AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ______________________________

Forename(s) ______________________________

Candidate signature ______________________________
I declare this is my own work.

AS
PHYSICS
Paper 1

Time allowed: 1 hour 30 minutes

Materials
For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet
- a protractor.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 70.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
TOTAL	

Do not write outside the box

Answer **all** questions in the spaces provided.

0 1 . 1 Identify the number of neutrons in a nucleus of polonium-210 $\left(^{210}_{84}\text{Po}\right)$.

Tick (✓) **one** box.

[1 mark]

84 ☐

126 ☑

210 ☐

294 ☐

210 − 84 = 126

0 1 . 2 A polonium-210 nucleus is formed when a stationary nucleus of bismuth-210 decays. A beta-minus (β^-) particle is emitted in this decay.

Outline, with reference to β^- decay, why bismuth-210 and polonium-210 have different proton numbers.

[2 marks]

A neutron decays into a proton.

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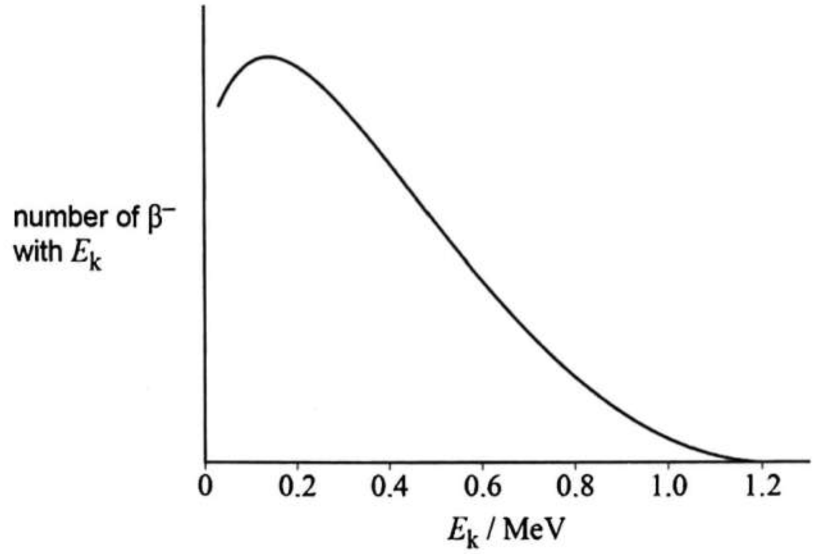
The kinetic energies of β^- particles emitted from a sample of bismuth-210 are analysed. These β^- particles have a range of kinetic energies.

The total energy released when each nucleus of bismuth-210 decays to a nucleus of polonium-210 is 1.2 MeV.

Figure 1 shows the variation with E_k of the number of β^- particles that have the kinetic energy E_k.

Figure 1



0 1 . 3 Explain how the data in **Figure 1** support the hypothesis that a third particle is produced during β^- decay.

[2 marks]

When the β^- has less than 1.2MeV, a third particle must be produced for conservation of energy.

Question 1 continues on the next page

0 1 . 4 This third particle is an electron antineutrino.

Explain why an electron antineutrino, rather than an electron neutrino, is produced during β^- decay.

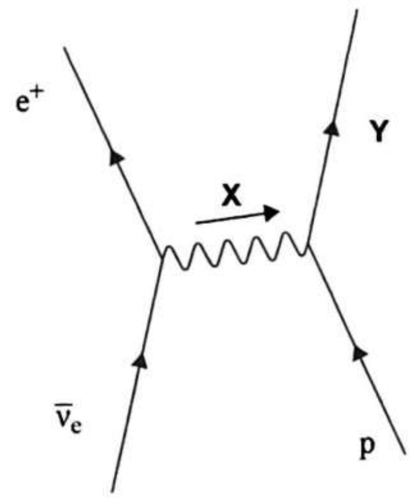
[2 marks]

To conserve lepton number.

0 1 . 5 A large tank of water is used as part of an electron antineutrino detector.
An electron antineutrino $\bar{\nu}_e$ enters the tank and interacts with a proton (p).

Figure 2 represents this interaction.

Figure 2



Identify **X** and **Y**.

[2 marks]

X = W^- (boson)

Y = neutron.

0 1 . 6 The positron produced in the interaction in **Figure 2** slows down and collides with a lepton in a molecule of water.

Describe the process that occurs when the positron collides with this lepton.
In your answer you should identify the lepton in the molecule of water.

[3 marks]

The lepton in the water molecule is an electron. The proton and electron annihilate and 2 gamma photons are produced, travelling in opposite directions.

0 1 . 7 The range of the electromagnetic interaction is infinite.
Table 1 gives the range of the strong nuclear interaction and the range of the weak nuclear interaction.

Table 1

Interaction	Range / m
strong nuclear	10^{-15}
weak nuclear	10^{-18}

Deduce whether the positron or the electron antineutrino is likely to travel the shorter distance in the tank of water before interacting.

[3 marks]

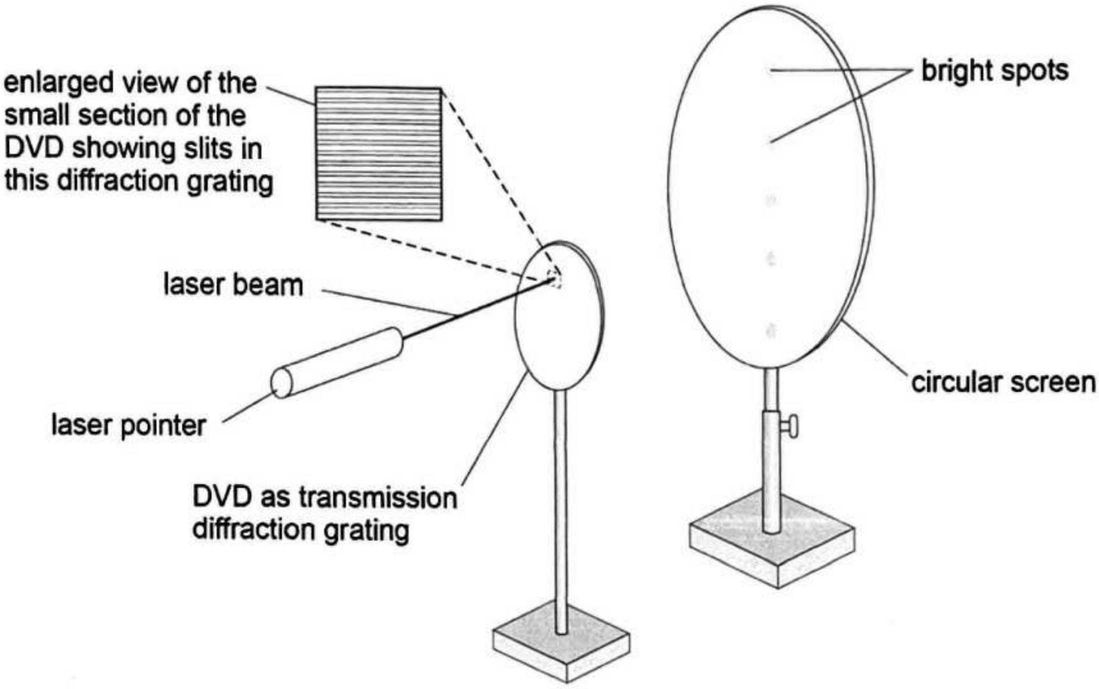
The positron has the shorter range because the positron is charged and the antineutrino is neutral, and so it only interacts via the weak interaction which has a shorter range than the electromagnetic interaction. The positron does not have to be as close to water molecules to interact.

15

0 2 A student removes the reflective layer from a DVD. She uses the DVD as a transmission diffraction grating.

Figure 3 shows light from a laser pointer incident normally on a small section of this diffraction grating. The grooves on this section act as adjacent slits of the transmission diffraction grating.
A vertical pattern of bright spots (maxima) is observed on a circular screen behind the disc.

Figure 3



0 2 . 1 Light of wavelength λ travels from each illuminated slit, producing maxima on the screen.

State the path difference between light from adjacent slits when this light produces a first-order maximum on the screen.

[1 mark]

One wavelength.

0 2 . 2 Explain how light from the diffraction grating forms a maximum on the screen.

[3 marks]

The light from the slits undergoes diffraction. where the light waves arrives at the screen with zero phase difference (where the path difference is equal to a whole number of wavelengths), the light waves superpose

Question 2 continues on the next page

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The student has three discs: a Blu-ray disc, a DVD and a CD. She removes the reflective coating from the discs so that they act as transmission diffraction gratings. These diffraction gratings have different slit spacings.

The student also has two laser pointers **A** and **B** that emit different colours of visible light.

Table 2 and **Table 3** show information about the discs and the laser pointers.

Table 2

Disc	Slit spacing / μm
Blu-ray disc	0.32
DVD	0.74
CD	1.60

Table 3

Laser pointer	Wavelength of light emitted / 10^{-7} m
A	4.45
B	6.36

0 2 . 3 Deduce the combination of disc and laser pointer that will produce the **greatest** possible number of interference maxima.

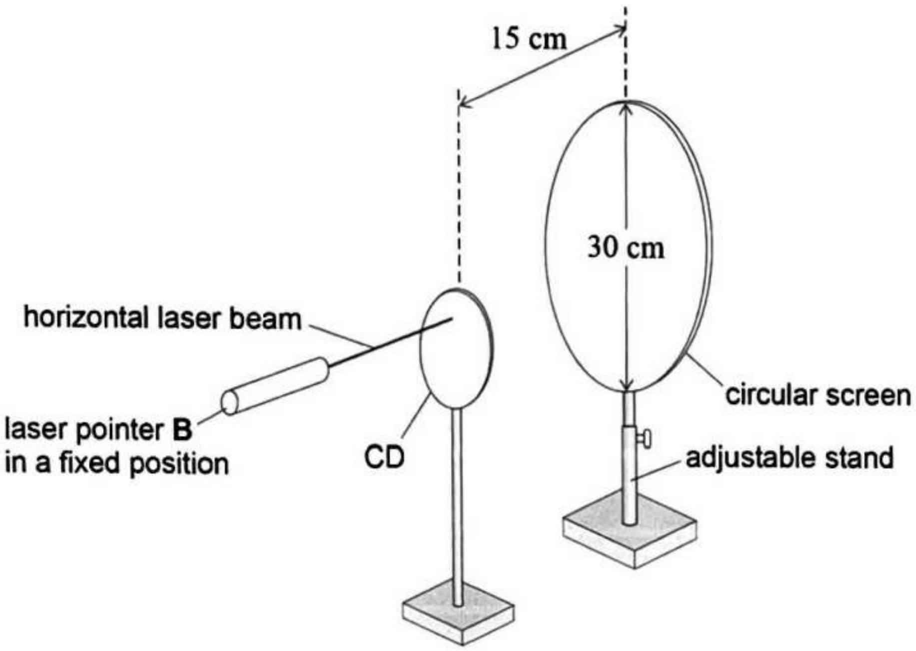
[2 marks]

Pointer A and CD.

The greatest number of maxima is given by $n_{max} = \frac{d}{\lambda}$

0 2 . 4 The student uses the CD and laser pointer **B** as shown in **Figure 4**. A diffraction pattern is produced on the screen. Laser pointer **B** and the CD are in fixed positions. The laser beam is horizontal and incident normally on the CD. The height of the screen can be adjusted.

Figure 4



The screen has a diameter of 30 cm and is positioned behind the CD at a fixed horizontal distance of 15 cm.
The student plans to adjust the height of the screen until she observes the greatest number of spots.

The student predicts that, using this arrangement, the greatest number of spots on the screen will be 3.

Determine whether the student's prediction is correct.

[3 marks]

$n\lambda = d\sin\theta$

$\theta_1 = \sin^{-1}\left(\frac{n\lambda}{d}\right)$

$= \sin^{-1}\left(\frac{1 \times 6.36\times10^{-7}}{1.6\times10^{-6}}\right) = 23^\circ$

$\theta_2 = \sin^{-1}\left(\frac{2\times 6.36\times10^{-7}}{1.6\times10^{-6}}\right) = 53^\circ$

$\theta_1 + \theta_2 = 23^\circ + 53^\circ = 76^\circ$

$\theta_1 + \theta_2 < 90 \Rightarrow$ can see 4 bright spots.

9

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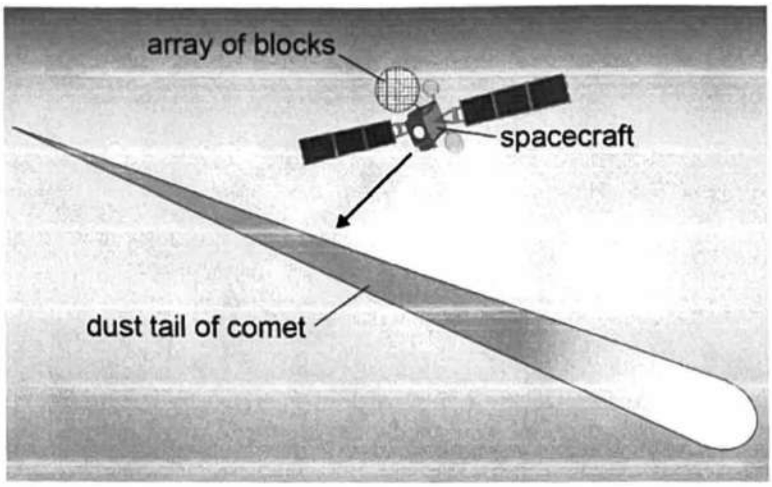
0 3 **Figure 5** shows a spacecraft travelling towards a comet.
The spacecraft has an array of blocks designed to capture small dust particles from the comet's tail.

Figure 5



To test the blocks before launch, a spherical dust particle **P** is fired at a right angle to the surface of a fixed, stationary block.
P has a mass of 1.1×10^{-9} kg. It has a speed of 5.9×10^{3} m s^{-1} when it hits the surface of the block.
P comes to rest inside the block.

0 3 . 1 Calculate the work done in bringing **P** to rest.

[1 mark]

work done = KE lost = $\frac{1}{2}mv^2$

$= \frac{1}{2} \times 1.1\times10^{-9} \times (5.9\times10^{3})^2$

work done = 0.019 J

0 3 . 2 **P** travels a distance of 2.9 cm in a straight line inside the block before coming to rest.
The resultant force on **P** varies as it penetrates the block.

Calculate the average force acting on **P** as it is brought to rest.

[2 marks]

$W = Fs$

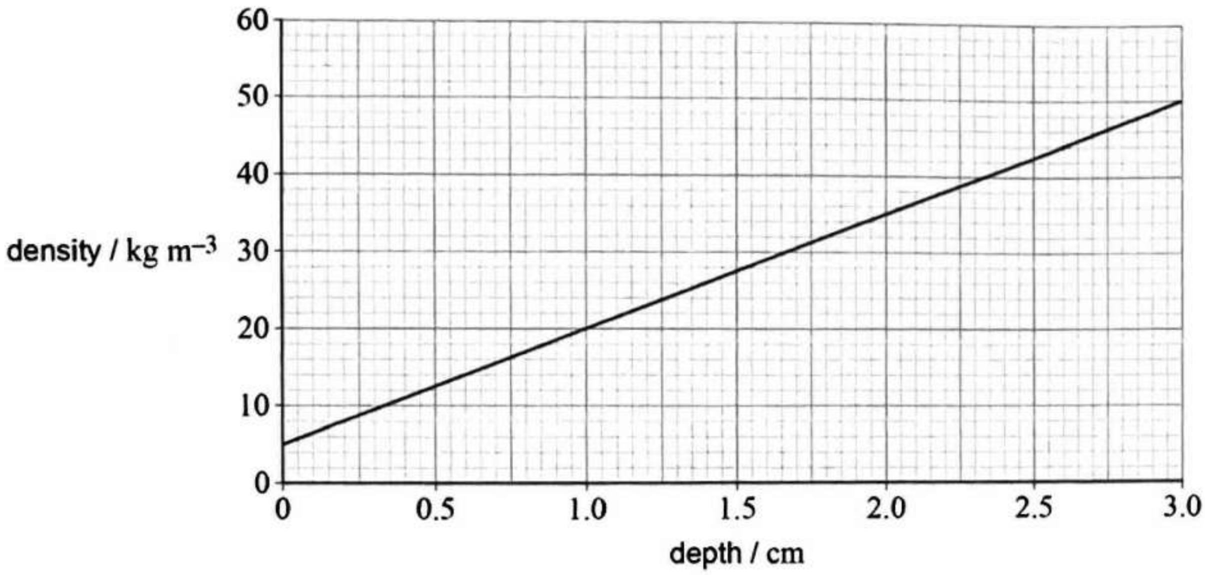
$F = \frac{W}{s} = \frac{0.019}{2.9\times10^{-2}} = 0.66$ N

average force = 0.66 N

0 3 . 3 The block is rectangular with an area of cross-section of 8.0 cm^2 and a thickness of 3.0 cm.

Figure 6 shows how the density of the block varies with depth up to its maximum thickness.

Figure 6



Calculate the mass of the block.

[4 marks]

Average density $= \frac{50+5}{2} = 27.5 \text{ kgm}^{-3}$

volume = thickness x area of cross section

$= 8.0 \times 3.0$

$= 24 \text{ cm}^2 = 24 \times 10^{-4} \text{ m}^2$

density $= \frac{\text{mass}}{\text{volume}}$

mass = density x volume

$= 27.5 \times 24 \times 10^{-4}$

$= 6.6 \times 10^{-4}$ kg.

mass = 6.6×10^{-4} kg

Question 3 continues on the next page

Turn over ▶

0 3 . 4 In another test, a spherical particle **Q** is fired at a right angle to the surface of an identical block.

Q has the same mass as **P** and is travelling at the same speed as **P** when it strikes the surface of the block.
Q is made from a less dense material than **P**.

Compare the distance travelled by **Q** with that travelled by **P** as they are brought to rest.

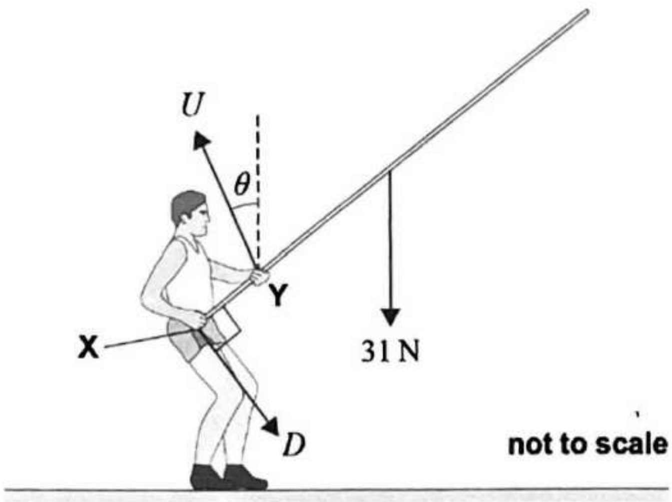
[3 marks]

Q has a larger volume than P and so will displace more matter per unit distance. Hence, Q will experience a greater desceleration and so will travel a shorter distance.

10

0 4 **Figure 7** shows an athlete holding a vaulting pole at an angle of 40° to the horizontal.

Figure 7

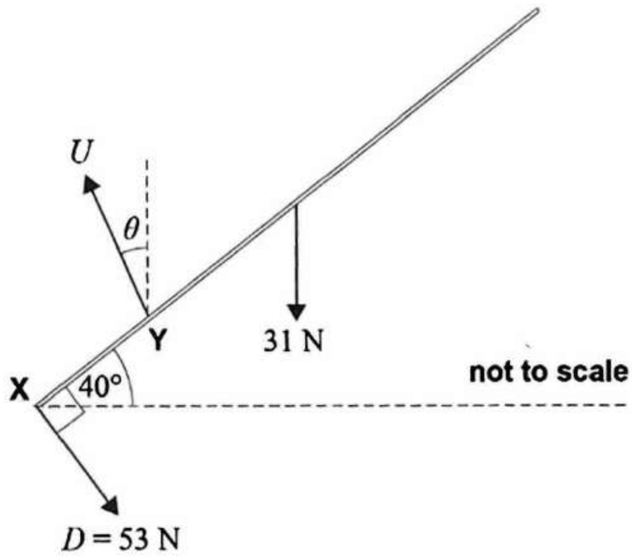


Forces D and U are exerted on the pole by the athlete's right and left hands respectively.
U is applied at point **Y** at an angle θ to the vertical.
The magnitude of D is 53 N and is applied at 90° to the pole at **X**.

The uniform pole is in equilibrium. It has a weight of 31 N.

Figure 8 shows the forces acting on the pole.

Figure 8



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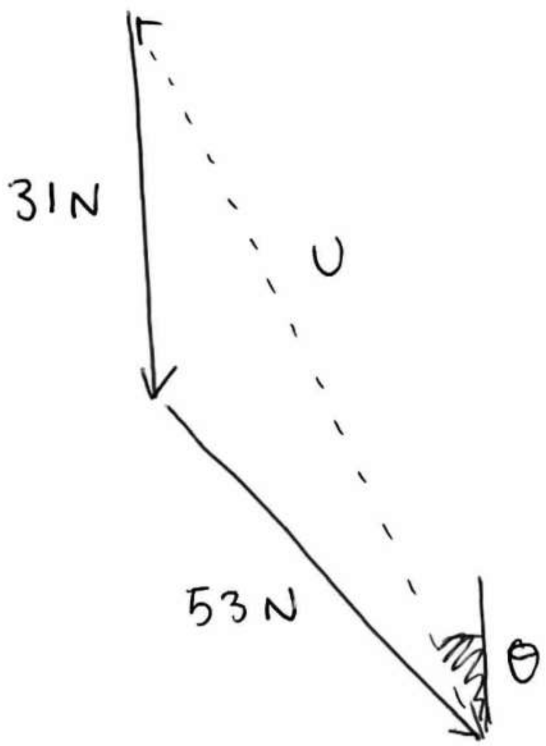
0 4 . 1 Determine, using a scale diagram, θ and the magnitude of U.

[4 marks]



$\theta = 24°$

$U = 78N$

Scale: 10N = 1cm.

$\theta =$ __________ °

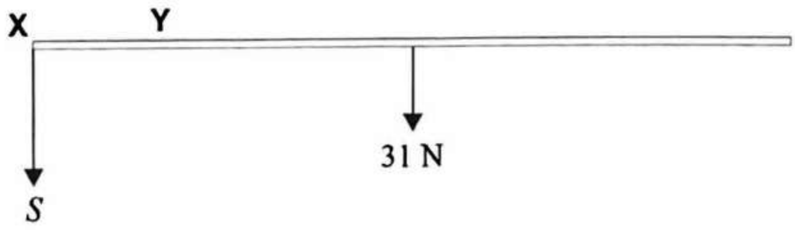
magnitude of $U =$ __________ N

Question 4 continues on the next page

0 4 . 2 The athlete now moves the pole to a horizontal position. The pole is held stationary in this position.
The athlete's right hand applies a force S vertically downwards at **X** as shown in **Figure 9**. The athlete's left hand applies a force V at **Y**.

Figure 9

not to scale



Discuss the differences between the magnitudes and directions of force U in **Figure 7** and force V applied at **Y** in **Figure 9**.

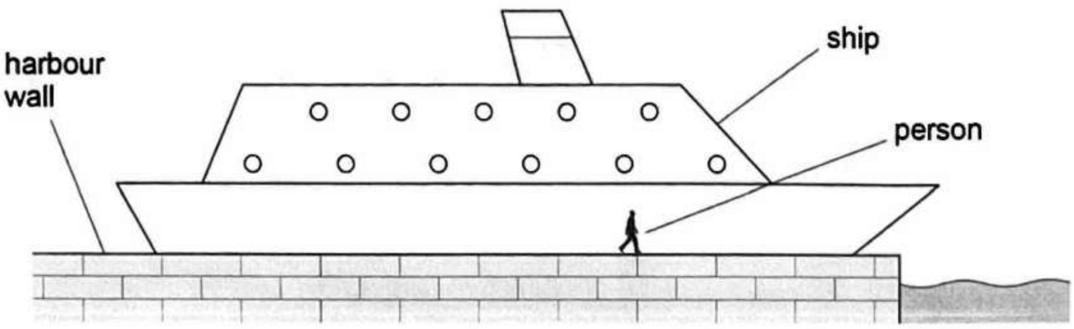
[3 marks]

V is vertical ~~and has a greater magnitude~~ because S and weight are both vertical. V has a greater magnitude because there is a greater moment of weight about Y in figure 9.

7

0 5 . 1 **Figure 10** shows a ship leaving a harbour at a constant velocity.
The ship moves at the same velocity as a person walking on the harbour wall alongside the ship.

Figure 10



The momentum of the ship is approximately 1×10^7 N s.

Estimate the mass of the ship.

[2 marks]

walking speed $\simeq 2 ms^{-1}$

$p = mv$

$m = \frac{p}{v} = \frac{1 \times 10^7}{2} = 5 \times 10^6$ kg

mass of ship = 5×10^6 kg

Question 5 continues on the next page

Turn over ▶

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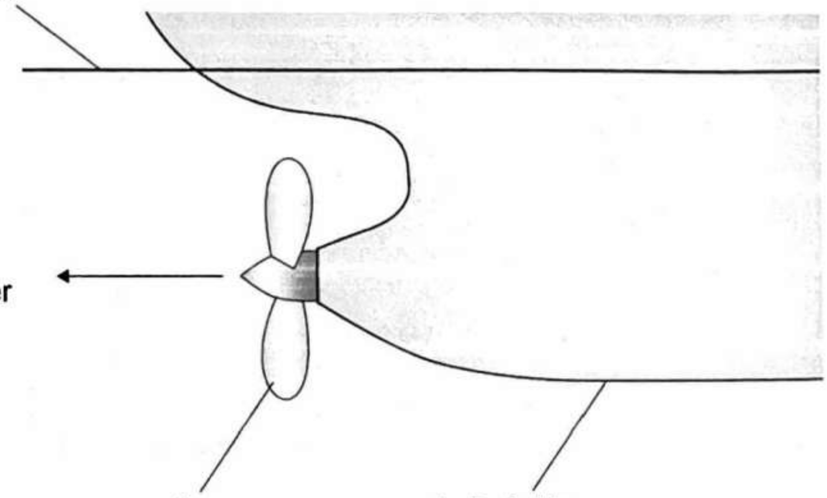
0 5 . 2 **Figure 11** shows the direction of the thrust exerted by the ship's propeller as the propeller rotates. The ship's engine makes the propeller rotate. When more water is accelerated, more work is done by the engine.

Figure 11



Explain, using Newton's laws of motion, how the thrust of the propeller on the water enables the ship to maintain a constant momentum.

[4 marks]

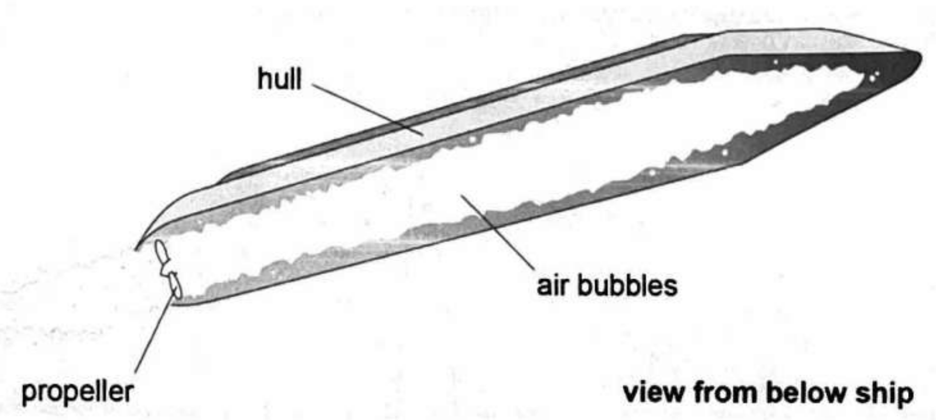
The propeller exerts a force on the water and because of Newton's 3rd law, the water exerts ~~a~~ an equal and opposite force on the propeller. Because the ship travels at constant velocity, resultant force = 0 (Newton's ~~2~~ 1st law). So the force on the ship from the water is equal to the drag force on the ship. A force is required to change the momentum of the water because. F=ma (Newton's 2nd law)

Do not write outside the box

0 5 . 3 **Figure 12** shows the bottom of the hull with a drag reduction system in operation. Air bubbles are introduced into the water below the hull. This reduces the work done per second against the drag on the hull at any given speed.

However, when the air bubbles reach the propeller they decrease the mass of water being accelerated by the propeller every second. This decreases the thrust produced by the propeller at a given speed of rotation.

Figure 12



The system enables the ship to save fuel while maintaining the same momentum.

Explain why the system delivers this fuel saving.
In your answer, consider the effects of the introduction of the system on

- the thrust
- the drag on the hull.

[3 marks]

when the system is enabled, the decrease in work done against drag is greater than the decrease in work done by the propeller. To maintain a constant momentum, the drag force must equal the thrust, and so the propeller can now operate at a lower ~~operational~~ rotational speed so that the thrust equals the drag, hence, less fuel is required.

9

Turn over ▶

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0 6 A battery has an emf of 5.30 V and negligible internal resistance.

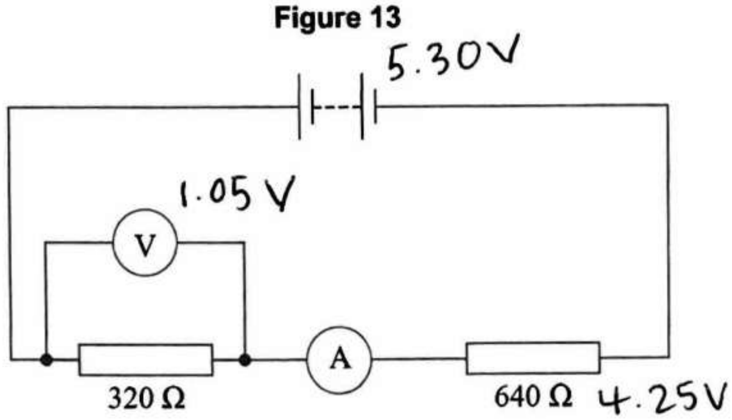
0 6 . 1 State what is meant by an emf of 5.30 V for this battery.

[2 marks]

5.30 J of energy is transferred from chemical energy to electrical energy for every coulomb of charge.

0 6 . 2 **Figure 13** shows the battery connected into a circuit.

Figure 13



The ammeter is ideal.
The voltmeter is non-ideal and has a resistance R.
The reading on the voltmeter is 1.05 V when it is connected across the 320 Ω resistor.

Show that the reading on the ammeter is approximately 7 mA.

[2 marks]

$5.30 - 1.05 = 4.25V$

$V = IR$

$I = \frac{V}{R} = \frac{4.25}{640} = 6.6 \times 10^{-3}$

$\simeq 7mA$.

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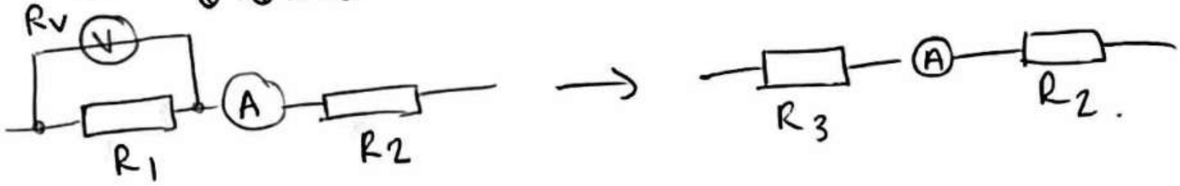
0 6 . 3 Show that the resistance R of the voltmeter is approximately 300 Ω.

[3 marks]

$R_T = \frac{V}{I} = \frac{5.30}{6.6 \times 10^{-3}} = 803\,\Omega$



$R_3 = R_T - R_2 = 803 - 640 = 163\,\Omega$

$\frac{1}{R_V} = \frac{1}{R_3} - \frac{1}{R_1} = \frac{1}{163} - \frac{1}{320} = 3 \times 10^{-3}$

$R_V = \frac{1}{3 \times 10^{-3}} = 332\,\Omega$

0 6 . 4 The voltmeter is now connected across the battery terminals.

Calculate the power dissipated in the voltmeter.

[2 marks]

$P = \frac{V^2}{R} = \frac{5.30^2}{332} = 0.085\,W$

power = 0.085 W

Question 6 continues on the next page

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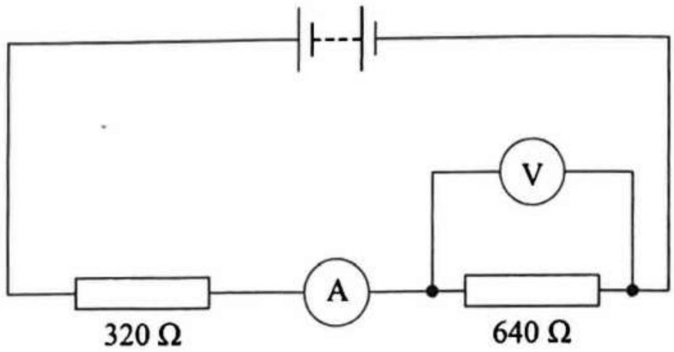
0 6 . 5 The voltmeter is now connected across the 640 Ω resistor as shown in **Figure 14**.

Figure 14



The reading on the voltmeter is 2.10 V.

When the voltmeter was connected across the 320 Ω resistor, as shown in **Figure 13**, the reading on the voltmeter was 1.05 V.

Explain why the sum of these voltmeter readings does **not** equal the emf of the battery.

[2 marks]

The current in the circuit changes as the position of the voltmeter changes because the resistance in the circuit changes.

11

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0 7 Optical fibres are used to carry pulses of light.

0 7 . 1 Explain what is meant by modal dispersion in an optical fibre.

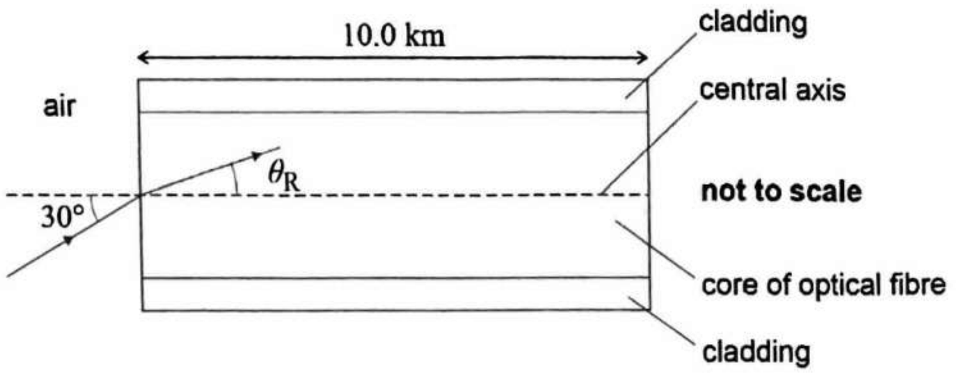
[2 marks]

Parts of a pulse take different amounts of time to travel through the fibre due to different paths through the fibre.

Question 7 continues on the next page

Figure 15 shows a ray of light incident on the central axis of an optical fibre at an angle of incidence of 30°. The optical fibre is straight and horizontal and has a length of 10.0 km.

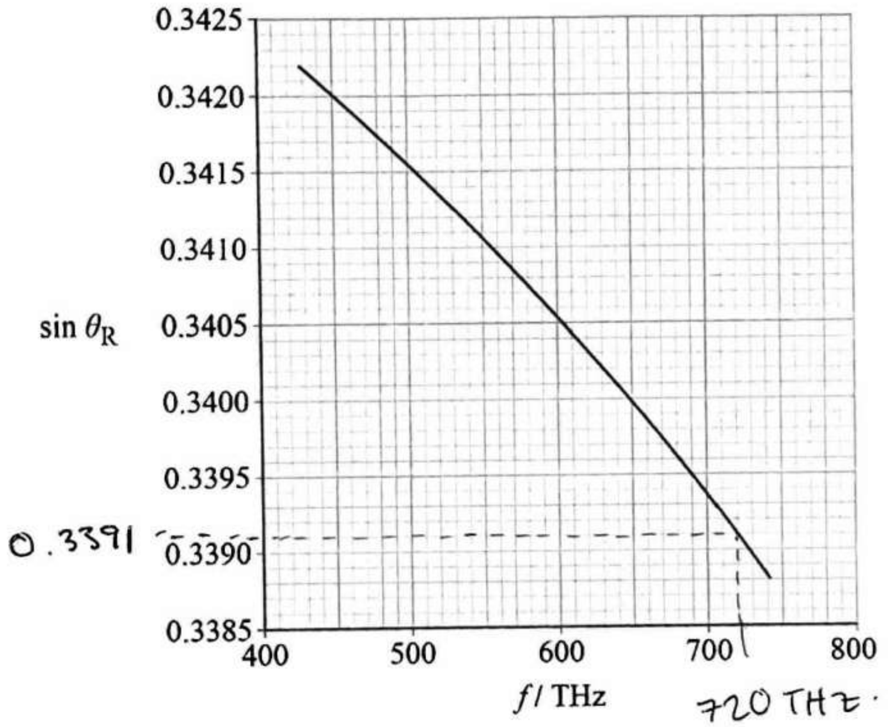
Figure 15



For light incident on the core at a given angle of incidence, the angle of refraction θ_R varies with the frequency f of the light.

Figure 16 shows how sin θ_R varies with f when the angle of incidence is 30°.

Figure 16



The transit time is the time between a pulse of light entering and leaving the optical fibre.
A single pulse of blue light is incident on the air–core boundary at an angle of incidence of 30°.

The transit time of this pulse along the 10 km length of the optical fibre is 5.225×10^{-5} s.

0 7 . 2 Show that the horizontal component of the velocity of the pulse is approximately 1.9×10^8 m s^{-1}.

[1 mark]

$$\text{Speed} = \frac{\text{distance}}{\text{time}} = \frac{10 \times 10^3}{5.225 \times 10^{-5}} = 1.91 \times 10^8 \text{ ms}^{-1}$$

0 7 . 3 The frequency of the blue light in the pulse is 720 THz.

Calculate the speed of the blue light in the core of the optical fibre.

[3 marks]

$\sin\theta_R = 0.3391$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$1 \times \sin 30 = n_2 \times 0.3391$

$n_2 = \frac{\sin 30}{0.3391} = 1.47$

$C_s = \frac{c}{n} = \frac{3.00 \times 10^8}{1.47} = 2.03 \times 10^8 \text{ ms}^{-1}$

speed = 2.03×10^8 m s^{-1}

Question 7 continues on the next page

Turn over ▶

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0 7 . 4 Two pulses of monochromatic light are incident normally on the air–core boundary. They then travel along the central axis of the core.
One pulse consists of blue light; the other consists of red light.

Explain, with reference to refractive index, why the pulse of red light has a shorter transit time than the pulse of blue light.

[2 marks]

The refractive index of core for blue light is greater than the refractive index for red. The speed of blue light is less than the speed of red light and they travel the same distance so red light takes less time.

0 7 . 5 Another two pulses, identical to the pulses in Question **07.4**, are incident on the central axis of the optical fibre and travel along its length.
However, the pulse of red light and pulse of blue light are now incident on the air–core boundary at an angle of incidence of 30°.

Suggest **one** reason why the difference in their transit times may **not** be the same as in Question **07.4**.

[1 mark]

The blue light now travels a shorter distances than the red light.
The difference between the blue's velocity parallel to the central axis and the red's velocity parallel to the central axis has decreased.

9

END OF QUESTIONS