

Please write clearly in block capitals.

Centre number

--	--	--	--	--

Candidate number

--	--	--	--

Surname

StemUp Model Solution

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	
8	
TOTAL	

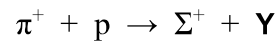


Answer **all** questions in the spaces provided.

0 1

A sigma-plus (Σ^+) particle and an unidentified particle **Y** are produced by the strong interaction between a positive pion (π^+) and a proton (p).

This interaction is represented by the equation:



0 1 . 1

Complete **Table 1** to show the baryon number B , charge Q and strangeness S for the particles in this interaction.

[2 marks]

Table 1

	π^+	p	Σ^+	Y
B	0	+1	+1	0
Q	+1	+1	+1	+1
S	0	0	-1	+1

0 1 . 2

Which particle in **Table 1** has the quark structure uus?

Tick (✓) **one** box.

[1 mark]

π^+

☐

p

☐

Σ^+

☒

Y

☐


0 1 3

Deduce which particle, π^+ or Y , has the greater charge-to-mass ratio. Justify your conclusion.

[3 marks]

Y has a strangeness of +1, a baryon number of 0 and a charge of +1, so Y is a kaon (K^+ meson). It contains an anti-strange quark, which is more massive than the u and d quarks in the pion.

So Y has a greater mass (rest energy) than the π^+ .

Both π^+ and Y have the same charge of +1e, so the π^+ has the greater charge-to-mass ratio (specific charge), because it has the same charge but a smaller mass than Y .

6

Turn over for the next question

Turn over ►



0 2

A sample of bromine gas contains a mixture of two isotopes. An experiment is done to find the percentage of each isotope in this sample.

0 2 . 1

In the experiment, the gas is ionised by a beam of electrons.

Explain how the beam of electrons causes a particle of the gas to have a charge of $+1e$.

[2 marks]

An electron in the beam collides with an electron in a gas particle

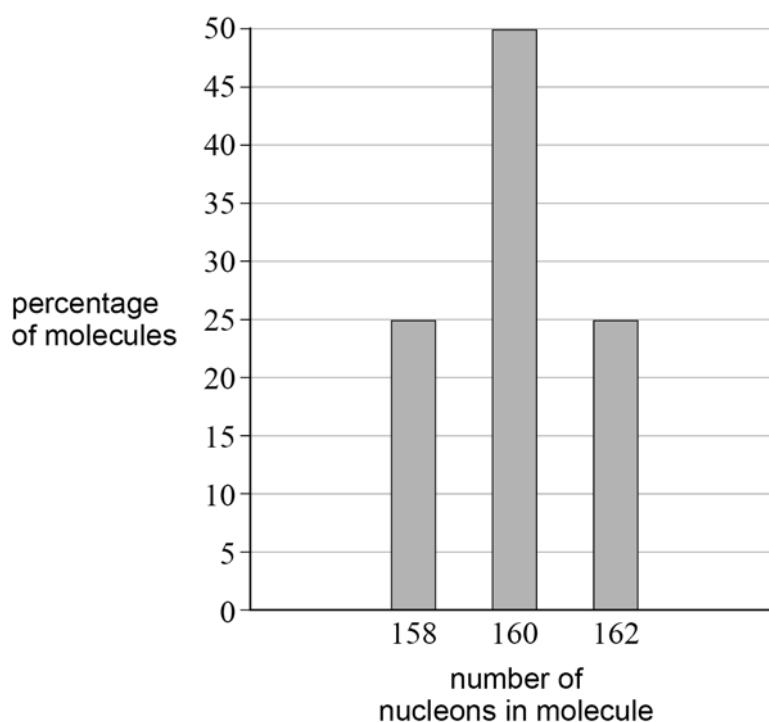
(atom) and transfers some of its kinetic energy to that atomic electron.

This atomic electron gains enough energy to leave the gas particle, so the particle has lost one electron and has a charge of $+1e$.

The gas consists of bromine molecules. Each molecule has two bromine atoms. The experiment finds that the bromine molecules contain 158, 160 or 162 nucleons.

Figure 1 shows the percentage of these different molecules in the sample.

Figure 1



0 2 . 2

Bromine has a proton number of 35

The two isotopes in the sample have different nucleon numbers.

Calculate the number of neutrons for the isotope that has the greater nucleon number.

[2 marks]*Heavier isotope: $162 \div 2 = 81$ nucleons**Neutrons = $81 - 35 = 46$* *(or $162 - (2 \times 35) = 92$, so $92 \div 2 = 46$)*number of neutrons = 46

0 2 . 3

Deduce the percentage of each isotope in the gas.

Justify your conclusion.

[2 marks]*Each isotope makes up 50% of the gas (the percentage is the same for both isotopes).**158 is two lighter atoms and 162 is two heavier atoms, and both are 25%, so the isotopes are in the same ratio. Also, half of the 160 is the lighter isotope and all of the 158 is lighter: $25\% + \frac{1}{2} \times 50\% = 50\%$.*

6

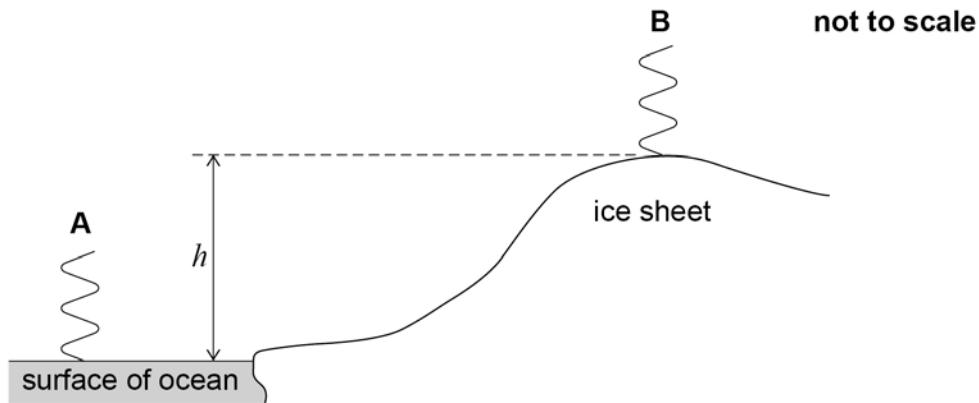
Turn over for the next question**Turn over ►**

0 3

A satellite system is used to measure the height h of the top of an ice sheet above the surface of the ocean.

The satellite emits two pulses **A** and **B** of infrared radiation. **A** is incident on the surface of the ocean and **B** is incident on the top of the ice sheet as shown in **Figure 2**.

Figure 2



0 3 . 1

The frequency of the infrared radiation is 3.8×10^{14} Hz.
Each pulse has a duration of 6.0 ns.

Calculate the number of cycles in each pulse.

[2 marks]

$$T = 1/f = 1 \div 3.8 \times 10^{14} = 2.63 \times 10^{-15} \text{ s}$$

$$\text{cycles} = 6.0 \times 10^{-9} \div 2.63 \times 10^{-15} = 2.28 \times 10^6$$

number of cycles = 2.3×10^6

0 3 . 2

A and **B** reflect and return to the satellite. The travel time is the time between the emission of a pulse and its return to the satellite.

The difference in the travel times of **A** and **B** is $10.7 \mu\text{s}$.

Calculate h .

[2 marks]

$$\text{Time for one way} = 10.7 \times 10^{-6} \div 2 = 5.35 \times 10^{-6} \text{ s}$$

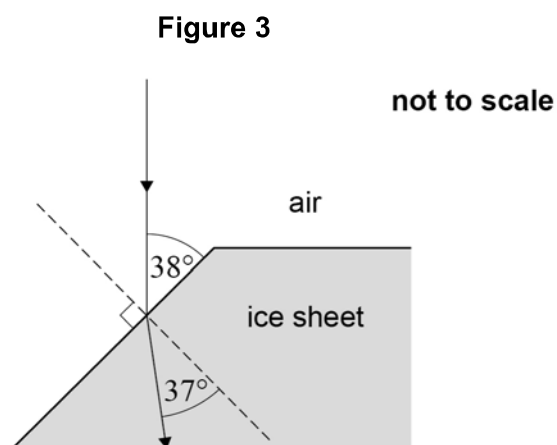
$$h = \text{speed} \times \text{time} = 3.0 \times 10^8 \times 5.35 \times 10^{-6} = 1605 \text{ m}$$

$h =$ 1.6×10^3 m



Some of the infrared radiation enters the ice sheet.

Figure 3 shows the path of infrared radiation that refracts at a sloping part of the ice sheet.



0 3 . 3 Calculate the refractive index of the ice.

[2 marks]

$$\text{Angle of incidence } \theta_1 = 90^\circ - 38^\circ = 52^\circ, \quad \theta_2 = 37^\circ$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad \text{with } n_{\text{air}} = 1$$

$$1 \times \sin 52^\circ = n_2 \times \sin 37^\circ$$

$$n_2 = \sin 52^\circ \div \sin 37^\circ = 0.788 \div 0.602 = 1.31$$

refractive index = 1.31

0 3 . 4 Calculate the wavelength of the infrared radiation when it is inside the ice sheet.

[2 marks]

$$n = c / c_s \quad \text{so} \quad c_s = 3.0 \times 10^8 \div 1.31 = 2.29 \times 10^8 \text{ m s}^{-1}$$

$$c_s = f\lambda \quad \text{so} \quad \lambda = 2.29 \times 10^8 \div 3.8 \times 10^{14}$$

$$\lambda = 6.03 \times 10^{-7} \text{ m}$$

wavelength = 6.0×10^{-7} m

8

Turn over ►



0 4

An isolated metal plate is given a negative charge. Electromagnetic radiation is incident on the plate. The plate loses its charge due to the photoelectric effect.

0 4 . 1

Discuss how the rate of loss of charge from the plate depends on the frequency and intensity of the incident radiation.

In your answer you should explain why:

- the plate loses its charge
- the photoelectric effect occurs only for frequencies greater than a particular value
- the rate of loss of charge increases with intensity for radiation above that particular value of frequency.

[6 marks]

The plate loses its charge because electromagnetic radiation of high enough frequency causes electrons to be emitted from the surface of the plate (photoelectrons). These photoelectrons carry away negative charge, so the number of surplus electrons remaining on the plate decreases with time.

Frequency: an electron needs a minimum energy, equal to the work function ϕ of the metal, to escape from the surface. The radiation consists of photons, and an electron can only absorb the energy of one photon in a single interaction, so one photon must supply all of this energy. The energy of a photon is directly proportional to its frequency, $E = hf$. So electrons are only emitted if $hf \geq \phi$, which means the radiation must have a frequency above the threshold frequency $f_0 = \phi/h$. Below the threshold frequency no electrons are emitted however intense the radiation is, so the plate does not lose charge.

Intensity: above the threshold frequency, increasing the intensity (at the same frequency) means more photons per second are incident on the plate. Each photon can release one electron, so more electrons are released from the plate every second and it loses its charge more rapidly. If the frequency is increased, each photon has more energy, so the



intensity must still increase the number of photons per second for the rate of loss of charge to increase.

0 4 . 2

Charged particles are emitted from the metal plate with a maximum kinetic energy of 1.1 eV when radiation of frequency 1.2×10^{15} Hz is incident on the plate.

Calculate, in eV, the work function of the metal.

[3 marks]

$$E = hf = 6.63 \times 10^{-34} \times 1.2 \times 10^{15} = 7.956 \times 10^{-19} \text{ J}$$

$$\text{In eV: } 7.956 \times 10^{-19} \div 1.6 \times 10^{-19} = 4.97 \text{ eV}$$

$$hf = \phi + E_{k(\max)}$$

$$\phi = hf - E_{k(\max)} = 4.97 - 1.1 = 3.87 \text{ eV}$$

work function = 3.9 eV

9

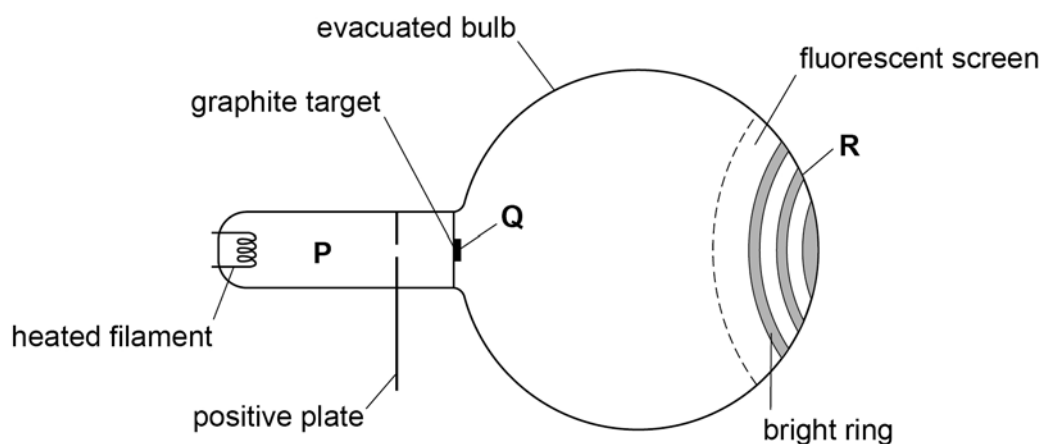
Turn over ►



0 5

Figure 4 shows apparatus used to demonstrate the wave–particle duality of electrons.

Figure 4



The heated filament emits slow-moving electrons.

In region **P**, the electrons are accelerated to a high speed.

At **Q**, the fast-moving electrons are incident on the graphite target.

R is a point on one of the bright rings that are formed where the electrons strike the fluorescent screen.

0 5 . 1

The electrons demonstrate wave-like and particle-like behaviour as they travel from the filament to the screen.

State and explain at which of **P**, **Q** or **R** the electrons are demonstrating wave-like behaviour.

[2 marks]

Q. The electrons diffract as they pass between the layers of atoms in the graphite target, because the gaps between the atoms act as slits for the electrons, so they spread out.



0 5 . 2

The apparatus is adjusted so that the electrons are incident on the graphite target with a greater speed.

Explain why the bright rings formed on the screen now have a smaller diameter.

[3 marks]

*Greater speed means the momentum of the electrons increases, so their (de Broglie) wavelength decreases, since $\lambda = h/mv$ (wavelength is inversely proportional to momentum).
So there is less diffraction, because the wavelength is shorter relative to the spacing between the layers of atoms in the graphite, so the rings are smaller.*

5

Turn over for the next question

Turn over ►

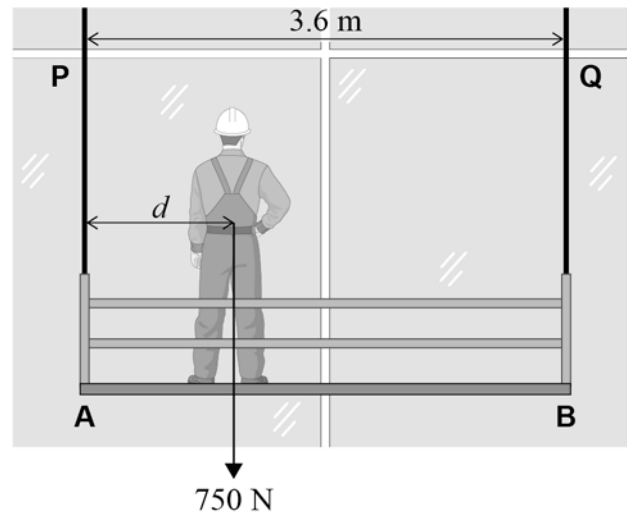


0 6

Figure 5 shows a worker of weight 750 N on a uniform platform. The weight of the worker is acting at a horizontal distance d from end **A**.

Throughout this question, assume that the platform is horizontal and that all cables obey Hooke's law.

Figure 5



The platform weighs 1800 N and is suspended by vertical cables **P** and **Q**. Each cable has an unstretched length of 3.0 m. The horizontal distance between **P** and **Q** is 3.6 m.

0 6 . 1

The worker moves to a position where the tension in the left-hand cable **P** is 1150 N.

Calculate d for this position.

[3 marks]

Taking moments about B (end of cable Q):

$$1150 \times 3.6 = (1800 \times 1.8) + 750 \times (3.6 - d)$$

$$4140 = 3240 + 2700 - 750d$$

$$750d = 1800$$

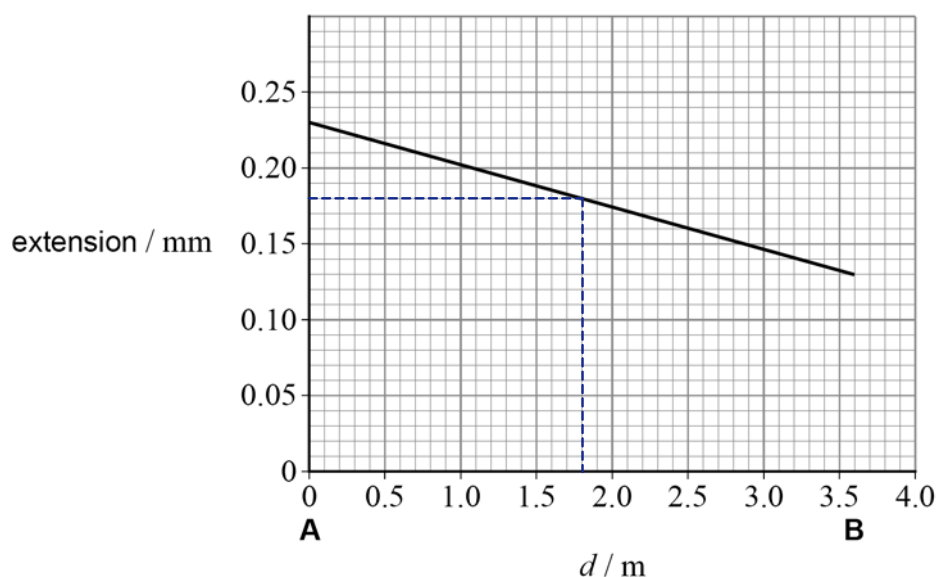
$$d = 2.4 \text{ m}$$

$$d = \underline{\quad 2.4 \quad} \text{ m}$$



Figure 6 shows how the extension of **P** varies with d as the worker walks slowly along the platform from **A** to **B**.

Figure 6



The worker moves to a position **X** where the strain in **P** is 6.0×10^{-5} .

0 6 . 2

Determine d for position **X**.

[2 marks]

$$\epsilon = \Delta L / L \text{ so } \Delta L = 6.0 \times 10^{-5} \times 3.0 = 1.8 \times 10^{-4} \text{ m}$$

$$\text{extension} = 0.18 \text{ mm, read off Figure 6: } d = 1.8 \text{ m}$$

$$d = \underline{1.8} \text{ m}$$

0 6 . 3

The cable material has a Young modulus of $1.9 \times 10^{11} \text{ N m}^{-2}$.

Calculate the tensile stress in **P** when the worker is at **X**.

[1 mark]

$$\sigma = E\epsilon = 1.9 \times 10^{11} \times 6.0 \times 10^{-5}$$

$$\text{tensile stress} = \underline{1.14 \times 10^7} \text{ N m}^{-2}$$

Question 6 continues on the next page

Turn over ►



0 6 . 4 The original cables **P** and **Q** are replaced.

Table 2 shows how the properties of the original cables compare with the replacement cables.

Table 2

	Unstretched length	Radius	Young modulus of cable material
Original cables	L	r	E
Replacement cables	L	$\frac{r}{2}$	$2E$

extension $\Delta L = FL / (AE)$, with F and L unchanged

Radius halved, so area $A = \pi r^2$ becomes $A/4$

Young modulus doubles to $2E$

So new extension = $\Delta L \times 4 \div 2 = 2\Delta L$ (extension doubles)

At $d = 0$: $2 \times 0.23 = 0.46 \text{ mm}$; at $d = 3.6 \text{ m}$: $2 \times 0.13 = 0.26 \text{ mm}$



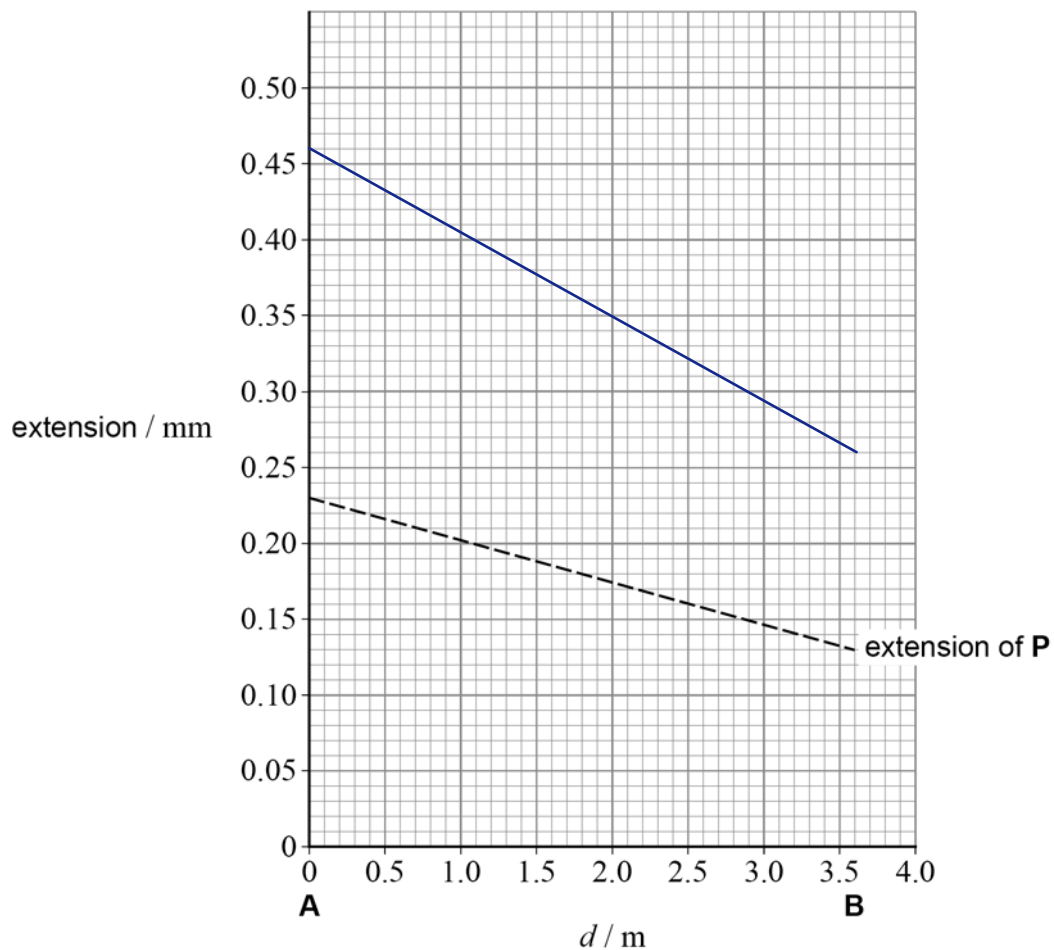
After the cables have been replaced, the worker walks slowly from **A** to **B**.

Draw on **Figure 7** a line to show the variation of the extension of the replacement left-hand cable with d .

The original line from **Figure 6** is shown on **Figure 7** as a dashed line to help you.

[3 marks]

Figure 7



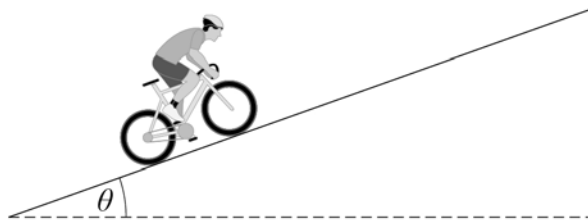
Turn over for the next question

Turn over ►



0 7 . 1 Figure 8 shows a cyclist going up a hill.

Figure 8



not to scale

The angle θ of the slope of the hill is constant.
The total mass m of the cyclist and bicycle is 65 kg.

Write an expression for the component of the total weight parallel to the slope.

[1 mark]

$$mg \sin \theta = 65 \times 9.81 \times \sin \theta = 640 \sin \theta \text{ (N)}$$

0 7 . 2 The useful power output of the cyclist is 310 W.
The cyclist has a steady speed of 1.63 m s^{-1} .

Assume that air resistance is negligible at this speed.

Calculate θ .

[2 marks]

$$P = Fv \text{ so } F = P / v = 310 \div 1.63 = 190 \text{ N}$$

$$F = mg \sin \theta: \sin \theta = 190.2 \div (65 \times 9.81) = 190.2 \div 637.7 = 0.298$$

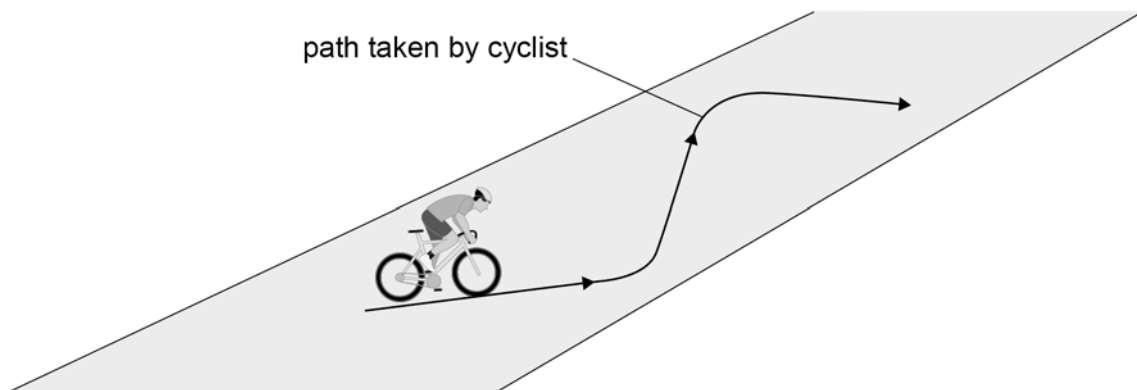
$$\theta = \sin^{-1} 0.298 = 17.4^\circ$$

$$\theta = \underline{17.4}^\circ$$



Figure 9 shows an alternative 'zig-zag' path taken by the cyclist up the same hill. She maintains a steady speed of 1.63 m s^{-1} .

Figure 9



0 7 . 3

Discuss how her useful power output when taking the path in **Figure 9** compares with her useful power output in Question 07.2.

[3 marks]

Her useful power output is less than in 07.2.

She gains the same height (same gain in gravitational potential energy) at the same speed, but the zig-zag path is longer, so the effective angle θ of her path to the horizontal is smaller.

So the component of the weight parallel to her path, $mg \sin \theta$, is smaller, and the vertical component of her velocity is smaller, so she gains less gravitational potential energy per second: $P = mgv \sin \theta$ has decreased.

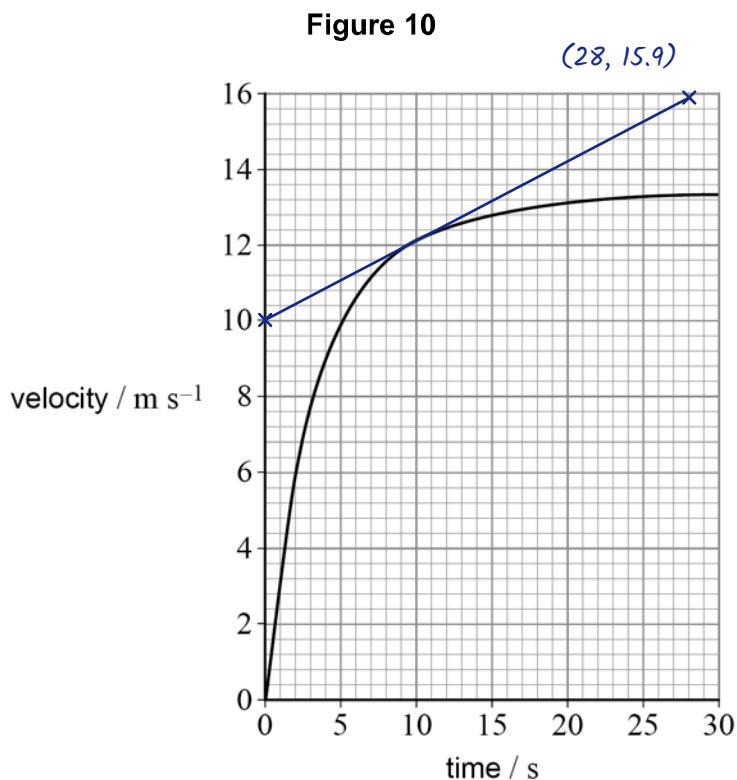
Question 7 continues on the next page

Turn over ►



The cyclist reaches the top of the hill. She then travels back down the hill in a straight line. The bicycle rolls freely without the cyclist pushing the pedals or applying the brakes.

Figure 10 shows the variation of her velocity with time as she goes down the hill.



0 7 4

Determine the acceleration of the cyclist 10.0 s after she begins to go down the hill.

[3 marks]

Tangent drawn to the curve at $t = 10.0$ s

Points on tangent: (0, 10.0) and (28, 15.9)

acceleration = gradient = $\Delta v / \Delta t$

$= (15.9 - 10.0) \div (28 - 0) = 5.9 \div 28 = 0.21 \text{ m s}^{-2}$

acceleration = 0.21 m s⁻²



0 7 . 5

Energy transfers occur as the cyclist travels down the hill.

Outline how these energy transfers explain the shape of the graph in **Figure 10**.

[4 marks]

At first her speed is low, so air resistance (resistive forces) is small and almost all of the gravitational potential energy transferred is transferred to kinetic energy of the cyclist, so she accelerates rapidly (steep gradient).

Air resistance increases with speed, so as the speed increases, more energy is transferred per second from the cyclist to the air by work done against resistive forces, and less of the gravitational potential energy transferred per second goes to kinetic energy, so the acceleration (gradient) decreases.

At top speed (about 13 m s^{-1}), all of the gravitational potential energy transferred per second is transferred to the air by work done against resistive forces, so kinetic energy stays constant and the graph levels off.

13

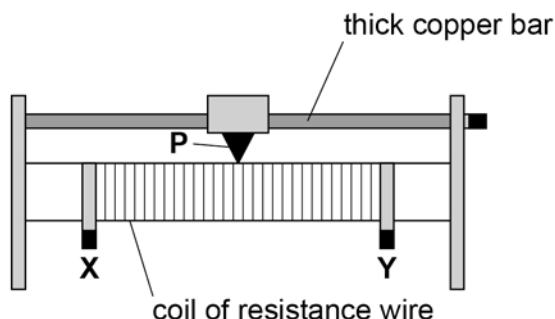
Turn over for the next question

Turn over ►



0 8

Figure 11 shows a variable resistor that has a maximum resistance of $25\ \Omega$. A sliding contact **P** is mounted on a thick copper bar. **P** can be set to any position between **X** and **Y**.

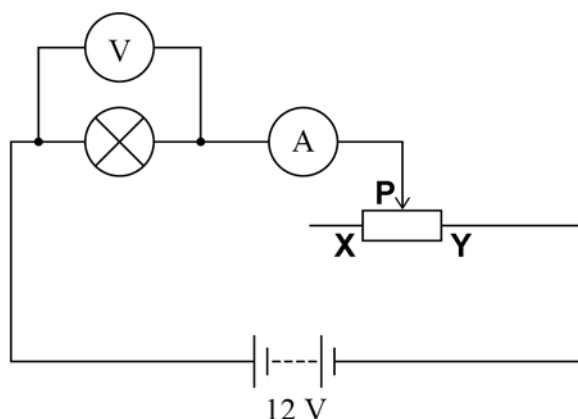
Figure 11

0 8 . 1

Figure 12 shows the variable resistor being used to investigate the variation of current with voltage for a filament lamp.

The normal operating voltage of the lamp is 12 V.

The 12 V battery has negligible internal resistance.

Figure 12

The position of **P** is adjusted so that the reading on the voltmeter is at its minimum value of 0.75 V.

Calculate the resistance of the lamp when the voltmeter reading is 0.75 V.

[2 marks]

$$pd \text{ across variable resistor} = 12 - 0.75 = 11.25 \text{ V}$$

$$I = V / R = 11.25 \div 25 = 0.45 \text{ A}$$

$$R_{\text{lamp}} = 0.75 \div 0.45 = 1.67 \ \Omega$$

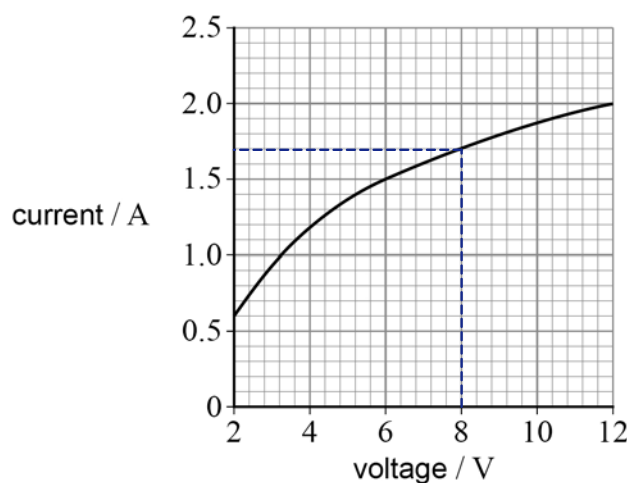
resistance = 1.7 Ω



0 8 . 2

Figure 13 shows the variation of current with voltage for the lamp between 2 V and 12 V.

Figure 13



Calculate the resistance of the lamp when the voltage across the lamp is 8.0 V.

[2 marks]

From Figure 13, at 8.0 V: $I = 1.7 \text{ A}$

$$R = V / I = 8.0 \div 1.7 = 4.7 \, \Omega$$

resistance = 4.7 Ω

0 8 . 3

Explain, in terms of electron movement, why the resistance of the filament lamp changes as the voltage changes as shown in **Figure 13**.

[3 marks]

As the voltage increases the current increases, so more electrons move through the filament per second.

The filament gets hotter, so the vibration of the lattice ions increases.

So there is a greater number of collisions per second between the conduction electrons and the lattice ions, which increases the resistance.

Question 8 continues on the next page

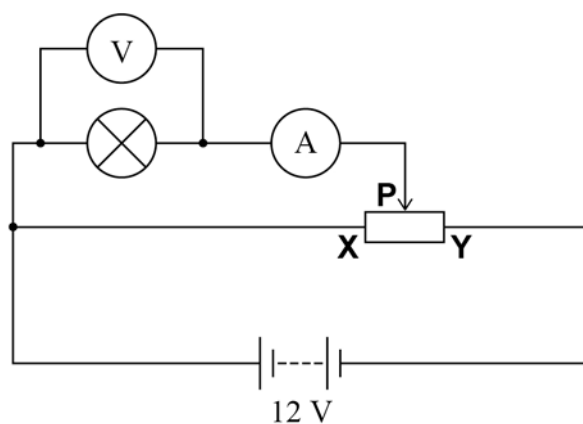
Turn over ►



0 8 . 4

Figure 14 shows an alternative circuit used to investigate the variation of current with voltage for the lamp.

Figure 14



The circuit components are the same as in **Figure 12**.
When the voltage across the lamp is 12 V its resistance is 6.0 Ω .

P is moved to position **Y**.

Calculate the total resistance of the circuit.

[2 marks]

Lamp (6.0 Ω) is in parallel with the whole of XY (25 Ω):

$$1/R_T = 1/R_1 + 1/R_2 = 1/6.0 + 1/25$$

$$R_T = (6.0 \times 25) \div (6.0 + 25) = 4.84 \Omega$$

total resistance = 4.84 Ω

0 8 . 5

Calculate the power transferred by the battery when **P** is at position **Y**.

[2 marks]

$$P = V^2 / R = 12^2 \div 4.84$$

$$P = 144 \div 4.84 = 29.8 \text{ W}$$

power = 30 W



0 8 . 6

A student wants to control the brightness of the lamp.

He gives two reasons why the circuit in **Figure 14** is better than the circuit in **Figure 12** for controlling the brightness. The two reasons are:

- the **Figure 14** circuit can achieve a greater range of voltages across the lamp
- the **Figure 14** circuit is more efficient at transferring energy to the lamp.

Discuss, without calculation, whether either of these two reasons is correct.

[3 marks]

The first reason is correct but the second is not: Figure 14 gives a wider range but is less efficient.

In Figure 14, XY is used as a potentiometer, so the lamp voltage can be varied from 0 to 12 V, whereas in Figure 12 the minimum is 0.75 V, so voltages between 0 and 0.75 V cannot be reached.

In Figure 14 there is always 12 V across the resistance wire, so for any voltage across the lamp there is always more current drawn from the battery and more power is wasted heating the resistor than in Figure 12 (where only the remaining part of the 12 V is across the resistor), so Figure 14 is less efficient.

14

END OF QUESTIONS



There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



[illegible]

[illegible]

Do not write
outside the
box

[illegible]

There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

Copyright information

For confidentiality purposes, all acknowledgements of third-party copyright material are published in a separate booklet. This booklet is published after each live examination series and is available for free download from www.aqa.org.uk.

Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and AQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team.

Copyright © 2022 AQA and its licensors. All rights reserved.



2 8



2 2 6 A 7 4 0 7 / 1