the various factors that an employer must consider when making an assessment of first-aid need.
- Outlined the training requirements for first aiders and appointed persons.

# Exam Skills

## QUESTION

(a) (i) **Identify SIX** factors that can affect the thermal comfort of an individual. **(6)**

(ii) **Outline** the role of heat indices when assessing a thermal environment. **(3)**

(iii) **Give** an example of a heat index **AND identify** the parameters that contribute to this index. **(3)**

(b) Catering staff prepare chilled meals for re-heating. A significant part of their working day is spent in an area where the ambient temperature is between 3°C and 5°C.

**Describe** the control measures that could be used to minimise the risks associated with working in this cold environment. **(8)**

## Approaching the Question

1. This is another of the long-answer-style questions from Section B of the paper, so it is worth 20 marks in total and therefore is worth spending much more time on than the 10-mark questions. NEBOSH suggests spending about 30 minutes on a question of this type. The exam paper will include five questions of this type, from which you need to select three to answer.
2. You will notice that this question has been divided into four parts – it may be worth tackling a question of this type even if you are unsure how to answer one of the subsections, as you can still gain good marks on the other parts.
3. By looking at the command words, you can see you are required to "identify", "outline", "give an example" and "describe". More depth and detail is clearly required for part (b) where you are asked to describe control measures. Remember that when you are asked to provide a specific number of factors, as in (a)(i), you should only give that number – if you provide more they won't be marked.
4. (a) (i) **Identify SIX** factors that can affect the thermal comfort of an individual. **(6)**

   (ii) **Outline** the role of heat indices when assessing a thermal environment. **(3)**

   (iii) **Give** an example of a heat index **AND identify** the parameters that contribute to this index. **(3)**

   (b) Catering staff prepare chilled meals for reheating. A significant part of their working day is spent in an area where the ambient temperature is between 3°C and 5°C.

   **Describe** the control measures that could be used to minimise the risks associated with working in this cold environment. **(8)**
5. For a 20-mark question, you might consider developing an answer plan. There are many ways to do this, from a simple list of bullet points to mind maps and spider diagrams. Whichever format you select, it is important that you clearly show which is your 'plan' and which is your 'answer'. Examiners are permitted to mark answer plans, so it is advisable not to cross it out (which would be an instruction to the examiner not to consider it) but to simply use headings to show where your plan finishes and your answer begins.

An example plan for this question, as a table of key points, could be as follows:

| | | |
|---|---|---|
| **Factors affecting thermal comfort** | Air temperature<br>Air circulation/flow rates<br>Humidity<br>Clothing worn<br>Work rate/activity | Length of time exposed<br>Radiant heat sources<br>Age<br>Weight/fitness levels<br>Acclimatisation |
| **Heat indices - roles** | Measure of thermal environment<br>Take into account a number of parameters<br>Provide an index number<br>Compared to tables/standards | |
| **Heat indices and parameters** | **WBGT** (wet bulb temp, dry bulb temp, globe temp) | |
| **Controls for cold environment** | Medicals (pre-employment and health surveillance)<br>**Individual**<br>Clothing (warm) including jackets, hats, gloves<br>Insulated footwear<br>**Organisational:**<br>Acclimatisation<br>Job rotation/reduced duration<br>Minimise static standing/sitting<br>**Workplace:**<br>Drying facilities for clothing<br>Breaks in warm environment<br>Warm drinks<br>Insulated matting on floor<br>Controls to prevent being locked in (handles on inside of cold stores) | |

6. Now have a go at answering the question. Remember to pay attention to the mark allocation and plan your time accordingly.

## Example of How the Question Could be Answered

*(a) (i) Six factors that can affect the thermal comfort of an individual include:*

- *Air temperature.*
- *Humidity of the working environment.*
- *The rate of airflow.*
- *The clothing that is being worn, e.g. is heavy PPE or a uniform required?*
- *The work rate required.*
- *The fitness level of the worker.*

*(ii) Heat indices are a way of measuring the thermal environment. They take a number of parameters into account and provide a result that can be compared to tables or standards in order to determine the acceptability of the thermal environment.*

*(iii) One index is the WBGT – this takes into account the wet bulb temperature, the dry bulb temperature and the globe temperature.*

*(b) Controls that could be used to minimise the risks to staff working in a cold catering environment are as follows:*

- *Medical surveillance should be carried out, both on new employees prior to recruitment in the form of pre-employment medicals (in order to identify any underlying health conditions which could place them at risk in such an environment) and on existing employees to ensure that their health is not compromised by working in the cold rooms.*
- *The individual could be protected through the provision of insulated clothing, which should be suitable for the catering environment but may include items such as warm clothing, jackets/coats, gloves and hats. Insulated footwear should also be provided as the person may lose heat through their feet to the cold floor.*
- *Organisational controls may include providing a period of acclimatisation for new employees so that they get used to working in the cold environment. This may be built up over a period of weeks on induction to the workplace. Other controls may include the use of job rotation in order to minimise the duration of exposure, with breaks provided to allow workers to leave the cold environment. It may also be possible to minimise static standing and sitting in order to keep the worker's metabolic rate elevated and hence keep them warm.*
- *Workplace controls include the provision of a warm rest room in which the workers can take breaks and have hot drinks. There should also be a room for drying clothing if necessary, so that workers are not re-entering the cold environment with wet or damp clothing. The workplace may also have insulated matting on the floor in order to prevent heat being lost to the cold floor. Finally, there should be controls in place to prevent anyone being accidentally locked in the room, such as handles on the inside of the cold rooms and alarms to warn of anyone unable to exit the room.*

## Reasons For Poor Marks Achieved By Candidates in Exam

An exam candidate would achieve poor marks for an answer which:

- Failed to provide six different thermal comfort factors.
- Showed a lack of understanding of the role of heat indices in assessing the thermal environment and knowledge of the various indices available.
- Suggested that risk assessment was a valid control measure, which it is not.
- Simply made reference to a general hierarchy of controls rather than describing those controls relevant to the scenario given.

# Revision and Examination

## The Last Hurdle

Now that you have worked your way through the course material, this section will help you prepare for your NEBOSH examination. This guide contains useful advice on how to approach your revision and the exam itself.

## Your NEBOSH Examination

You will need to successfully complete a three-hour examination for each of Units IA, IB and IC, as well as completing Unit DNI, a workplace-based assignment, before you achieve the International Diploma.

Your examination will consist of one exam paper which consists of two parts:

- **Section A** has six short-answer questions worth 10-marks each. These questions are compulsory, and are designed to test your breadth of knowledge across the full range of elements in the syllabus.
- **Section B** has five long-answer questions worth 20-marks each. Only three questions need to be answered from this section which are designed to test your depth of knowledge across the full range of elements in the syllabus.

You are allowed three hours in which to complete the exam and are given ten minutes' reading time before the exam begins.

As a guide, you will need to achieve a minimum of 45% to pass the Unit IA, IB and IC exams, and 50% in the workplace-based assignment (Unit DNI). When you have passed each Unit, you will then be issued with a Unit Certificate, showing a pass grade.

Once you have been awarded a Unit Certificate for all four Units (Units IA, IB, IC and DNI), you will receive an overall grade as follows:

| | |
|---|---|
| **Pass** | **185 to 239 marks** |
| **Credit** | **240 to 279 marks** |
| **Distinction** | **280 marks or more** |

The overall mark is calculated by adding together your four Unit Percentage scores.

Remember that your overall grade includes Unit DNI, the workplace-based assignment. Although at this stage of your studies you are quite a way off being ready to attempt the assignment, be aware that you will need to apply what you have learnt throughout your Unit studies when you write your assignment.

## Revision Tips

### Using the RRC Course Material

You should read through all of your course material once before beginning your revision in earnest. This first read-through should be done slowly and carefully.

Having completed this first revision reading of the course materials, consider briefly reviewing all of it again to check that you understand all of the elements and the important principles that they contain. At this stage, you are not trying to memorise information, but simply checking your understanding of the concepts. Make sure that you resolve any outstanding queries with your tutor.

Remember that understanding the information and being able to remember and recall it are two different things. As you read the course material, you should understand it; in the exam, you have to be able to remember and recall it. To do this successfully, most people have to go back over the material repeatedly.

Re-read the course material and make notes that summarise important information from each element. You could use index cards and create a portable, quick and easy revision aid.

## Using the Syllabus Guide

We recommend that you downlaod a copy of the *Guide to the NEBOSH International Diploma in Occupational Health and Safety*, which contains the syllabus for your course. If a topic is in the syllabus then it is possible that there will be an examination question on that topic.

Map your level of knowledge and recall against the syllabus guide. Look at the **Content** listed for each Unit element in the syllabus guide. Ask yourself the following question:

> *"If there is a question in the exam about that topic, could I answer it?"*

You can even score your current level of knowledge for each topic in each element of the syllabus guide and then use your scores as an indication of your personal strengths and weaknesses. For example, if you scored yourself as 5 out of 5 for a specific topic in Element 1, then obviously you don't have much work to do on that subject as you approach the exam. But, if you scored yourself at 2 out of 5 for a topic in Element 3, then you have identified an area of weakness. Having identified your strengths and weaknesses in this way, you can use this information to decide on the topic areas that you need to concentrate on as you revise for the exam.

**Another way of using the syllabus guide is as an active revision aid:**

- Pick a topic at random from any of the International Diploma elements.
- Write down as many facts and ideas that you can recall that are relevant to that particular topic.
- Go back to your course material and see what you missed, and fill in the missing areas.

Your revision aim is to achieve a comprehensive understanding of the syllabus. Once you have this, you are in a position to say something on each of the topic areas and attempt any question set on the syllabus content.

## Exam Hints

Success in the exam depends on averaging half marks, or more, for each question. Marks are awarded for setting down ideas that are **relevant to the question asked** and demonstrating that you understand what you are talking about. If you have studied your course material thoroughly then this should not be a problem.

One common mistake in answering questions is to go into too much detail on specific topics and fail to deal with the wider issues. If you only cover half the relevant issues, you can only achieve half the available marks. Try to give as wide an answer as you can, without stepping outside the subject matter of the question altogether. Make sure that you cover each issue in appropriate detail in order to demonstrate that you have the relevant knowledge. Giving relevant examples is a good way of doing this.

We mentioned earlier the value of using the syllabus to plan your revision. Another useful way of combining syllabus study with examination practice is to create your own exam questions by adding one of the words you might find at the beginning of an exam question (such as 'explain' or 'identify' or 'outline') in front of the syllabus topic areas. In this way, you can produce a whole range of questions similar to those used in the exam.

## Before the Exam

You should:

- Know where the exam is to take place.
- Arrive in good time.
- Bring your examination entry voucher, which
  includes your candidate number, photographic proof of identity, pens, pencils, ruler, etc. (Remember, these must be in a clear plastic bag or wallet.)
- Bring water to drink and sweets to suck, if you want to.

## During the Exam

- Read through the whole exam paper before starting work, if that will help settle your nerves. Start with the question of your choice.
- Manage your time. The exam is three hours long. You should attempt to answer all six questions from Section A and any three questions from Section B in the three hours.

  Check the clock regularly as you write your answers. You should always know exactly where you are, with regard to time.
- As you start each question, read the question carefully. Pay particular attention to the wording of the question to make sure you understand what the examiner is looking for. Note the verbs (command words), such as 'describe', 'explain', 'identify', or 'outline' that are used in the question. These indicate the amount of depth and detail required in your answer. As a general guide:
  - 'Explain' means to provide an understanding. To make an idea or relationship clear.
  - 'Describe' means' to give a detailed written account of the distinctive features of a subject. The account should be factual, without any attempt to explain.
  - 'Outline' means to indicate the principal features or different parts of.
  - 'Identify' means to give a reference to an item, which could be its name or title.
- Pay close attention to the number of marks available for each question, or part of a question – this usually indicates how many key pieces of information the examiner expects to see in your answer.
- Give examples wherever possible, based either on your own personal experience, or things you have read about. An example can be used to illustrate an idea and demonstrate that you understand what you are saying.
- If you start to run out of time, write your answers in bullet-point or checklist style, rather than failing to answer a question at all.
- Keep your handwriting under control; if the examiner cannot read what you have written, then he or she cannot mark it.
- You will not be penalised for poor grammar or spelling, as long as your answers are clear and can be understood. However, you may lose marks if the examiner cannot make sense of the sentence that you have written.

Unit IB - Part 2

# Suggested Answers


## No Peeking!

Once you have worked your way through the study questions in this book, use the suggested answers on the following pages to find out where you went wrong (and what you got right), and as a resource to improve your knowledge and question-answering technique.

# Element IB6: Noise and Vibration

## Question 1

Under Article 3 of **ILO C148, Working Environment Convention 1977**, noise is defined as: "all sound which can result in hearing impairment or be harmful to health or otherwise dangerous".

## Question 2

- The amplitude is the maximum displacement of sound wave pressure.
- The frequency is the number of cycles per second that pass a given location.

## Question 3

Pitch is the way the brain interprets the frequency of sound; shrill or piercing sound is high-pitched and associated with high frequencies. Rumbles or drones are low-pitched sound and associated with low frequencies.

## Question 4

The A-weighted scale on a sound level meter electronically assimilates the sound pressure and mimics the human ear's response across the range of frequencies. The measurement of noise in dB(A) is a good indication of the physical harm caused to hearing.

## Question 5

Because sound intensity levels are given in a logarithmic form.

## Question 6

The ear transmits nerve impulses to the brain as a result of detecting and transmitting mechanical vibration through the outer ear, the middle ear and the inner ear.

## Question 7

The dose of noise the ear receives depends on the level of noise and the duration of exposure. Short exposure to a high level of noise is considered to cause comparable hearing damage to a long exposure to a lower level of noise.

## Question 8

Sensorineural hearing loss (when the hair cells in the cochlea are damaged), in an occupational setting occurs mainly from exposure to excessive noise. Conductive hearing loss (breakdown of the conducting mechanism of the ear from acute acoustic trauma) is a rarer occupational problem.

## Question 9

A threshold shift is a reduction in a person's ability to hear, i.e. they need more sound intensity to stimulate their hearing; the condition may be permanent or temporary.

## Question 10

Technical limitations, learning effect, and headphone fit.

## Question 11

Simple sound level meters (unlikely to be useful for most noise surveys); integrating sound level meters; personal sound exposure meters (dosimeters); octave band analyser (often incorporated into integrating sound level meter).

## Question 12

Reflection, absorption and transmission.

## Question 13

Noise reduction at source, attenuation in transmission, control at the receiver.

## Question 14

It must be airtight, mounted so that it does not transmit noise and vibrations to the floor, have a heavy noise-reflecting outer skin and a noise-absorbent lining.

It must also have appropriate hatches and doors to allow access to maintenance, etc. It may need to be suitably ventilated and lit if entry has to be gained by workers. It may need windows or vision panels.

## Question 15

A noise enclosure encloses the source of the noise; noise havens enclose the worker from the noise.

## Question 16

Earplugs and earmuffs.

Plugs can be disposable or re-usable types, or custom moulded to fit the ear.

Special types of protector are also available, such as level dependent, flat response, active noise-cancelling and communication protectors.

## Question 17

The amount of harm done by exposure to vibration is dependent on the dose of vibration energy received.

A given dose of vibration energy, however delivered, will cause an equivalent degree of harm. The dose is determined by the:

- Magnitude of the vibration (RMS acceleration).
- Duration of exposure.

The daily dose of vibration received by a worker can be expressed as the eight-hour energy-equivalent vibration magnitude.

## Question 18

Those working with:

- Percussive metalwork tools.
- Rotary tools and grinders.
- Percussive hammers and drills.
- Chainsaws.

## Question 19

Drivers of heavy vehicles; drivers of forklift trucks; operators of heavy machines; aircraft personnel. Exposure is most significant for those operating plant and vehicles over rough terrain.

## Question 20

Hand-arm vibration affects the body through the hands and is caused by vibrating tools or workpieces grasped in thehands. Effects include nerve, muscle and circulatory system damage.

Whole-body vibration, which can be felt when the body is supported on a vibrating surface, e.g. transport employment. Effects are principally back pain.

## Question 21

In the early stages, vibration causes slight tingling and numbness in the fingers. With further exposure, the tips of one or more fingers suffers blanching and, with continued exposure, blanching will extend to the base of the finger. When the condition abates, after about an hour, the fingers become flushed, accompanied by considerable pain. There is reduced sensitivity to temperature, pressure and pain, and less manipulative ability.

## Question 22

Identify where there is likely to be a significant hand-arm vibration risk - consider which tools and processes expose employees, manufacturer handbooks, ill-health records; discuss with employees and safety representatives. Next, identify who is at risk. Decide on the level of risk - vibration information from tools and processes identified or from measurements; duration of exposure; comparison with the EAV and ELV. Finally, decide what more needs to be done to eliminate or control the risk (including the need for health surveillance).

## Question 23

- Use equations for single and multiple exposures.
- Use the vibration exposure calculator available from the HSE website.
- Use the hand-arm vibration exposure ready reckoner, available in the guidance to the regulations or from the HSE website.

## Question 24

Elimination at source, followed by reduction of vibration at source using control options, such as:

- Alternative working methods.
- Ergonomically-designed work equipment.
- Provision of auxiliary equipment.
- Appropriate maintenance programmes.
- Design and layout of workplaces, workstations and rest facilities.
- Provision of suitable information and training.
- Limitation of duration and magnitude of exposure.
- Appropriate work schedules and rest periods.
- Provision of PPE.
- No exposure above an exposure limit value.
- Health surveillance.

# Element IB7: Radiation

## Question 1

Optical radiation and electromagnetic fields (or radiofrequencies).

## Question 2

Ultraviolet; visible; infrared; microwave; radiowave.

## Question 3

It results from the radioactive decay of certain radioactive substances or radionuclides. Beta radiation is used in many applications, such as medical and biological research and in thickness gauges.

## Question 4

Gamma radiation originates in the nucleus of an atom; x-rays originate in the atom's electron layers surrounding the nucleus. Gamma-rays are naturally produced during radioactive decay of radionuclides; x-rays are artificially produced by an x-ray generator (or 'set').

(Historically, gamma-rays and x-rays were simply differentiated by wavelength. This can be a little misleading, however, so it is the way that they are produced that determines their radiation type.)

## Question 5

- Acute effects, such as sunburn and arc-eye (photokeratitis).
- Chronic effects, such as premature ageing of the skin, skin cancer (melanoma) and cataracts.
- Indirect effects, such as photosensitisation and the formation of toxic contaminants.

## Question 6

Biological harm is caused by the process of heating. Certain tissues, such as the lens of the eye, have poor or non-existent blood supplies and a poor capacity for temperature control by heat transfer. It is such tissue that is most at risk from microwave exposure, since only a relatively small temperature increase is needed to damage cell protons.

To control exposure to microwave radiation, the system should be enclosed in a metal structure; access doors should be introduced by fail-safe means; panels not interlocked should be secured by fasteners that require special tools for their release.

## Question 7

The framework or approach for control of exposure to non-ionising radiation:

- Eliminate as far as possible – explore alternative technologies.
- Other working methods that reduce the risk – administrative controls for routine operation, maintenance, etc. (also permits).
- Choose equipment emitting less radiation (depends on work).
- Technical measures to reduce the emission of radiation, e.g. interlocks, shielding, enclosures, screens, etc.
- Maintenance.
- Design, siting and layout of workplaces and workstations – control over direction, stray fields/reflections (by painting surfaces matt black), etc.
- Limit duration and level/intensity of exposure, e.g. time, distance (except lasers where distance doesn't work!).
- PPE, e.g. eye protection.

- Follow manufacturer instructions.
- Signs.

## Question 8

Half-life is the time required for one half of a quantity of radionuclide to disintegrate.

The activity of a quantity of radionuclide is given by the rate at which it decays (measured in Becquerels (Bq) or disintegrations per second).

Absorbed dose is a measure of energy deposited by the radiation (expressed in a unit called the Gray (Gy)).

The equivalent dose (measured in Sieverts (Sv)) gives a measure of the likely biological damage resulting from radiation exposure, taking into account the type of radiation involved.

## Question 9

- Stochastic effects are those that can occur after any level of exposure and are essentially random and unpredictable.
- Non-stochastic effects are those that are dose-dependent and only occur if the dose received is above a certain level, they are therefore predictable.

## Question 10

Alpha radiation: in the nuclear industry, static eliminators and smoke detectors.

Beta particles: in medical research, thickness gauges.

X-rays: medical use, security scanning, in chemistry for crystallography.

Gamma-rays: in industrial radiography (as a form of non-destructive testing), radiotherapy treatment.

Neutrons: in the nuclear industry, research applications.

## Question 11

Thermo-luminescent dosimeters.

## Question 12

External radiation, which arises from outside the body, may irradiate skin, tissue or internal organs, depending on the type of radiation and the ability to penetrate the body. Internal radiation stems from radioactive materials deposited in the body by inhalation, ingestion, injection or absorption through the skin, which are continually irradiating internal organs and tissues from within.

## Question 13

Time - by reducing the time for a particular dose rate, the accumulated dose is reduced.

Distance - the intensity of all radiation is reduced by the distance travelled.

Shielding - the absorption of radiation energy by interaction with a dense medium.

## Question 14

The classification system for lasers:

- Class 1 is considered safe under reasonably foreseeable use.
- Class 1M is similar to Class 1, but the beam is not safe if viewed with the aid of magnifying optical instruments.
- Class 1C is for contact application to skin, such as in cosmetic skin treatments.
- Class 2 (for lasers emitting in the visible range) - low-power devices - eye protection is normally afforded by the aversion response and the blink reflex of the eye.
- Class 2M is similar to Class 2, but beam is not safe if viewed with the aid of magnifying optical instruments.
- Class 3R laser products limited to maximum output power of 5mW - these can potentially cause eye injury.
- Class 3B laser products limited to a maximum output power of 500mW - these are considered hazardous to the eye, both directly and reflections.
- Class 4 high-powered devices (> 500 mW) - they are hazardous to eyes and skin and can cause fires.

## Question 15

Control measures to prevent harmful exposure to laser radiation:

- Engineered controls:
  - Interlocks on equipment and rooms.
  - Screening/enclosures.
  - Non-reflective surfaces.
- Administrative controls:
  - Warning lights (to indicate 'in operation').
  - Signs.
  - Training for users of Classes 3R, 3B and 4 (and possibly for lower classes).
  - Work methods.
  - Appointment of people with specific responsibility (laser safety officers).
- PPE:
  - Laser safety eyewear.
  - Skin protection (if appropriate).

# Element IB8: Mental Ill Health and Dealing with Violence and Aggression at Work

## Question 1

Raised heart rate, increased sweating, headaches, dizziness, blurred vision, aching neck and shoulders, skin rashes, lowered resistance to infection.

## Question 2

- How work is organised, such as awkward shift patterns, unpredictable working hours, unsociable working hours, excessively long working hours and disruptive changes to shift pattern.
- Workplace culture, such as lack of recognition of stress as an issue to be managed, a culture of belittling or penalising weakness or signs of stress, poor leadership, lack of support for staff facing change, lack of resources, inadequate training, poor communications within the organisation and poor management structure.

## Question 3

Anxiety is a "feeling of unease, such as worry or fear that can be mild or severe". Depression is when you have feelings of extreme sadness, despair or inadequacy that last for a long time.

## Question 4

The headings of the HSE six management standards are:

- Demands.
- Control.
- Support.
- Relationships.
- Role.
- Change.

## Question 5

Discuss issues, such as: flexibility towards individual wishes, trying to vary working conditions to increase ownership of the job, an open attitude from management, fair treatment for staff, training and resources to cope with new environments.

## Question 6

Describe: interpersonal skills training, and effective systems to deal with various types of interpersonal conflict.

## Question 7

A useful definition of work-related violence is: "any incident in which a person is abused, threatened or assaulted in circumstances relating to their work".

## Question 8

Handling money/valuables (cashiers); people working with the public in caring/teaching professions (nurses); carrying out inspection or enforcement duties (traffic wardens); working with potentially violent people (mental health workers); working alone (home visitors).

## Question 9

- Find out if there is a problem.
- Decide what action to take.
- Take action.
- Check what you have done.

## Question 10

Change the job; use cash-free systems; change layout of public working areas; re-design counters; vet credentials of clients and customers; use panic buttons, personal alarms, etc.; use security measures such as protective screens, cameras, etc.; plan work schedules of vulnerable staff, etc.

# Element IB9: Musculoskeletal Risks and Control

## Question 1

WRULD stands for 'work-related upper limb disorder' and refers to ill-health conditions affecting the upper limbs, particularly the soft connecting tissues, muscles and nerves of the hand, wrist, arm and shoulder.

WRULDs arise from the repetition of ordinary movements (such as gripping, twisting, reaching or moving), often in a forceful and awkward manner, without sufficient rest or recovery time.

## Question 2

Back injury and back pain; tendon and ligament injuries; muscle injuries; hernias; WRULDs; cuts, burns and broken bones.

## Question 3

- The ergonomic design of tools, equipment and workplaces.
- Job rotation.
- Adjusting the work routine.
- Training.

## Question 4

(a) The work surface or desk should be large enough to accommodate all necessary equipment and other items used from time to time, and to allow them to be arranged to suit the individual's needs. If necessary, it should also be deep enough to accommodate DSE for viewing at a distance of about 350 to 600mm without cramping the work surface in front of it.

(b) The keyboard should be of appropriate design to be usable with comfort, with the keys being of sufficient size and clarity to suit the demands of the task. It should be able to be tilted and separated from the screen, so the operator can find a comfortable position.

(c) A work chair must have an adjustable seat back, good lumbar support and be adjustable in height to suit the user.

(d) There should be sufficient clear and unobstructed space at each workstation to enable the work to be done safely, allowing for the manoeuvring and positioning of materials. This should also provide for adequate freedom of movement and the ability to stand upright.

## Question 5

Providing regular breaks, job or task rotation, assigning a second worker to perform particular tasks, enlarging job responsibilities to avoid repetition, limiting overtime.

## Question 6

Its weight, size, shape, resistance to movement, rigidity or lack of it, position of its centre of gravity, presence or absence of handles, surface texture, stability of any contents and the contents themselves.

## Question 7

- Space constraints on movement and posture.
- Conditions of floors and other surfaces.
- Variations in levels.
- Temperature and humidity.
- Strong air movements
- Lighting conditions.

## Question 8

The elimination of risk by the use of automation or mechanisation.

## Question 9

- Sequencing – adjusting the sequence of tasks in a process to minimise the number of operations involving lifting and carrying loads.
- Work routine – reducing repetitive operations to allow variation in movement and posture, by such means as introducing breaks, job rotation and providing ways in which workers can operate more at their own pace, rather than the work being conditioned by a continuous supply of materials to be handled.
- Using teams – sharing the load by using teams of workers to carry out the task.

# Element IB10: Work Environment Risks and Controls

## Question 1

Radiation; evaporative cooling; convection and conduction.

## Question 2

Relative humidity is an expression of the ratio of water vapour in air relative to the maximum concentration of water vapour that would be required to saturate air at the given temperature.

## Question 3

Liquid thermometer: depends on the fact that liquids expand in a regular manner with temperature change. A relatively large volume of liquid expands into a narrow capillary tube. Measurement is made by use of a marked scale.

Thermocouples: depend on the variation of current with temperature produced by two different metals in contact with each other and incorporated in an electric circuit.

Resistance thermometers: depend on the variation in resistance with temperature, and hence current flow, within materials when incorporated in an electrical circuit.

## Question 4

For the dry bulb air temperature, the sensing head is protected from radiant heat exchange by placing a polished silver or aluminium shield around it. The wet bulb air temperature is obtained with the sensing head covered with a muslin sock wetted with distilled water and protected from radiant heat.

## Question 5

WBGT is a heat stress index used to make a prediction of the heat stress on a worker carrying out a particular rate of work. WBGT is calculated from:

WBGT = 0.7 WB + 0.3 GT indoors

or

WBGT = 0.7 WB + 0.2 GT + 0.1 DB outdoors

where:

- WB is the wet bulb temperature.
- GT is the globe thermometer temperature.
- DB is the dry bulb temperature.

The index value (WBGT) must be used in conjunction with empirical recommendations (set out in **ISO 7243**) to indicate a level that is safe for most people who are physically fit and in good health. Different values are quoted to distinguish persons acclimatised or unacclimatised to heat. If conditions of exposure fluctuate, a time-weighted average exposure can be derived and used.

## Question 6

Circulation of air and ventilation; workplace design; work organisation; PPE; health surveillance; information, instruction, training and supervision.

## Question 7

- Irritation of the eyes (inflammation, itchiness).
- Degradation of vision (blurred or double vision).
- Referred symptoms (headaches, giddiness, fatigue).
- Strain injuries, such as neck and backache, due to poor posture.

## Question 8

There are two main requirements that relate specifically to special clothing:

- Changing facilities – suitable and sufficient facilities shall be provided to change the clothing. Separate facilities must be provided for men and women. They should be provided with seating and should ensure the privacy of the user.
- Storage facilities – suitable and sufficient accommodation for clothing. This is for clothing which is not worn during working hours and special clothing which is worn for work but not taken home.

## Question 9

- Number of employees.
- Nature of the work and workplace hazards and risks.
- Nature of the workforce.
- Accident history.
- Travelling, remote and lone workers.
- Work patterns and shifts.
- Geographic distribution of the workforce.
- Remoteness from emergency services.
- Shared sites.
- Absence cover.
- Provision for non-employees.