Week 12

IGCSE Physics

Homework bundle for this week

本周作业合集

exercises.lol

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IGCSE Physics Name: ____________ Score: ______

1. A wave carries matter along with it from place to place.

☐ True ☐ False

2. A ray hits a plane mirror at 30° to the normal. At what angle to the normal does it reflect?

☐ 30° (angle of reflection = angle of incidence)

☐ 60°

☐ 90°

☐ 0°

3. A converging lens makes parallel rays of light:

☐ meet at the principal focus

☐ spread out as if from a point

☐ carry straight on unchanged

☐ stop completely

4. In a vacuum, how do the speeds of radio waves, light and gamma rays compare?

☐ they all travel at the same speed

☐ gamma rays are fastest

☐ radio waves are fastest

☐ visible light is fastest

5. Sound travels as a series of:

☐ compressions and rarefactions (a longitudinal wave)

☐ crests and troughs at right angles to travel

☐ electromagnetic waves

☐ still particles

6. A wave has frequency 5.0 Hz and wavelength 2.0 m. What is its speed, in m/s?

______________ m/s

7. An image in a plane mirror is:

☐ virtual, the same size, and as far behind the mirror as the object is in front

☐ real and can be shown on a screen

☐ smaller than the object

☐ upside down

8. The distance from the lens to its principal focus is called the ______ length.

____

9. Sound can travel through a vacuum (empty space).

☐ True ☐ False

10. A sound wave travels at 330 m/s with a frequency of 110 Hz. What is its wavelength, in m?

_________________ m

IGCSE Physics

1. **False**

   A wave carries energy, not matter. A floating cork bobs up and down but does not travel with the wave.

2. **30° (angle of reflection = angle of incidence)**

   The law of reflection: the angle of reflection equals the angle of incidence, both measured from the normal.

3. **meet at the principal focus**

   A converging (convex) lens bends parallel rays inward so they meet at the principal focus.

4. **they all travel at the same speed**

   All electromagnetic waves travel at the same speed in a vacuum, 3.0×10^8 m/s.

5. **compressions and rarefactions (a longitudinal wave)**

   A vibrating source squeezes and stretches the air into compressions and rarefactions — a longitudinal wave.

6. **10 m/s**

   $v = f\lambda = 5.0 \times 2.0 = 10$ m/s.

7. **virtual, the same size, and as far behind the mirror as the object is in front**

   A plane mirror gives a virtual image, the same size, the same distance behind the mirror — it cannot be caught on a screen.

8. **focal**

   The focal length is the distance from the centre of the lens to the principal focus.

9. **False**

   Sound needs particles to pass the vibration along, so it cannot travel through a vacuum.

10. **3 m**

    Rearrange $v = f\lambda$: $\lambda = \dfrac{v}{f} = \dfrac{330}{110} = 3.0$ m.

3.1 General properties of waves

Name: ______________ Class: __________ Date: ____________ **Total: 10 marks**

KEY WORDS wave 波 • transverse wave 横波 • longitudinal wave 纵波 • wavelength 波长 • amplitude 振幅

Objective

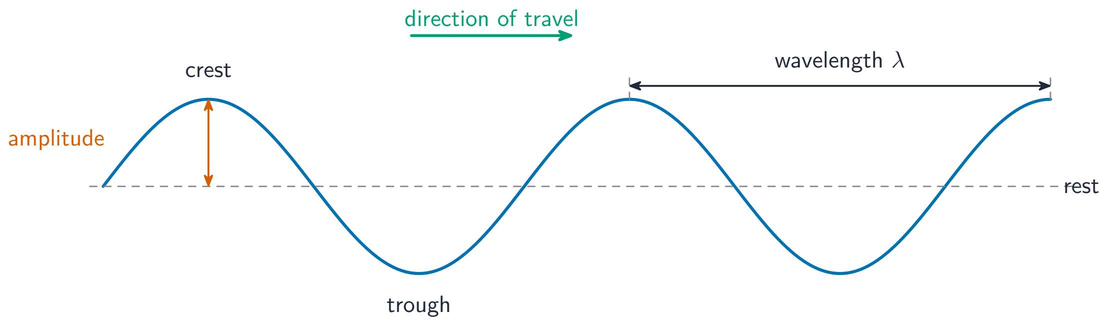
Build the skills to answer exam questions on the **general properties of waves** 波的性质 — the wave terms, the **wave equation** $v = f\lambda$, transverse vs longitudinal, and reflection/refraction/**diffraction** 衍射.

You must be able to:

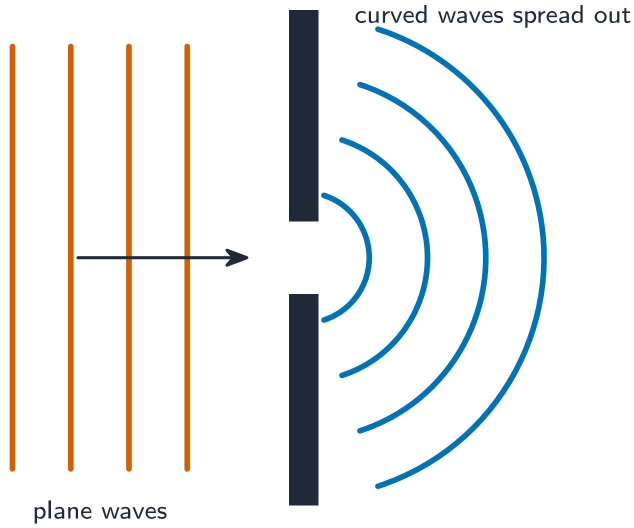
- use $v = f\lambda$ and define wavelength, frequency, amplitude
- distinguish transverse and longitudinal waves
- describe reflection, refraction and diffraction

1 Worked examples

■ The wave equation



Wavelength = crest-to-crest distance; amplitude = rest-to-crest height; $v = f\lambda$



Diffraction is strongest when the gap is about one wavelength wide

Sound $v = 340$ **m/s,** $f = 170$ **Hz:** $\lambda = \frac{v}{f} = \frac{340}{170} = 2.0$ m.

2 Practice

2.1 A wave has frequency 50 Hz and wavelength 0.40 m. Find its speed. [2]

2.2 State the difference between a transverse and a longitudinal wave. [1]

3 Exam-style questions

3.1 The number of complete waves passing a point each second is the: [1]

- **A** wavelength
- **B** amplitude
- **C** frequency
- **D** wave speed

3.2 Water waves of wavelength 0.020 m travel at 0.30 m/s.

(a) Find their frequency. [2]

(b) State and explain what happens to the waves as they pass through a gap about 0.02 m wide. [2]

3.3 A radio wave has a speed of 3.0×10^8 m/s and a frequency of 1.0×10^8 Hz. Find its wavelength. [2]

Solutions

2.1 $v = f\lambda = 50 \times 0.40 = 20$ m/s.

2.2 in a transverse wave the particles vibrate at right angles to the travel direction; in a longitudinal wave they vibrate along it.

3.1 **C**. Frequency is the number of waves per second.

3.2 (a) $f = \dfrac{v}{\lambda} = \dfrac{0.30}{0.020} = 15$ Hz.
(b) the waves spread out (diffract); because the gap is about the same size as the wavelength.

3.3 $\lambda = \dfrac{v}{f} = \dfrac{3.0 \times 10^8}{1.0 \times 10^8} = 3.0$ m.

18 Parallel waves in a ripple tank are diffracted as they pass through a gap in a barrier.

Three changes that can be made to this arrangement are listed.

1 Decrease the wavelength of the waves.

2 Increase the amplitude of the waves.

3 Decrease the size of the gap.

Which changes will cause the shape of the diffracted waves to be less curved?

A 1, 2 and 3 **B** 1 and 3 only **C** 1 only **D** 2 and 3 only

IGCSE Physics: **w25 22**

17 An earthquake-monitoring station records the arrival of 16 complete wavelengths of an earthquake wave in a time of 20 s.

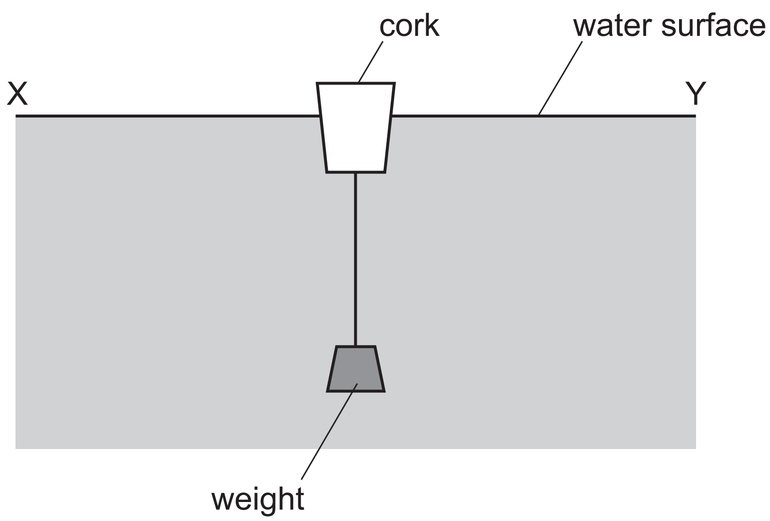
The speed of the earthquake wave is 6.0 km / s.

What is the wavelength of the earthquake wave?

A 1.3×10^{-4} m **B** 2.1×10^{-4} m **C** 4.8×10^{3} m **D** 7.5×10^{3} m

IGCSE Physics: **s25 21**

17 The diagram shows a cork with a weight attached so that the cork floats upright in water.



Transverse waves travel across the water from X to Y.

In which direction do the waves make the cork move?

A $\rightarrow \leftarrow$ right and left

B $\uparrow\downarrow$ up and down

C $\rightarrow$ only to the right

D $\leftarrow$ only to the left

16 Which statement about waves is correct?

A Waves do not transfer either energy or matter.

B Waves transfer both energy and matter.

C Waves transfer energy without transferring matter.

D Waves transfer matter without transferring energy.

5 **(a)** Describe how a longitudinal wave differs from a transverse wave.

....

....

.... [2]

(b) Fig. 5.1 represents a seismic wave produced by an earthquake.

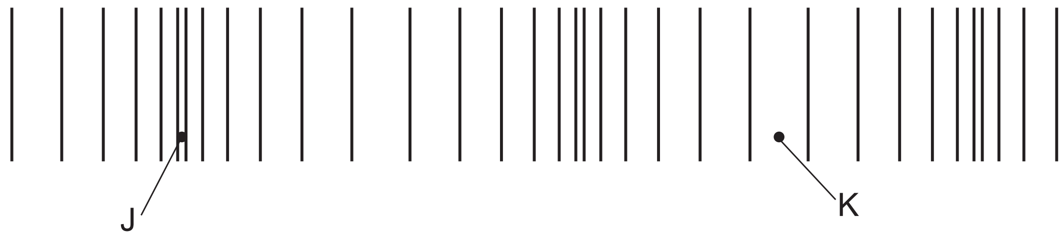


Fig. 5.1

(i) State whether this seismic wave is a P-wave (primary) or an S-wave (secondary). Justify your choice.

....

.... [1]

(ii) The wave represented in Fig. 5.1 has a wavelength of 1.2×10^4 m.

Calculate the actual distance between point J and point K.

distance = ... [2]

(iii) The wave in **(ii)** travels through the ground at a speed of 4600 m/s.

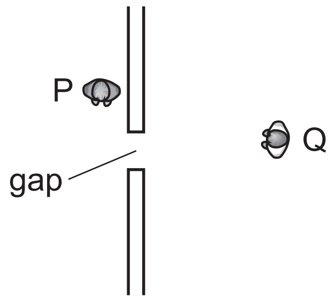
As the wave passes a certain point, the ground completes 5 oscillations.

Calculate the time that it takes for the wave to pass. Show your working.

ime = ... [3]

[Total: 8]

17 Two men, P and Q, stand close to a gap in a wall, as shown. Man P cannot see man Q but man P can hear man Q speaking.



Which statement explains this?

A Light waves do not diffract at all because they are electromagnetic waves.

B Light waves have a range of frequencies but sound has just one frequency.

C Sound waves are of a higher frequency than light waves.

D Sound waves diffract a lot because their wavelength is a similar size to the width of the gap.

18 Which quantities relating to a wave on the surface of water can **both** be measured in metres?

A amplitude and frequency

B amplitude and wavelength

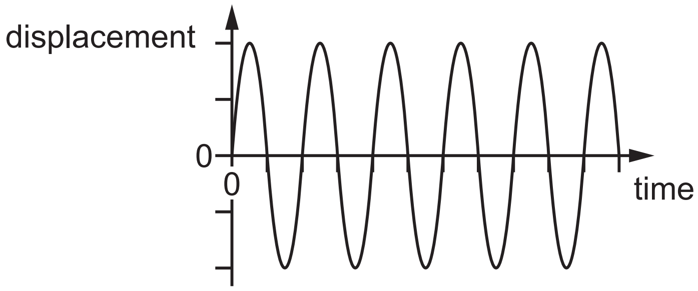
C amplitude and wave speed

D frequency and wavelength

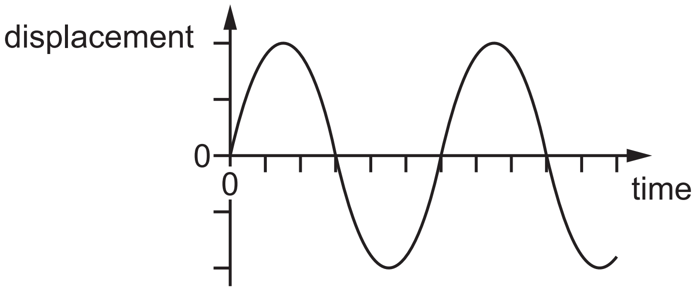
17 The diagrams show graphs of displacement against time for four waves. All the graphs are drawn to the same scale.

Which wave has the largest amplitude and the highest frequency?

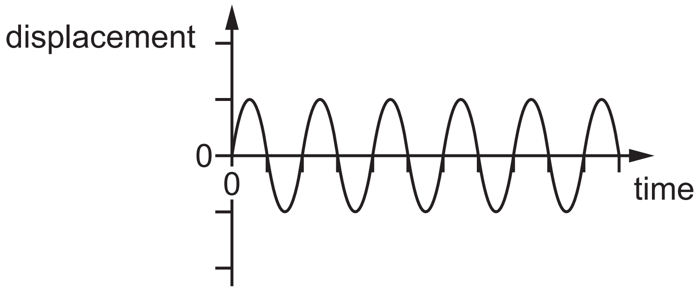
A



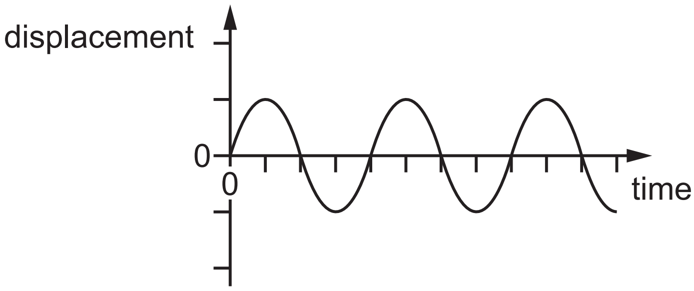
B



C



D



3.2 Light

Name: ____________ Class: ________ Date: __________ **Total: 47 marks**

KEY WORDS refractive index 折射率 • plane mirror 平面镜 • critical angle 临界角 • focal length 焦距 • normal 法线 • reflection 反射 • normal 法线 • total internal reflection 全反射 • refractive index 折射率 • converging lens 凸透镜

Objective

Build the skills to answer exam questions on **light 光**: images in a **plane mirror 平面镜**, **refraction 折射** and the **refractive index 折射率**, **total internal reflection 全反射**, ray diagrams for lenses, and **dispersion 色散**.

You must be able to:

- use the law of reflection and describe the image in a plane mirror
- describe the glass-block experiment and use $n = \dfrac{\sin i}{\sin r}$
- use $n = \dfrac{1}{\sin c}$ and describe total internal reflection and its uses
- draw ray diagrams for a converging lens and describe the image with the right words
- explain how lenses correct short sight and long sight
- describe dispersion and the order of the colours

1 Worked examples

■ Reflection in a plane mirror

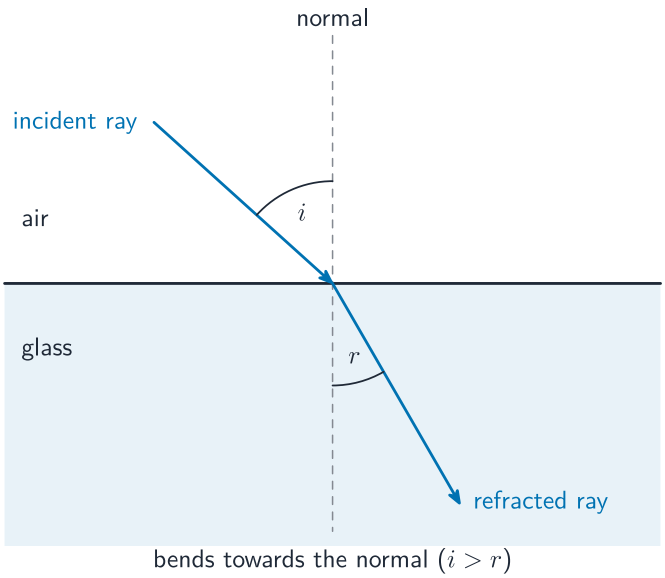
The **normal 法线** is the line at 90° to the mirror. The **angle of incidence 入射角** equals the **angle of reflection 反射角**, both measured from the normal. The image in a plane mirror is the same size as the object, the same distance behind the mirror as the object is in front, and **virtual 虚像** (the rays only seem to come from it, so it cannot be shown on a screen). It is also laterally inverted: left and right are swapped.

Worked example 1. A point object is 3.0 cm in front of a mirror. Where is the image? To draw a ray from the object to an eye, first mark the image 3.0 cm behind the mirror, on the normal through the object. Draw a straight line from the image to the eye; where it crosses the mirror is the reflection point. The real ray goes from the object to that point and then to the eye. Check: the two angles at the mirror are equal.

Refraction and the glass-block experiment

Shine a narrow ray from a **ray box** 光线盒 into a rectangular glass block. Mark the ray in and the ray out, remove the block, and draw the ray inside. Draw the normal where the ray enters and measure i and r with a protractor. Entering glass, light slows down and bends **towards** the normal; leaving, it speeds up and bends **away** from the normal, so the ray comes out parallel to the way it went in.

$$n = \frac{\sin i}{\sin r}$$



Entering glass the light slows and bends towards the normal, so $i > r$

Worked example 2. $i = 60°$ and $r = 35°$ ($\sin 60° = 0.87$, $\sin 35° = 0.57$). Then $n = \dfrac{0.87}{0.57} = 1.5$.

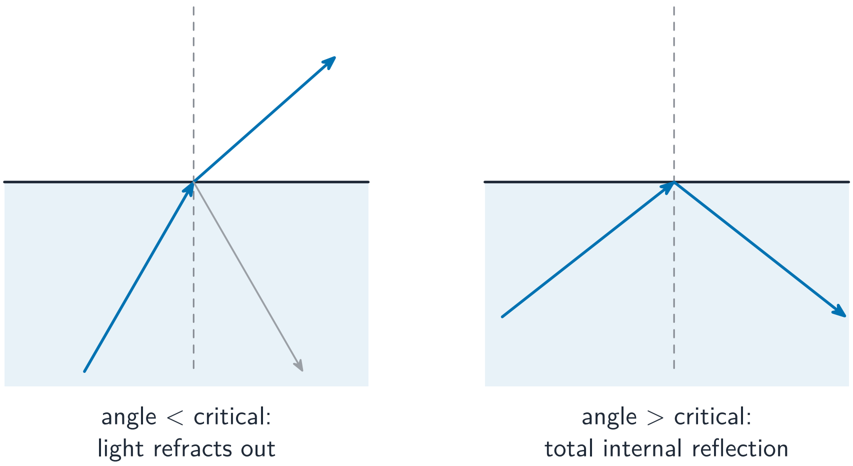
Worked example 3. Light enters water ($n = 1.33$) at $i = 40°$. Find r.

1. Rearrange: $\sin r = \dfrac{\sin i}{n}$.
2. Substitute: $\sin r = \dfrac{0.643}{1.33} = 0.483$.
3. Answer: $r = \sin^{-1}(0.483) = 29°$.

Total internal reflection

When light tries to leave glass, the angle of refraction is bigger than the angle inside. At the **critical angle** 临界角 c the refracted ray runs along the surface; above c no light gets out and it is all reflected inside:

$$n = \frac{1}{\sin c}$$



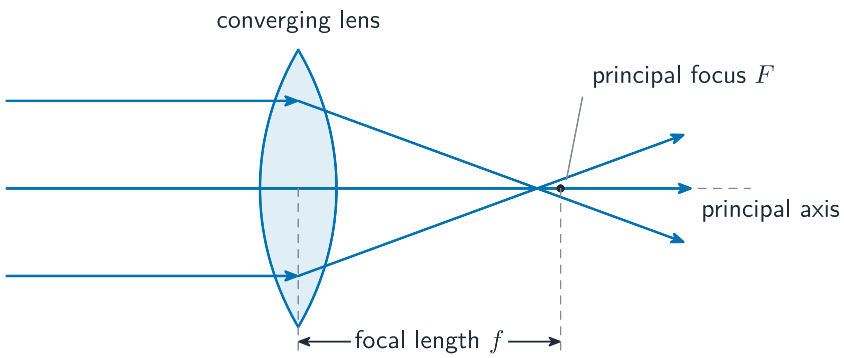
Above the critical angle the light is totally internally reflected

Worked example 4. Glass has $n = 1.5$. Find its critical angle. $\sin c = \dfrac{1}{1.5} = 0.667$, so $c = \sin^{-1}(0.667) = 42°$.

A ray aimed at the centre of a **semicircular block** 半圆形玻璃块 meets the curved surface along the normal, so it does not bend there; whether it escapes at the flat face depends only on the angle at that face. Total internal reflection is used in **optical fibres** 光纤 (telephone and internet signals), in prisms in binoculars, and in reflectors on bicycles and roads.

■ Lenses and ray diagrams

A **converging lens** 凸透镜 brings parallel rays to the **principal focus** 焦点 F; the **focal length** 焦距 is the distance from the centre of the lens to F, and the **principal axis** 主光轴 is the line through the centre of the lens at right angles to it. A **diverging lens** 凹透镜 spreads parallel rays out.



Parallel rays meet at the principal focus; the focal length is measured from the centre of the lens

To find an image, draw any two of the three standard rays from the top of the object:

1. a ray parallel to the axis, which refracts through F on the far side;

2. a ray through the centre of the lens, which does not bend;
3. a ray through F on the near side, which refracts parallel to the axis.

Where the two rays cross is the top of the image. If the rays cross on the far side, the image is **real** 实像 (it can be shown on a screen) and **inverted** 倒立. If the object is inside F, the rays spread out; extend them backwards and they meet on the same side as the object, giving a **virtual** image that is **upright** 正立 and **enlarged** 放大的: a **magnifying glass** 放大镜. Describe every image with three pairs of words: enlarged / same size / **diminished** 缩小的; upright / inverted; real / virtual.

Worked example 5. A ray diagram shows an object 6.0 cm from a lens and F marked 4.0 cm from it. The parallel ray from the top of the object refracts through F; the ray through the centre goes straight on; they cross 12 cm beyond the lens, below the axis. So the image is real, inverted and enlarged, 12 cm from the lens. Reading the focal length off a finished diagram works the same way backwards: the parallel ray crosses the axis at F, so measure the distance from the lens to that crossing.

■ Correcting sight

Short-sightedness 近视: distant objects are blurred because the eye focuses the light in front of the **retina** 视网膜. A diverging lens in front of the eye spreads the rays first, so they meet on the retina. **Long-sightedness** 远视: near objects are blurred because the light would focus behind the retina; a converging lens brings the rays together a little first.

■ Dispersion

A **prism** 棱镜 splits white light into a **spectrum** 光谱: red, orange, yellow, green, blue, indigo, violet. Red has the longest wavelength and the lowest frequency and is refracted least; violet is the opposite. Light of one frequency is **monochromatic** 单色.

2 Practice

2.1 State the law of reflection. [1]

2.2 An object is 5 cm in front of a plane mirror. State three characteristics of its image. [3]

2.3 Light enters glass with $\sin i = 0.80$ and $\sin r = 0.50$. Find the refractive index. [2]

2.4 Light enters a plastic block of refractive index 1.4 at an angle of incidence of 50°. Calculate the angle of refraction. ($\sin 50° = 0.766$) [3]

2.5 Diamond has a refractive index of 2.4. Calculate its critical angle. [2]

2.6 Describe what happens to a ray inside glass that meets the surface at an angle greater than the critical angle, and give one use of this effect. [2]

2.7 Define the terms focal length and principal focus of a converging lens. [2]

2.8 A converging lens is used as a magnifying glass. State where the object must be placed, and describe the image using three words. [3]

2.9 State the order of the colours of the spectrum, starting with the one of highest frequency, and state what monochromatic light is. [2]

3 Exam-style questions

3.1 A ray of light travelling in glass ($n = 1.5$) meets a glass–air surface at an angle of incidence of 45°. What happens to the ray? [1]

- **A** It refracts into the air, bending towards the normal.
- **B** It refracts into the air, bending away from the normal.
- **C** It travels along the surface.
- **D** It is totally internally reflected.

3.2 Which row describes the image of a person standing in front of a plane mirror? [1]

- **A** virtual, same size, laterally inverted
- **B** real, same size, upright
- **C** virtual, diminished, upright
- **D** real, enlarged, laterally inverted

3.3 A semicircular block of plastic has a refractive index of 1.5. A ray of light travelling inside the block, along a radius, reaches the centre of the flat face.

(a) Calculate the critical angle for the plastic. [2]

(b) The ray meets the flat face at an angle of incidence of 50°. State and explain what happens to the ray. [2]

(c) A different ray, in the air, meets the flat face at an angle of incidence of 40°. Calculate the angle of refraction inside the plastic. ($\sin 40° = 0.643$) [3]

(d) State two uses of total internal reflection. [2]

(e) State what happens to the speed of the light as it passes from the air into the plastic. [1]

3.4 Fig. 3.1 shows an object 2.0 cm tall placed 6.0 cm from a converging lens. The two principal foci are marked F.

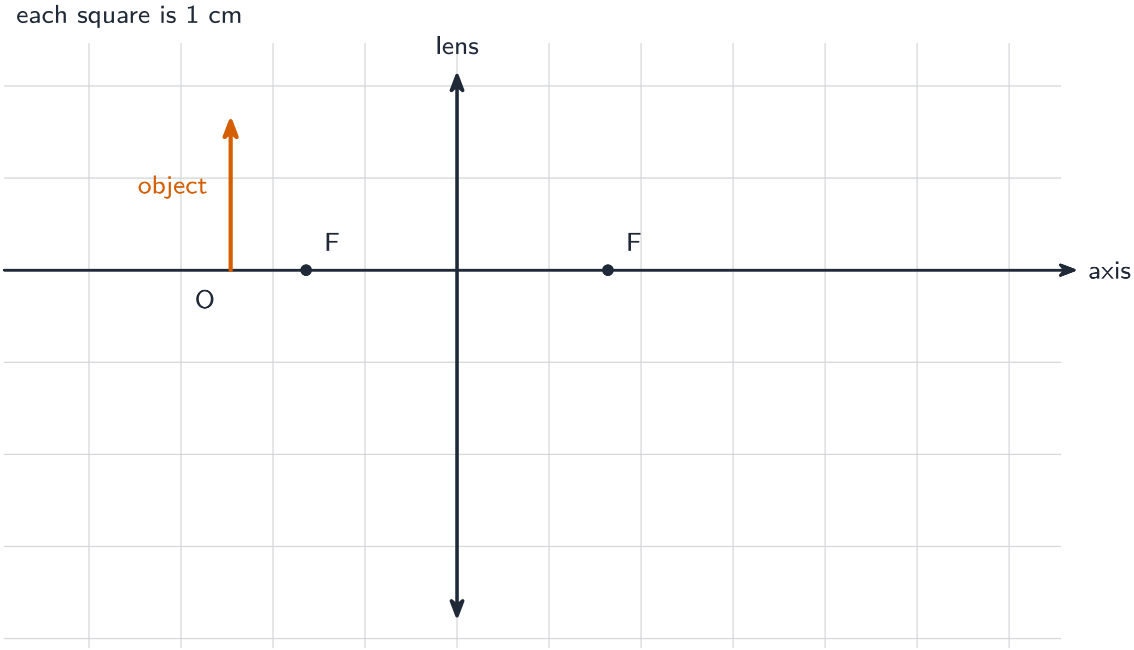


Fig. 3.1 (each square is 1 cm)

(a) On Fig. 3.1, draw two rays from the top of the object to locate the image. Label the image I, and determine the distance of the image from the lens. [3]

(b) Describe the image using three words. [2]

(c) The object is moved to 3.0 cm from the lens. State two ways in which the image changes. [2]

(d) Explain how a diverging lens placed in front of an eye corrects short-sightedness. [2]

3.5 A narrow beam of white light enters a glass prism.

(a) Describe what is seen on a screen placed after the prism, and name this effect. [2]

(b) State which colour is refracted the most, and explain why in terms of frequency. [2]

(c) A student says that the image in a plane mirror can be shown on a screen. Explain why the student is wrong. [2]

Solutions

2.1 The angle of incidence equals the angle of reflection, both measured from the normal.

2.2 Any three of: virtual; the same size as the object; 5 cm behind the mirror (the same distance as the object is in front); laterally inverted.

2.3 $n = \dfrac{\sin i}{\sin r} = \dfrac{0.80}{0.50} = 1.6.$

2.4 $\sin r = \dfrac{\sin i}{n} = \dfrac{0.766}{1.4} = 0.547;\ r = 33°.$

2.5 $\sin c = \dfrac{1}{n} = \dfrac{1}{2.4} = 0.417;\ c = 25°.$

2.6 It is totally internally reflected: none of the light leaves the glass and the angle of reflection equals the angle of incidence. Use: optical fibres (or prisms in binoculars, or road and bicycle reflectors).

2.7 Focal length: the distance from the centre of the lens to the principal focus. Principal focus: the point on the principal axis where rays parallel to the axis meet after passing through the lens.

2.8 Between the lens and its principal focus (closer to the lens than F); the image is enlarged, upright and virtual.

2.9 Violet, indigo, blue, green, yellow, orange, red. Monochromatic light is light of a single frequency (a single colour).

3.1 D. The critical angle is $\sin^{-1}(1/1.5) = 42°$, and 45° is larger, so the ray cannot escape. A describes light entering glass, B describes refraction below the critical angle, and C happens only exactly at 42°.

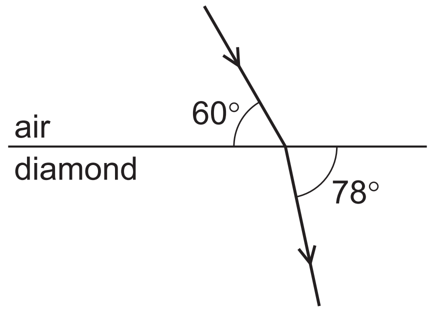
3.2 A. A plane mirror image is virtual, the same size, and laterally inverted; it is never real (B, D) and never diminished (C).

3.3 (a) $\sin c = \dfrac{1}{1.5} = 0.667;\ c = 42°.$
(b) The ray is totally internally reflected at the flat face, because 50° is greater than the critical angle of 42°.
(c) $\sin r = \dfrac{\sin i}{n} = \dfrac{0.643}{1.5} = 0.429;\ r = 25°.$
(d) Any two of: optical fibres for telephone and internet signals; prisms in binoculars or periscopes; reflectors on bicycles and roads; endoscopes in medicine.
(e) It slows down.

3.4 (a) Ray from the top of the object parallel to the axis, refracting at the lens through the far F; ray from the top of the object through the centre of the lens, undeviated; the two rays cross 12 cm beyond the lens, 4 cm below the axis, so the image I is drawn from the axis to that point and is 12 cm from the lens.
(b) Real, inverted and enlarged.
(c) The object is now inside F, so the image becomes virtual and upright, on the same side of the lens as the object; it is still enlarged. (Any two correct changes.)
(d) The eye focuses light from a distant object in front of the retina; the diverging lens spreads the rays out before they enter the eye, so they now meet on the retina.

3.5 (a) A band of colours (a spectrum) from red to violet; the effect is dispersion.
(b) Violet; it has the highest frequency (shortest wavelength), and the glass slows and bends higher-frequency light more.
(c) The image is virtual: the reflected rays only appear to come from behind the mirror, so no light actually passes through the image position and none can fall on a screen there.

20 The diagram shows a ray of light passing from air into diamond.



What is the refractive index of the diamond?

A 0.89 **B** 1.1 **C** 2.4 **D** 2.5

21 The ray diagrams show the formation of an image by two different converging lenses.

diagram 1

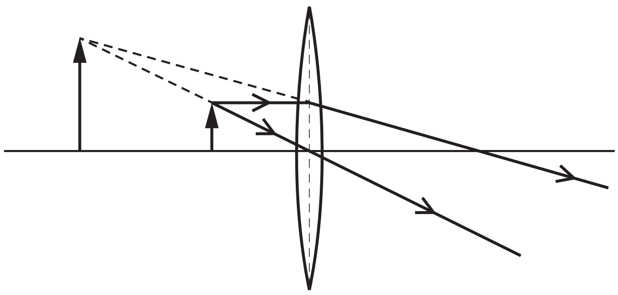
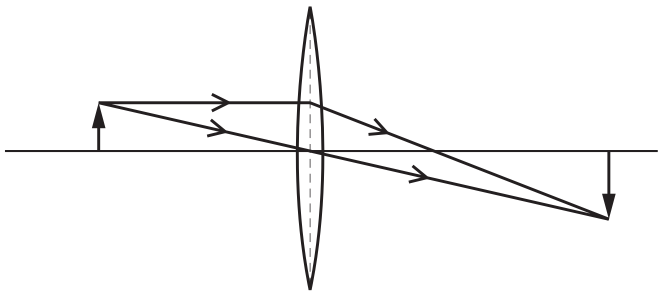


diagram 2



Which row describes the images produced?

	diagram 1	diagram 2
A	real	real
B	real	virtual
C	virtual	real
D	virtual	virtual

6 Fig. 6.1 shows a full-scale diagram of an object O and its image I produced by a converging lens. The lens and its position on the principal axis are not shown.

Fig. 6.1

(a) On Fig. 6.1, draw:

- a single ray to locate the position of the centre of the converging lens
- a line to represent the position of the lens and label the line L.

[2]

(b) Determine the focal length of the lens by drawing another ray on Fig. 6.1.

focal length = ... [2]

(c) The object is moved 2.0 cm closer to the lens.

State **two** changes to the characteristics of the image.

1 ....

2 ....

[2]

[Total: 6]

5 **(a)** Fig. 5.1 shows a semicircular transparent plastic block.

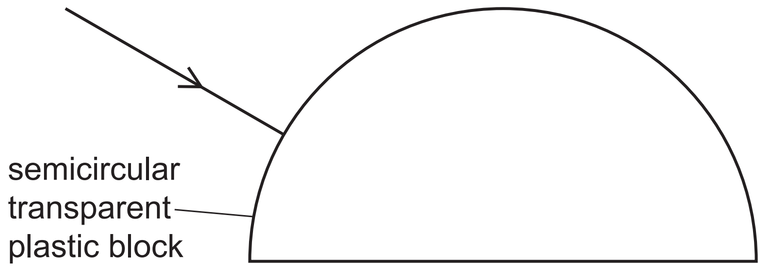


Fig. 5.1

A ray of light is incident normally on the curved surface of the block. The refractive index of the plastic is 1.5.

(i) Calculate the critical angle for the plastic.

critical angle = ... [2]

(ii) On Fig. 5.1, draw the path of the ray in the block and after the ray emerges from the block. [2]

(b) Fig. 5.2 is a full-scale diagram of a lens and an object O.

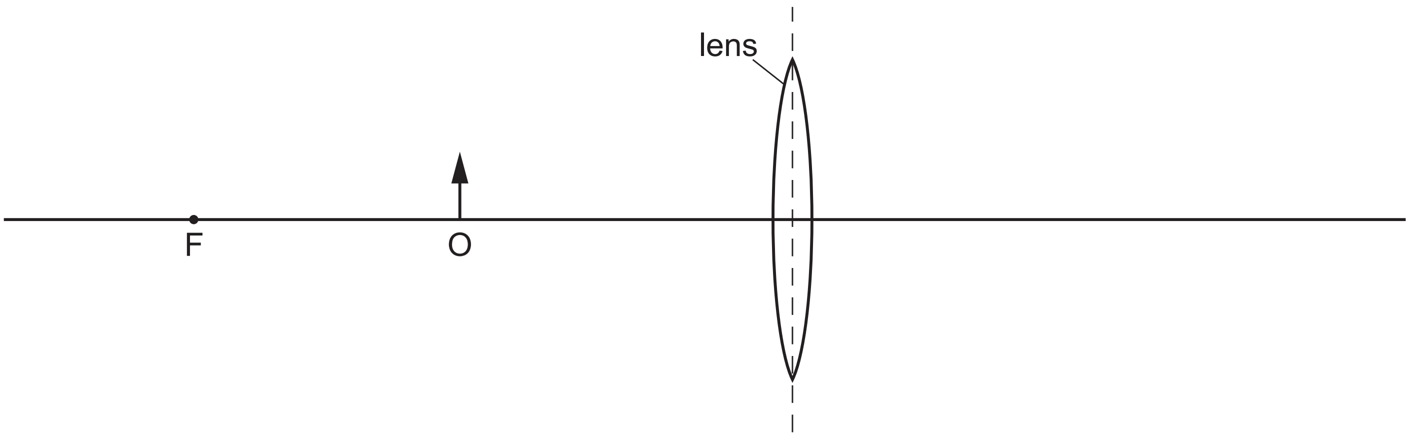


Fig. 5.2

The point marked F shows the position of a principal focus of the lens.

(i) Determine the focal length of the lens.

focal length = ... [1]

(ii) On Fig. 5.2, draw **two** rays from the object to locate the image. Label the image I. [3]

(c) Fig. 5.3 shows a simplified diagram of an eye with rays from a distant object and the path of the rays inside the eye of a person with short sight.

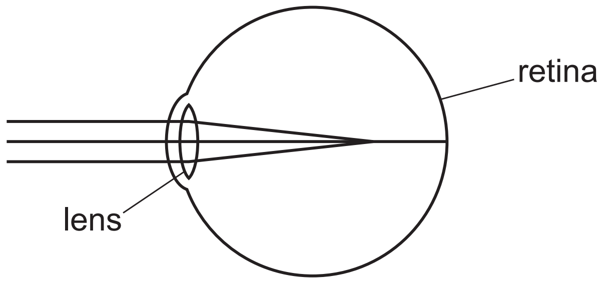


Fig. 5.3

On Fig. 5.4, draw an additional lens outside the eye to correct short-sightedness and show the path of the rays inside the eye.

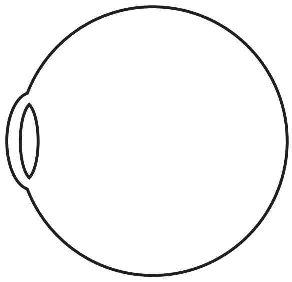


Fig. 5.4

[2]

[Total: 10]

5 A boy looks at the image of a clock in a plane mirror. Fig. 5.1 shows the mirror, the clock and the position of one of the boy's eyes.

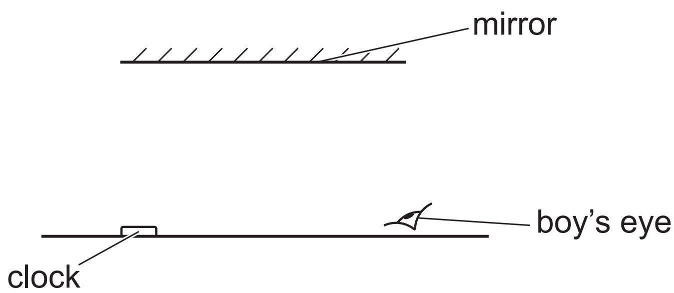


Fig. 5.1

(a) **(i)** On Fig. 5.1, draw a ray of light from the clock, reflected to the boy's eye. [2]

(ii) On Fig. 5.1, mark with an X the position of the image of the clock. [1]

(iii) State whether the image formed by the mirror is virtual or real.

Explain your answer.

....

.... [1]

(iv) Fig. 5.2 shows the image of the clock seen by the boy.

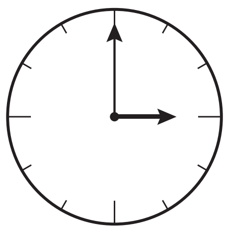


Fig. 5.2

The boy now looks directly at the clock.

On Fig. 5.3, draw what the boy sees.

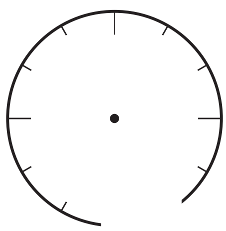


Fig. 5.3

[1]

(b) **(i)** The clock is illuminated by a source of monochromatic green light.

State the meaning of monochromatic.

.... [1]

(ii) The green light has a wavelength of 5.6×10^{-7} m.

Calculate the frequency of this green light.

frequency = ... [3]

[Total: 9]

IGCSE PHYSICS • EXERCISE SHEET

3.3 Electromagnetic spectrum

Name: ______________ Class: __________ Date: ____________ **Total: 36 marks**

KEY WORDS electromagnetic spectrum 电磁波谱 • digital 数字 • analogue 模拟 • spectrum 光谱 • microwave 微波 • electromagnetic spectrum 电磁波谱 • spectrum 光谱 • microwaves 微波 • radio waves 无线电波 • infrared 红外线

Objective

Build the skills to answer exam questions on the **electromagnetic spectrum 电磁波谱**: the order of the regions, their speed, their uses and dangers, communication with **artificial satellites 人造卫星**, and **digital 数字** and **analogue 模拟** signals.

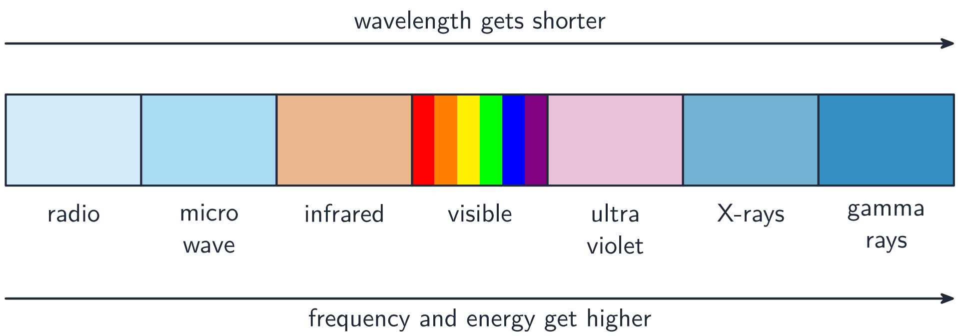
You must be able to:

- give the regions in order of wavelength and of frequency
- state the speed of electromagnetic waves in a vacuum and in air
- give a typical use and a harmful effect for each region
- describe how satellites in low and geostationary orbits are used
- explain the difference between digital and analogue signals, and the benefits of digital

1 Worked examples

The spectrum, in order

All electromagnetic waves are transverse, transfer energy, and travel at the same speed in a **vacuum 真空**: 3.0×10^8 m/s (almost the same in air). Going from radio waves to gamma rays, the wavelength falls while the frequency and the energy rise.



From radio to gamma rays: wavelength falls, frequency and energy rise

Region	A typical use	Harm from too much
radio waves	radio and TV, astronomy, RFID tags	—
microwaves	mobile phones, satellite TV, cooking	internal heating of body cells
infrared	remote controls, thermal imaging, grills, optical fibres	skin burns
visible light	seeing, photography	—
ultraviolet	sterilising water, security marking, checking bank notes	skin cancer, eye damage
X-rays	medical and security scans	damage to cells
gamma rays	sterilising equipment, detecting and treating cancer	mutation of cells

Read a “match the use to the region” question from the use: security marking uses **ultraviolet** (the ink glows); Bluetooth uses **radio waves**; optical fibres carry **infrared**; detecting and treating cancer uses **gamma rays**.

Satellites

Communication with artificial satellites is mainly by **microwaves**, because they pass through the atmosphere and the ionosphere, need only a short aerial, and carry data at a high rate. Some satellite phones use satellites in **low orbit** 低轨道, close to the Earth. Direct broadcast satellite television, and some satellite phones, use satellites in **geostationary orbit** 地球静止轨道, which stay above the same point on the Earth so the dish never has to move.

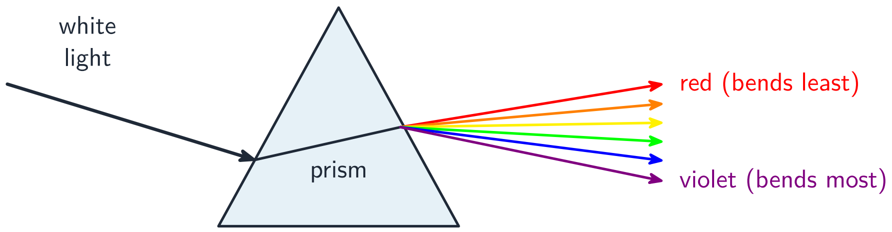
Digital and analogue signals

An **analogue signal** varies continuously and can take any value. A **digital signal** is a stream of only two values, on or off (1 or 0). A sound can be sent either way: a microphone produces an analogue signal, which can be converted to digital.

Digital signalling is better for two reasons the exam wants:

- a **higher rate** of data transmission;
- a **greater range**, because a weak digital signal can be **regenerated** back to clean 1s and 0s: only two levels have to be told apart, so the noise picked up on the way is removed. An analogue signal cannot be cleaned up like this, so its noise builds up along the route.

Worked example. A signal travels 600 km along an optical fibre and is regenerated three times. Explain why the message arrives without noise. Each regenerator only has to decide whether the level is nearer 1 or nearer 0; it then transmits a fresh, clean pulse, so the noise added in the previous section is discarded rather than passed on.



Visible light is one narrow band of the spectrum; a prism spreads it into its colours

2 Practice

2.1 List the regions of the electromagnetic spectrum in order of increasing frequency. [2]

2.2 State the speed of electromagnetic waves in a vacuum. [1]

2.3 Give one use of infrared radiation and one harmful effect of too much ultraviolet. [2]

2.4 State the difference between a digital and an analogue signal. [2]

2.5 State two benefits of sending information as a digital signal. [2]

2.6 State which region of the spectrum is used to communicate with satellites, and give one reason why. [2]

2.7 A radio wave has a frequency of 1.5×10^8 Hz. Calculate its wavelength in a vacuum. [3]

3 Exam-style questions

3.1 Which row is correct for two regions of the electromagnetic spectrum? [1]

- **A** X-rays have a longer wavelength than radio waves.
- **B** Microwaves travel faster than gamma rays in a vacuum.
- **C** Ultraviolet has a higher frequency than infrared.
- **D** Gamma rays have the lowest energy of all the regions.

3.2 A digital signal and an analogue signal both travel a long distance and pick up noise. Which statement is correct? [1]

- **A** Only the analogue signal can be regenerated to remove the noise.
- **B** Only the digital signal can be regenerated, because it has just two levels.
- **C** Neither signal can be regenerated once noise is added.
- **D** Both can be regenerated equally well.

3.3 Electromagnetic waves have many uses.

(a) Draw one line from each use to the region of the spectrum that it uses. [2]

Use	**Region**
security marking	gamma rays
Bluetooth	ultraviolet
optical fibres	infrared
detecting cancer	radio waves

(b) State one advantage of using microwaves rather than radio waves to transmit mobile phone signals. [1]

(c) Describe the difference between a satellite in a low orbit and one in a geostationary orbit, and state one use of each. [4]

(d) State the harmful effect on people of too much exposure to microwaves, and to X-rays. [2]

3.4 A telephone company replaces a copper cable carrying analogue signals with an optical fibre carrying digital signals.

(a) Explain what is meant by an analogue signal and by a digital signal. [2]

(b) Explain, in terms of noise and regeneration, why the digital system can send a signal a greater distance without losing quality. [3]

(c) State one other benefit of the digital system. [1]

(d) The infrared signal in the fibre has a wavelength of 1.5×10^{-6} m. Calculate its frequency. Take the speed as 3.0×10^{8} m/s. [3]

(e) The company says the signal "travels faster because it is digital". Explain why this statement is wrong. [2]

Solutions

2.1 Radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays.

2.2 3.0×10^8 m/s.

2.3 Any one use of infrared: remote controls, thermal imaging, grills, optical fibres. Ultraviolet: skin cancer or eye damage.

2.4 An analogue signal varies continuously and can take any value; a digital signal has only two values, on or off, 1 or 0.

2.5 A higher rate of data transmission; a greater range, because the signal can be regenerated without the noise.

2.6 Microwaves; any one of: they pass through the atmosphere and ionosphere; only a short aerial is needed; they carry a large amount of data at high speed.

2.7 $\lambda = \dfrac{v}{f} = \dfrac{3.0 \times 10^8}{1.5 \times 10^8} = 2.0$ m.

3.1 C. Ultraviolet sits above infrared in frequency. A reverses the order, B is wrong because all electromagnetic waves travel at the same speed in a vacuum, and D reverses the energy order.

3.2 B. A digital signal has only two levels, so a regenerator can decide which was sent and transmit a clean pulse; an analogue signal has no such reference, so its noise is amplified along with the signal.

3.3 (a) security marking → ultraviolet; Bluetooth → radio waves; optical fibres → infrared; detecting cancer → gamma rays.
(b) Any one of: microwaves need only a short aerial; they pass through the atmosphere to satellites; they transmit data at a higher rate.
(c) A low-orbit satellite is close to the Earth and moves quickly across the sky, so it is only in view for a short time; a geostationary satellite orbits above the equator once a day, so it stays above the same point and a dish can point permanently at it. Low orbit: satellite phones. Geostationary: direct broadcast satellite television.
(d) Microwaves: internal heating of body cells. X-rays: damage to cells, which can cause cancer.

3.4 (a) Analogue: the signal varies continuously and can take any value. Digital: the signal has only two values, 1 and 0.
(b) Both signals pick up noise as they travel; a digital signal is regenerated at intervals, and because only two levels must be told apart the original 1s and 0s are recovered exactly and a clean signal is sent on; an analogue signal cannot be separated from its noise, so amplifying it amplifies the noise too and the quality falls with distance.
(c) A higher rate of data transmission.
(d) $f = \dfrac{v}{\lambda} = \dfrac{3.0 \times 10^8}{1.5 \times 10^{-6}} = 2.0 \times 10^{14}$ Hz.
(e) All electromagnetic waves travel at the same speed in a given medium, whether the signal is digital or analogue; what digital gives is a higher rate of data transfer and a greater range, not a higher wave speed.

22 Ultraviolet radiation and infrared radiation are both parts of the electromagnetic spectrum.

However, they differ in wavelength and frequency.

Which row describes how they differ?

	ultraviolet	infrared
A	longer wavelength than infrared	higher frequency than ultraviolet
B	longer wavelength than infrared	lower frequency than ultraviolet
C	shorter wavelength than infrared	higher frequency than ultraviolet
D	shorter wavelength than infrared	lower frequency than ultraviolet

IGCSE Physics: **w25 23**

22 Visible light, X-rays and microwaves are all components of the electromagnetic spectrum.

Which statement about the waves is correct?

A In a vacuum, microwaves travel faster than visible light and have a shorter wavelength than visible light.

B In a vacuum, microwaves travel at the same speed as visible light and have a shorter wavelength than visible light.

C In a vacuum, X-rays travel faster than visible light and have a shorter wavelength than visible light.

D In a vacuum, X-rays travel at the same speed as visible light and have a shorter wavelength than visible light.

5 **(a)** **(i)** Electromagnetic waves have many uses.

On Fig. 5.1 draw **one** line from each use to the region of the electromagnetic (e-m) spectrum it uses.

Use	**Region of e-m spectrum**
security marking	gamma rays
Bluetooth	ultraviolet
optical fibres	infrared
detection of cancer	radio waves

Fig. 5.1

[2]

(ii) State **one** advantage of using microwaves compared with radio waves to transmit mobile (cell) phone signals.

....

.... [1]

(b) Describe the difference between transverse waves and longitudinal waves.

....

....

....

.... [2]

(c) Fig. 5.2 shows a simplified diagram of seismic P-waves travelling through the Earth. The paths of the waves are curved.
Seismic waves are produced by rock movements in earthquakes.

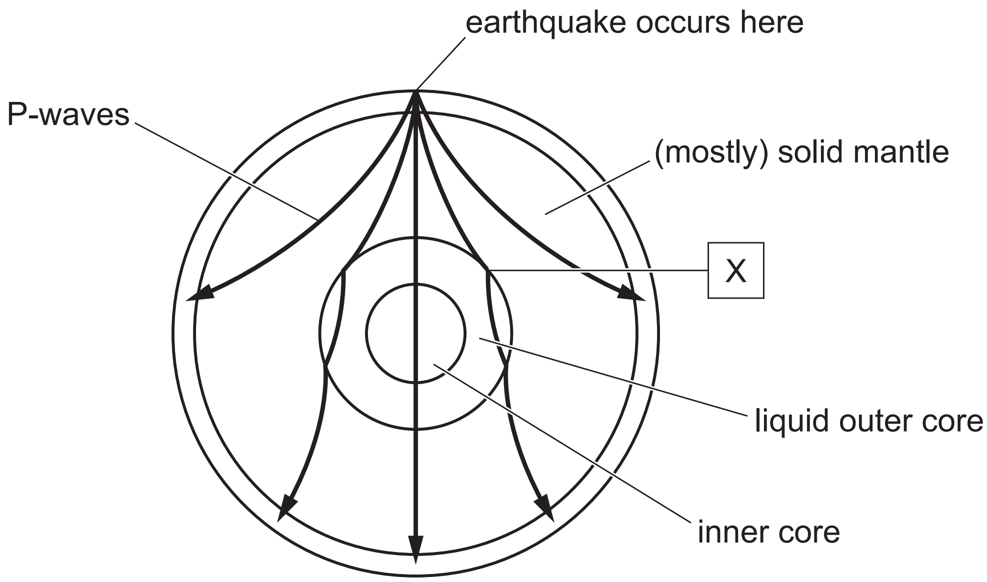


Fig. 5.2 (not to scale)

(i) State the type of wave that P-waves can be modelled as.

.... [1]

(ii) At point X, the P-wave travels from the solid mantle to the liquid core. There is a sudden change in direction of the path of the wave.

Explain the change in direction of the P-wave at point X.

....

....

.... [2]

(d) The Earth's surface absorbs incoming radiation from the Sun and also emits thermal radiation from its surface.

Over the past 50 years, scientists estimate that the average temperature of the Earth's surface has increased by approximately 0.75 °C.

Explain what is causing this average temperature rise.

....

....

....

.... [2]

[Total: 10]

22 Satellites are sometimes used to receive and re-transmit television signals.

Which row shows the type of satellite and the electromagnetic waves used?

	type of satellite	electromagnetic waves used
A	low orbit	infrared
B	low orbit	microwaves
C	geostationary	infrared
D	geostationary	microwaves

IGCSE Physics: **s24 21**

21 Which region of the electromagnetic spectrum is used for detecting fake bank notes?

A radio

B microwaves

C ultraviolet

D X-rays

IGCSE Physics: **w23 21**

22 A radio transmitter broadcasts at a frequency of 200 kHz.

What is the wavelength of these radio waves?

A 6.7×10^{-4} m **B** 1.5 m **C** 1.5×10^{3} m **D** 1.5×10^{6} m

IGCSE Physics: **s23 21**

21 Visible light has wavelengths in the range 4.0×10^{-7} m to 7.0×10^{-7} m.

What is the range of the frequencies of visible light?

A 0.12 Hz to 0.21 Hz

B 120 Hz to 210 Hz

C 4.3×10^{11} Hz to 7.5×10^{11} Hz

D 4.3×10^{14} Hz to 7.5×10^{14} Hz

6 A mobile phone (cell phone) network uses microwaves of frequency 1.9×10^9 Hz to transmit and receive signals.

The speed of microwaves in air is 3.0×10^8 m/s.

(a) Calculate the wavelength of these microwaves in air.

wavelength = ... [2]

(b) State **two** reasons why microwaves are used for mobile phone (cell phone) signals.

1 ....

....

2 ....

....
[2]

(c) All mobile phone (cell phone) networks use digital signals to communicate with the phone.

(i) Describe, with the aid of a diagram, how a digital signal differs from an analogue signal.

....

....

....

.... [3]

(ii) State **two** advantages of using digital signals rather than analogue signals.

1 ....

....

2 ....

....
[2]

[Total: 9]

3.4 Sound

Name: ____________ Class: ________ Date: __________ **Total: 9 marks**

KEY WORDS longitudinal wave 纵波 • echo 回声 • compression 压缩 • rarefaction 稀疏 • sound 声音

Objective

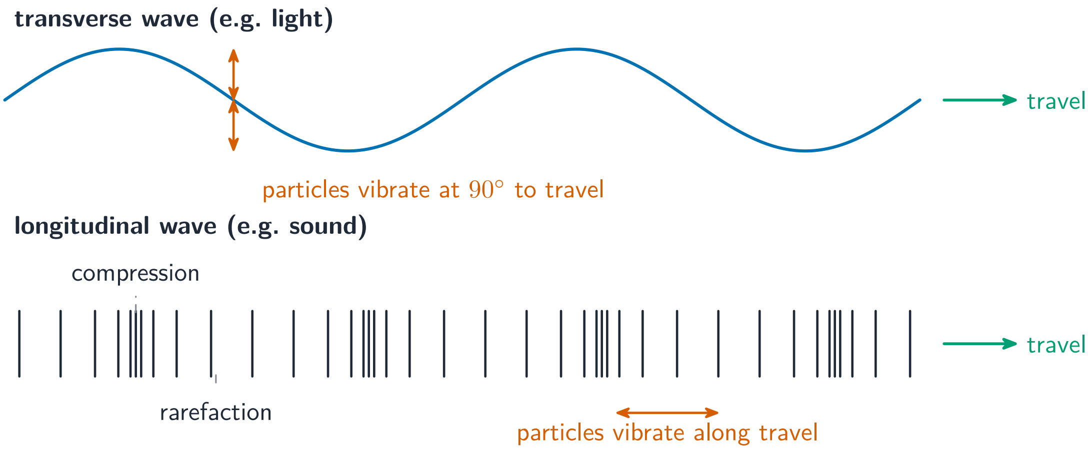
Build the skills to answer exam questions on **sound 声音** — sound as a **longitudinal wave 纵波**, the need for a medium, the range of human hearing, and **echoes 回声**.

You must be able to:

- describe sound as a longitudinal wave (compressions and rarefactions)
- state that sound needs a medium and give the hearing range
- find the speed of sound from an echo

1 Worked examples

■ Speed of sound from an echo



Sound is longitudinal: the air vibrates along the travel direction, making compressions and rarefactions

Clap 85 **m from a wall, echo after** 0.50 **s:** the sound goes there and back, $2 \times 85 = 170$ m, so $v = \dfrac{170}{0.50} = 340$ m/s.

2 Practice

2.1 State why sound cannot travel through a vacuum. [1]

2.2 State the approximate range of frequencies a human can hear. [1]

3 Exam-style questions

3.1 Sound is a: [1]

- **A** transverse wave that needs no medium
- **B** longitudinal wave that needs a medium
- **C** transverse wave that needs a medium
- **D** longitudinal wave that needs no medium

3.2 A person stands 660 m from a cliff and shouts. The echo returns 4.0 s later.

(a) Find the speed of sound. [3]

(b) State whether sound travels faster or slower in water than in air. [1]

3.3 Explain why you see lightning before you hear the thunder. [2]

Solutions

2.1 sound needs a medium (particles) to travel through, and a vacuum has none.

2.2 about 20 Hz to 20 000 Hz.

3.1 B. Sound is a longitudinal wave that needs a medium.

3.2 (a) distance there and back $= 2 \times 660 = 1320$ m; $v = \dfrac{1320}{4.0}$; $= 330$ m/s.
(b) faster in water.

3.3 light travels much faster than sound; so the light from the lightning reaches you almost at once, while the sound takes longer to arrive.

23 A police car with its siren sounding is stationary in heavy traffic. A pedestrian notices that, although the loudness of the sound produced does **not** change, the pitch varies.

Which row describes the amplitude and the frequency of the sound?

	amplitude	frequency
A	constant	constant
B	constant	varying
C	varying	constant
D	varying	varying

IGCSE Physics: **w25 22**

23 Sound travels through air as a series of compressions and rarefactions.

Which statement correctly compares a compression with a rarefaction?

A In a compression, the wavelength is longer than in a rarefaction.

B In a compression, the wavelength is shorter than in a rarefaction.

C In a compression, the density of the air is greater than in a rarefaction.

D In a compression, the density of the air is lower than in a rarefaction.

IGCSE Physics: **w25 23**

23 Both the amplitude and the frequency of a sound wave decrease.

What happens to the sound that is heard?

A The sound is louder and has a higher pitch.

B The sound is louder and has a lower pitch.

C The sound is quieter and has a higher pitch.

D The sound is quieter and has a lower pitch.

5 A dolphin communicates with other dolphins underwater by emitting sounds in the range 7–15 kHz.

(a) State the value of the speed of sound in air and state how the speed of sound in water differs from the speed of sound in air.

speed of sound in air .... m/s

speed of sound in water ....
[1]

(b) State and explain if humans with normal hearing can hear all the sounds emitted by the dolphin.

statement ....

explanation ....

....
[2]

(c) Complete Table 5.1 to describe differences in loudness and pitch of two different dolphin sounds.

Table 5.1

Frequency /kHz	amplitude	loudness	pitch
14	large		
8	small		

[2]

(d) Complete the sentences to describe how sound is transmitted through water.

Sound waves are made of vibrating .... which produce

compressions and rarefactions. A compression is a region of ....

and a rarefaction is a region of .... The sound waves travel

.... to the direction of the vibrations.
[3]

[Total: 8]

23 A sound wave travels through the air and strikes a solid block of steel.

Some of the sound is reflected from the steel, and some is transmitted through the steel.

How does the speed and the wavelength of the sound in steel compare to the speed and the wavelength of the sound in air?

	speed in steel	wavelength in steel
A	less than in air	less than in air
B	less than in air	greater than in air
C	greater than in air	less than in air
D	greater than in air	greater than in air

IGCSE Physics: **s24 21**

22 A sound wave travels at 330 m/s. The distance between the centre of a compression and the centre of the nearest rarefaction in the sound wave is 2.5 cm.

What is the frequency of the sound wave?

A 66 Hz **B** 130 Hz **C** 6600 Hz **D** 13 000 Hz

23 Which waves are used in the medical scanning of soft tissue?

A gamma rays

B infrared

C microwaves

D ultrasound

IGCSE Physics: **s23 21**

22 Student X fires a starting pistol which produces smoke and sound. Student Y is standing 100 m away and sees the smoke the instant it is produced. The speed of sound in air is 340 m/s.

What is the time delay between student Y seeing the smoke and hearing the sound?

A 0.29 s **B** 0.59 s **C** 1.7 s **D** 3.4 s