Oxford Cambridge and RSA

AS Level Physics A

H156/01 Breadth in physics

Tuesday 15 May 2018 – Morning

Time allowed: 1 hour 30 minutes

You must have:
- the Data, Formulae and Relationships Booklet (sent with general stationery)

You may use:
- a scientific or graphical calculator
- a ruler (cm/mm)

First name	
Last name	StemUp Model Solution

Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. HB pencil may be used for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- This document consists of **24** pages.

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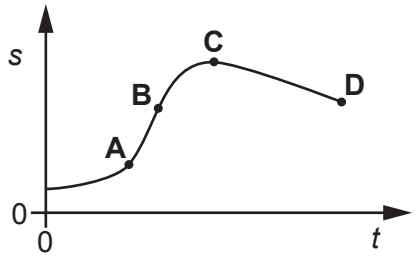
SECTION A

You should spend a maximum of 25 minutes on this section.

Answer **all** the questions.

Write your answer to each question in the box provided.

1 The graph below shows the variation of displacement *s* with time *t* for an object.



At which point, **A**, **B**, **C** or **D**, does the object have maximum velocity?

Your answer B **[1]**

2 Which definition is correct and uses only quantities rather than units?

A Acceleration is the change in velocity per second.

B Resistance is potential difference per ampere.

C Intensity is energy per unit cross-sectional area.

D Electromotive force is energy transferred per unit charge.

Your answer D **[1]**

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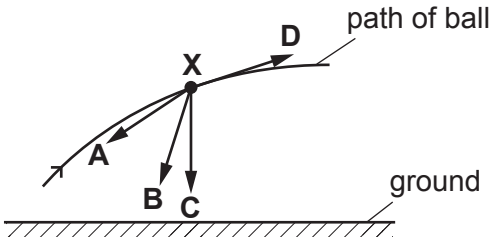
3 A ball is thrown through the air. The ball experiences a small amount of drag compared to its weight.
At a particular time the ball is at point **X**.
Which arrow best represents the direction of the resultant force on the ball when it is at **X**?



Your answer B **[1]**

4 An object **P** is travelling to the right with a momentum of $40\,\text{kg}\,\text{m}\,\text{s}^{-1}$. It collides with another object **Q** travelling to the left along the same path.

The final momentum of **P** is $10\,\text{kg}\,\text{m}\,\text{s}^{-1}$ to the right.

What is the change in the momentum of **Q**?

A $0\,\text{kg}\,\text{m}\,\text{s}^{-1}$

B $10\,\text{kg}\,\text{m}\,\text{s}^{-1}$

C $30\,\text{kg}\,\text{m}\,\text{s}^{-1}$

D $50\,\text{kg}\,\text{m}\,\text{s}^{-1}$

Your answer C **[1]**

5 Wire **P** has length L, diameter d and a resistance of $1.00\,\Omega$.
Another wire **Q** made from the same metal has length $3L$ and diameter $2d$.

What is the resistance of wire **Q**?

A $0.750\,\Omega$

B $1.00\,\Omega$

C $1.33\,\Omega$

D $1.50\,\Omega$

Your answer A **[1]**

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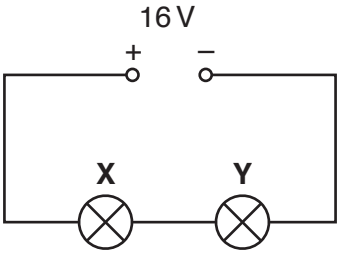
6 Two filament lamps **X** and **Y** are connected in series with a 16 V d.c. supply. The supply has negligible internal resistance.



Lamp **X** emits a power of 2.0 W and lamp **Y** emits a power of 6.0 W.

What is the potential difference across the lamp **X**?

A 1.0 V

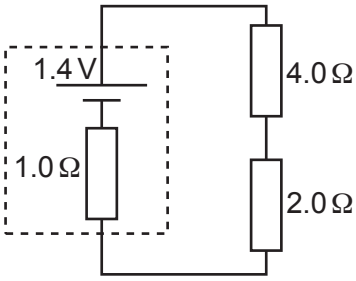
B 4.0 V

C 12 V

D 16 V

Your answer B **[1]**

7 Two resistors of resistances 2.0 Ω and 4.0 Ω are connected in series across the terminals of a cell of e.m.f. 1.4 V and internal resistance 1.0 Ω.



What is the potential difference across the 2.0 Ω resistor?

A 0.40 V

B 0.47 V

C 0.80 V

D 0.93 V

Your answer A **[1]**

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8 A student determines the power P dissipated in a resistor. The measured values of the current I in the resistor and the resistance R of the resistor are:

$$I = (4.0 \pm 0.2)\ \text{A and } R = (3.0 \pm 0.3)\ \Omega$$

The equation $P = I^2R$ is used to calculate P.
What is the percentage uncertainty in the value of P?

A 15%

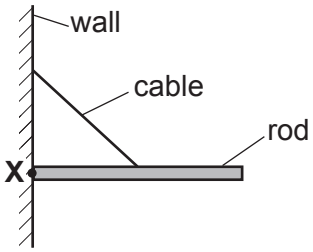
B 20%

C 25%

D 30%

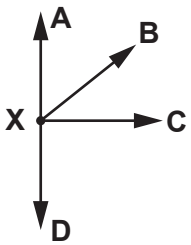
Your answer B **[1]**

9 The diagram shows a uniform rod at rest in a horizontal position.



The rod is hinged at point **X**. A cable is attached to a vertical wall and the midpoint of the rod.

Which arrow best represents the direction of the force on the rod at point **X**?



Your answer C **[1]**

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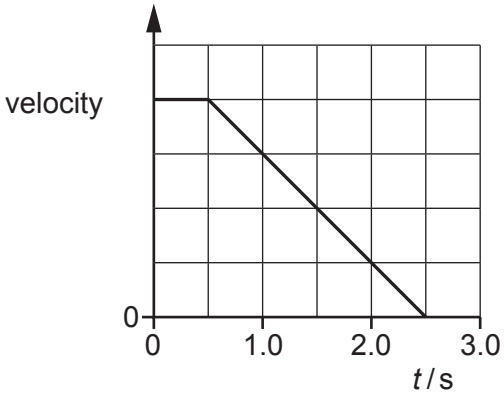
10 A car is driven at constant velocity until the driver sees an obstruction ahead at time $t = 0$. The velocity against time graph below shows the motion of the car as the driver brings it to a stop.



The thinking distance is 10 m.
What is the stopping distance for the car?

A 20 m

B 30 m

C 40 m

D 50 m

Your answer B **[1]**

11 A javelin thrower exerts a force of 100 N on a javelin for a time of 0.30 s.
The javelin has a mass of 0.80 kg.

What is the rate of change of the momentum of the javelin?

A $24\,kg\,m\,s^{-2}$

B $30\,kg\,m\,s^{-2}$

C $100\,kg\,m\,s^{-2}$

D $125\,kg\,m\,s^{-2}$

Your answer C **[1]**

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12 One end of a wire is fixed to the ceiling and a 3.0 kg object is suspended from its other end. The wire has diameter 0.62 mm and negligible mass.

What is the tensile stress in the wire?

A 1.5×10^4 Pa

B 2.5×10^6 Pa

C 2.4×10^7 Pa

D 9.7×10^7 Pa

Your answer D **[1]**

13 The intensity of light incident on a light-dependent resistor (LDR) is increased. Its resistance decreases.
Which statement gives the correct reason for this behaviour?

A The cross-sectional area of the LDR decreases.

B The mean drift velocity of the charge carriers decreases.

C The number density of the charge carriers increases.

D The magnitude of the charge on the charge carriers increases.

Your answer C **[1]**

14 The total energy gained by 20 electrons travelling through a potential difference *V* is 30 keV.
What is the potential difference *V*?

A 1.5 V

B 3.0 V

C 1500 V

D 3000 V

Your answer C **[1]**

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15 A trolley of mass 1.0 kg is moving on a horizontal surface at a constant velocity of $2.0\,m\,s^{-1}$. A force of 3.0 N is applied to the trolley in the opposite direction to its motion for a time of 1.5 s and then the force is removed.

What is the magnitude of the final momentum of the trolley?

A $2.0\,kg\,m\,s^{-1}$

B $2.5\,kg\,m\,s^{-1}$

C $4.5\,kg\,m\,s^{-1}$

D $6.5\,kg\,m\,s^{-1}$

Your answer B **[1]**

16 The current at a point in a circuit is 10 mA.
Expressed to the nearest power of ten, how many electrons pass the point in 10 s?

A 10^{2}

B 10^{15}

C 10^{18}

D 10^{21}

Your answer C **[1]**

17 Electromagnetic radiation is incident on a metal. The radiation has constant wavelength with each photon having an energy of 5.0 eV. The work function of the metal is 3.0 eV.

Which of the following **cannot** be the kinetic energy of an emitted photoelectron?

A 0 eV

B 1.0 eV

C 2.0 eV

D 3.0 eV

Your answer D **[1]**

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18 The waves emitted from two sources are coherent.
Which quantity must be constant for these emitted waves?

A amplitude

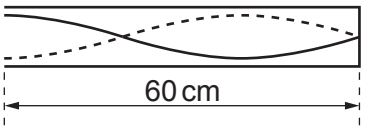
B frequency

C intensity

D phase difference

Your answer D **[1]**

19 The diagram below shows a stationary wave pattern for a sound wave in a tube. The tube has one open end and one closed end.



The length of the tube is 60 cm.
What is the wavelength of the sound?

A 20 cm

B 40 cm

C 60 cm

D 80 cm

Your answer D **[1]**

20 What are the correct base units for work done or energy?

A kg m

B $kg\,m\,s^{-2}$

C $kg\,m^2\,s^{-1}$

D $kg\,m^2\,s^{-2}$

Your answer D **[1]**

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SECTION B

Answer **all** the questions.

21 A trolley is placed on a long ramp and is released from rest from the top of the ramp. It travels to the bottom of the ramp with a constant acceleration.

(a) Describe how a metre rule and a stopwatch can be used to determine the **final** velocity v of the trolley at the bottom of the ramp.

Measure the distance s travelled down the ramp with the metre rule and the time t taken with the stopwatch.

u = 0, so s = ½(u + v)t gives v = 2 × average velocity = 2s/t.

..... **[2]**

(b) A motion sensor is used to determine the velocity of the trolley at points **X** and **Y**, as shown in Fig. 21.

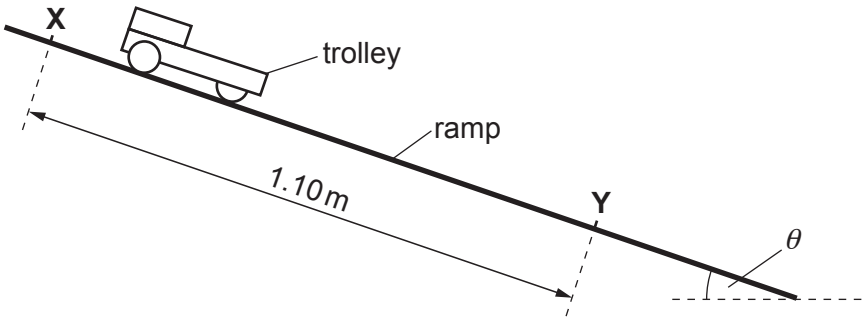

Fig. 21 (not to scale)

The distance between **X** and **Y** is 1.10 m. The trolley has velocity 1.3 m s^{-1} at **X** and velocity 2.5 m s^{-1} at **Y**.

(i) Calculate the acceleration a of the trolley.

$v^2 = u^2 + 2as$

$2.5^2 = 1.3^2 + 2 \times 1.10 \times a$

$6.25 = 1.69 + 2.20a$

$a = 4.56 \div 2.20 = 2.07$ m s^{-2}

a = ...2.1..... m s^{-2} **[2]**

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(ii) The frictional forces acting on the trolley are negligible.
The acceleration of the trolley down the ramp is equal to the component of the acceleration of free fall parallel to the ramp.
Use your answer to **(b)(i)** to calculate the angle θ between the ramp and the horizontal.

$a = g \sin \theta$

$2.07 = 9.81 \times \sin \theta$

$\sin \theta = 2.07 \div 9.81 = 0.211$

$\theta = 12.2°$

θ = ...12..... ° **[2]**

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22 Fig. 22 shows two identical springs supporting an object.

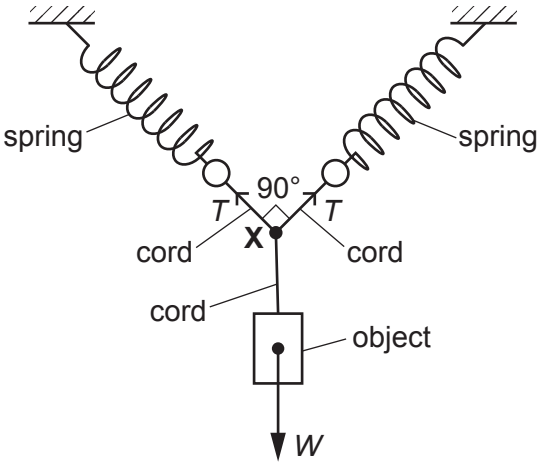


Fig. 22

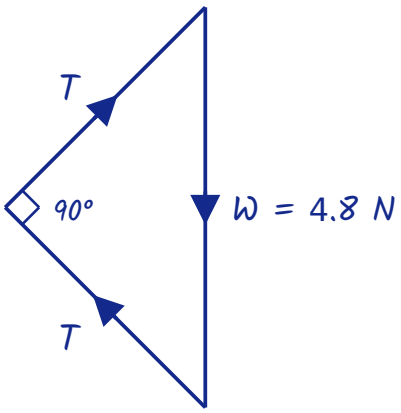
Three short lengths of cord are tied together at point **X**. The other ends of the cords are attached to the ends of the springs and the object as shown in Fig. 22. The angle between the central axes of the springs is 90°.
The tension in each spring is the same and equal to *T*. The weight *W* of the object is 4.8 N.
The point **X** is in equilibrium.

(a) State and explain the magnitude and the direction of the resultant force at **X** due to the two forces exerted by the extended springs.

Magnitude = 4.8 N (equal to W). Direction: vertically upwards, opposite to the weight.

X is in equilibrium, so the resultant force on X is zero; the springs' resultant must balance W. **[2]**

(b) Sketch a **labelled** triangle of forces diagram for the three forces acting at point **X**.
You do not need to draw this diagram to scale.



[2]

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(c) Show that the tension T in each extended spring is 3.4 N.

The triangle is right-angled and isosceles, with W as the hypotenuse:

$T^2 + T^2 = W^2$

$2T^2 = 4.8^2$

$T = 4.8 \div \sqrt{2}$ (or $T = 4.8 \sin 45°$)

$T = 3.39$ N, which is 3.4 N

[2]

(d) The force constant of each spring is 24 N m^{-1}.
Calculate the energy stored in each spring.

$F = kx$, so $x = T/k = 3.4 \div 24 = 0.142$ m

$E = \frac{1}{2}kx^2 = \frac{1}{2} \times 24 \times 0.1417^2$

$E = 0.241$ J

energy = ...0.24..... J **[2]**

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23 This question is about **upthrust** and other forces acting on a sealed hollow tube in water.

One end of a string is attached to the bottom of the tube and the other end of the string is attached to the bottom of the container. The string exerts a downward force *F* on the tube.
At time $t = 0$, the tube is half submerged in the water, as shown in Fig. 23.1.

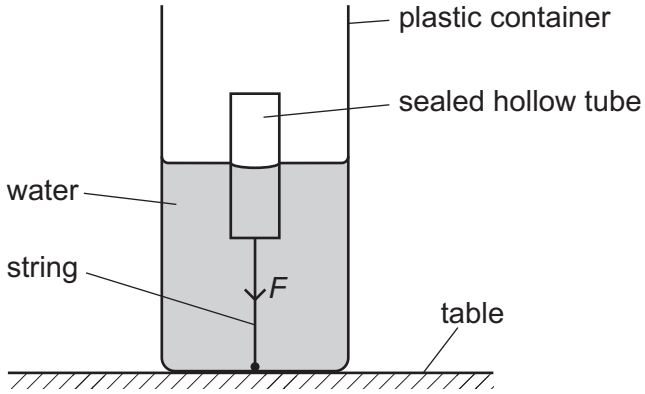

Fig. 23.1

The container is slowly filled with water at a constant rate until the container is full.
Fig. 23.2 shows the graph of *F* against time *t.*

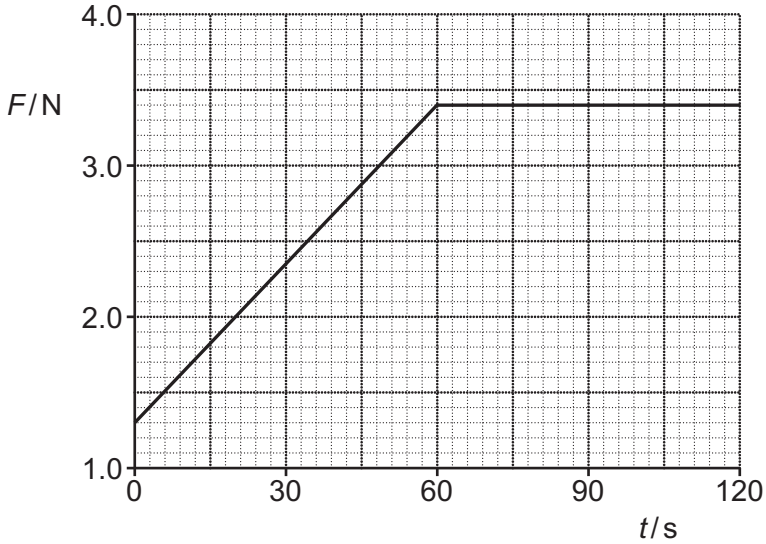

Fig. 23.2

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(a) By considering the forces acting on the tube, explain the general shape of the graph shown in Fig. 23.2.

Forces on the tube: weight (down), tension F (down) and upthrust (up), so F = upthrust − weight.

Up to 60 s the upthrust increases because the weight of water displaced increases as the water level rises. Water is added at a constant rate, so the upthrust and F increase at a constant rate (constant gradient).

After 60 s the tube is fully submerged, so the weight of water displaced and the upthrust are constant, so F is constant. **[3]**

(b) The container is now full of water.
The string is cut and the tube accelerates vertically upwards through the water.
The weight of the tube is 0.80 N and the upthrust on the tube is 4.2 N.

Calculate the **initial** upward acceleration *a* of the tube.

resultant force = upthrust − weight = 4.2 − 0.80 = 3.4 N

m = W/g = 0.80 ÷ 9.81 = 0.0815 kg

a = F/m = 3.4 ÷ 0.0815

a = 41.7 m s^{-2}

a = 42 m s^{-2} **[3]**

(c) State why the acceleration of the tube decreases as it travels vertically upwards through the water.

There is an increasing drag (water resistance) on the tube as its speed increases, so the resultant force decreases. **[1]**

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24 **(a)** A student is investigating an unidentified component found in the laboratory.
The table shows the results from the lab book of the student.

V/V	I/mA
− 5.0	− 5.0
+ 5.0	+ 5.0
+ 10.0	+ 30.0

The potential difference across the component is V and the current through it is I.

(i) Calculate the power dissipated by the component when V is +10.0 V.

$P = VI = 10.0 \times 30.0 \times 10^{-3}$

power = ...0.30..... W **[1]**

(ii) Analyse the data in the table and hence identify the component.

R = V/I: at 5.0 V, R = 5.0 ÷ 0.0050 = 1000 Ω; at 10.0 V, R = 10.0 ÷ 0.030 = 333 Ω. The resistance decreases as V (and I) increases. It conducts equally in both directions (−5.0 V gives −5.0 mA), so it cannot be a diode or LED. The component is an (NTC) thermistor: as the current increases it gets warmer, so the number density of charge carriers increases and its resistance decreases.

..... **[3]**

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(b) Fig. 24 shows a circuit with a battery and two resistors.

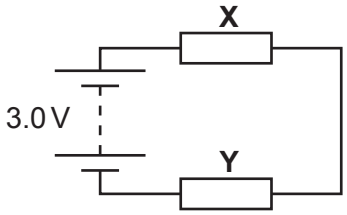

Fig. 24

The resistor **X** has length 8.0×10^{-3} m, cross-sectional area 1.2 mm^2 and is made of a material of resistivity $1.5 \times 10^{-2}\,\Omega$m. The battery has e.m.f. 3.0 V and negligible internal resistance. The resistor **Y** has resistance 68 Ω.

Calculate the current I in the circuit.

$R_X = \rho L/A = (1.5 \times 10^{-2} \times 8.0 \times 10^{-3}) \div 1.2 \times 10^{-6}$

$R_X = 100\ \Omega$

total resistance (series) = 100 + 68 = 168 Ω

$I = V/R = 3.0 \div 168 = 0.0179$ A

I = ...0.018..... A **[3]**

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25 **(a)** An oscilloscope is connected to a microphone. The oscilloscope is used to determine the frequency of sound waves emitted from a loudspeaker.
Describe how the trace on the oscilloscope screen can be used to determine the frequency *f* of the sound waves.

Adjust the time-base so that one or more complete cycles are shown on the screen.

Measure the horizontal distance (number of squares) for one complete cycle (or several cycles and divide) and multiply by the time-base setting (s per division) to find the period T.

Then the frequency f = 1/T.

..... **[2]**

(b) Fig. 25.1 shows two loudspeakers $\mathbf{L_1}$ and $\mathbf{L_2}$ connected to the same signal generator. The loudspeakers emit sound of the same wavelength but with different amplitudes. The points **P** and **Q** are at different distances from the loudspeakers.

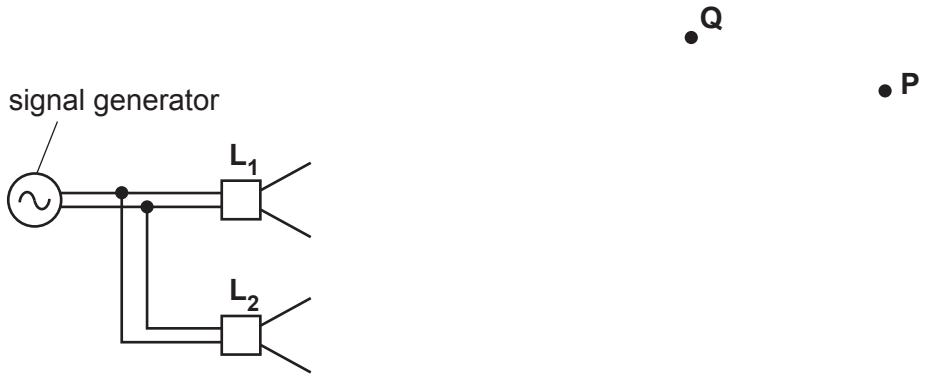

Fig. 25.1

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The sound at point **P** from $\mathbf{L_1}$ alone has displacement x_1. The sound from $\mathbf{L_2}$ alone has displacement x_2. Fig. 25.2 shows the variation of x_1 with time t.

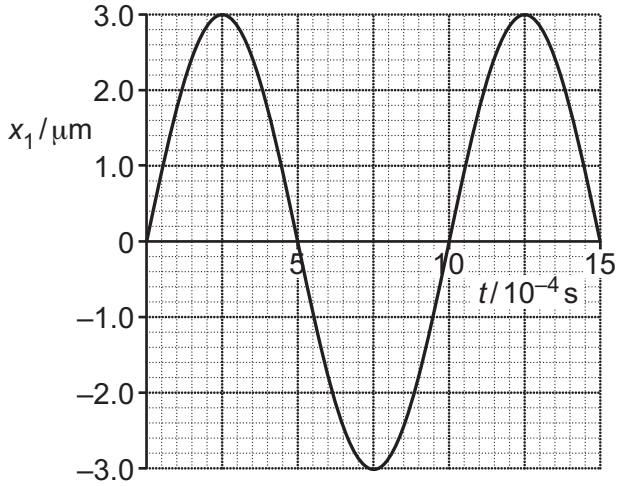

Fig. 25.2

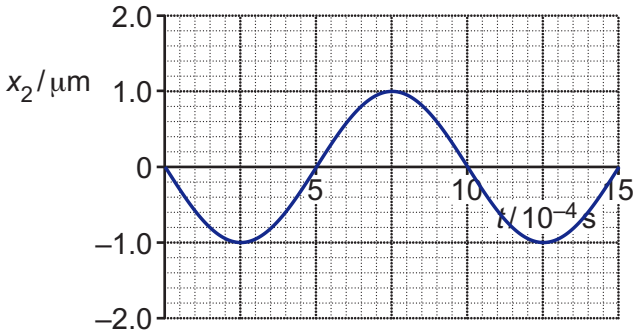

Fig. 25.3

The sound from $\mathbf{L_2}$ alone at point **P** has amplitude 1.0 μm, a phase difference of 180° compared with the sound from $\mathbf{L_1}$ and the same frequency as the sound from $\mathbf{L_1}$.

(i) On Fig. 25.3, draw the variation of x_2 with time t at point **P**. **[1]**

(ii) Explain why the intensity at **P** due to the sound from both $\mathbf{L_1}$ and $\mathbf{L_2}$ is not the same as the intensity of the sound at **P** from only $\mathbf{L_1}$.

The waves are 180° out of phase, so they superpose destructively: the resultant amplitude at P is 3.0 – 1.0 = 2.0 μm, smaller than 3.0 μm. Intensity ∝ amplitude², so the intensity is less: (2.0/3.0)² = 0.44 of the intensity from L_1 alone. **[2]**

(iii) The wavelength of the sound is 34 cm. The distance $\mathbf{L_1Q}$ is 200 cm and the distance $\mathbf{L_2Q}$ is 217 cm.
Explain the type of interference occurring at point **Q**.

Path difference = 217 – 200 = 17 cm = λ/2 (half a wavelength), so the waves arrive in antiphase.
Hence destructive interference occurs at Q (a minimum). **[2]**

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26 **(a)** Fig. 26.1 shows an arrangement used to demonstrate a particular wave phenomenon.

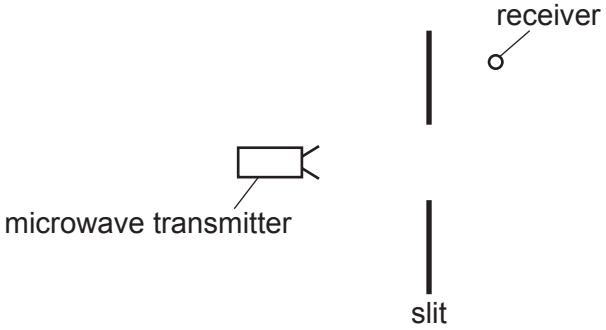

Fig. 26.1

A metal sheet with a wide slit is placed between a microwave transmitter and a receiver. The microwaves have a frequency of 11 GHz.

(i) Calculate the wavelength λ of the microwaves.

$\lambda = c/f = 3.00 \times 10^8 \div 11 \times 10^9$

$\lambda = 0.0273$ m

λ = ...0.027..... m **[1]**

(ii) The receiver detects no microwaves in the position shown in Fig. 26.1.
The metal sheet is replaced by another sheet with a narrow slit of width of a few centimetres, as shown in Fig. 26.2. The positions of the transmitter, receiver and the metal sheet are unchanged.

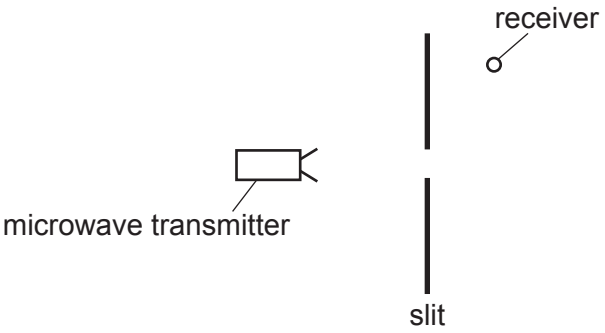

Fig. 26.2

Explain why the receiver now detects microwaves.

Diffraction (spreading out) of the microwaves occurs at the narrow slit, so they reach the receiver.
This is because the wavelength (2.7 cm) is similar to the width of the slit, so the diffraction is significant. **[2]**

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(b) Light travels from air to water. The refractive index of water is greater than the refractive index of air.
Compare the speed, frequency and wavelength of light in air and in water.

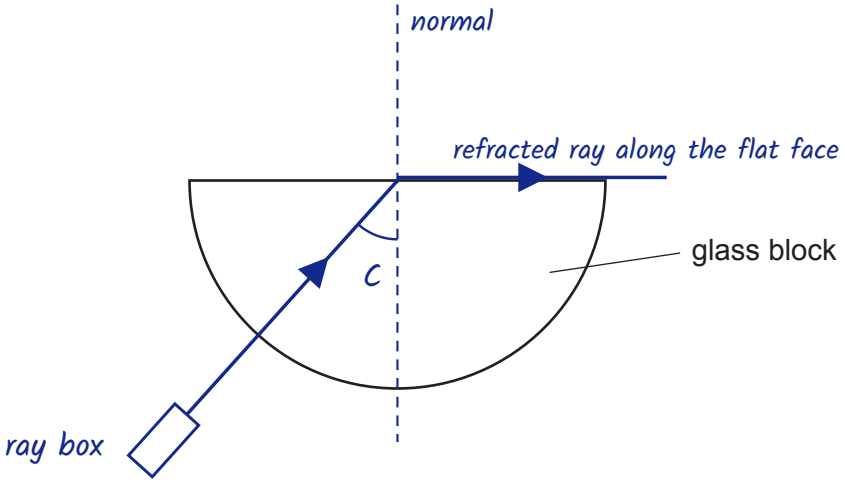
Speed: the speed of light is less in water than in air.

Frequency: the frequency is the same in air and in water.

Wavelength: the wavelength is smaller in water than in air ($v = f\lambda$).

[3]

(c) A student is given a semi-circular glass block.
Describe with the aid of a ray diagram how an experiment can be conducted to accurately determine the critical angle for light within the glass block and hence the refractive index of the glass.



Draw round the block on paper and draw the normal at the centre of the flat face. Using a ray box (or laser), aim a ray through the curved surface at the centre, so it enters along a radius without bending.

Move the ray box until the refracted ray just travels along the flat face (refraction angle 90°). Mark the incident ray, remove the block and measure the angle C between the incident ray and the normal with a protractor.

Repeat (also on the other side of the normal) and average C, in a darkened room.

Refractive index $n = 1/\sin C$. (For $C = 42°$, $n = 1.5$.)

[3]

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27 **(a)** Radio waves and X-rays are both electromagnetic waves.
State one difference between radio waves and X-rays.

X-rays have a much shorter wavelength (higher frequency and photon energy) than radio waves. **[1]**

(b) Procyon is a star of radius 1.4×10^9 m. The total output power of the electromagnetic radiation from its surface is 2.7×10^{27} W. The average wavelength of the electromagnetic waves from Procyon is 5.0×10^{-7} m.

(i) Show that the surface intensity of the radiation from Procyon is 1.1×10^8 W m^{-2}.

surface area $= 4\pi r^2 = 4\pi \times (1.4 \times 10^9)^2 = 2.46 \times 10^{19}$ m^2

intensity $= P/4\pi r^2 = 2.7 \times 10^{27} \div (4\pi \times (1.4 \times 10^9)^2)$

intensity $= 2.7 \times 10^{27} \div 2.46 \times 10^{19}$

intensity $= 1.10 \times 10^8 \approx 1.1 \times 10^8$ W m^{-2}

[2]

(ii) Calculate the energy of a photon of wavelength 5.0×10^{-7} m.

$E = hc/\lambda$

$E = (6.63 \times 10^{-34} \times 3.00 \times 10^8) \div 5.0 \times 10^{-7}$

$E = 3.98 \times 10^{-19}$ J

energy = 4.0×10^{-19} J **[2]**

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(iii) Estimate the total number of photons emitted per second from the surface of Procyon.

number per second = power ÷ energy of one photon

$= 2.7 \times 10^{27} \div 3.98 \times 10^{-19}$

$= 6.8 \times 10^{45}\ s^{-1}$

number per second = 6.8×10^{45} s^{-1} **[1]**

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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