Name: ____

Topic 1: Working as a Physicist Part 1

Date:

Time:

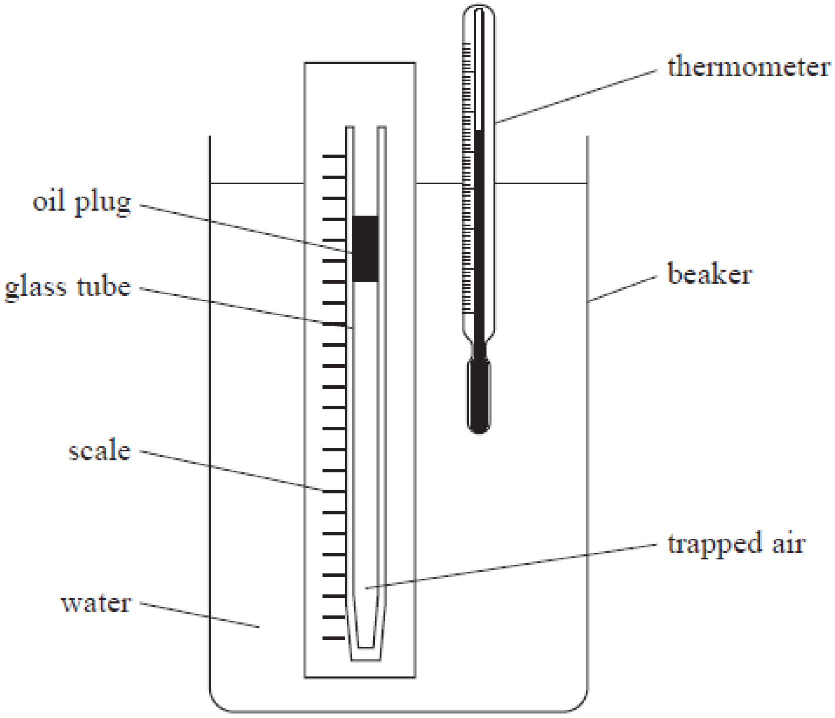
Total marks available:

Total marks achieved: ______

Questions

Q1.

A student investigated how the volume of a fixed mass of air varies with the temperature of the air. She used the apparatus shown.



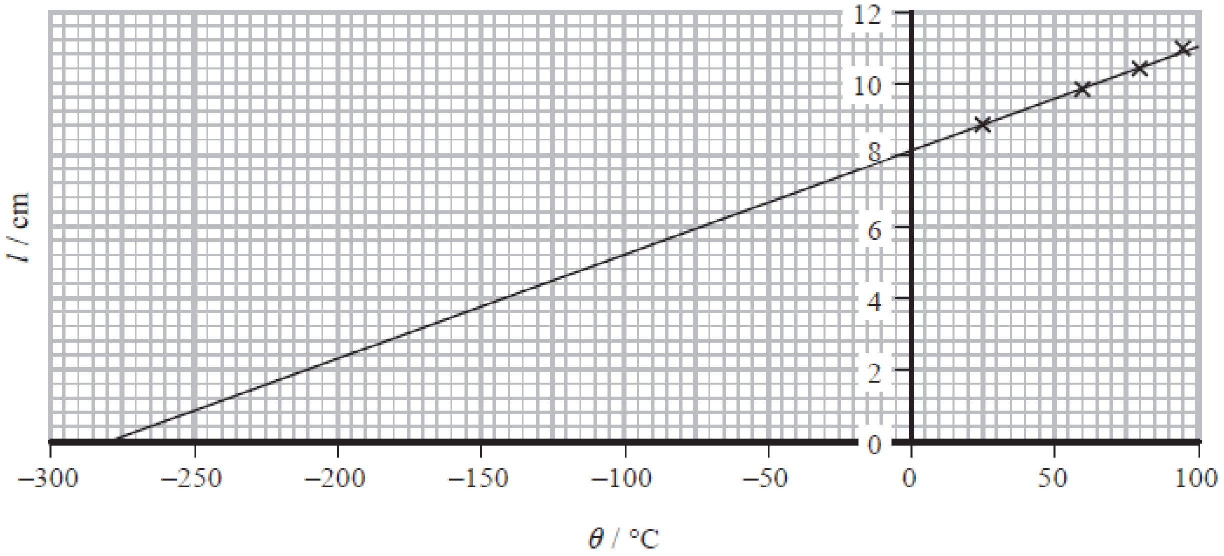
A glass tube was sealed at one end. A plug of oil trapped a length *l* of air in the tube. The water in the beaker was heated to a temperature *θ*. The corresponding value of *l* was measured. This was repeated for a range of temperatures.

The thermometer had a resolution of 0.5 °C. The scale had mm divisions.

The student's results are shown in the table.

θ / °C	*l* / cm
24	8.8
60	9.8
78.5	10.3
95.5	10.9

The student plotted a graph of *l* against *θ* as shown.



(i) Explain the significance of the intercept on the *x*-axis.

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(ii) The student wrote a report of the investigation in her lab book. In the conclusion she wrote:

"In this investigation uncertainties were minimised by selecting measuring instruments with a high resolution. The points lie on a perfect straight line, indicating that the investigation is accurate."

Discuss the student's conclusion.

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(Total for question = 7 marks)

Q2.

A practical physics textbook states that "measurements may give a precise value for the quantity being determined but this may not necessarily be an accurate value".

Describe what physicists mean by the terms accuracy and precision.

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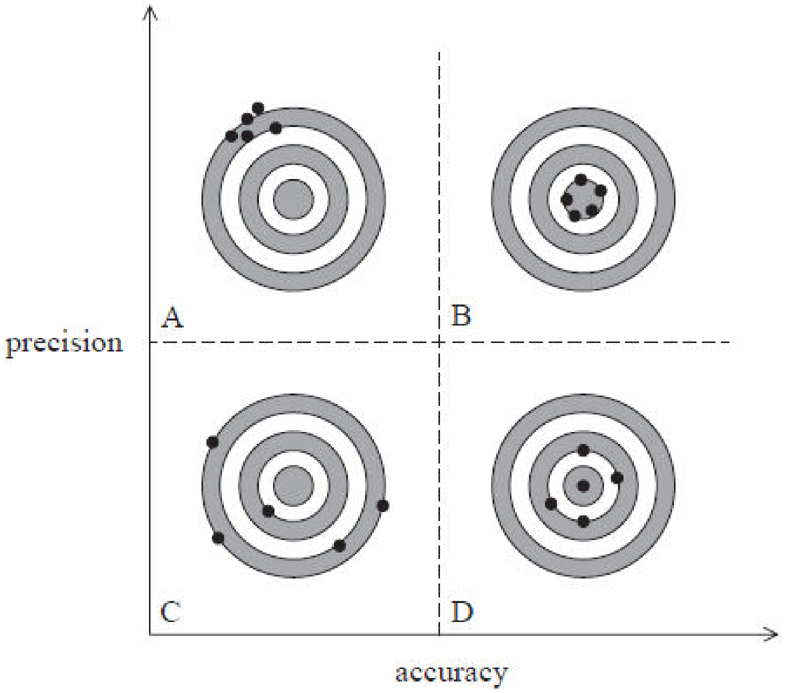
(Total for question = 2 marks)

Q3.

A teacher is explaining the differences between accuracy and precision to her students.

She draws the following diagram, which shows different degrees of accuracy and precision. The circles represent targets A, B, C and D and the dots represent arrows hitting the targets.



Explain how targets A, B, C and D represent differing degrees of accuracy and precision.

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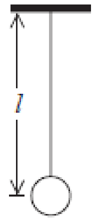
(Total for question = 4 marks)

Q4.

A student is using a simple pendulum to determine a value for the acceleration of free fall *g*.



She measures the length *l* of the pendulum four times with a metre rule and records the following values.

l / cm			
l_1	l_2	l_3	l_4
85.5	86.0	87.5	85.5

She calculates the mean length l_m of the pendulum using the following method:

$$l_m = \frac{85.5 + 86.0 + 87.5 + 85.5}{4} = 86.1 \text{ cm}$$

(i) Calculate a more accurate value for l_m.

(2)

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l_m = ...

(ii) Determine the time period of the oscillations of this pendulum, using your calculated value for l_m.

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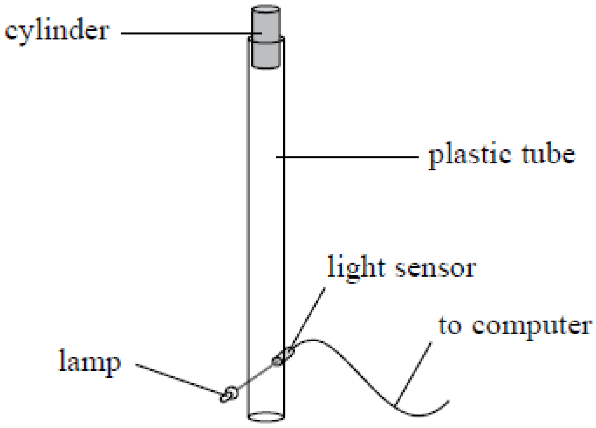
Time period of oscillations = ...

(Total for question = 4 marks)

Q5.

A student uses a lamp and a light sensor as a light gate connected to a data logger and computer to determine the speed of a falling object. He drops a small cylinder through a clear plastic tube. The light gate and data logger measure the time of fall of the cylinder and the speed is calculated.



The student repeats the experiment five times and records the results in a table.

Speed / m s^{-1}	Mean speed / m s^{-1}
4.52 4.59 4.43 4.63 4.58	4.55

Explain **one** advantage of using a light gate and data logger in this experiment.

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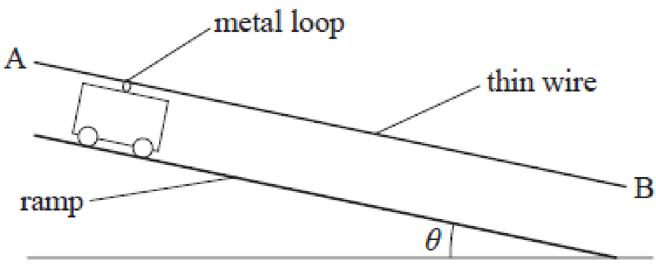
(Total for question = 2 marks)

Q6.

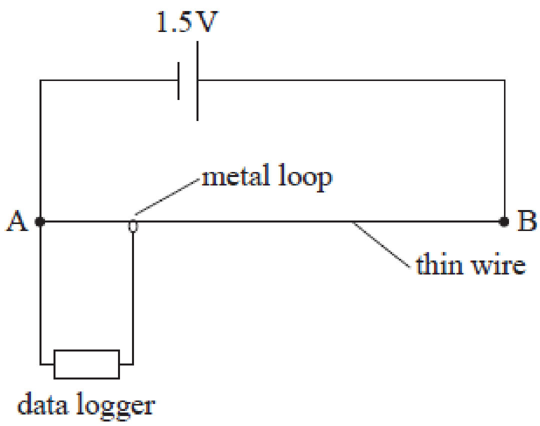
A student investigates the motion of a friction-free trolley down a ramp. On the top of the trolley there is a metal loop which makes contact with a length of thin resistance wire, AB, fixed above the ramp. The resistance wire has a uniform diameter.

The trolley accelerates down the ramp and the metal loop stays in contact with the wire along the full length of the ramp.



The student uses a protractor to measure the angle θ between the ramp and the horizontal and records a value of 4° with an uncertainty of ±1°.

(a) The two ends of the wire are connected to a 1.5 V cell. A data logger, set to measure potential difference, is connected to the metal loop and to the negative terminal of the cell.



Explain how the potential difference recorded by the data logger will vary as the loop moves along the length of the
wire AB.

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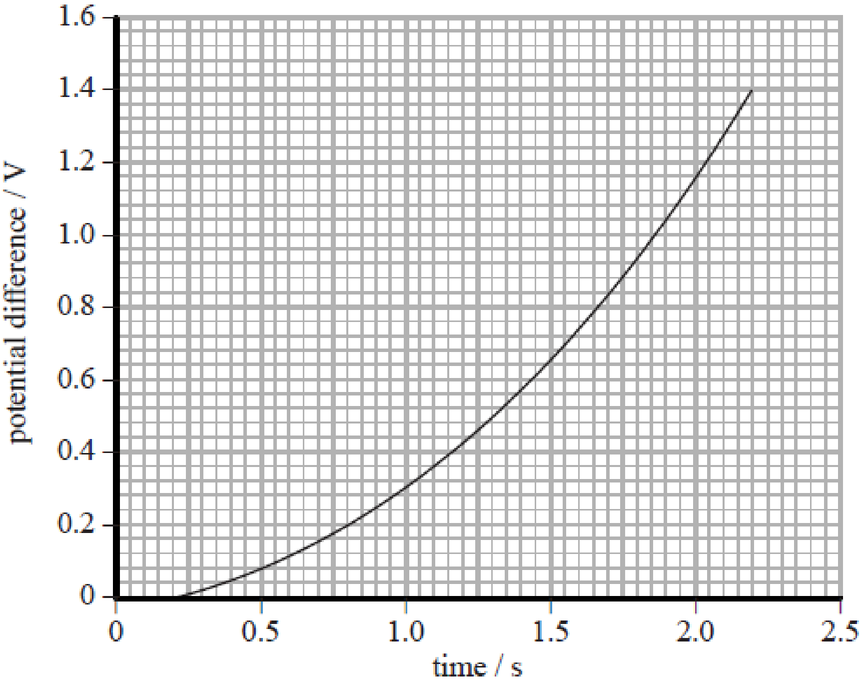
(b) The graph shows the data obtained from the data logger.



Determine the velocity of the trolley at 1.5 s.

1.5 V represents a distance of 2.00 m.

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Velocity = ...

(c) The student calculated the velocity of the trolley at 2.0 s to be 1.5 m s^{-1}.

By considering the acceleration of the trolley, determine whether the student's measurement of θ was within the uncertainty quoted.

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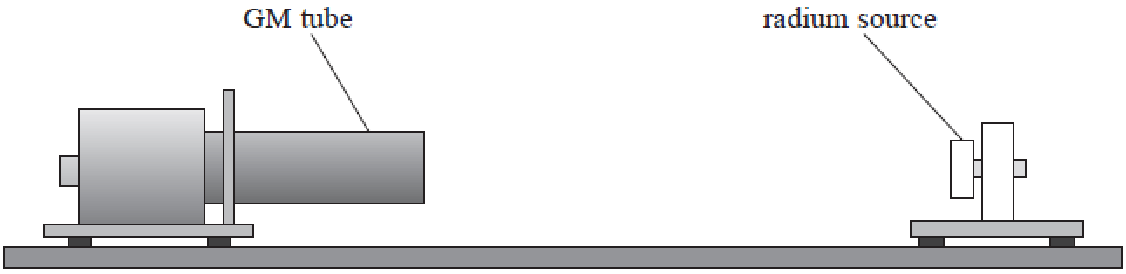
(Total for question = 11 marks)

Q7.

A student used a Geiger-Müller (GM) tube to determine the activity of a radium source. Radium emits α, β, and γ radiation.

He positioned the source 20 cm from the GM tube, as shown, and recorded the count for 1 minute. He repeated the measurement and calculated a mean count.



The student recorded the following results.

Count 1	Count 2	Mean count
183	178	181

Criticise the student's method for determining the count at this position.

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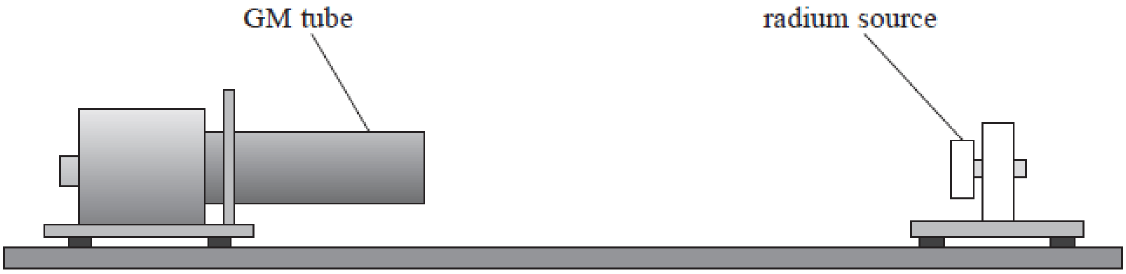
(Total for question = 3 marks)

Q8.

A student used a Geiger-Müller (GM) tube to determine the activity of a radium source. Radium emits α, β, and γ radiation.

He positioned the source 20 cm from the GM tube, as shown, and recorded the count for 1 minute. He repeated the measurement and calculated a mean count.



The student recorded the following results.

Count 1	Count 2	Mean count
183	178	181

From his results the student determined that the activity of the source was 3.0 Bq.

Comment on his value for the activity of the source.

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(Total for question = 5 marks)

Q9.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of the following is a base SI unit?

☐ **A** ampere

☐ **B** coulomb

☐ **C** joule

☐ **D** newton

(Total for question = 1 mark)

Q10.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

Which of the following are the base units for impulse?

☐ **A** kg m s^{-1}

☐ **B** kg m s^{-2}

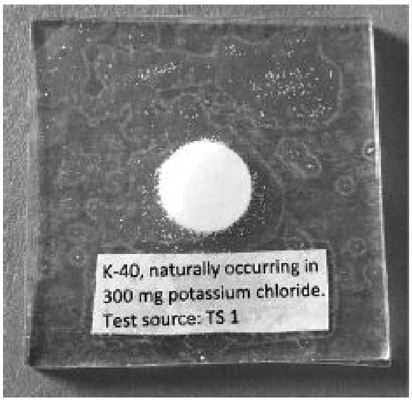
☐ **C** N m

☐ **D** N s

(Total for question = 1 mark)

Q11.

A school science department keeps a sample of potassium chloride to use as a test source for Geiger-Müller tubes.



Potassium contains 0.012% of the unstable isotope potassium-40.

The science department also has a sample of strontium-90. This undergoes beta decay with a half-life of 29 years.

State why the half-life of potassium-40 makes the potassium chloride a more suitable material than strontium-90 for the test.

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(Total for question = 1 mark)

Q12.

Genuine crystal balls are made from clarified quartz rather than glass. A student was given a small crystal ball and wanted to know whether it was genuine.

The student measured the diameter of the crystal ball using vernier calipers with a resolution of 0.01 cm.
She measured the mass of the crystal ball using a balance with a resolution of 1 g.

The table gives the densities of clarified quartz and glass.

Material	Density / $kg\ m^{-3}$
Clarified quartz	2650
Glass	2590

Determine whether the crystal ball was genuine.

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(Total for question = 6 marks)

Q13.

Small electrical devices are often powered by electric cells; different devices use different types of cell.

The cells normally used in a television remote control have an e.m.f. of 1.5 V.

(i) Describe a procedure to determine the internal resistance and e.m.f. of an electrical cell. You should include a circuit diagram.

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(ii) Describe how you would use your results to find a value for the e.m.f. and internal resistance of the cell.

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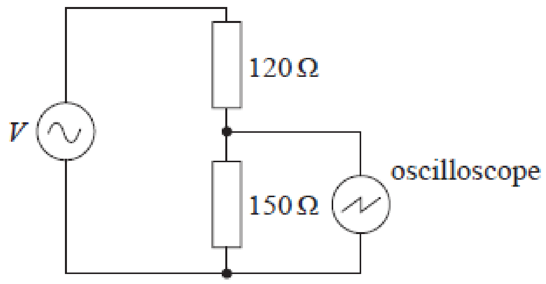
(Total for question = 6 marks)

Q14.

A student connected the output from a source of alternating potential difference (p.d.) to a series resistor combination.

She connected an oscilloscope across the 150 Ω resistor as shown.



Another student suggested that a voltmeter would be more accurate than using an oscilloscope to determine the magnitude of the p.d.

Comment on this suggestion.

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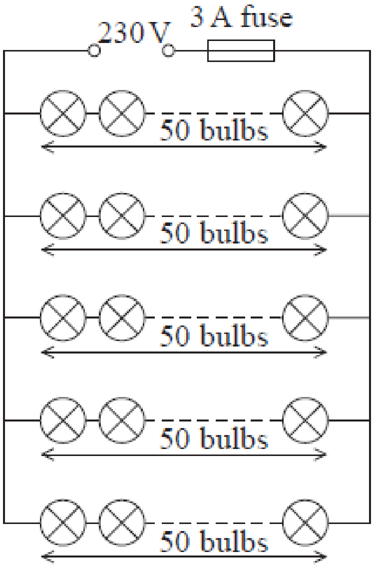
(Total for question = 3 marks)

Q15.

A set of festive lights is made up of five parallel strands of filament bulbs. Each strand contains 50 bulbs in series as shown.



(a) When a bulb is working normally its resistance is 8.0 Ω. If the filament of the bulb breaks, the lamp is designed to still conduct and its resistance becomes 3.0 Ω.

(i) The filament of one bulb on a strand breaks.
By considering the effect this has on the remaining bulbs in that strand, explain why it is recommended that broken bulbs are replaced as soon as possible.

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(ii) The set of festive lights are fitted with a 3 A fuse. Five bulbs in one strand break.

Determine whether the fuse blows.

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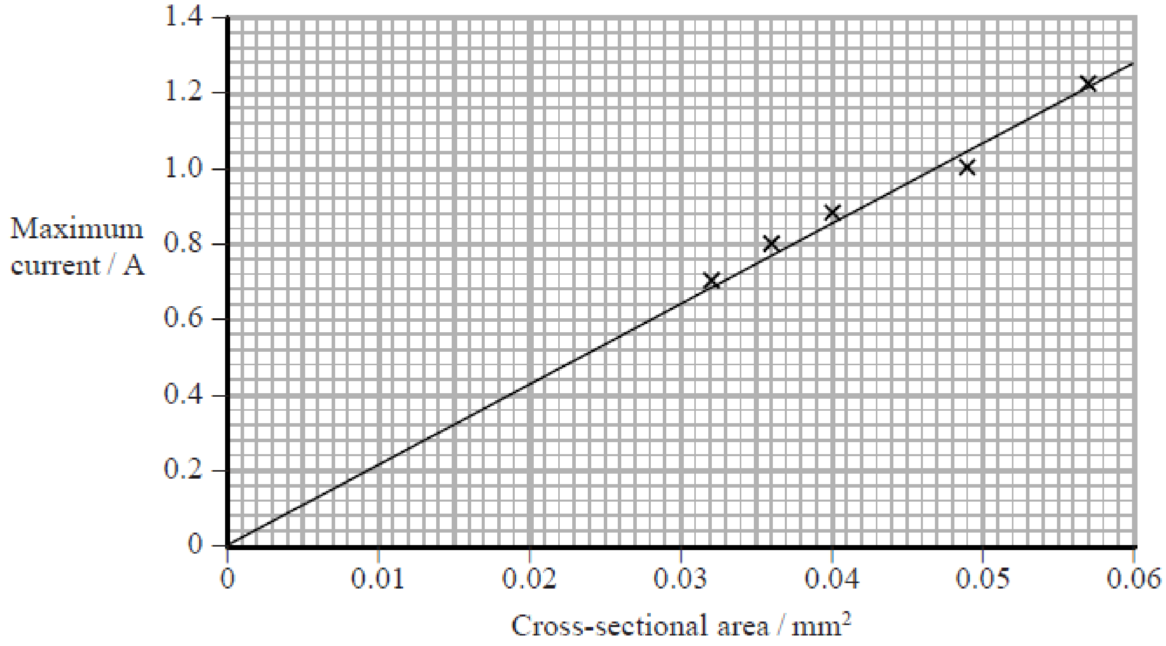
(b) A student investigates how the cross-sectional area of a fuse wire affects the current at which the fuse blows. She uses pieces of wire of the same material and length, but different cross-sectional areas. She steadily increases the current through each piece of wire and records the maximum current through the wire before it breaks.

She then plots a graph of maximum current against cross-sectional area.



(i) Describe how the student should determine the cross-sectional area of the wire.

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(ii) State the relationship between the maximum current and the cross-sectional area of the wire.

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(iii) The student chooses a piece of wire, of the same material and length as used in the investigation. The piece of wire has a diameter of 0.40 mm.

Use the graph to determine whether the piece of wire is suitable to use as the 3A fuse wire for the set of festive lights.

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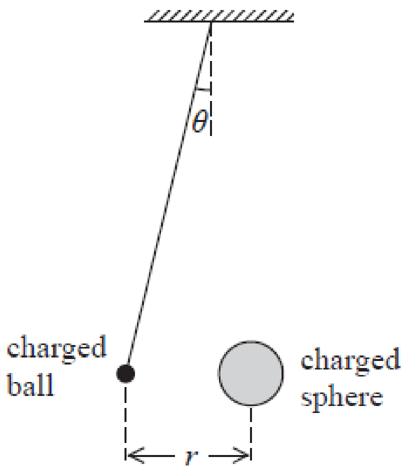
(Total for question = 14 marks)

Q16.

A student carries out an experiment to investigate the force acting between two charged objects. A lightweight negatively-charged ball is freely suspended from the ceiling by an insulating thread. The ball is repelled by a negatively-charged sphere that is placed near it on an insulated support.
The angle of deflection is θ and r is the distance between the centres of the ball and the sphere.



(a) (i) Draw a free-body force diagram for the suspended ball.

(2)

(ii) The weight of the suspended ball is W.

Show that the force of repulsion F on the suspended ball is given by

$$F = W \tan \theta$$

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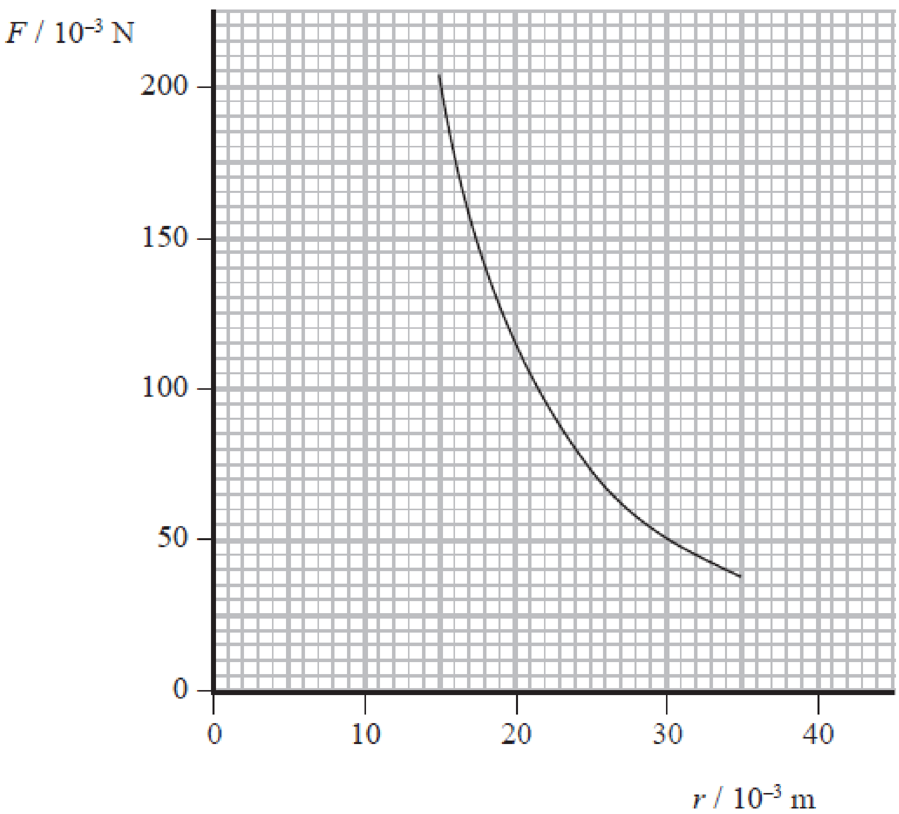
(b) (i) The student can increase the magnitude of the force by moving the sphere towards the suspended ball.
She takes pairs of measurements of r and θ and calculates the magnitude of the force F. She then plots a graph of F against r.



Use readings from the graph to demonstrate that the relationship between *F* and *r* obeys an inverse square law.

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(ii) The charge on the sphere is 100 times greater than the charge on the ball.

Calculate the charge on the ball.

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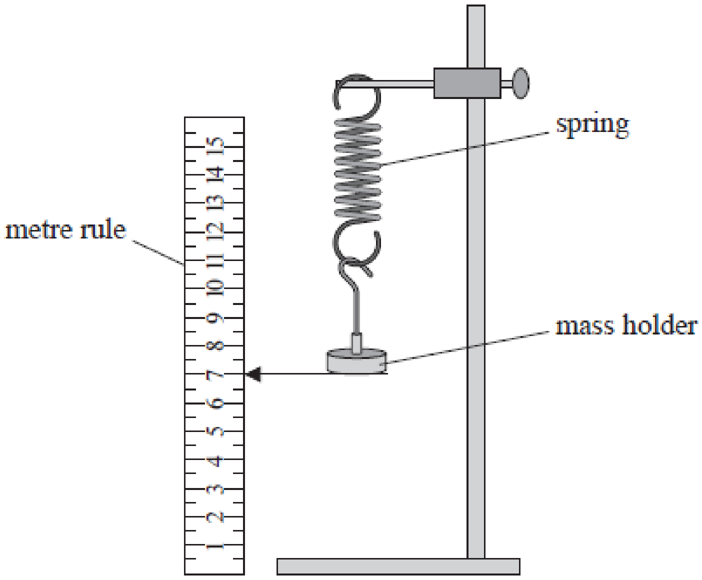
Charge = ...

(Total for question = 11 marks)

Q17.

A student investigated the behaviour of a spring under tension. The spring was hung vertically with a mass holder attached.



The position of the bottom of the mass holder was recorded. The spring was stretched by adding masses to the mass holder and the new positions were recorded. The extension of the spring each time was calculated.

The student produced the following table.

Mass added / g	Extension / cm	Stretching force / N
50	1.9	0.49
70	3	0.69
90	3.5	0.9
110	4.5	1.08
130	5.3	1.28
150	5.8	1.47

Criticise the student's table.

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(Total for question = 2 marks)

Q18.

A student carries out an experiment to investigate the stretching of a liquorice lace.

(a) The student fixes one end of the lace to a support and adds different masses to the end of it, measuring the extension each time with a metre rule. His results are shown in the table.

Mass/kg	Force/N	Extension/m
0.03	0.294	0.005
0.04	0.392	0.0075
0.06	0.589	0.011
0.07	0.687	0.012

Criticise the recording of these results.

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(b) Describe how the student should measure the extension of the lace to make his results as accurate as possible.

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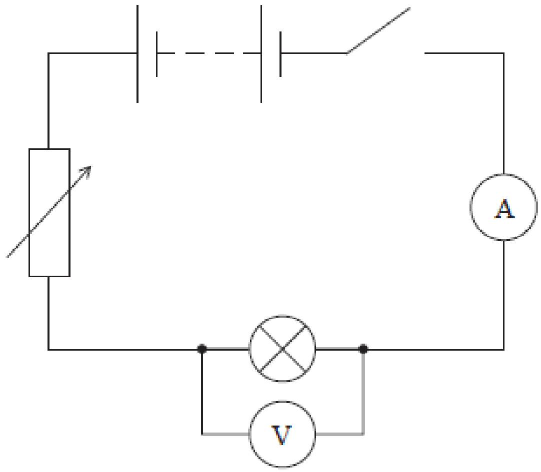
(Total for question = 5 marks)

Q19.

A student set up the circuit shown and measured the current *I* through the filament lamp for a range of values of potential difference (p.d.) *V*.



The student's data is shown in the table.

V / V	*I* / A
3.0	0.6
4.0	0.75
6.0	1.00
8.0	1.20
10.0	1.35
12.0	1.5

Criticise the student's recording of the data.

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(Total for question = 1 mark)

Q20.

A magician did a trick which he claimed was the most dangerous ever. He positioned himself midway between two charged spheres which were separated by a distance of about two metres. Each sphere was charged to a potential that would cause ionisation at a distance of one metre. He wore a protective suit of chain mail and a helmet consisting of a metal cage. The protective suit and helmet were earthed to a potential of 0 V.

A scientist said "there is no danger in this and I would happily do it tomorrow".

Explain whether this statement is justified.

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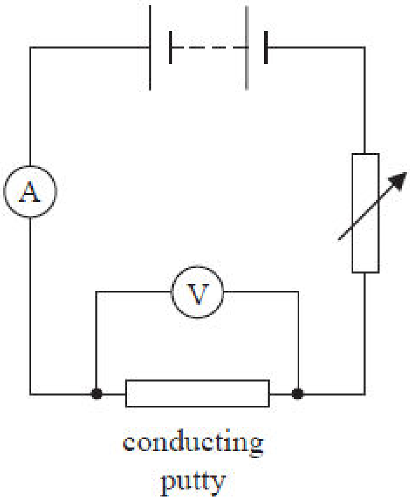
(Total for question = 3 marks)

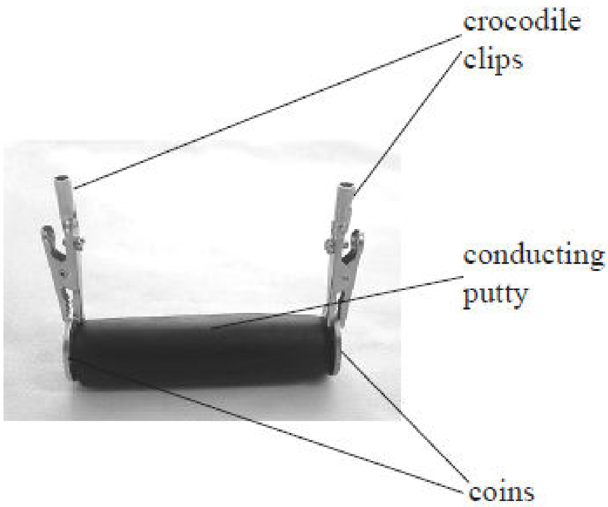
Q21.

Conducting putty is a material that is a relatively good conductor and can be easily moulded into different shapes.

A student decides to investigate how the resistance R of a cylinder of conducting putty depends upon the cross-sectional area A of the cylinder.

(a) She sets up the circuit shown and keeps the length l of the cylinder constant at 7.5 cm. She uses the ammeter and voltmeter readings to determine the resistance of cylinders of different cross-sectional areas.





The student's results are shown in the table.

Diameter / cm	Resistance / Ω	(l / A) / m^{-1}
0.4	56.0	1490
1.0	37.5	968
1.5	16.7	430
2.0	9.44	242
2.5	6.00	155

(i) Plot a graph of *R* against *l*/*A*.

(4)

(ii) Use your graph to determine a value for the resistivity of the putty.

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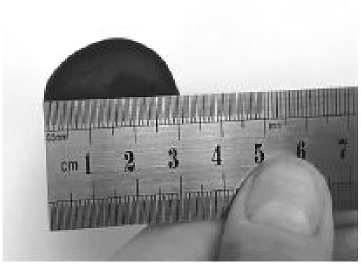
Resistivity = ...

(b) The photographs show how the student obtained measurements for the length and diameter of a cylinder.



The student records the following readings:

length = 90 mm; diameter = 31 mm

Identify two problems with this method of determining the dimensions of the cylinder and for each problem identify a solution.

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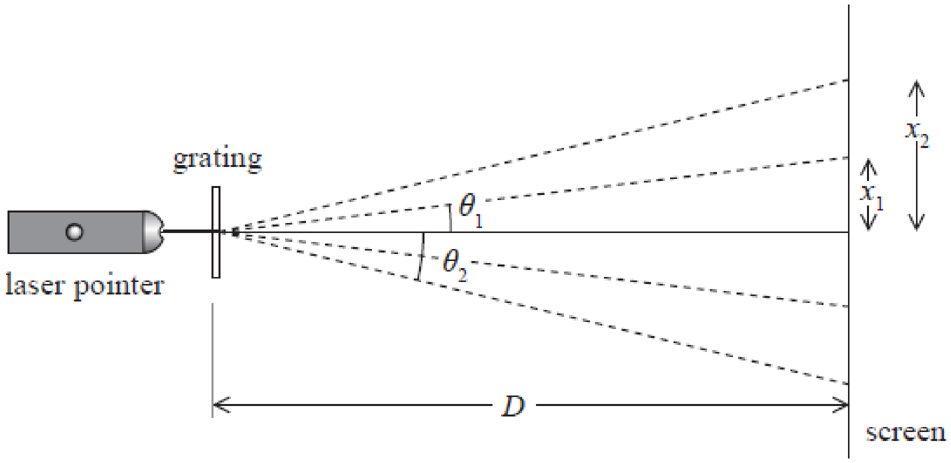
(Total for question = 10 marks)

Q22.

A student is using a diffraction grating to determine the wavelength of the light emitted by a laser pointer. The light from the laser pointer is directed so that it is normal to the plane of the grating. The diffracted light is viewed on a screen a distance *D* from the grating.



The diagram shows the first two diffracted orders where x_1 and x_2 are the distances of the maxima for these orders from the central maximum of the diffraction pattern.

(a) Before carrying out the experiment, the student carries out a risk assessment to ensure that the experimental procedure is safe.

Explain one precaution that should be taken.

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(b) The student measures the distances from the central maximum of the diffraction pattern for various diffracted orders *n*, using a metre rule.

n	x_n / cm	θ / °	sin θ
0	0	0.00	0.000
1	35.5	11.4	0.20
2	74		
3	126.5	35.9	0.586
4	211	50.4	0.771

(i) Criticise the results that are recorded.

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(ii) Complete the data for the 2nd order maximum.

D = 1.750 m

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(iii) Add your data to the axes and draw a line of best fit.

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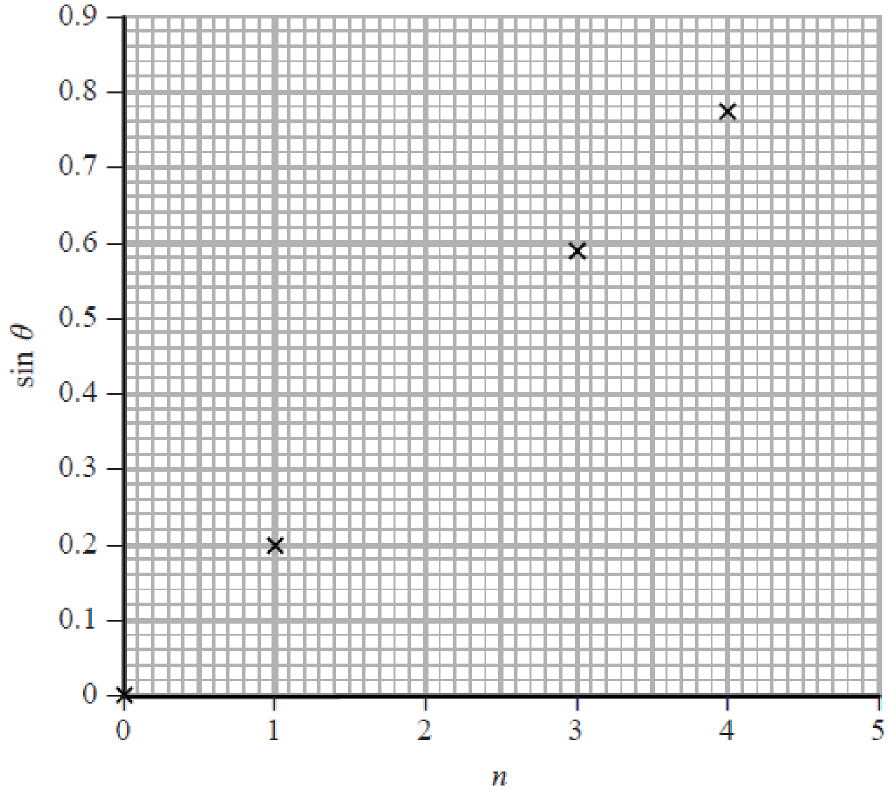

(iv) Use your graph to determine a value for the wavelength of the laser light.
The grating has 300 lines per mm

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Wavelength = ...

(c) State and justify two modifications to the experimental method which would have improved the accuracy of the value obtained for the wavelength.

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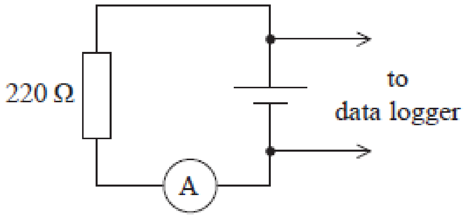
(Total for question = 15 marks)

Q23.

A student is investigating how the internal resistance of a dry cell varies over time. She sets up the circuit shown to draw current from the cell.



The student proposes to use a data logger to monitor the terminal potential difference (p.d.) of the cell over a period of time.

State why a data logger would be suitable to collect data in this investigation.

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(Total for question = 1 mark)

Q24.

The photograph shows a vase made of uranium glass. Uranium glass is radioactive.

Uranium glass usually contains a maximum of 2% uranium. Uranium glass made in the early part of the 20th century can contain up to 25% uranium.

A student carried out an investigation to determine the percentage of uranium in the glass.

The student measured the count rate by placing a Geiger Muller (GM) tube against the vase at a single position. This value was used to calculate the decay rate for the whole vase.

(i) Show that the decay constant for uranium is about $5 \times 10^{-18}\ s^{-1}$

half-life of uranium = 1.41×10^{17} s

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(ii) Calculate the percentage of uranium, by mass, in the glass.

area of GM tube window = $6.36 \times 10^{-5}\ m^2$
surface area of vase = $0.0177\ m^2$
background count rate = 525 counts in 10 minutes
count rate when GM tube next to vase = 3623 counts in 5 minutes
mass of vase = 149 g
mass of uranium atom = 238 u

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Percentage of uranium = ...

(iii) The uranium decays by emitting alpha particles.

Criticise the method used to determine the percentage of uranium in the vase.

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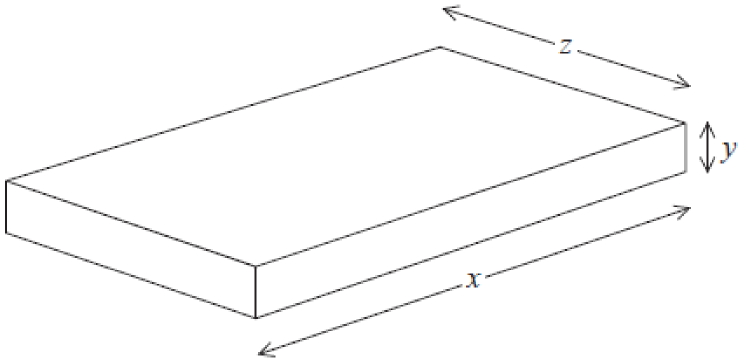
(Total for question = 10 marks)

Q25.

A student carries out measurements to determine the density of glass. The student has 20 glass microscope slides available.

The approximate dimensions of one slide are shown.



$x \approx 75\,\text{mm}$
$y \approx 1\,\text{mm}$
$z \approx 25\,\text{mm}$

(a) The density is calculated using the equation

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Describe how the student can determine an accurate value for the density of the glass.
Your answer should include the measuring instruments required.

(4)

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(b) State one precaution that the student should take to ensure the measurements are accurate.

(1)

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....

(Total for question = 5 marks)

Q26.

A physics textbook states that "when carrying out experimental measurements there will always be errors and uncertainties".

Describe what physicists mean by error and by uncertainty.

(2)

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(Total for question = 2 marks)

Q27.

Photograph 1 shows a toy known as a popper. It is a hollow hemisphere made of rubber.

Photograph 1

When the top of the popper is pushed down, it changes shape as in Photograph 2.

Photograph 2

It remains in this shape for two to three seconds. It then returns to its original shape and is launched from the surface, rising nearly a metre.

The initial speed of the popper can be determined using only a metre rule to measure the maximum height reached by the popper.

(i) Describe how the maximum height measurement can be used to determine the launch speed.

(3)

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(ii) Comment on using the maximum height measurement as a means of determining an accurate value for the launch speed.

(3)

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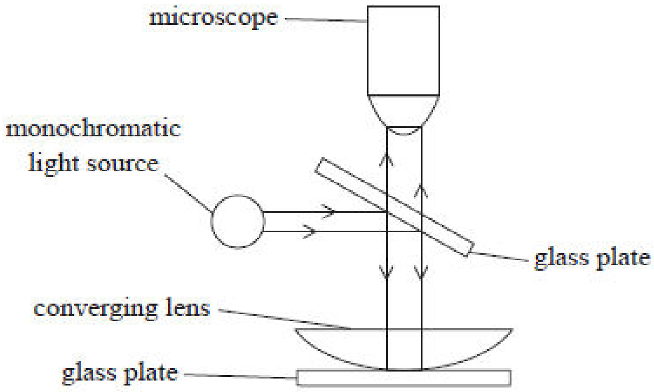
(Total for question = 6 marks)

Q28.

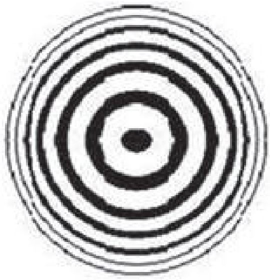
A method to determine the wavelength of light using a converging lens was first proposed by Sir Isaac Newton.

A converging lens is placed on a plane glass plate. The lens is illuminated from above with a parallel beam of monochromatic light, as shown.

Some of the light is reflected from the upper surface of the lower glass plate and some from the lower surface of the lens. Interference between these two reflected waves produces circular fringes. The pattern is viewed through a microscope.



Side view of apparatus


Pattern seen through microscope

The diameter *D* of each circular fringe, numbered *N* from the centre, is measured using the microscope. The data obtained from such an experiment is shown.

N	*D* / mm		
1	5.13		
2	7.08		
3	8.71		
4	10.23		
5	11.48		

The relationship between *N* and *D* is of the form $D = pN^q$ where *p* and *q* are constants.

Determine *p* and *q* for this data using a graphical method. Use the additional columns for your processed data.

(8)

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p = ...

q = ...

(Total for question = 8 marks)

Q29.

A spring is made from loops of thick steel wire as shown.

There are two extra loops, one on each end of the spring.

The student measured the diameter *d* of the steel wire and obtained a value of 2.52 mm.

(i) Explain which instrument he used to measure the diameter.

(2)

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....

....

(ii) Estimate the percentage uncertainty in the student's value for *d*.

(1)

....

....

% uncertainty in *d* = ...

(iii) The student used a balance to measure the mass *m* of the spring.

He obtained a value of 32.0 ± 0.5 g.

Estimate the percentage uncertainty in the mass of the spring.

(1)

....

....

% uncertainty in *m* = ...

(iv) The student calculated the density *ρ* of the steel using the equation

$$\rho = \frac{m}{V}$$

Calculate the percentage uncertainty in his value for the density of steel.

(1)

....

....

% uncertainty in value for density of steel = ...

(v) Determine whether the data collected leads to a value for the density of steel in agreement with the standard value.

density of steel = 7 800 $kg\,m^{-3}$

(4)

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(Total for question = 9 marks)

Q30.

A practical physics textbook states that "measurements may give a precise value for the quantity being determined but this may not necessarily be an accurate value".

The temperature of the air in a room is measured using a mercury-in-glass thermometer.

Describe how the value for the temperature may be precise but not accurate.

(2)

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(Total for question = 2 marks)

Mark Scheme

Q1.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • The intercept represents the temperature of the air at which the volume occupied would be zero • This is the absolute zero (of temperature) • Absolute zero is the lowest attainable temperature **Or** absolute zero is the temperature at which the atoms/molecules of the gas have zero kinetic energy	(1) (1) (1)	For MP3 accept atoms/molecules stop moving	3
(ii)	**MAX 4** **Resolution:** • It is correct that uncertainties would be reduced by using high resolution instruments • But the instruments are not high resolution • There could be a systematic error (in the measurements) **Graph:** • The points do not lie on a perfect straight line **Or** the true relationship may not linear • Temperature intercept may not be accurate **Or** there may be extrapolation errors • More points are needed **Or** a wider range is needed	(1) (1) (1) (1) (1) (1)		4

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Accuracy is (a measure of) how close a measured/calculated value is to the true value **(1)** • Precision is (a measure of) the consistency of values obtained by repeated measurements **(1)**		**2**

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • High precision means a small spread of values (1) • High accuracy means close to the true value (1) Any **TWO** from: • A is precise but not accurate (as there is a small spread but displaced from the centre of the target) (1) • B is both accurate and precise (as there is a small spread centred on the target) (1) • C is neither accurate nor precise (as there is a large spread displaced from the centre of the target) (1) • D is accurate but not precise (as there is a moderate spread centred on the target) (1)	Credit MP1/MP2 if the explanation of high accuracy/precision is made by reference to a relevant part of the diagram.	**4**

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• discards value for l_3 (1) • l_m=85.7 (cm) (1)	MP2: answer to 1 d.p. only <u>Example of calculation</u> $l_m = \frac{85.5+86.0+85.5}{3} = 85.7$ cm	2
(ii)	• Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ (1) • T=1.86 s (1)	ECF from (i) MP2: accept T = 1.9 s <u>Example of calculation</u> $T = 2\pi\sqrt{\frac{\ell}{g}}$ $= 2\pi \times \sqrt{\frac{0.857\text{ m}}{9.81\text{ m s}^{-2}}} = 1.86$ s	2

Q5.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: • Light gates can record short times accurately **(1)** **OR** with smaller uncertainty **(1)** • Because human reaction time is not involved **(1)**		2

Q6.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• V at top/start = 0V **Or** recognition "potential divider" **Or** V increases (by implication) **Or** V at bottom = 1.5V • Two sections of wire act as series resistors **Or** $R=\rho l/A$ **Or** comment about R proportional to length **Or** $\frac{V}{1.5}=\frac{R}{R_T}$ • potential difference proportional to length of wire	(1) (1) (1)	**Alternative MS** Constant Current (I) in wire (1) p.d. across section of wire $=Ir$ between A and loop (1) Increases from 0V to 1.5V linearly (1)	3

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Tangent drawn at 1.5 s • Scales p.d. to give distance • Gradient determined using a base of triangle of at least 1.0 s **Or** use of $s=\frac{(u+v)}{2}t$ and correct V read from graph • velocity = 1.0 m s^{-1} – 1.3 m s^{-1}	(1) (1) (1) (1)	Example of calculation $\text{Gradient}=\frac{1.1\text{V}-0.2\text{V}}{1.0\text{s}}=0.9\text{Vs}^{-1}$ As 1.5 V represents 2.00 m $v=0.9\text{ Vs}^{-1}\times\frac{2.00\text{m}}{1.5\text{V}}=1.2\text{ ms}^{-1}$	4

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Use of $v=u+at$ • Use of $a=g\sin\theta$ • Calculates a value for a, θ or v (using a SUVAT AND $a=g\sin\theta$) • Valid comparison of their calculated quantity and the stated quoted uncertainty.	(1) (1) (1) (1)	Example of calculation $1.5\text{ ms}^{-1}=1.2\text{ m s}^{-1}+a\times0.5\text{ s}$ $a=\frac{0.3\text{ m s}^{-1}}{0.5}=0.6\text{ m s}^{-2}$ $0.6\text{ m s}^{-2}=9.81\text{ m s}^{-2}\sin\theta$ $\theta=3.6°$	4

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Counting for 1 minute is too short a time **Or** he should count for at least 3 minutes (1) • He hasn't recorded the background count rate (1) • More than one reading taken and a mean calculated **Or** should have taken more than two readings (to calculate mean) (1)		3

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
	MAX 5 An explanation that makes reference to the following points: • The student has calculated the coun rate rather than the activity of the source (1) • The counts haven't been corrected for background (so there is systematic error in his data) (1) • The GM tube is too far away from the source (1) • α-radiation won't reach the GM-tube as it only has a short range in air (1) • Radiation spreads out from the source, so not all the emitted radiation reaches the GM-tube (1) • GM tube won't detect all the gammas which enter it (1)		5

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A **ampere**	B,C and D are not base units	**1**

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A B *is not correct because these are base units of force* C *is not correct because these are not base units* D *is not correct because these are not base units*	kg m s^{-1}	**1**

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	• so the proportion of unstable nuclei does not change significantly over time **Or** activity does not change significantly over time **(1)**		**1**

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of half resolution to calculate % uncertainty (1) • % uncertainty in V = 3 × % uncertainty in r (1) • % uncertainty in ρ = (% uncertainty in m + % uncertainty in V) (1) • Use of % uncertainty to calculate upper value of density (1) • Upper value of density 2596 (kg m^{-3}) [2616 (kg m^{-3}) if "show that" value used] (1) • Glass is in the range and Quartz isn't, so it may not be genuine (1) Allow use of half resolution in either r or m to calculate minimum V and maximum m and then calculate maximum ρ for MP1 → MP4 ECF from (a)	% uncertainty in $r = \frac{0.005\text{ cm}}{5.06\text{ cm}} \times 100\,\% = 0.10\,\%$ % uncertainty in $m = \frac{0.5\text{ g}}{175\text{ g}} \times 100\,\% = 0.29\,\%$ % uncertainty in $\rho = (3 \times 0.1\%) + 0.29\% = 0.59\%$ Range = $\pm\frac{0.6}{100} \times 2580\text{ kg m}^{-3} = \pm 15.5\text{ kg m}^{-3}$ Density range = 2565 → 2596 kg m^{-3}	6

Q13.

Question number	Acceptable answers	Additional guidance	Mark
(i)	A description that makes reference to the following points: Circuit diagram showing: • Cell, variable resistor and ammeter in series and voltmeter in parallel with cell **(1)** • Recording pairs of readings of terminal p.d. and current **(1)** • Use the variable resistor to obtain 5 other pairs of readings **(1)**	Should be between 5 and 10 other pairs	3
(ii)	A description that makes reference to the following points: • Plot a graph of terminal potential difference on the y-axis and current on the x-axis **(1)** • Intercept on the y-axis equals e.m.f. **(1)** • And gradient = -r **(1)**		3

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	MAX 3 • Voltmeter must measure alternating p.d.s (1) **Or** voltmeter would indicate zero for a.c. (1) • A.C. voltmeter would give an r.m.s. p.d. directly (1) • Voltmeter may draw current and affect the circuit it was connected to (1) **Or** oscilloscope would have little effect on the circuit it was connected to (1) • Accuracy would depend upon the calibration of the voltmeter • A (digital) voltmeter would give better resolution than measuring trace height on an oscilloscope.	Accept "voltmeter reading would change too fast to measure"	3

Q15.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(i)	An explanation that makes reference to the following points: • total resistance of strand decreases (1) • this increases the current in the strand <u>OR</u> remaining bulbs are brighter (1) • greater power / energy consumption with blown bulbs <u>OR</u> reduces the life of the remaining bulbs (1)		**(3)**

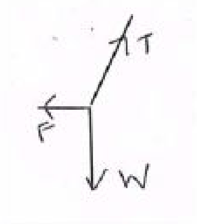
Question Number	Acceptable Answer		Additional guidance	Mark
(a)(ii)	• use of $V = IR$ and addition of resistances in series to determine current in strand with 5 blown bulbs OR use of $V = IR$ and addition of resistances in series to determine current in healthy strands OR use of resistance in parallel and series to determine total resistance	(1)	Example of calculation: Total current = sum of current in the four healthy strands + current in the unhealthy strand $I = 4\left(\frac{230\text{ V}}{50\times 8.0\ \Omega}\right) + \left(\frac{230\text{ V}}{(45\times 8.0\ \Omega)+(5\times 3.0\ \Omega)}\right)$ $I = 2.9$ A	
	• $I = 2.9$ A	(1)		
	• 2.9 A < 3 A so fuse does not blow	(1)	Allow credit for a consistent conclusion from an incorrect calculation of current	**(3)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(i)	• use a micrometer	(1)		
	• $A = \pi\left(\frac{d}{2}\right)^2$ OR $A = \pi r^2$ and $r = \frac{d}{2}$	(1)		
	• repeats readings in different planes/positions	(1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• current directly proportional to cross-sectional area		**(1)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(iii)	• calculates area = 0.13 (mm^2) • use of $y = mx + c$ • I = 2.8 A • 2.8 A < 3 A so the wire is suitable to use as a fuse wire	**(1)** **(1)** **(1)** **(1)**	Example of calculation: $A = \pi\left(\frac{0.4\text{ mm}}{2}\right)^2 = 0.13\text{ mm}^2$ $I = \frac{1.28\text{ A} \times 0.13\text{ mm}^2}{0.06\text{ mm}^2} = 2.8\text{ A}$ Wire is suitable as I < 3 A Allow credit for a consistent conclusion from an incorrect calculation of current Accept converse working to find diameter of 3 A fuse wire	**(4)**

Q16.

Question Number	Answer	Mark
(a)(i)	*W/mg* and *T* correct (1) *F/E/* electric force correct (1) Example of diagram  	2
(a)(ii)	See $T\cos\theta = W$ (1) See $T\sin\theta = F$ (1) **Or** Draws a correct triangle of forces (1) Correctly labels θ (1) (if a triangle is drawn it must be a closed polygon with correctly orientated direction of arrows)	2
(b)(i)	Records 1pair of values from graph (1) Records 2nd pair of values from graph (1) Use of $F\,r^2$ (1) Shows that $F_1r_1^2 = F_2r_2^2$ (1) (accept answers with or without the powers of ten included) Example of answer Ignoring powers of 10 $115\text{ N} \times 20^2\text{ m}^2 = 46000$ $51\text{ N} \times 30^2\text{ m}^2 = 45900$	4
(b)(ii)	Uses constant from (b) ignoring powers of ten errors **Or** uses a pair of values from graph (1) Use of $F = kQ_1\,Q_2\,/r^2$ with 1.6×10^{-19} C (1) $Q = 7.2 \times 10^{-9}$ C (1) Example of answer $100\,Q^2 = 46000 \times 10^{-9}\text{ N m}^2 / 8.99 \times 10^9\text{ N m}^2\text{ C}^{-2}$ $Q^2 = 5.12 \times 10^{-17}\text{ C}^2$ $Q = 7.2 \times 10^{-9}$ C	3
	Total for question	**11**

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Data not recorded to the same sf/dp (1) • Positions of mass holder not recorded (1)		2

Q18.

Question number	Acceptable answers	Additional guidance	Mark
(a)	Any three from: • Inconsistent precision for extension **(1)** • Lack of precision on mass, should be shown to 3 DP **(1)** • No evidence of repeat readings **(1) OR** there should be more readings to compensate for repeat readings being inappropriate **(1)** • Inconsistent intervals between readings **(1)**	Uncertainty suggested by 1 sf is far greater than that expected in practice	**3**

Question number	Acceptable answers	Additional guidance	Mark
(b)	A description that makes reference to two of the following points: • use of ficidual mark **(1)** • eye close to liquorice lace to avoid parallax errors **(1)** • Fixed metre rule close to lace **(1)** • Use of set square to ensure rule vertical **(1)**		**2**

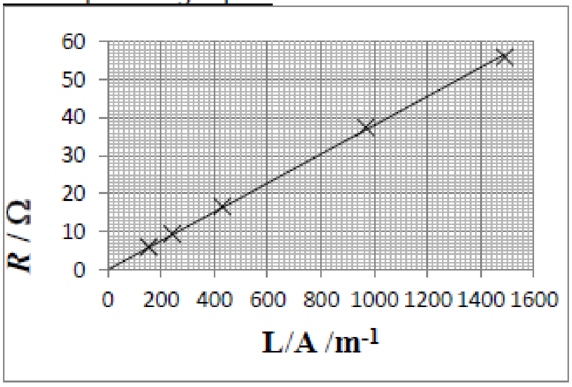
Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• all *I* values should be recorded to the same number of decimal places **(1)** **Or** all *I* values should be recorded to the same resolution	Do not accept same number of significant figures	**1**

Q20.

Question Number	Acceptable Answers	Additional guidance	Mark
	Maximum 3 marks • There cannot be a p.d. across his body (1) • Electric field strength inside cage is zero (1) • As no potential gradient (1) • Current/electrons/charge would conduct through suit **Or** the current would not pass through body (1)	Accept reference to Faraday cage for MP2	3max

Q21.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• axes and labels (1) • suitable scale (1) • all points plotted correctly (1) • line of best fit drawn (1)	Example of graph:  	**(4)**
(a)(ii)	• attempt to measure gradient using large triangle (1) • ρ = (0.035 – 0.041) Ωm to 2 sf (1)		**(2)**

Question Number	Acceptable Answer		Additional Guidance	Mark
(b)	Two problems identified with solutions from: • taking only one reading could produce an unreliable result • so take repeat readings of length and diameter • metre ruler cannot be used to measure the diameter with sufficient precision <u>OR</u> metre rule can only measure diameter at ends of cylinder • so use Vernier callipers instead • comment about non-uniform shape • so take repeat readings at different positions/ orientations	(1) (1) (1) (1) (1) (1)	Accept micrometer giving precision of 0.01 mm for diameter	**(4)**

Q22.

Question Number	Acceptable Answer		Additional Guidance	Mark
(a)	• laser light should not be aimed directly into the eye • as concentrated beam can cause damage to the retina	(1) (1)		**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	<u>EITHER</u> • all x values should be recorded to the same number of decimal places, so x_2 and x_4 are incorrectly recorded (1) <u>OR</u> • all processed data should be recorded to the same number of significant figures, so sin θ for x_1 is incorrectly recorded	Do not award repeat readings, not appropriate in this experiment	**(1)**
(b)(ii)	• use of $\tan\theta = \frac{x}{D}$ [θ = 22.9°] (1) • sinθ = 0.390 (1)	<u>Example of calculation:</u> $\tan\theta = \frac{0.741}{1.75} = 0.423$ $\therefore \theta = 22.9°$ $\therefore \sin\theta = 0.3899$	**(2)**
(b)(iii)	point plotted correctly <u>and</u> best straight line drawn through points (1)		**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iv)	• $\sin\theta = \frac{n\lambda}{d}$, so gradient = $\frac{\lambda}{d}$ (1) • gradient = 0.194 (1) • use of d = 1/number of lines per mm (1) • d = 3.33 × 10^{-6} (m) (1) • λ = 6.5 × 10^{-7} m (1)	<u>Example of calculation:</u> $d = \frac{1}{3\times10^5\,\mathrm{m}^{-1}} = 3.33\times10^{-6}\,\mathrm{m}$ $\lambda = 3.33\times10^{-6}\,\mathrm{m}\times0.194$ $= 6.47\times10^{-7}\,\mathrm{m}$	**(5)**

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)	An answer that makes reference to two of the following pairs:		Do not award repeat readings, not appropriate in this experiment	
	• use a Vernier scale to record *x*	(1)		
	• so that data to the nearest 0.1 cm could be obtained to reduce the percentage uncertainty	(1)		
	• use a larger grating to screen distance	(1)		
	• so that all *x* values would be greater to reduce the percentage uncertainty	(1)		
	• measure from nth order on one side to nth order on the other side	(1)		
	• so that the distance measured is larger hence reducing the percentage uncertainty in x	(1)		
	• use a grating with more lines per mm	(1)		
	• so that values of *x* will be greater to reduce the percentage uncertainty	(1)		**(4)**

Q23.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• The data has to be collected over a long period of time	(1)		1

Q24.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $\ln 2 = \lambda t_{1/2}$ • $\lambda = 4.92 \times 10^{-18}$ (s^{-1})	(1) (1)	Example of calculation $\lambda = \ln 2 / 1.41 \times 10^{17}$ s $= 4.92 \times 10^{-18}$ s^{-1}	2
(ii)	• Calculate rate = counts / time • Subtract background radiation • Use of $A = -\lambda N$ • Calculates $N \times$ atomic mass • Calculates percentage by mass • Answer = 0.17% (ecf for λ from (a)(i))	(1) (1) (1) (1) (1) (1)	Example of calculation background rate = 525 / (10 × 60) s = 0.875 s^{-1} vase count rate = 3623 / (5 × 60) s = 12.077 s^{-1} corrected rate = 11.2 s^{-1} for whole vase = 11.2 s^{-1} × 0.0177 m^2 / 6.36 × 10^{-5} m^2 = 3117 s^{-1} $N = 3117 / 4.91 \times 10^{-18}$ $s^{-1} = 6.348 \times 10^{20}$ Mass = $6.348 \times 10^{20} \times 238 \times 1.66 \times 10^{-27}$ kg = 2.51×10^{-4} kg Percentage = 2.51×10^{-4} kg × 100 / 0.149 = 0.17%	6
(iii)	**Max 2 from:** • Alpha particles could have been absorbed by the glass • Alpha particles will be emitted in all directions, not just towards the detector • Some alpha particles could have been detected from other parts of the vase • The count could include radiation from decay products • Some alpha particles could be absorbed by the GM tube window	(1) (1) (1) (1) (1)		2

Q25.

Question Number	Acceptable Answer		Additional Guidance	Mark
(a)	• Use a micrometer to measure y and/or z • Use Vernier/digital calipers to measure x and/or	(1) (1)	**(Part (a) and (b) to be marked holistically** **MP1** accept <u>digital</u> calipers for a single slide Accept Vernier calipers if it is clear that the thickness of a number of slides is being measured. To award both MP1 & 2, *x*, *y* & *z* must all be referred to.	
	• Mass of slide(s) measured using (top pan) balance/scales • Repeat and determine mean for at least one measurement	(1) (1)	MP4 can be awarded for a reference to averaging any of the measurements.	**4**

Question Number	Acceptable Answer		Additional Guidance	Mark
(b)	Check zero error on micrometer/callipers/balance **Or** measure *x/y/z* of slide in different places **Or** measure thickness/mass of multiple slides	(1)	Accept 'tare' for zero error check on balance	**1**

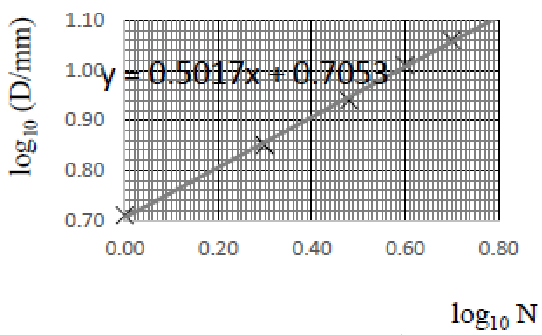
Q26.

Question Number			Additional Guidance	Mark
	• An error is the difference between the (measured) result and the true value • An uncertainty is the interval/range in which the (true) value can be considered to lie	(1) (1)	Accept calculated/their for measured result/value Accept theoretical/actual value for true value	**2**

Q27.

Question number	Acceptable answers	Additional guidance	Mark
	A description that makes reference to the following points: • Refer to $v^2 = u^2 + 2as$ **(1)** • Where s is height reached, v is zero, $a = -g$ **(1)** • So $u = \sqrt{2gs}$ **(1)**	Allow argument $\frac{1}{2} mv^2 = mgh$ to get the same results.	**3**
(ii)	• Air resistance will act on the popper… **(1)** • …As a decelerating force **(1)** **OR**… dissipating energy **(1)** • So the initial speed will be lower than in the absence of air resistance, so the suggestion is not correct **(1)**		**3**

Q28.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td></td>
<td>
• Log values calculated in table (1)
• Axes correctly labelled (1)
• Suitable scales (1)
• All points plotted correctly (1)
• Line of best fit drawn (1)
• Determine gradient using large triangle (1)
• Intercept read from graph (1)
• $p = 5.0 - 5.2$ (mm) (1)
Or $p = (5.0 - 5.2) \times 10^{-3}$ (m)
$q = 0.5$
</td>
<td>
Accept $\log_{10}$ or ln ($\log_e$)
<table>
<tr><th>$\log_{10}$ (D/mm)</th><th>$\log_{10}$ N</th><th>ln (D/mm)</th><th>ln N</th></tr>
<tr><td>0.710</td><td>0.000</td><td>1.64</td><td>0.000</td></tr>
<tr><td>0.850</td><td>0.301</td><td>1.96</td><td>0.693</td></tr>
<tr><td>0.940</td><td>0.477</td><td>2.16</td><td>1.10</td></tr>
<tr><td>1.01</td><td>0.602</td><td>2.33</td><td>1.39</td></tr>
<tr><td>1.06</td><td>0.699</td><td>2.44</td><td>1.61</td></tr>
</table>


</td>
<td>8</td>
</tr>
</table>

Q29.

Question Number	Acceptable Answer	Additional Guidance Whole question to be clipped together to allow full ECF	Mark
(i)	• Micrometer (screw gauge) **Or** <u>digital</u> calipers (1) • Because the measured value indicates a resolution of 0.01 mm (1)		2
(ii)	• % uncertainty = 0.2 % (1)	<u>Example of calculation:</u> $\% \text{ uncertainty} = \frac{0.005 \text{ mm}}{2.52 \text{ mm}} \times 100\,\% = 0.20\,\%$	1
(iii)	• % uncertainty = 1.6 % (1)	<u>Example of calculation:</u> $\% \text{ uncertainty} = \frac{0.5 \text{ g}}{32.0 \text{ g}} \times 100\,\% = 1.56\,\%$	1
(iv)	• % uncertainty = 2.7 % [1 or 2 sf] (1) **Allow ECF from (a)(ii), (bii) and (b)(iii)**	<u>Example of calculation:</u> % uncertainty = 0.7 % + 1.6 % + (2 × 0.2 %) = 2.7 %	1
(v)	• Use of $V = L \times \frac{\pi d^2}{4}$ (1) • Use of $\rho = \frac{m}{V}$ (1) • Uncertainty in density = 200 kg m^{-3} (1) • So maximum density is 7600 kg m^{-3} which is lower than the standard value **Or** comment consistent with their calculated value (1) **Allow ECF from (a)(iii) and (b)(iv)**	<u>Example of calculation:</u> $V = 0.866\ m \times \frac{\pi(2.52\times10^{-3})^2}{4} = 4.32\times 10^{-6}\ m^3$ $\rho = \frac{3.20\times10^{-2}\ kg}{4.32\times10^{-6} m^3} = 7400\ kg\ m^{-3}$ Uncertainty in $\rho = \pm(7400\ kg\ m^{-3} \times \frac{2.7}{100})$ $= 200\ kg\ m^{-3}$	4

Q30.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Repeat readings can give very similar measurements so value precise (1) • Value is not accurate because of a systematic error (1)	In MP2 accept zero error or calibration or parallax error for systematic error	2