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OCR A LEVEL PHYSICS A (H556): QUESTIONS BY TOPIC

Making measurements and analysing data (2.2)

A Level Physics A (H556) · Module 2: Foundations of physics

34 questions · 262 marks · Mark schemes included

OCR A Level Physics A (H556), June 2017 – June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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2.2.1 MEASUREMENTS AND UNCERTAINTIES		18 Qs · 98 marks	4
1. Q5	H556/01 Modelling physics June 2017	1	5
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	QUESTION	SOURCE	MARKS	PAGE
32.	Q2 <i>also 4.5 & 6.4</i>	H556/03 Unified physics June 2019	15	74
33.	Q23 <i>also 2.1 & 4.4 & 5.5 & 5.4</i>	H556/01 Modelling physics November 2021	15	79
34.	Q17 <i>also 5.4</i>	H556/01 Modelling physics June 2018	16	81



QUESTIONS

34 questions · 262 marks · 2 sub-topics



SUB-TOPIC 2.2.1

MEASUREMENTS AND UNCERTAINTIES

Sub-topic 2.2.1 · 18 questions · 98 marks · lowest tariff first



5 Which is the **best** estimate of the area of a rectangular field of length 98 ± 3 m and width 47 ± 2 m?

A $4600 \pm 5 \text{ m}^2$

B $4600 \pm 6 \text{ m}^2$

C $4600 \pm 300 \text{ m}^2$

D $4606 \pm 337 \text{ m}^2$

Your answer

[1]



- 11 The acoustic impedance Z of a material in the shape of a cube can be determined using the equation

$$Z = \frac{Mc}{L^3}$$

where M is the mass of the material, L is the length of each side of the cube and c is the speed of ultrasound in the material.

The percentage uncertainty in L is 1.2% and the percentage uncertainty in c is 1.8%. The percentage uncertainty in M is negligible.

What is the percentage uncertainty in Z ?

- A 2.2%
- B 3.0%
- C 4.2%
- D 5.4%

Your answer

[1]

- 3 A solid cylindrical glass rod has length 20.0 ± 0.1 cm and diameter 5.00 ± 0.01 mm.

What is the percentage uncertainty in the calculated volume of this rod?

- A** 0.1%
B 0.2%
C 0.7%
D 0.9%

Your answer

[1]

4 A solid cylindrical glass rod has length 20.0 ± 0.1 cm and diameter 5.00 ± 0.01 mm.

- 13 The Young modulus E of a metal can be determined using the expression $E = \frac{4F}{\varepsilon\pi d^2}$, where F is the tension in the wire, d is the diameter of the wire and ε is the strain of the wire.

Here is some data.

Quantity	Percentage uncertainty
F	5.3
ε	1.2
d	1.0

What is the percentage uncertainty in the calculated value of E ?

- A 2.1 %
B 6.4 %
C 7.5 %
D 8.5 %

Your answer

[1]



- 2 The diameter of a wire is measured in five different places along its length. The results are shown below.

1.92 mm

1.88 mm

1.90 mm

1.86 mm

1.89 mm

What is the absolute uncertainty in the diameter of this wire?

A 0.01 mm

B 0.03 mm

C 0.05 mm

D 0.06 mm

Your answer

[1]

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- 2 The accepted value of g is 9.81 ms^{-2} . In an experiment to verify the value of g , students obtained a value of 10.20 ms^{-2} .

What is the percentage difference between the students' value and the accepted value of g ?

- A 1%
- B 2%
- C 4%
- D 8%

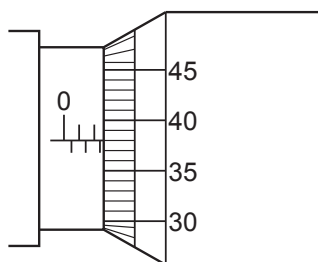
Your answer

[1]



- 5 The image shows a micrometer that is being used to measure the diameter of a wire.

The micrometer has a zero error of +0.07 mm. The measured value of the diameter from the micrometer scale is 2.88 mm.



What is the correct area of cross-section of the wire?

- A $2.21 \times 10^{-6} \text{ m}^2$
- B $6.20 \times 10^{-6} \text{ m}^2$
- C $6.51 \times 10^{-6} \text{ m}^2$
- D $6.84 \times 10^{-6} \text{ m}^2$

Your answer

[1]

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Turn over

- 9 The radius R of the nucleus of an unknown isotope with nucleon number is calculated using the formula

$$R = r_0 A^{1/3}, \text{ where } r_0 \text{ is a constant.}$$

The percentage uncertainty in r_0 is $\pm 5\%$.

The percentage uncertainty in A is $\pm 3\%$.

What is the percentage uncertainty in R ?

A $\pm 2\%$

B $\pm 4\%$

C $\pm 6\%$

D $\pm 8\%$

Your answer

[1]



- 24** A group of students are conducting an experiment to determine the wavelength of monochromatic light from a laser.

Fig. 24.1 shows the laser beam incident normally at a diffraction grating.

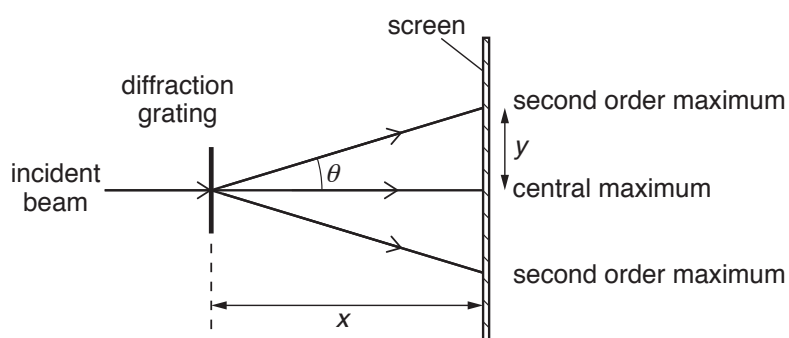


Fig. 24.1

The students use a diffraction grating with $600 \text{ lines mm}^{-1}$. They vary the distance x between the grating and the screen from 1.000 m to 2.000 m . They measure the distance y from the **central** maximum to the **second order** maximum.

- (a)** The students decide to plot a graph of y against $\sqrt{x^2 + y^2}$.

Show that the gradient of the graph is equal to $\sin \theta$, where θ is the angle between the central maximum and the **second order** maximum.

[1]

(b) Fig. 24.2 shows the graph plotted by the students.

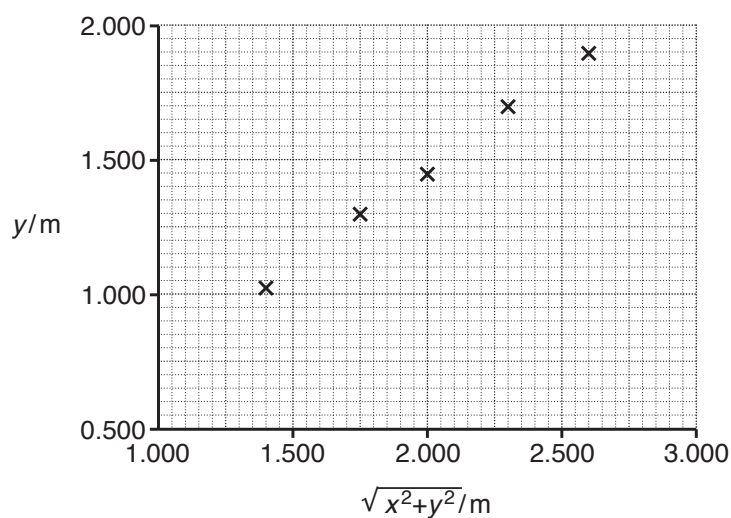


Fig. 24.2

- (i) Use Fig. 24.2 to determine an accurate value of the wavelength λ of the light from the laser.

$\lambda = \dots\dots\dots \text{ m}$ [3]

- (ii) Suggest why there are no error bars shown in Fig. 24.2.

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 [1]

- (iii) Suggest how the precision of this experiment may be affected by using a protractor to measure the angle θ .

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 [1]

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21 Fig. 21 shows the drum of a washing machine.

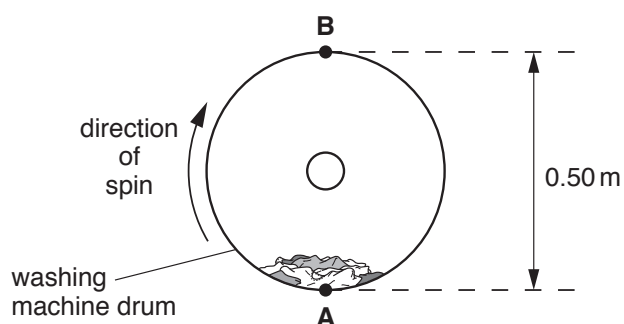


Fig. 21

The clothes inside the drum are spun in a **vertical** circular motion in a clockwise direction.

- (a) When the drum is at rest, the weight of the clothes is equal to the normal contact force on the clothes at point A.

Explain why these two forces are not an example of Newton's Third Law of motion.

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..... [2]

- (b) The drum has diameter 0.50 m. The manufacturer of the washing machine claims that the drum spins at 1600 ± 100 revolutions per minute.

Calculate the speed of rotation of the drum and the absolute uncertainty in this value.

speed = ... $\pm$ ms^{-1} [3]

- (c) The washing machine is switched off and the speed of the drum slowly decreases. The clothes at the top of the drum at point **B** start to drop off at a certain speed v .

At this speed v , the normal contact force on the clothes is zero.

Calculate the speed v .

$v = \dots\dots\dots \text{ m s}^{-1}$ [3]

- 22 (a)** A team of astronomers have measurements to determine the peak surface temperature T and luminosity L of a distant star. They plan to use Stefan's law to estimate the radius r of this star.

Explain whether the astronomers should attempt to measure T or L more precisely to reduce the uncertainty in r .

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..... [2]

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Turn over



(b)* It is suggested that the luminosity L and the mass M of a star can be compared to the Sun by the equation

$$\frac{L}{L_{\odot}} = \left(\frac{M}{M_{\odot}}\right)^b$$

where $L_{\odot}$ is the luminosity of the Sun and $M_{\odot}$ is the mass of the Sun.

The value of b is between 3 and 4.

Table 22 shows some data of five stars.

Main sequence star	$\frac{M}{M_{\odot}}$	$\frac{L}{L_{\odot}}$
Pi Andromedae A	6.5	800
Alpha Coronae Borealis A	3.2	80
Gamma Virginis	1.7	6.0
Eta Arietis	1.3	2.5
70 Ophiuchi A	0.78	0.4

Table 22

Fig. 22 shows the $\lg\left(\frac{L}{L_{\odot}}\right)$ against $\lg\left(\frac{M}{M_{\odot}}\right)$ plot for these stars.

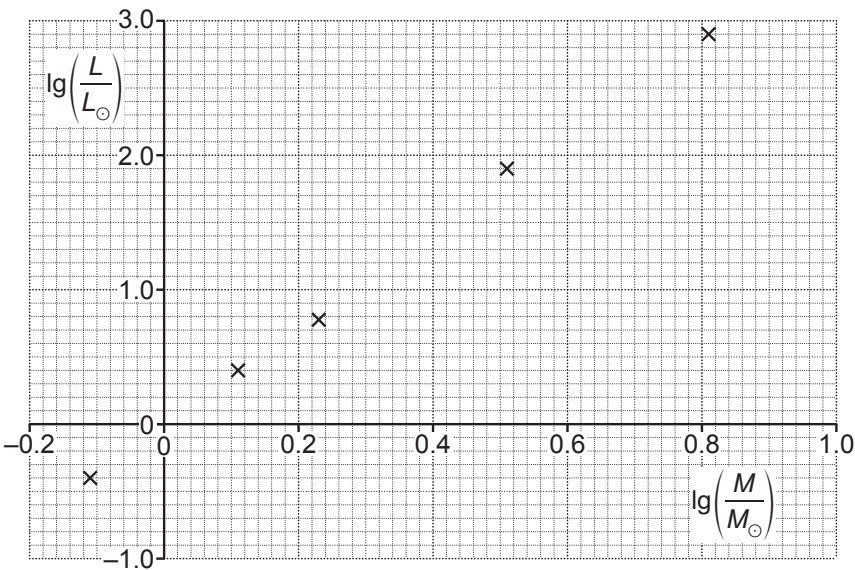


Fig. 22

The luminosity of a star is directly proportional to the rate of fusion of hydrogen nuclei.

Use **Fig. 22** to determine b and use your knowledge of Hertzsprung–Russell (HR) diagrams to deduce how the lifespan of hotter stars compares with lifespans of cooler stars. **[6]**

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Additional answer space if required

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- 17 (a) State **one** S.I. base quantity other than length, mass and time.

..... [1]

- (b) Fig. 17 shows two resistors **X** and **Y** connected in series.

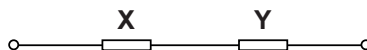


Fig. 17

The resistors are wires. Both wires have the same length L and diameter d . The material of **X** has resistivity ρ and the material of **Y** has resistivity 2ρ .

- (i) Show that the total resistance R of the wires is given by the equation

$$R = \frac{12\rho L}{\pi d^2}.$$

[2]

- (ii) A student uses the equation in (i) to determine R .
The table below shows the data recorded by the student in her lab book.

Quantity	Value
ρ	$4.7 \times 10^{-7} \Omega \text{ m}$
L	$9.5 \pm 0.1 \text{ cm}$
d	$0.270 \pm 0.003 \text{ mm}$

1. Name the likely instruments used by the student to measure L and d .

L :

d : [1]

2. Use the data in the table and the equation in (i) to determine R and the absolute uncertainty. Write your answer to the correct number of significant figures.

$R = \dots \pm \dots \Omega$ [4]

3. The instrument used to measure d has a zero-error. The measured d is much **larger** than the actual value.
Discuss how the actual value of R compares with the value calculated above.

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..... [1]

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- 5 Hydrogen atoms excited in a discharge tube only emit four different discrete wavelengths of visible photons.

*(a) In a semi-darkened room, a single slit is placed in front of the discharge tube. A student holds a diffraction grating which has 300 lines per millimetre. The student looks through the grating at a 15 cm plastic ruler placed 0.50 m away, as shown in Fig. 5.1. The paths of the different colours of light from the slit to the student's eye are shown in Fig. 5.2.

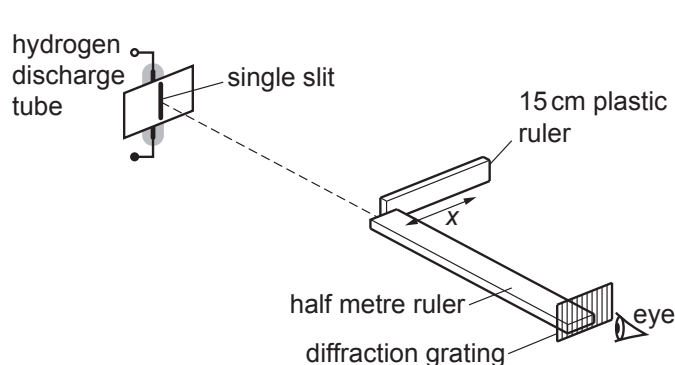


Fig. 5.1 (not to scale)

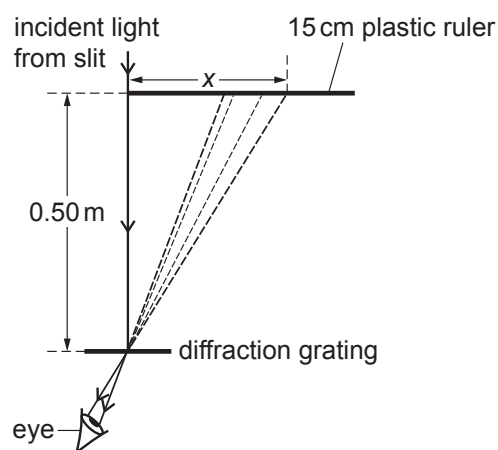


Fig. 5.2 (not to scale)

Four **first** order images of the slit, one at each photon wavelength, are observed as vertical lines against the background of the plastic ruler, as shown in Fig. 5.3.

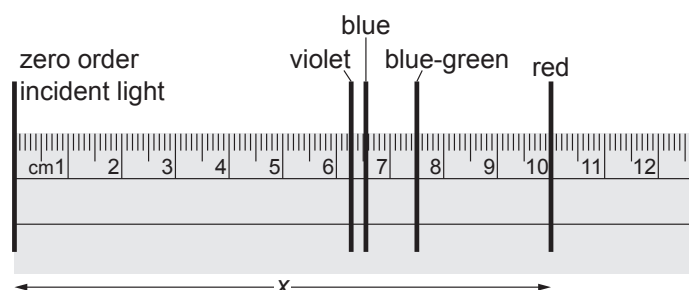


Fig. 5.3

The student decides to determine the wavelength of the photons which form the **red** line observed at $x = 10$ cm on the ruler.

- Describe how the information that has been given can be used to determine the wavelength of the red photons.
- Estimate the percentage uncertainty in the measured value of the wavelength. [6]

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Question 5 continues on page 18

- (b) (i) Show that the energy of a photon of wavelength 486 nm is 4.09×10^{-19} J.

[1]

- (ii) Fig. 5.4 shows some of the energy levels of an electron in a hydrogen atom.

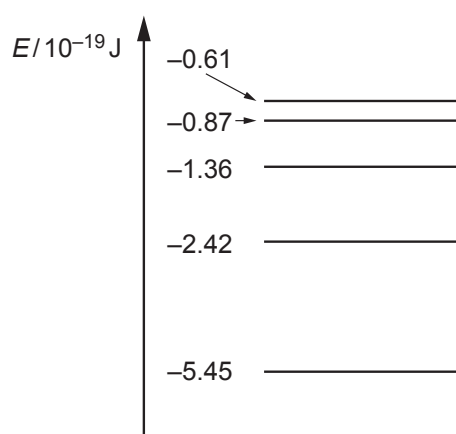


Fig. 5.4 (not to scale)

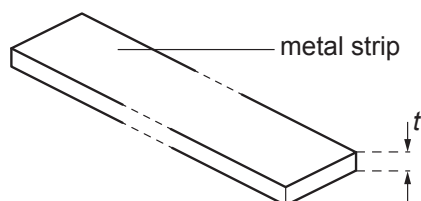
Draw an arrow on Fig. 5.4 to show an electron transition which would cause the **emission** of a photon of wavelength 486 nm. [2]

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Question 6 begins on page 20



- 17 (a) A metal strip has thickness t , as shown below.



Five measurements of the thickness t at different positions along the length of the strip are shown below.

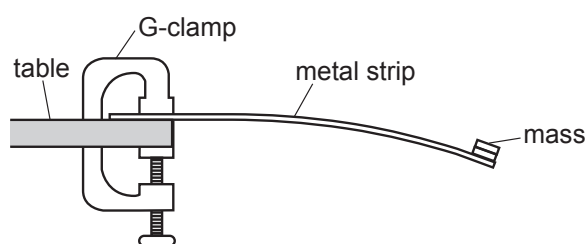
1.86 mm 1.88 mm 1.85 mm 1.89 mm 1.88 mm

Determine the percentage uncertainty in the thickness t .

percentage uncertainty = ... % [3]

- (b)* A student wants to determine the Young modulus E of the metal of the strip in (a).

The student clamps the metal strip to the edge of a table using a G-clamp. A mass is **permanently** fixed to the end of the strip as shown.



The mass oscillates freely when it is moved away from its equilibrium position and then released.

The Young modulus E of the metal can be determined using the equation $E = \frac{16\pi^2 mL^3}{wt^3 T^2}$, where m is the mass fixed to the end of the strip, L is the length of the strip from the end of the table to the centre of the mass, w is the width of the strip, t is the thickness of the strip, and T is the period of oscillations.

Describe how an experiment may be safely conducted, and how the data can be analysed to determine an accurate value for E . [6]

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Additional answer space if required.

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- 23** The Hipparcos space telescope used stellar parallax with a precision of 9.7×10^{-4} arcseconds to determine the distance to stars.

One of the stars studied was Polaris A. Data about this star is in the table below.

Parallax angle	7.5×10^{-3} arcseconds
Radius	2.1×10^{10} m
Mass	1.1×10^{31} kg
Surface temperature	6000 K
Temperature of the atmosphere of the star	4.0×10^6 K

- (a)** **(i)** Estimate the maximum stellar distance in parsecs that could be measured using Hipparcos.

maximum stellar distance = ...pc **[1]**

- (ii)** Calculate the percentage uncertainty in the calculated value of the distance to Polaris A.

percentage uncertainty = ... % **[2]**

- (b)** A continuous stream of particles called a solar wind flows from the surface of the star into the surrounding space.

These particles include helium nuclei of mass 6.6×10^{-27} kg.

Assume that the atmosphere is modelled as an ideal gas.

- (i)** Show that the typical kinetic energy of a helium nucleus in the atmosphere is about 10^{-16} J.

[2]

- (ii) The gravitational potential energy of a helium nucleus in the outer layer of the star is $-2.3 \times 10^{-16} \text{ J}$.

Calculate the gravitational potential energy U at the maximum distance from the star that a helium nucleus could reach.

$$U = \dots\dots\dots \text{ J [1]}$$

- (iii) Calculate the distance from the centre of the star reached by this helium nucleus.

$$\text{distance} = \dots\dots\dots \text{ m [3]}$$

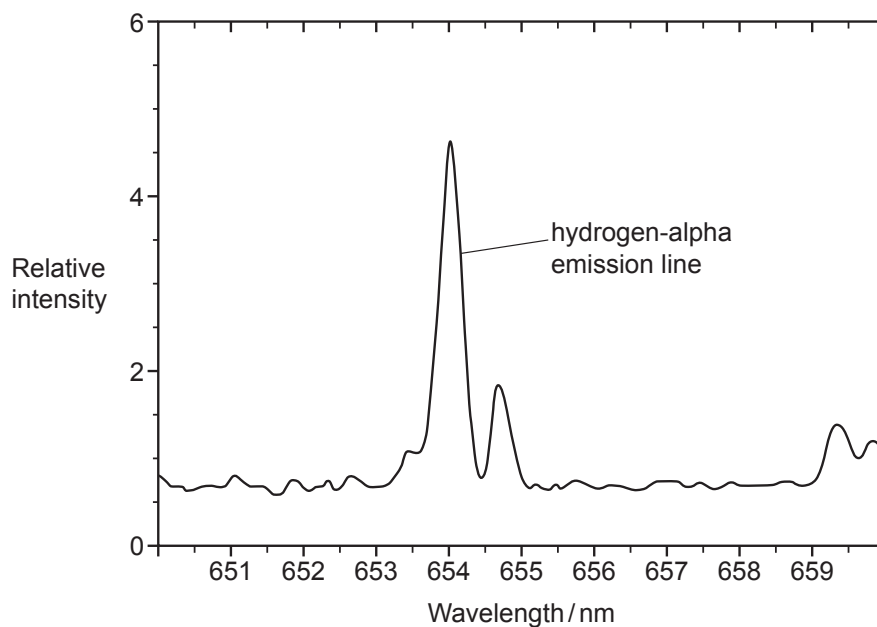
- (iv) Explain why the star has a solar wind that reaches a much greater distance from the star than found in (iii).

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..... [1]



- 23** The diagram below shows the part of the spectrum of light from the galaxy M87 with a strong hydrogen-alpha emission line.

The spectrum of a sample of hydrogen gas analysed in a laboratory on Earth showed this emission line to be at 656.3 nm.



- (a)** Calculate the magnitude of the recession velocity of M87.

velocity = ... km s^{-1} [3]

- (b)** Estimate the distance in light years to M87 using Hubble's law.

Hubble's constant $H_0 = 2.5 \times 10^{-19} \text{ s}^{-1}$

distance = ... ly [2]

- (c) Estimate the percentage uncertainty in the distance calculated in part (b) using the width of the emission line in the diagram.

percentage uncertainty = $\pm$ % [2]

- (d) Other methods have shown M87 is actually 50 million light years from Earth.

Suggest why M87 might contradict Hubble's law.

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..... [2]

- (e) Suggest **one** reason why the Big Bang theory is still the accepted model of the origin of the Universe.

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..... [1]



- 4 Fig. 4.1 shows an arrangement used by a student to determine the acceleration of free fall.

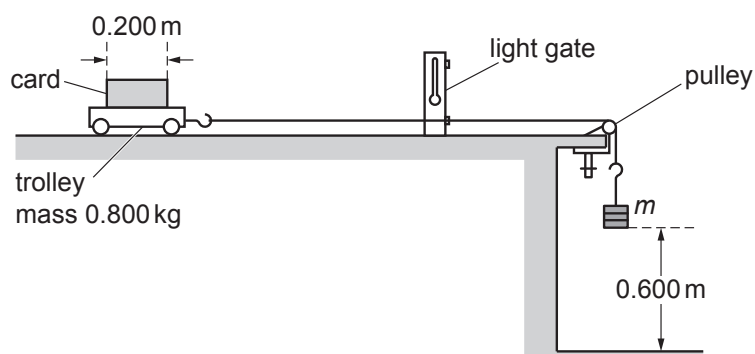


Fig. 4.1

A trolley is attached to a variable mass m by a string which passes over a pulley.

The mass m is released from rest and falls through a fixed height of 0.600 m accelerating the trolley of mass 0.800 kg. When the mass m hits the floor, the trolley then continues to move at a **constant** velocity v .

This constant velocity v is determined by measuring the time t for the card of length 0.200 m to pass fully through a light gate connected to a timer.

Frictional forces on the trolley and the falling mass m are negligible.

- (a) Show that the relationship between v and m is

$$v^2 = \frac{1.20mg}{(m + 0.800)}$$

where g is the acceleration of free fall.

[2]

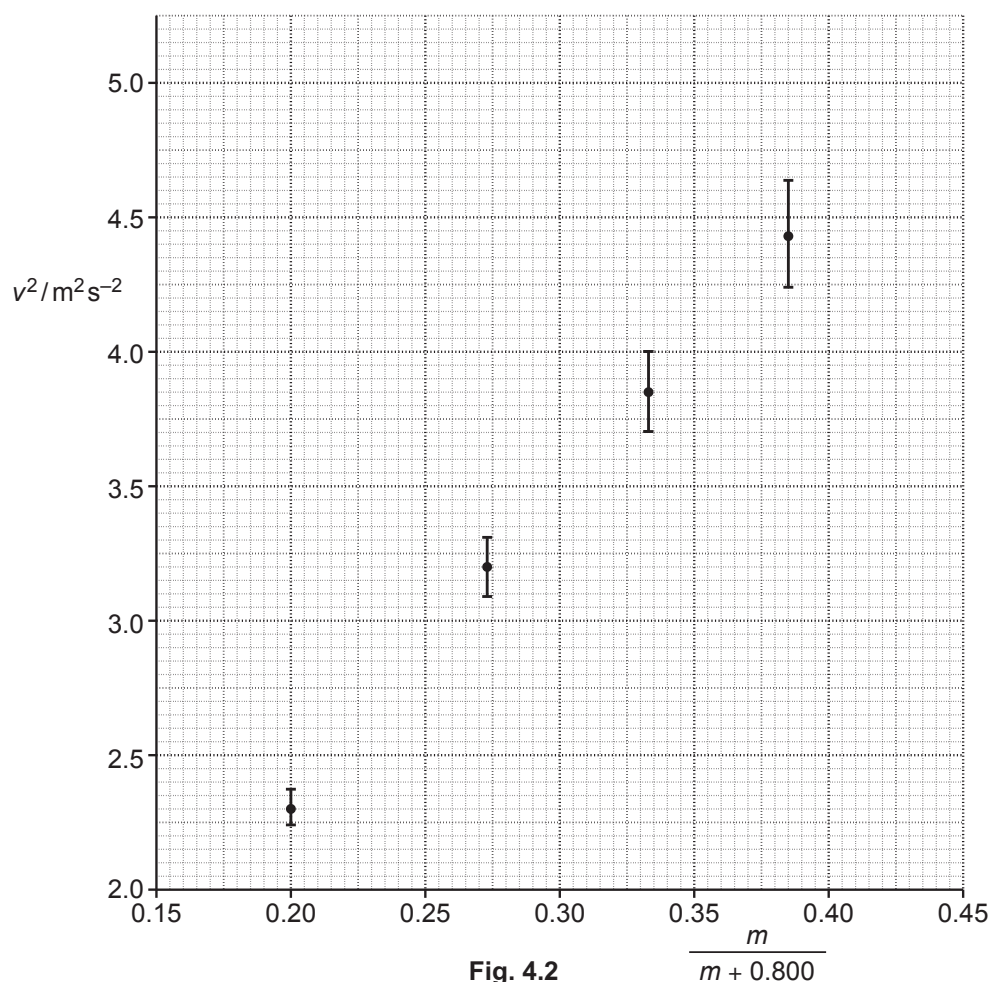
- (b) The student records the information from the experiment in a table. The column headings and just the last row for $m = 0.600$ kg from this table are shown below.

m/kg	$t/10^{-3}\text{s}$	$\frac{m}{(m + 0.800)}$	v/ms^{-1}	$v^2/\text{m}^2\text{s}^{-2}$
0.600	90 ± 2	0.429	2.22 ± 0.05	

- (i) Complete the missing value of v^2 in the table including the absolute uncertainty.

[2]

- (ii) Fig. 4.2 shows some of the data points plotted by the student. Plot the missing data for $m = 0.600 \text{ kg}$ on Fig. 4.2 and draw the straight line of best fit. [2]



- (c) (i) Use the equation given in (a) to show that the gradient of the graph of v^2 against $\frac{m}{(m + 0.800)}$ is equal to $1.20g$. [1]

- (ii) Assume that the best-fit straight line through the data points gives 9.5 m s^{-2} for the experimental value of g . Draw a worst-fit line through the data points on Fig. 4.2 and determine the absolute uncertainty in the value for g .

absolute uncertainty = $\pm \dots\dots\dots \text{ m s}^{-2}$ [4]

- (d) It is suspected that the card on the trolley did not pass at right angles through the light beam.

Discuss, without doing any calculations, the effect this may have on the experimental value for the acceleration of free fall g .

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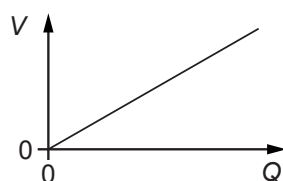
SUB-TOPIC 2.2.2

GRAPHS

Sub-topic 2.2.2 · 16 questions · 164 marks · lowest tariff first



- 7 The graph below shows the variation of potential difference V with charge Q for a capacitor.



Which row is correct for the gradient of the graph and the area under the graph?

	Gradient of graph	Area under the graph
A	capacitance ⁻¹	work done
B	capacitance ⁻¹	permittivity
C	capacitance	power
D	capacitance	energy

Your answer

[1]

- 3 A student has plotted a velocity against time graph for a trolley moving down a ramp.

Which of the following pair of quantities can be determined from the gradient of the graph and the area under the graph?

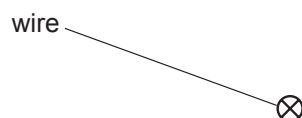
- A acceleration, displacement
- B acceleration, impulse
- C displacement, kinetic energy
- D force, work done

Your answer

[1]



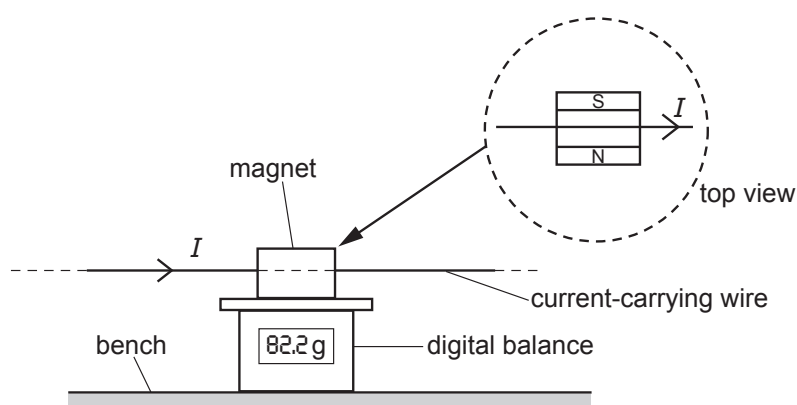
- 19 (a) The diagram below shows the top-view of a long current-carrying wire.



The direction of the current in the wire is into the plane of the paper.

Draw at least **three** field lines to indicate the magnetic field pattern around this wire. [2]

- (b) The arrangement shown in the diagram below is used to determine the magnetic flux density between the poles of a permanent magnet.



The magnet is placed on the digital balance. The current-carrying wire is horizontal and at right angles to the magnetic field between the poles of the magnet. The wire is fixed.

The following results are collected.

- length of the wire in the uniform field of the magnet = 6.0 ± 0.2 cm
- balance reading with no current in wire = 80.0 g
- balance reading with current in wire = 82.2 g
- current in wire = 5.0 ± 0.1 A

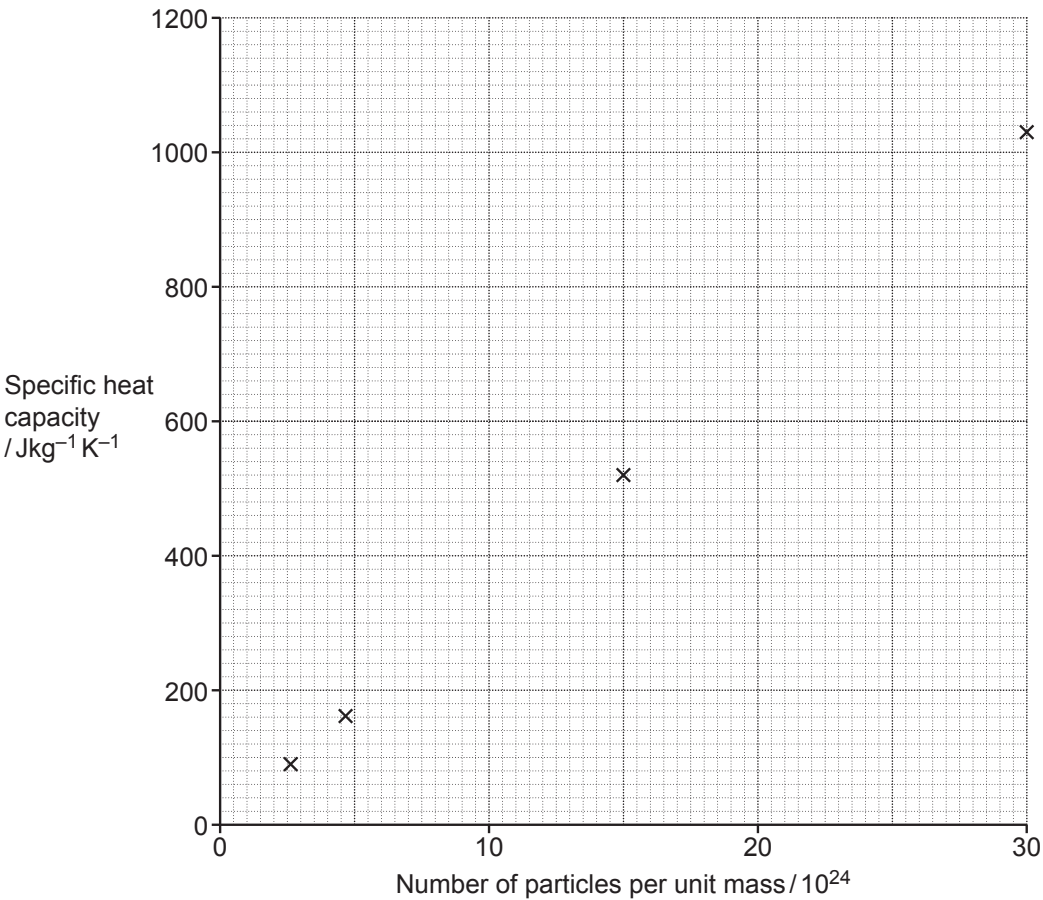
Calculate the magnetic flux density B , including the absolute uncertainty.
Ignore the absolute uncertainty in the balance readings.
Write your value for B to **2** significant figures and the absolute uncertainty to **1** significant figure.

$B = \dots\dots\dots \pm \dots\dots\dots \text{ T [4]}$

20 The specific heat capacities and molar masses of some common gases are given in the table.

Gas	Specific heat capacity / Jkg ⁻¹ K ⁻¹	Molar mass / kg mol ⁻¹	Number of particles per unit mass / 10 ²⁴
Neon	1030	0.020	30
Argon	520	0.040	15
Krypton	250	0.084	
Xenon	160	0.130	4.6
Radon	90	0.220	2.7

(a) Complete the missing value in the table. [1]



(b) Plot the missing data point on the graph above and draw a line of best fit. [2]

(c) Describe the relationship suggested by the graph and suggest an explanation.

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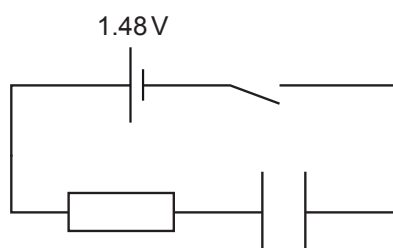
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.....

..... [4]



20 (a) The diagram below shows a circuit to charge a capacitor.

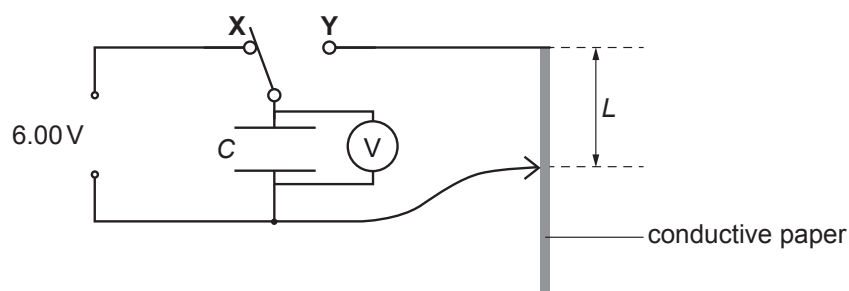


The electromotive force (e.m.f.) E of the cell is 1.48 V and it has negligible internal resistance. The resistance of the resistor is $120\text{ k}\Omega$ and the capacitance of the capacitor is $2000\text{ }\mu\text{F}$. At time $t = 0$ the capacitor is uncharged. The switch is closed at time $t = 0$.

Calculate the time t when the potential difference across the capacitor is 1.00 V .

$t = \dots\dots\dots\text{ s}$ [4]

(b) A capacitor of capacitance C is connected across a strip of conductive paper.



The switch is moved from **X** to **Y**, and the time t for the potential difference across the capacitor to halve is measured.

The time t is given by the expression

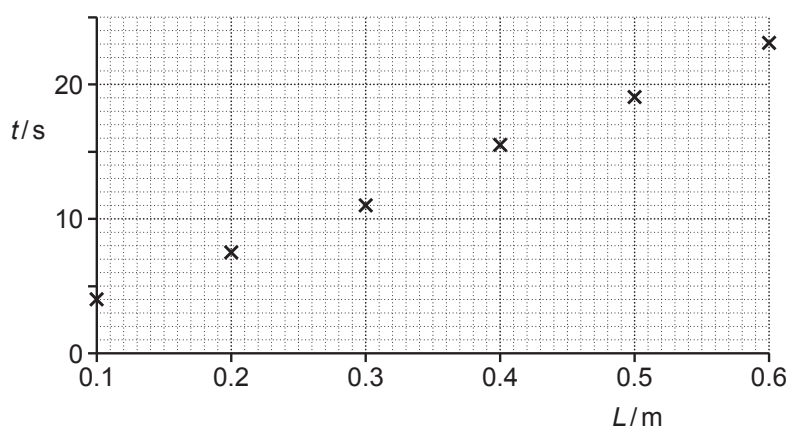
$$t = (Ck \ln 2) \times L$$

where k is the resistance of the conductive paper per unit length and L is the length of the conductive paper.

The value of C is $1.2 \times 10^{-3} \text{ F}$.

In an experiment, L is changed and t measured.

The data points are plotted on a t against L grid as shown below.

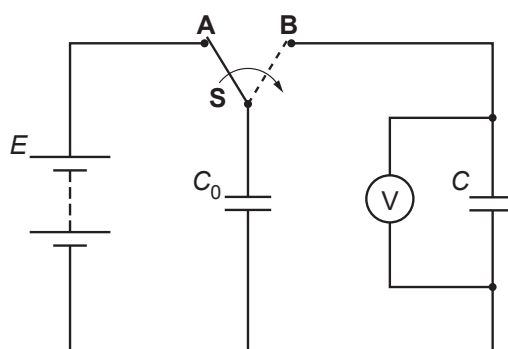


Draw a straight line of best fit through the data points, and use the gradient of this line to determine k .

$k = \dots\dots\dots \Omega \text{ m}^{-1}$ [4]

- 2 The diagram below shows a circuit containing two capacitors which are both initially uncharged. The battery has e.m.f. E and negligible internal resistance.

The switch **S** is first moved to position **A** until the capacitor of capacitance C_0 is fully charged.



The switch **S** is then moved to position **B**. The initial charge stored by the capacitor of capacitance C_0 is shared between the two capacitors. The final reading on the voltmeter is V .

- (a) Show that $V = \frac{C_0}{C + C_0} E$.

[2]

- (b) A student wants to determine the values of E and C_0 by repeating the experiment above and measuring the potential difference (p.d.) V for a selection of capacitors of capacitance C .

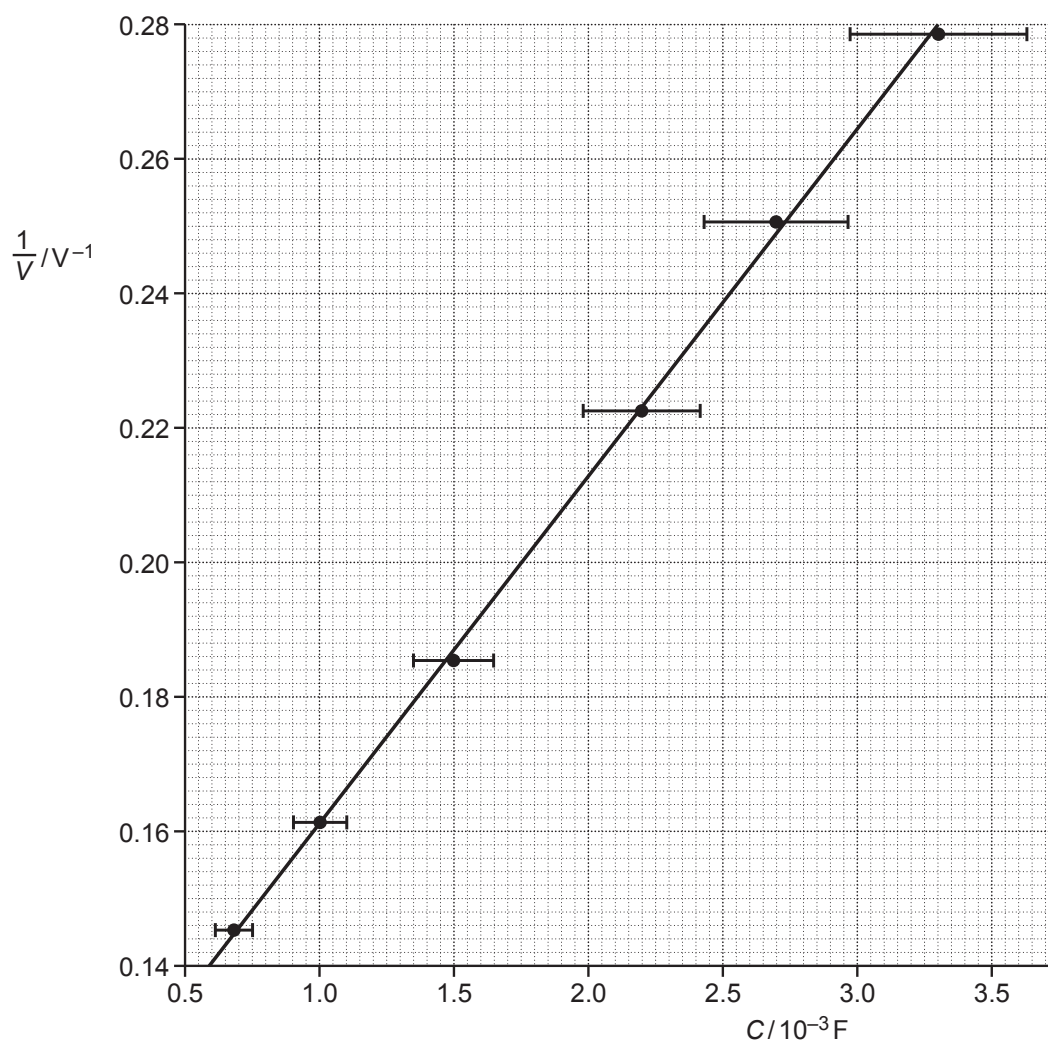
The student decides to plot a graph of $\frac{1}{V}$ against C .

- (i) Use the expression in (a) to show that the graph should be a straight line of gradient $\frac{1}{C_0 E}$ and y-intercept $\frac{1}{E}$.

[1]

Question 2 continues on page 6

- (ii) The data points, error bars and the line of best fit drawn by the student are shown in the graph below.



The gradient of the line of best fit is $51 \text{ V}^{-1} \text{ F}^{-1}$. The value of E is 9.1 V .

Determine the value of C_0 in millifarads (mF). Write your answer to 2 significant figures.

$C_0 = \dots\dots\dots \text{ mF}$ [2]

- (iii) Draw on the graph a straight line of worst fit.

Use this line to determine the absolute uncertainty in your value of C_0 . Write your answer to an appropriate number of significant figures.

absolute uncertainty = ... mF [4]

- (c) The experiment is repeated with a resistor of resistance $10\text{ k}\Omega$ placed in series between **S** and the capacitor of capacitance C_0 .

State with a reason what effect, if any, this would have on the experiment.

.....
.....
.....
..... [1]

- 22 (a)** A particle-accelerator uses a ring of electromagnets to keep protons moving continuously in a circle.

The speed v of the protons depends on the frequency f of rotation of the protons in the circular orbit.

Fig. 22 shows data points plotted on a v against f grid.

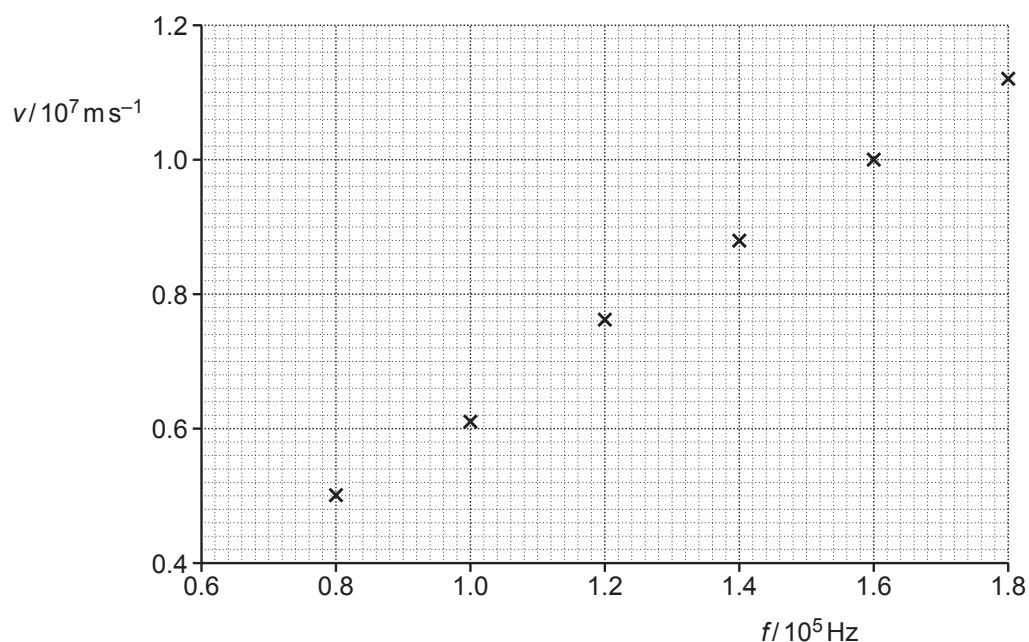


Fig. 22

- (i) Show that the gradient of the graph of v against f is equal to $2\pi r$, where r is the radius of the circular path of the protons.

[2]

- (ii) Show that r is about 10 m by determining the gradient of the line of best fit through the data points in **Fig. 22**.

[3]

- (iii) The maximum speed of the protons from this accelerator is $2.0 \times 10^7 \text{ m s}^{-1}$.

Calculate the maximum centripetal force F acting on a proton at this speed.

- mass of proton = $1.7 \times 10^{-27} \text{ kg}$.

$F = \dots\dots\dots \text{ N}$ [3]

- (b) A new particle-accelerator is now built for moving the protons in a circle of a radius 20 m.

The ring of electromagnets for this new accelerator provides the same **maximum** centripetal force as the accelerator in (a).

Calculate the maximum speed of the protons in this new accelerator.

maximum speed = $\dots\dots\dots \text{ m s}^{-1}$ [2]

- 3 A student is investigating how the discharge of a capacitor through a resistor depends on the resistance of the resistor.
The equipment is set up as shown in Fig. 3.1.

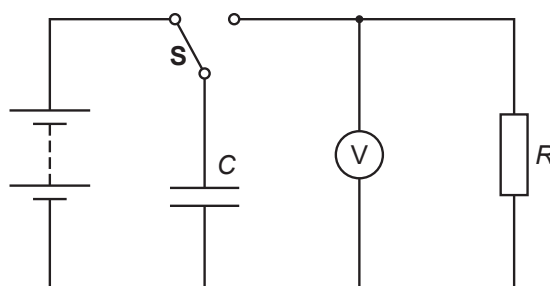


Fig. 3.1

The student charges the capacitor of capacitance C and then discharges it through a resistor of resistance R using switch **S**. After a time $t = 15.0\text{ s}$ the student records the potential difference V across the capacitor. The student repeats this procedure for different values of R .

It is suggested that V and R are related by the equation

$$V = V_0 e^{-\frac{t}{CR}}$$

where V_0 is the initial potential difference across the capacitor and t is the time over which the capacitor has discharged.

- (a) The student decides to plot a graph of $\ln(V/V_0)$ on the y -axis against $\frac{1}{R}$ on the x -axis to obtain a straight line graph. Show that the magnitude of the gradient is equal to $\frac{15}{C}$.

[2]

- (b) Values of R and V at $t = 15.0\text{ s}$ are given in the table below.

$R/\text{k}\Omega$	V/V_0	$\left(\frac{1}{R}\right)/10^{-6}\text{ }\Omega^{-1}$	$\ln(V/V_0)$
56	3.0 ± 0.2	18	
68	3.7 ± 0.2	15	1.31 ± 0.06
100	5.0 ± 0.2	10	1.61 ± 0.04
150	6.4 ± 0.2	6.7	1.86 ± 0.03
220	7.3 ± 0.2	4.5	1.99 ± 0.03
330	8.1 ± 0.2	3.0	2.09 ± 0.03

- (i) Complete the missing value of $\ln(V/V_0)$ and its absolute uncertainty in the table above.

[1]

- (ii) Use the data to complete the graph of Fig. 3.2. Four of the six points have been plotted for you. [2]

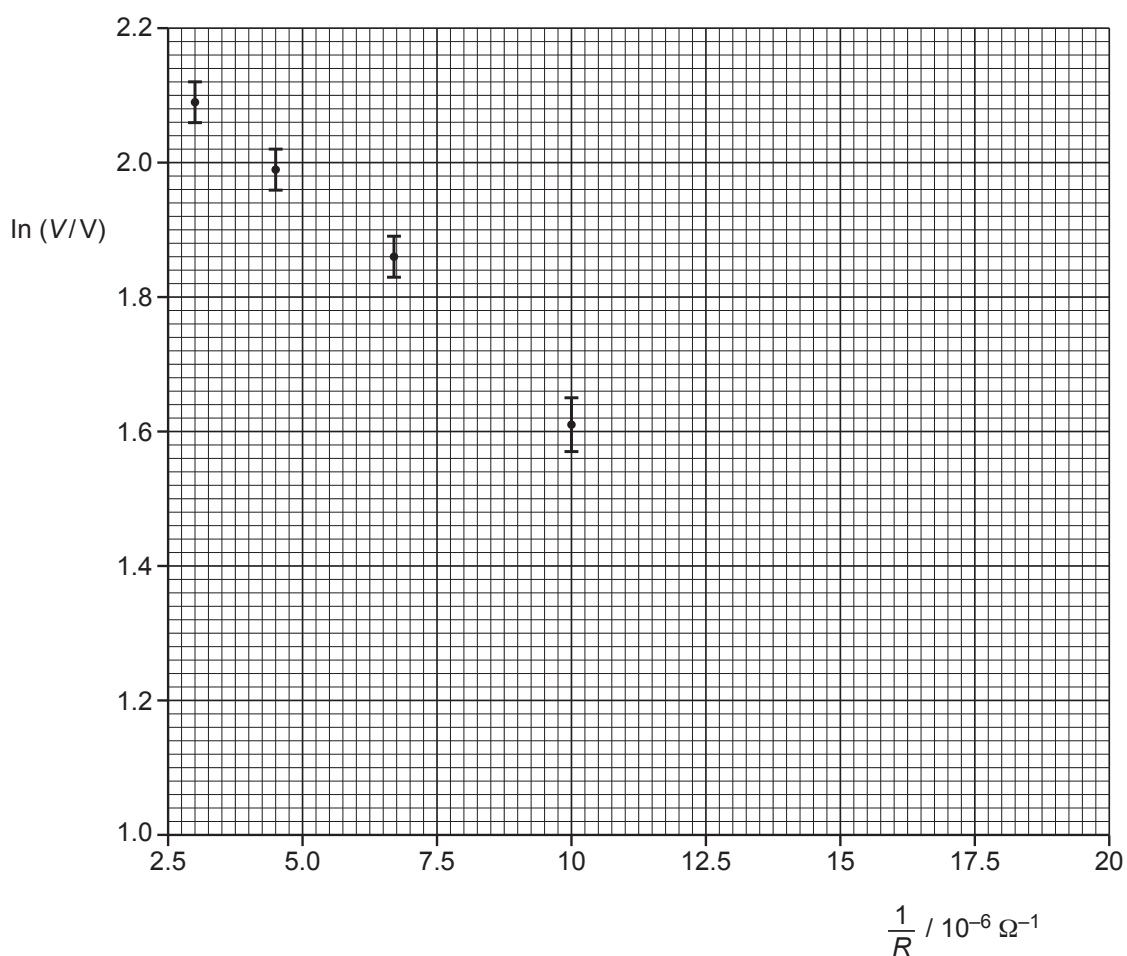


Fig. 3.2

- (iii) Use the graph to determine a value for C . Include the absolute uncertainty and an appropriate unit in your answer.

$C = \dots \pm \dots$ unit $\dots$ [4]

Turn over

- (c) Determine the value of R , in $\text{k}\Omega$, for which the capacitor discharges to 10% of its original potential difference in 15.0 s. Show your working.

$R = \dots\dots\dots \text{k}\Omega$ [2]

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Question 4 begins on page 10.



- 19 (a) The Planck constant h is an important fundamental constant in quantum physics.

Determine the S.I. base units for h .

base units = ... [2]

- (b) A researcher is investigating the de Broglie wavelength of charged particles.

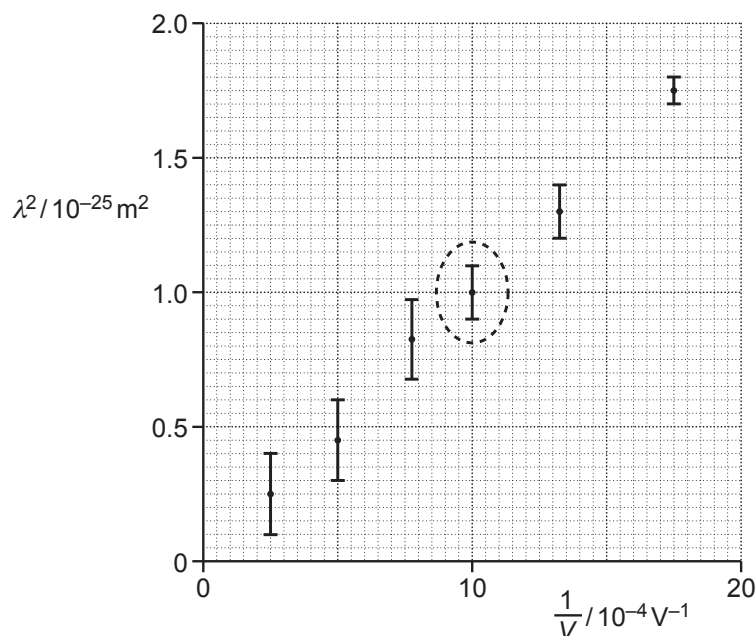
The charged particles are accelerated through a potential difference V . The de Broglie wavelength λ of these particles is then determined by the researcher.

Each particle has mass m and charge q .

- (i) Show that the de Broglie wavelength λ is given by the expression $\lambda^2 = \frac{h^2}{2mq} \times \frac{1}{V}$.

[2]

- (ii) The researcher plots data points on a λ^2 against $\frac{1}{V}$ grid, as shown below.



- 1 Calculate the percentage uncertainty in λ for the data point circled on the grid.

percentage uncertainty = ... % [2]

- 2 Draw a straight line of best fit through the data points. [1]

- 3 The charge q on the particle is $2e$, where e is the elementary charge.

Use your best fit straight line to show that the mass m of the particle is about 10^{-26} kg.

[4]

- 2 A student investigates the oscillations of a uniform rod of length L which is pivoted at the top, as shown in **Fig. 2.1**.

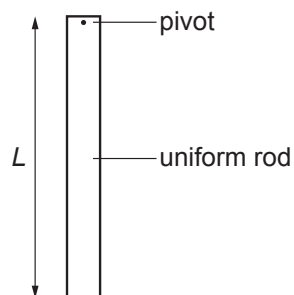


Fig. 2.1

- (a) Describe how to determine accurately the period T of oscillations of this rod.

.....

.....

.....

..... [2]

- (b) The relationship between the frequency f of the oscillations of the rod and its length L is

$$f = \frac{1}{2\pi} \sqrt{\frac{3g}{2L}},$$

where g is the acceleration of free fall.

The student varies the length L of the rod and determines the period T for each length.

The student plots a graph of T^2 against L , shown in **Fig. 2.2**. A line of best fit has already been drawn.

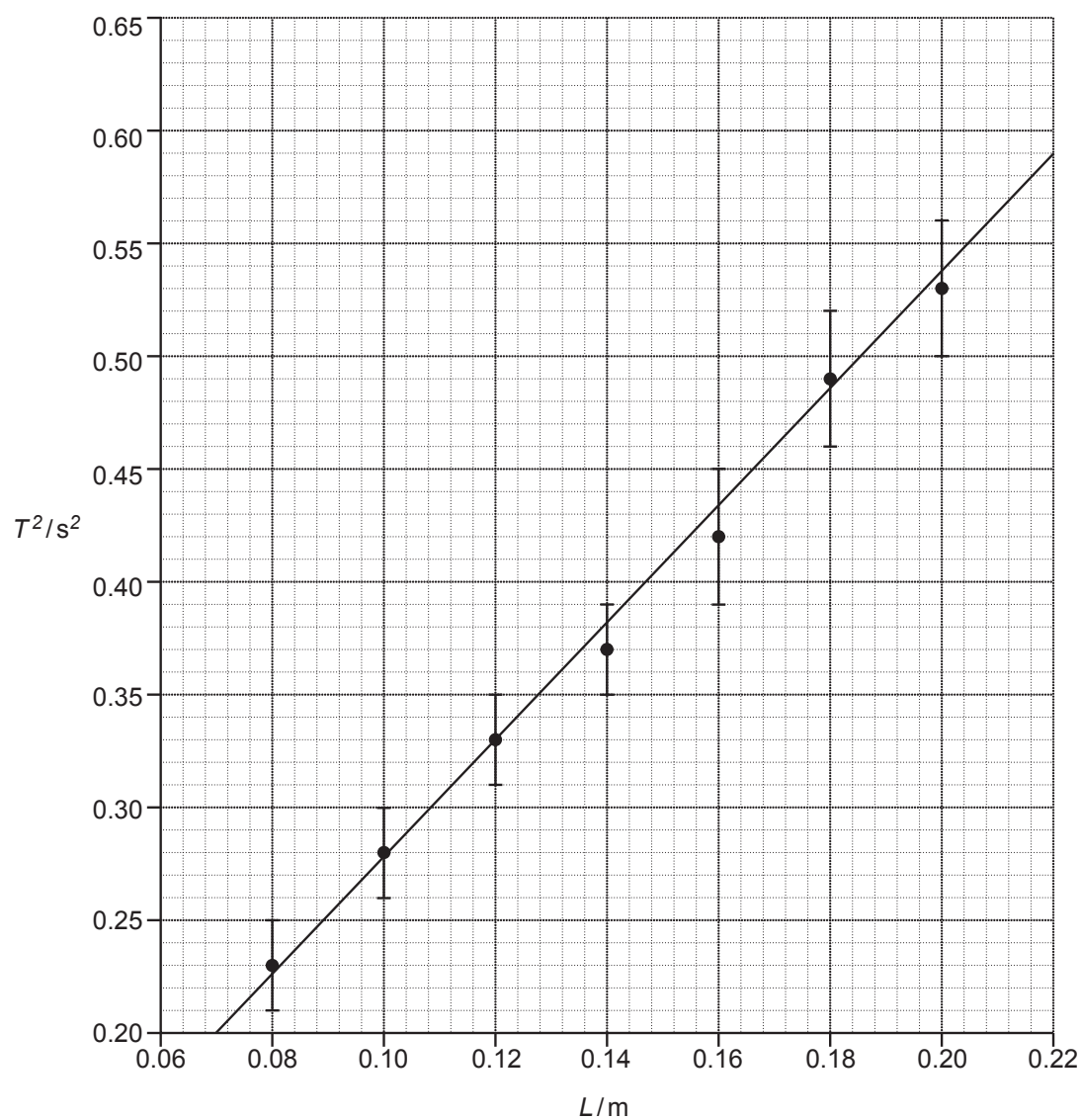


Fig. 2.2

- (i) Show that the gradient of the graph is given by the equation

$$\text{gradient} = \frac{8\pi^2}{3g}$$

[2]

- (ii) The gradient of the line of best fit on **Fig. 2.2** is $2.64 \text{ s}^2 \text{ m}^{-1}$.

Use this value to determine g .

$$g = \dots\dots\dots \text{ ms}^{-2} \text{ [2]}$$

- (iii) Draw a line of worst fit on **Fig. 2.2**.

[1]

- (iv) Use your line of worst fit to calculate the percentage uncertainty in g .

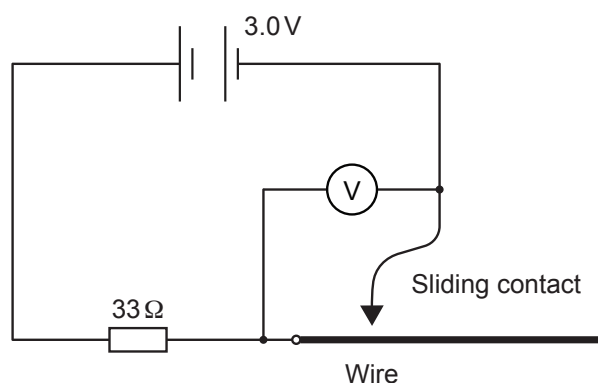
$$\text{percentage uncertainty} = \dots\dots\dots \% \text{ [3]}$$

- (v) Use the true value of g (9.81 ms^{-2}) to evaluate the accuracy of the student's value of g from this experiment. Include a calculation in your answer.

.....

 [2]

- 23 A student is investigating the resistance of a metal wire using the circuit shown below.



The battery has electromotive force (e.m.f.) 3.0V and negligible internal resistance.

- (a) Show that the resistance, R , of a length of this wire in terms of the p.d. across it, V , is given by the expression $R = \frac{33 V}{3.0 - V}$.

[2]

- (b) The student records the voltmeter reading V for different lengths l of the wire. The resistance of the wire is R .

l/cm	V/mV	R/Ω
40	320	3.94
50	390	
60	456	5.92
70	519	
80	579	7.89

- (i) Use the expression given in (a) to complete the two missing R values in the table.

[2]

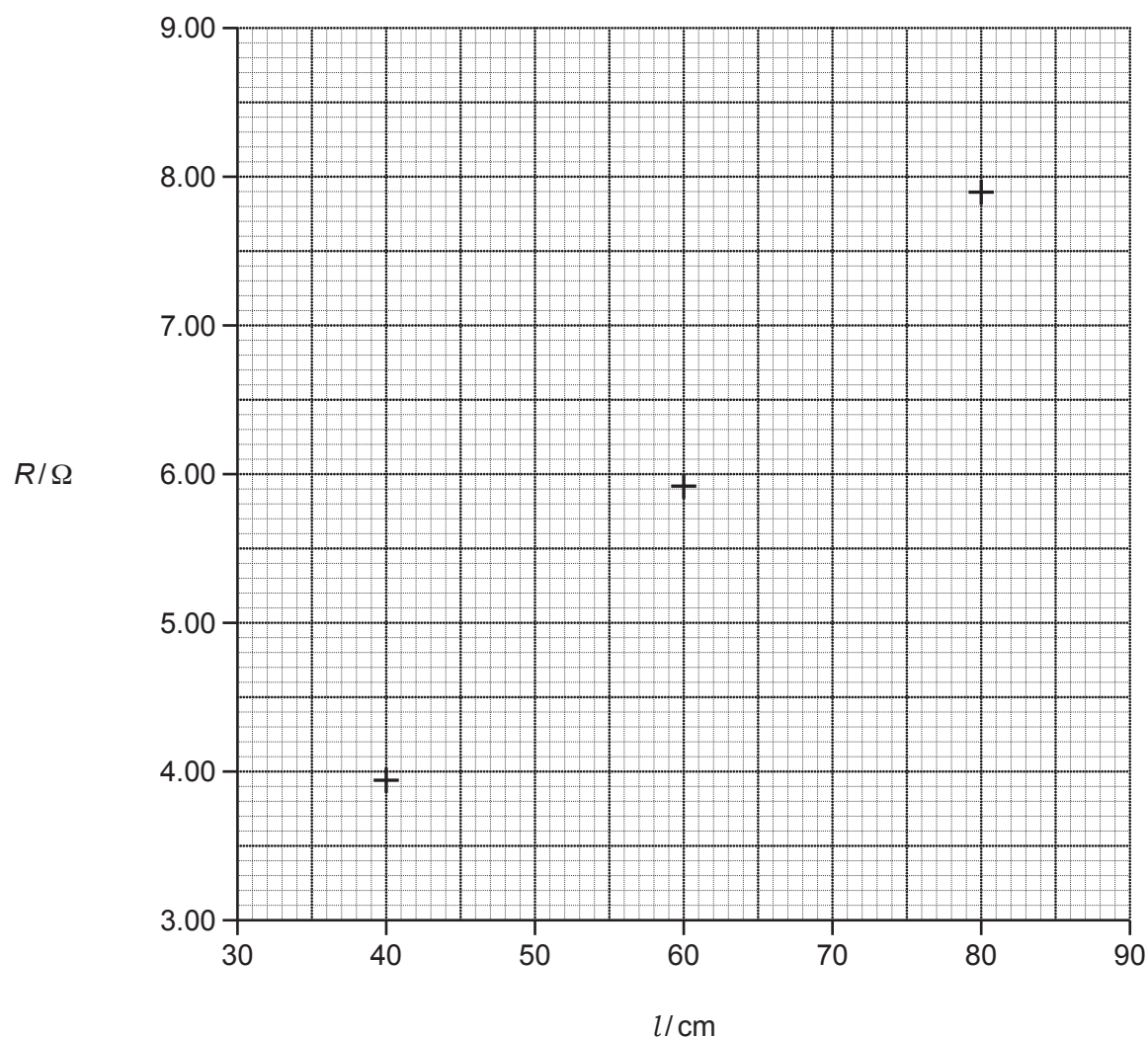
- (ii) The axes below show a plot of R against l .
Three points from the table have already been plotted.

Plot the remaining points.

[1]

- (iii) Draw on your plot a line of best fit.

[1]

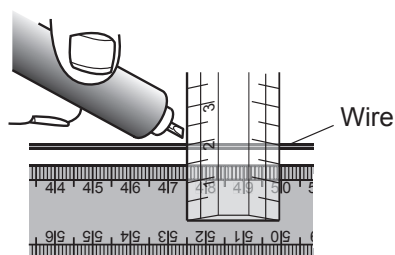


- (c) The wire is made of constantan which has a resistivity of $5.00 \times 10^{-7} \Omega \text{ m}$.

Use the gradient of the line of best fit to determine the diameter, d , of the wire.

$d = \dots\dots\dots \text{ m}$ [4]

- (d) The diagram below shows how the student uses the sliding contact to complete the circuit for a known length of wire.



Explain how this arrangement helps the student to make high-quality measurements.

.....

.....

.....

..... [3]

- 20 (a) An approximate value of the Planck constant h can be determined in the laboratory using light-emitting diodes (LEDs). An LED suddenly starts to conduct and emit monochromatic light when the potential difference across an LED exceeds a minimum value V_0 . The potential difference V_0 and the wavelength λ of the emitted light are related by the equation

$$V_0 = \left(\frac{hc}{e} \right) \times \frac{1}{\lambda}$$

where e is the elementary charge and c is the speed of light in a vacuum.

Fig. 20.1 shows some data points plotted by a student on a V_0 against $\frac{1}{\lambda}$ graph for five different LEDs.

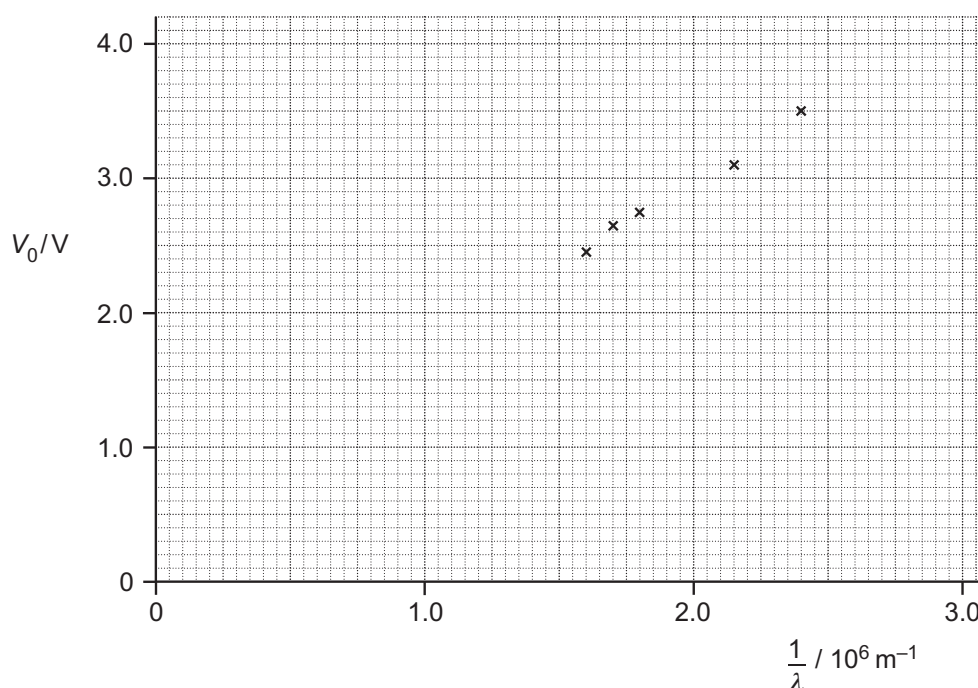


Fig. 20.1

The potential difference across each LED was measured using a digital voltmeter with divisions $\pm 0.01 \text{ V}$. The values for the wavelengths are accurate and were provided by the manufacturer of the LEDs.

The value of V_0 was determined by directly observing the state of the LED in the **brightly** lit laboratory.

- (i) Draw the straight line of best fit on Fig 20.1 and determine the gradient of the line.

- (ii) Use your answer in (i) and the equation on page 20 to determine a value for h to 2 significant figures. Show your working.

$h =$ Js [3]

- (iii) Calculate the percentage difference between your value in (ii) and the accepted value of the Planck constant.

difference = ... % [1]

- (iv) Identify the two types of errors shown by the data in Fig. 20.1 and suggest how you could have refined the experiment to reduce or eliminate these errors.

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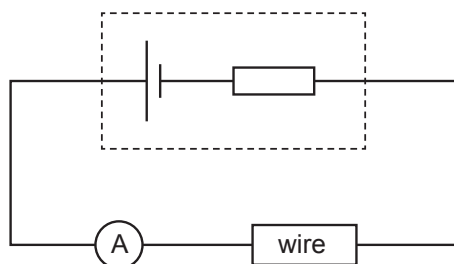
..... [4]

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Question 21 is on page 24
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- 2 A student uses the circuit below to investigate the resistivity of a wire.



The cell has e.m.f. ε and internal resistance r . The wire has resistivity ρ and diameter d .

- (a) The student takes five measurements of the diameter of the wire, which are shown in the table below.

Diameter/mm	0.460	0.450	0.455	0.495	0.455
-------------	-------	-------	-------	-------	-------

- (i) Suggest how the student made these measurements.

.....

 [2]

- (ii) The student calculates the value of the diameter as $d = 0.455 \pm 0.005$ mm.

Explain how the student calculated the value of the diameter, and its uncertainty, from the data in the table above.

.....

 [3]

(b) The student varies the length L of the wire in the circuit and records the current I using the ammeter.

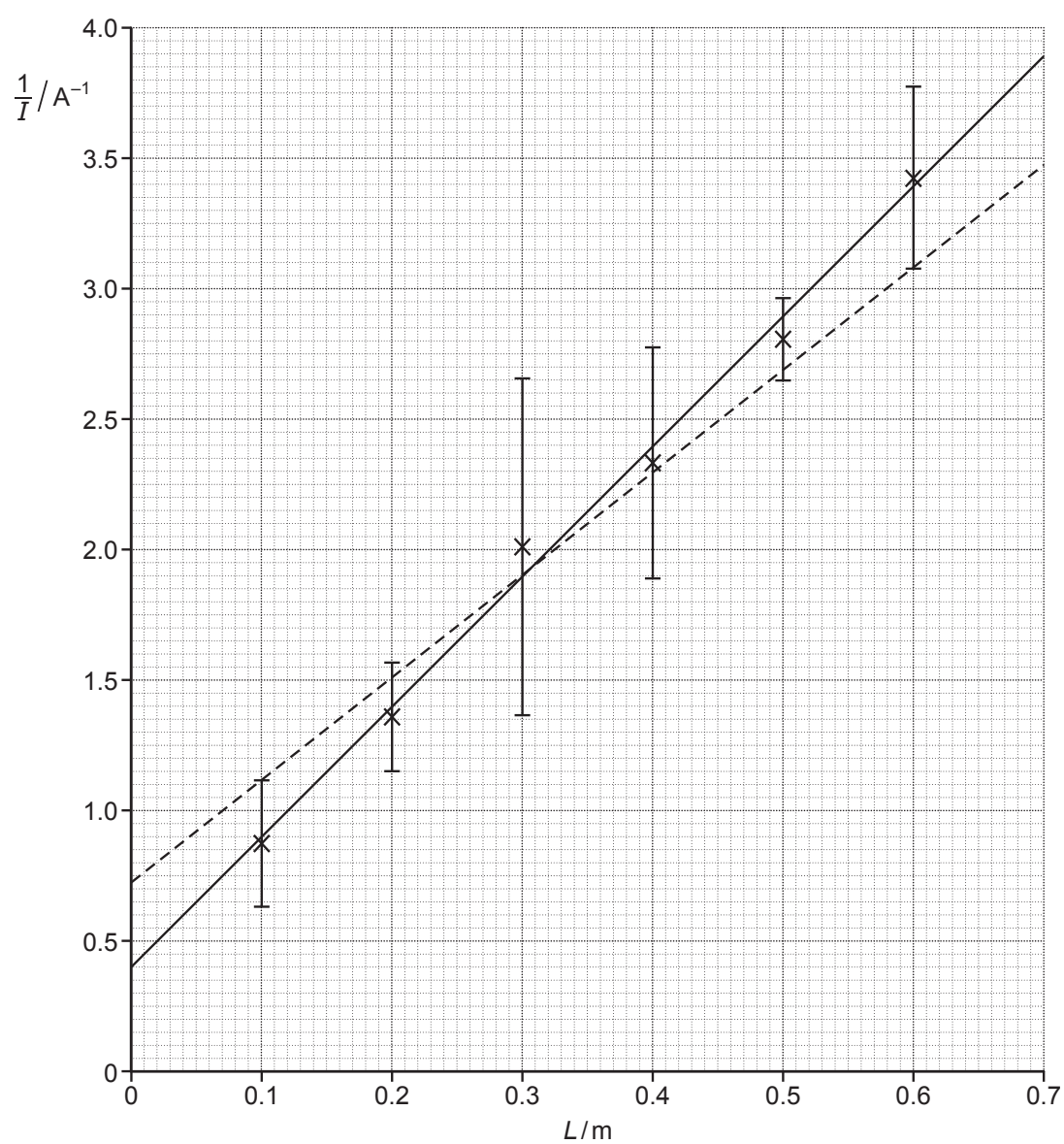
(i) Show that

$$\frac{1}{I} = \left(\frac{4\rho}{\pi \epsilon d^2} \right) L + \frac{r}{\epsilon}$$

[3]

Question 2 continues on page 6

- (ii) The student plots a graph of $\frac{1}{I}$ against L . The data points, error bars, line of best fit and a line of worst fit are shown in the graph below.



The cell has e.m.f. $\mathcal{E} = 1.45 \pm 0.05 \text{ V}$

The wire has diameter $d = 0.455 \pm 0.005 \text{ mm}$

- 1 Calculate the gradient of the best fit line and use this to determine a value for the resistivity ρ of the wire.

You are **not** required to determine an uncertainty.

$\rho = \dots\dots\dots \Omega \text{ m}$ [2]

- 2 Determine a value for the internal resistance r of the cell **and** its absolute uncertainty.

$r = \dots\dots\dots \pm \dots\dots\dots \Omega$ [4]

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- 2 $^{60}_{27}\text{Co}$ is produced by irradiating the stable isotope $^{59}_{27}\text{Co}$ with neutrons.

Each nucleus of $^{60}_{27}\text{Co}$ then decays into a nucleus of nickel (Ni) by the emission of a low energy beta-minus particle, one other particle and two gamma photons.

- (a) Complete the nuclear equations for these two processes.



- (b) Students want to carry out an investigation into gamma photon absorption using a source of $^{60}_{27}\text{Co}$.

They add sheets of lead between the source **S** and a radiation detector **T**, to give a total thickness d of lead. **S** and **T** remain in fixed positions, as shown in Fig. 2.1.

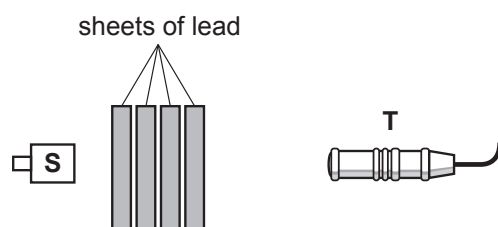


Fig. 2.1

- (i) The $^{60}_{27}\text{Co}$ source emits beta radiation as well as gamma radiation.

Explain why this would not affect the experiment.

.....
 [1]

Question 2 continues on page 6

- (ii) The students record the number N of gamma photons detected by **T** in 10 minutes for each different thickness d of lead. The background count is negligible.

The results are shown in a table. The table includes values of $\ln N$, including the absolute uncertainties.

N	d/mm	$\ln N$
4300 ± 440	0	8.37 ± 0.10
2500 ± 250	10	7.82 ± 0.10
1400 ± 150	20	7.24 ± 0.11
800 ± 90	30	6.68 ± 0.11
500 ± 60	40	6.21 ± 0.12
300 ± 40	50	

N and d are related by the equation $N = N_0 e^{-\mu d}$ where N_0 and μ are constants.

1. The students decide to plot a graph of $\ln N$ against d .

Show that this should give a straight line with gradient $= -\mu$ and y -intercept $= \ln N_0$.

[1]

2. Complete the missing value of $\ln N$ in the table, including the absolute uncertainty.

Show your calculation of the absolute uncertainty in the space below.

[2]

3. In Fig. 2.2, five of the data points have been plotted, including error bars for $\ln N$.
- Plot the missing data point and error bar.
 - Draw a straight line of best fit and one of worst fit.

[2]

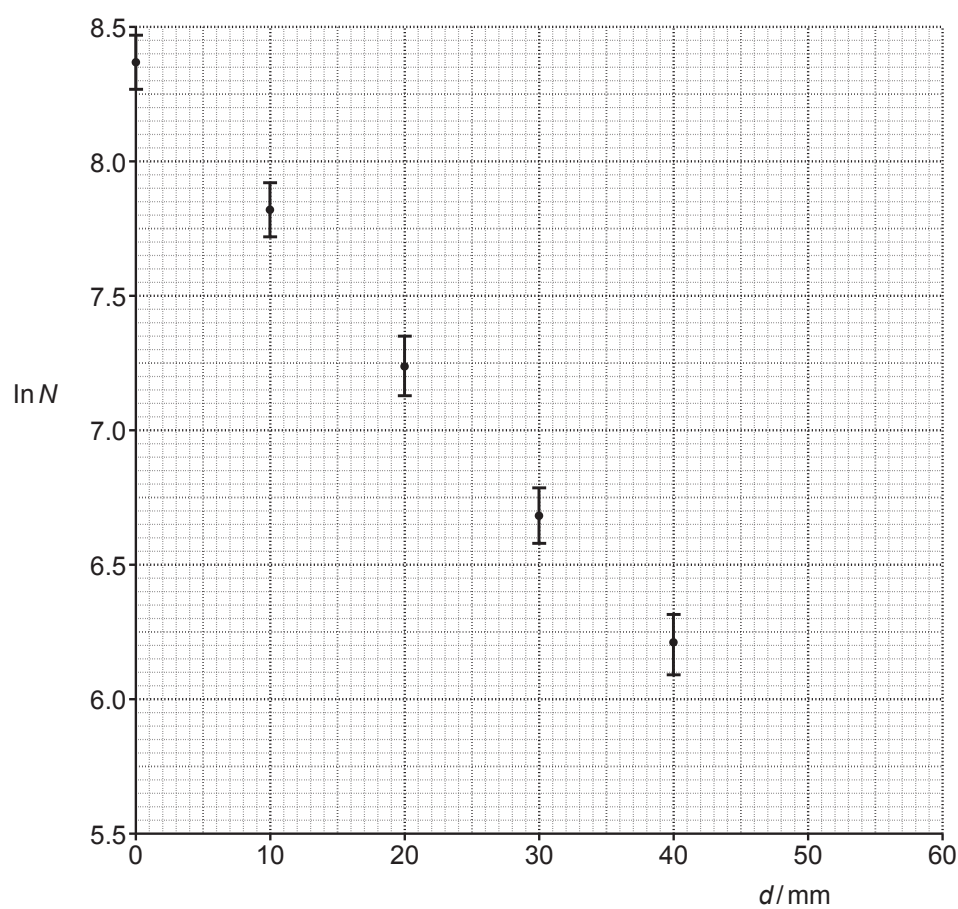


Fig. 2.2

Question 2 continues on page 8

4. Use Fig. 2.2 to determine the value of μ in m^{-1} , including the absolute uncertainty.

$$\mu = \dots\dots\dots \pm \dots\dots\dots \text{m}^{-1} \text{ [4]}$$

5. Determine the thickness, $d_{1/2}$, of lead which halves the number of gamma photons reaching T.

$$d_{1/2} = \dots\dots\dots \text{m} \text{ [2]}$$

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Question 3 begins on page 10.



23 Algol is a triple-star system, with stars Aa1, Aa2 and Aa3 orbiting each other. This triple-star is 90 light-years from the Earth.

(a) Here is some data on the star Aa1.

- radius = $(1.90 \pm 0.14) \times 10^9 \text{ m}$
- mass = $(6.31 \pm 0.42) \times 10^{30} \text{ kg}$.

Calculate the gravitational field strength g at the surface of Aa1 to **3** significant figures. Include the absolute uncertainty in your answer. Assume that the other stars of the system exert negligible gravitational force on Aa1.

$$g = \dots\dots\dots \pm \dots\dots\dots \text{ N kg}^{-1} \text{ [4]}$$

(b) The table shows some data about the three stars of Algol.

Star	Luminosity of star / $L_{\odot}$	Surface temperature of star / K
Aa1	182	13 000
Aa2	6.92	4500
Aa3	10.0	7500

The luminosity of each star is in terms of the solar luminosity $L_{\odot}$.

(i) Define the **luminosity** of a star.

.....
 [1]

(ii) Use Stefan's law to determine the ratio $\frac{\text{radius of star Aa2}}{\text{radius of star Aa3}}$.

$$\text{ratio} = \dots\dots\dots \text{ [2]}$$

- (iii) Use Wien's displacement law to explain which star would have the **longest** wavelength at the peak intensity of the emitted electromagnetic radiation.

.....

 [2]

- (iv) Suggest how an astronomer using just an optical telescope can deduce that the three stars of Algol have different surface temperatures.

.....
 [1]

- (v) The light from each star passing through a diffraction grating shows an absorption line spectrum.

Explain how a specific absorption line is produced in this type of spectrum in terms of **photons** and **electrons**.

.....

 [3]

- (c) The Aa1 star could evolve into a black hole.

State **two** ways in which the black hole would differ from the Aa1 star.

1.

 2.

 [2]



- 17 (a) Phobos is one of the two moons orbiting Mars. Fig. 17.1 shows Phobos and Mars.

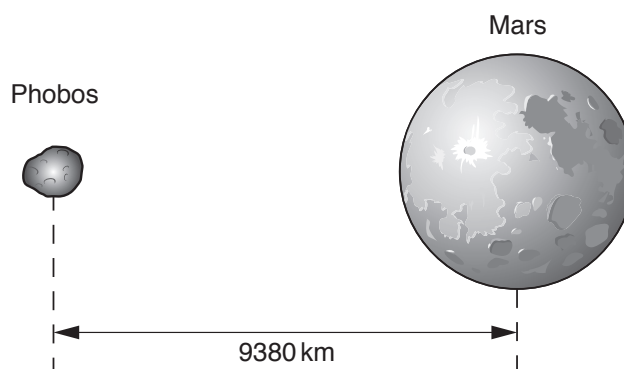


Fig. 17.1

The orbit of Phobos may be assumed to be a circle. The centre of Phobos is at a distance 9380 km from the centre of Mars and it has an orbital speed $2.14 \times 10^3 \text{ m s}^{-1}$.

- (i) On Fig. 17.1, draw an arrow to show the direction of the force which keeps Phobos in its orbit. [1]
- (ii) Calculate the orbital period T of Phobos.

$T = \dots\dots\dots \text{ s}$ [2]

- (iii) Calculate the mass M of Mars.

$M = \dots\dots\dots \text{ kg}$ [3]

- (b) The gravitational field strength at a distance r from the centre of Mars is g .

The table below shows some data on Mars.

$g/\text{N kg}^{-1}$	r/km	$\lg (g/\text{N kg}^{-1})$	$\lg (r/\text{km})$
1.19	6 000	0.076	3.78
0.87	7 000		
0.67	8 000	-0.174	3.90
0.53	9 000	-0.276	3.95
0.43	10 000	-0.367	4.00

- (i) Complete the table by calculating the missing values. [1]
- (ii) Fig. 17.2 shows the graph of $\lg (g/\text{N kg}^{-1})$ against $\lg (r/\text{km})$.

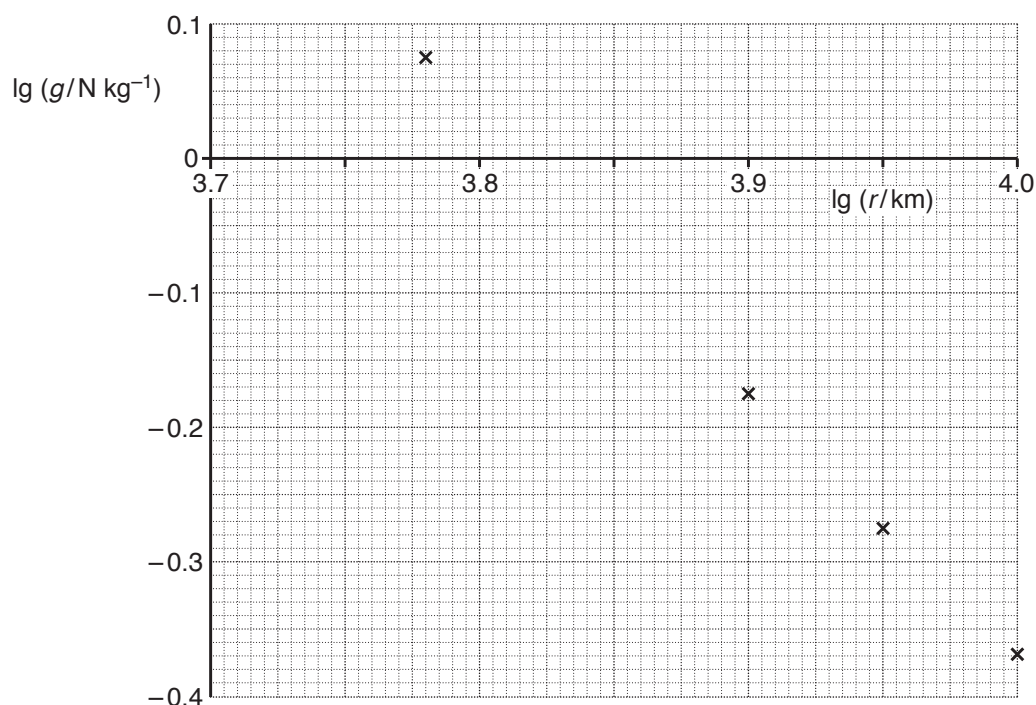


Fig. 17.2

- 1 Plot the missing data point on the graph and draw the straight line of best fit. [2]

- 2 Use Fig. 17.2 to show that the gradient of the straight line of best fit is -2 .

[1]

- 3 Explain why the gradient of the straight line of best fit is -2 .

[2]

- (c) In July 2018, the closest distance between the centre of Mars and the centre of Earth will be 5.8×10^{10} m.

Fig. 17.3 shows the variation of the **resultant** gravitational field strength g between the two planets with distance r from the centre of the **Earth**.

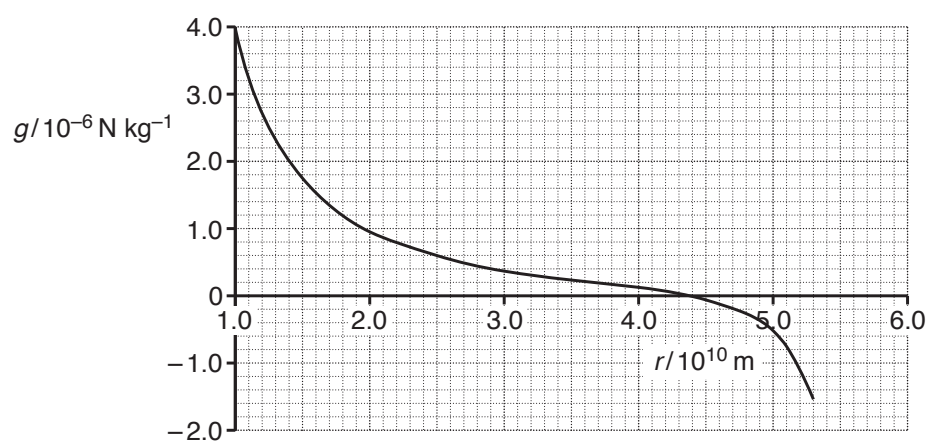


Fig. 17.3

- (i) Explain briefly the overall shape of the graph in Fig. 17.3.

.....

.....

.....

.....

..... [2]

- (ii) Use the value of r when $g = 0$ from Fig. 17.3 to determine the ratio

$$\frac{\text{mass of Earth}}{\text{mass of Mars}}.$$

$$\frac{\text{mass of Earth}}{\text{mass of Mars}} = \dots\dots\dots [2]$$



MARK SCHEMES

official mark schemes



5	C		1	
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11	D		1	
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3	D	1	
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13	D	1	
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2	B		1	
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2	C	1	
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5	B	1	
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9	C	1	
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24	(a)		$y = \sin(\theta) \sqrt{x^2 + y^2}$ compared with “ $y=mx+c$ ”	B1	Allow: gradient = $\frac{\Delta y}{\Delta(\sqrt{x^2+y^2})}$ with $\sin(\theta) = O/H$ Not: gradient = $\frac{y}{(\sqrt{x^2+y^2})}$ unless “$c=0$” seen.
	(b)	(i)	(Straight line of best fit showing) <u>gradient</u> = 0.73 ($d\sin\theta = n\lambda$) $\frac{1.0 \times 10^{-3}}{600} \times 0.73 = 2 \times \lambda$ $\lambda = 6.1 \times 10^{-7} \text{ (m)}$	C1 C1 A1	Allow: gradient in range 0.70-0.76. Allow: evaluation of $\theta = 44$-50 (degrees) in place of gradient Allow: any subject Note: Gradient in range 0.70-0.76 gives λ in range $(5.8 - 6.4) \times 10^{-7} \text{ m}$
		(ii)	(Scales/distances are large compared with the absolute uncertainty so) absolute uncertainty is too small to be shown (reasonably on this graph's scale) (AW)	B1	Ignore: error too small
		(iii)	(The values for λ or θ will be) less precise (as independent measurements less likely to agree) (AW)	B1	
			Total	6	



18		Level 3 (5–6 marks) Detailed quantitative discussion and comparison of uncertainties, and clear description of graphical analysis <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some quantitative discussion of uncertainty for one method and clear description of graphical analysis Or Discussion, with some quantitative ideas and comparison of uncertainty for both methods with some graphical analysis <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Incomplete discussion of uncertainty with no comparison Or Description of analysis <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i>	B1 x 6	Use level of response annotations in RM Assessor Indicative scientific points may include: Discussion of uncertainty • No repeat makes experiment inherently uncertain • Height +/- 1cm • Ramp length +/- 1mm • Resolution/"precision" of stopclock is 0.01s, but reaction time is much greater • Times +/- 0.1 s (or more) • Calculation of g will use time squared so double the percentage uncertainty in t • Angle likely to be +/- 1 or 2 degrees • Ramp calculation uses sine of angle, so difficult to quantify the uncertainty as a percentage to combine with other variables Comparison • Ramp method has greater time and length both greater so smaller percentage uncertainties • Frictional effects ramp method more • More difficult to measure times for drop • Uncertainty for height and ramp different Analysis • Ignore references to comparisons of the value of g found from both methods • Find g from $s = \frac{1}{2} a t^2$ for multiple values of s and average
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Question			Answer	Mark	Guidance
			0 marks <i>No response or no response worthy of credit.</i>		• Appropriate graphs plotted i.e. plotting t^2 on y-axis and s on x-axis, following some analysis/comparison with “$y=mx+c$” • Significance of gradient (e.g. t^2 against 2s gives gradient $1/g$ for drop method • Determine uncertainty graphically using best/worst line method
			TOTAL	6	

21	(a)	Both forces act on the same object (AW) The types of forces are different / one force is gravitational and the other force is electrostatic	B1 B1	 Allow: one force is gravitational (and the other is not)
	(b)	$T = 60/1600$ or $T = 3.75 \times 10^{-2}$ (s) $(v = \pi \times 0.50/3.75 \times 10^{-2})$ speed = 42 (m s ⁻¹) uncertainty = 3 (m s ⁻¹)	C1 A1 A1	Allow: $f = 26.7$ or $\frac{1600}{60}$ (Hz) or $\omega = 168$ (s ⁻¹) Note: v must be to 2 or more SF Note: uncertainty must be to 1 SF Allow: ecf on candidate's value for speed i.e. uncertainty = candidate's value / 16 (to 1 SF) Allow for 2 marks max: 84 ± 5 (m s⁻¹)
	(c)	$mv^2/r = mg$ or $v^2/r = g$ $v^2 = 9.81 \times 0.25$ $v = 1.6$ (m s ⁻¹)	C1 C1 A1	Allow: $v^2/r = a$ <u>and</u> $a = g$ or $mv^2/r = ma$ <u>and</u> $a = g$ Allow: any subject Allow: any subject Note: qualified 2.21 (ms ⁻¹) scores 2 marks.
		Total	8	



22	(a)	(%) uncertainty of T will be 4 times as significant as the uncertainty of L Should improve measurements leading to T	M1 A1	Allow reference to 4th power of T Allow comparison of $L^{(-)1/2}$ and T^2
	(b)*	Level 3 (5–6 marks) Clear description of method and analysis of data and correct explanation. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description of method and analysis of data or explanation. <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description or Limited analysis or Limited explanation <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1× 6	Indicative scientific points may include: Description of method - Equation using $\lg$ of both sides - Use of the $\lg X^b = b \lg X$ - Comparison with $y = mx (+ c)$ (y-intercept = 0) Analysis of data - Straight line through the origin - Gradient of the graph is b - Gradient calculated to be between 3 and 4 Explanation - Labelled sketch of HR diagram - Reference to Stefan's Law - Hotter stars (than the Sun) have greater luminosity (ratio) / luminosity ratio >1 - Hotter stars have much smaller mass ratio than luminosity ratio - Use of data (e.g luminosity of $\times 10,000$ means mass of about $\times 14$) therefore hotter stars lose mass at a much higher rate (compared to their mass) therefore hotter star lifespans are very much shorter than cooler stars
		Total	8	

17	(a)		Any <u>one</u> from: current, temperature, light intensity and amount of substance / matter	B1	Not: ampere, kelvin, candela and mole Not correct quantity with its unit, e.g. current in <u>A</u> or current (A)
	(b)	(i)	$R = \frac{\rho L}{A} \quad \text{and} \quad A = \pi \left(\frac{d}{2} \right)^2$ $R_x = \frac{4\rho L}{\pi d^2} \quad \text{and} \quad R_y = \frac{8\rho L}{\pi d^2}$ Clear steps leading to $R = \frac{12\rho L}{\pi d^2}$	M1 A1	
		(ii)1	Ruler / tape measure (for L) and micrometer (for d)	B1	Allow (vernier / digital) calipers or travelling microscope for micrometer
		(ii)2	$R = 2.3(4) (\Omega)$ $\frac{0.1}{9.5} \quad \text{or} \quad 2 \times \frac{0.003}{0.270}$ $\frac{0.1}{9.5} + 2 \times \frac{0.003}{0.270} \quad \text{or} \quad 0.0327 \quad \text{or} \quad 3.27\%$ absolute uncertainty in $R = 0.0327 \times 2.34 = 0.077$ $R = 2.3 \pm 0.1 (\Omega)$	C1 C1 C1 A1	Allow other correct methods for getting $2.3 \pm 0.1 (\Omega)$ Allow 2 or more sf for this C1 mark Note 0.0105 or 1.05% or 0.0222 or 2.22% scores this mark, allow 2sf or more Allow: $2.34 \pm 0.08 (\Omega)$ Note use of R_x or R_y instead of R can score the second and third C1 marks only
		(ii)3	(The actual) R is large(r) because (the actual) d is small(er) or (the actual) A is small(er) or $R \propto 1/d^2$	B1	Allow: The <u>calculated</u> R is small(er) because (the measured) A is large(r) or $R \propto 1/d^2$
			Total	9	

8

Question	Answer	Marks	Guidance
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5	(a)	Level 3 (5 - 6 marks) Clear procedure or correct determination of wavelength, plus reasonable estimation of uncertainty in λ or $(\sin) \theta$ <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Description of procedure or correct determination of λ, but no estimation of uncertainty or Clear estimation of uncertainty in wavelength but limited description of procedure and/or determination of λ or $(\sin) \theta$ or Some description of procedure, an attempt to determine the wavelength, and an attempt to estimate uncertainty in some of the measurements (e.g. in x) <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) A limited selection from the scientific points worthy of credit. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6 Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. <u>L1 maximum for any answers which use formula $\lambda = ax/D$</u> Indicative scientific points may include: Procedure • use formula $n\lambda = d\sin\theta$ • $n = 1$ since first order spectrum • find d using number of lines/mm = 300 mm⁻¹ • find θ using distance of grating from plastic ruler = 0.50 m and $x = 0.10$ m (not protractor) Determination of wavelength • calculate d ($= 10^{-3}/300$) = 3.3×10^{-6} m • use $x = 0.10$ m and distance to grating = 0.50 m to calculate $\tan \theta$ ($= 0.2$) • $\theta = 11.3^\circ$ • $\sin \theta = 0.196$ • alternatively, calculate hypotenuse of triangle (using Pythagoras's theorem) = 0.51 m, giving $\sin \theta$ ($= 0.10/2600^{1/2}$) = 0.196 • allow use of small angle rule ($\sin \theta \approx \tan \theta \approx \theta = 0.2$) • calculate λ ($= 0.196 \times 10^{-3}/300$) = 650 nm Estimation of uncertainty • negligible uncertainty in d (and n) • uncertainty in $\sin \theta$ is found using uncertainty in distance measurements • uncertainty in each distance measurement is ± 1.0 mm or ± 0.5 mm or ± 2.0 mm • maximum % uncertainty in $\tan \theta / \theta / \sin \theta = 3\%$ • so % uncertainty in $\lambda =$ % uncertainty in $\sin \theta = 3\%$
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H556/03

Mark Scheme

June 2019

Question			Answer	Marks	Guidance
5	(b)	(i)	$E = (hc/\lambda) = 6.63 \times 10^{-34} \times 3(.00) \times 10^8 / 486 \times 10^{-9}$ $E = 4.09 \times 10^{-19} \text{ (J)}$	M1 A0	This is a 'show that' question so the mark is for giving the full substitution of values leading to an answer correct to 3 SF
		(ii)	(vertical) arrow pointing downwards from -1.36 to -5.45	B1 B1	
			Total	9	



H556/03

Mark Scheme

June 2019

Question	Answer	Marks	Guidance
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17	(a)	(mean) = 1.87(2) (mm)	C1	
		(range) = 0.04 mm	C1	Allow use of resolution of micrometer (gives percentage uncertainty of 0.5%) Allow use of maximum or minimum deviation from the mean
		(percentage uncertainty) = $\frac{0.02}{1.872} \times 100$ percentage uncertainty = 1 (%)	A1	Allow 2 or 3 SF answer

	(b)*	Level 3 (5–6 marks) Clear description and clear analysis <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description and some analysis or Clear description or Clear analysis <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description or Limited analysis <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	B1 × 6	Use level of response annotation in RM Assessor. Indicative scientific points may include: Description • Determine T by measuring several oscillations • Independent and dependent variables identified (e.g. L and T) • Variables kept constant (e.g. for L and T experiment, m is kept constant) • Repeating to determine average T • Measure length L and width w with ruler • Measure thickness t with a vernier (calliper) / micrometer • Use video/phone camera / stopwatch / data-logger and motion sensor / light gates and timer • Use top-pan balance / scales to measure m Analysis • Plot an <u>appropriate</u> graph, e.g. T^2 against L^3 or tabulate $T^2 \div L^3$ • Gradient of best line determined or average of $T^2 \div L^3$ • Use a large triangle to determine gradient • Gradient (or equivalent) related to E, e.g. gradient = $16\pi^2 m / wEt^3$ for T^2 against L^3 graph
		Total	9	

23	(a)	(i)	$= 1 \div 0.00097$ $= 1000$ parsecs	A1	1030 to 3sf
		(ii)	$= 0.00097 \div 7.5 \times 10^{-3} (\times 100\%)$ $= 13\%$	C1 A1	NOT half of the precision here (reference specification) Accept 1 sig fig value 10% Unrounded answer is 12.93... %
	(b)	(i)	Use of $KE_{\text{mean}} = \frac{3}{2} kT = \frac{3}{2} \times k \times 4.0 \times 10^6$ $= \frac{3}{2} \times 1.38 \times 10^{-23} \times 4 \times 10^6$ $= 8.3 \times 10^{-17} \text{ J.}$	C1 A1	Allow k Unrounded answer is $8.28 \dots \times 10^{-17}$
		(ii)	$= -2.3 \times 10^{-16} + 8.3 \times 10^{-17}$ $= -1.5 \times 10^{-16} \text{ J.}$	B1	Allow use of 10^{-16} J from stem to give $-1.3 \times 10^{-16} \text{ J}$ Reject response without negative sign

Question			Answer	Mark	Guidance
		(iii)	selection of GMm/r Substitution of values for M, m and energy and rearrangement $3.2 \times 10^{10} \text{ m}$ e.g. $(-) \frac{GMm}{r} = (-) 1.5 \times 10^{-16}$ $r = \frac{6.67 \times 10^{-11} \times 1.1 \times 10^{31} \times 6.6 \times 10^{-27}}{1.5 \times 10^{-16}}$ $= 3.2 \times 10^{10} \text{ m}$	C1 C1 A1	Allow ECF from (b)(ii) NB Use of values in stem gives 3.7×10^{10}
		(iv)	Reference to Boltzmann distribution / AW OR Some particles will have greater kinetic energies / lower masses	B1	
			TOTAL	10	



23	(a)	$\Delta\lambda = 656.3 - 654 \text{ (nm) or } 2.3 \text{ (nm)}$ $v = c \times \Delta\lambda / \lambda = 3 \times 10^8 \times 2.3 / 656.3$ $= 1050 \text{ km s}^{-1}$	C1	Allow between 2.25 and 2.35
			C1	Check denominator is 656.3 and not 654 (XP)
			A1	Ignore minus sign Accept 1100 (km s ⁻¹)
	(b)	$d = v/H_0 = 1050000 \div 2.5 \times 10^{-18} = (4.2 \times 10^{23} \text{ m})$ $4.2 \times 10^{23} \text{ m} \div 9.5 \times 10^{15} = 4.4 \times 10^7 \text{ light years}$	C1	ECF from (a) Using 1100 km s ⁻¹ gives $4.6 \times 10^7 \text{ ly}$
			A1	
	(c)	Absolute uncertainty in $\Delta\lambda$ in range of 0.4-1.2 nm $\% \text{ Uncertainty} = (\text{candidate's abs uncertainty} \div 2.3) \times 100 = 21\%$	C1	Allow value that if rounded to 1sf would be in the range
			A1	Accept 1sf answer Allow in range 17 – 52 %

Question		Answer	Mark	Guidance
(d)		Any two from: Hubble's law assumes/predicts all galaxies moving away / AW	B1	i.e. correct statement of Hubble's law
		(from evidence in question) M87 is blue shifted/moving towards the Milky Way / AW	B1	Accept has a negative recession velocity
		Idea that M87 may 'gravitationally associated' with Milky Way/Local cluster/Virgo supercluster	B1	Allow any reasonable alternative
		Suitable comment comparing absolute uncertainty with difference in velocities or percentage uncertainty with percentage difference	B1	E.g. percentage uncertainty from change in wavelength s larger than the percentage difference in the quoted distance and the calculated distance
e		One from • Cosmic microwave background evidence • Very few galaxies are blue shifted	B1	Allow decipherable truncations or acronyms e.g. CMBR, MBR Allow other reasonable ideas that supports model (e.g. nucleosynthesis ratios, He:H ratio enhancement (extra helium), universe may not be uniform and/or isotropic, no other model is consistent with the evidence, universe is still expanding)
TOTAL			10	



Question	Answer	Mark	Comments
4 (a)	(change in) KE = (change in) GPE /AW $\frac{1}{2}(m + 0.8)v^2 = 0.6 mg$ (and hence equation as shown on QP)	M1 A1	allow $mgh = \frac{1}{2}Mv^2$ as long as it is clear that m and M are different, i.e. NOT $mgh = \frac{1}{2}mv^2$ allow linear motion equation $v^2 = u^2 + 2as$ <u>and</u> $F = Ma$ (W =) $mg = (m + 0.8)a$; $u = 0$ and $s = 0.6$
(b) (i)	(v^2 =) 4.93 ($\pm$) 0.22	B1 B1	allow 4.9 ($\pm$) 0.2 (same number of decimal places)
(ii)	Point (and error bar) plotted correctly Line of best-fit drawn through all points shown (use protractor tool at 49°)	B1 B1	tolerance $\pm\frac{1}{2}$ small square; possible ecf from (b)(i) allow ecf from point plotted incorrectly or point omitted
(c) (i)	$v^2 = \frac{1.20mg}{(m + 0.800)}$ compared with $y = mx + c$	B1	allow minimum of gradient = $v^2/[m/(m + 0.8)] = 1.2 g$ or expect $y = v^2$ <u>and</u> $x = m/(m + 0.800)$ so gradient = $1.20g$
(ii)	one acceptable worst-fit line drawn large triangle used to determine gradient Gradient (used to determine 'worst' g) absolute uncertainty given to one decimal place	B1 B1 B1 B1	roughly between extremes of top and bottom error bars or by eye; consequential ecfs for rest of (ii) $\Delta x > 0.13$; expect steepest 12.5 ± 0.2 or shallowest 10.3 ± 0.2 if point from bii not plotted steepest line is 12.9 answer from ± 0.8 to $1.1(m s^{-2})$; allow ecf from gradient value
(d)	card appears shorter or time measured shorter calculated speed of trolley larger gradient of graph steeper or $v^2 \propto g$ /AW so calculated g is greater	B1 B1 B1 B1	N.B. each B mark is consequential on the previous statement; e.g. ecf max of 3 marks for correct consequences of stating card appears longer or time longer
	Total	15	

7	A	1	
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3	A		1	
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19	(a)	Direction of field shown as clockwise <u>Three</u> field lines shown as concentric circles and distance between adjacent field lines increasing as distance from wire increases	B1 B1	Expect at least one field line with an arrow Allow more than three lines, but distance between adjacent field lines increasing distance from wire must increase for all
	(b)	(force =) $2.2 \times 10^{-3} \times 9.81$ $2.2 \times 10^{-3} \times 9.81 = B \times 5.0 \times 0.060 (= 0.072 \text{ T})$ (absolute uncertainty =) $\frac{0.2}{6.0} + \frac{0.1}{5.0} \quad (\times 0.072 = 0.0038 \text{ T})$ $B = 0.072 \pm 0.004$	C1 C1 C1 A1	Allow calculation of percentage uncertainty = 5.3% Allow calculation of max B (=0.0759 T) and min B (=0.0683 T) Note B must be given to 2 SF and the uncertainty given to 1 SF. Special case: allow follow through from incorrect B calculation.
		Total	6	

20	(a)		7.1 or 7.2	B1	2sf answer required
	(b)		Correct plotting at (7.2, 250) within half a small square Straight line of best fit with balanced spread of points either side of the line.	B1 B1	ECF allowed from (a)
	(c)		Relationship - s.h.c is directly proportional to the number of particles per unit mass Explanation Any three from: - Straight line through the origin - s.h.c. is the energy required to increase temperature of unit mass by unit temperature - Increasing temperature requires increasing <u>KE</u> of particles - More particles (per unit mass) will therefore require more energy	B1 B1 B1 B1	Do not allow inversely proportional to molar mass Allow equation with correct constant (3.4×10^{-23}) Allow 'kg' for 'unit mass' and 'degree or kelvin' for 'unit temperature' Allow equation with terms defined Allow both number of particles and required energy are both directly proportional to mass
			TOTAL	7	

20	(a)	$(CR =) 2000 \times 10^{-6} \times 120 \times 10^3$ $1.00 = 1.48 \times [1 - e^{-t/240}]$ or $0.48 = 1.48e^{-t/240}$ $(t =) -240 \times \ln(0.48/1.48)$ $t = 270 \text{ (s)}$	C1 C1 C1 A1	$CR = 240 \text{ (s)}$ Special case: 94 (s) for use of discharging equation. Max 2 marks
	(b)	Line of best fit drawn through the data points Gradient = 38 $(Ck \ln 2 = \text{gradient})$ $1.2 \times 10^{-3} \times k \times \ln 2 = 38$ $k = 4.6 \times 10^4 \text{ (}\Omega \text{ m}^{-1}\text{)}$	B1 C1 C1 A1	Allow ± 2 . Not calculated through use of a single point. Possible ECF from incorrect gradient Note: gradient of 40 gives 4.8×10^4 and gradient of 36 gives 4.3×10^4
		Total	8	

2	(a)		(initial charge) $Q = EC_0$ or (Q conserved so final) $Q = V(C + C_0)$ (as capacitors are in parallel) <u>so</u> $EC_0 = V(C + C_0)$ (and hence $V = C_0 E / (C + C_0)$)	M1 A1	At least one correct expression for Q for first mark The two correct expressions equated for the second mark
	(b)	(i)	$1/V = 1/E + C/EC_0$ (and compare to $y = c + mx$)	B1	Mark is for rearrangement into linear equation
		(ii)	$1/EC_0 = 51 = 1/(9.1 C_0)$ giving $C_0 = 1/(51 \times 9.1) \text{ F}$ $C_0 = 2.2 \text{ (mF)}$	B1 B1	$C_0 = 2.1547 \times 10^{-3} \text{ F}$ Answer must be correct, rounded correctly and given in mF Candidate's answer must be given to 2 SF
		(iii)	(at least) one correct worst fit line drawn gradient calculated correctly using a large triangle uncertainty = $C_0 - 1/(\text{wfl gradient} \times 9.1)$ uncertainty given is to the same number of decimal places as C_0	B1 B1 B1 B1	Top and bottom points chosen must be from opposite extremes of uncertainty limits, accurate to within half a small square $\Delta x \geq 1.5 \times 10^{-3}$; expect 59 ± 1 or 44 ± 1 (or 0.059 or 0.044); allow ECF from poorly drawn line; readings must be accurate to within half a small square ECF from b(ii) ; expect uncertainty of up to 0.4 (mF) ECF from b(ii) If no value for C_0 given in b(ii) , allow any answer given to 1dp
	(c)		Only effect is to slow the charging and/or discharging (of capacitor(s)) <u>and so</u> the final charges are unchanged / the values for V are unchanged / the graph is unchanged / the gradient is unchanged / there is no effect on the experiment (results)	B1	Allow and so the experiment takes longer
Total				10	

Question	Answer	Marks	Guidance
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22	(a)	(i)	$\{v = \omega r \text{ and } \omega = 2\pi f\} \text{ or } v = 2\pi fr$ Comparison with $y = mx$ leading to gradient = $2\pi r$ or $\Delta v / \Delta f = 2\pi r$	B1 B1	Allow $v/f = 2\pi r$
		(ii)	Line of best fit drawn Gradient = 62.5 (m) $2\pi r = 62.5$ $r = 9.9$ (m)	B1 M1 M1 A0	Allow ± 3 Allow ECF on gradient
		(iii)	$F = \frac{mv^2}{r} \text{ or } F = ma \text{ and } a = \frac{v^2}{r}$ $F = \frac{1.7 \times 10^{-27} \times [2.0 \times 10^7]^2}{9.9}$ $F = 6.8 \times 10^{-14} \text{ (N)}$	C1 C1 A1	Allow use of candidate's answer for (ii) or use of '10' Expect answers of 6.8 or 6.9×10^{-14} (N)
	(b)		$r \propto v^2$ / speed increases by a factor of $\sqrt{2}$ maximum speed = $2.8 \times 10^7 \text{ (m s}^{-1}\text{)}$	C1 A1	Allow substitution into correct equation with r doubled Allow recalculation from previous value of force in (a)(iii)
			Total	10	

Question	Answer	Marks	Guidance
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Question	Answer	Mark	Guidance
3 (a)	Take $\ln$ to give $\ln V = -(t/C).1/R + \ln V_0$ gradient (m) = $(-)\ t/C$ where $t = 15$	M1 A1	allow $\ln(V/V_0) = -(t/C).1/R$
(b) (i)	1.10 ± 0.07	B1	value plus uncertainty required for the mark
(ii)	two points plotted correctly to within $\frac{1}{2}$ small square on x-axis; line of best fit	B1 B1	ignore accuracy of length of error bar; ecf bi value or both worst acceptable lines drawn
(iii)	gradient ($= 15/C$) = 6.6×10^4 ; $C = 15 / 6.6 \times 10^4 = 2.3 \times 10^{-4}$ (F) worst acceptable straight line drawn $(C) \pm 0.3 \times 10^{-4}$ F	C1 A1 B1 B1	accept 6.4 to 6.8 ignore power of 10 accept $2.3 \pm 0.1 \times 10^{-4}$ allow ecf for the point calculated incorrectly in b(ii) ; steepest or shallowest possible line that passes through <u>all</u> the error bars; should pass from top of top error bar to bottom of bottom error bar or bottom of top error bar to top of bottom error bar allow e.g. $(C) \pm 0.2 \times 10^{-4}$; allow value of C to 4 SF but N.B. the uncertainty and the value of C must be to the same number of decimal places allow $230 \pm 30 \mu\text{F}$ etc allow equivalent unit including $\text{s } \Omega^{-1}$, C V^{-1} , A s V^{-1}
(c)	$\ln(0.1) = -15/RC$ or $R = -15/C \ln(0.1)$ or $R = 0.65/C$ $R = 0.65/2.3 \times 10^{-4}$ giving $R = 28 \text{ k}\Omega$	C1 A1	$\ln(0.1) = -2.30$ ecf (b)(iii)
Total		11	

H556/03

Mark Scheme

June 2017

Question	Answer	Marks	Guidance
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19	(a)		$h \rightarrow \text{J s} \quad / \quad h \rightarrow \text{N m s} \quad / \quad \text{J} \rightarrow \text{kg m}^2 \text{s}^{-2}$ base unit = $\text{kg m}^2 \text{s}^{-1}$	C1	
				A1	
	(b)	(i)	$Vq = \frac{1}{2} mv^2$ and $\lambda = \frac{h}{mv}$ Clear algebra leading to $\lambda^2 = \frac{h^2}{2mq} \times \frac{1}{V}$	M1	Allow p for mv Allow e for q in (b)(i) – this is to be treated as a ‘slip’
				A1	
		(ii)1	(% uncertainty in λ^2) 10%	C1	
			(% uncertainty in λ) 5%	A1	Note 10 (%) on answer line will score the C1 mark
		(ii)2	Straight line of best fit passes through all error bars	B1	
		(ii)3	gradient = $1.0 (\times 10^{-22})$ $\frac{h^2}{2mq} = \text{gradient}$ $\frac{(6.63 \times 10^{-34})^2}{2 \times m \times 3.2 \times 10^{-19}} = \text{gradient}$ $m = 6.9 \times 10^{-27} \text{ (kg)}$ (hence about 10^{-26} kg)	C1	Ignore POT for this mark; Allow $\pm 0.20 (\times 10^{-22})$
				C1	
				C1	Possible ECF for incorrect value of gradient
				A1	Note check for AE (condone rounding error here) and answer must be about 10^{-26} (kg) for any incorrect gradient value for this A1 mark Special case: $1.37 \times 10^{-26} \text{ kg}$ scores 3 marks for $q = 1.6 \times 10^{-19} \text{ C}$ because answer is about 10^{-26} kg
			Total	11	

2	(a)		use of stopclock (or stopwatch or timer) time n oscillations and divide by n	B1 B1	If n is specified then $n \geq 5$
	(b)	(i)	$f = 1/T$ working shown to give $T^2 = \left(\frac{8\pi^2}{3g}\right)L$	B1 B1	Allow $T = 2\pi \left(\frac{2L}{3g}\right)^{\frac{1}{2}}$ or $f^2 = 1/T^2$ Subject must be T^2 Allow $T^2/L = 8\pi^2/3g$
		(ii)	$g = \left(\frac{8\pi^2}{3 \times 2.64}\right)$ $g = 9.97 \text{ (m s}^{-2}\text{)}$	C1 A1	Answer must be given to at least 3sf
		(iii)	line of worst fit drawn	B1	Steepest or shallowest possible line that passes through all the error bars (allow $\pm\frac{1}{2}$ small square tolerance vertically) If two lines are drawn then they must both be correct
		(iv)	gradient of worst line calculated with large triangle working to find percentage uncertainty in g answer consistent with candidate's worst line	B1 M1 A1	$\Delta L \geq 0.06\text{m}$ Shallowest gradient $\approx 2.1(\text{s}^2 \text{ m}^{-1})$ and steepest $\approx 2.9 (\text{s}^2 \text{ m}^{-1})$ $\frac{\text{worst value of } g - 9.97}{9.97} (\times 100\%)$ Allow % uncertainty in gradient = $\frac{\text{gradient of wfl} - 2.64}{2.64} (\times 100\%)$ Expect answer $\approx 10\%$ (steepest wfl) and $\approx 27\%$ (shallowest wfl) Allow a negative answer
		(v)	percentage difference = $\frac{9.97 - 9.81}{9.81} \times 100\% = 1.6\%$ or absolute difference = $9.97 - 9.81 = 0.16$ or absolute uncertainty = $(9.97 - \text{value of } g \text{ from wfl})$ conclusion consistent with candidate's answer to (b)(iv)	M1 A1	Possible ECF from (b)(ii) Value for g is accurate if % uncertainty > % difference or if absolute uncertainty > absolute difference or if 9.81 lies within the uncertainty range for g
			Total	12	

Question	Answer	Mark	Guidance
23	(b) (i)	4.93 and 6.90	B1
		Both rounded to 2dp	
23	(b) (ii)	Two points within ½ square tolerance	B1
23	(b) (iii)	Line of best fit	B1
23	(c)	Evidence of use of at least half of the line in calculation of gradient	B1
		Evidence of calculation of gradient of their line using a pair of points	B1
		Identify that gradient = ρ / A	C1
		Area = $\pi d^2/4 = \rho / \text{gradient}$, so	
		$d = \sqrt{\frac{4 \times \rho}{\pi \times \text{gradient}}} = \sqrt{\frac{4 \times 5.00 \times 10^{-7}}{\pi \times 9.9}}$	
		$d = 2.5 \times 10^{-4} \text{ (m)}$	A1

[illegible]

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20	(a)	(i)	A straight line with non-zero V_0 intercept gradient = 1.3×10^{-6}	B1 B1	Ignore spread of data points on either side of the line Allow Intercept > 0 and < 1.0 V Allow $(1.10 \text{ to } 1.60) \times 10^{-6}$; no need to check calculation
		(ii)	gradient = $\frac{hc}{e}$ (Any subject) $h = \frac{1.3 \times 10^{-6} \times 1.60 \times 10^{-19}}{3.00 \times 10^8}$ (Any subject) $h = 6.9 \times 10^{-34}$ (J s)	C1 C1 A1	Possible ECF from (i) Note the answer must be given 2 SF only
		(iii)	difference = $\frac{6.9 \times 10^{-34} - 6.6(3) \times 10^{-34}}{6.6(3) \times 10^{-34}} \times 100 \%$ difference = 4.1 %	B1	Possible ECF from (ii) Ignore sign Not division by value from (ii) Allow 1 SF answer
		(iv)	Random (error) / data points are spread about line Systematic (error) / line does not pass through origin Take (many) repeat readings (of V_0) and average Conduct the experiment in a darkroom / use (black) tube over the LED to view when it is lit / use a (digital) voltmeter with no zero error	B1 B1 B1 B1	Allow other sensible suggestion Not faulty voltmeter

Question		Answer	Marks	Guidance
	(b)	Any one from: Energy of visible light photon < work function (of zinc) (frequency of) visible (light/photon) < threshold frequency Any one from: Energy of UV photon > work function (of zinc) (frequency of) UV (radiation/photon) > threshold frequency Any two from: • Collapse of leaf linked to removal of electrons • One-to-one interaction of photon and (surface) electron • Photon energy is independent of intensity / Intensity linked to rate of photons (incident on the zinc plate)	B1 B1 B1 × 2	Allow f for frequency, λ for wavelength and ϕ for work function throughout Allow 'overcome' / 'met' / 'reached' when describing > or < Allow photons Not f_0 for threshold frequency Allow equivalent statement with wavelength Allow = instead of > or < throughout for UV Allow equivalent statement with wavelength Ignore stem / plate / leaf / electroscope becoming positive
		Total	14	

2	(a)	(i)	use (vernier / digital / dial) calliper(s) or micrometer (taking readings) at different positions / orientations (along the wire)	B1 B1	 Ignore take multiple readings
		(ii)	exclude the 0.495 (mm) anomaly add the remaining 4 values and divide by 4 / calculate mean of the remaining values calculate half the range of the remaining values	M1 A1 A1	May be inferred from calculations Allow the correct calculation which leads to 0.455 Ignore references to median or mode or average Allow the correct calculation which leads to 0.005 Ignore difference between mean and highest (or lowest) value Ignore references to resolution of the measuring instrument
	(b)	(i)	$\varepsilon = I(R + r)$ $R = \rho L/A$ and $A = \pi d^2/4$ clear steps leading to given equation	M1 M1 A1	Allow $\varepsilon = V + Ir$ and $V = IR$ Allow $A = \pi r^2$ and $r = d/2$ Allow area formula by inference, if clear

Question			Answer	Mark	Guidance
2	(b)	(ii)1	(gradient = $\Delta y/\Delta x$ where $\Delta x \geq 0.35$) gradient = 5.0 (A⁻¹ m⁻¹) $\rho = \frac{\pi \times (0.455 \times 10^{-3})^2 \times 1.45 \times \text{gradient}}{4}$ $\rho = 1.2 \times 10^{-6}$ ($\Omega \text{ m}$)	C1 A1	Allow answer to 1sf Mark is either for the correct gradient or for working which would lead to 5.00 ± 0.10, seen anywhere in the question Correct to at least 2sf Allow the correct answer with no working shown for ρ if the gradient (or working for the gradient) is correct Allow ECF for gradient ($\rho = 2.358 \times 10^{-7} \times \text{gradient}$)

Question			Answer	Mark	Guidance
2	(b)	(ii)2	$r = \text{y-intercept} \times \varepsilon = 0.40 \times 1.45$ $r = \mathbf{0.58(\Omega)}$ $\text{y-intercept}_{\text{MAX}} = 0.73 \text{ (A}^{-1}\text{)}$ EITHER Fractional uncertainty in $r =$ $0.05/1.45 + 0.33/0.40 = 0.034 + 0.825$ $= 0.86$ $0.86 \times 0.58 = 0.5(\Omega)$ to 1sf so $r = \mathbf{0.6 \pm 0.5 (\Omega)}$ OR $r_{\text{MAX}} = \text{y-intercept}_{\text{MAX}} \times \varepsilon_{\text{MAX}} = 0.73 \times 1.5$ $= 1.1(\Omega)$ $1.1 - 0.58 = 0.5(\Omega)$ to 1sf so $r = \mathbf{0.6 \pm 0.5 (\Omega)}$	B1 M1 A1 A1 (A1) (A1)	Mark is for working leading to the correct value of r . $r = 0.58(\Omega)$ seen either in working or on answer line implies B1 Allow answers in the range 0.70 to 0.75 Ignore any attempt to calculate uncertainty in gradient Expect answers in the range 0.78 – 0.91 (or 78% to 91%) Ignore units if given Expect answers for absolute uncertainty in the range 0.45–0.53 Value and uncertainty <u>must</u> be given to same number of dp Expect answers in the range 1.05 - 1.13 Expect answers for absolute uncertainty in the range 0.45–0.55 Value and uncertainty <u>must</u> be given to same number of dp Special case: allow abs unc of 0.55 giving $r = 0.6 \pm 0.6 (\Omega)$
			Total	14	

2	(a)		superscripts 1,60,0 subscripts 0,28,-1 $\bar{\nu}_{(e)}$ (nu-bar)	B1 B1 B1	recognisable correct symbol required If superscripts and subscripts included, both must be 0
	(b)	(i)	Beta radiation would not penetrate/ would be absorbed by the lead	B1	Not gamma radiation would be stopped Ignore reference to alpha radiation
		(ii)1	$\ln N = -\mu d + \ln N_0$ compared to $y = mx + c$ (so $m = -\mu$ and $c = \ln N_0$)	B1	or $\ln N = \ln(N_0 e^{-\mu d}) = \ln N_0 - \mu d$
		(ii)2	5.70 ± 0.14	B1 B1	Both answers must be to 2d.p. Allow ± 0.13 not second B1 mark without correct working shown e.g. $\ln 300 - \ln 260$ or $(5.83 - 5.56)/2$ Allow $\Delta N/N$ ($= 40/300$) but only if $\Delta(\ln N) \approx \Delta N/N$ is quoted
		(ii)3	Point plotted correctly to within $\frac{1}{2}$ small square Best fit and worst fit line(s) drawn	B1 B1	Ignore accuracy of length of error bar ECF (ii)2 for incorrect value(s) in table ECF (ii)2 for incorrect value(s) in table Best fit line should have an equal scatter of points about the line Worst fit line should be steepest/shallowest possible line that passes through <u>all</u> the error bars (allow $\pm \frac{1}{2}$ small square tolerance vertically)

H556/03			Mark Scheme		June 2019
Question			Answer	Marks	Guidance
		(ii)4	gradient of best fit line = $(-) \mu = (-) 54 \text{ (m}^{-1}\text{)}$	B1	Allow 51 to 56 Allow value of μ up to 4 SF ECF(ii)3 for wrongly plotted point
			large triangle used to determine gradient of best fit line	B1	$\Delta d > 25\text{mm}$ (seen from graph or working)
			calculation of absolute uncertainty using their values in the formula ($ \text{wfl gradient} - \text{bfl gradient} $)	B1	ECF (ii)3 for worst fit line Ignore any POT error in gradients Allow value of absolute uncertainty up to 3 SF only
			uncertainty and value of μ to same number of dp	B1	e.g. 53.4 ± 5.6 or 54 ± 6
		(ii)5	$\mu d_{1/2} = \ln 2$ (or 0.693)	C1	ECF (ii)4 for μ Alternative method: $\ln(N_0/2) = 7.67$ (C1)
			$d_{1/2} = 0.013 \text{ (m)}$	A1	then use of graph to give $d_{1/2} = 0.013 \pm 0.001 \text{ (m)}$ (A1)
			Total	15	

H556/03		Mark Scheme		June 2019
Question	Answer	Marks	Guidance	



23	(a)	$g = \frac{G \times 6.31 \times 10^{30}}{(1.90 \times 10^9)^2}$ $g = 117 \text{ (N kg}^{-1}\text{)}$ $2 \times \frac{0.14}{1.90} + \frac{0.42}{6.31} \quad \text{or} \quad 0.21 \quad \text{or} \quad 21\%$ (absolute uncertainty =) 25 (N kg⁻¹)	C1 C1 C1 A1	Reject 0.42/(0.14²) = 21.4 Note: final answer of $g = 117 \pm 25 \text{ (N kg}^{-1}\text{)}$ with no working scores all 4 marks. Allow correct identification of %(r) and %(m) for 1 mark max if no other marks scored. Allow alternate method using max/min values of m and r that give the correct absolute uncertainty (28)	
	(b)	(i)	The (total radiant) power (of a star) /AW	B1	
		(ii)	$(L = 4\pi r^2 \sigma T^4)$ $\text{ratio} = \sqrt{\left(\frac{6.92 \times 7500^4}{10.0 \times 4500^4}\right)}$ ratio = 2.3(1)	C1 A1	Allow 1 mark for 5.3; square root omitted Allow 1 mark for 1:2.3 or 0.43
		(iii)	$\lambda_{(\text{max})} \propto \frac{1}{T}$ Lower temperature star will have the longest wavelength, so it is Aa2	B1 B1	Allow word equation Note Must mention wavelength <u>and</u> temperature
		(iv)	From their (different) colours	B1	



		(v)	Any <u>three</u> from: • Continuous spectrum • Light / radiation / photons passes through cooler gas/star's atmosphere • Photon(s) absorbed by electron(s) • Electron(s) excited / jump / make transition to higher energy level(s) • Electron only promoted if energy of photon matches energy gap between two given levels • Photons remitted in different directions • (so) idea of contrast with non-absorbed wavelengths	B1 × 3	
		(c)	Any <u>two</u> from: • Black hole has smaller mass / radius / size • Black hole has higher density/gravitational field strength/stronger gravitational field • black hole absorbs light / does not emit visible light • Has an escape velocity $\Rightarrow c$ • No fusion in a black hole (ORA)	B1 B1	Allow black hole emits Hawking radiation
			Total	15	



17	(a)	(i)	Horizontal arrow pointing to the right.	B1	Judgement by eye
		(ii)	$2.14 \times 10^3 = \frac{2 \times \pi \times 9380 \times 10^3}{T}$ (Any subject) $T = 2.75 \times 10^4$ (s)	C1 A1	Allow 2SF answer Note: 2.75×10^n scores 1 mark.
		(iii)	$\frac{GMm}{r^2} = \frac{mv^2}{r}$ or $v^2 = \frac{GM}{r}$ $(2.14 \times 10^3)^2 = 6.67 \times 10^{-11} \times M / 9380 \times 10^3$ $M = 6.44 \times 10^{23}$ (kg)	C1 C1 A1	Allow ecf of answer for T from (a)(ii) Allow 2 SF answer Note: Use of 2.8×10^4 seconds gives 6.3×10^{23} (kg) for 3 marks. Alternative Method for C1C1 $M = 4\pi^2 R^3 / (T^2 G)$ (Databook formula re-arranged with M as subject) $M = 4\pi^2 (9380 \times 10^3)^3 / ((2.75 \times 10^4)^2 \times 6.67 \times 10^{-11})$ (i.e. M as subject) Note: In alternative method, PoT error forgetting km->m conversion gives 6.46×10^{14} (kg) for 2 marks.
	(b)	(i)	- 0.060 and 3.85 (Both to 2 sf after the decimal point)	B1	Allow - 0.06 or -0.0605 (the minus sign is required) Not: 0.06 Allow: 3.845(1) Note: Use of ln gives -0.14 and 8.854 for 0 marks.



Question		Answer	Marks	Guidance
	(ii)1	Missing data point plotted to $\pm$ half small square consistent with candidate's value. Straight best fit line drawn	B1 B1	Allow ECF from (b)(i) Allow ECF for incorrectly plotted point or data point from (i) omitted
	(ii)2	(Triangle used to determine gradient and) gradient calculation is shown to be within range -1.90 to -2.20	B1	
	(ii)3	$\lg(g) = \lg(GM) - 2\lg(r)$ or $\lg(g) = -2\lg(r) + \lg(GM)$ seen Compared with $y = mx + c$, and hence gradient = - 2	M1 A1	Allow: incorrect handling of negative g .
(c)	(i)	Any <u>two</u> from: - Direction of g for Earth and Mars are in opposite directions - For small values of r / $r <$ about $4.4 (\times 10^{10} \text{ m})$ g for Earth is greater or resultant g is towards the Earth - At r about $4.4 (\times 10^{10} \text{ m})$ the g values are the same/AW - Inverse square law for g for either planet causes curve near to either planet's surface/AW - Zero point for (resultant) g is further from the Earth (than the midpoint) since Earth has a larger mass than Mars g at Earth's surface is larger than g at surface of Mars because Earth has a larger mass than Mars	B1 $\times$ 2	Allow field / (gravitational) force for g Allow for r values larger than $4.4 (\times 10^{10} \text{ m})$ g for Mars is greater or resultant g is towards Mars



Question			Answer	Marks	Guidance
		(ii)	Any valid equation relating g_{Earth} and g_{Mars} e.g. $GM_{\text{Earth}}/r_{\text{E}}^2 = GM_{\text{Mars}}/r_{\text{M}}^2$ ratio <u>consistent</u> with values above	C1 A1	Note: the correct ratio is in the range 8.2 to 12 allowing for values of r of $4.4 \pm 0.1 (\times 10^{10} \text{ m})$ when $g = 0$
			Total	16	

