3.5 Unit 3: Physics 3

P3.1 Medical applications of physics

Physics has many applications in the field of medicine. These include the uses of X-rays and ultrasound for scanning, and of light for image formation with lenses and endoscopes

Candidates should use their skills, knowledge and understanding to:

- draw and interpret ray diagrams in order to determine the nature of the image

Additional guidance:

In ray diagrams a convex lens will be represented by:

A concave lens will be represented by:

- evaluate the use of different lenses for the correction of defects of vision

- compare the medical use of ultrasound and X rays

Additional guidance:

Candidates should understand that some of the differences in use are because ultrasound waves are non-ionising and X rays are ionising.

- evaluate the advantages and disadvantages of using ultrasound, X-rays and Computerised Tomography (CT) scans.

Limited to safety issues and the quality of image formed.

P3.1.1 X-rays

a) X-rays are part of the electromagnetic spectrum. They have a very short wavelength and cause ionisation.

Additional guidance:

Properties of X-rays include:

- they affect a photographic film in the same way as light
- they are absorbed by metal and bone
- they are transmitted by soft tissue
- their wavelength is of the same order of magnitude as the diameter of an atom.

b) X-rays can be used to diagnose and treat some medical conditions.

Examples include CT scans, bone fractures, dental problems and killing cancer cells.

The use of charge-coupled devices (CCDs) allows images to be formed electronically.

c) Precautions to be taken when X-ray machines and CT scanners are in use.

P3.1.2 Ultrasound

a) Electronic systems can be used to produce ultrasound waves, which have a frequency higher than the upper limit of hearing for humans.

Additional guidance:

Candidates should know that the range of human hearing is about 20 Hz to 20 000 Hz.

b) Ultrasound waves are partially reflected when they meet a boundary between two different media. The time taken for the reflections to reach a detector can be used to determine how far away such a boundary is.

c) Calculation of the distance between interfaces in various media.

$s = v \times t$

Additional guidance:

Candidates may be required to use data from diagrams of oscilloscope traces.

s is distance in metres, m

v is speed in metres per second, m/s

t is time in seconds, s

d) Ultrasound waves can be used in medicine.

Examples include pre-natal scanning and the removal of kidney stones.

P3.1.3 Lenses

a) Refraction is the change of direction of light as it passes from one medium to another.

b) A lens forms an image by refracting light.

c) In a convex or converging lens, parallel rays of light are brought to a focus at the principal focus. The distance from the lens to the principal focus is called the focal length.

$$\text{refractive index} = \frac{\sin i}{\sin r}$$

Additional guidance:

i is the angle of incidence

r is the angle of refraction

d) The nature of an image is defined by its size relative to the object, whether it is upright or inverted relative to the object and whether it is real or virtual.

e) The nature of the image produced by a converging lens for an object placed at different distances from the lens.

f) The use of a converging lens as a magnifying glass.

g) The nature of the image produced by a concave or diverging lens.

h) The construction of ray diagrams to show the formation of images by converging and diverging lenses.

Additional guidance:

Candidates may be asked to complete ray diagrams drawn on graph paper.

i) The magnification produced by a lens is calculated using the equation:

$$\text{magnification} = \frac{\text{image height}}{\text{object height}}$$

P3.1.4 The eye

a) The structure of the eye.

The structure of the eye is limited to:

- retina
- lens
- cornea
- pupil / iris
- ciliary muscle
- suspensory ligaments.

Additional guidance:

Candidates should know the function of these named parts.

Candidates should understand how the action of the ciliary muscle causes changes in the shape of the lens, which allows the light to be focused at varying distances.

b) Correction of vision using convex and concave lenses to produce an image on the retina:

- long sight, caused by the eyeball being too short, or the eye lens being unable to focus
- short sight, caused by the eyeball being too long, or the eye lens being unable to focus.

c) Range of vision. The eye can focus on objects between the near point and the far point.

Additional guidance:

Candidates should know that the near point is approximately 25 cm and the far point is infinity.

d) Comparison between the structure of the eye and the camera.

Candidates should be aware that the film in a camera or the CCDs in a digital camera is the equivalent of the retina in the eye.

e) The power of a lens is given by:

$$P = \frac{1}{f}$$

Candidates should know that the power of a converging lens is positive and the power of a diverging lens is negative.

P is power in dioptres, D

f is focal length in metres, m

f) The focal length of a lens is determined by:

- the refractive index of the material from which the lens is made, and
- the curvature of the two surfaces of the lens.

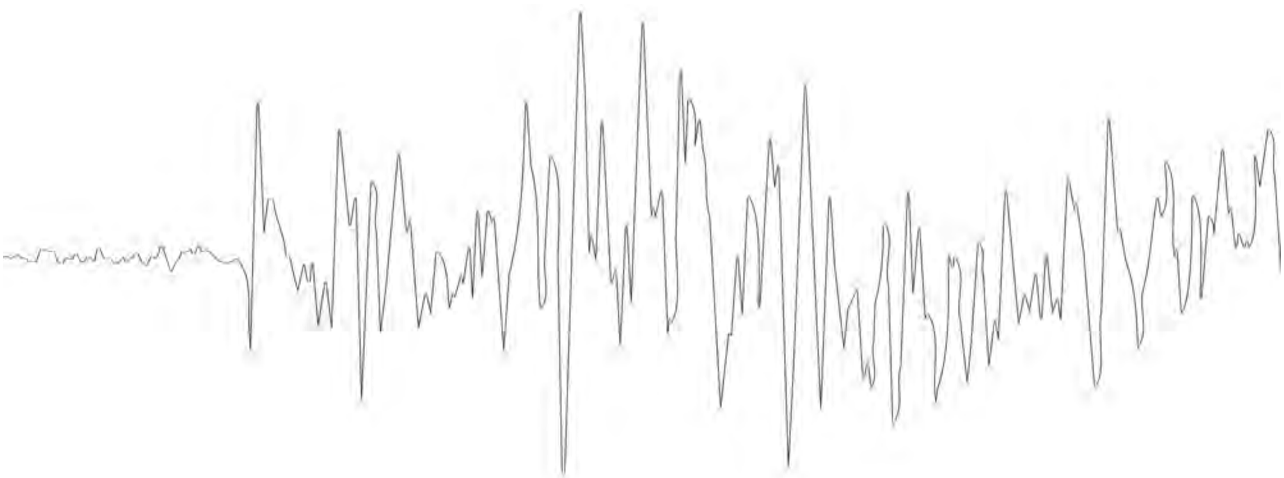
	Additional guidance:
g) **For a given focal length, the greater the refractive index, the flatter the lens. This means that the lens can be manufactured thinner.**	**HT only**

P3.1.5 Other applications using light

	Additional guidance:
a) Total internal reflection and critical angle. **refractive index** $= \dfrac{1}{\sin c}$	Candidates need to understand the concept of critical angle but knowledge of the values of critical angles is not required. **HT only** ***c* is the critical angle**
b) Visible light can be sent along optical fibres.	Examples of use should include the endoscope for internal imaging.
c) The laser as an energy source for cutting, cauterising and burning.	Knowledge of how lasers work is **not** required. Applications should include use in eye surgery.

Suggested ideas for practical work to develop skills and understanding include the following:

- demonstrating the range of frequencies audible to the human ear, using a signal generator, loudspeaker and oscilloscope
- demonstrating long and short sight by placing a screen, not at the focal point, and rectifying the image through the use of appropriate lenses
- using a round bottom flask filled with a solution of fluorescein to represent the eye
- investigating total internal reflection using a semi-circular glass block.



P3.2 Using physics to make things work

Many things, from simple toys to complex fairground rides, are constructed from basic machines such as the lever. A knowledge of the physics involved in balancing and turning can help us to make these appliances work.

Candidates should use their skills, knowledge and understanding to:	Additional guidance:
■ analyse the stability of objects by evaluating their tendency to topple	Candidates should use a range of laboratory equipment to model real-life situations, eg cranes.
■ recognise the factors that affect the stability of an object	Candidates should recognise that objects with a wide base and low centre of mass are more stable than those with a narrow base and a high centre of mass.
■ evaluate how the design of objects affects their stability	
■ interpret and evaluate data on objects moving in circular paths.	**Additional guidance:** Candidates should understand that a centripetal force does not exist in its own right but is always provided by something else such as gravitational force, friction or tension.

P3.2.1 Centre of mass

	Additional guidance:
a) The centre of mass of an object is that point at which the mass of the object may be thought to be concentrated.	Candidates will be expected to be able to describe how to find the centre of mass of a thin, irregular sheet of a material.
b) If freely suspended, an object will come to rest with its centre of mass directly below the point of suspension.	
c) The centre of mass of a symmetrical object is along the axis of symmetry.	
d) For a simple pendulum: $T = \frac{1}{f}$	**Additional guidance:** T is periodic time in seconds, s f is frequency in hertz, Hz
e) The time period depends on the length of a pendulum.	The equation $T = 2\pi\sqrt{l/g}$ is **not** required. Applications of the pendulum should include simple fairground and playground rides.

P3.2.2 Moments

a) The turning effect of a force is called the moment.

b) The size of the moment is given by the equation:

$M = F \times d$

Additional guidance:

M is the moment of the force in newton-metres, Nm

F is the force in newtons, N

d is the perpendicular distance from the line of action of the force to the pivot in metres, m

c) If an object is not turning, the total clockwise moment must be exactly balanced by the total anticlockwise moment about any pivot.

d) The calculation of the size of a force, or its distance from pivot, acting on an object that is balanced.

Additional guidance:

HT only

e) Ideas of simple levers.

Limited to levers as force multipliers.

f) If the line of action of the weight of an object lies outside the base of the object there will be a resultant moment and the body will tend to topple.

HT only

Applications should include vehicles and simple balancing toys.

P3.2.3 Hydraulics

a) Liquids are virtually incompressible, and the pressure in a liquid is transmitted equally in all directions.

Additional guidance:

Candidates should understand that this means that a force exerted at one point on a liquid will be transmitted to other points in the liquid.

b) The use of different cross-sectional areas on the effort and load side of a hydraulic system enables the system to be used as a force multiplier.

c) The pressure in different parts of a hydraulic system is given by:

$$P = \frac{F}{A}$$

Additional guidance:

P is the pressure in pascals, Pa

F is the force in newtons, N

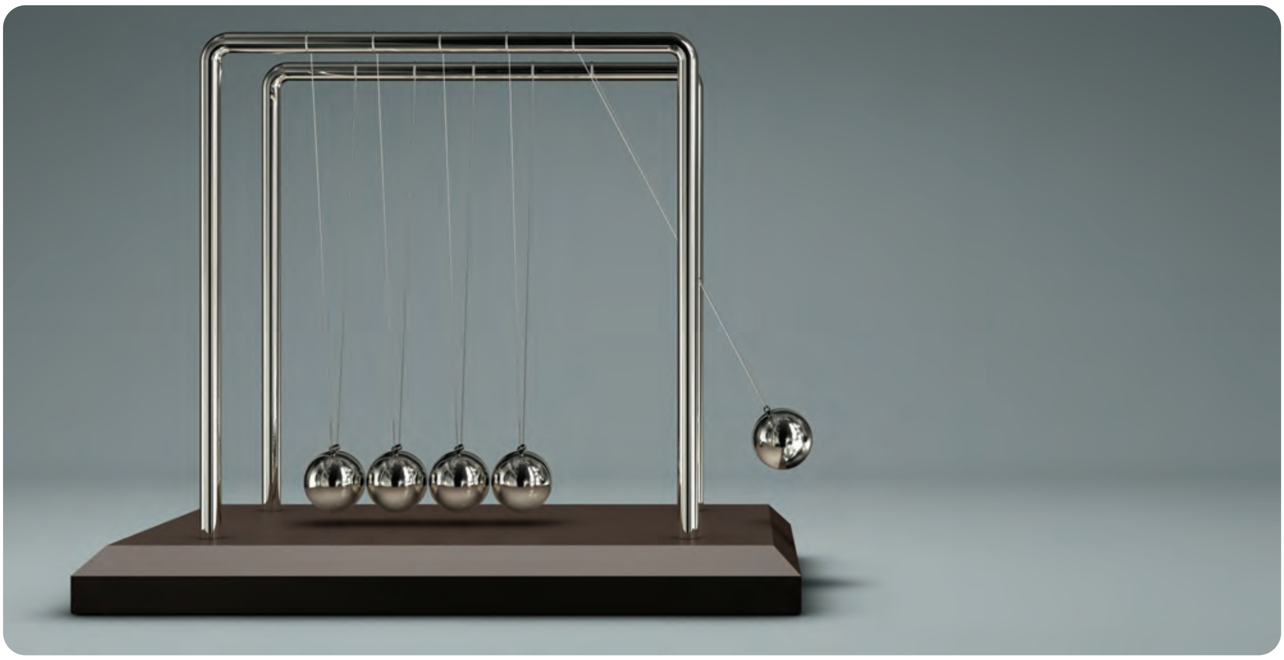
A is the cross-sectional area in metres squared, m^2

P3.2.4 Circular motion

	Additional guidance:
a) When an object moves in a circle it continuously accelerates towards the centre of the circle. This acceleration changes the direction of motion of the body, not its speed.	
b) The resultant force causing this acceleration is called the centripetal force and is always directed towards the centre of the circle.	Candidates should be able to identify which force(s) provide(s) the centripetal force in a given situation.
c) The centripetal force needed to make an object perform circular motion increases as: ■ the mass of the object increases ■ the speed of the object increases ■ the radius of the circle decreases.	The equation $F = \frac{mv^2}{r}$ is **not** required.

Suggested ideas for practical work to develop skills and understanding include the following:

- demonstrating that pressure in liquids acts in all directions using a circular container with holes around it
- finding the centre of mass of an irregularly shaped card
- using a balanced metre ruler and masses to verify the principle of moments
- plan and carry out an investigation into factors that affect the period of a simple pendulum (mass, length of pendulum, amplitude of swing)
- whirling a bung on the end of a piece of string to demonstrate the factors that affect centripetal force
- investigating objects and slopes to find out the point at which the object topples.



P3.3 Keeping things moving

Electric currents produce magnetic fields. Forces produced in magnetic fields can be used to make things move. This is called the motor effect and is how appliances such as the electric motor create movement.

Many appliances do not use 230 volts mains electricity. Transformers are used to provide the required potential difference.

Candidates should use their skills, knowledge and understanding to:

- interpret diagrams of electromagnetic appliances in order to explain how they work
- compare the use of different types of transformer for a particular application.

Additional guidance:

Examples might include some mobile phone chargers and power supplies for lap top computers.

P3.3.1 The motor effect

	Additional guidance:
a) When a current flows through a wire a magnetic field is produced around the wire.	Applications of electromagnets could include their use on cranes for lifting iron/steel.
b) The motor effect and its use.	Candidates should be able to apply the principles of the motor effect in any given situation.
c) The size of the force can be increased by: ■ increasing the strength of the magnetic field ■ increasing the size of the current.	The equation $F = BIL$ is **not** required.
d) The conductor will not experience a force if it is parallel to the magnetic field.	
e) The direction of the force is reversed if either the direction of the current or the direction of the magnetic field is reversed.	**Additional guidance:** Candidates will be expected to identify the direction of the force using Fleming's left-hand rule.

P3.3.2 Transformers

a) If an electrical conductor 'cuts' through a magnetic field a potential difference is induced across the ends of the conductor.

b) If a magnet is moved into a coil of wire a potential difference is induced across the ends of the coil.

c) The basic structure of the transformer.

d) An alternating current in the primary coil produces a changing magnetic field in the iron core and hence in the secondary coil. This induces an alternating potential difference across the ends of the secondary coil.	**Additional guidance:** Knowledge of laminations and eddy currents in the core are **not** required.
e) In a step-up transformer the potential difference across the secondary coil is greater than the potential difference across the primary coil.	
f) In a step-down transformer the potential difference across the secondary coil is less than the potential difference across the primary coil.	
g) The potential difference across the primary and secondary coils of a transformer are related by the equation: $\frac{V_p}{V_s} = \frac{n_p}{n_s}$	**Additional guidance:** V_p is the potential difference across the primary coil in volts, V V_s is the potential difference across the secondary coil in volts, V n_p is the number of turns on the primary coil n_s is the number of turns on the secondary coil
h) If transformers are assumed to be 100% efficient, the electrical power output would equal the electrical power input. $V_p \times I_p = V_s \times I_s$	Candidates should be aware that the input to a transformer is determined by the required output. V_p is the potential difference across the primary coil in volts, V I_p is the current in the primary coil in amperes (amps), A V_s is the potential difference across the secondary coil in volts, V I_s is the current in the secondary coil in amperes (amps), A
i) Switch mode transformers operate at a high frequency, often between 50 kHz and 200 kHz.	
j) Switch mode transformers are much lighter and smaller than traditional transformers working from a 50 Hz mains supply.	**Additional guidance:** Candidates should be aware that this makes them useful for applications such as mobile phone chargers.
k) Switch mode transformers use very little power when they are switched on but no load is applied.	

Suggested ideas for practical work to develop skills and understanding include the following:

- placing a foil strip with a current going through it in a strong magnetic field
- building a motor
- making a loudspeaker
- making a transformer using C cores and insulated wire
- demonstrating a transformer to show the difference between using d.c. and a.c.