

OCR A-LEVEL PHYSICS A • H556

PHYSICS



EXAM QUESTION PACK

2.1-2.3 FOUNDATIONS OF PHYSICS

SCORE

/334

PERCENTAGE

%

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- 1 A length x is $50 \text{ mm} \pm 2 \text{ mm}$. Length y is $100 \text{ mm} \pm 6 \text{ mm}$. The length z is given by $z = y - x$.

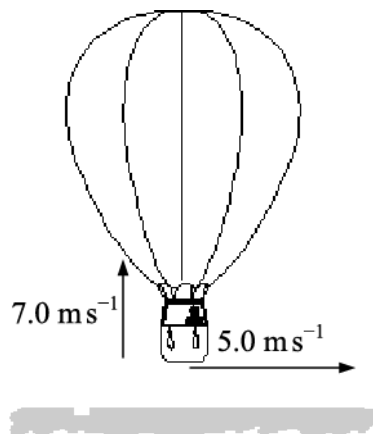
What is the best estimate of the uncertainty in z ?

- A $\pm 1 \text{ mm}$
- B $\pm 4 \text{ mm}$
- C $\pm 5 \text{ mm}$
- D $\pm 8 \text{ mm}$

Your answer

[1]

- 2 When a sandbag is dropped from a balloon hovering 1.3 m above the ground, it hits the ground at 5.0 ms^{-1} .
On another occasion, the sandbag is released from the balloon which is rising at 7.0 ms^{-1} when 1.3 m above the ground. There is also a crosswind of 5.0 m s^{-1} .



At what speed does the sandbag hit the ground?

- A 2.0 ms^{-1}
- B 5.4 ms^{-1}
- C 10 ms^{-1}
- D 13 ms^{-1}

Your answer

[1]

3 What is the correct unit for specific heat capacity?

- A $\text{m}^2\text{s}^{-2}\text{K}^{-1}$
- B $\text{ms}^{-2}\text{K}^{-1}$
- C $\text{m}^2\text{s}^{-1}\text{K}^{-1}$
- D $\text{m}^2\text{s}^{-2}\text{K}$

Your answer

[1]

4 Which physical quantity has the same base units as energy?

- A moment
- B momentum
- C force
- D pressure

Your answer

[1]

5 A car travels a distance 166 ± 2 m in a time 5.2 ± 0.1 s.

What is the best estimate of the speed of the car?

- A $32 \pm 1 \text{ m s}^{-1}$
- B $32.0 \pm 2.1 \text{ m s}^{-1}$
- C $32.0 \pm 0.2 \text{ m s}^{-1}$
- D $32 \pm 0.999 \text{ m s}^{-1}$

Your answer

[1]

- 6 Fig.16 shows typical thinking, braking and stopping distances for cars driven at different initial speeds. The speed is shown in miles per hour (mph).

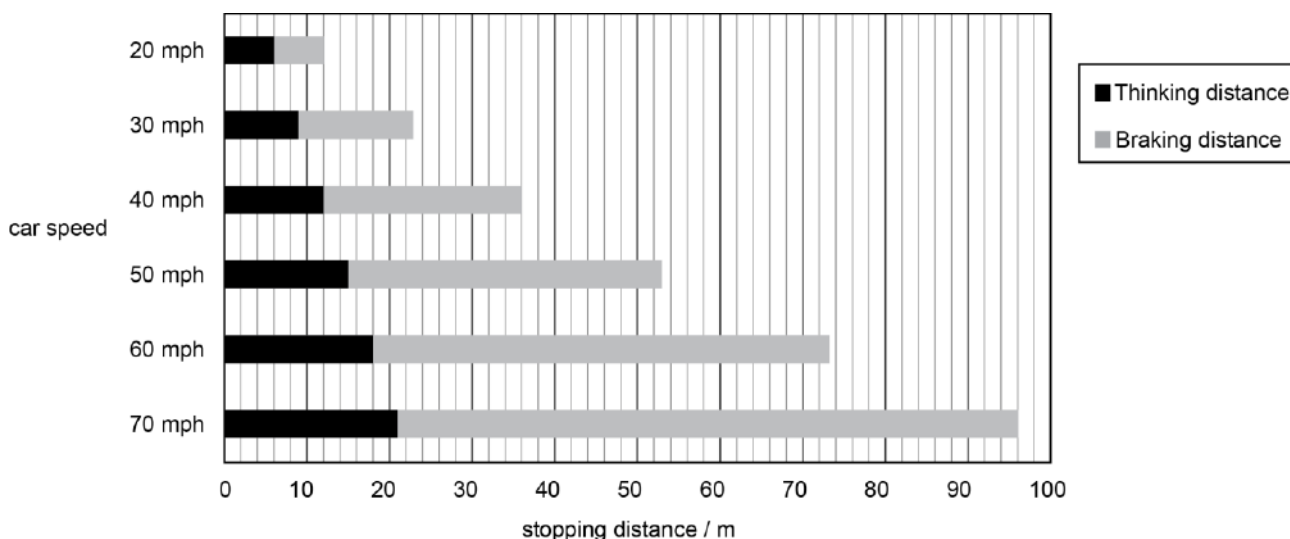


Fig. 16

A **truck** of mass 2300 kg is travelling at a constant speed of 22 m s^{-1} along a dry, level road. The driver reacts to a hazard ahead and applies the brakes to stop the truck. The reaction time of the driver is 0.97 s. The brakes exert a constant braking force of 8700 N.

- (i) Calculate the magnitude of the deceleration of the truck when braking.

deceleration = _____ m s^{-2} [2]

- (ii) Show that the stopping distance of the truck is about 85 m.

[3]

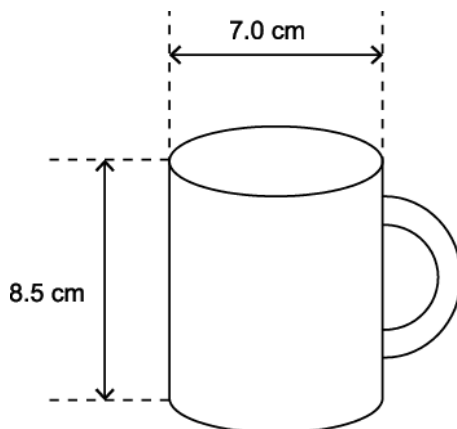
(iii) Show that a speed of 22 m s^{-1} is equivalent to about 50 mph (miles per hour). 1 mile = 1600 m

[1]

(iv) Use Fig. 16 and your answer to (ii) to compare the stopping distance of the car and the truck at 50 mph.
Suggest relevant factors that may have affected the stopping distance of the truck.

[4]

7(a) A cylindrical cup of internal diameter 7.0 cm and height 8.5 cm is filled to the top with water.



The density of water is 1000 kg m^{-3} . The mass of one mole of water is 18 g. The specific heat capacity of water is $4200 \text{ J kg}^{-1} \text{ K}^{-1}$.

Show that the minimum time taken for a 0.50 kW camping kettle to bring a cup of water at 20°C to boiling point is about 200 s.

[3]

(b) In a laboratory test, the camping kettle was found to bring a cup of water to the boil in 320 seconds.

Explain why your previous answer is an underestimate and suggest **two** ways that you can refine the test to ensure that the time to boil is closer to 200 s.

[3]

- 8 Fig. 19 shows a crane lifting a car of mass 850 kg at constant velocity through a height of 12 m in a time of 40 s. The crane has a working efficiency of 60 %.

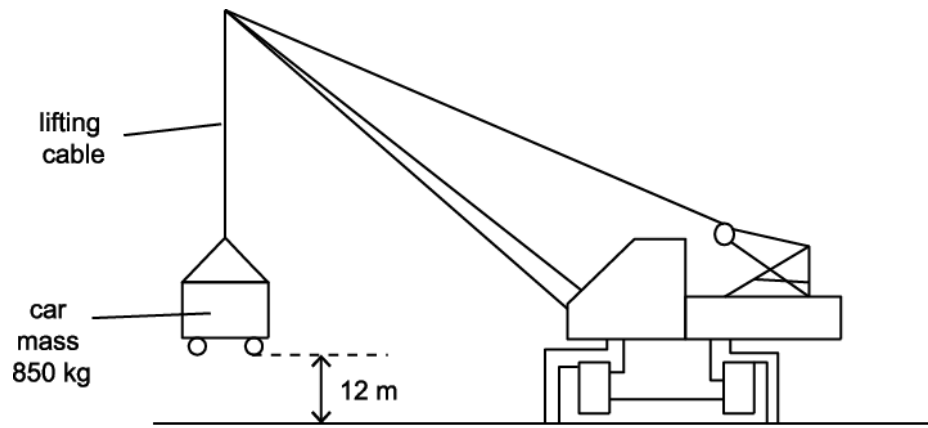


Fig. 19

- (i) Calculate the tension in the lifting cable.

tension = ... N [1]

- (ii) Calculate the total input power required by the crane to lift the car.

total input power = ... W [4]

- (iii) Suggest and explain **two** ways the crane can be modified to improve its efficiency.

.....

.....

.....

- 9 Hubble's law can be used to estimate the age of the universe. Fig. 23 shows some of Hubble's early measurements of nearby galaxies plotted on a v against d graph, where v is the recessional speed of a galaxy and d is its distance from us.

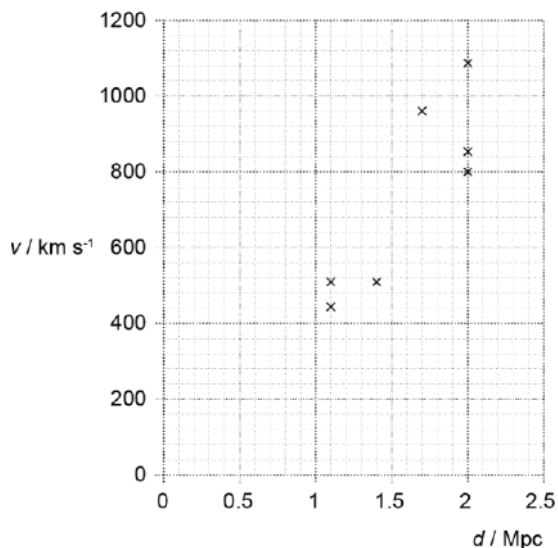


Fig. 23

- (i) State how v was determined.

----- [1]

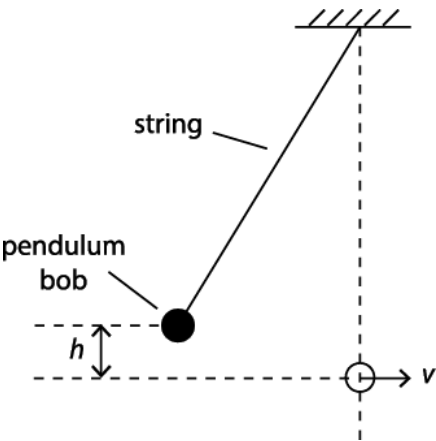
- (ii) Use Fig. 23 to estimate a value for the Hubble constant H_0 in $\text{km s}^{-1} \text{Mpc}^{-1}$.

$$H_0 = \text{-----} \text{ km s}^{-1} \text{Mpc}^{-1} \text{ [3]}$$

- (iii) Use your answer to part (ii) to estimate Hubble's initial value for the age of the universe in years.

age = _____ years [3]

10(a) A group of students are conducting an experiment in the laboratory to determine the acceleration of free g using a simple pendulum as shown below.



The pendulum bob is released from **rest** from a height h . The speed of the pendulum bob as it passes through the vertical position is v . The speed v is measured using a light-gate and a computer.
The results from the students are shown in a table.

h / m	$v / \text{m s}^{-1}$	$v^2 / \text{m}^2 \text{s}^{-2}$
0.052	1.0 ± 0.1	1.0 ± 0.2
0.100	1.4 ± 0.1	2.0 ± 0.3
0.151	1.7 ± 0.1	2.9 ± 0.3
0.204	1.9 ± 0.1	
0.250	2.2 ± 0.1	4.8 ± 0.4
0.302	2.4 ± 0.1	5.8 ± 0.5

Complete the missing value of v^2 in the table.

[1]

(b) Fig. 24 shows the graph of v^2 against h .

11(a) A cyclist moves along a horizontal road. She pushes on the pedals with a constant power of 250 W. The mass of the cyclist and bicycle is 85 kg. The total drag force is $0.4v^2$, where v is the speed of the cyclist.

The cyclist now moves up a slope at a constant speed of 6.0 ms^{-1} and continues to exert a power of 250 W on the pedals.

Fig. 17.1 represents the cyclist and bicycle as a single point P on the slope.

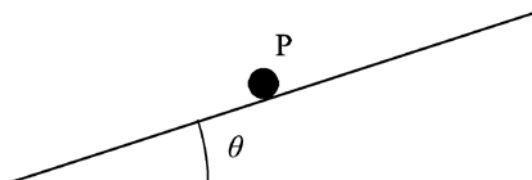


Fig. 17.1

(i) Draw arrows on Fig. 17.1 to represent the forces acting on P. Label each arrow with the force it represents.

[1]

(ii) Calculate the angle θ of the slope to the horizontal.

$\theta = \text{-----}^\circ$ [2]

- (b) The cyclist continues to move up the slope at 6.0 ms^{-1} and approaches a gap of width 2.5 m as shown in Fig. 17.2.

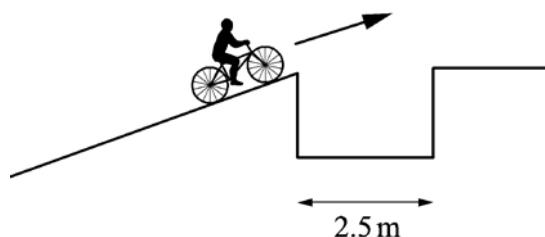


Fig. 17.2

A student has calculated that the cyclist will be able to clear the gap and land on the other side. Another student suggests that this calculation has assumed there is no drag and has not accounted for the effect caused by the front wheel losing contact with the slope before the rear wheel.

Without calculation, discuss how drag and the front wheel losing contact with the slope will affect the motion and explain how these might affect the size of the gap that can be crossed successfully.

[4]

- 12 A solar-powered ion propulsion engine creates and accelerates xenon ions. The ions are ejected at a constant rate from the rear of a spacecraft, as shown in Fig. 2.1.

The ions have a fixed mean speed of $3.2 \times 10^4 \text{ ms}^{-1}$ relative to the spacecraft.

The initial mass of the spacecraft is $5.2 \times 10^3 \text{ kg}$.

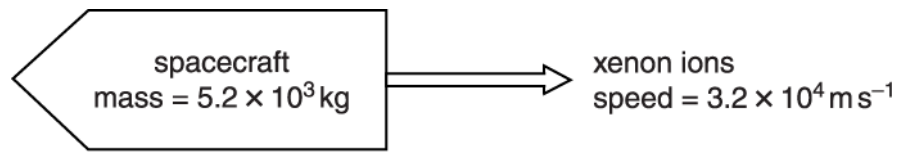


Fig. 2.1

- (i) Calculate the mass of one xenon ion.
molar mass of xenon = $0.131 \text{ kg mol}^{-1}$

mass = ... kg [1]

- (ii) The engine is designed to eject 9.5×10^{18} xenon ions per second.
Determine the initial acceleration of the spacecraft.

acceleration = ... m s^{-2} [3]

- (iii) State in words the law that you have used to solve (ii).



In your answer, you should use appropriate technical terms spelled correctly.

----- [1]

- (iv) State and explain how you would expect the acceleration of the spacecraft to change, if at all, while the engine is running.

----- [3]

- 13 To find the density ρ of a metal wire, a student makes the following measurements:

length $l = 100 \pm 1$ mm

diameter $d = 2.50 \pm 0.05$ mm

mass $m = 4.00 \pm 0.02$ g

The equation $\rho = \frac{4m}{\pi d^2 l}$ is used to calculate the density of the metal.

What is the percentage uncertainty in the answer?

A $\pm 2.5\%$

B $\pm 3.5\%$

C $\pm 4.5\%$

D $\pm 5.5\%$

Your answer

[1]

14 Fluorodeoxyglucose (FDG) is a radioactive tracer often used for PET scans. It contains radioactive fluorine-18, which is a positron-emitter. Some information about FDG and fluorine-18 is given below.

- 9.9% of the mass of FDG is fluorine-18.
- The half-life of fluorine-18 is 6600 s.
- The molar mass of fluorine-18 is $0.018 \text{ kg mol}^{-1}$.

A patient is injected with FDG. The initial activity of FDG is 400 MBq.

Use the information given to calculate the initial mass of FDG given to the patient.

mass = _____ kg [4]

15 What is the de Broglie wavelength in nm of a proton travelling at $1.5 \times 10^4 \text{ m s}^{-1}$?

- A $2.6 \times 10^{22} \text{ nm}$
- B 2.6 nm
- C 49 nm
- D $4.9 \times 10^4 \text{ nm}$

Your answer

[1]

16 A student records the following data during an experiment to determine the internal resistance of a battery.

$$\text{e.m.f.} = (4.5 \pm 0.2) \text{ V}$$

$$\text{terminal p.d.} = (3.0 \pm 0.1) \text{ V}$$

$$\text{current} = (2.0 \pm 0.1) \text{ A}$$

What is the percentage uncertainty in the value for the internal resistance of the battery?

A 5.0 %

B 6.1 %

C 13 %

D 25 %

Your answer

[1]

17 What is the correct SI unit for acoustic impedance?

A kg s

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

C $\text{kg m}^{-3} \text{ s}^{-1}$

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

Your answer

[1]

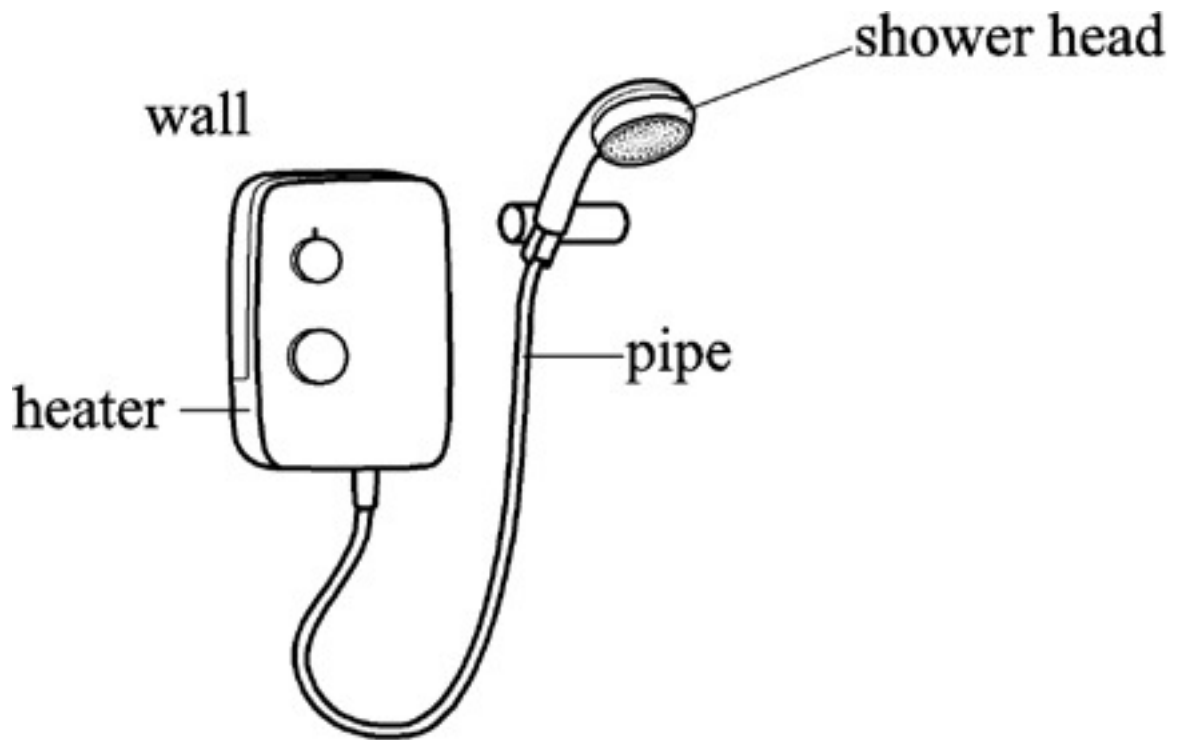


Fig.1.1

The water enters the heater at a temperature of $14\text{ }^{\circ}\text{C}$. At the maximum flow rate of 0.070 kg s^{-1} , the water leaves the shower head at a temperature of $30\text{ }^{\circ}\text{C}$.

Calculate the rate at which energy is transferred to the water. Give a suitable unit for your answer.

specific heat capacity of water = $4200\text{ J kg}^{-1}\text{ K}^{-1}$

rate of energy transfer = _____ unit _____ [3]

19 The kilogram, metre and second are SI base units.

Determine the unit for *power* in terms of these SI units.

unit for power = _____ [1]

20 Which quantity has the unit hertz (Hz)?

- A frequency
- B acceleration
- C phase difference
- D angular frequency

Your answer

[1]

21 The cross-sectional area of a wire is recorded as $0.14 \pm 0.01 \text{ mm}^2$.
The length of the wire is recorded as $100 \pm 1 \text{ mm}$.

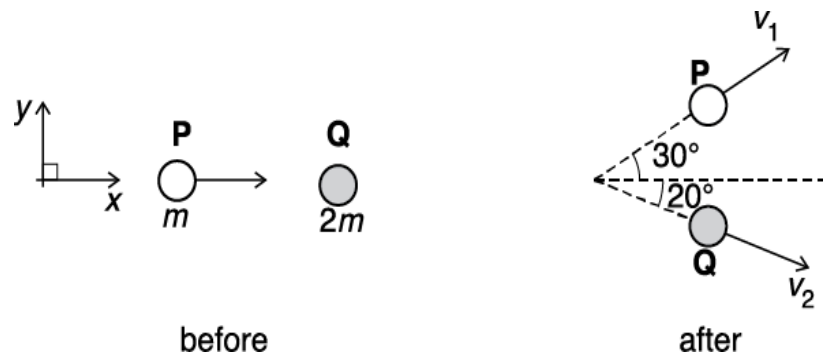
What is the percentage uncertainty in the volume of the wire?

- A 1.0 %
- B 4.6 %
- C 7.1 %
- D 8.1 %

Your answer

[1]

- 22 A ball P of mass m has a velocity in the positive x -direction. It makes a collision with a stationary ball Q of mass $2m$. After the collision, the ball P has velocity v_1 , ball Q has velocity v_2 and the balls travel in the directions shown in the diagram below.



After the collision, the total momentum of the balls in the x -direction is p_x and the total momentum in the y -direction is p_y .

Which row is correct for p_x and p_y ?

	p_x	p_y
A	$2mv_2 \cos 20^\circ + mv_1 \cos 30^\circ$	0
B	$2mv_2 \sin 20^\circ + mv_1 \sin 30^\circ$	0
C	$2mv_2 \cos 20^\circ + mv_1 \cos 30^\circ$	$2mv_2 \sin 30^\circ + mv_1 \sin 20^\circ$
D	$2mv_2 \sin 20^\circ + mv_1 \sin 30^\circ$	$2mv_2 \cos 30^\circ + mv_1 \cos 20^\circ$

Your answer ☐

[1]

- 23 Fig. 16.1 shows an arrangement used by a group of students to determine the acceleration of free fall g in the laboratory.

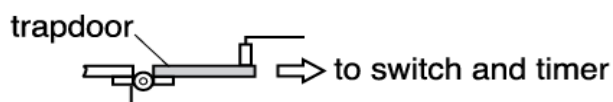
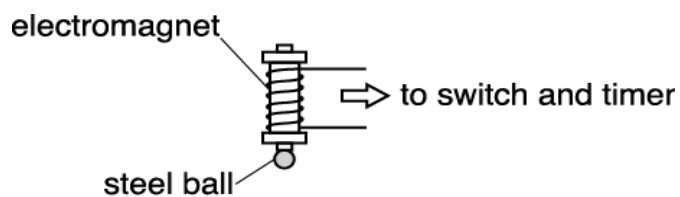


Fig. 16.1

An electromagnet is used to hold a small steel ball in position above a trapdoor. A timer starts as soon as the ball is released, and is stopped when the ball hits and opens the trapdoor. The clamp stands holding the trapdoor mechanism and the electromagnet are not shown in Fig. 16.1.

The distance between the bottom of the steel ball and the top of the trapdoor is 1.200 ± 0.001 m. The steel ball takes 0.50 ± 0.02 s to fall through this distance.

- (i) Calculate a value for g using these results.

$$g = \text{-----} \text{ m s}^{-2} [2]$$

(ii) Determine the percentage uncertainty in the value for g .

percentage uncertainty = _____ % [2]

24(a) The ball-release mechanism of a pinball machine is shown in Fig. 17.1.

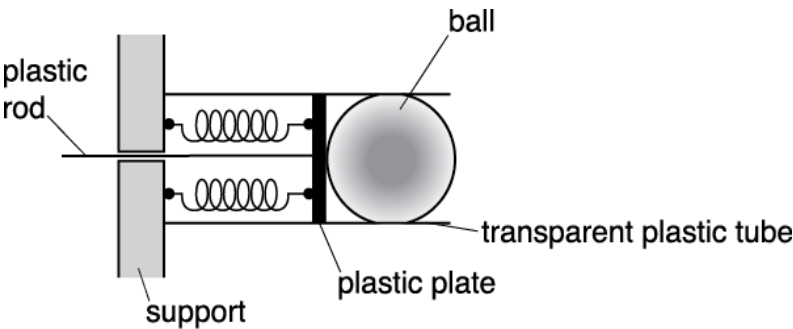


Fig. 17.1

A pair of identical compressible springs are fixed between a plastic plate and a support. The springs are in parallel. A plastic rod attached to the plate is pulled to the left to compress the springs. A ball, initially at rest, is fired when the plate is released.

A group of students are conducting an experiment to investigate the ball-release mechanism shown in Fig. 17.1. The students apply a force F and measure the compression x of the springs. The table below shows the results.

F / N	x / cm
1.1 ± 0.2	2.0
2.0 ± 0.2	4.0
2.9 ± 0.2	6.0
4.0 ± 0.2	8.0
5.1 ± 0.2	10.0

Fig. 17.2 shows four data points from the table plotted on a F against x graph.

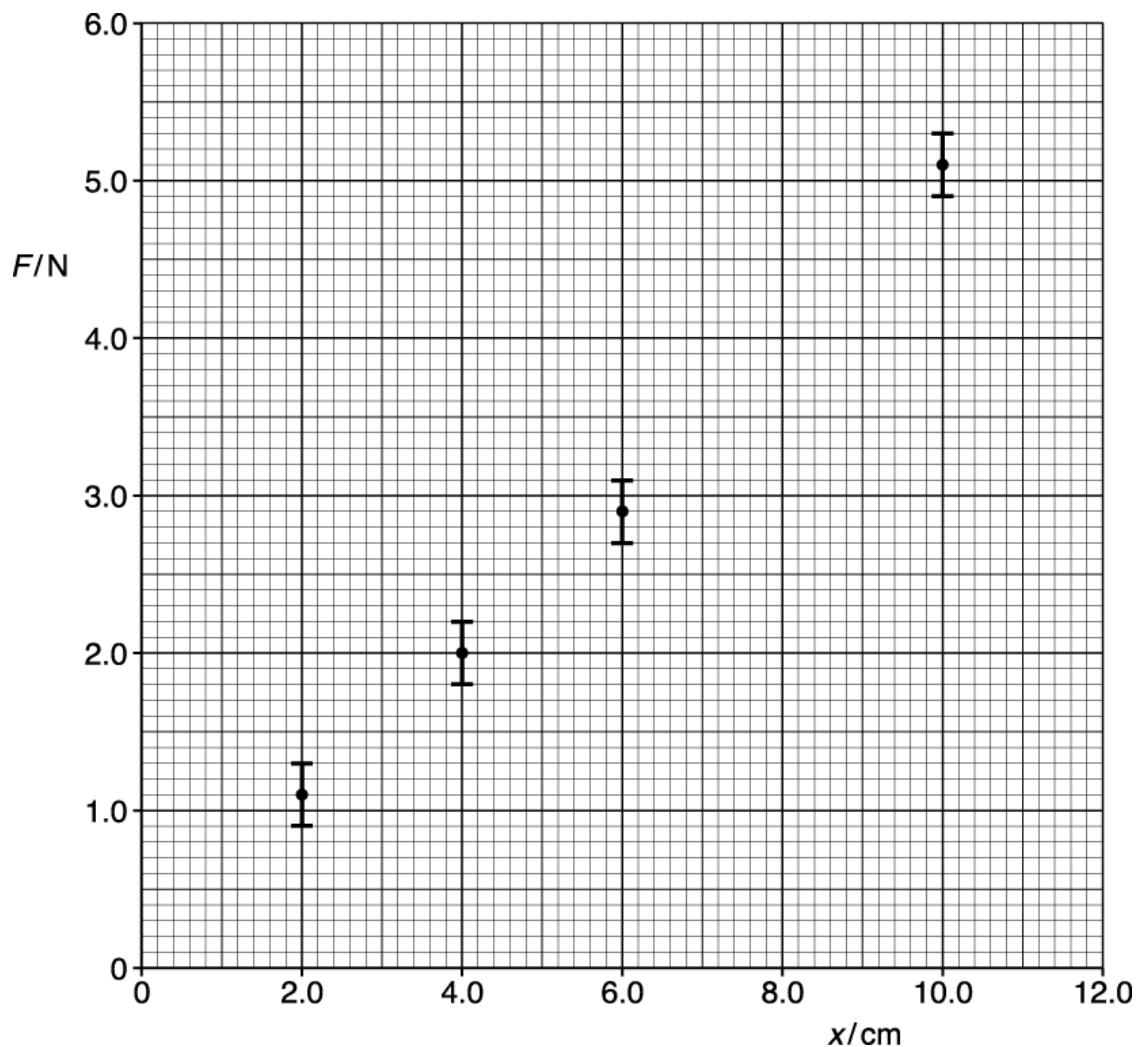


Fig. 17.2

- (i) Plot the missing data point and the error bar on Fig. 17.2.

[1]

- (ii) Describe how the data shown in the table may have been obtained in the laboratory.

[2]

- (iii) Draw the best fit and the worst fit straight lines on Fig. 17.2.

Use the graph to determine the force constant k for a **single** spring and the absolute uncertainty in this value.

$$k = \text{-----} \pm \text{-----} \text{ N m}^{-1} \text{ [4]}$$

(iv) State the feature of the graph that shows Hooke's law is obeyed by the springs.

----- [1]

(v) The mass of the ball is 0.39 kg.

Use your answer from (iii) to calculate the launch speed v of the ball when the plastic plate shown in Fig. 17.1 is pulled back 12.0 cm.

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

(b) A new arrangement for the ball-release mechanism using three identical springs is shown in Fig. 17.3.

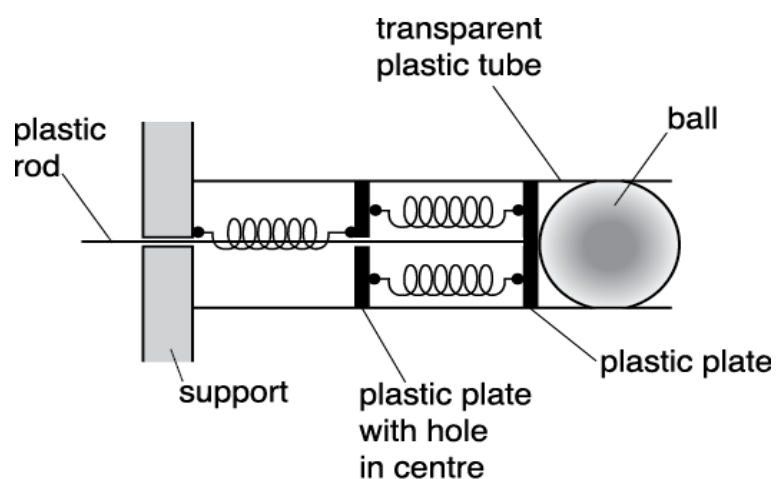


Fig. 17.3

The force constant of each spring is k .

The same ball of mass 0.39 kg is used. The plastic rod is pulled to the left by a distance of x .

Show that initial acceleration a of this ball is given by the equation

$$a = 1.7\ kx.$$

[2]

- 25 The Big Bang theory explains the origin and the evolution of the early Universe.
The table below shows the distance d and recession velocity v of some galaxies close to our own galaxy.

Galaxy	d / Mpc	$v / \text{km s}^{-1}$
NGC-5357	0.45	200
NGC-3627	0.90	650
NGC-4151	1.7	960
NGC-4472	2.0	850

The chemical composition of the stars in our galaxy can be determined by analysing in the laboratory the absorption spectral lines for these stars.

The closest star to us is the Sun. The wavelength of the hydrogen-beta spectral line from the Sun is 486 nm.

- (i) Use the information from the table to calculate the **observed** wavelength λ of the hydrogen-beta spectral line from a star in the galaxy NGC-4151.

$\lambda =$ _____ nm [3]

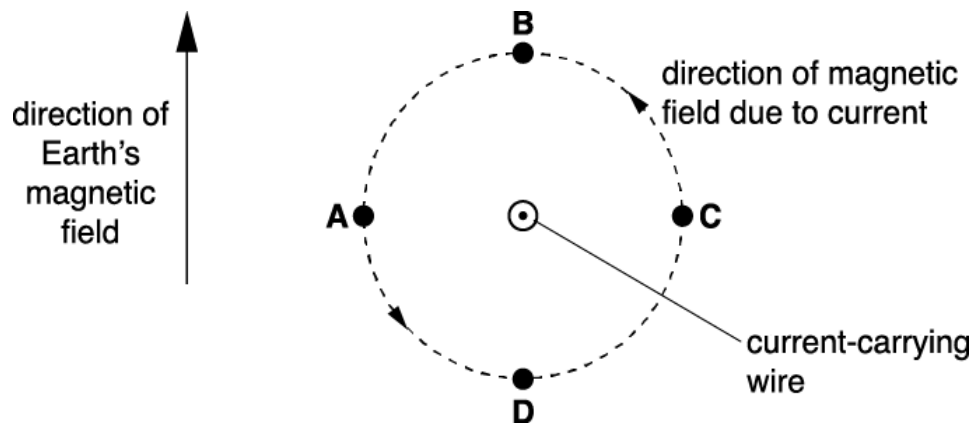
- (ii) A diffraction grating with 800 lines per mm is used to observe and analyse the light from the Sun in the laboratory.

A narrow beam of light from the Sun is incident normally at the diffraction grating.

Calculate the angle θ between the central beam of light through the grating and the hydrogen-beta spectral line in the **second** order spectrum.

$$\theta = \text{-----}^\circ \text{ [2]}$$

- 26 The diagram below shows a current-carrying wire coming out from the plane of the paper. The current in the wire produces a magnetic field in an **anticlockwise** direction around the wire.



The direction of the Earth's magnetic field is also shown.

The Earth's magnetic field interacts with the magnetic field of the current-carrying wire.

At which point A, B, C or D is the resultant magnetic field strength a **minimum**?

Your answer

[1]

- 27 In Fig. 18.1 the solid line represents the displacement s against distance x graph for a **progressive** transverse wave on a stretched string at time $t = 0$. The dotted line shows the graph for the same wave at a later time $t = 2.5$ ms.

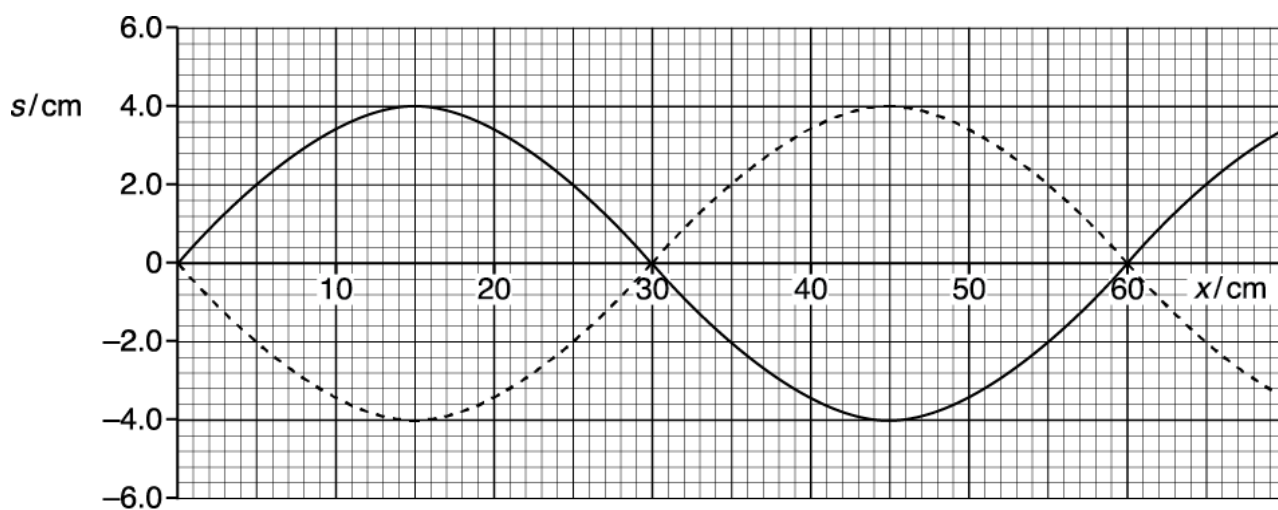


Fig. 18.1

Determine the frequency f of this wave.

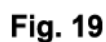
$f =$ _____ Hz [3]

28(a) Electromagnetic radiation of wavelength 300 nm is incident on the surface of two metals X and Y. Metal X has work function 2.0 eV and metal Y has work function 5.0 eV.

With the help of calculations, explain any difference between the emission of photoelectrons from the surfaces of the metals X and Y.

[4]

- Fig. 19 shows incomplete graphs of $KE_{\max}$ against f from the groups A and B.



group B: $h = (6.6 \pm 0.6) \times 10^{-34} \text{ J s}$

This image shows a blank sheet of white paper with ten horizontal dashed lines, typical of primary-ruled notebook paper. The lines are evenly spaced and extend across the width of the page. There is no handwriting or other markings on the paper.

[6]

29 Fig. 21.1 shows two oppositely charged ions to the left of a point X.



Fig. 21.1

The separation between the centres of the ions is 3.0×10^{-10} m. Each ion has charge of magnitude 1.6×10^{-19} C.

- (i) Explain why the direction of the **resultant** electric field strength at point X is to the left.

----- [2]

- (ii) Calculate the minimum energy in eV required to completely separate the ions.

energy = ----- eV [3]

- 30 A patient with a blood clot in his muscle is having an ultrasound A-scan.
Fig. 24.1 shows an ultrasound transducer placed on the patient's skin.

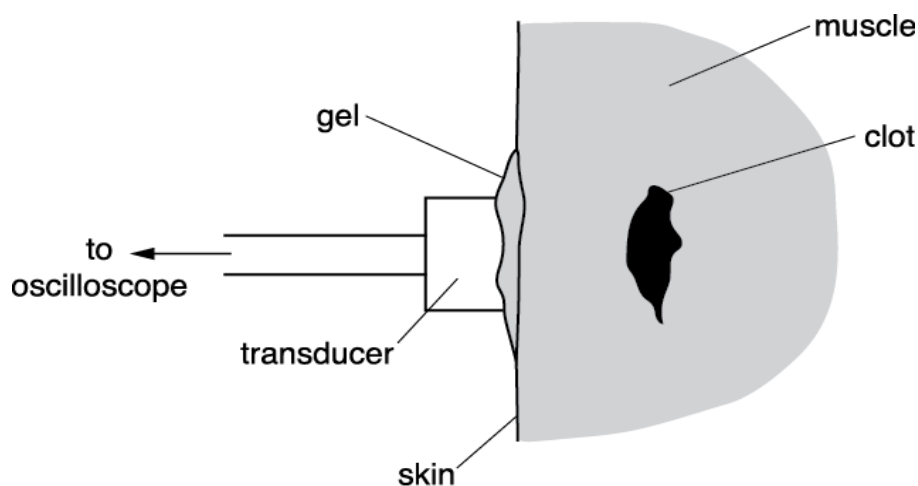


Fig. 24.1 (not to scale)

The ultrasound transducer produces pulses of ultrasound. An oscilloscope is connected to the transducer. Fig. 24.2 shows part of the oscilloscope display.

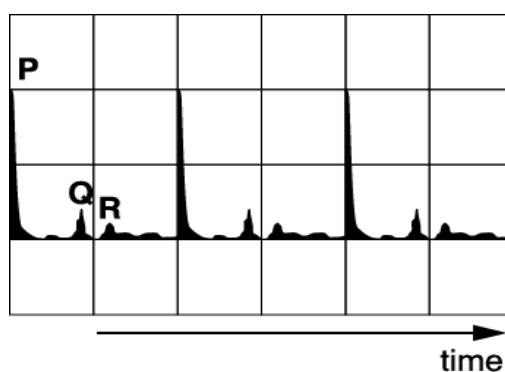


Fig. 24.2

The **front** of the blood clot is 1.5 cm from the skin.

The density of the patient's muscle is 1070 kg m^{-3} .

The time difference between pulses P and Q in Fig. 24.2 is $19 \mu\text{s}$.

Determine the acoustic impedance Z of patient's muscle. State an appropriate unit for your answer.

$Z =$ _____ unit: _____ [4]

31 Which is **not** a unit of energy?

A kW h

B eV

C J

D W

Your answer

[1]

32(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.

$R =$ ----- $\pm$ ----- Ω [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]

33(a)

Fig. 20.1 shows a positively charged metal sphere and a negatively charged metal plate.

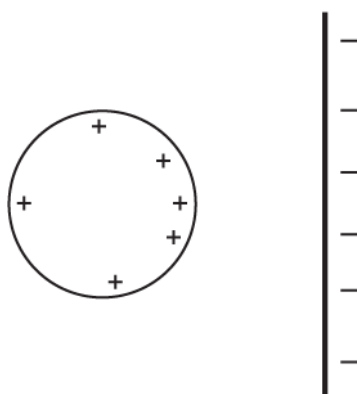


Fig. 20.1

On Fig. 20.1, draw a minimum of **five** electric field lines to show the field pattern between the sphere and the plate.

[2]

(b) Define *electric potential* at a point in space.

----- [1]

(c) A metal sphere is given a positive charge by connecting its surface briefly to the positive terminal of a power supply. The electric potential at the surface of the sphere is + 5.0 kV. The sphere has radius 1.5 cm.

(i) Show that the charge Q on the surface of the sphere is 8.3×10^{-9} C.

[2]

- (ii) Fig. 20.2 shows the charged sphere from (i) suspended from a nylon thread and placed between two oppositely charged vertical plates.

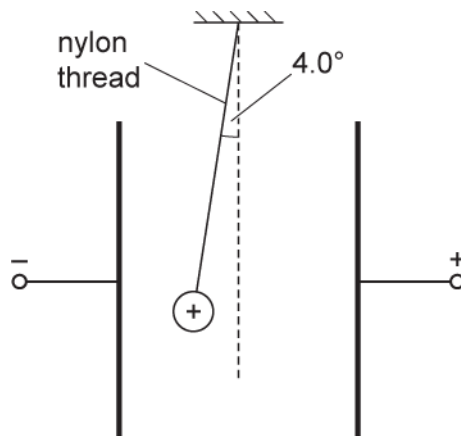


Fig. 20.2 (not to scale)

The weight of the sphere is 1.7×10^{-2} N. The string makes an angle of 4.0° with the vertical.

- 1 Show that the electric force on the charged sphere is 1.2×10^{-3} N.

[1]

- 2 Calculate the uniform electric field strength E between the parallel plates.

$$E = \text{-----} \text{ N C}^{-1} \text{ [2]}$$

34(a)

A capacitor of capacitance 7.2 pF consists of two parallel metal plates separated by an insulator of thickness 1.2 mm. The area of overlap between the plates is $4.0 \times 10^{-4} \text{ m}^2$. Calculate the permittivity of the insulator between the capacitor plates.

permittivity = _____ F m^{-1} [2]

(b) Fig. 21 shows a circuit.

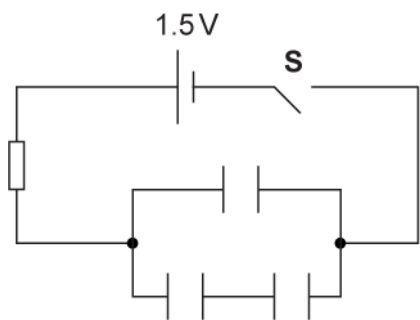


Fig. 21

The capacitance of each capacitor is $1000\ \mu\text{F}$. The resistance of the resistor is $10\ \text{k}\Omega$. The cell has e.m.f. $1.5\ \text{V}$ and negligible internal resistance.

(i) Calculate the total capacitance C in the circuit.

$C = \text{-----}\ \mu\text{F}$ [2]

(ii) The switch S is closed at time $t = 0$. There is zero potential difference across the capacitors at $t = 0$. Calculate the potential difference V across the resistor at time $t = 12\ \text{s}$.

$V = \text{-----}\ \text{V}$ [2]

35(a)



A student conducts an experiment to confirm that the uniform magnetic flux density B between the poles of a magnet is 30 mT.

A current-carrying wire of length 5.0 cm is placed perpendicular to the magnetic field.

The current I in the wire is changed and the force F experienced by the wire is measured. Fig. 22.1 shows the graph plotted by the student.

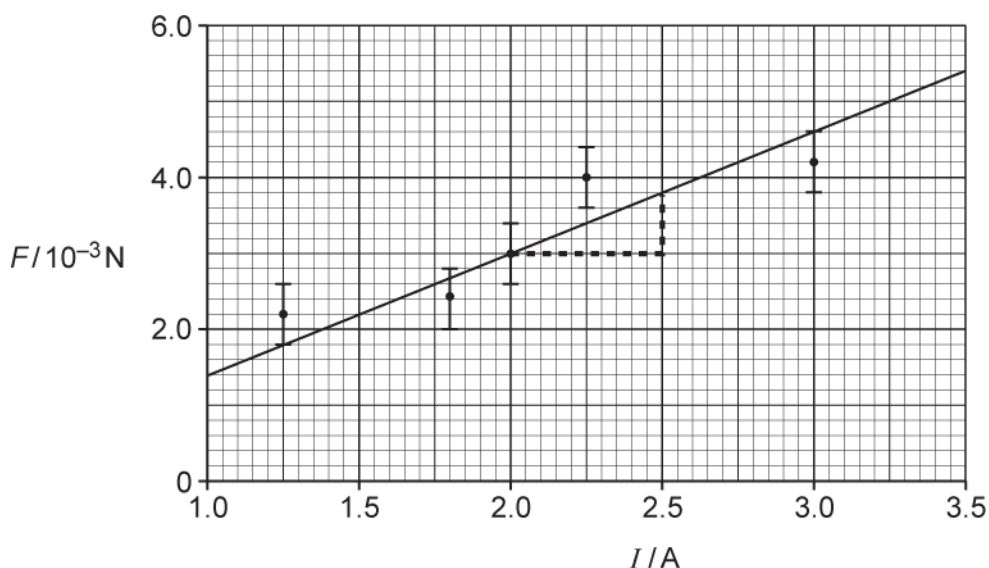


Fig. 22.1

The student's analysis is shown on the graph of Fig. 22.1 and in the space below.

$$F = BIL$$

$$\text{gradient} = BL = \frac{(3.8 - 3.0) \times 10^{-3}}{2.5 - 2.0} = 0.0016$$

$$B = \frac{0.0016}{0.05} = 0.032 \text{ T} = 32 \text{ mT}$$

This is just 2 mT out from the 30 mT value given by the manufacturer, so the experiment is very accurate.

Evaluate the information from Fig. 22.1 and the analysis of the data from the experiment. No further calculations are necessary.

[6]

(b) Fig. 22.2 shows a transformer circuit.

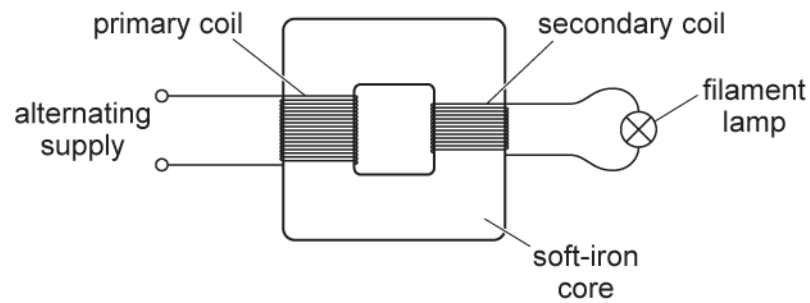


Fig. 22.2

The primary coil is connected to an alternating voltage supply. A filament lamp is connected to the output of the secondary coil.

(i) Use Faraday's law of electromagnetic induction to explain why the filament lamp is lit.

----- [3]

(ii) The primary coil has 400 turns and the secondary coil has 20 turns. The potential difference across the lamp is 12 V and it dissipates 24 W. The transformer is 100% efficient.

1 Calculate the current in the primary coil.

current = ----- A [2]

2 The alternating voltage supply is replaced by a battery and an open switch in series. The switch is closed. The lamp is lit for a short period of time and then remains off. Explain this observation.

----- [2]

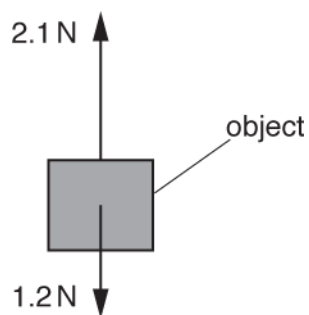
36 Which is the **best** estimate of the area of a rectangular field of length 98 ± 3 m and width 47 ± 2 m?

- 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]

37 The diagram shows two opposite vertical forces of magnitude 1.2 N and 2.1 N acting on an object.



Which of the following statements could be correct?

- 1 The object is accelerating and moving up.
- 2 The object is decelerating and moving down.
- 3 The magnitude of the resultant force is 0.9 N.

- A Only 3
- B Only 1 and 3
- C Only 2 and 3
- D 1, 2 and 3

Your answer

[1]

38(a) A group of students are conducting an experiment in the laboratory to determine the value of absolute zero by heating a fixed mass of gas. The volume of the gas is kept constant.

Fig. 17.1 shows the arrangement used by the students.

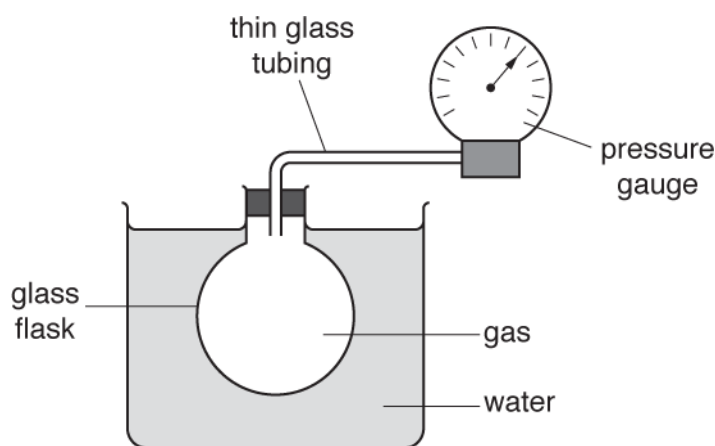


Fig. 17.1

The gas is heated using a water bath. The temperature θ of the water is increased from 5 °C to 70 °C. The temperature of the water bath is assumed to be the same as the temperature of the gas. The pressure p of the gas is measured using a pressure gauge.

The results from the students are shown in a table.

$\theta / ^\circ\text{C}$	p / kPa
5 ± 1	224 ± 3
13 ± 1	231 ± 3
22 ± 1	238 ± 3
35 ± 1	248 ± 3
44 ± 1	
53 ± 1	262 ± 3
62 ± 1	269 ± 3
70 ± 1	276 ± 3

Describe and explain how the students may have made accurate measurements of the temperature θ .

[2]

- (b) Fig. 17.2 shows the pressure gauge. Measurements of p can be made using the kPa scale or the psi (pounds per square inch) scale. The students used the psi scale to measure pressure and then converted the reading to pressure in kPa.



Fig. 17.2

- (i) Suggest why it was sensible to use the psi scale to measure p .

[1]

- (ii) The students made a reading of p of 37.0 ± 0.5 psi when θ was $44 \pm 1^\circ\text{C}$.

Convert this value of p from psi to kPa. Complete the table for the missing value of p . Include the absolute uncertainty in p .

$$1 \text{ pound of force} = 4.448 \text{ N}$$

$$1 \text{ inch} = 0.0254 \text{ m}$$

[2]

(c) Fig. 17.3 shows the graph of p against θ .

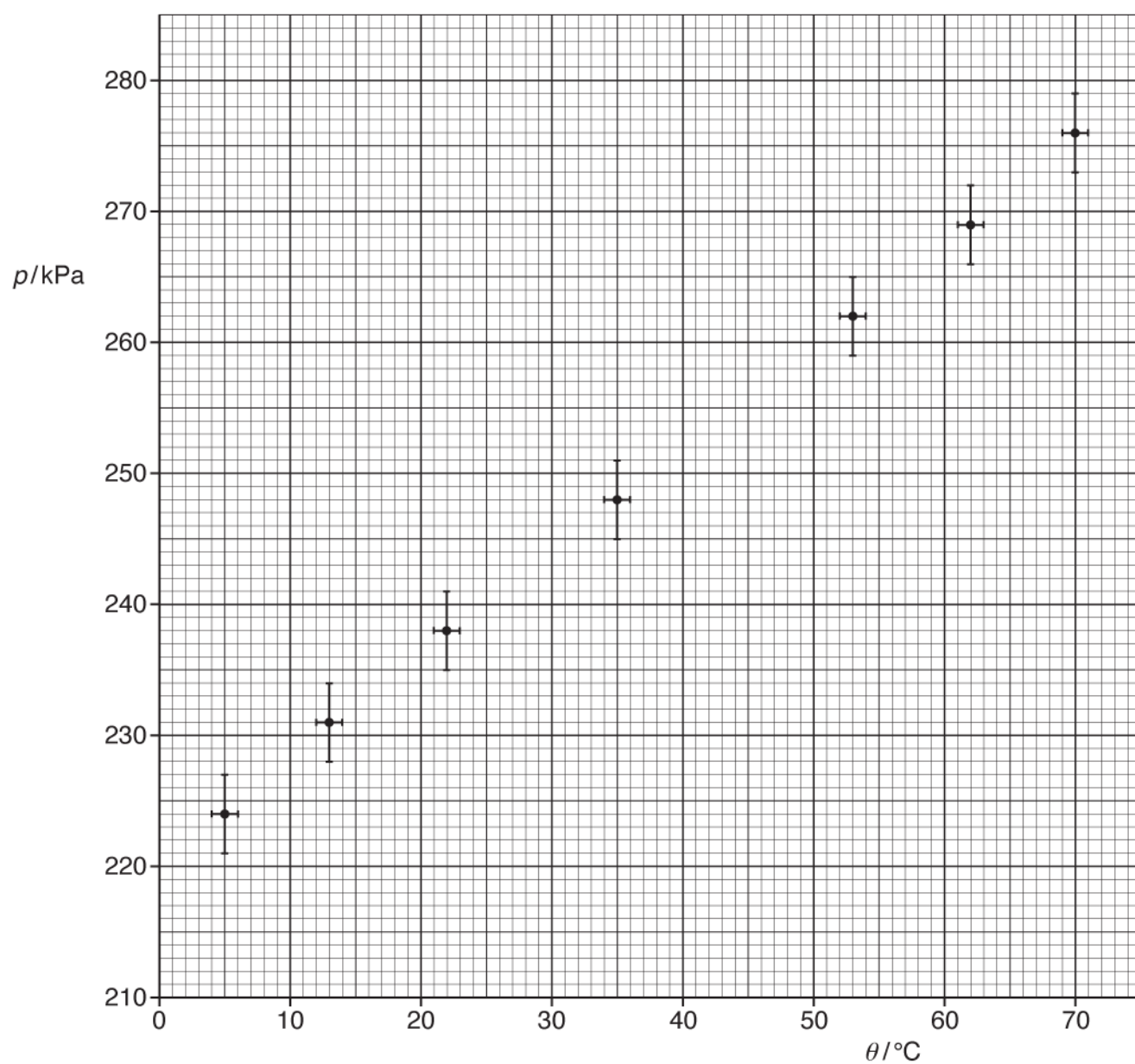


Fig. 17.3

(i) Plot the missing data point and the error bars on Fig. 17.3.

[1]

(ii)



Explain what is meant by *absolute zero*. Describe how Fig. 17.3 can be used to determine the value of absolute zero.

Determine the value of absolute zero. You may assume that the gas behaves as an ideal gas.

[6]

- [2]

- Compare this value with your value from (c)(ii) and explain why the values may differ. Describe an experimental approach that could be taken to avoid systematic error in the determination of absolute zero.

[4]

39(a) Fig. 16 shows a hydraulic jack used to lift a car which has a mass of 1200 kg. A mechanic exerts a downwards force of 400 N on the handle of the jack, moving it 80.0 cm downwards. As he moves the handle, the car rises 2.0 cm.

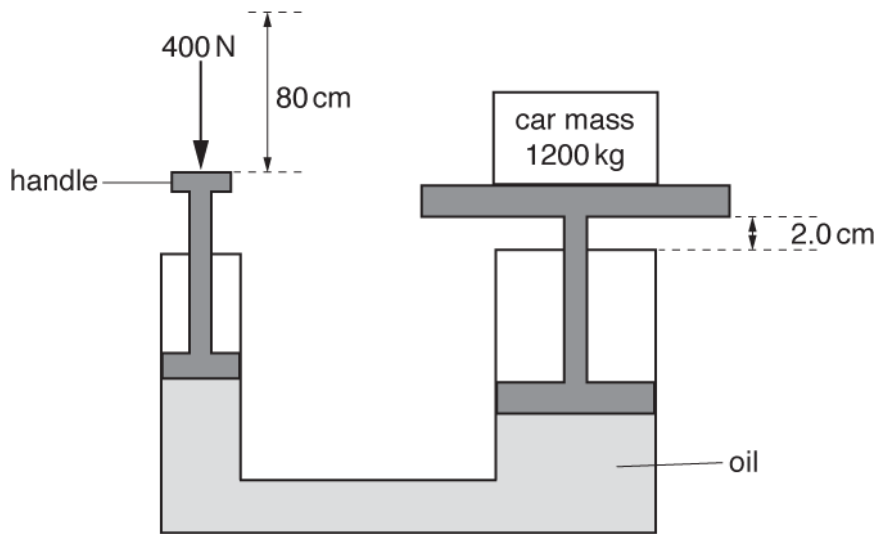


Fig. 16

Calculate the work done by the 400 N force exerted by the mechanic.

work done = _____ J [2]

(b) Calculate the ratio

$$\frac{\text{speed of handle moving down}}{\text{speed of car moving up}}.$$

ratio = _____ [2]

(c) Calculate the useful work done on the car and hence the percentage efficiency of the jack.

efficiency = _____ % [2]

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

- A ampere
- B mole
- C volt
- D kilogram

Your answer

[1]

41 Which set of quantities are all scalar?

- A acceleration, displacement, velocity
- B energy, mass, power
- C extension, force, gravitational potential energy
- D weight, kinetic energy, work done

Your answer

[1]

42 The latent heat of vaporisation of a liquid is 2300 kJ kg^{-1} and it has a molar mass of $0.018 \text{ kg mol}^{-1}$.

What is the energy required to change 30 moles of the liquid to gas?

- A $4.1 \times 10^4 \text{ J}$
- B $1.2 \times 10^6 \text{ J}$
- C $6.9 \times 10^7 \text{ J}$
- D $3.8 \times 10^9 \text{ J}$

Your answer

[1]

43(a)

A tennis ball is struck with a racket.

The initial velocity v of the ball leaving the racket is 30.0 m s^{-1} and it makes an angle of 70° to the horizontal as shown in Fig. 16.

Air resistance is negligible

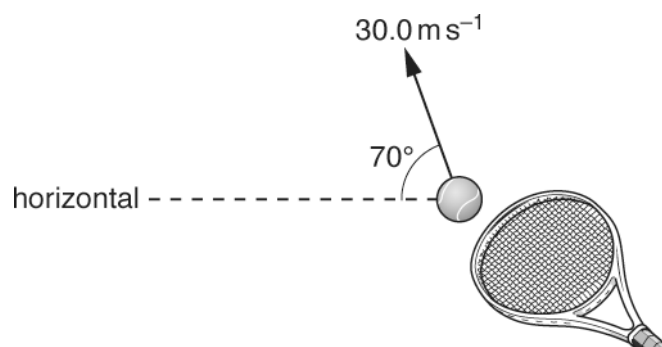


Fig. 16

(i) Calculate the vertical component of the initial velocity of the ball.

vertical component = ----- m s^{-1} [1]

(ii) Use your answer in (i) to show that the ball reaches a maximum height h of about 40 m.

h = ----- m [2]

(iii) Explain why the kinetic energy of the ball is not zero at maximum height.

----- [1]

(iv) The mass m of the ball is 57.0 g.

Calculate the kinetic energy E_k of the ball when it is at its maximum height.

$E_k =$ ----- J [2]

(b)



A metal ball is rolled off the edge of a horizontal laboratory bench. The initial horizontal velocity of the ball is v . The ball travels a horizontal distance x before it hits the level floor.

Use your knowledge of projectile motion to suggest the relationship between v and x . Describe how an experiment can be safely conducted to test this relationship and how the data can be analysed.

[6]

44(a)

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	6000	0.076	3.78
0.87	7000		
0.67	8000	-0.174	3.90
0.53	9000	-0.276	3.95
0.43	10000	-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 $\lg (r / \text{km})$.

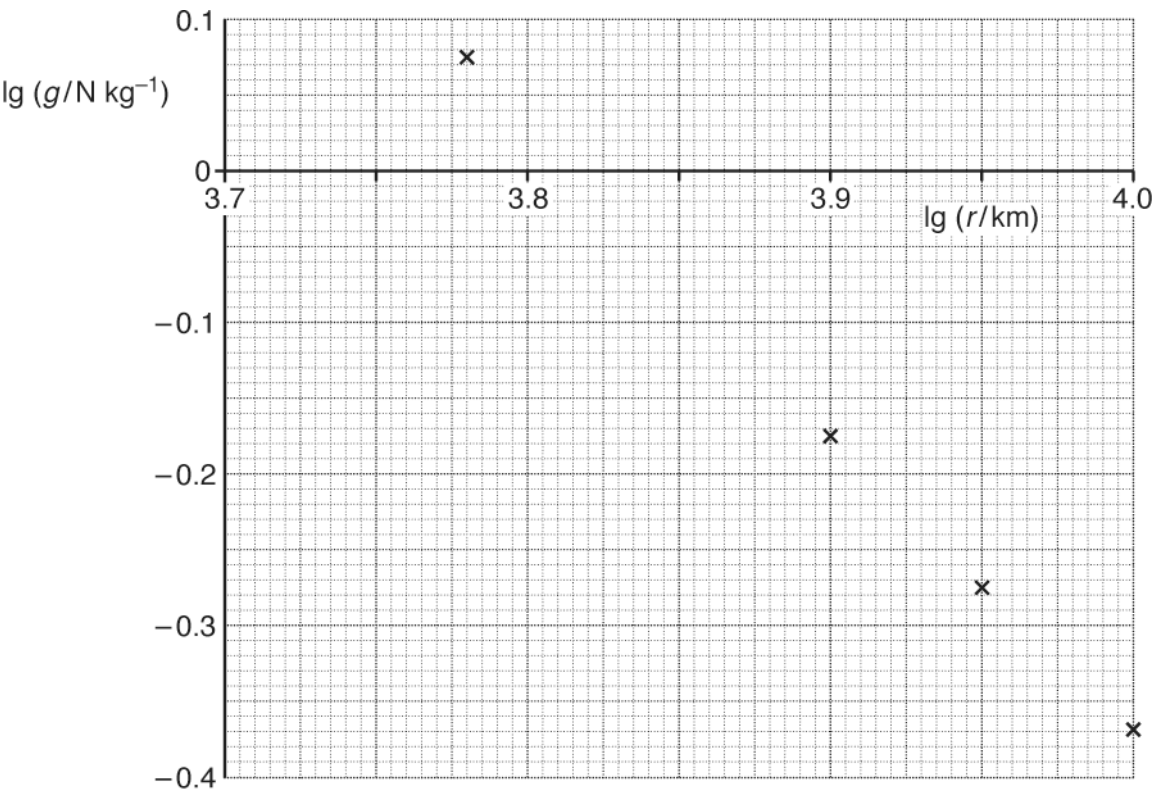


Fig. 17.2

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 .

3 Explain why the gradient of the straight line of best fit is -2 . [1]

[2]

- (b) 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**.

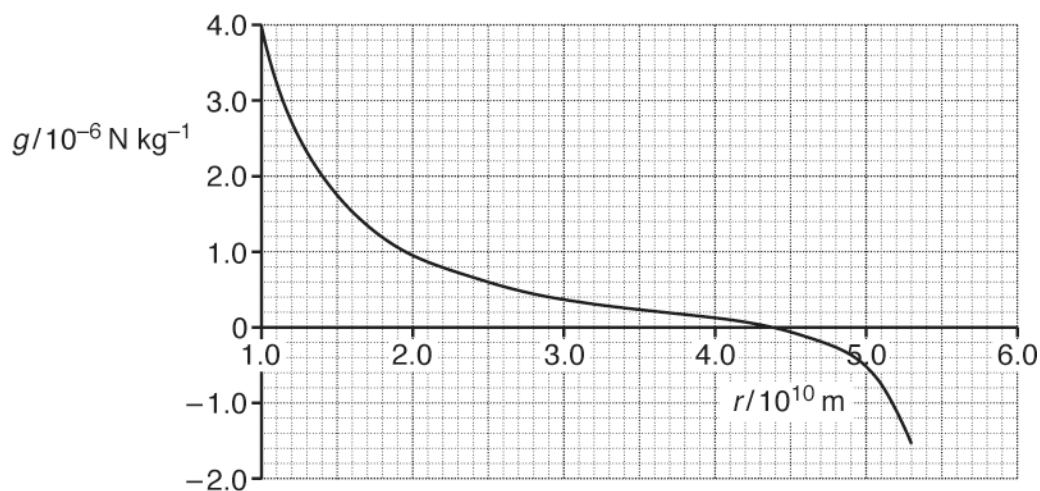


Fig. 17.3

- (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

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

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

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

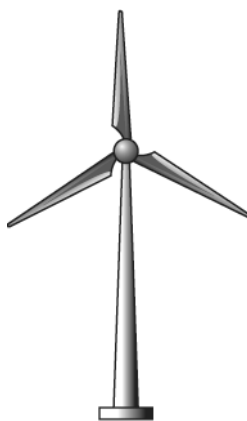


Fig. 18

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]

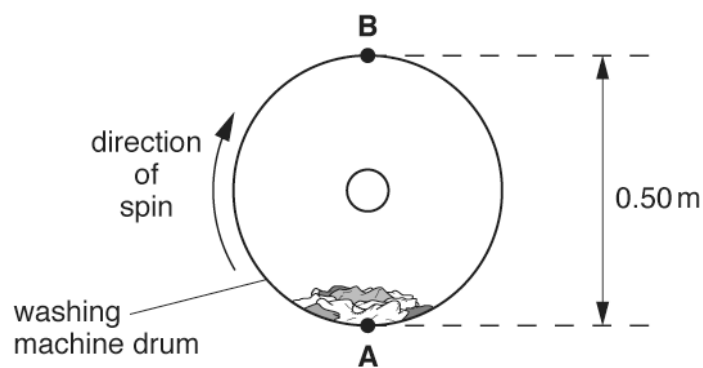


Fig. 21

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

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]

47(a) 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.

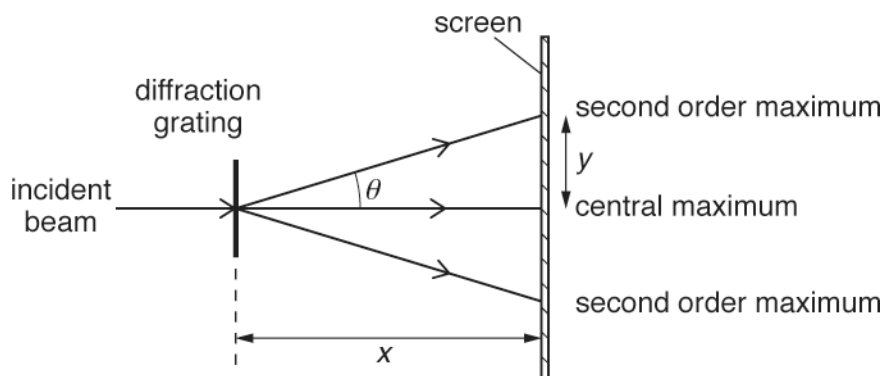


Fig. 24.1

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.

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.

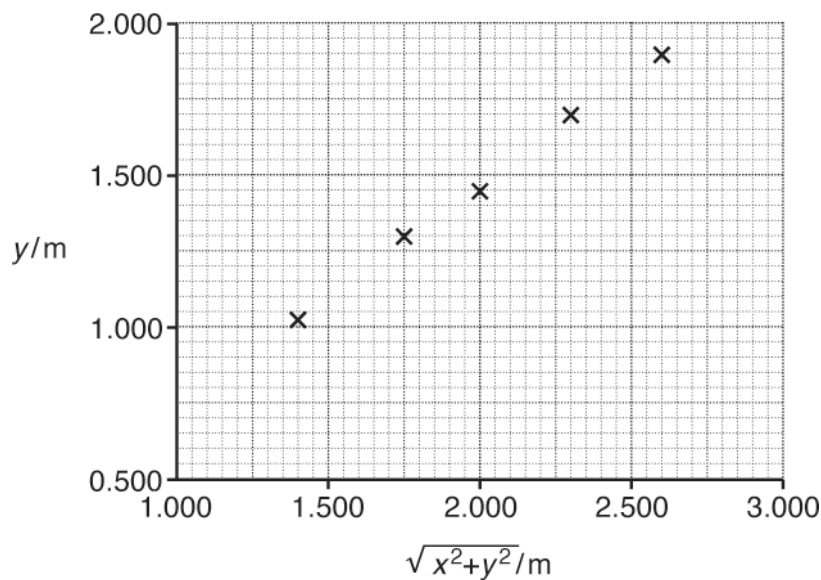


Fig. 24.2

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

λ = _____ m [2]

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

 _____ [1]

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

48(a) Fig. 4.1 shows an arrangement used by a student to determine the acceleration of free fall.

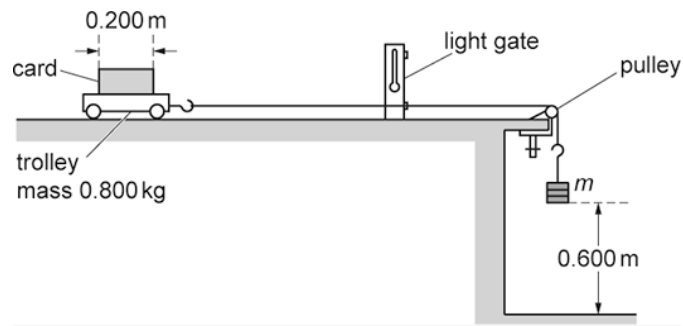


Fig. 4.1

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.

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 $m = 0.600$ kg on Fig. 4.2 and draw the straight line of best fit. [2]

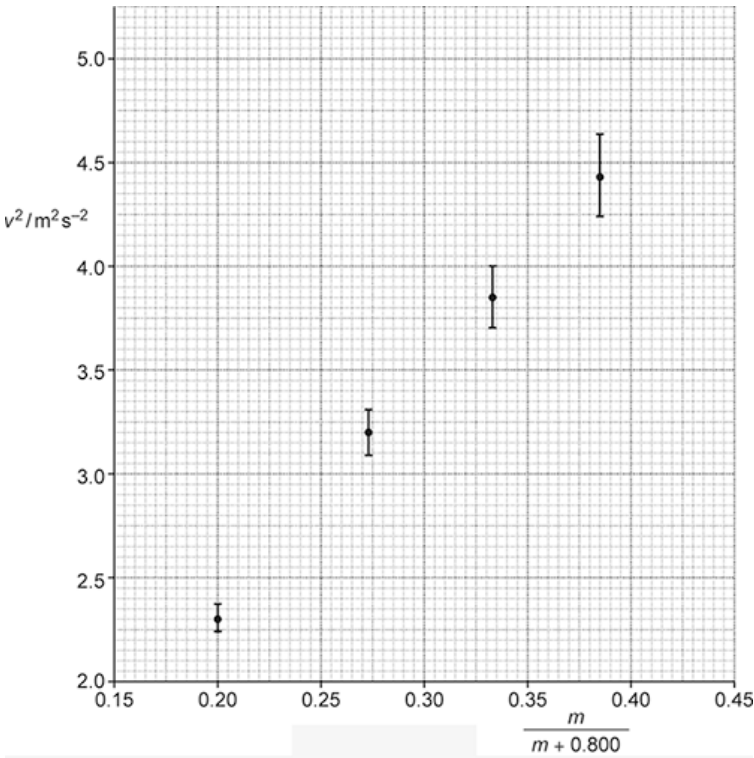


Fig. 4.2

(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 $1.20 g$.

[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 = $\pm$ ----- ms^{-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 .

[4]

- 49 Which electrical quantity has S.I. units ampere-second (A s)?

A charge

B current

C resistance

D potential difference

Your answer

□

[1]

- 50 Which is the **best** value for the elementary charge e in terms of both accuracy and uncertainty?

A $(1.5 \pm 0.5) \times 10^{-19} \text{ C}$

B $(1.5 \pm 0.4) \times 10^{-19} \text{ C}$

C $(1.7 \pm 0.2) \times 10^{-19} \text{ C}$

D $(1.8 \pm 0.2) \times 10^{-19} \text{ C}$

Your answer

[1]

51 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]

Derive the S.I. base units for resistance.

base units:----- [2]

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.

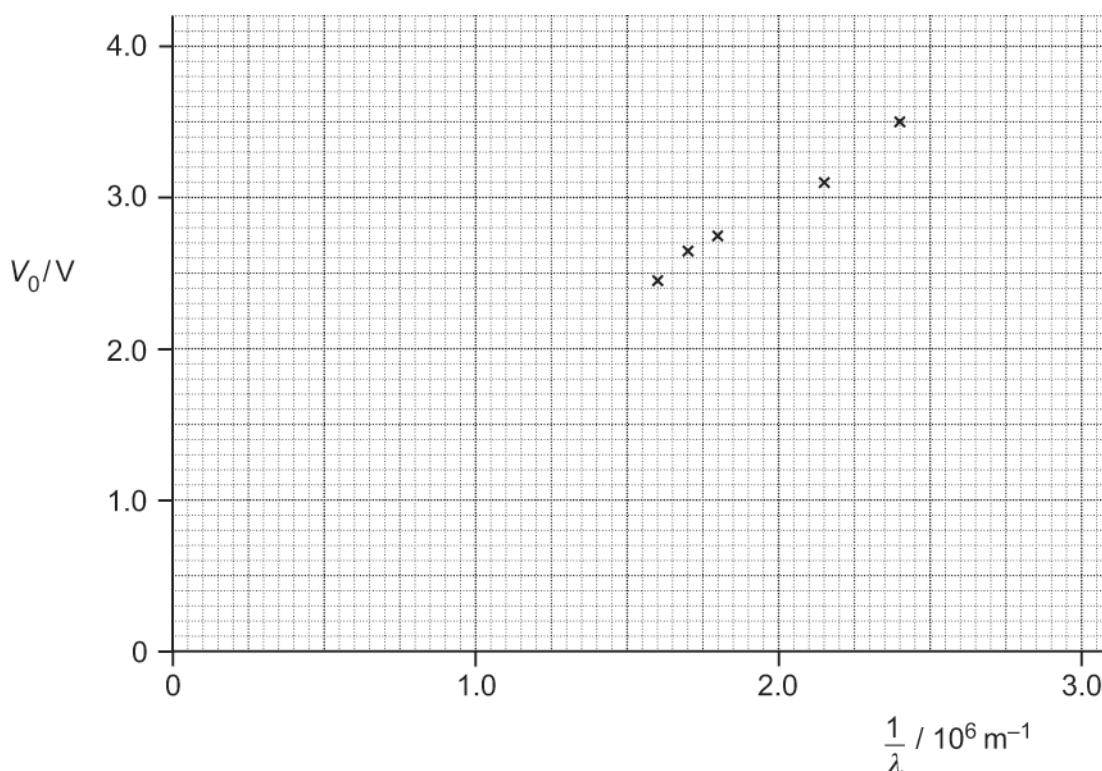


Fig. 20.1

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.

gradient =----- V m [2]

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

h =----- J s [3]

${}^{60}_{27}\text{Co}$ 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.

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.

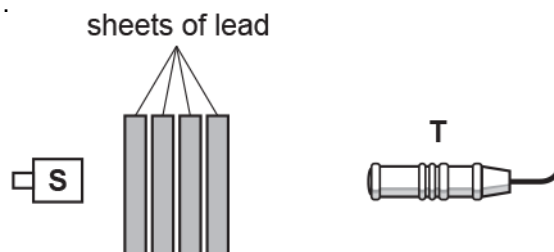


Fig. 2.1

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

Explain why this would not affect the experiment.

[1]

- (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	0	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]

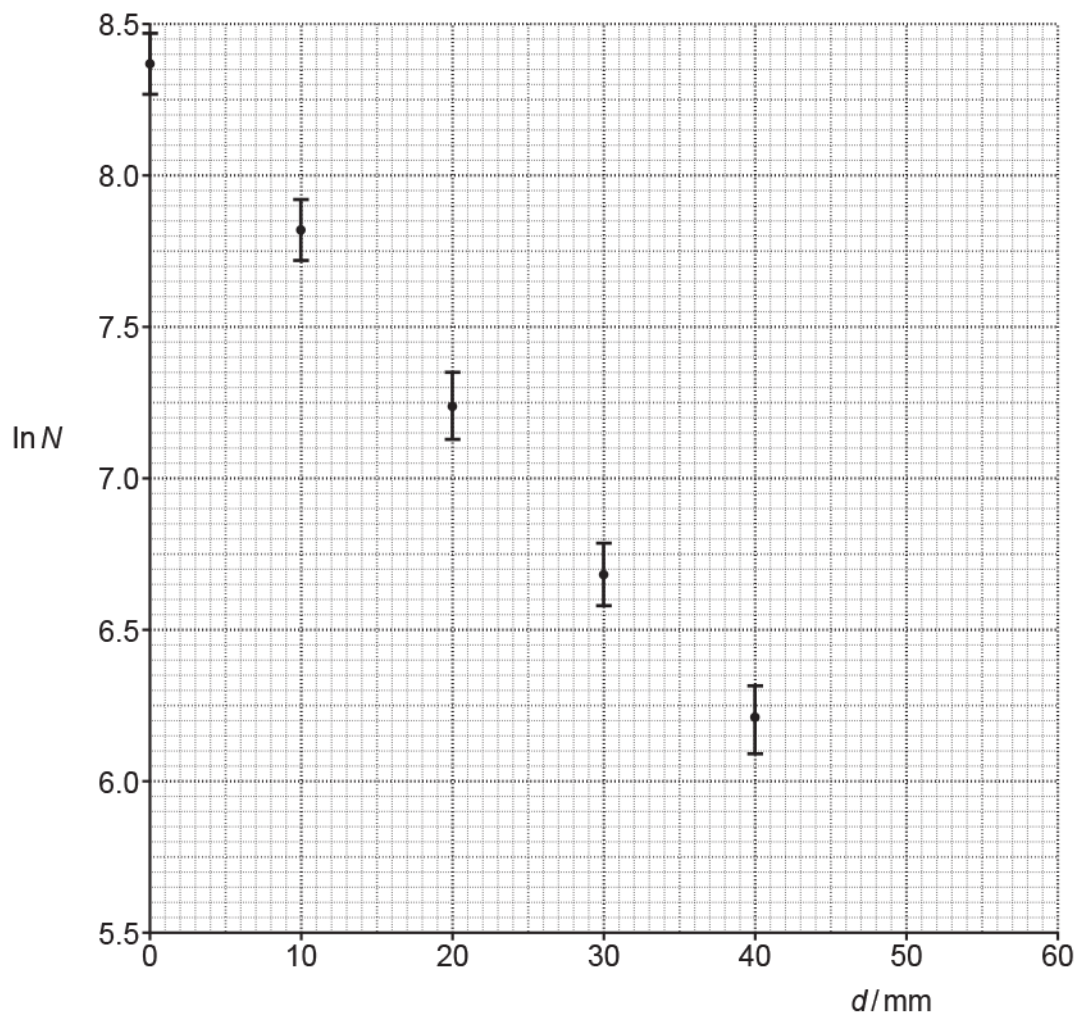


Fig. 2.2

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

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

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

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

55(a) At an airport, the conveyor belt for suitcases moves at a constant speed of 1.5 m s^{-1} .
In Fig. 4.1, a suitcase of mass 8.0 kg has reached the line labelled XX' .

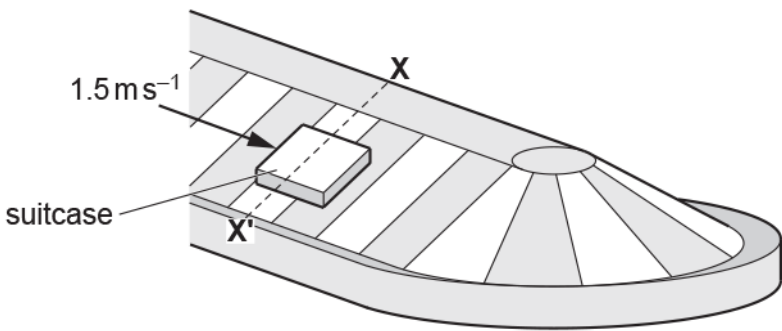


Fig. 4.1

Fig. 4.2 shows the situation in vertical cross-section. The frictional force F prevents the suitcase of weight W from sliding to the bottom of the belt.

The normal contact force on the suitcase is R .

The belt is inclined at an angle of 30° to the horizontal.

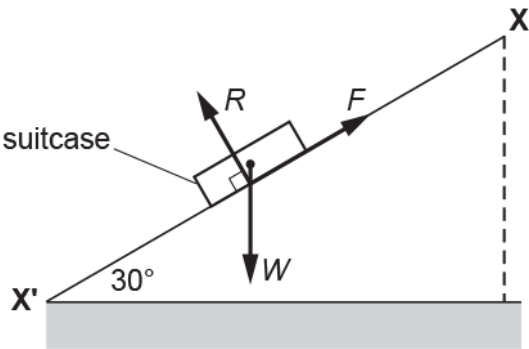


Fig. 4.2 (not to scale)

By using a vector triangle, or by resolving forces, calculate the magnitude of forces F and R .

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

(b) Fig. 4.3 shows the suitcase and the forces acting on it at the line labelled YY'.

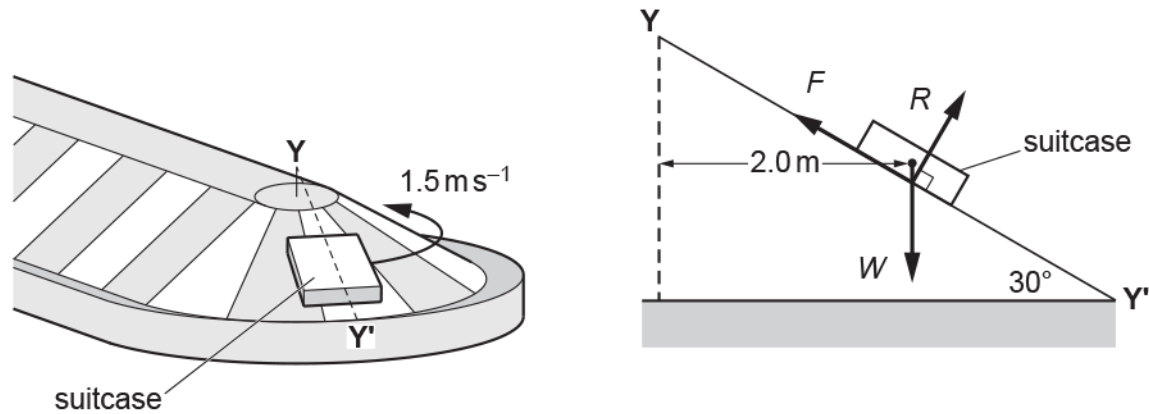


Fig. 4.3

The centre of mass of the suitcase is now moving at 1.5 m s^{-1} along a semi-circular arc of radius 2.0 m .

- (i) Calculate the magnitude of the centripetal force acting on the suitcase.

centripetal force = ... N [2]

- (ii) When the suitcase is at line YY', the magnitude of force F is larger and the magnitude of force R is smaller than at XX'.
Explain why this is so.

----- [4]

*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.

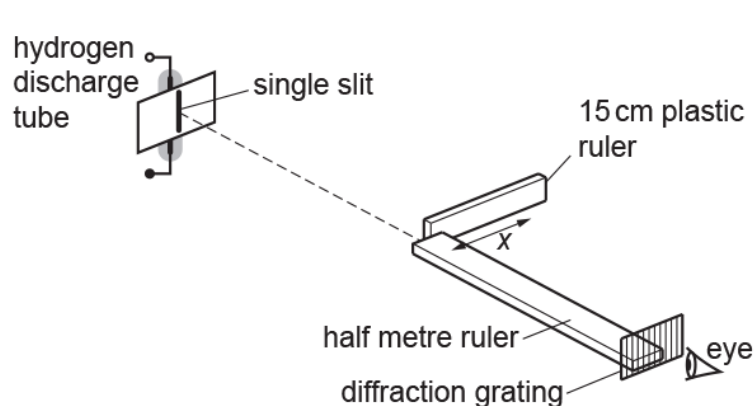


Fig. 5.1 (not to scale)

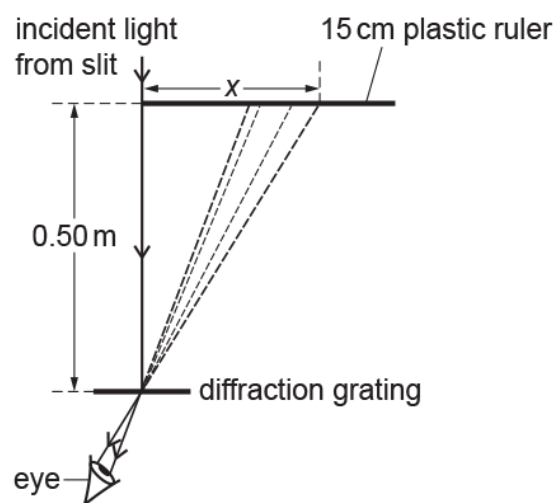


Fig. 5.2 (not to scale)

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.

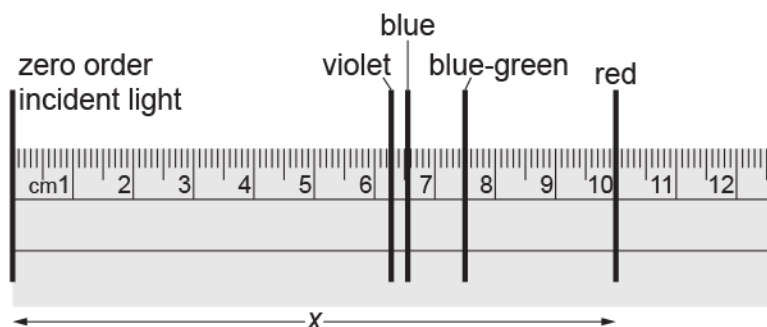


Fig. 5.3

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.

Blank lined paper for writing.

- 57 In their laboratory notes, one student writes about the **accuracy** of the measurements whereas the other writes about their **precision**.

Define these terms.

accuracy:

.....

precision:

.....

[2]

- 58 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]

- 59 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]

- 60 An object is falling.
The weight of the object is 4.5 N.
The wind provides a horizontal force of magnitude F on the object.
The **resultant** force on the object is 5.8 N.
Air resistance and upthrust on the object are negligible.

What is the value of F ?

- A 1.3 N
- B 3.7 N
- C 7.3 N
- D 13 N

Your answer

[1]

- 61 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]

62(a) 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]

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

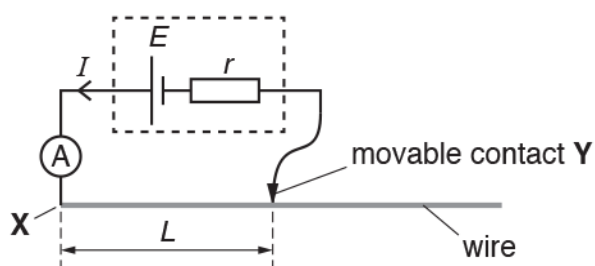


Fig. 18.1

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.

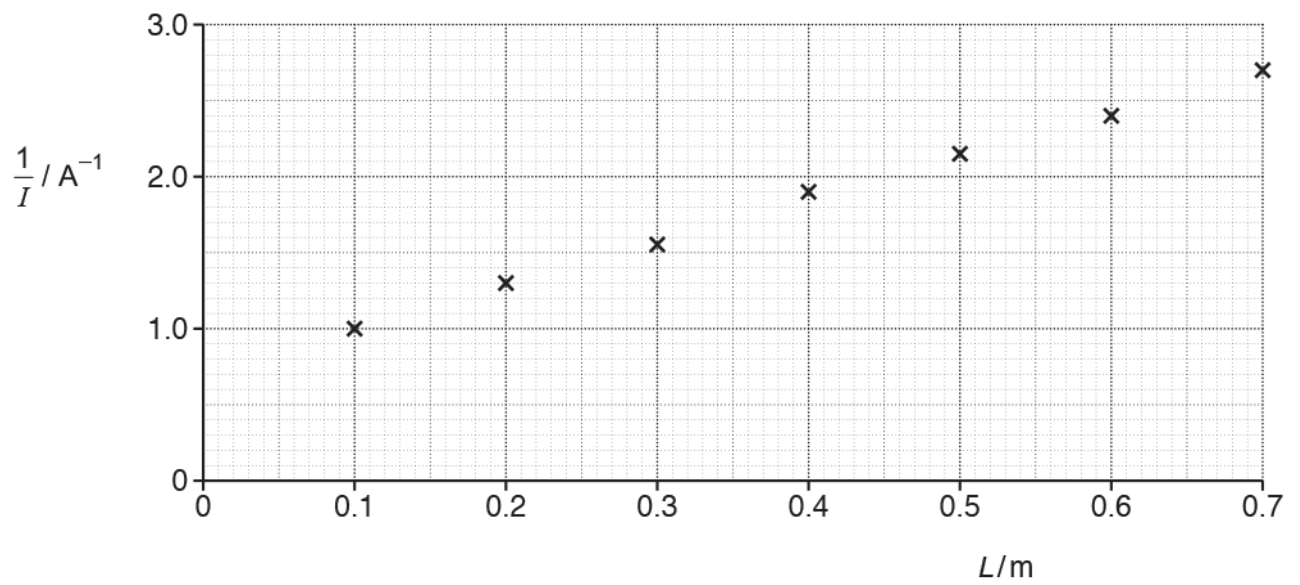


Fig. 18.2

- (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 .

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

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

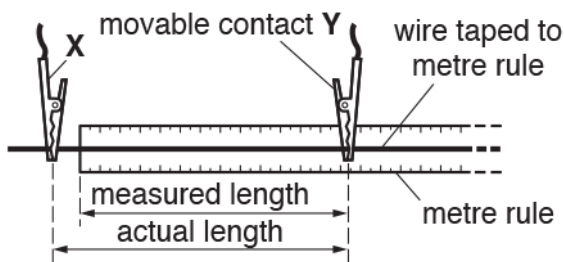


Fig. 18.3

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]

63 An athlete is running at a speed of about 5 m s^{-1} .

What is a reasonable estimate for the kinetic energy of this athlete?

- A 12 J
- B 100 J
- C 900 J
- D 800 000 J

Your answer

[1]

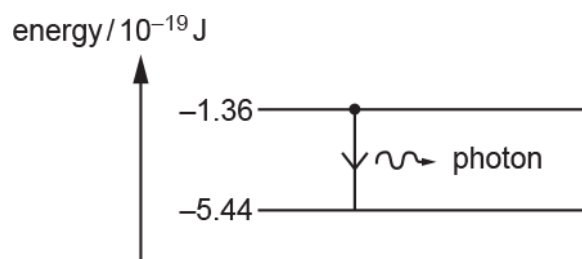
64 Which pair of quantities have the same S.I. base units?

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

Your answer

[1]

65 The diagram below shows two energy levels for the electron in the hydrogen atom.



The electron makes the transition shown by the arrow.

What is the wavelength of the photon emitted?

- A 293 nm
- B 366 nm
- C 488 nm
- D 1460 nm

Your answer

[1]

66 In astronomy, distance can be measured in different units.

Which one of the following distances is the **largest**?

- A 4.22×10^{16} m
- B 1.91 pc
- C 3.42 ly
- D 593AU

Your answer

[1]

67

The Young modulus E of a metal can be determined using the expression $E = \frac{4F}{\epsilon\pi d^2}$, 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]

- 68 A student is doing an experiment on the magnetic force experienced by a current-carrying wire in a uniform magnetic field. The magnetic flux density B can be varied.

For a particular flux density, the current in the wire is 2.0A. The length of the wire in the field is 0.12 m. The angle between the current and the magnetic field is 30° . The force experienced by the wire is 7.7×10^{-2} N.

The student calculates B and records the results in a table.

Which row shows the correct table heading for B and the correct value for B ?

	Table heading for B	Value for B
A	B / T	0.37
B	B / T	0.64
C	B / Wb	0.37
D	B / Wb	0.64

Your answer

[1]

69 The total energy released in a single fusion reaction is 4.0 MeV.

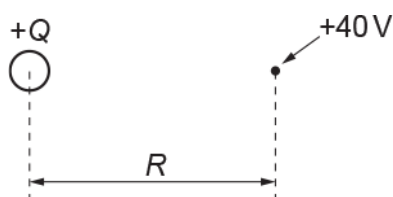
What is the change in mass in this fusion reaction?

- A 7.1×10^{-36} kg
- B 7.1×10^{-30} kg
- C 2.1×10^{-21} kg
- D 4.4×10^{-17} kg

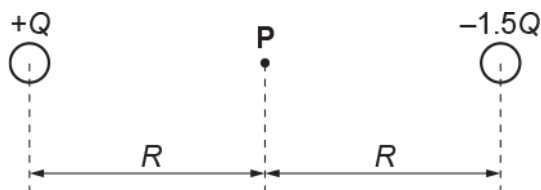
Your answer

[1]

70 The electric potential at a distance R from the centre of a charge $+Q$ is $+40$ V.



What is the potential at the point **P** for the arrangement of the charges $+Q$ and $-1.5Q$ as shown below?



- A -20 V
- B -60 V
- C $+80$ V
- D $+100$ V

Your answer

[1]

71(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.

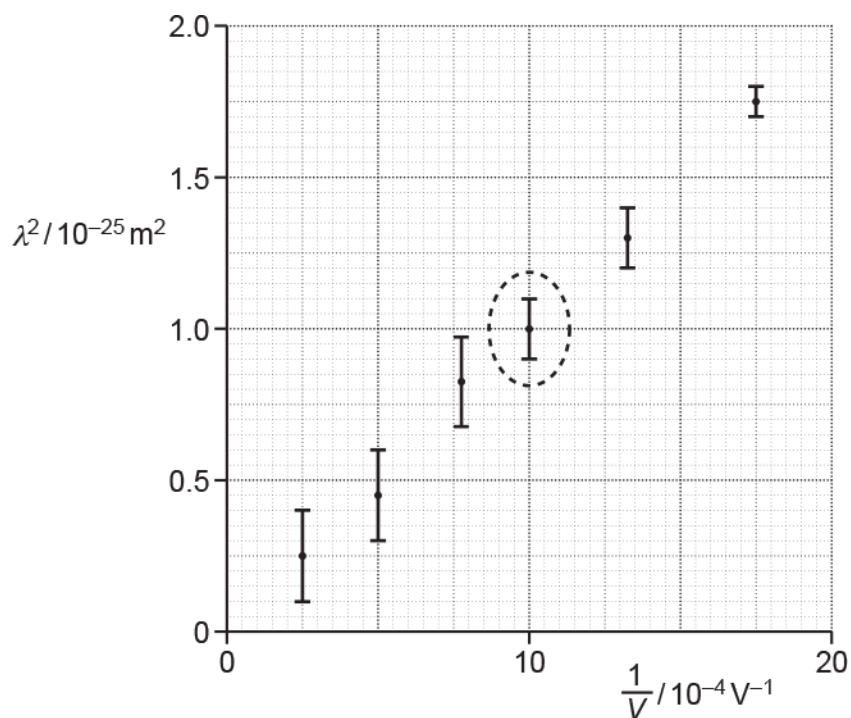
The charged particles are accelerated through a potential difference V . The de Broglie wavelength λ of these particles is then determined by the researcher.

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]

72 A sound wave is incident at the ear.

The amplitude of the sound wave is 7.8 nm. The intensity of the sound at the earhole is $4.8 \times 10^{-7} \text{ W m}^{-2}$.

- (i) Determine the power of the sound incident at the earhole by estimating the diameter of the earhole in mm.

diameter of earhole $\approx$ mm

power = ... W [2]

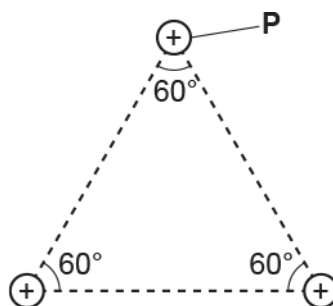
- (ii) A different sound wave is now incident at the ear.

The intensity of this wave is $9.6 \times 10^{-7} \text{ W m}^{-2}$.

Calculate the amplitude A in nm of this sound wave.

$A =$ nm [2]

The diagram below shows the arrangement of the 3 protons inside the nucleus of lithium-6 (${}^6_3\text{Li}$).



The separation between each proton is about $1.0 \times 10^{-15} \text{ m}$.

- (i) Calculate the magnitude of the repulsive electric force F experienced by the proton P.

$F = \dots\dots\dots \text{ N [4]}$

- (ii) On the diagram above, draw an arrow to show the direction of the electric force F experienced by P.

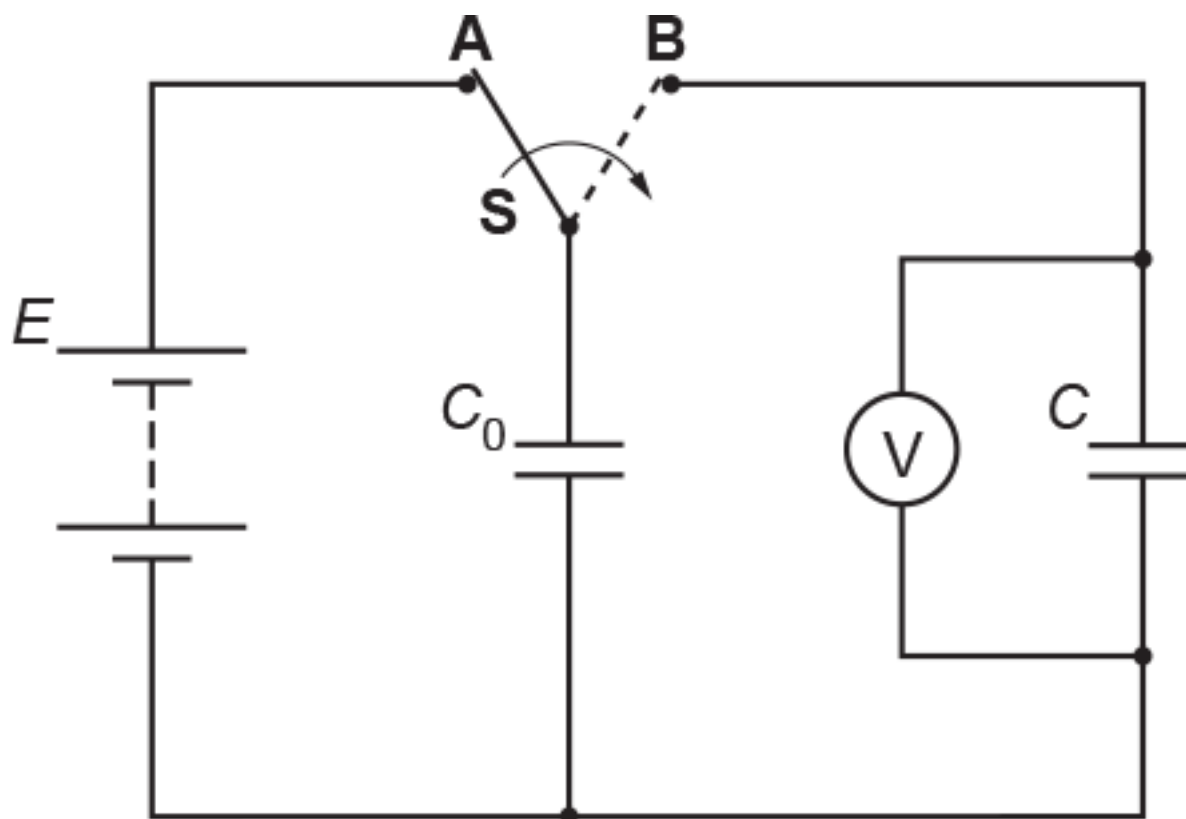
[1]

- (iii) Explain how protons stay within the nucleus of lithium-6.

[2]

74(a) 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 .

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 .

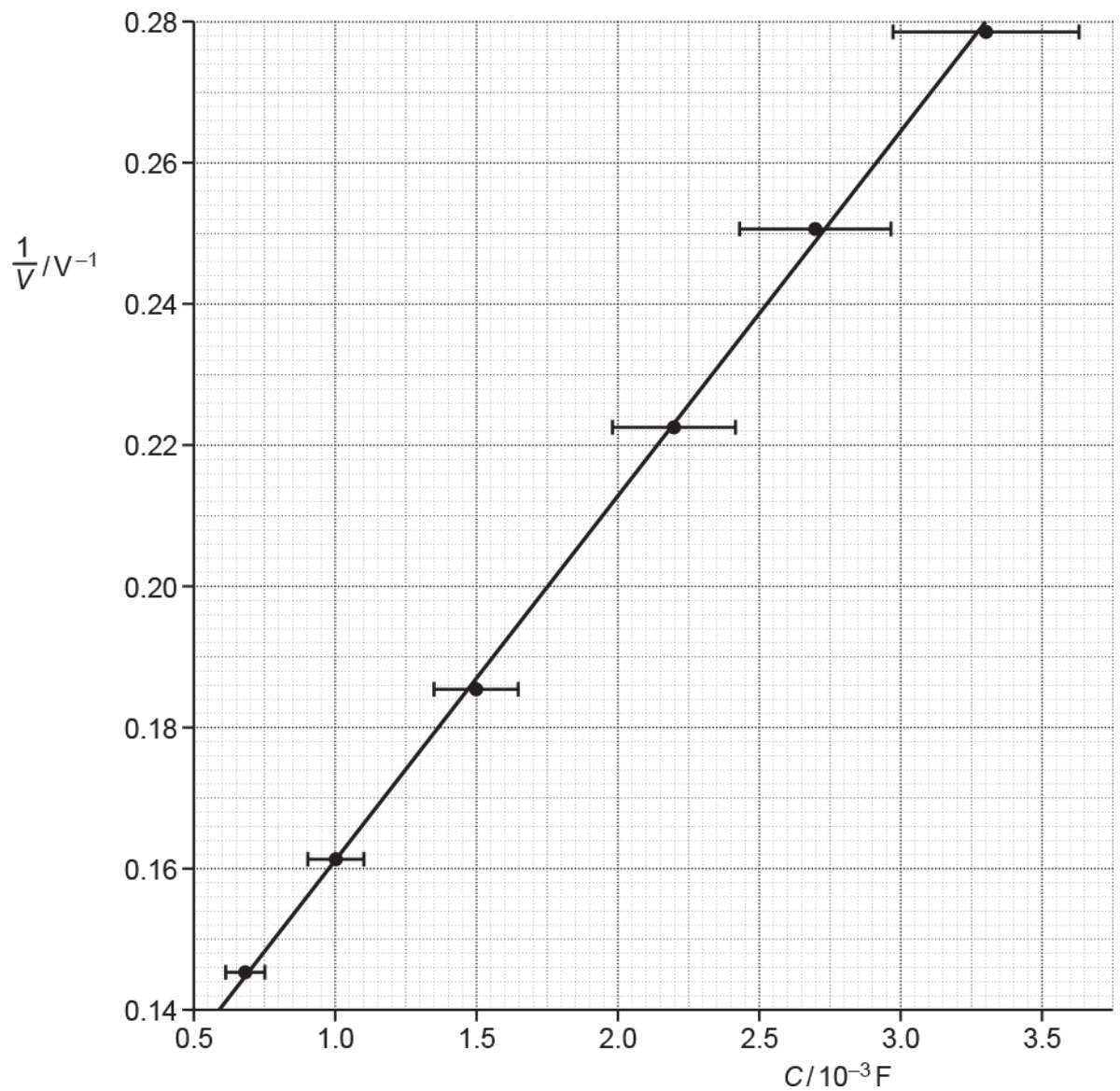
The student decides to plot a graph of $\frac{1}{V}$ against C .

- (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]

- (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 .

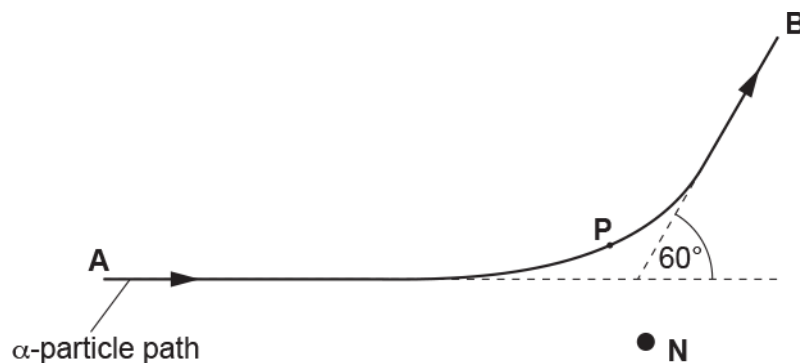
State with a reason what effect, if any, this would have on the experiment.

----- [1]

- 75 A beam of α -particles is incident on a thin gold foil. Most α -particles pass straight through the foil. A few are deflected by gold nuclei.

The diagram shows the path of one α -particle which passes close to a gold nucleus **N** in the foil. The α -particle is deflected through an angle of 60° as it travels from **A** to **B**.

P marks its position of closest approach to the gold nucleus.



The **magnitude** of the final momentum of the α -particle at **B** is equal to its initial value at **A**.

The gold nucleus **N** is initially at rest. During the passage of the α -particle from **A** to **B**, no other forces act on the two particles.

In the following questions label any relevant angles.

- (i) Draw two vectors in the spaces below to represent the initial momentum and the final momentum of the α -particle.

initial momentum at **A**

final momentum at **B**

[2]

- (ii) Draw a vector in the space below to represent the momentum of the nucleus **N** when the α -particle reaches **B**.

Explain how you determined this momentum.

[2]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1			D	1	
			Total	1	
2			C	1	
			Total	1	
3			A	1	
			Total	1	
4			A	1	
			Total	1	
5			A	1	
			Total	1	
6		i	$a = F / m \quad / \quad a = 8700 / 2300$	C1	Note answer is 3.78 to 3 s.f.
		i	$a = 3.8$	A1	
		ii	$D_{\text{thinking}} = u \times t = 22 \times 0.97 = 21.3 \text{ (m)}$	C1	Allow 21.34
		ii	$D_{\text{braking}} = u^2 / 2a \quad \text{or} \quad 22^2 / (2 \times 3.8) = 64.0 \text{ (m)}$	C1	Allow 63.98
		ii	stopping distance = $D_{\text{thinking}} + D_{\text{braking}}$ or $21.3 + 64.0$	C1	Allow ecf
		ii	stopping distance = 85.3 (m)	A0	Allow 85.32
		iii	$22 \times 3600 / 1600 (= 49.5 \text{ mph})$	B1	
		iv	Thinking distance for truck longer than in chart	B1	Allow any relevant factor
		iv	Suggested reason e.g. tired	B1	
		iv	Braking distance for truck longer than in chart	B1	
		iv	Suggested reason e.g. truck more massive than a car, truck's brakes are poor quality	B1	Ignore reference to road conditions
			Total	10	
7	a		energy input = $mc\Delta\theta = 0.327 \times 4200 \times 80 = 110 \text{ kJ}$	C1 M1	Allow 0.3 kg in the calculation
			energy input = power $\times$ time	C1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			time = 220 (s)	A0	
	b		Thermal losses to kettle and surroundings	B1	
			Lagging the kettle	B1	
			Cover to prevent evaporation	B1	
			Total	6	
8		i	tension = $850 \text{ kg} \times 9.81 = 8300 \text{ N}$	B1	
		ii	work done = $mgh = 850 \times 9.81 \times 12$	C1	
		ii	work done = 100 kJ	C1	
		ii	output power = $100 \times 10^3 / 40 (=2501 \text{ W})$	C1	
		ii	input power (= $2501 / 0.6$) = 4200 (W)	A1	
		iii	Suggestion to reduce heat losses through friction in moving parts e.g. oil, bearings	B1	
		iii	Use a stiffer / stronger cable to reduce energy loss through stretching	B1	
			Total	7	
9		i	Velocity determined by Doppler shift of spectral lines	B1	
		ii	Suitable straight line of best fit though origin	M1	
		ii	Appropriate pair of values (d, v) taken from line, $H_0 = v/d$	M1	
		ii	$400 \text{ km s}^{-1} \text{ Mpc}^{-1} \leq H_0 \leq 600 \text{ km s}^{-1} \text{ Mpc}^{-1}$	A1	
		iii	$H_0 = 500 \times 10^3 / 10^6 \times 3.1 \times 10^{16} = 1.6 \times 10^{-17} \text{ s}^{-1}$	C1	
		iii	$t = 1 / H_0 = 1 / 1.6 \times 10^{-17} = 6.2 \times 10^{16} \text{ s}$	C1	
		iii	age = 2.0×10^9 (years)	A1	Accept answers between 1.6×10^9 (years) and 2.5×10^9 (years) CF
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10	a		$3.6 \pm 0.4 \text{ (m}^2 \text{ s}^{-2}\text{)}$	B1	
	b	i	Data point and error bar correctly plotted	B1	Allow ecf from previous part.
		ii	* Level 3 (5–6 marks) Detailed analysis of the graph clearly linked to the principle of conservation of energy, including determination of the value of g and the related uncertainty in the answer. <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) Analysis of the graph linked to kinetic energy and / or potential energy, with an attempt to find the value of g. Mention of where one would find uncertainties in the answer but without 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) Line of best fit drawn and gradient attempted. Mention of energy and / or where uncertainties may occur. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	B1 × 6	Explanation 1 Principle of conservation of energy used to derive relationship. 2 $mgh = \frac{1}{2} mv^2$ or $v^2 = 2gh$ 3 A graph of v^2 against h will be a straight line (through the origin). 4 Gradient of line = $2g$. Determination 1 Line of best fit drawn through all data points. 2 Gradient in the range 17 to 21 ($\text{m}^2 \text{ s}^{-2}$). 3 g determined correctly from the gradient. Uncertainty 1 Worst line of fit drawn. 2 Correct attempt to determine the uncertainty.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
11	a	i	weight; (tractive) force up slope; drag; (normal) reaction	B1	
		i	All forces in correct direction and correctly labelled.		
		ii	$14.4 + (85 \times 9.81 \times \sin \theta) = 41.7$	C1	e cf from (a)(ii)
		ii	$\theta = 1.9^\circ$	A1	
	b		any three from: • drag reduces velocity or increases time to cross or some kinetic energy of cyclist goes to heat. • longer crossing time results in cyclist at lower point on other side of gap. • moment on bicycle • rotation lowers height of front wheel. Conclusion based on argument(s). The maximum gap width is smaller.	B1 × 3 B1	Allow argument based on: • very short crossing time ($< 0.43\text{s}$ at speed of 6 ms^{-1} up slope). • energy changed to heat insignificant compared to KE • amount of rotation very small in short time. conclusion based on argument(s). So no change in maximum gap width.
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
12		i	$m = \frac{0.131}{6.02 \times 10^{23}}$ $m = 2.18 \times 10^{-25} \text{ (kg)}$	A1	Examiner's Comments Most candidates were able to score the mark for dividing the molar mass of xenon by Avogadro's number. A small number, however, obtained answers which were many orders of magnitude greater than the required value. Candidates are advised to ask themselves the simple question 'Is this a reasonable answer' before moving on to the next question. This check often suggests an error has occurred which may hopefully be found and corrected thus avoiding an unnecessary loss of marks.
		ii	mass of xenon ejected / s = $m_{Xe} = 2.2 \times 10^{-25} \times 9.5 \times 10^{18} (= 2.07 \times 10^{-6})$	C1	Possible ECF
		ii	$F_{Xe} = \left(m_{Xe} \frac{\Delta v}{\Delta t} \right) = 2.2 \times 10^{-25} \times 9.5 \times 10^{18} \times 3.2 \times 10^4 (= 0.06627)$ $a_s = \left(\frac{F_{Xe}}{m_s} \right) = \frac{2.2 \times 10^{-25} \times 9.5 \times 10^{18} \times 3.2 \times 10^4}{5.2 \times 10^3}$	C1	Allow: $5.2 \times 10^3 \Delta v = 2.07 \times 10^{-6} \times 3.2 \times 10^4$ $\Delta v = 1.3 \times 10^{-5}$ $a_s = 1.3 \times 10^{-5} \text{ (m s}^{-2}\text{)}$
		ii	$a_s = 1.3 \times 10^{-5} \text{ (m s}^{-2}\text{)}$	A1	Examiner's Comments There were three stages to this calculation: firstly, the determination of the mass of xenon ejected per second which most were able to complete successfully; secondly, the application of Newton's second law to determine the force on the xenon ions and hence, by Newton's third law, the force on the spacecraft; finally, the acceleration which could be calculated from Newton's second law. The majority of candidates followed this process through accurately and presented their working logically. The most common error, made by weaker candidates, was the use of the spacecraft's mass to determine the force on the xenon. This resulted in excessively high acceleration

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Rate of change of momentum (of an object) is proportional to the resultant / net (external) force acting upon it. (AW) OR statement of law of Conservation of momentum in a closed system / no external forces	B1	 Momentum must be spelled correctly Allow: 'equal to' instead of 'proportional to' Allow: statement of Newton's 3 rd Law provided it is clear the forces act on different bodies and opposite is spelled correctly Examiner's Comments The mark scheme was made particularly flexible here in order to reward candidates for accurately quoting either of Newton's second and third laws or a statement of conservation of linear momentum. This ensured that most candidates were in a position to score the mark. A significant number of candidates lost this mark by not making it clear that Newton's second law refers to the resultant force acting on the system.
		iv	Force (on spacecraft) is constant	B1	Enter text here. Not: Weight (of spacecraft) or 'it is lighter' Examiner's Comments Most candidates realised that the mass of the spacecraft would decrease as xenon is ejected and this would cause an increase in acceleration. Only a minority were aware that this conclusion required the force on the spacecraft to be constant and correctly drew attention to this fact. On the whole this question discriminated well across the range of candidates.
		iv	Mass (of spacecraft) decreases (as xenon is ejected)	M1	
		iv	Acceleration increases	A1	
			Total	8	
13			D	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14			$\lambda = \frac{\ln 2}{6600} = 1.050 \times 10^{-4} \text{ (s}^{-1}\text{)}$	C1	Correct use of $A = \lambda N$
			$N = \frac{400 \times 10^6}{1.050 \times 10^{-4}} = 3.809 \times 10^{12}$	C1	
			mass of FDG = $\frac{3.809 \times 10^{12}}{6.02 \times 10^{23}} \times 0.018 \div 0.099$	C1	
			mass of FDG = $1.15 \times 10^{-12} \text{ (kg)}$ or $1.2 \times 10^{-12} \text{ (kg)}$	A1	
			Total	4	
15			A	1	
			Total	1	
16			D	1	
			Total	1	
17			B	1	
			Total	1	
18			$P = (m/t)c\theta = 0.070 \times 4200 \times (30 - 14)$	C1	or 4.7 allow kW if consistent with the value for P.
			= 4700	A1	
			unit = W or J s ⁻¹	B1	
			Total	3	
19			power or P: kg m ² s ⁻³	B1	power = force × distance / time = force × velocity
			Total	1	
20			A	1	
			Total	1	
21			D	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
22			A	1	
			Total	1	
23		i	$g = \frac{2s}{t^2} \quad / \quad g = \frac{2 \times 1.200}{0.50^2}$	C1	
		i	$g = 9.6 \text{ (m s}^{-2}\text{)}$	A1	
		ii	(% uncertainty in s) = 0.08 % or		
		ii	(% uncertainty in t) = 4.00 %	C1	
			% uncertainty in $g = ((2 \times 4.00) + 0.08)$		
		ii	% uncertainty in $g = 8.08 \text{ (%)}$	A1	Allow 8.1% or 8 %
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
24	a	i	Missing data point and error bar plotted correctly.	B1	Allow $\frac{1}{2}$ square tolerance.
		ii	Force measured by pulling back plate with a newton-meter.	B1	
		ii	Extension measured with a ruler (placed close to the transparent plastic tube).	B1	
		iii	Best fit line drawn correctly and gradient determined correctly.	B1	Ignore POT for this mark; gradient = 50 ± 4 (N m^{-1})
		iii	Worst fit line drawn correctly and its gradient determined correctly.	B1	Note: The line must have a greater/smaller gradient than the best fit line and must pass through all the error bars. Ignore POT for this mark.
		iii	$2k = 50$ (N m^{-1}), therefore $k = 25$ (N m^{-1})	B1	Possible ECF.
		iii	Absolute uncertainty determined correctly.	B1	Possible ECF within calculation.
		iv	$F \propto x$ / straight line passing through the origin.	B1	
		v	energy stored = $\frac{1}{2} \times 50 \times 0.12^2$	C1	Possible ECF from (iii)
		v	$\frac{1}{2} \times 50 \times 0.12^2 = \frac{1}{2} \times 0.39 \times v^2$	C1	Allow 1 mark for $v = 0.96 \text{ m s}^{-1}$; used k for single spring
		v	$v = 1.4$ (m s^{-1})	A1	
	b		force constant of spring arrangement) = $\frac{2k}{3}$ $\frac{2k}{3}x = ma$ $a = \frac{2}{3 \times 0.39}kx$ $a = 1.7 \text{ } kx$	M1 M1 A0	
			Total	13	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
25		i	$\Delta\lambda = \frac{\lambda v}{c} = \frac{486 \times 10^{-9} \times 960 \times 10^3}{3.00 \times 10^8}$	C1	
		i	$\Delta\lambda = 1.56 \text{ (nm)}$	C1	
		i	$\lambda = 486 + 1.56 = 488 \text{ (nm)}$	A1	
		ii	$d = 1.25 \times 10^{-6} \text{ m}$ $\theta = \sin^{-1}\left(\frac{2 \times 486 \times 10^{-9}}{1.25 \times 10^{-6}}\right)$	C1	Allow 1 mark $\theta = \sin^{-1}\left(\frac{2 \times 488 \times 10^{-9}}{1.25 \times 10^{-6}}\right) = 51^\circ$; incorrect 488 nm used instead of 486 nm.
		ii	$\theta = 51^\circ$	A1	
			Total	5	
26			A	1	
			Total	1	
27			wavelength = 60 (cm)	C1	Ignore POT Possible ECF from incorrect value of speed v
			$v = 0.30/2.5 \times 10^{-3} = 120 \text{ (m s}^{-1}\text{)}$	C1	
			$f = 120/0.60 = 200 \text{ (Hz)}$	A1	
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
28	a		5.0 eV = 8.0×10^{-19} (J) and 2.0 eV = 3.2×10^{-19} (J) photon energy = $\frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{300 \times 10^{-9}} = 6.6(3) \times 10^{-19}$ (J) energy of photon > work function of X Or energy of photon < work function of Y Hence electrons emitted from X with speed / KE from zero to a maximum value and no electrons are emitted from Y	B1 B1 B1 B1	Allow correct answers in terms of threshold frequency / wavelength for the metals and the frequency / wavelength of the photon Allow first two B1 marks for photon energy quoted as 6.6×10^{-19} J and 4.1 eV
	b		*Level 3 (5–6 marks) Clear explanation and discussion <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 explanation and some discussion <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 explanation or limited discussion <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	B1 × 6	Indicative scientific points may include: Explanation • $hf = \Phi + KE_{\max}$ (any subject) • A graph of $KE_{\max}$ against f is a straight line graph with gradient = h (and intercept = $-\Phi$) • Draw a straight best-fit line through points and determine the gradient using a 'large triangle' Discussion of accuracy and precision • % uncertainties are 4.8% for A and 9.1% for B • Data points widely spread out for B. (ORA) • For B the value of h is accurate because its closer to the real / actual value (but the results are not precise) • For A the value of h is precise because of the smaller % uncertainty (but the result is not accurate)
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
29		i	The direction of the electric field due to the negative charge is to the left and right for the positive charge.	B1	
		i	The magnitude of the electric field strength due to the positive charge is smaller than that for the negative charge (because of greater distance). (Hence the resultant electric field strength is to the left.)	B1	
		ii	$\text{energy} = \frac{Qq}{4\pi\epsilon_0 r} = \frac{(1.60 \times 10^{-19})^2}{4\pi\epsilon_0 \times 3.0 \times 10^{-10}}$	C1	
		ii	energy = $7.67(2) \times 10^{-19}$ (J)	C1	
		ii	energy = 4.8 (eV)	A1	
			Total	5	
30			speed = $2 \times 1.5 \times 10^{-2} / 19 \times 10^{-6}$ (= 1579 m s ⁻¹)	C1	Allow 2 marks for 8.4×10^5 ; factor of 2 omitted
			$Z = \rho c = 1070 \times 1579$	C1	
			$Z = 1.7 \times 10^6$	A1	
			unit: kg m ⁻² s ⁻¹	B1	
			Total	4	
31			D	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
32	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 A or current (A) Examiner's Comment Most candidates could not state an unambiguous base quantity. There was no credit for a correctly named quantity accompanied by its S.I. unit, e.g. ' <i>current in ampere</i> '. Some answers were just wrong; these include <i>force, charge, energy</i> and <i>kelvin</i> .
	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	Examiner's Comment Most candidates were familiar with the equations $R = \rho L / A$ and $A = \pi d^2 / 4$. The modal score here was two marks. Most scripts had well-structured answers and demonstrated excellent algebraic skills. A variety of techniques were employed to determine the total resistance of the two resistors in series.
		ii	1 Ruler / tape measure (for L) and micrometer (for d) 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 $R = 0.0327 \times 2.34 = 0.077$ $R = 2.3 \pm 0.1 (\Omega)$ 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 C1 C1 C1 A1 B1	Allow (vernier / digital) calipers or travelling microscope for micrometer 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 Allow: The calculated R is small(er) because (the measured) A is large(r) or R $\propto 1/d^2$

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Examiner's Comment Almost all candidates correctly identified the measuring instrument for L and d. Some answers were spoilt by mentioning both a ruler and a micrometer for measuring the length of the wire. This question produced a range of marks and discriminated well. According to the data shown in the table on page 13, the final value for the resistance R had to be given to 2 significant figures (SF), but an answer to 3 SF was also allowed. Top-end candidates produced flawless answers and quoted R as either $2.3 \pm 0.1 \Omega$ or $2.34 \pm 0.08 \Omega$. Some candidates successfully calculated the maximum and the minimum values for R and then the absolute uncertainty from half the range. The most common mistakes being made were: • Omitting the factor of 2 when determining the percentage uncertainty in d^2. • Calculating the resistance of either resistor X or resistor Y. • Inconsistency between R and its absolute uncertainty, e.g. $R = 2.3 \pm 0.077 \Omega$. Some candidates realised that the actual value of R would be '<i>larger because d was smaller or $R \propto 1/d^2$</i>'. On most scripts, it was difficult to follow if the resistance was the actual one or the calculated one.
			Total	9	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33	a		Correct pattern	B1	Note: At least five field lines must be drawn and of these, two must be perpendicular (by eye) to the surface of the sphere and plate
			Correct direction of the field	B1	Note: This may be shown on just one line Examiner's Comment Most candidates drew decent field patterns and showed the correct direction of the electric field. It is difficult to draw curved field lines, but those who were careful and had the field lines perpendicular at both the surface of the sphere and the metal plate were rewarded.
	b		(Electric potential) is the <u>work</u> done per (unit) charge in bringing a <u>positive</u> charge from infinity (to the point).	B1	Allow: <u>work</u> done / <u>energy</u> required to bring a unit <u>positive</u> charge from infinity (to the point) Examiner's Comment This was not well-answered; the modal mark was zero. Definition for electric potential lacked precision and often made no reference to a 'unit positive charge' or 'per unit positive charge'. At times, other quantities such as electric field strength and gravitational field strength were being defined. This was a missed opportunity -definitions just need to be learnt.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	$V = Q/4\pi\epsilon_0 r$ (Allow any subject) $Q = 4\pi \times 8.85 \times 10^{-12} \times 0.015 \times 5000$ $Q = 8.3(4) \times 10^{-9} \text{ (C)}$	C1 C1 A0	Note using $E = V/d$ with $E = Q/4\pi\epsilon_0 r^2$ is wrong physics and hence scores zero Note if the value of ϵ_0 is not given here, it could be implied in the correct 3sf answer Allow any subject here if the answer is given to more than 2sf Allow the use of $1/4\pi\epsilon_0 = 9 \times 10^9$ Examiner's Comment By contrast to the last question, the answers here were perfect. Correct values were substituted into the equation for electric potential to show that the charge was that stated in the question. In a 'show' question, always give the final answer to more significant figures than the required answer. It was good to see many scripts with the final answer written as $8.34 \times 10^{-9} \text{ C}$.
		ii	1 (electric force =) $1.7 \times 10^{-2} \times \tan 4.0$ (Allow any subject) (electric force = $1.19 \times 10^{-3} \text{ N}$) 2 $E = 1.2 \times 10^{-3}/8.3(4) \times 10^{-9}$ $E = 1.4 \times 10^5 \text{ (N C}^{-1}\text{)}$	M1 (A0) C1 A1	Not $1.7 \times 10^{-2} \sin 4$ or $1.7 \times 10^{-2} \cos 86$ Allow $1.7 \times 10^{-2} \times \sin 4/\cos 4$ Allow 2 marks for $1.45 \times 10^5 \text{ (N C}^{-1}\text{)}$, 8.3×10^{-9} used Allow 2 marks for $1.43 \times 10^5 \text{ (N C}^{-1}\text{)}$, $1.19 \times 10^{-3} \text{ (N)}$ used Examiner's Comment This was a good discriminator with high-scoring candidates either using triangle of forces, or resolution of forces, to determine the electric force on the sphere. The value of the force was given so that it could be used to answer the next question. More than half of the candidates correctly calculated the electric field strength using the information provided in (c)(i) and (c)(ii)1. Some candidates used the elementary charge rather than the value from (c)(i) to calculate the field strength; this gave an incorrect answer of $7.5 \times 10^{15} \text{ N C}^{-1}$.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
34	a		$\epsilon = 7.2 \times 10^{-12} \times 1.2 \times 10^{-3} / 4.0 \times 10^{-4}$ permittivity = 2.2×10^{-11} (F m ⁻¹)	C1 A1	Allow any subject Allow ϵ_0 instead of ϵ Note answer to 3 sf is 2.16×10^{-11} (F m⁻¹) Allow 1 mark for bald 2.4; relative permittivity calculated Examiner's Comment Most candidates effortlessly used the equation $C = \epsilon A / d$ to determine the permittivity s of the insulator between the capacitor plates. Once again, most answers were well-structured and showed good calculator skills. The most common errors were: • Taking the prefix pico (p) to be a factor of 10^{-9}. • Confusing permittivity ϵ and permittivity of free space ϵ_0. • Calculating relative permittivity (2.4).
	b	i	capacitance of two capacitors in series = 500 (nF) $C = 1000 + 500$ $C = 1500$ (μF)	C1 A1	Examiner's Comment The modal score here was two marks, with most scripts showing excellent understanding of capacitors in combination. Many candidates arrived at the final answer of 1500 μF without much calculation. A small number incorrect swapped the equations for series and parallel combinations and arrived at the incorrect answer of 670 μF.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$V = 1.5 \times e^{-12/15}$ $V = 0.67 \text{ (V)}$	C1 A1	Possible ecf from (i) Allow 1 mark for 0.83 V, $V = 1.5[1 - e^{-12/15}]$ used Examiner's Comment Many candidates correctly calculated the time constant of the circuit and then either determined the p.d. across the capacitors (0.83 V) or the resistor (0.67 V) - the latter being the correct answer. The most common mistake was calculating $e^{-12/15}$ rather than $1.5 \times e^{-12/15}$. Weaker candidates got nowhere by attempting to use $V = IR$ and $Q = VC$.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35	a		Level 3 (5-6 marks) Clear evaluation of Fig. 22.1 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 evaluation of Fig. 22.1 and some 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 evaluation of Fig. 22.1 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 annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Ignore incorrect references to the terms precision and accuracy Indicative scientific points may include: Evaluation of Fig. 22.1 • Comment on the line • The straight line misses one error bar / anomalous point ringed or indicated • Too few data points plotted • The triangle used to calculate the gradient is (too) small • Some plots should have been repeated / checked • No error bars for current • 'Not regular intervals' (for current) • No origin shown (AW) Evaluation of analysis • The value of B is close to the accepted value • The difference of only 7% • No absolute or percentage uncertainty in B shown (AW) • Worst-fit line or maximum / minimum gradient line could have been used to determine the (absolute or percentage) uncertainty in B • F against I graph should be a straight line or • $BL = \text{gradient}$ (any subject) Examiner's Comment This was the second level of response (LoR) question in the paper. It required evaluation of a graph drawn by a student and the analysis shown in the box on page 24. Most candidates realised that the graph had few data points, the triangle used for the gradient was too small and the line drawn totally missed one of the error bars. The analysis shown by the candidate did not include an absolute uncertainty in B,

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					which made the statement written by the student lack credibility. Many candidates wrote about drawing doing a line of worst-fit and determining the percentage uncertainty. This was only possible if there were more data points and the error bars for the F values reduced by perhaps repeating the measurements. Once again, there was a good spread of marks amongst the three levels.
	b	i	There is a changing / fluctuating (magnetic) field / flux (linkage) (magnetic) field / flux (linkage) in <u>core</u> and <u>secondary</u> (coil) Statement of Faraday's law: e.m.f. (induced) $\propto$ <u>rate</u> of change of (magnetic) flux <u>linkage</u>	M1 A1 B1	Note: This changing flux can be anywhere Allow 'the direction of the field oscillates' Allow 'the core helps to link the flux to the secondary coil' Allow 'equal to / =' Ignore 'cutting of flux' Not just $E = (-)\Delta(N\phi)/\Delta t$ Examiner's Comment The topic electromagnetic induction always challenges candidates. Successful responses often showed correct use of technical terms such as <i>magnetic flux</i> or <i>flux linkage</i>. Most candidates scored a mark for correctly stating Faraday's law of electromagnetic induction. Many realised that an alternating current produced an alternating magnetic flux within the iron core and this change in flux produced an e.m.f. at the secondary coil. One of the popular misconceptions was that there was an alternating current (or induced e.m.f.) within the iron-core. A small number of candidates referred to electromagnetic field in their descriptions rather than magnetic field.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	1 ($I_S =$) 24/12 or 2.0 (A) $(I_P =) \frac{20}{400} \times 2.0$ (current in primary =) 0.10 (A) or $(V_P =) 12 \times 20$ or 240 (V) $(I_P =) \frac{24}{240}$ (current in primary =) 0.10 (A) 2 Idea of changing / increasing (magnetic) field / flux / current (in primary) at the start Eventually current and flux (linkage) are constant, therefore no e.m.f.	C1 A1 C1 A1 B1 B1	Allow 1 sf answer Allow 1 sf answer Note: Any labels used must be clearly defined Examiner's Comment This question on current in the primary coil was successfully answered by most candidates. The most favourable method was to calculate the current in the secondary and then the current in the primary coil. The turn-ratio equation and $P = VI$ were effortlessly used to arrive at the correct answer of 0.10 A. Full marks were rarely scored but many top-end candidates did manage to score a mark for suggesting that the lamp was lit for a short period of time at the start because '<i>there was a changing magnetic flux as the current increased from zero to a steady value</i>'. Too many answers focussed on the requirement of an alternating supply for an induced e.m.f. in the secondary coil and how a battery is not an alternating supply.
			Total	13	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
36			C	1	Examiner's Comments In this question, candidates generally forgot that the practical skills guide recommends that uncertainties are usually given to one significant figure, ruling out option D. Furthermore, the length and width are both given to two significant figures, which means that the area should also be to two significant figures. The correct procedure is to add the percentage uncertainties in the length and width, which gives the percentage uncertainty in the area and hence the absolute uncertainty of 300 m. This question provided opportunities for middle-grade candidates.
			Total	1	
37			D	1	Examiner's Comments This question showed that candidates had generally forgotten that the resultant force does not have to be in the direction of travel, hence all three statements could be correct, giving option D. This question provided opportunities for middle-grade candidates.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
38	a		Use a thermometer (with $\pm 1\text{ }^{\circ}\text{C}$) Stir water bath / avoid parallax (for glass thermometer)	B1 B1	Allow 'temperature sensor / gauge' Allow 'avoid touching sides of water bath with thermometer' Allow 'take temperature in several places / times and average' Allow idea of 'leave thermometer for long time (to reach thermal equilibrium)' Not idea of 'use thermometer with finer resolution' Examiner's Comments A large majority included a correct measuring device, such as a thermometer. Significantly fewer described a technique for accurate measurements such as stirring the water or taking the temperature at several points and calculating a mean temperature.
	b	i	Smaller (spacing between) divisions / increments (AW)	B1	Ignore any reference to accuracy or precision Allow 'less uncertainty' Allow better or smaller or greater or higher resolution Examiner's Comments Approximately half of the candidature made a correct comment regarding resolution or that the smaller intervals on the psi scale made it a sensible choice of scale.
		ii	$p = 37.0 \times 4.448 / (1000 \times 0.0254^2)$ 255 (kPa) uncertainty = 3 (kPa)	B1 B1	Allow clearly identified correct answer in table or in working area. Must be 3sf Must be 1sf Allow 255.1 ± 3.4 scores mark 1 Examiner's Comments The vast majority of candidates correctly calculated the pressure in kPa and stated that the absolute uncertainty was 3 kPa. A very small number of responses were rounded inappropriately.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	Point plotted at (44, 255)	B1	ECF from (b)(ii) Plot to with $\pm$ half a small square Ignore checking error bars Examiner's Comments Most candidates correctly plotted the point with error bars. In this instance during marking Examiners were instructed to ignore the error bars as they were too difficult to view when scanned.
		ii	Level 3 (5–6 marks) Clear explanation, description and determination <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 explanation, description and determination Or Some explanation and clear determination <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 explanation or description or determination <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	B1 $\times$ 6	Indicative scientific points may include: Explanation and Description • Absolute zero is the minimum possible temperature / at absolute zero KE is zero • At absolute zero p is zero • At absolute zero, the internal energy is minimum (allow 0) • Absolute zero should be (about) $-273\text{ }^{\circ}\text{C}$ • Reference to $pV = nRT$ or $pV = NkT$ or $p \propto T$ • A graph of p against θ is a straight line / straight line drawn on graph • Intercept of straight line with x-axis or θ-axis is absolute zero calculated by using $y = mx + c$ Determination • Gradient in the range 0.7 to 0.9 (kPa K^{-1})

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					$y = mx + c$ used to determine the intercept c or absolute zero - Absolute zero in the range $-320\text{ }^{\circ}\text{C}$ to $-240\text{ }^{\circ}\text{C}$ Use only L1, L2 and L3 in RM Assessor. Examiner's Comments It was clear that the majority of candidates had either performed this experiment themselves or had otherwise seen it before. The concept of absolute zero was very successfully described and many knew that an extrapolation or calculation involving the equation of a straight line was required to find absolute zero as the x-intercept of the straight line. Common errors included mis-calculating the gradient, inability to rearrange the equation or inappropriate conversion to kelvin. Re-plotting the graph was not required and merely wasted time for little reward.
	d		Draw the worst fit line (through all the error bars) (AW). Determine the new value for absolute zero and find the difference between the value in (c)(ii) and this new intercept. (AW)	B1 B1	Examiner's Comments Many candidates realised that drawing a line of worst fit was sensible. Far fewer were clear that using the line of worst fit to find a new x-intercept, leading to a spread in values for absolute zero was the correct procedure. Many incorrectly suggested finding the difference in gradients, or percentage differences in gradients.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	e		Cooling gas value of absolute zero is lower than (c)(ii) (Whilst cooling, the) temperature of gas lags behind the temperature of water (AW, ORA) Graph is shifted to the left Stir water / <u>wait</u> for temperatures to be the same / attempt at measuring temperature of gas directly (AW)	B1 B1 B1 B1	Allow: gradient is too shallow Allow: p measured is higher than expected for incorrect measurement of T (so affects the graph) (AW, ORA) Not insulation of water bath Not heat losses Examiner's Comments The first mark for this item was intended to be for a straightforward comparison that the repeated experiment yielded a lower value than that from part c(ii). Many candidates calculated a percentage difference yet did not refer to the direction of difference. Some candidates successfully suggested that the water would always be cooler than the gas and so the thermometer reading would be systematically lower than the true temperature of the gas. Rather fewer discussed that the pressure reading would therefore be higher than it should be for the thermometer reading. Very few candidates linked this idea to the effect on the graph, namely that the points would all be shifted to the left, causing a lower x-intercept or a less steep line of best fit. There were three acceptable experimental approaches to avoid this systematic error. Stirring the water and waiting until the gas and water equilibrated would have reduced the effects of the rapid cooling. A sensible approach employed by some candidates was to take the temperature of the gas directly using a thermometer or temperature inside the flask.
			Total	18	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
39	a		work done = 400×0.80 work done = 320 (J)	C1 A1	Examiner's Comments This was answered correctly by most candidates; a tiny number did not convert from cm to m correctly.
	b		ratio of speeds = ratio of distances (since same time) or ratio = $80 / 2$ ratio = 40	C1 A1	Allow 40:1 Allow 2 marks for ratio 29.4 (assuming p same) Not 1:40 for A1 Examiner's Comments Unsuccessful candidates tried to employ 'suvat' equations, although many candidates realised that the required ratio was also the ratio of the distances travelled in the same time period. Some credit was given for those candidates that assumed constant pressure and 100% efficiency.
	c		work done = $1200 \times 9.81 \times 0.02$ (= 235.4) efficiency = $235.4 / 320 \times 100$ efficiency = 74 %	C1 A1	Note: Using $g = 10 \text{ N kg}^{-1}$ gives 75%: allow 1 mark max Possible ECF from (a) Note: 0.74 scores 1 mark Allow 2 marks for using $235/320 \times 100 = 73\%$ Allow use of 9.8 N kg^{-1} gives 73.5% for 2 marks Allow 1 mark for 71%, force = $(1200g - 400) \text{ N}$ used Allow 1 mark for 76%, force = $(1200g + 400) \text{ N}$ used Examiner's Comments The majority of candidates successfully calculated the work done on the car and hence the efficiency of the system.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
40			C	1	<u>Examiner's Comments</u> About three quarters of all candidates recognised that the volt is not an S.I. base unit.
			Total	1	
41			B	1	
			Total	1	
42			B	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
43	a	i	vertical component = $30.0 \sin(70^\circ)$ or $30.0 \cos(20^\circ)$ vertical component = $28.2 \text{ (m s}^{-1}\text{)}$	A1	Allow 2 SF answer of 28
		ii	Evidence of $v^2 = u^2 + 2as$ and $v = 0$ or $gh = \frac{1}{2} u^2$ $h = \frac{28.2^2}{2 \times 9.81}$ (Any subject) $h = 40.5 \text{ (m)}$	C1 M1 A0	Allow v and u interchanged; a and g interchanged Allow use of candidate's answer for (a)(i) at this point Ignore sign Allow $h = \frac{28^2}{2 \times 9.81}$ or $(30 \sin(70)) / (2 \times 9.81)$ No ECF from (a)(i) for the second mark
		iii	The ball has horizontal motion / velocity (AW)	B1	Allow idea of horizontal e.g. sideways, forwards Not: 'moving' unqualified
		iv	(horizontal velocity =) $30.0 \cos 70^\circ$ or $10.2 \dots \text{ (m s}^{-1}\text{)}$ or $30.0 \sin 20^\circ$. $E_k = \frac{1}{2} \times 0.057 \times 10.26^2$ $E_k = 3.0 \text{ (J)}$	C1 A1	Allow 1 SF answer Not 22 (J), $v = 28$ used Not 23 (J), $v = 28.2$ used Not 140 (J), $v = 70$ used <u>Examiner's Comments</u> Part (i) was particularly well answered by 95% of all candidates. Nine out of ten candidates scored full marks in part (a)(ii), as they remembered that the question asks to <i>show</i> that the maximum height is around 40m. Working for this type of question is essential. In part (a)(iii), three quarters of all candidates correctly talked about the ball still having a horizontal velocity (which wasn't zero) and therefore still possessing some KE. The key to this part (a)(iv), remembered by most candidates, was to use the horizontal component of velocity to find the KE at the maximum height. Some used the initial speed and others used the initial vertical velocity component found in part (a)(i).

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	b	Level 3 (5–6 marks) Clear description and 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. <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 and limited analysis or 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 (NR) or no response worthy of credit (0).	B1 x 6	Indicative scientific points may include: Description • Ruler used to determine x • Average readings to determine x • x recorded for various v • Suitable method for consistent v or varying v e.g. • Released from same point on a track • Ejected from a spring device with different compressions • Suitable method of determining point of impact e.g. • trial run to get eye in approximate correct position • carbon paper so that ball makes a mark on paper • scale in frame of video recording • tray of sand to catch ball • Suitable instrument used to determine v (light-gate / motion sensor / video techniques) or suitable description of inference of v from other measurements such as energy released from spring of known k and x • Ensuring the initial velocity of ball is horizontal Analysis • Horizontal velocity is constant • Time of fall is independent of v /horizontal velocity • Suggested relationship: e.g. $x \propto v$, x d.p. to V^2, etc • Plot a graph of x against v or graph consistent with candidate's suggested relationship • If relationship is correct, then a straight line through the origin. • Suggested relationship supported by correct physics or algebra. • Correct relationship supported by physics.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Note: L1 is used to show 2 marks awarded and L1^ is used to show 1 mark awarded. Examiner's Comments Many candidates had plenty to say that was sensible. There was plenty of evidence that candidates had seen this experiment or had performed a similar one themselves. A few confused the question, instead describing how to find the time of flight or that the ball was falling vertically. Others described what they thought would happen to the vertical component of velocity when they changed the vertical distance that the ball dropped. Exemplar 2 Use your knowledge of projectile motion to suggest the relationship between v and x. Describe how an experiment can be safely conducted to test this relationship and how the data can be analysed. As m a projectile the horizontal component of velocity is constant given air resistance is negligible then an equation of $x = \frac{1}{2}(uv)t$ could become $x = vt$ where x is distance traveled v is velocity of ball and t is time of flight. However for a constant time of flight it can be said $x \propto v$. To test this it is very hard to keep time of flight constant as this is due to its time of freefall. To test this a ball would be rolled off a table at varying speeds. To calculate this speed a light gate can be used passing through the center of the metal ball. As distance travelled is equal to the diameter of the ball, measured by a ruler, speed can be calculated using distance/time from light gate. For safety the ball should land in sand as not to shatter or land on someone's foot. This also makes measuring x much easier as x is equal to the horizontal distance from the edge of the table to the center in the sand measured using a ruler. If the time taken to fall is kept constant measured by using a stop watch and controlled by raising or lowering the launch point then v is plotted against x on a graph it can be expected to be linear and pass through the origin.

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					In the first paragraph, the candidate has made clear that the time of flight is constant and goes on to explain why towards the end of the response. This supports the prediction that $v \propto x$. In addition, the candidate takes time to explain how to obtain data for both the horizontal velocity and horizontal distance. It was pleasing to see light gates and motion sensors being employed, with the best answers explaining how to use the data provided by the sensors to calculate the velocity of projection. The exemplar response also includes the correct analysis. There is a graph of v against x and the resulting best fit straight line through the origin supports the idea that these two variables are directly proportional. Too many candidates did not mention the crucial statement about the line going through the origin, limiting their response to a high L1 or low L2.
			Total	12	

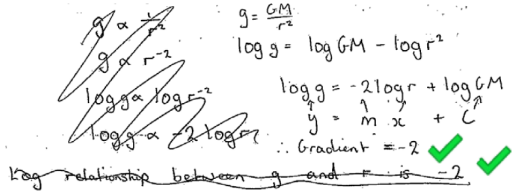
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
44	a	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. <u>Examiner's Comments</u> Although some candidates were confused by the appearance of 'lg', most candidates were not. This notation is on the specification and was used in the previous specification.
		ii	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 <u>Examiner's Comments</u> Providing the candidate had entered values in the tables, the data point was almost always plotted correctly. The best fit line caused slightly more problems. Candidates should take a ruler into the examination and be careful about the positioning of the ruler for the fairest best fit straight line. The Practical Skills Handbook is helpful on this topic. Exemplar 3

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					$\frac{dy}{dx} = \frac{(4, -0.37) - (3.75, 0.076)}{3.75 - 4} = -2.02$ ✓ In this example, the candidate's line has missed the final data point. The line of best fit for this item should just graze each of the given points.
		iii	(Triangle used to determine gradient and) gradient calculation is shown to be within range -1.90 to -2.20	B1	Examiner's Comments Most candidates correctly found the gradient of their best fit straight line.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	$\lg(g) = \lg(GM) - 2\lg(r)$ 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. <u>Examiner's Comments</u> Exemplar 4  The exemplar shows both an unsuccessful and a successful approach. The crossed-out working was typical across many candidates, with incorrect maths and no handling of the 'GM' term. The successful approach was very clear mathematically, as well as making a clear comparison with the general equation for a straight line. Some candidates decided to find the gradient of their best fit line again, showing that they did not see the distinction between these two questions, despite the change in command verb.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	Any <u>two</u> from: - Direction of g for Earth and Mars are in opposite directions - For small values of r / $r <$ about 4.4×10^{10} m) g for Earth is greater or resultant g is towards the Earth - At r about 4.4×10^{10} 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	B1x2	Allow field / (gravitational) force for g Allow for r values larger than 4.4×10^{10} m) g for Mars is greater or resultant g is towards Mars <u>Examiner's Comments</u> Most candidates mis-read the question and tried to describe the shape of the curve, rather than explain why the curve has that shape. Many candidates also mis-used the term 'exponential' to describe a curve that is related to $1/r^2$. Others thought that the graph showed the effect of Mars and the Earth on each other, rather than on a small mass between them. They went on to describe what happened when Mars and Earth were separated by an increasingly large distance. It is good practice to be specific about which section of the graph you are talking about. 'When r is below 2.0×10^{10} m' is much clearer than 'At the start'. <i>Potential, potential difference, potential energy, field strength and force</i> These terms are all very similar yet subtly different and with differing formula. Be careful you know which is which.

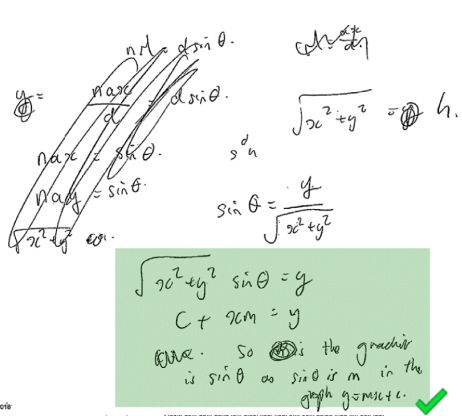
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Any valid equation relating g_{Earth} and g_{Mars} e.g. $GM_{\text{Earth}}/r_E^2 = GM_{\text{Mars}}/r_M^2$ 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 ± 0.1 ($\times 10^{10}$ m) when $g = 0$ <u>Examiner's Comments</u> To correctly answer this question, the candidate should equate the gravitational field strength from Earth (GM_{Earth}/x^2 where x is the distance to the point where $g=0$ from the centre of Earth) and the gravitational field strength from Mars (GM_{Mars}/y^2 where y is the distance to the point where $g=0$ from the centre of Mars). Many candidates did not get this far, yet some that did substituted and re-arranged correctly get a value in the correct range. Errors occurred when candidates were unsure of which distances to use in the equation. The commonest error was to use 0.9×10^{10} m for the distance of the zero-point since the graph stops at 5.3×10^{10} m, rather than using the data provided that the distance between the centres of the two planets was 5.8×10^{10} m and so the correct value for r was 1.4×10^{10} m.
			Total	10	
45			$1.2 \times 10^6 = \frac{1}{2} \times (\text{mass per second}) \times 8.0^2$ mass per s = 3.8×10^4 (kg s ⁻¹)	C1 A1	Answer is 3.75×10^4 (kg s⁻¹) to 3sf Note: 3.8×10^4 (kg s⁻¹) scores 1 for PoT error. <u>Examiner's Comments</u> A large majority of candidates got this right. Those that did not usually forgot to square the velocity.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
46			$T = 60/1600$ 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) <u>Examiner's Comments</u> About half of the candidates got this item right or provided clear working to show where they were going. There was much confusion about which quantity was which. 1600 revolutions per minute refers to the frequency of the rotation, not the angular speed, angular frequency or the speed itself. The percentage error of the frequency was 6.25%, prior to rounding. Some candidates multiplied this by their value for the speed to get the correct absolute uncertainty, although good practice is to round uncertainties to 1 SF.
			Total	3	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
47 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 $\sin(\theta) = \text{O/H}$ Not: gradient = $\frac{y}{(\sqrt{x^2 + y^2})}$ unless "c=0" seen. Examiner's Comments Candidates found this item tricky even if they realised that $\sin(\theta) = y/\sqrt{x^2 + y^2}$ and then re-arranged the equation into a form comparable with the general equation of a straight line, "y=mx +c". Unless that comparison was clear, then the mark could not be credited. Exemplar 8  The exemplar shows a clear way of demonstrating how to show that the gradient of the line of the graph should be $\sin(\theta)$.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	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 $\theta = 44\text{--}50$ (degrees) in place of gradient Allow: any subject Note: Gradient in range 0.70–0.76 gives λ in range $(5.8 - 6.4) \times 10^{-7} \text{ m}$ <u>Examiner's Comments</u> Many candidates could plot the best fit straight line and attempted to calculate the gradient. Not many candidates after that point realised that the gradient had given them $\sin(\theta)$ and could make no further meaningful progress. Common errors included not calculating d correctly from the quoted number of lines mm^{-1} or, less frequently, was using a value different from 2 for n.
		ii	(Scales/distances are large compared with the absolute uncertainty so) <u>absolute uncertainty</u> is too small to be shown (reasonably on this graph's scale) (AW)	B1	Ignore: error too small <u>Examiner's Comments</u> 20 per cent of candidates did not attempt this item. Some candidates were on the right lines but very few mentioned about absolute uncertainty and that for these instruments and this graph, the absolute uncertainty was too small to view on this scale.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	(The values for λ or θ will be) less precise (as independent measurements less likely to agree) (AW)	B1	Examiner's Comments About two fifths of candidates appreciated that the precision would not be as good with a protractor, as repeated measurements would be less likely to cluster in close proximity. <i>Precision</i> The term 'precision' is defined on page 40 of the Practical Skills Handbook, along with other useful terms that attempt to describe the quality of data
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
48	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 $v^2 = u^2 + 2as$ and $F = Ma$ (W =) $mg = (m + 0.8)a$; $u = 0$ and $s = 0.6$ Examiner's Comments The challenge to candidates in answering this <i>show that</i> question was to produce a convincing proof. More chose to use constant acceleration equations and $F = ma$ rather than loss of potential energy equates to gain in kinetic energy. The difficulty in the former method was justifying the statement $F = mg = (m + 0.800) a$. Most just quoted that $a = mg / (m + 0.800)$ which immediately gave the relationship shown in the question. The difficulty with the second method was that most candidates wrote $mgh = \pm \frac{1}{2}mv^2$ as the first line of their answer. In the next line one m became $(m + 0.800)$ without explanation to give the required relationship. Only candidates who gave more explanation were credited the marks. The candidate who wrote this perfect answer (exemplar 7) solved the problem in the first method of solution by introducing the tension in the string (labelled T on Fig. 4.1). Exemplar 7 (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. $T = 0.800 a$ $mg - T = ma$ $mg = a(0.800 + m)$ $s = 0.600$ $v = ?$ $a = ?$ $t = ?$ $v^2 = u^2 + 2as$ $v^2 = 2(0.600)a$ $v^2 = \frac{1.20mg}{(0.800 + m)}$
	b	i	($v^2 =$) 4.93 ($\pm$) 0.22	B1 B1	allow 4.9 ($\pm$) 0.2 (same number of decimal places)

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		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 <u>Examiner's Comments</u> Most candidates calculated the value of v^2 to two decimal places successfully. Fewer were successful in giving the absolute uncertainty as ± 0.22. A popular distractor was ± 0.10. On the graph of Fig. 4.2 only the correct position of the point was required to gain the mark. The length of the uncertainty bar was ignored. A significant number of candidates forgot to draw the line of best fit on the graph.
	c	i	$v^2 = \frac{1.20mg}{(m + 0.800)}$ compared with $y = mx + c$	B1	allow minimum of gradient = $v^2/[m/(m + 0.8)] = 1.2g$ or expect $y = v^2$ <u>and</u> $x = m/(m + 0.800)$ so gradient = $1.20g$ <u>Examiner's Comments</u> The common successful method employed by the majority was to compare the given equation with standard form for a straight line $y = mx + c$. A simple rearrangement of the relationship without any explanation was not considered to be adequate.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	one acceptable worst-fit line drawn	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 $1.1(\text{m s}^{-2})$; allow ecf from gradient value <u>Examiner's Comments</u> To avoid the problem of various lengths of error bar, candidates were judged to have drawn an acceptable worst fit line if it passed through opposite ends of the top and bottom bars on their graphs. Almost all gained the mark for using a triangle to determine the gradient of the line which spanned more than 0.13 on the x – scale. Most candidates were able to gain credit for finding the gradient of their graph correctly. The determination of the absolute uncertainty to one decimal place then proved to be too difficult a challenge for the majority.
			large triangle used to determine gradient	B1	
			Gradient (used to determine 'worst' g)	B1	
			absolute uncertainty given to one decimal place	B1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	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 <u>Examiner's Comments</u> Candidates gave full and usually clear answers to this part. There were four consequential marking points in this answer. Each candidate was given credit for every point that followed logically from the previous one, even when that previous one was incorrect. In the example (exemplar 8) shown here the candidate stated that the card appeared longer, which is incorrect. There were still three marks available for stating that the speed would appear lower and deducing that g would appear smaller. By this method most candidates were credited with at least half of the available marks. Exemplar 8 The time taken ~~to~~ is increased.  SO constant velocity V decreases.  (ECF) $v^2 = \frac{m}{m+300} \cdot 1.20g$  (ECF) Gradient would be smaller, therefore, the experimental value of g would be smaller.  (ECF)
			Total	15	
49			A	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
50			C	1	<u>Examiner's Comments</u> There was an erratum issues for this question. The term precision was replaced with <i>uncertainty</i>. The performance of the candidates was as expected with most opting for the correct answer C. A very small number of candidates opted for D because this value had the smallest percentage uncertainty.
			Total	1	
51			D	1	
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
52	$(R = \frac{V}{I} = \frac{W}{QI}; Q = It)$ charge → A s or energy → kg m s⁻² × m or kg m² s⁻² (base units) kg m² 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 $\frac{\text{kg m}^2}{\text{A}^2 \text{s}^3}$ or kg m² / (A² s³) Not kg m² / A² / s³ or kg m² / s³ / A² Examiner's Comments This was a challenging question, which provided the ideal opportunity for top-end candidates to use a variety of methods to get the correct S.I. base units of kg m² A⁻² s⁻³ for resistance. A significant number of candidates secured 1 mark for a partial answer with either charge → A s, or energy → kg m² s⁻². The rules for exponents were a bit perplexing for the low-scoring candidates. Many also misunderstood S.I. units. Exemplar 4 Derive the S.I. base units for resistance. $V = IR \quad R = \frac{V}{I} \quad V = \frac{W}{Q} = \frac{\text{Joules}}{\text{Coulombs}} = \frac{\text{kg m}^2 \text{s}^{-2}}{\text{A s}}$ $R = \frac{\text{kg m}^2 \text{s}^{-2}}{\text{A s}} \div \text{A} = \text{kg m}^2 \text{A}^{-2} \text{s}^{-3}$ base units: kg m² A⁻² s⁻³ This exemplar illustrates a flawless answer from a top-end candidate. The equations are clear to see and follow. The units of each physical quantities are clearly identified and the appropriate S.I. units for the quantities have been

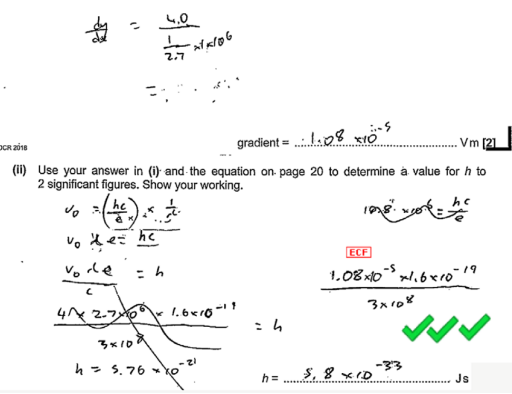
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					successfully manipulated to give the correct answer. Compare this with the exemplar below which illustrates a common misconception. Exemplar 5 $\rho = \frac{m}{V}$ $R = \frac{\rho L}{A} = \frac{\text{kg m}^{-3} \frac{\text{m}}{\text{V}} L}{\text{m}^2}$ $R = \frac{\text{kg m}^{-3} \text{m}}{\text{m}^2} = \text{kg m}^{-5} \text{m} = \text{kg m}^{-4}$ base units: ~~kg m⁻⁴~~ This exemplar illustrates a common error made by some candidates across the ability spectrum.  The resistivity ρ in the equation for resistance has been mistaken for density (which unfortunately has the same label). There can be no credit for wrong physics. It is vital to know your equations. Key:  Misconception
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
53		i	A straight line with non-zero V_0 intercept	B1	Ignore spread of data points on either side of the line Allow Intercept > 0 and < 1.0 V
			gradient = 1.3×10^{-6}	B1	Allow $(1.10 \text{ to } 1.60) \times 10^{-6}$; no need to check calculation <u>Examiner's Comments</u> Most candidates scored either 1 or 2 marks. The straight lines of best fit were generally well drawn. A significant number of the candidates forced their lines to go through the origin. The tolerance for the value of the gradient was deliberately made large. The ultimate penalty was the power of ten. Very few made two errors here – straight line through the origin and missing 10^{-6} factor.
		ii	gradient = $\frac{hc}{e}$ (Any subject)	C1	Possible ECF from (i) Note the answer must be given 2 SF only <u>Examiner's Comments</u> This was not an easy question, but a good number of candidates did exceptionally well on this practical-style question. The first mark was for correctly identifying 'gradient = hc/e ', and subsequent marks were for correct substitution and writing the final to 2 significant figures (SF). A significant number of candidates quoted their correct h value to more than the required SF. Many candidates were scoring full marks through the error carried forward rule.
			$h = \frac{1.3 \times 10^{-6} \times 1.60 \times 10^{-19}}{3.00 \times 10^8}$ (Any subject)	C1	
			$h = 6.9 \times 10^{-34}$ (J s)	A1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 9  This exemplar illustrates how full marks can always be scored from error carried forward (ECF) rule. The gradient of 1.08×10^{-5} was well outside the range allowed. This had already been penalised in the earlier part 20(b)(i). This erroneous value has been used correctly in this section. The answer is nowhere close to the Planck constant, but this is irrelevant – the physics has been applied correctly here, the answer is correctly written with 2 SF, so well deserved 3 marks for this E-grade candidate.
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

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		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 Examiner's Comments The two errors in this experiment were <i>systematic</i> and <i>random</i> errors (see learning outcome 2.2.1a in the H556 specification). Many candidates did not name these two errors, instead focussing on nebulous terms such as <i>human error</i>, <i>equipment error</i>, etc. Appropriate descriptions of these two errors were allowed. Only a small number of candidates appreciated that taking multiple readings of V_0 and averaging will lead to reduction in the random error. A pleasing number of candidates realised that the main reason for the non-zero intercept (systematic error) was the ambient light and switching off the lights would improve matters. Sorting out the zero-error on the voltmeter was an acceptable alternative. Descriptions about using 'precise instruments' for measuring potential difference or light intensity often led to no credit.
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
54		i	Beta radiation would not penetrate/ would be absorbed by the lead	B1	Not gamma radiation would be stopped Ignore reference to alpha radiation <u>Examiner's Comments</u> Most candidates were obviously very familiar with this and gave a clear response. Credit was given for either Gradient of best fit line: - a clear comparison of $\ln N = -\mu d + \ln N_0$ with $y = mx + c$ - using log rules to give $\ln(N_0 e^{-\mu d}) = -\mu d + \ln N_0$
		ii	$\ln N = -\mu d + \ln N_0$ compared to $y = mx + c$ (so $m = -\mu$ and $c = \ln N_0$)	B1	or $\ln N = \ln(N_0 e^{-\mu d}) = \ln N_0 - \mu d$ <u>Examiner's Comments</u> Candidates who gained the uncertainty mark mostly used the standard method of finding half the range i.e. $(\ln 340 - \ln 260)/2$. However, a very common response was to calculate the fractional uncertainty in N (i.e. $40/300$) rather than the absolute uncertainty in $\ln N$. This was not given without mathematical justification e.g. $\Delta(\ln N) \approx (\Delta N)/N$.

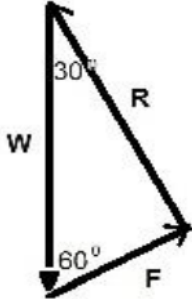
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		iii	5.70 ± 0.14	B1 B1	Both answers must be to 2d.p. Allow ± 0.13 not second B1 mark without correct working shown e.g. $\ln 300 - \ln 260$ or $(5.83 - 5.56)/2$ Allow $\Delta N/N$ ($= 40/300$) but only if $\Delta(\ln N) \approx \Delta N/N$ is quoted <u>Examiner's Comments</u> The majority of candidates had no difficulty in plotting the point (50, 5.70) correctly. Both best and worst fit lines were usually drawn well enough, although some had very thick pencil lines and a surprising number had not been extended to the $\ln N$ axis. Almost all candidates gained the mark for using a sufficiently large triangle ($\Delta d > 25\text{mm}$) for calculating the gradient of their best fit line.
		iv	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) <u>Examiner's Comments</u> Most mathematically able candidates quickly obtained the result $\mu d^{1/2} = \ln 2$ and then used it with their value of μ . Other candidates used a variety of (usually correct) graphical methods with Fig. 2.2.

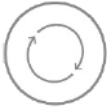
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		v	gradient of best fit line = $(-) \mu = (-) 54 \text{ (m}^{-1}\text{)}$ large triangle used to determine gradient of best fit line calculation of absolute uncertainty using <u>their</u> values in the formula (wfl gradient – bfl gradient) uncertainty and value of μ to same number of dp	B1 B1 B1 B1	Allow 51 to 56 Allow value of μ up to 4 SF ECF(ii)3 for wrongly plotted point $\Delta d > 25\text{mm}$ (seen from graph or working) ECF (ii)3 for worst fit line Ignore any POT error in gradients Allow value of absolute uncertainty up to 3 SF only e.g. 53.4 ± 5.6 or 54 ± 6
		vi	$\mu d_{1/2} = \ln 2$ (or 0.693) $d_{1/2} = 0.013 \text{ (m)}$	C1 A1	ECF (ii)4 for $\frac{1}{2}$ <u>Alternative method:</u> $\ln(N_0 / 2) = 7.67 \text{ (C1)}$ then use of graph to give $d_{1/2} = 0.013 \pm 0.001 \text{ (m)}$ (A1)
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
55	a		$W (= mg) = 8.0 \times 9.81$ $F = (W \sin 30 = 78.5 \times 0.5 =) 39 \text{ (N)}$ $R = (W \cos 30 = 78.5 \times 0.87) = 68 \text{ (N)}$	C1 A1 x 2	= 78(.5) (N) not 80 (N) Allow 8g Allow 1/2 for F and R the wrong way round  Credit full marks for use of a scale drawing which gives answers correct to $\pm 2\text{N}$ Special case: Allow 2/3 for use of $W = 80 \text{ (N)}$ giving $F = 40 \text{ (N)}$ and $R = 69 \text{ (N)}$ <u>Examiner's Comments</u> Most candidates were able to answer this question easily, although a few got their answers for F and R the wrong way around.
	b	i	$F = (mv^2/r =) 8.0 \times 1.5^2/2.0$ $F = 9.0 \text{ (N)}$	C1 A1	Allow answer to 1s.f. <u>Examiner's Comments</u> Question 4(b)(ii) proved very difficult and highlighted poor understanding of circular motion. Almost all candidates described the centripetal force as an additional force that had appeared out of nowhere. This centripetal force 'pulled the suitcase inwards' (or, in some cases, outwards) or 'balanced the frictional force' or 'added to the frictional force' and so on.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 5 <i>At 4.4' the bag is moving in an arc, meaning that centripetal force is acting on it as well as weight, friction and the normal. In order to keep the bag in equilibrium, friction has to increase and R has to decrease, as this centripetal force works against friction (F) and with R.</i> The candidate who gave the response in Exemplar 5 clearly thinks that an additional force, called the centripetal force, now acts on the suitcase. The forces F and R have to adjust in order to keep the suitcase in equilibrium. They have not realised that the suitcase is no longer in equilibrium horizontally but is accelerating. This means that the available forces have to adjust in order to provide a resultant force towards the centre of the circle, while still balancing vertically. Exemplar 6 <i>The suitcase is now accelerating towards the center of the semicircle. This means there is a net force acting to the left (on the diagram). W has no component to the left so F must increase so that there is a component to the left allowing it to accelerate allowing it to stay on course. The centripetal force required is 9N so the horizontal component of F must be 9N bigger than the horizontal component of R. The suitcase must not move down or up though so the vertical components must still add to 78.48N so F increases and R decreases. F</i> In contrast, the candidate who wrote the response in Exemplar 6 has a much better grasp of the situation.  afl Rather than using the phrase 'centripetal force', candidates could be encouraged to think of motion in a circle as a special case of $F = ma$ where the resultant force F points towards the centre of the circle and the acceleration a is given by v^2/r. This should hopefully encourage them to think about which of the forces available in the situation could provide the resultant force for this motion to occur.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	- Suitcase accelerates / changes its velocity / (constantly) changes direction / has a resultant force acting on it / is no longer in equilibrium - The resultant force must act (horizontally) towards centre of circle / to the left - The centripetal force can only be provided by (an increase in) F - Increased vertical component of F means the vertical component of R must decrease (in order to balance W) So R must decrease	B1 x 4 A0	Any answer that mentions centrifugal force scores 0/4 Ignore any statement that treats the centripetal force as an extra force Allow net or unbalanced or total for resultant throughout or $F\cos 30^\circ - R\sin 30^\circ$ increases (from 0 to 9.0 (N)) / the (magnitude of the) horizontal component of F must exceed the (magnitude of the) horizontal component of R not a resultant force acts towards Y e.g. Friction is the only force able to provide the centripetal force / only F has a component to the left Allow F provides the centripetal force Not the horizontal force must increase / increases or $F\sin 30^\circ + R\cos 30^\circ = W$ / W is the vector sum of F and R / $W = (F^2 + R^2)^{1/2}$ (and F increases while W remains constant) Total
			Total	9	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
56	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 No response or no response worthy of credit. <u>Frontal</u>	1 (AO3)	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 $\lambda = \% \text{ uncertainty in } \sin \theta = 3\%$

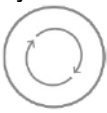
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			<u>Examiner's Comments</u> Unfortunately, a significant number of candidates did not recognise the diffraction grating experiment here, confusing it with the double slit experiment and so using the formula $\lambda = ax/D$. This may be because the formula $n\lambda = d\sin\theta$ is in the astrophysics section of the formula sheet. Candidates who chose to use the correct formula $n\lambda = d\sin\theta$ were given for choosing the correct values for n, d and θ, for a correct calculation of λ, and for an accurate error analysis. Candidates who did not calculate λ could still gain full marks, as long as they gave accurate instructions as to how this could be done. Strong candidates successfully calculated a reasonable estimate of uncertainty in λ by combining the uncertainties in the distance measurements which had been used to find $\sin\theta$.  AfL The experiment to measure the wavelength of light using a diffraction grating is PAG 5.1 and so is often carried out in Year 12. It may be beneficial to carry out this practical activity in Year 13 instead during the study of spectral lines, to reinforce use of the formula $n\lambda = d\sin\theta$.  OCR support Being aware of the contents of the data, formulae and relationship booklet and its layout will support candidates, alleviating the need to recall numerical values of constants and allowing retrieval of correct formulae, or giving assurance that the student has recalled correctly.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Exemplar 7 Red photons occur only at the 4th order (a). There are 300 lines per millimeter, which is 300,000 per meter. ~~Very small separation is~~ Need to measure the angle θ between the 3rd and 4th order to use equation $d \sin \theta = n \lambda$ to solve for λ. A more fully decked room would be better as it's ~~more~~ easier to determine what the colours and see the light. Exemplar 7 illustrates many aspects of a Level 1 response. Although the correct formula has been identified, it will not give a correct value for λ because incorrect values for n, d and θ have been chosen. The response has been put at the bottom of Level 1 because, although there is an attempt at a logical structure, almost all of the information it contains is inaccurate and therefore not relevant.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
57			Accuracy is (a quality denoting) the closeness of the measured value to the true value Precision is (a quality denoting) the closeness of agreement between measured values (obtained by repeated measurements)	B1 B1	Allow readings/results/data/values/measurements for <i>measured value</i>; actual/real/allowed/correct for <i>true</i> Allow measurements are close together/are similar/have small range/have low spread/have low scatter/have good agreement/are all close to the average Examiner's Comments This was generally well answered, although a few candidates reversed the definitions. Some candidates thought that the precision of an answer was determined by its number of significant figures.  AfL Centres should make sure that they are using the latest definitions, which can be found in <i>The Language of Measurement</i> (ASE 2010).
			Total	2	
58			A	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
59			D	1	<u>Examiner's Comments</u> Most candidates understood that the percentage uncertainties, rather than the absolute uncertainties should be combined here. The percentage uncertainty in the length is 0.5% and the percentage uncertainty in the diameter is 0.2%. The most common incorrect response here was C, because this is what you get when you add the 2 percentage uncertainties. The percentage uncertainty in the diameter must be doubled, because the formula for the volume of the cylinder include diameter^2. This gives the correct answer D.
			Total	1	
60			B	1	
			Total	1	
61			C	1	<u>Examiner's Comments</u> Since $P = F/A$, we need the units of force and area in base units. $F = ma$, so force has the base units of kg m s^{-2}. Area's unit in base units is m^2. Hence pressure has the base units $\text{kg m s}^{-1}/\text{m}^2 = \text{kg m}^{-1} \text{s}^{-2}$, which is answer C.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
62	a		$L \rightarrow [m]$ and $A \rightarrow [m^2]$ or $L/A \rightarrow [m^{-1}]$ $kg\ m^3\ s^{-3}\ A^{-2}$	C1 A1	Allow $\frac{kg\ m^3}{s^3\ A^2}$ or $kg\ m^3/s^3\ A^2$ <u>Examiner's Comments</u> The majority of the candidates effortlessly showed the base units for resistivity to be $kg\ m^3\ s^{-3}\ A^{-2}$. The structure from most was immaculate. It was good to see shortcuts being used too. Some candidates went straight to the units for resistivity ($\Omega\ m$), and then multiplied the units given for resistance multiplied by m.  Misconception The most common misconception, mainly at the lower end, was that the A in the resistance equation was the unit for current, the ampere A. This led to the incorrect answer $kg\ ms^{-3}\ A^{-1}$
	b	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 <u>Examiner's Comments</u> In (c)(i), the lines of best fit were generally very good, as were the gradient calculations with most candidates getting values in the range 2.60 to 3.00. Only a small number of candidates calculated the inverse of the gradient.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		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 $R = \rho L/A$ <u>Examiner's Comments</u> Most candidates struggled with (c)(ii). Less than 1 in 10 candidates successfully used the equations $E = V + Ir$ and $R = \frac{\rho L}{A}$ to derive the expression $\frac{1}{I} = \frac{\rho}{AE} L + \frac{r}{E}$, and then identified the gradient as $\frac{\rho}{AE}$ by comparison with the equation for a straight-line $y = mx + c$.
		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 <u>Examiner's Comments</u> Most candidates in (c)(iii) did exceptionally well to calculate the resistivity using the equation for the gradient. Calculations were generally well-structured, and the final answer showed good use of powers of ten and significant figures.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		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' Examiner's Comments Finally, (c)(iv) provided good discrimination with many of the top end candidates realising the gradient of the line was unaffected, the line was just shifted horizontally. 'Systematic error' and 'zero error' were allowed as alternative answers for the horizontal translation of the line.  Misconception There were some missed opportunities, with some candidates making the following mistakes. - In (c)(ii), ignoring the internal resistance r of the cell shown in the circuit of Fig. 18.1 to get the wrong expression $\frac{1}{I} = \frac{\rho}{AE} L$ - In (c)(iii), a small number of candidates either used 0.38 mm as the radius of the wire to get a resistivity of $1.9 \times 10^{-6} \Omega \text{ m}$ or forgot to convert the millimetres into metres to get a value of $0.48 \Omega \text{ m}$. - In (c)(iv), a significant number of low-end candidates, mentioned that resistivity of the wire did not depend on its physical dimensions, and therefore the resistivity value calculated will be the same. There was no reasoning in terms of gradient = $\frac{\rho}{AE}$
			Total	10	
63			C	1	
			Total	1	
64			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
65			C	1	
			Total	1	
66			B	1	
			Total	1	
67			D	1	
			Total	1	
68			B	1	
			Total	1	
69			B	1	
			Total	1	
70			A	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
71	a		$h \rightarrow \text{J s} \quad / \quad h \rightarrow \text{N m s} \quad / \quad \text{J} \rightarrow \text{kg m}^2 \text{s}^{-2}$	C1	
			base unit = $\text{kg m}^2 \text{s}^{-1}$	A1	
	b	i	$Vq = \frac{1}{2} mv^2$ and $\lambda = \frac{h}{mv}$	M1	Allow p for mv Allow e for q in (b)(i) – this is to be treated as a ‘slip’
			Clear algebra leading to $\lambda^2 = \frac{h^2}{2mq} \times \frac{1}{V}$	A1	
		ii	1 (% uncertainty in λ^2) = 10% (% uncertainty in λ) = 5% 2 Straight line of best fit passes through all error bars 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 A1 B1 C1 C1 C1 A1	Note 10 (%) on answer line will score the C1 mark 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	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
72		i	sensible diameter, e.g. 7 (mm) (power = $4.8 \times 10^{-7} \times \pi \times (0.0035)^2$) power = 1.8×10^{-11} (W)	C1 A1	Allow 2 – 16 (mm) Not πd^2 ; this is XP Note check for AE (condone rounding error here) Possible ECF for diameter outside the range 2 – 16 (mm) Allow 1 SF answer here
		ii	($I \propto A^2$; intensity doubles) $A = \sqrt{2} \times 7.8$ (or equivalent) $A = 11$ (nm)	C1 A1	Allow the C1 mark for $4.8 (\times 10^{-7}) = k \times [7.8 \times (10^{-9})]^2$
			Total	4	
73		i	(force =) $\frac{(1.6 \times 10^{-19})^2}{4\pi\epsilon_0 \times (1.0 \times 10^{-15})^2}$ (F =) 230 (N) $F^2 = 230^2 + 230^2 - 2 \times 230 \times 230 \times \cos 120^\circ$ or $F = 2 \times 230 \cos 30^\circ$ $F = 400$ (N)	C1 C1 C1	Special case: $F = \frac{Qq}{4\pi\epsilon_0 r^2} = \frac{2 \times 1.6 \times 10^{-19}}{4\pi\epsilon_0 \times (1.0 \times 10^{-15})^2}$ loses this C1 mark, then ECF for the rest of the marks Not the first two C1 marks for incorrect charge, then allow ECF for the final C1A1 marks Note force to 4 SF is 230.2 N Allow sine rule / scale drawing Allow this mark for $230 \cos 30^\circ$ or 200 (N) Allow ± 10 (N) if scale drawing used
		ii	F / arrow vertical up the page	B1	Allow correct arrow direction anywhere on the figure
		iii	Strong (nuclear) force (acts on the protons) The strong (nuclear) force is attractive	B1 B1	Ignore gravitational force Allow pulls / holds (the protons) / binds (the protons) for 'attractive'
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
74	a		(initial charge) $Q = EC_0$ or (Q conserved so final) $Q = V(C + C_0)$ (as capacitors are in parallel) so $EC_0 = V(C + C_0)$ (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 Examiner's Comments Some candidates obtained $Q = EC_0$ by applying the definition of capacitance at A, but then did not realise that charge would be conserved on switching from A to B. Some chose the wrong formula for capacitors in parallel or attempted to use the potential divider equation.
	b	i	$1/V = 1/E + C/EC_0$ (and compare to $y = c + mx$)	B1	Mark is for rearrangement into linear equation Examiner's Comments Some candidates correctly took the reciprocal of both sides of the given equation but were then unable to show a rearrangement into the standard linear form. A common difficulty was an inability to expand the bracket in $\frac{1}{E} \times \frac{(C + C_0)}{C_0}$ to give $\frac{C}{EC_0} + \frac{C_0}{EC_0}$

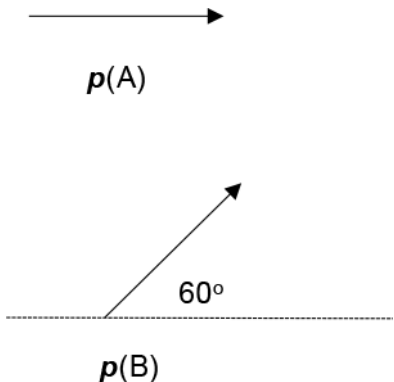
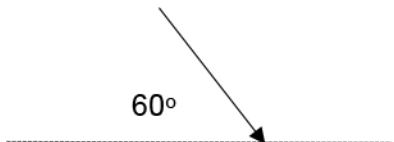
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		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 <u>Examiner's Comments</u> Some candidates gave their response to 2 d.p. instead of to 2 s.f. as required.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		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 Examiner's Comments Most candidates gained the mark for using a large triangle (spanning more than 1.5 on the x-axis) to determine the gradient of the worst-fit line. Lower ability candidates were unable to gain credit for finding the gradient of their line because they read the scales on the axes incorrectly. Candidates should take a ruler into the examination and be careful about the positioning of the ruler for drawing a worst-fit straight line. A worst-fit line should join opposite extremes of uncertainty limits and pass between all the uncertainty limits. The Practical Skills Handbook is helpful on this topic. Several candidates performed the unnecessary step of calculating the fractional (or percentage) uncertainty instead of using $\Delta C_0 = \pm C_{0 \text{ best}} - C_{0 \text{ worst}}$ directly.
	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	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
75		i	Example (not to scale):  $p(A)$ 60° $p(B)$	B1 B1	horizontal arrow (judge by eye), in the direction shown arrow drawn at an angle of 60° to the horizontal (angle must be shown), in the direction shown
		ii	Example (not to scale):  60° (Can apply principle of) conservation of momentum (since no external forces are acting)	B1 B1	arrow drawn at an angle of 60° to the horizontal (angle must be shown), in the direction shown <u>Examiner's Comments</u> This was not an easy question but, even so, a good number of candidates did well. The marks were given for the direction (rather than for the magnitude) of the momentum vectors. Some of the common errors were: • forgetting to label relevant angles • not using arrows to show direction • drawing a vector triangle without any indication of which arrow was meant to be the final momentum.
			Total	4	