



GuideMyGrades

— YOUR GOALS. OUR EXPERTISE. —

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

Physical quantities and units (2.1)

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

29 questions · 187 marks · Mark schemes included

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

 guidemygrades.com

 @Guidemygrades

 @Guidemygrades

 @Guidemygrades

 info@guidemygrades.com

 Piccadilly Business Centre, Unit C, Aldow Enterprise Park
Blackett Street, Manchester, M12 6AE

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.

QUESTION	SOURCE	MARKS	PAGE
2.1.1 PHYSICAL QUANTITIES AND ESTIMATION		2 Qs · 13 marks	3
1. Q15 <i>also 3.3 & 4.5 & 6.5</i>	H556/02 Exploring physics June 2024	1	4
2. Q1 <i>also 3.2 & 3.1 & 5.4 & 5.2</i>	H556/03 Unified physics June 2022	12	6
2.1.2 S.I. UNITS, PREFIXES AND HOMOGENEITY		27 Qs · 174 marks	9
3. Q1	H556/01 Modelling physics June 2018	1	10
4. Q1	H556/01 Modelling physics June 2019	1	11
5. Q10 <i>also 3.2</i>	H556/01 Modelling physics June 2019	1	12
6. Q2 <i>also 3.4 & 3.2</i>	H556/01 Modelling physics November 2020	1	13
7. Q7 <i>also 5.5</i>	H556/01 Modelling physics November 2020	1	14
8. Q2	H556/01 Modelling physics November 2021	1	15
9. Q5 <i>also 3.4</i>	H556/01 Modelling physics June 2023	1	16
10. Q1	H556/02 Exploring physics June 2023	1	17
11. Q1 <i>also 5.1</i>	H556/01 Modelling physics June 2024	1	18
12. Q2 <i>also 5.1</i>	H556/01 Modelling physics June 2024	1	19
13. Q8 <i>also 3.2 & 5.3</i>	H556/01 Modelling physics June 2024	1	20
14. Q1 <i>also 4.2</i>	H556/02 Exploring physics June 2024	1	21
15. Q19 <i>also 2.2 & 3.2 & 6.3</i>	H556/02 Exploring physics November 2021	6	22
16. Q20 <i>also 3.1 & 5.2</i>	H556/01 Modelling physics November 2020	7	24
17. Q17 <i>also 4.5 & 4.4 & 4.3 & 4.1</i>	H556/02 Exploring physics June 2022	8	26
18. Q17 <i>also 2.2 & 4.2</i>	H556/02 Exploring physics June 2017	9	28
19. Q18 <i>also 3.3 & 3.2</i>	H556/01 Modelling physics June 2018	9	31
20. Q23 <i>also 4.4 & 5.5</i>	H556/01 Modelling physics June 2018	9	33
21. Q2 <i>also 2.2 & 4.3 & 4.2 & 6.1</i>	H556/03 Unified physics November 2020	10	35
22. Q16 <i>also 4.3 & 4.2 & 4.1</i>	H556/02 Exploring physics June 2018	11	38
23. Q19 <i>also 2.2 & 4.5 & 4.4 & 4.1</i>	H556/02 Exploring physics November 2020	11	40
24. Q18 <i>also 4.3 & 4.2</i>	H556/02 Exploring physics June 2019	12	42
25. Q16 <i>also 3.1</i>	H556/01 Modelling physics November 2021	12	45
26. Q20 <i>also 3.2 & 3.1 & 5.3</i>	H556/01 Modelling physics June 2022	12	47
27. Q20 <i>also 2.2 & 4.5 & 4.4 & 4.3 & 4.1</i>	H556/02 Exploring physics June 2018	14	49
28. Q23 <i>also 2.2 & 4.4 & 5.5 & 5.4</i>	H556/01 Modelling physics November 2021	15	53
29. Q21 <i>also 3.4 & 3.2 & 3.1 & 5.3</i>	H556/01 Modelling physics June 2023	17	55



QUESTIONS

29 questions · 187 marks · 2 sub-topics



SUB-TOPIC 2.1.1

PHYSICAL QUANTITIES AND ESTIMATION

Sub-topic 2.1.1 · 2 questions · 13 marks · lowest tariff first



15 Which sequence shows the energies below in **increasing** order of magnitude?

- 1 The change in kinetic energy of an electron accelerated through a potential difference of 1 V.
- 2 The kinetic energy of a proton with a velocity of 1000 m s^{-1} .
- 3 The energy of an X-ray photon with a frequency of $3 \times 10^{17} \text{ Hz}$.

A 1 2 3

B 3 1 2

C 2 1 3

D 1 3 2

Your answer

[1]

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE



- 1 The table shows some data on the planet Venus.

Mass/kg	4.87×10^{24}
Radius/km	6050
Density of atmosphere at surface/ kg m^{-3}	65
Period of rotation about its axis/hours	5830

- (a) Calculate the magnitude of the gravitational field strength g at the surface of Venus.

Give your answer to **3** significant figures.

$$g = \dots\dots\dots \text{N kg}^{-1} \text{ [3]}$$

- (b) Two identical space probes, **A** and **B**, land on a flat surface on Venus.

Probe **A** lands at the north pole. Probe **B** lands on the equator.

Each probe has mass 760 kg and volume 1.7 m^3 .

- (i) Calculate the centripetal acceleration a of probe **B** at the equator due to the rotation of Venus about its axis.

$$a = \dots\dots\dots \text{ms}^{-2} \text{ [3]}$$

- (ii) The atmosphere exerts the same upthrust on each probe.

Using your answer to (a), calculate the upthrust acting on each probe.

upthrust = ... N [3]

- (iii) Explain which probe will experience the greater normal contact force from the surface of Venus.

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

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE



SUB-TOPIC 2.1.2

S.I. UNITS, PREFIXES AND HOMOGENEITY

Sub-topic 2.1.2 · 27 questions · 174 marks · lowest tariff first



1 Which of the following units is **not** an S.I. base unit?

A ampere

B mole

C volt

D kilogram

Your answer

[1]



1 Which set of prefixes **A**, **B**, **C** or **D** are in order of **increasing** magnitude?

A micro, milli, centi, kilo

B milli, centi, micro, kilo

C kilo, centi, milli, micro

D centi, micro, milli, kilo

Your answer

[1]



10 Which of the following shows the correct base units for pressure?

A kg m^{-2}

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

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

D $\text{kg m}^2 \text{s}^{-3}$

Your answer

[1]

© OCR 2019

Turn over



2 Which pair of quantities have the same S.I. base units?

- A force, strain
- B force, stress
- C pressure, stress
- D strain, upthrust

Your answer

[1]



- 7 Recent analysis of the data collected from the Hubble and Gaia telescopes gave the Hubble constant a value of $73.5 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

What is this value, written to 2 significant figures, in s^{-1} ?

A $2.4 \times 10^{-21} \text{ s}^{-1}$

B $2.4 \times 10^{-18} \text{ s}^{-1}$

C $2.4 \times 10^{-12} \text{ s}^{-1}$

D $2.4 \times 10^{21} \text{ s}^{-1}$

Your answer

[1]

© OCR 2020



2 Which one of the following prefixes represents the **smallest** multiplication factor?

A femto (f)

B micro (μ)

C nano (n)

D pico (p)

Your answer

[1]

© OCR 2021



- 5 A wire of cross-sectional area $3.9 \times 10^{-6} \text{ m}^2$ carries a load of 240 N. The strain in the wire is 0.30%.

Which value of the Young modulus, in Pa, is correct and expressed to an appropriate number of significant figures?

A 2.05×10^8

B 2.1×10^8

C 2.05×10^{10}

D 2.1×10^{10}

Your answer

[1]

© OCR 2023



1 Which of these units is a base unit?

A A

B J

C m^2

D N

Your answer

[1]

© The copyright material in this page is the property of Cambridge Assessment and is not to be distributed or reproduced in any form without the prior written permission of Cambridge Assessment.

- 1 Which row in the table shows two equivalent physical quantities?

A	0 °C	−273.15 K
B	1 kg ms ^{−1}	1000 N s
C	10 kW	10 000 N m
D	1.0 mPa	0.0010 N m ^{−2}

Your answer

[1]



2 What are the SI base units of the Boltzmann constant k ?

A J K^{-1}

B $\text{kg m s}^{-2} \text{K}^{-1}$

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

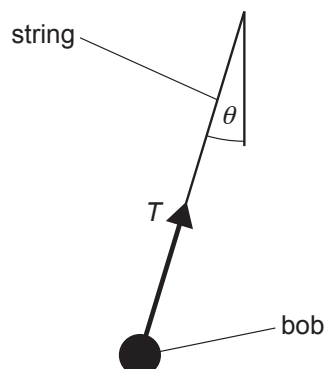
D Nm K^{-1}

Your answer

[1]

- 8 The bob of a pendulum is displaced slightly so that the string forms a small angle $\theta < 10^\circ$ with the vertical.

The tension in the string is T . The small angle approximation applies.



Which of the following pairs of quantities would give approximately, within 2 significant figures, the same value for the horizontal component of T ?

- 1 $T \cos \theta$ and $T \sin \theta$
- 2 $T \cos \theta$ and $T \tan \theta$
- 3 $T \sin \theta$ and $T \tan \theta$

- A 1 only
- B 1 and 3
- C 3 only
- D 2 and 3

Your answer

[1]

1 What are the base units of a kilowatt-hour?

A J

B $\text{kg m}^2 \text{s}^{-1}$

C $\text{kg m}^2 \text{s}^{-2}$

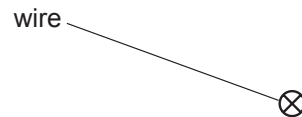
D Ws

Your answer

[1]



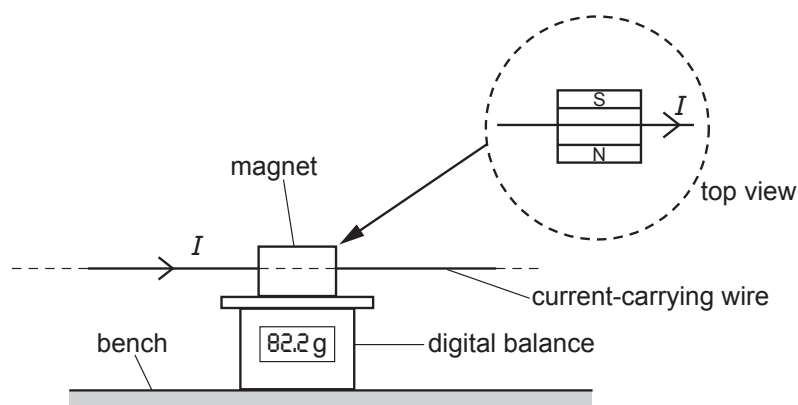
- 19 (a) The diagram below shows the top-view of a long current-carrying wire.



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.

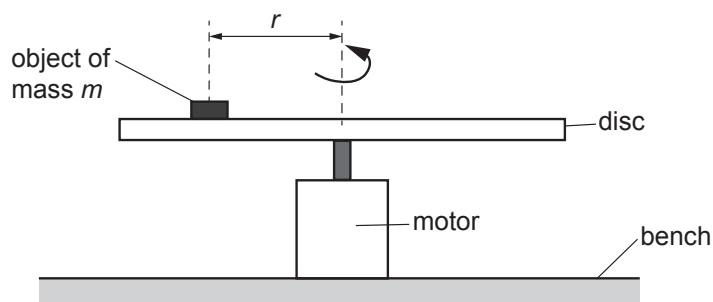
The following results are collected.

- 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 A small object of mass m is placed on a rotating horizontal metal disc at a distance r from the centre of the disc.



The frequency of rotation is adjusted using a motor attached to the disc.

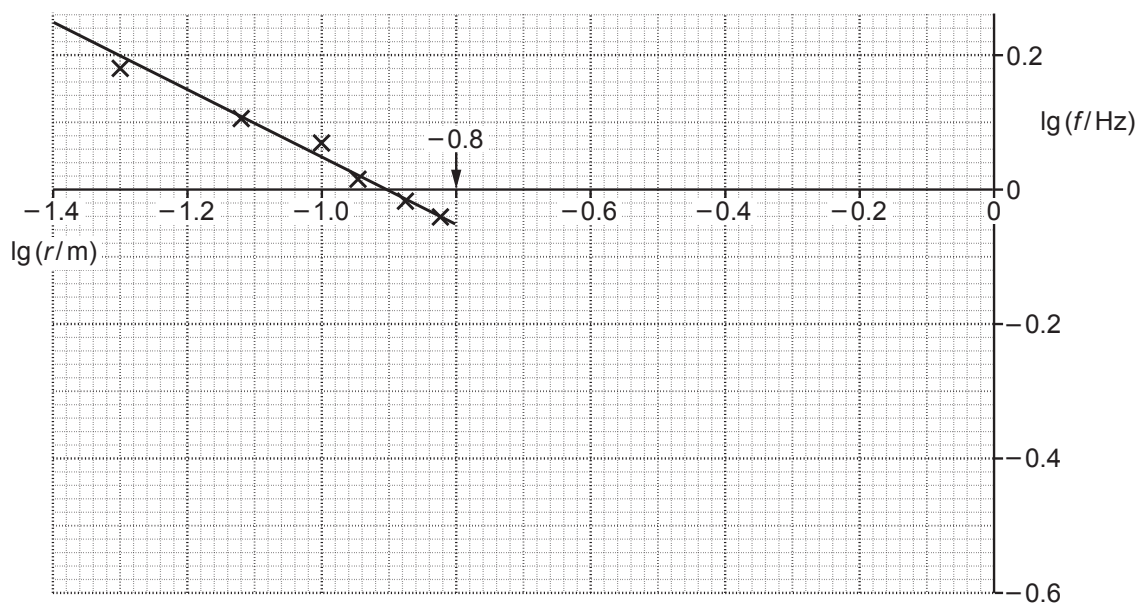
The frequency of rotation of the disc is slowly increased from zero, until the object slips off. At this point, the friction F acting on the object is equal to the centripetal force.

The friction F is given by the expression $F = kmg$, where k is a constant and g is the acceleration of free fall. The constant k has no units.

- (a) Show that the frequency f at which the object slips off is given by the equation $f^2 = \left(\frac{gk}{4\pi^2}\right) \times \frac{1}{r}$.

[3]

(b) A student plots a graph of $\lg(f/\text{Hz})$ against $\lg(r/\text{m})$.



For this graph: $y\text{-intercept} = \frac{1}{2} \times \lg\left(\frac{gk}{4\pi^2}\right)$

Use the graph to determine the constant k . Write your answer to 2 significant figures.

$k = \dots\dots\dots$ [4]

Additional answer space if required

.....

.....

.....

.....

.....

.....

.....

.....

- 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.

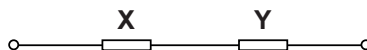


Fig. 17

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.

.....

.....

..... [1]



BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE



- 18 Wind turbines convert the kinetic energy of the wind into electrical energy.
Fig. 18 shows a wind turbine.

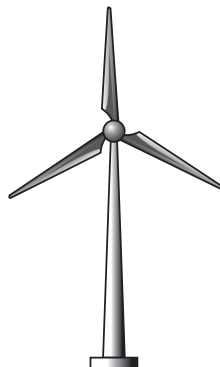


Fig. 18

- (a) When the wind speed is 8.0 m s^{-1} , the kinetic energy of the air incident at the turbine per second is 1.2 MJ s^{-1} .
Calculate the mass of the air incident at the turbine per second.

mass per second = ... kg s^{-1} [2]

- (b) A group of engineers are investigating the design of wind turbines.
The maximum **input** power P from the wind is given by the equation

$$P = \frac{1}{2} \rho A v^3$$

where A is the area swept out by the rotating blades, ρ is the density of air and v is the speed of the wind.

- (i) Show that the equation is homogeneous with both sides of the equation having the same base units.

[3]

- (ii) The input power to the wind turbine is 1.2 MW when the wind speed is 8.0 m s^{-1} . The density of air is 1.3 kg m^{-3} .

Calculate the length L of the turbine blades.

$L = \dots\dots\dots \text{ m}$ [2]

- (iii) A wind farm is required to produce an output power of 50 MW when the average wind speed is 8.0 m s^{-1} . The efficiency of each wind turbine is 42%.

Calculate the minimum number N of wind turbines required to meet this demand.

$N = \dots\dots\dots$ [2]
Turn over



- 23 (a) According to the Cosmological principle, the Universe is isotropic, homogeneous and the laws of physics are universal.

State what is meant by the term *homogeneous*.

.....
 [1]

- (b) Astronomers often use absorption spectral lines to determine the relative velocity of distant galaxies. The wavelength of a specific absorption spectral line observed in the laboratory is 280 nm.

The galaxy RXJ1242-11 is 200 Mpc away from the Earth and it has a massive black hole at its centre.

- (i) Calculate in nm the wavelength λ of the same spectral line from RXJ1242-11 when **observed** from the Earth. Assume the Hubble constant is $68 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

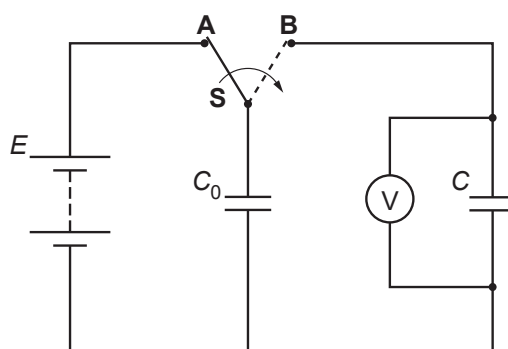
$\lambda = \dots\dots\dots \text{ nm}$ [3]

- (ii) State one of the characteristics of a black hole.

.....
 [1]

- 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 .

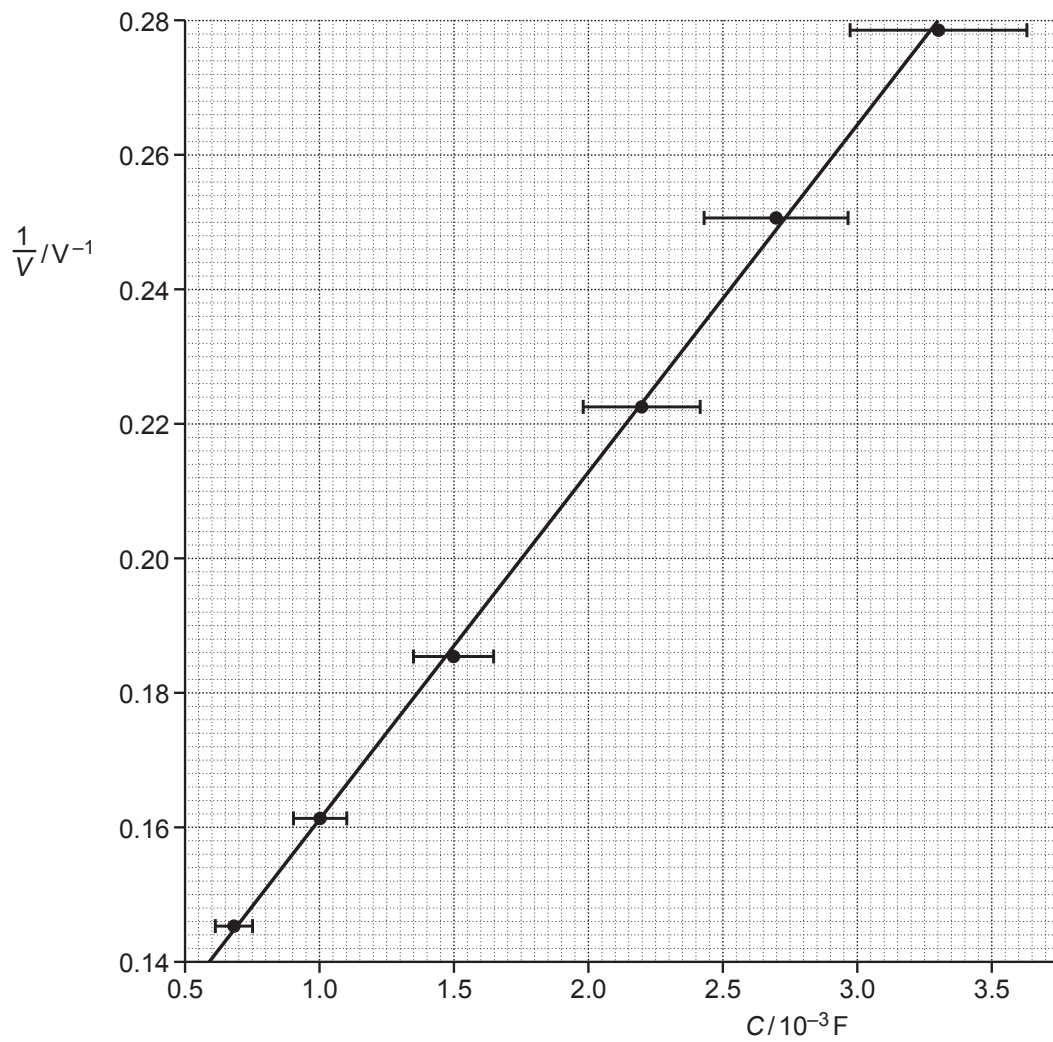
The student decides to plot a graph of $\frac{1}{V}$ against C .

- (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]

16 (a) Derive the S.I. base units for resistance.

base units: [2]

(b) Fig. 16.1 shows the I - V characteristics of two electrical components **L** and **R**.

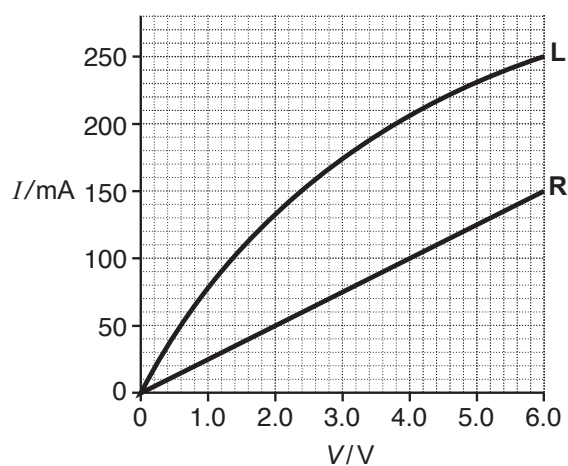


Fig. 16.1

The component **L** is a filament lamp and the component **R** is a resistor.

(i) Show that the resistance of **R** is $40\ \Omega$.

- (ii) Fig. 16.2 shows the components **L** and **R** connected in series to a battery of e.m.f. 6.0V.

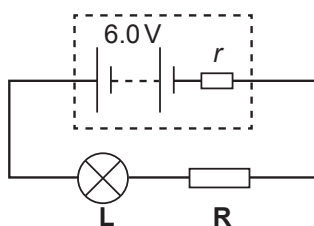


Fig. 16.2

The resistor **R** is a cylindrical rod of length 8.0 mm and cross-sectional area $2.4 \times 10^{-6} \text{ m}^2$. The current in the circuit is 100 mA.

- 1 Use Fig. 16.1 to determine the internal resistance r of the battery.

$$r = \dots\dots\dots \Omega \text{ [3]}$$

- 2 Calculate the resistivity ρ of the material of the resistor **R**.

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

- 3 There are 6.5×10^{17} charge carriers within the volume of **R**.

Calculate the mean drift velocity v of the charge carriers within the resistor **R**.

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

Turn over

- 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.

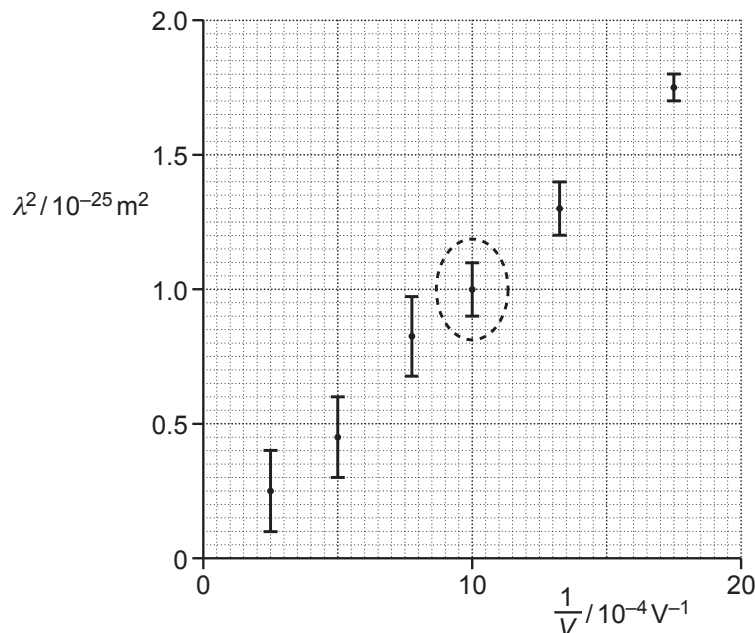
The charged particles are accelerated through a potential difference V . The de Broglie wavelength λ of these particles is then determined by the researcher.

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]

- 18 (a) State Kirchhoff's second law **and** the physical quantity that is conserved according to this law.

.....

.....

.....

..... [2]

- (b) The S.I. base units for the ohm (Ω) are $\text{kg m}^2 \text{s}^{-3} \text{A}^{-2}$.

Use the equation $R = \frac{\rho L}{A}$ to determine the S.I. base units for resistivity ρ .

base units for ρ [2]

Question 18 continues on page 16

- (c) Fig. 18.1 shows a circuit used by a student to determine the resistivity of the material of a wire.

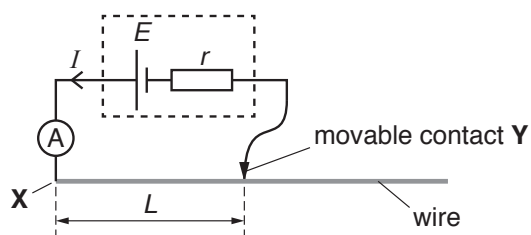


Fig. 18.1

The wire is uniform and has diameter 0.38 mm. The cell has electromotive force (e.m.f.) E and internal resistance r . The length of the wire between **X** and **Y** is L .

The student varies the length L and measures the current I in the circuit for each length.

Fig. 18.2 shows the data points plotted by the student.

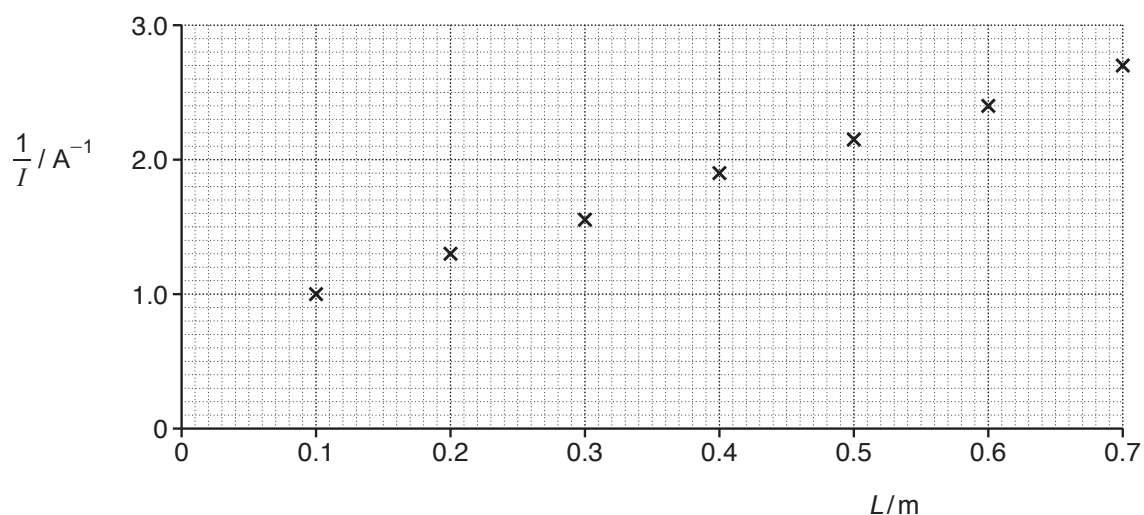


Fig. 18.2

- (i) On Fig. 18.2 draw the straight line of best fit. Determine the gradient of this line.

gradient = ... $A^{-1} m^{-1}$ [2]

- (ii) Show that the gradient of the line is $\frac{\rho}{AE}$, where ρ is the resistivity of the material of the wire, A is the area of cross-section of the wire and E is the e.m.f. of the cell.

[2]

- (iii) The e.m.f. E of the cell is 1.5 V. The diameter of the wire is 0.38 mm.

Use your answer to (i) and the equation given in (ii) to determine ρ .

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

- (iv) Fig. 18.3 illustrates how the student had incorrectly measured all the lengths L of the wire.

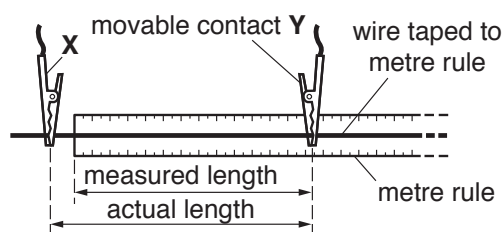


Fig. 18.3

According to the student, re-plotting the data points using the **actual** lengths of the wire will not affect the value of the resistivity obtained in (iii).

Explain why the student is correct.

.....

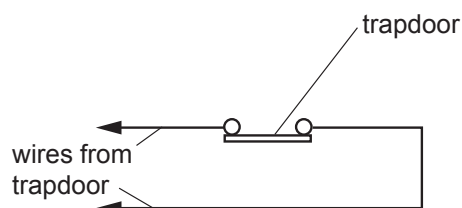
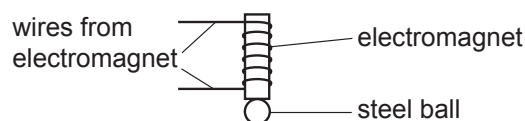
.....

.....

..... [2]

16 A student wants to determine the value of the acceleration of freefall g .

(a) The diagram below shows part of the arrangement which the student used.



A steel ball is dropped from an electromagnet. The ball falls vertically. The ball hits a trapdoor and opens the trapdoor.

The ball travels a distance s from the bottom of the electromagnet to the trapdoor in a time t . The student uses the equation $s = \frac{1}{2}gt^2$ to determine g .

(i) Show that the equation $s = \frac{1}{2}gt^2$ is homogeneous, with both sides of the equation having the same base units.

[2]

(ii) Describe how the student could use standard laboratory equipment to take accurate measurements of the distance s and the time t .

.....

.....

.....

.....

.....

.....

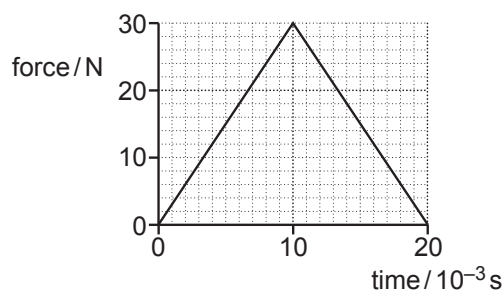
.....

.....

[4]

- (b) The trapdoor falls downwards when the ball hits it.
The ball collides **elastically** with the trapdoor with a speed of 4.4 m s^{-1} .

The graph of force acting on the ball against time is shown below.



The mass of the ball is 0.050 kg .

- (i) Calculate the initial momentum p_1 of the ball just before it hits the trapdoor.

$$p_1 = \dots\dots\dots \text{ kg m s}^{-1} \text{ [1]}$$

- (ii) Use the graph to calculate the magnitude of the final momentum p_2 of the ball immediately after the collision.

$$p_2 = \dots\dots\dots \text{ kg m s}^{-1} \text{ [3]}$$

- (iii) The mass of the trapdoor is 100 g .

Calculate the final speed v of the trapdoor immediately after the collision.

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

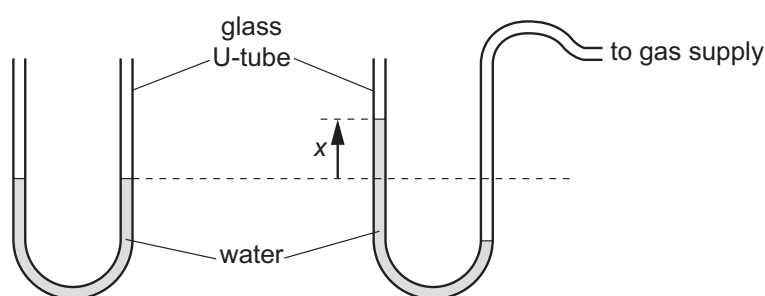
Turn over

- 20 (a) For a simple harmonic oscillator, the acceleration a is given by the equation $a = -\omega^2 x$, where ω is the angular frequency and x is the displacement.

Show that this equation is homogeneous by reducing both sides to S.I. base units.

[2]

- (b) The diagram shows a glass U-tube partially filled with a mass of water.



One end of the U-tube is connected to a gas supply of **constant** pressure and the other end is open to the atmosphere. The displacement of the water from its equilibrium position is x . The density ρ of water is 1000 kg m^{-3} .

- (i) The pressure from the gas supply raises the water in the U-tube. The vertical distance between the two levels of water in the two vertical sections of the U-tube is 10.0 cm ($x = 5.0 \text{ cm}$).

Δp is the difference between the gas pressure and atmospheric pressure. Calculate Δp .

$\Delta p = \dots\dots\dots \text{ Pa}$ [2]

- (ii) When the gas supply is disconnected, the water levels in the U-tube oscillates with simple harmonic motion. The acceleration a of the water level in the left-hand side of the U-tube is given by the equation

$$a = -\frac{2\rho g A}{m} x$$

where m is the mass of the water in the U-tube, A is the internal cross-sectional area of the U-tube, ρ is the density of water, g is the acceleration of free fall and x is the displacement of the water level in the left-hand side of the U-tube.

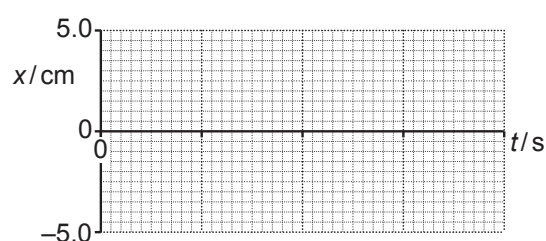
For this U-tube, $A = 1.0 \times 10^{-4} \text{ m}^2$ and $m = 0.052 \text{ kg}$.

- 1 Show that the period T of the oscillations is about 1 second.

[3]

- 2 The oscillations of the water level are slightly **damped**.
At time $t = 0$, $x = 5.0 \text{ cm}$.

Sketch a suitable graph of displacement x against time t for the oscillating water level. Add suitable values to the time t axis.



[3]

- 3 The U-tube is now connected to another gas supply where the pressure oscillates at a frequency of about 1 Hz.

Explain the effect this will have on the water in the U-tube.

.....

 [2]

- 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.

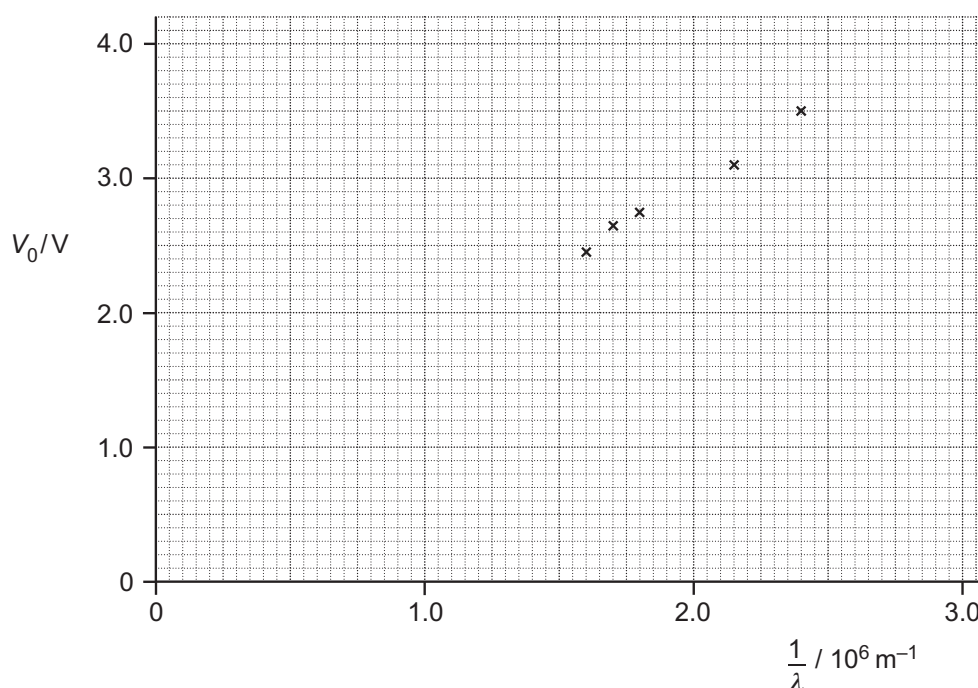


Fig. 20.1

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.

BLANK PAGE

**Question 21 is on page 24
PLEASE DO NOT WRITE ON THIS PAGE**



- 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]

21 (a) Fig. 21.1 shows a stationary glider of mass m on an air track.

The glider has identical springs with force constant k attached to each end which are secured to fixed posts.

The air track blower is turned on and the glider is displaced a small distance x_0 , as seen in Fig. 21.2. It is then released.

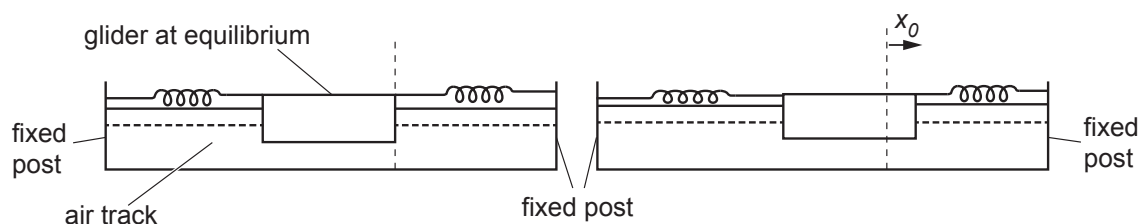
The glider moves horizontally in simple harmonic motion.

The springs remain in tension throughout the motion.

The time taken for 20 complete oscillations is measured, and the period T calculated.

Fig. 21.1

Fig. 21.2



The relationship between the period T , the mass of the glider m and the force constant k is described by the equation

$$T^2 = \frac{2\pi^2 m}{k}.$$

- (i) Show that the equation above is homogeneous by reducing the equation to SI base units.

[2]

- (ii) Explain why the magnitude of the resultant force F on the glider is given by $F = 2kx$ where x is the displacement at any time.

.....

.....

.....

..... [2]

(iii) State and explain the effect, if any, of increasing the initial displacement on the period of the subsequent motion.

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

(b) Masses are added to the glider, and the measurement of $20T$ repeated.

The results table is below.

m/kg	$20T/\text{s}$	T	T^2
0.200	12.2	0.61	0.372
0.300	13.6	0.68	0.462
0.400	15.6	0.78	0.608
0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1

(i) Describe **two** different errors in the table.

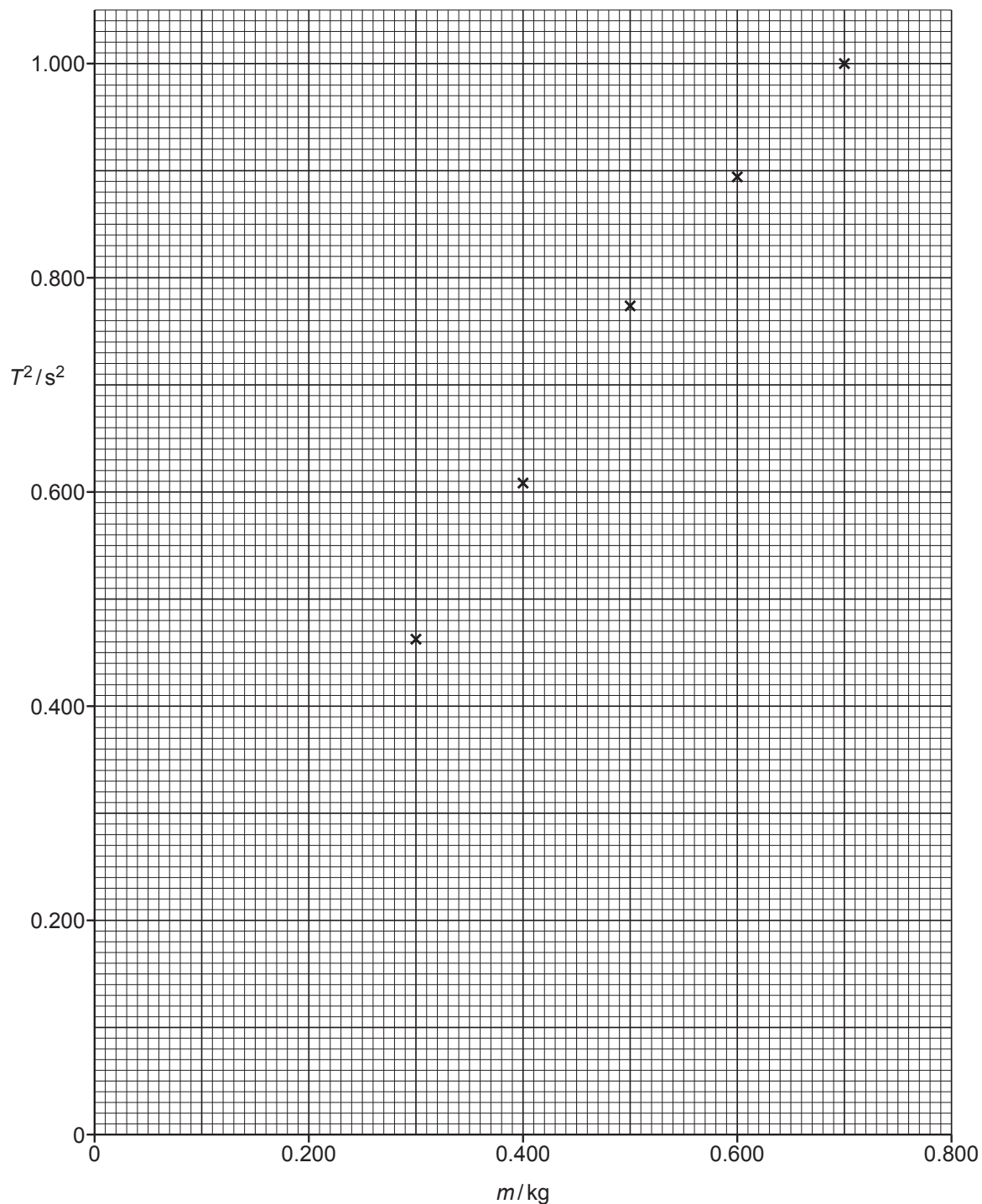
1
.....
2
..... [2]

(ii) Plot the **first** data point from the table on the graph below.

The other points have all been plotted. The table of results is repeated on the opposite page.

Include on your graph a line of best fit.

[2]



m/kg	$20T/\text{s}$	T	T^2
0.200	12.2	0.61	0.372
0.300	13.6	0.68	0.462
0.400	15.6	0.78	0.608
0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1

(iii) Use the graph to determine the value of k .

$k = \dots\dots\dots \text{Nm}^{-1}$ [3]

- (c) When the initial displacement is increased, one spring increases its extension while the extension of the other spring decreases.

Explain why the **maximum** kinetic energy of the motion increases.

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

MARK SCHEMES

official mark schemes



15	C	1	
	Total	15	

9

SECTION B

General rule: For substitution into an equation, allow any subject - unless stated otherwise in the guidance

Question	Answer	Mark	Guidance
----------	--------	------	----------



1	(a)		$g = GM/r^2$ $g = \frac{6.67 \times 10^{-11} \times 4.87 \times 10^{24}}{(6\,050 \times 10^3)^2}$ $g = 8.87 \text{ (N kg}^{-1}\text{)}$	C1 Allow m for M Allow d or D or x or X or R for r C1 Full substitution needed Allow $r = 6\,050$ for this C1 mark A1 Allow a negative answer Answer must be to exactly 3sf for the A1 mark. Do not use the SF penalty for the paper here
	(b)	(i)	$a = \omega^2 r$ and $\omega = 2\pi / T$ or $a = v^2 / r$ and $v = 2\pi r / T$ Either $\omega = \frac{2\pi}{5830 \times 3600}$ or $v = \frac{2\pi \times 6050 \times 10^3}{5830 \times 3600}$ or $a = \frac{4\pi^2}{(5830 \times 3600)^2} \times 6050 \times 10^3$ $a = 5.42 \times 10^{-7} \text{ (m s}^{-2}\text{)}$	C1 Allow use of $T^2 = 4\pi^2 r^3 / (GM)$ and $v = 2\pi r / T$ C1 $\omega = 2.99 \times 10^{-7} \text{ (rad s}^{-1}\text{)}$ $v = 1.81 \text{ (m s}^{-1}\text{)}$ $a = \omega^2 r = (2.99 \times 10^{-7})^2 \times 6050 \times 10^3$ $a = v^2 / r = 1.81^2 / (6050 \times 10^3)$ Do not allow incorrect or omitted conversion of T A1 Allow answer given to 2sf Allow any answer which rounds to 5.4×10^{-7} Do not penalise incorrect km conversion (giving $a = 5.42 \times 10^{-10}$) if already penalised in (a)



[illegible]

1	C	1	
---	---	---	--



1	A	1	
---	---	---	--



10	C	1	
----	---	---	--



2	C	1	
---	---	---	--



7	B	1	
---	---	---	--



2	A	1	
---	---	---	--



5	D	1	
---	---	---	--



1	A	1	
----------	----------	----------	--



1	D	1	
---	---	---	--



2	C	1	
----------	----------	----------	--



8	C	1	
---	---	---	--



1	C	1	
---	---	---	--



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)	$F = m\omega^2 r$ and $\omega = 2\pi f$ $kmg = m\omega^2 r$ Clear algebra leading to $f^2 = \left(\frac{gk}{4\pi^2}\right) \times \frac{1}{r}$	M1 M1 A1	Allow $F = mv^2/r$ and $v = 2\pi fr$ Allow this mark for $kmg = mv^2/r$
	(b)	y-intercept = - 0.45 $\frac{1}{2} \lg\left(\frac{gk}{4\pi^2}\right) = -0.45$ $\left(\frac{gk}{4\pi^2}\right) = 10^{-0.9}$ $k = \frac{0.126 \times 4 \times \pi^2}{9.81}$ $k = 0.51$	C1 C1 C1 A1	Allow ± 0.05 Allow attempt at calculating y-intercept using gradient and a point on the line . Not $e^{-0.9}$ wrong physics Allow k in range 0.48 to 0.63 Note Answer must be to 2 SF
		Total	7	

17	(a)	eV or J $\rightarrow$ [kg m ² s ⁻²] in base units by any method base units = kg m ² s ⁻¹	C1 A1	Allow kg (m s ⁻¹) ² Allow base units in any order
	*(b)	Level 3 (5–6 marks) Clear description of method and analysis of data <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 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 <i>No response or no response worthy of credit.</i>	B1× 6	Indicative scientific points may include: Description • Circuit with LED connected to a variable supply (and series /current limiting resistor) / or use of variable resistor • p.d. across LED increased until LED emits light • Voltmeter (across LED) used to measure V • Use a range of LEDs • λ determined using diffraction grating / spectrometer / double-slit / use $n\lambda = d \sin \theta$ / $\lambda = ax/D$ OR λ determined from manufacturer's data / known wavelength • Darkroom used / tube placed over LED used to establish switching of LED / switch-on identified from finite ammeter reading Analysis of data • Plot of V against λ^{-1} / eV against λ^{-1} / eV against c/λ • Line of best-fit drawn through the points • Straight line (through origin) • Correct gradient for described graph hc/e or hc or h • Correct arrangement for determination of h $h = (\text{gradient} \times e) / c$ or $h = \text{gradient} / c$ (allow numerical values for e and/or c)
		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	

Question	Answer	Marks	Guidance
----------	--------	-------	----------



18	(a)		$1.2 \times 10^6 = \frac{1}{2} \times (\text{mass per second}) \times 8.0^2$ $\text{mass per s} = 3.8 \times 10^4 \text{ (kg s}^{-1}\text{)}$	C1 A1	Answer is $3.75 \times 10^4 \text{ (kg s}^{-1}\text{)}$ to 3sf Note: $3.8 \times 10^n \text{ (kg s}^{-1}\text{)}$ scores 1 for PoT error.
	(b)	(i)	$A \rightarrow \text{m}^2$ <u>and</u> $\rho \rightarrow \text{kg m}^{-3}$ $P \rightarrow \text{kg m}^2 \text{ s}^{-3}$ Clear working to show units are equivalent on either side of equation	M1 M1 A1	Note: No mark for $v \rightarrow \text{m s}^{-1}$ since units are in (a) Allow $P \rightarrow \text{kg m s}^{-2} \text{ m s}^{-1}$ (from $P = Fv$ or $P = \text{Work done/t}$) Note: clear working includes $\text{m}^3 \text{ s}^{-3}$ seen.
		(ii)	$1.2 \times 10^6 = \frac{1}{2} \times 1.3 \times A \times 8.0^3$ or $A = 3600 \text{ (m}^2\text{)}$ seen $L = 34 \text{ (m)}$	C1 A1	Allow volume $\text{s}^{-1} = 28846 \text{ (m}^3\text{)}$ using $3.75 \times 10^4 \text{ (kg s}^{-1}\text{)}$ or $29231 \text{ (m}^3\text{)}$ using $3.8 \times 10^4 \text{ (kg s}^{-1}\text{)}$ Allow ECF from (a) Note: $3.4 \times 10^n \text{ (m)}$ scores 1 for PoT error.
		(iii)	(output power =) 0.42×1.2 / 0.504 (MW) $(N = 50/0.504 = 99.2)$ $N = 100$	C1 A1	Allow: $50 \times 10^6 / 0.42 = 119 \text{ MW}$ and then $119 / 1.2$ Not 99 Note: answer of 99.2 scores 1 mark max
			Total	9	

[illegible]

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	At least one correct expression for Q for first mark
				A1	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
----------	--------	-------	----------



16	(a)	$(R = \frac{V}{I} = \frac{W}{QI}; Q = It)$ charge $\rightarrow A\ s$ or energy $\rightarrow kg\ m\ s^{-2} \times m$ or $kg\ m^2\ s^{-2}$ (base units) $kg\ m^2\ A^{-2}\ s^{-3}$	C1 A1	Allow other correct methods Allow Q or C or coulomb for 'charge'; E or W or joule or J or work done for 'energy' Allow 1 mark for $J\ s^{-1}\ A^{-2}$ Allow $\frac{kg\ m^2}{A^2\ s^3}$ or $kg\ m^2 / (A^2\ s^3)$ Not $kg\ m^2 / A^2 / s^3$ or $kg\ m^2 / s^3 / A^2$
	(b) (i)	$(R =) \frac{6.0}{0.150}$ $R = 40\ \Omega$	M1 A0	Allow any correct value of V ($\pm 0.1\ V$) divided by the correct value of I ($\pm 10\ mA$) from the straight line for R
	(ii)1	$(V_L =) 1.4\ (V)$ or $(V_R =) 4.0\ (V)$ or $(R_T =) 6.0/0.1\ (\Omega)$ $(V_{terminal} =) 5.4\ (V)$ or $(V_r =) 0.6\ (V)$ or $(r =) 60 - 54\ (\Omega)$ $r = 6.0\ (\Omega)$	C1 C1 A1	Allow full credit for other correct methods Possible ECF from (i) Allow $\pm 0.1\ V$ for the value of p.d. from the graph Note getting to this stage will also secure the first C1 mark Allow 1 SF answer here without any SF penalty
	(ii)2	$\rho = \frac{40 \times 2.4 \times 10^{-6}}{8.0 \times 10^{-3}}$ (Any subject) $\rho = 0.012\ (\Omega\ m)$	C1 A1	Allow ECF Allow 1 mark for either 0.018 for using $60\ \Omega$, 0.016(2) for using $54\ \Omega$ or for 0.0018 for $6.0\ \Omega$
	(ii)3	$n = \frac{6.5 \times 10^{17}}{2.4 \times 10^{-6} \times 0.008}$ or $n = 3.385 \times 10^{25}\ (m^{-3})$ $v = \frac{0.100}{2.4 \times 10^{-6} \times 3.385 \times 10^{25} \times 1.60 \times 10^{-19}}$ (Any subject) $v = 7.7 \times 10^{-3}\ (m\ s^{-1})$	C1 C1 A1	Note do not penalise again for the same POT error Allow 1 mark for $4(.0) \times 10^5\ (m\ s^{-1})$; $n = 6.5 \times 10^{17}$ used
		Total	11	

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 A1	Allow p for mv Allow e for q in (b)(i) – this is to be treated as a ‘slip’
		(ii)1	(% uncertainty in λ^2) 10% (% uncertainty in λ) 5%	C1 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 C1 C1 A1	Ignore POT for this mark; Allow $\pm 0.20 (\times 10^{-22})$ Possible ECF for incorrect value of gradient 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	

18	(a)	Sum of e.m.f(s) is equal to the sum of p.d.(s) (in a loop of a circuit) Energy is conserved	B1 B1	Allow total / Σ instead of 'sum' Allow voltage instead of p.d. Not sum of IR, unless I and R are defined Expect 'sum' at least once in the statement Not $\Sigma E = \Sigma V$, unless V and E are defined
	(b)	$L \rightarrow [\text{m}]$ and $A \rightarrow [\text{m}^2]$ or $L/A \rightarrow [\text{m}^{-1}]$ $\text{kg m}^3 \text{s}^{-3} \text{A}^{-2}$	C1 A1	Allow $\frac{\text{kg m}^3}{\text{s}^3 \text{A}^2}$ or $\text{kg m}^3/\text{s}^3 \text{A}^2$
	(c) (i)	Line of best fit drawn gradient = 2.8	B1 B1	Expect the extrapolated line to have a y-intercept in the range 0.60 to 0.85 and at least one data point on each side of the line Allow gradient of line in the range 2.60 to 3.00
	(ii)	$E = I(r + R)$ and $R = \rho L/A$ $\frac{1}{I} = \frac{r}{E} + \frac{\rho}{AE} L$ (and comparison with $y = mx + c$ leads to gradient = $\frac{\rho}{AE}$)	C1 A1	Allow $E = V + IR$ and $R = \rho L/A$
	(iii)	$(\rho = \text{gradient} \times AE)$ $\rho = 2.8 \times \pi \times (0.19 \times 10^{-3})^2 \times 1.5$ $\rho = 4.8 \times 10^{-7} (\Omega \text{ m})$	C1 A1	Possible ECF from (i) Note not using $A = \pi r^2$ is wrong physics (XP) Allow 1 mark for 1.9×10^{-6} , diameter used instead of radius
	(iv)	The graph / points just shift horizontally (AW) The gradient is unchanged (and ρ will be the same)	B1 B1	Allow shifted to the right or left / 'systematic error' / zero error / change in length stays the same / 'no change in vertical values'
		Total	12	

16	(a)	(i)	$(g \rightarrow) [\text{m s}^{-2}]$ and $(t \rightarrow) [\text{s}]$ or $(gt^2 \rightarrow) [\text{m s}^{-2} \times \text{s}^2]$ Clear evidence of working leading to m on both sides	M1 A1	
		(ii)	s / distance measured with a ruler / tape measure Timer mentioned for measuring t / time Measure distance from bottom of ball to (top of) trapdoor Any <u>one</u> from: - Take repeated readings (for t for same s) to determine average t - Avoid parallax error when using the ruler	B1 B1 B1 B1	
	(b)	(i)	$(p_1 = 4.4 \times 0.050) = 0.22 \text{ (kg m s}^{-1}\text{)}$	B1	
		(ii)	(impulse =) $\frac{1}{2} \times 30 \times 0.02$ or $0.30 \text{ (kg m s}^{-1}\text{)}$ $-0.30 = p_2 - 0.22$ $p_2 = (-) 0.08 \text{ (kg m s}^{-1}\text{)}$	C1 C1 A1	Allow any correct re-arrangement Possible ECF from (b)(i) Ignore sign Allow 0.52 for 2 marks
		(iii)	(momentum of trapdoor =) $0.30 \text{ (kg m s}^{-1}\text{)}$ $v = 3.0 \text{ (m s}^{-1}\text{)}$	C1 A1	Allow $(KE_{\text{trapdoor}} =) \frac{1}{2} \times 0.05 \times (4.4^2 - 1.6^2)$ or 0.42 (J) Possible ECF from (b)(ii) Allow 1 SF answer here Allow alternate methods involving CoE (giving 2.9) and e(giving 2.8)
			Total	12	

20	a			$\omega \rightarrow \text{s}^{-1}$ or $\omega^2 \rightarrow \text{s}^{-2}$ LHS = m s^{-2} and RHS = m s^{-2} clearly shown by unit algebra	M1 A1	Allow $\omega \rightarrow (\text{radians}) \text{s}^{-1}$ Allow $\omega^2 = (2\pi f)^2$ or $(2\pi/T)^2$ with some evidence of units afterwards e.g. RHS = $\text{m} \cdot (\text{s}^{-1})^2$
	b	i		$\Delta p = 0.10 \times 1000 \times 9.81$ $\Delta p = 980 \text{ (Pa)}$	C1 A1	Allow 1 mark for 490 Pa; 5.0 cm used
		ii	1	$\omega^2 = \frac{2\rho g A}{m}$ or $\omega^2 = 37.7 \text{ (rad}^2 \text{ s}^{-1})$ $\omega = 6.1$ $T = \frac{2\pi}{6.1}$ $T = 1.02 \text{ (s)}$	C1 C1 C1 A0	NOT $\omega = 37.7$ Alternative route: • Substitution of expression for omega • Re-arrangement to make T subject • Evidence of evaluation to $T = 1.02 \text{ (s)}$
			2	Oscillation is isochronous starting from (0,5) Correct value(s) on the horizontal axis At least 2 oscillations shown and amplitude is decreasing	B1 B1 B1	Period same by eye. Note scale must be linear and increasing Amplitude of 2nd oscillation smaller by eye.
			3	The (driving) frequency is close to the natural frequency (of the system) / resonance will occur (Level of) water will oscillate with large amplitude	B1 B1	Allow a description of consequence such as water leaving the tube or being unable to measure the height of liquid
				Total	12	

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	



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/(0.14 ²) = 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)	$(L = 4\pi r^2 \sigma T^4)$ 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	



21	(a)	(i)	newton in base units is kg m s^{-2}	C1	
			Substitution and cancelling of kg and m arriving at $\text{s}^2 \rightarrow \text{s}^2$	A1	
		(ii)	One force is increased by kx and one is reduced by kx /AW Some working to include $kx - (-kx)$	B1 B1	reject 2 springs in series or 2 springs in parallel idea XP. accept one extension is reduced by x and one is increased by x / AW
		(iii)	period is independent of <u>amplitude</u> / AW No effect	M1 A1	Allow isochronous
	(b)	(i)	Units omitted from T and T^2 Valid statement about significant figures	B1 B1	allow correct statement about individual data points or decimal place or "precision" e.g. sf of T does not match sf of $20T$ or sf of T not consistent throughout column or idea that 1 sf never enough
		(ii)	Correct plotting within half a small square Correct line of best fit	B1 B1	ECF for incorrect plotting. NB Same number of points above and below the line AND fair distribution of distances from line

		(iii)	Gradient between 1.22 and 1.44	C1	reject use of data table
			$k=2\pi^2 \div \text{gradient}$	C1	ECF use of candidate's line
			k between 13.7 and 16.2	A1	ECF use of candidate's gradient as per rubric
	(c)		maximum four from: EPE gain (in stretched spring) > EPE lost (in relaxed spring) EPE is dependent on x^2 Total energy increases (and so KE increases since EPE $\rightarrow$ KE) Max KE when the system has minimum EPE / at equilibrium position/when $x=0$ Minimum EPE is unchanged Omega is same, amplitude has increased $v_{\max}$ when $x=0$ so $v_{\max}$ has increased ($\omega^2 = \sqrt{A^2 - x^2}$) $v_{\max}$ increased so $KE_{\max}$ increased	4 x B1	Allow EPE max is dependent on A^2 NOT EPE dependent on x alone Allow EPE dependent on x and F which is dependent on x (EPE = $\frac{1}{2} Fx$ idea) KE = $\frac{1}{2} kx^2$ is XP
			TOTAL	17	