A

Surname ______________________________

Other Names ______________________________

Centre Number ______________________________

Candidate Number ______________________________

Candidate Signature ______________________________

I declare this is my own work.

AS

PHYSICS

Paper 1

7407/1

Time allowed: 1 hour 30 minutes

At the top of the page, write your surname and other names, your centre number, your candidate number and add your signature.

[Turn over]

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.**
- **Answer ALL questions.**
- **You must answer the questions in the spaces provided. Do not write 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.

DO NOT TURN OVER UNTIL TOLD TO DO SO

Answer ALL questions in the spaces provided.

0 1 . 1

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

Tick (✓) ONE box. [1 mark]

- [ ] 84
- [ ] 126
- [ ] 210
- [ ] 294

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]

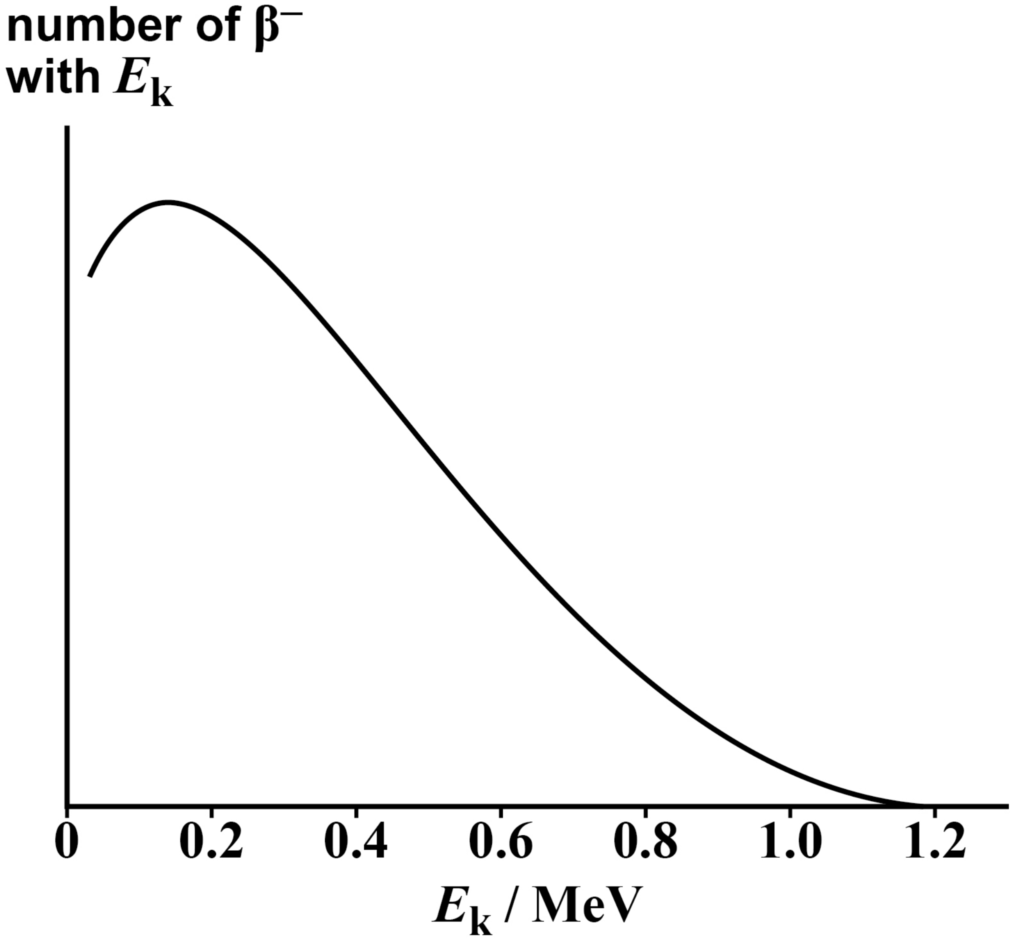
[Turn over]

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]

[Turn over]

BLANK PAGE

01.4

This third particle is an electron antineutrino.

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

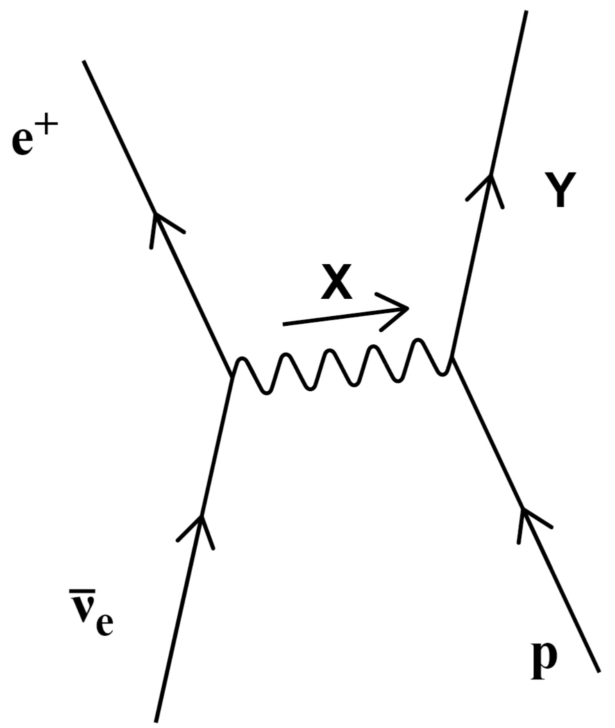
[Turn over]

0 1 . 5

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

FIGURE 2 represents this interaction.

FIGURE 2



Identify X and Y. [2 marks]

X = ____

Y = ____

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]

[Turn over]

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]

[Turn over]

15

0 2

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

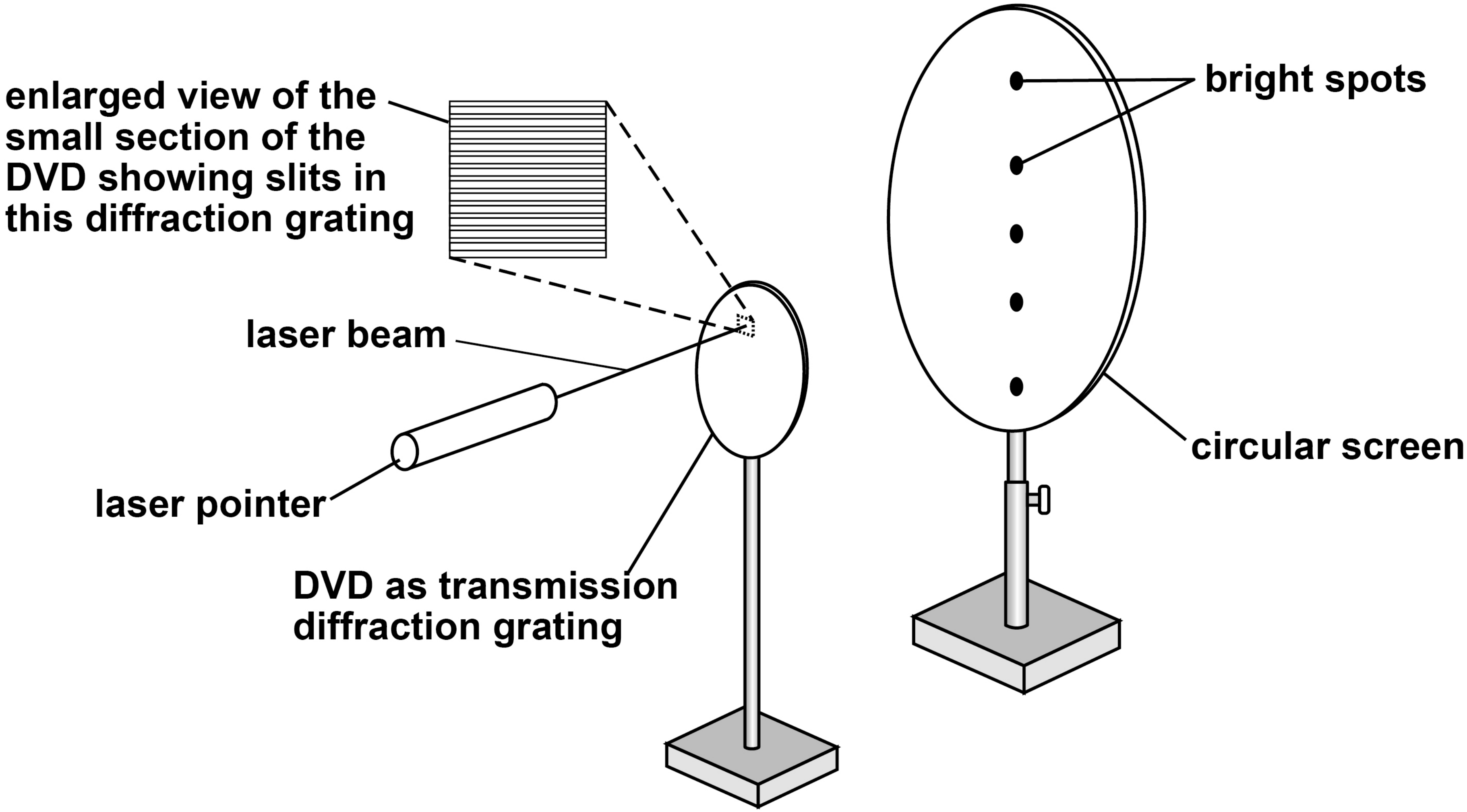
FIGURE 3, on the opposite page, shows light from a laser pointer incident normally on a small section of this diffraction grating. The grooves on this section act as adjacent slits of the transmission diffraction grating.
A vertical pattern of bright spots (maxima) is observed on a circular screen behind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

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]

FIGURE 3


enlarged view of the small section of the DVD showing slits in this diffraction grating
laser beam
laser pointer
DVD as transmission diffraction grating
bright spots
circular screen

BLANK PAGE

0 2 . 2

Explain how light from the diffraction grating forms a maximum on the screen.
[3 marks]

[Turn over]

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]

[Turn over]

0 2 . 4

The student uses the CD and laser pointer B as shown in FIGURE 4, on page 22. 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.

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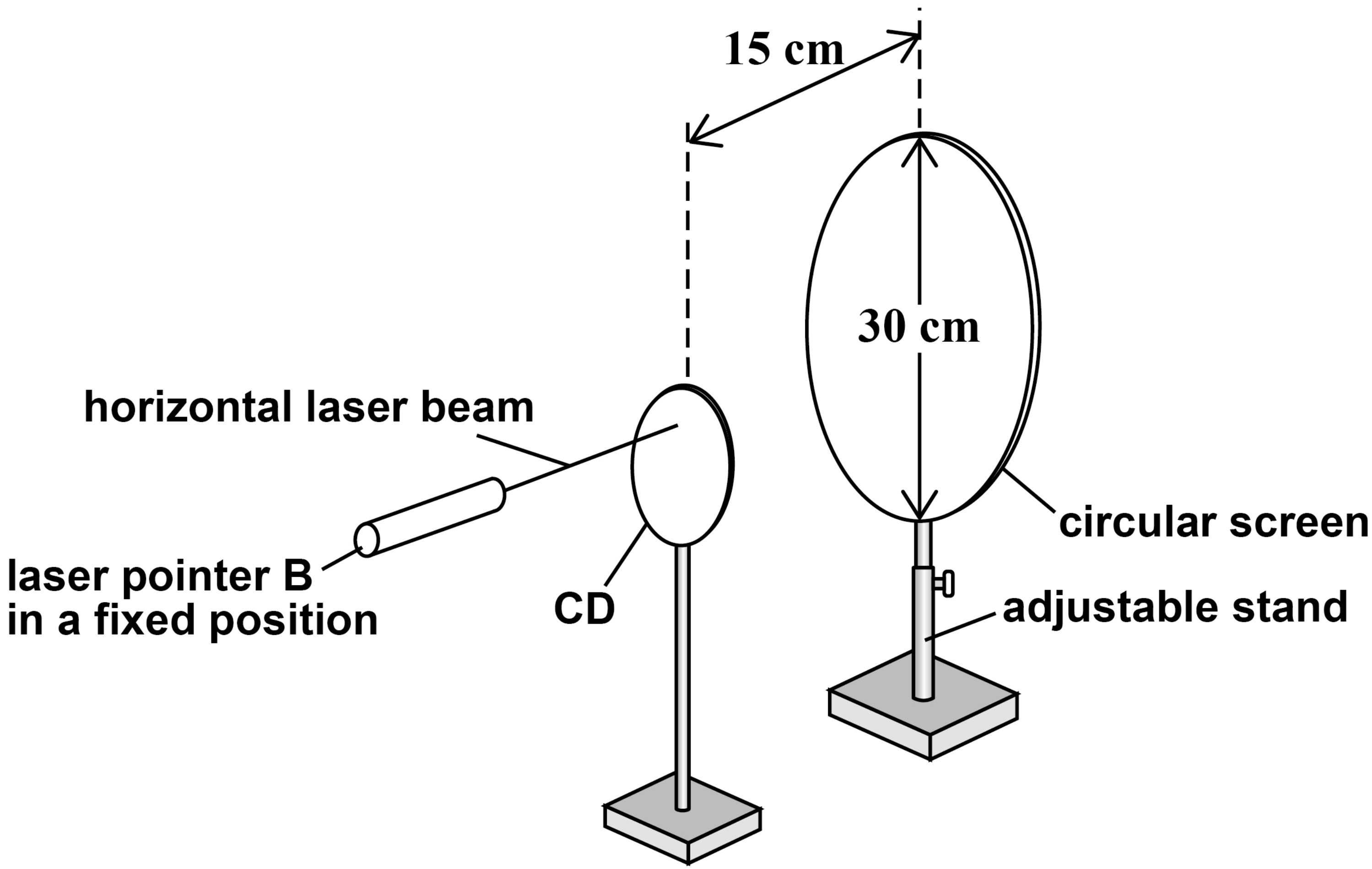
[Turn over]

FIGURE 4


15 cm
30 cm
horizontal laser beam
laser pointer B
in a fixed position
CD
circular screen
adjustable stand

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

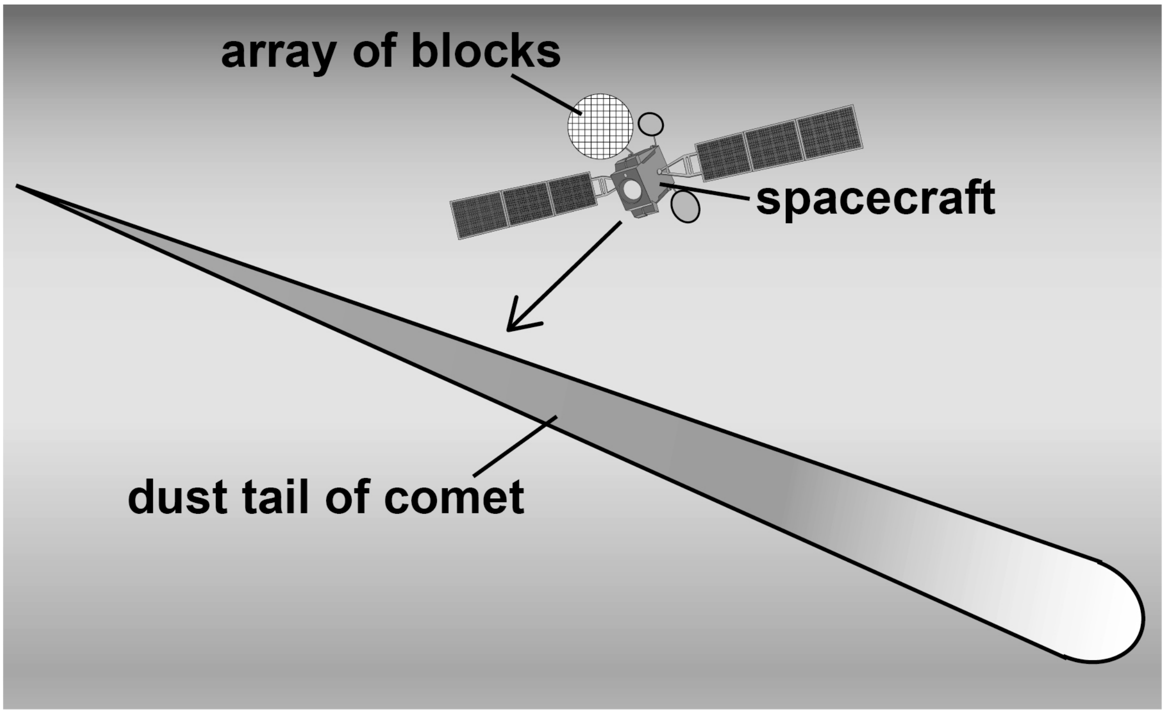
The student predicts that, using this arrangement, the greatest number of spots on the screen will be 3.

Determine whether the student's prediction is correct. [3 marks]

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 = ________________________________ 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]

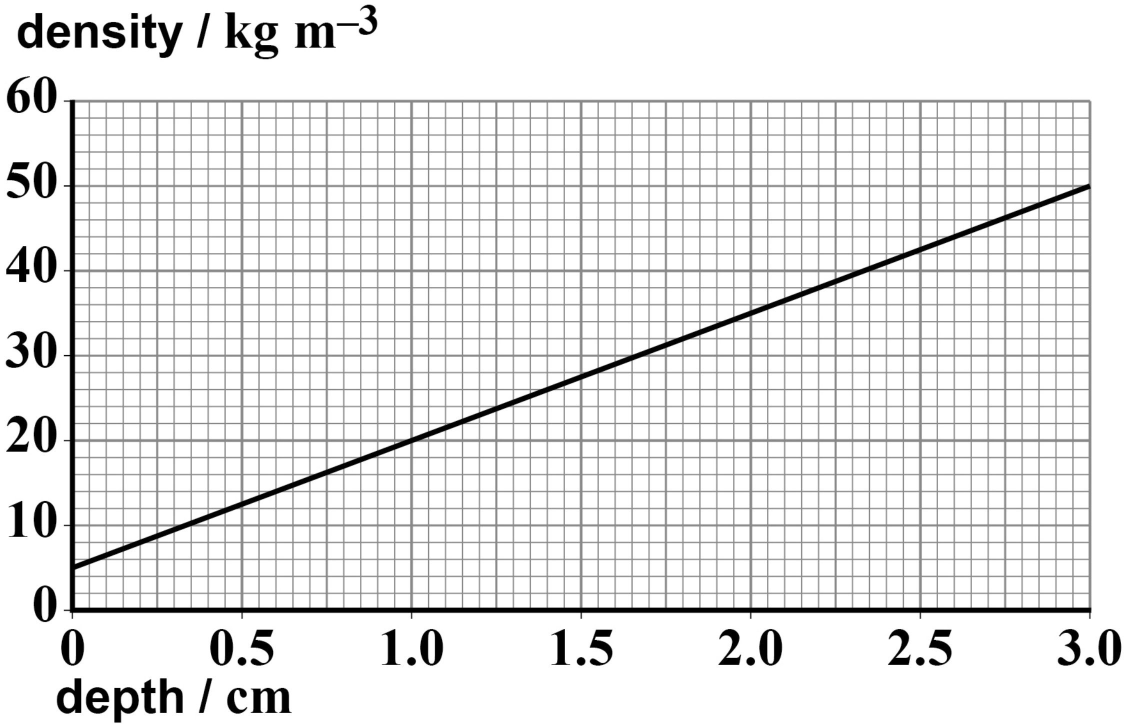
average force = ________________________________ N

0 3 . 3

The block is rectangular with an area of cross-section of $8.0\ \text{cm}^2$ and a thickness of $3.0\ \text{cm}$.

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]

mass = ______________________________ kg

[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]

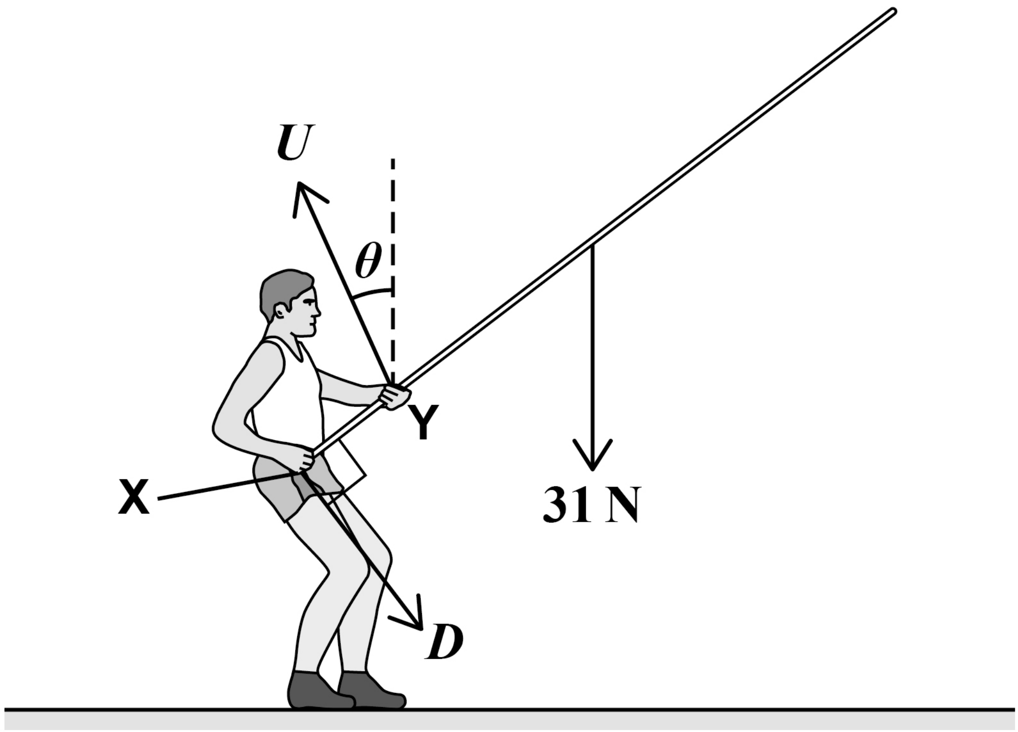
10

0 4

FIGURE 7 shows an athlete holding a vaulting pole at an angle of $40°$ to the horizontal.

FIGURE 7

The diagram is NOT drawn to scale.



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.

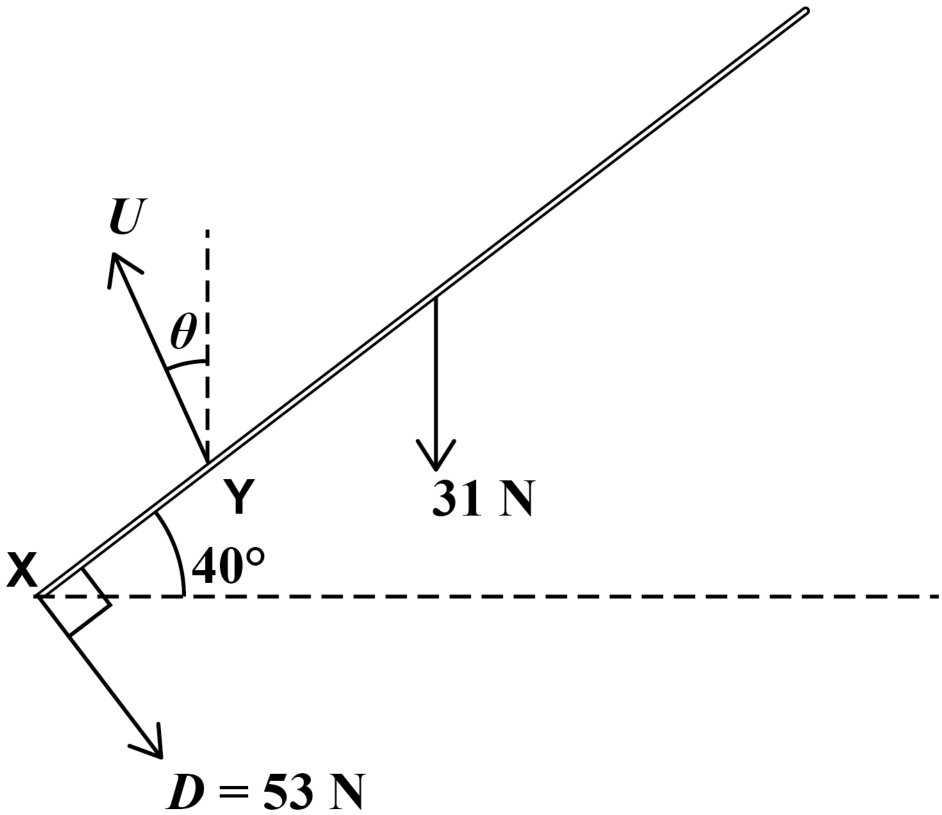
The uniform pole is in equilibrium. It has a weight of 31 N.

[Turn over]

FIGURE 8 shows the forces acting on the pole.

FIGURE 8

The diagram is NOT drawn to scale.



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[Turn over]

0 4 . 1

Determine, using a scale diagram, θ and the magnitude of U. [4 marks]

θ = ______________________________ °

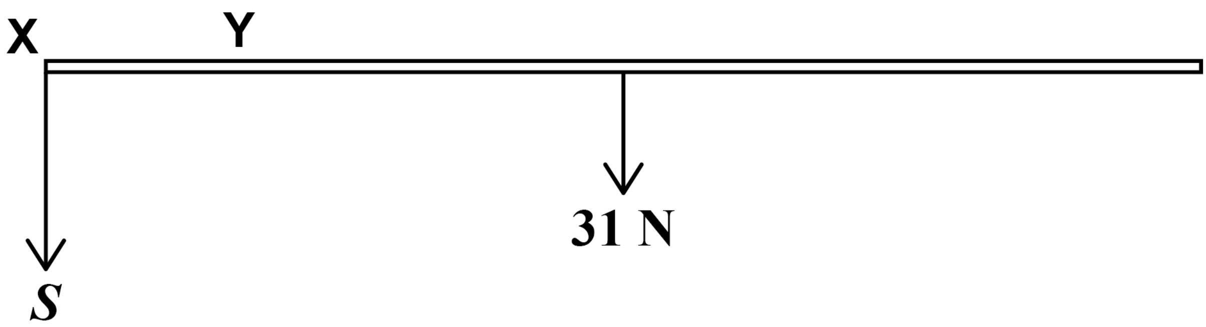
magnitude of U = ______________________________ N

04.2

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

The diagram is NOT drawn to scale.



Discuss the differences between the magnitudes and directions of force U in FIGURE 7, on page 29, and force V applied at Y in FIGURE 9. [3 marks]

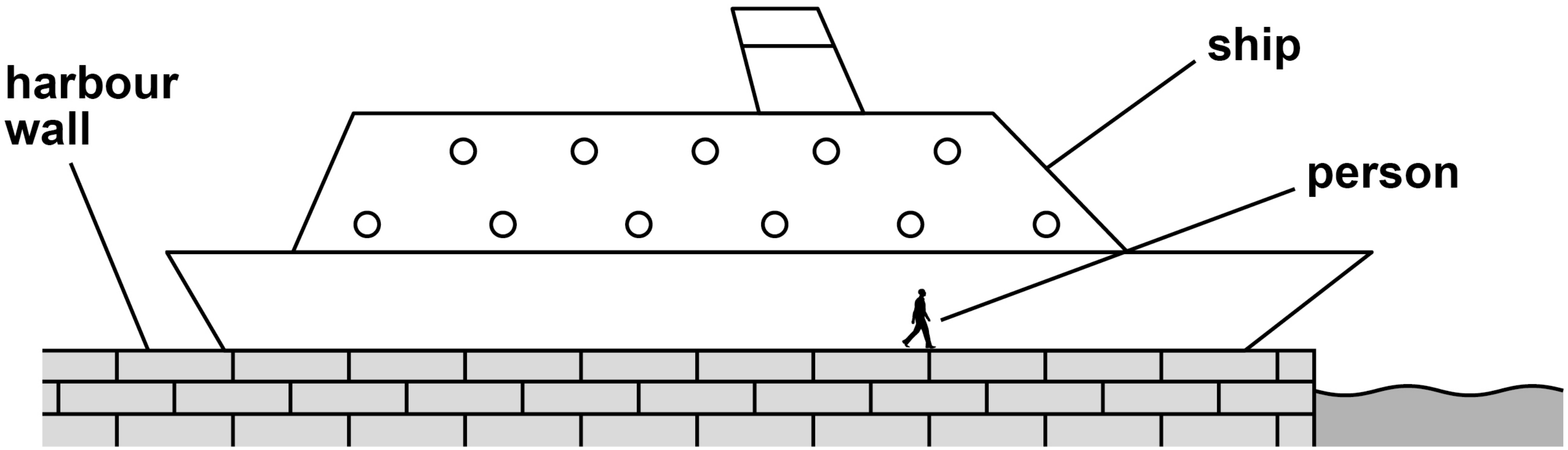
[Turn over]

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]

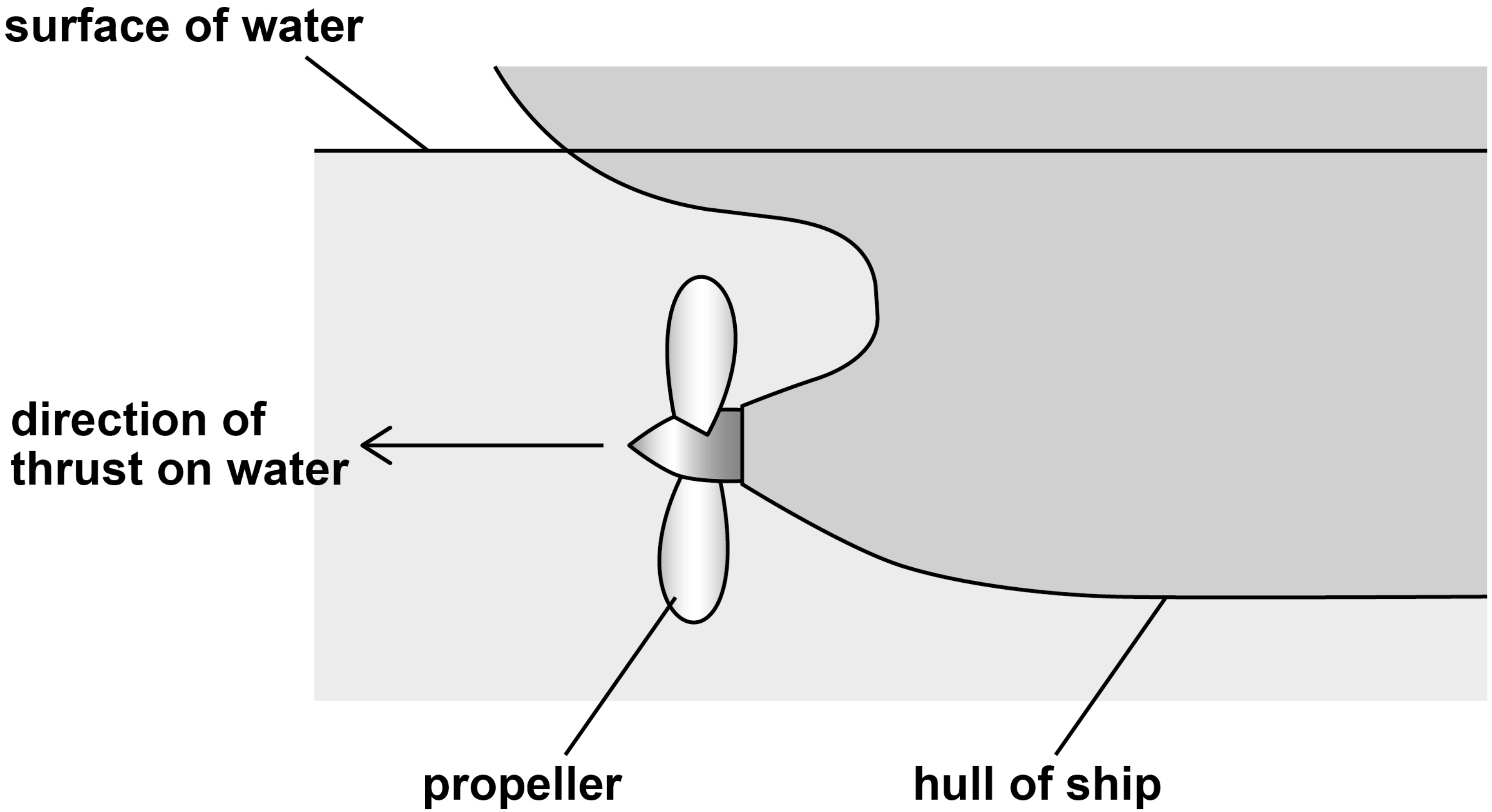
mass of ship = ______________________________ kg

[Turn over]

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]

[Turn over]

BLANK PAGE

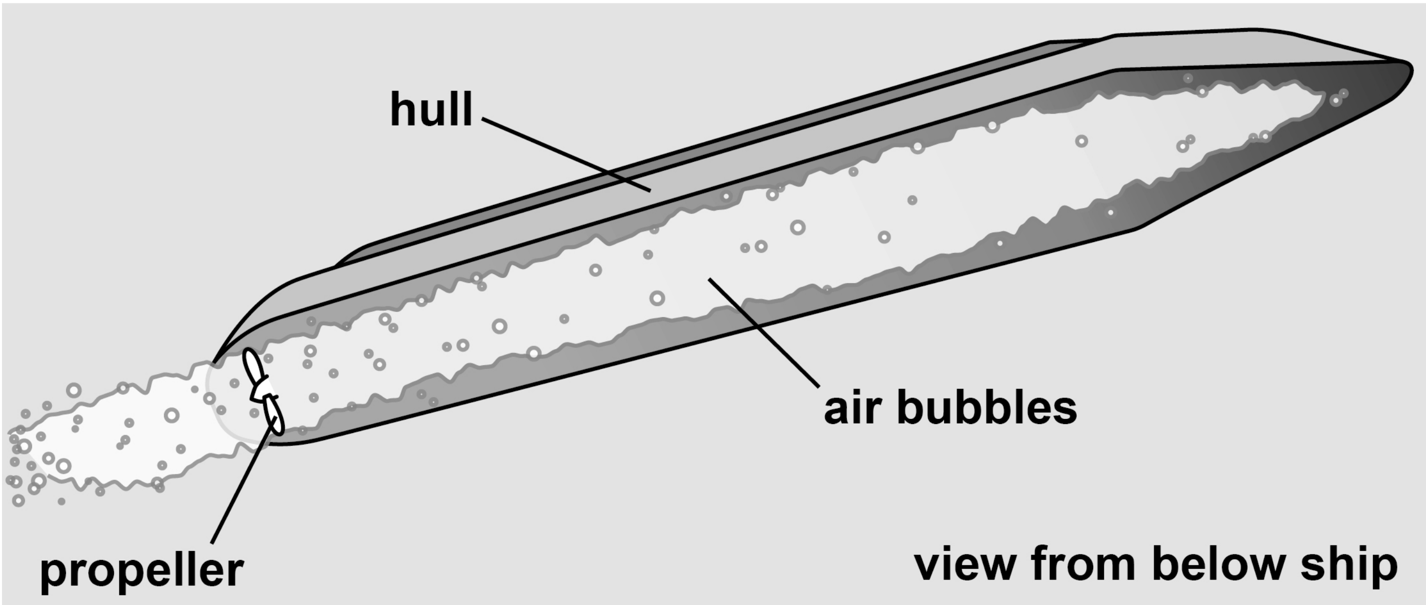
[Turn over]

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]

[Turn over]

6

0 6

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

0 6 . 1

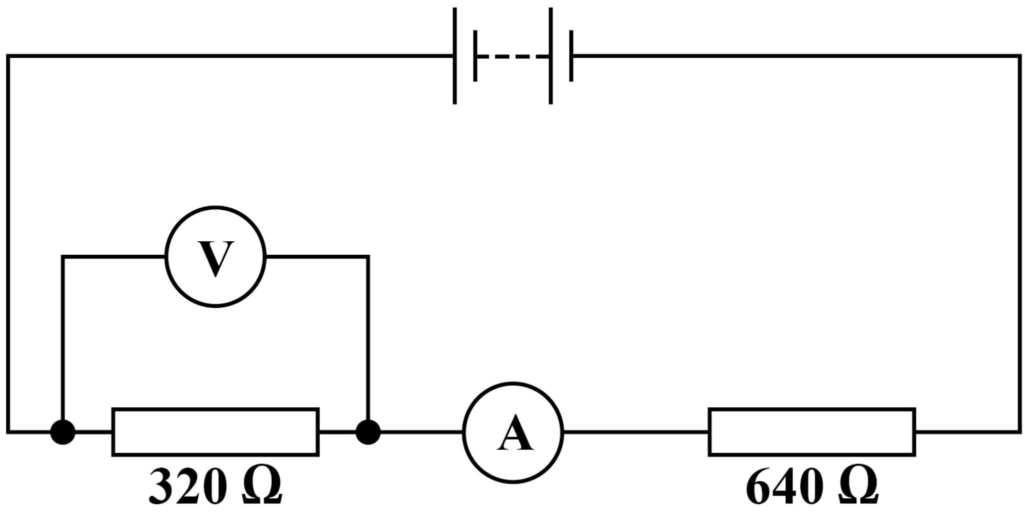
State what is meant by an emf of 5.30 V for this battery. [2 marks]

[Turn over]

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 $320\ \Omega$ resistor.

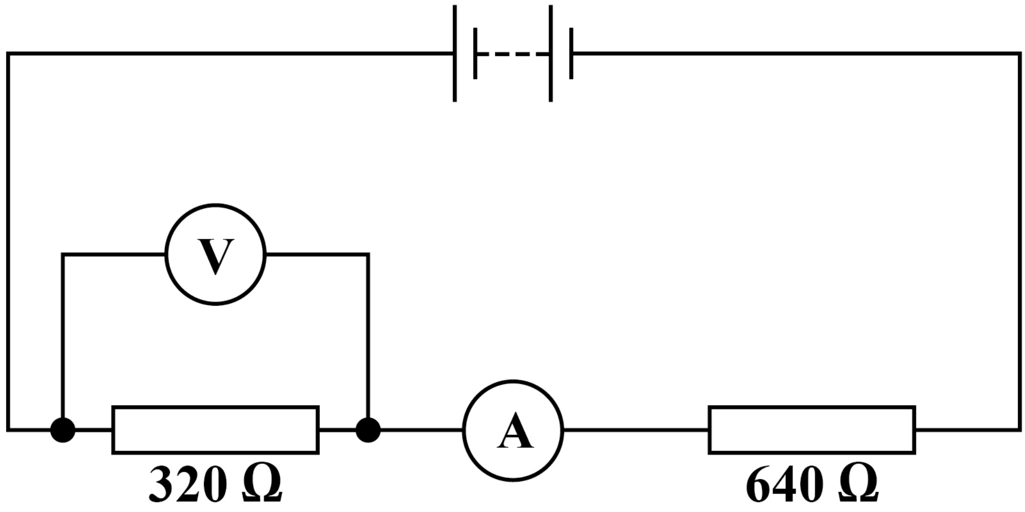
Show that the reading on the ammeter is approximately $7\ mA$. [2 marks]

0 6 . 3

Show that the resistance R of the voltmeter is approximately $300\ \Omega$. [3 marks]

[Turn over]

REPEAT OF FIGURE 13



0 6 . 4

The voltmeter is now connected across the battery terminals.

Calculate the power dissipated in the voltmeter.
[2 marks]

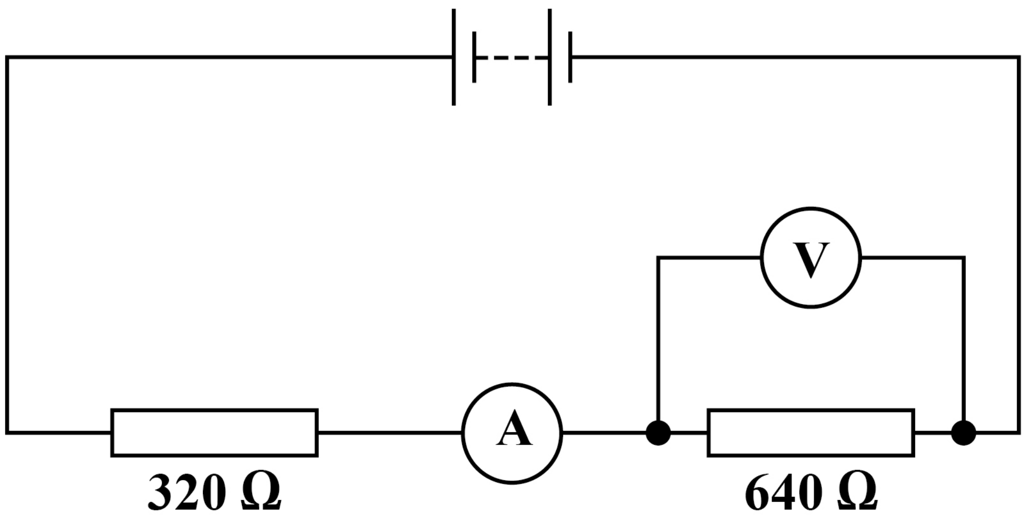
power = ____________________ W

[Turn over]

0 6 . 5

The voltmeter is now connected across the $640\ \Omega$ resistor as shown in FIGURE 14.

FIGURE 14



The reading on the voltmeter is 2.10 V.

When the voltmeter was connected across the $320\ \Omega$ resistor, as shown in FIGURE 13, on page 48, 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]

[Turn over]

11

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]

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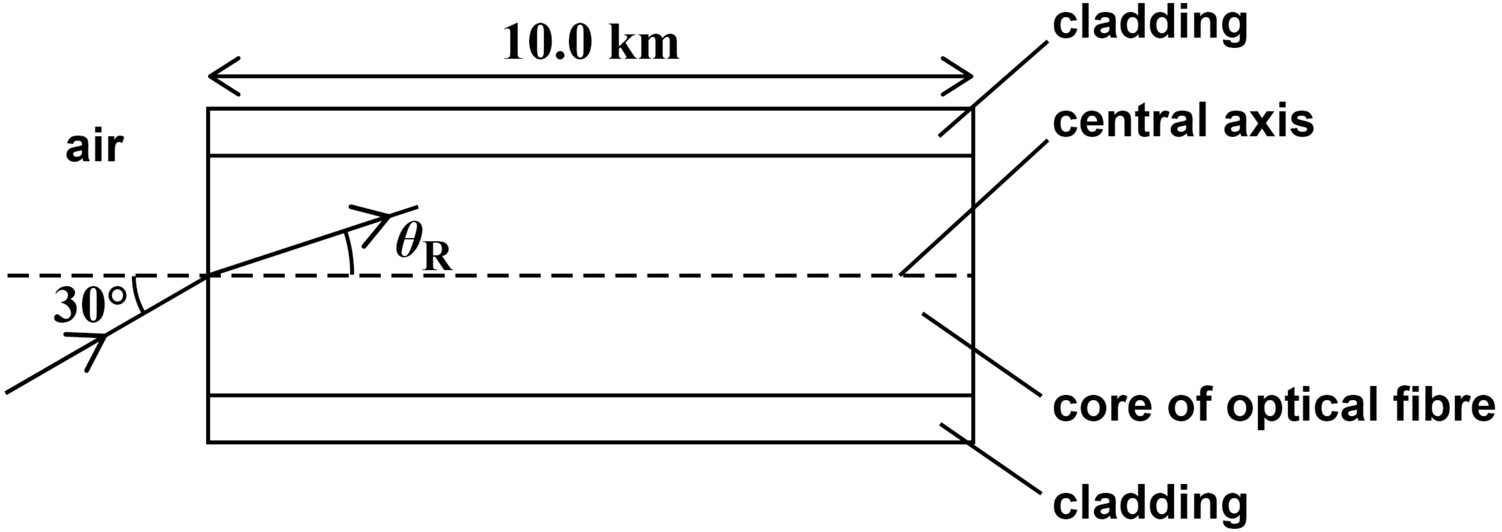
[Turn over]

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 $10.0\ \mathrm{km}$.

The diagram is NOT drawn to scale.

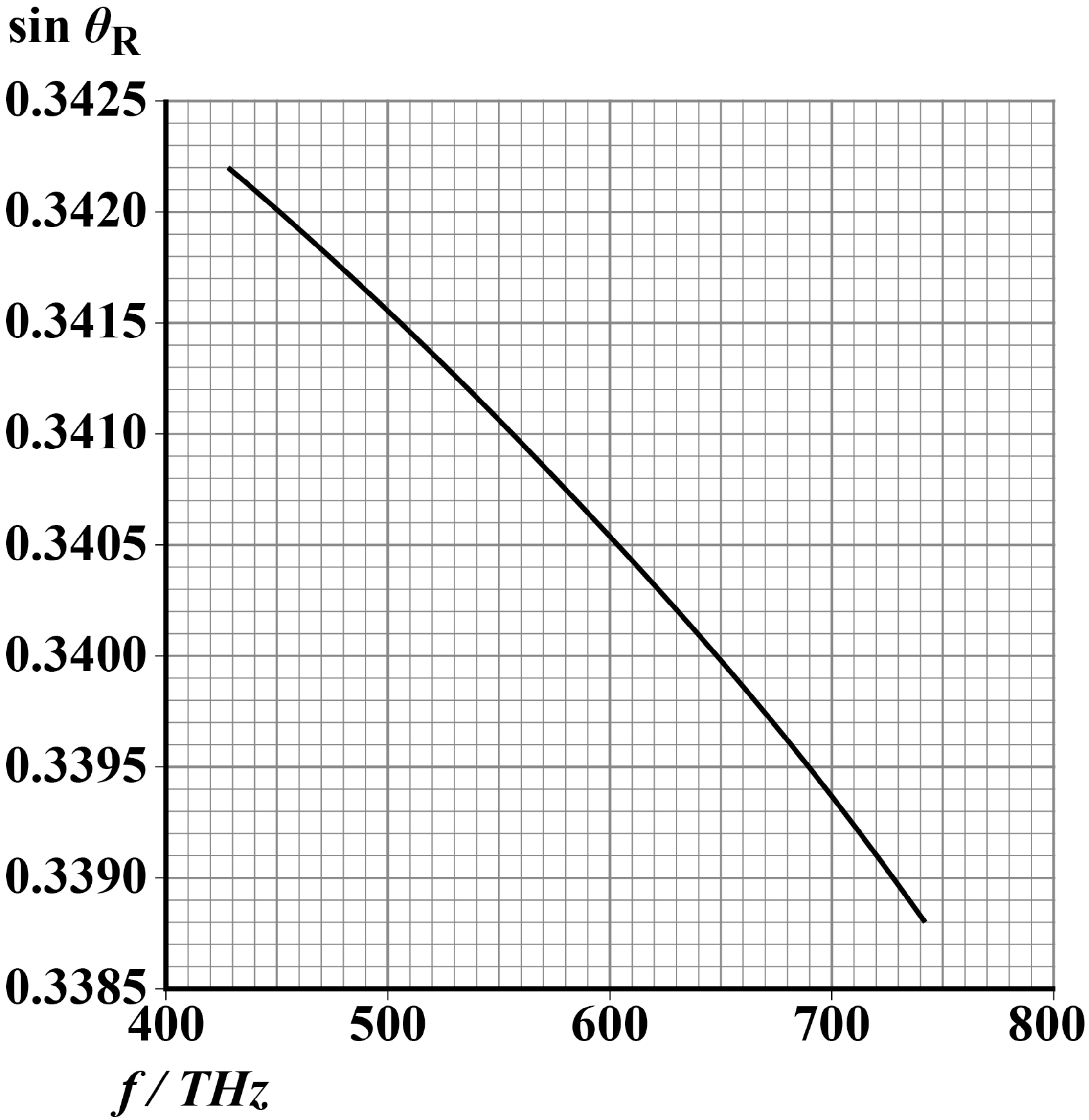
FIGURE 15



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, on the opposite page, shows how sin θ_R varies with f when the angle of incidence is $30°$.

FIGURE 16



sin θ_R
0.3425
0.3420
0.3415
0.3410
0.3405
0.3400
0.3395
0.3390
0.3385
400
500
600
700
800
f / THz

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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]

[Turn over]

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]

speed = ______________________ $\mathrm{m\ s^{-1}}$

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]

[Turn over]

07.5

Another two pulses, identical to the pulses in Question 07.4 on page 59, 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]

END OF QUESTIONS

9

Additional page, if required.

Write the question numbers in the left-hand margin.

Additional page, if required.

Write the question numbers in the left-hand margin.

Additional page, if required.

Write the question numbers in the left-hand margin.

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For Examiner's Use	
Question	Mark
1	
2	
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4	
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TOTAL	

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2 1 6 A 7 4 0 7 / 1