Working as a Physicist

Q1.

Which of the following is an equivalent unit to the newton?

☐ **A** kg m s^{-1}

☐ **B** kg m s^{-2}

☐ **C** kg m^{-1} s^{-2}

☐ **D** kg m^2 s^{-2}

(Total for question = 1 mark)

Q2.

The newton can be written in base units as

☐ **A** kg m

☐ **B** kg m s^{-1}

☐ **C** kg m s^{-2}

☐ **D** kg m^2 s^{-2}

(Total for question = 1 mark)

Q3.

Which of the following gives the S.I. base units equivalent to the volt?

☐ **A** J C^{-1}
☐ **B** J A^{-1} s^{-1}
☐ **C** kg m^2 s^{-2} C^{-1}
☐ **D** kg m^2 s^{-3} A^{-1}

(Total for question = 1 mark)

Q4.

All quantities may be expressed in terms of SI base units.

Select the row of the table that states the SI base units for the given quantity.

		Quantity	SI base unit
☒	**A**	charge	C
☒	**B**	charge	A s^{-1}
☒	**C**	power	J s^{-1}
☒	**D**	power	kg m^2 s^{-3}

(Total for question = 1 mark)

Q5.

Which of the following is the SI base unit for resistance?

☒ **A** Ω

☒ **B** V A^{-1}

☒ **C** kg m^2 s^{-3} A^{-2}

☒ **D** kg m^2 s^{-1} C^{-2}

(Total for question = 1 mark)

Q6.

Select the row of the table that identifies an SI base unit and a derived unit.

		Base unit	Derived unit
☒	**A**	coulomb	ampere
☒	**B**	joule	volt
☒	**C**	newton	kilogram
☒	**D**	second	watt

(Total for question = 1 mark)

Q7.

Which of the following is a S.I. base quantity?

- ☐ **A** energy
- ☐ **B** length
- ☐ **C** speed
- ☐ **D** velocity

(Total for question = 1 mark)

Q8.

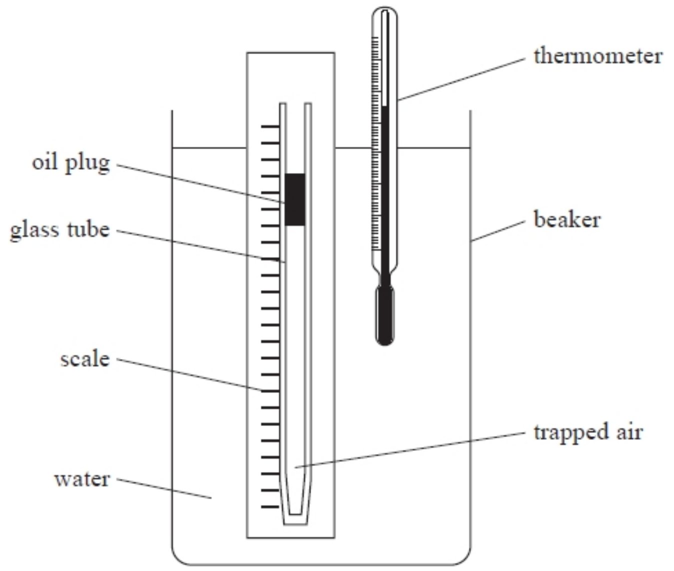
Which of the following lenses would produce a real image of an object placed 15 cm away from the lens?

- ☐ **A** converging, focal length = 10 cm
- ☐ **B** converging, focal length = 20 cm
- ☐ **C** diverging, focal length = 10 cm
- ☐ **D** diverging, focal length = 20 cm

(Total for question = 1 mark)

Q9.

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



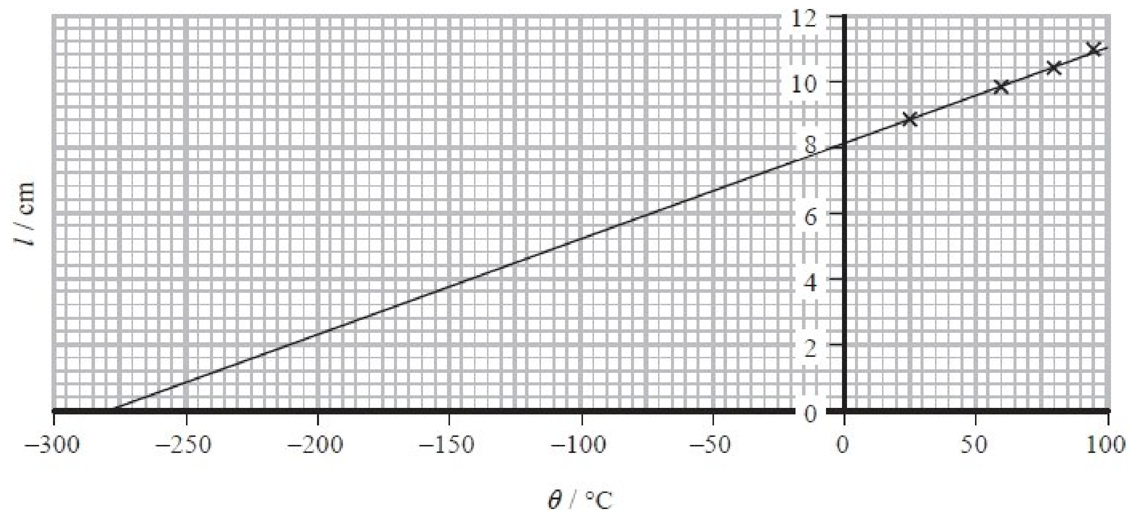
A glass tube was sealed at one end. A plug of oil trapped a length *l* of air in the tube. The water in the beaker was heated to a temperature *θ*. The corresponding value of *l* was measured. This was repeated for a range of temperatures.

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.

(3)

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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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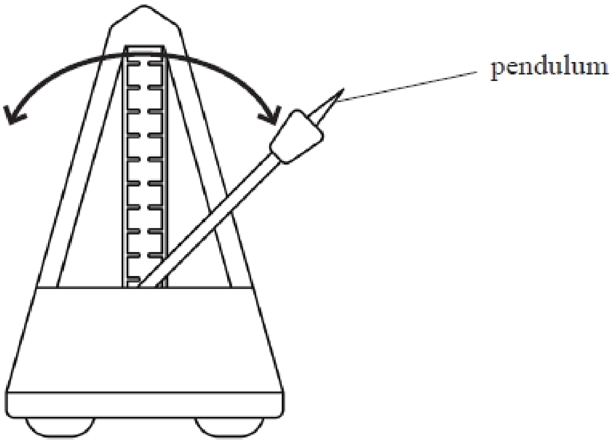
(Total for question = 7 marks)

Q10.

The diagram shows a metronome, which includes an inverted pendulum, used by musicians to set a tempo. The pendulum oscillates with simple harmonic motion and makes a loud click at regular intervals.



(Source: Getty Images)

A faulty metronome stopped making a clicking noise. A student tried to check the accuracy of the period *T* of the metronome, using a stopwatch. The student timed the pendulum as it moved from one extreme of the oscillation to the other.

Explain how the procedure used by the student to determine *T* could have been improved.

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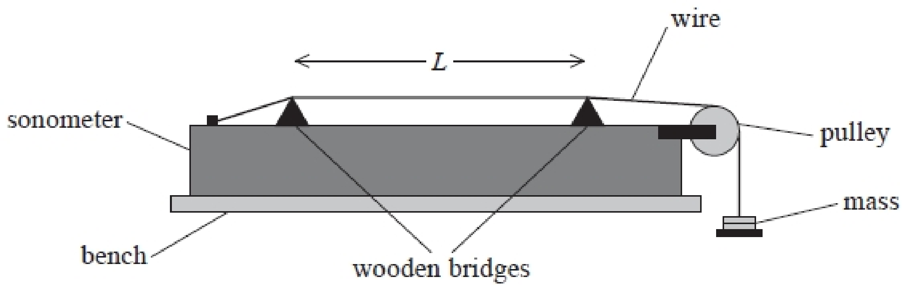
(Total for question = 5 marks)

Q11.

A student used a sonometer to investigate the properties of a stretched wire. The sonometer is a long hollow wooden box.

A steel wire is attached to one end of the box and rests on two wooden bridges. The wire is placed under tension T by hanging a mass from the end of the wire, as shown.



The student placed the base of a vibrating tuning fork in contact with the wire, at one of the bridges. This set the wire into oscillation. He adjusted the position of the other bridge until a single-loop standing wave was produced on the wire between the bridges.

The student repeated this for a series of tuning forks with different frequencies f. For each fork he measured the distance L between the bridges.

The steel wire, of mass per unit length μ, was placed under tension T by hanging a mass of 2.10 kg from the end of the wire.

(i) State one safety precaution that should be taken when carrying out the investigation.

(1)

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(ii) The student plotted a graph of L^2 against $1/f^2$.

Show that the gradient of this graph is equal to $\dfrac{T}{4\mu}$

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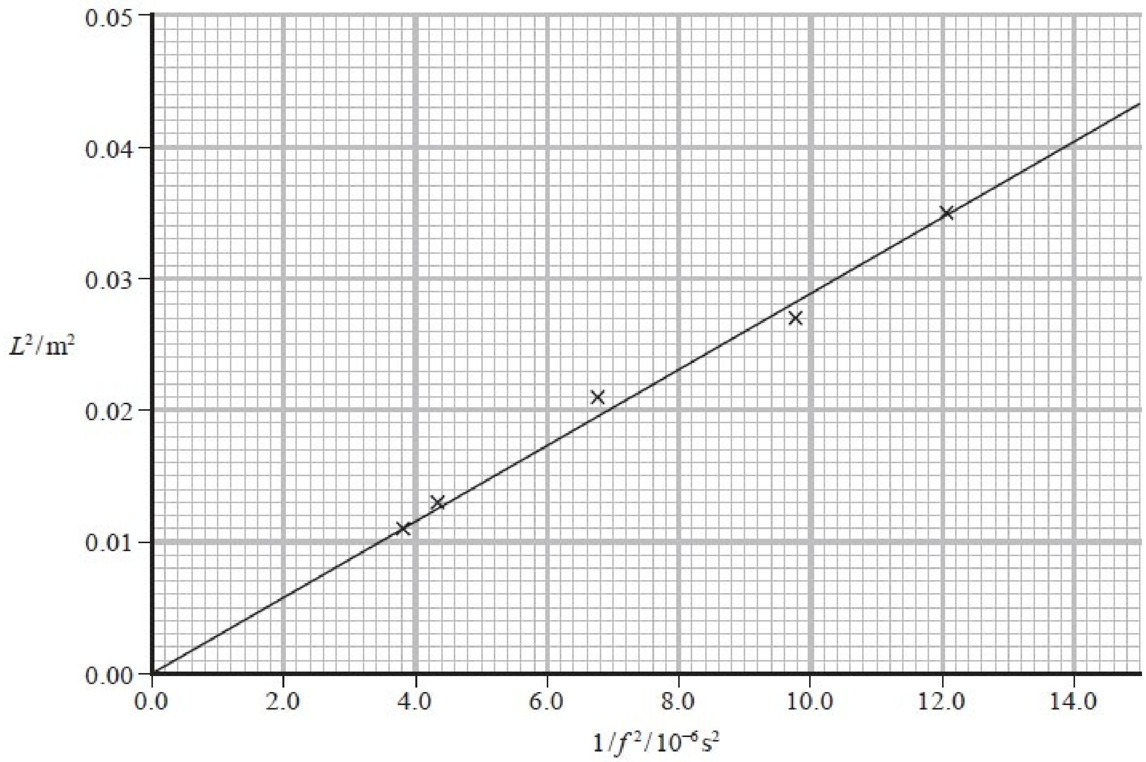
(iii) The student's graph is shown below.



The value of μ for different standard wire gauge (SWG) steel wire is shown in the table.

SWG	$\mu / g\,m^{-1}$
22	3.15
24	1.95
26	1.31

Deduce which wire the student used in the investigation.

(4)

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(Total for question = 8 marks)

Q12.

The student then found a value of μ for a brass wire, using a different method.

(i) He measured the diameter d of the wire using a micrometer.

Explain one technique the student should use when measuring d.

(2)

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(ii) The student obtained the following data.

d / mm			
0.55	0.59	0.57	0.58

The stated value of μ for the brass wire used by the student was 2.14×10^{-3} kg m^{-1}.

Deduce whether the student's data supports this value for μ.

density of brass = 8700 kg m^{-3} ± 200 kg m^{-3}

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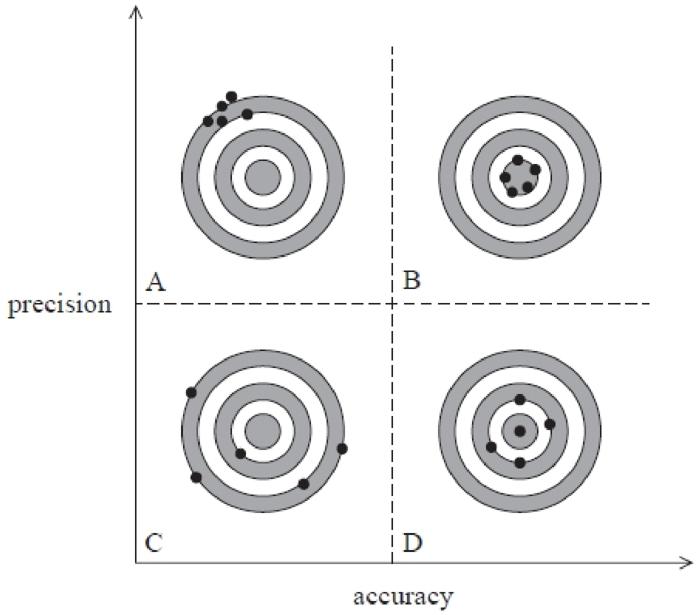
(Total for question = 8 marks)

Q13.

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)

Q14.

The length of a tooth from a dinosaur is approximately 10 cm.

Scientist A measures this length with a metre rule, and scientist B measures this length with callipers.

Scientist B claims that his measurement will produce a more accurate value for the length of the tooth.

Comment on the claim made by scientist B.

(3)

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(Total for question = 3 marks)

Q15.

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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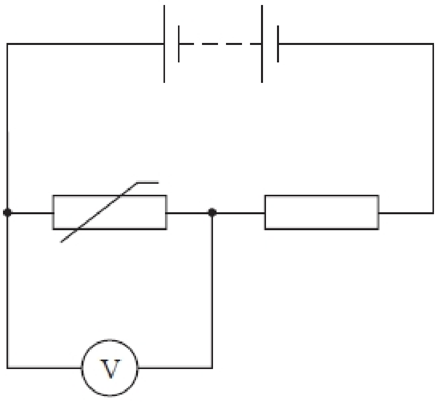
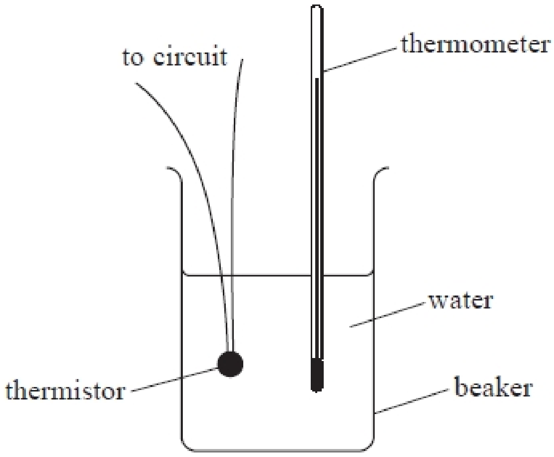
(Total for question = 2 marks)

Q16.

A student carried out an experiment to calibrate a thermistor. She connected the thermistor in series with a resistor and a power supply as shown. Then she placed the thermistor in a beaker of hot water and used a thermometer to record the temperature θ of the water.





The student recorded θ and corresponding values of the reading V on the voltmeter as the water cooled.

Over a limited temperature range V varies with θ according to the expression

$$V = V_0 e^{-b\theta}$$

where b and V_0 are constants.

(i) Explain why a graph of ln V against θ would give a straight line.

(2)

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(ii) The student's data is shown in the table below.

θ / °C	V / V	
89.0	1.9	
74.0	2.9	
53.5	4.9	
32.5	9.1	
18.5	12.6	
3.5	18.7	

Plot a graph of ln V against θ on the grid opposite. Use the column provided to show any processed data.

(5)

(iii) Determine values for b and V_0.

(4)

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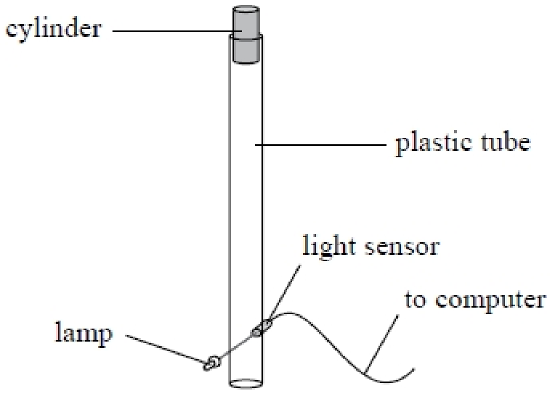
b = ...

V_0 = ...

(Total for question = 11 marks)

Q17.

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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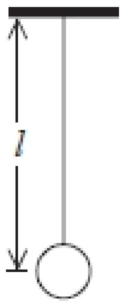
(Total for question = 2 marks)

Q18.

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.

(2)

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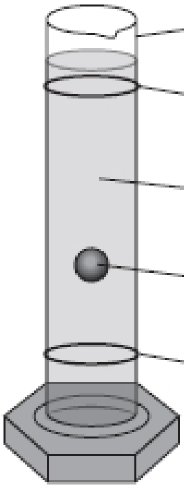
Time period of oscillations = ...

(Total for question = 4 marks)

Q19.

A student carried out an experiment to determine the viscosity of some honey. He filled a tall glass cylinder with honey as shown, and timed a ball bearing as it fell through the honey.



The student placed rubber bands near the top and bottom of the cylinder. He started a stopwatch when the ball bearing passed the first band and stopped the stopwatch when the ball bearing passed the second band. He repeated this several times to determine a mean time.

The time *t* for the sphere to fall through a distance of 25.0 cm is shown in the table.

t / s			
6.40	6.35	6.36	6.38

(i) Show that the mean velocity v of the ball bearing is about 0.04 m s^{-1}.

(3)

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(ii) The student had three different types of honey available.

Viscosity η is given by the following expression

$$\eta = \frac{2r^2 g\left(\rho_B - \rho_H\right)}{9v}$$

radius r of ball bearing = 5.50×10^{-3} m

density of ball bearing ρ_B = 7750 kg m^{-3}

density of honey ρ_H = 1360 kg m^{-3}

Viscosity (at 20 °C) / Pa s		
Honey A	Honey B	Honey C
10.6	12.5	13.6

Deduce which honey the student used.

(2)

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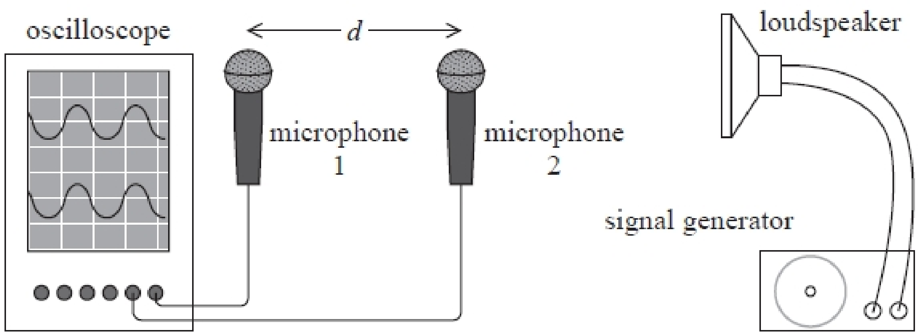
(Total for question = 5 marks)

Q20.

In an experiment to determine the speed of sound in air a student connected two microphones to an oscilloscope, as shown.



The microphones detect sound from the loudspeaker, converting it to an electrical signal. The signal is displayed on the oscilloscope screen.

Both microphones were initially positioned the same distance from the loudspeaker. The two signals were in phase on the oscilloscope screen. The student slowly moved microphone 2 towards the loudspeaker, until the two signals on the oscilloscope were in phase again. He then measured the distance *d* between the microphones to determine the wavelength λ of the sound waves.

d = 20.5cm

Comment on the student's experimental technique to determine *λ*.

(2)

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(Total for question = 2 marks)

Q21.

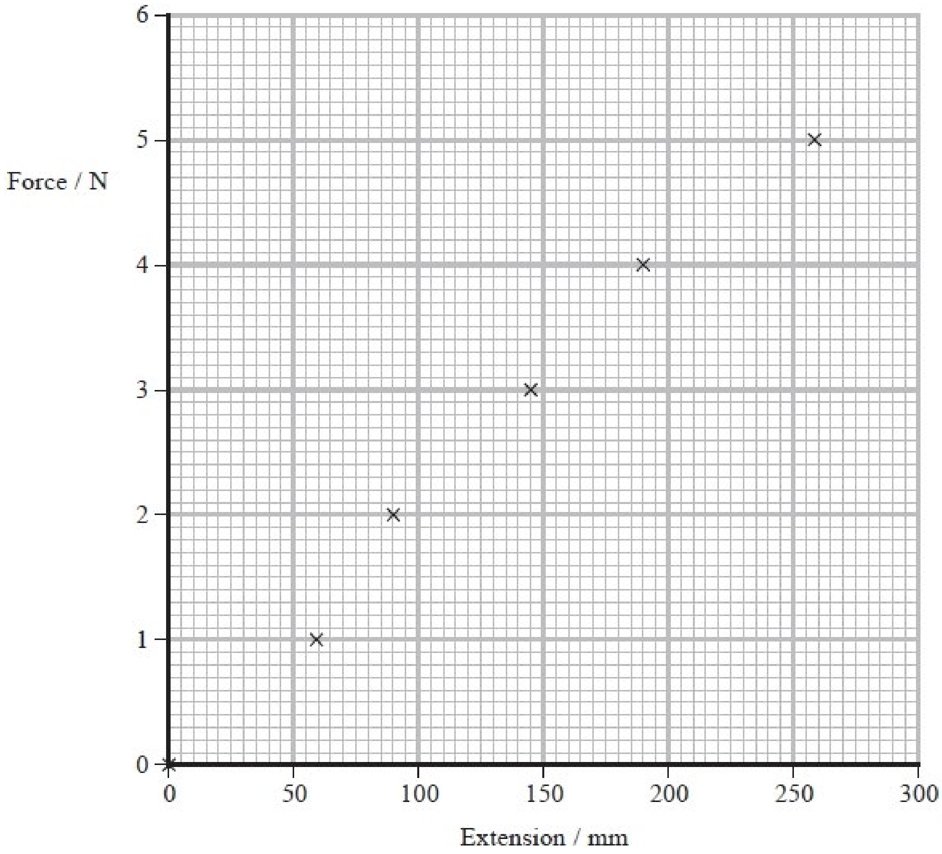
A manufacturer gives the following information about a spring.

1. Follows Hooke's law up to loads of 5 N
2. Maximum extension without permanent deformation 0.4 m
3. Stiffness 21 $N m^{-1}$ ±5%
4. Stores up to 1.6 J

A student carried out an investigation on the spring to test this information.

She applied a range of forces from 0 N to 5 N to the spring. She measured the length of the spring and recorded the extension for each force.

She plotted a graph of force against extension.



Discuss the extent to which the student's results are consistent with the information given by the manufacturer.

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(Total for question = 6 marks)

Q22.

Two students are carrying out an investigation to determine a value for the speed of sound in air.

They stand 80 m from a building. One student hits two pieces of wood together to make a loud sound and a short time later an echo is heard. The other student uses a stopwatch to measure the time interval *t* between the two pieces of wood being hit and the echo being heard. The procedure is repeated. The students also measure the air temperature.

(a) Explain how a sound wave travels through air.

(2)

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(b) The students repeat the investigation on a different day. The results are shown in the table.

	temperature / °C	t_1 / s	t_2 / s	t_3 / s	mean t / s
Day 1	12	0.51	0.43	–	0.47
Day 2	18	0.44	0.69	0.48	0.46

(i) Deduce why the students thought it necessary to make a third measurement on day 2.
(1)

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(ii) Calculate the percentage uncertainty in the mean value of time on day 1.
(2)

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Percentage uncertainty = ...

(iii) Calculate the difference in the value for the speed of sound between day 1 and day 2 obtained from these results.
(2)

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Difference in speed = ...

(iv) The students state that the difference in the speed of sound between day 1 and day 2 is due to the change in air temperature.

Explain whether the results obtained are sufficient for this statement to be made.
(2)

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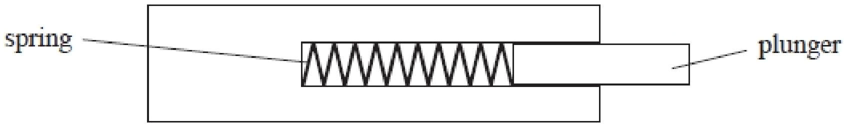
(Total for question = 9 marks)

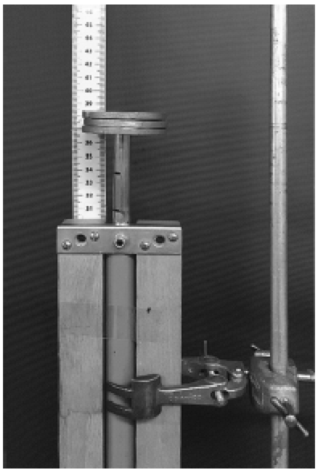
Q23.

A school dynamics trolley has a plunger attached to a spring. When the plunger is pushed in, the spring is compressed. When the plunger is released, it is pushed back out by the spring.



(a) A student investigated the spring to determine whether it obeys Hooke's law in compression.

The trolley was placed vertically in front of a scale and weights were added in turn to the top of the plunger, as shown. The position of the end of the plunger was recorded each time.



The recorded results are shown in the table.

Weight / N	Position of plunger / cm	
0.00	37.3	
2.00	37.0	
4.00	36.6	
6.00	36.2	
8.00	35.9	
10.00	35.5	

(i) Use the results to plot a graph of weight against compression. You may use the additional column for your processed data.

(5)

(ii) The student concluded that the spring obeys Hooke's law with a spring constant of about 600 N m^{-1}.

Determine whether the student's conclusion is justified.

(4)

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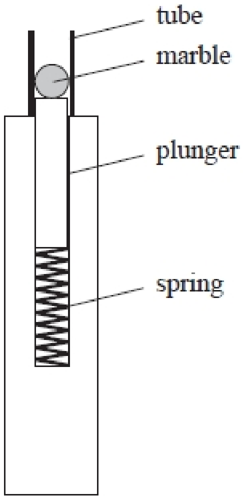
(b) Another trolley was adapted by placing a tube around the plunger so that it could be used to launch marbles. A marble was placed in the tube while the plunger was depressed. When the plunger was released it launched the marble.



Determine the maximum possible launch velocity of the marble when the spring is compressed by 5.4 cm.
spring constant = 610 N m^{-1}
mass of marble = 4.1 g
mass of plunger = 35.4 g

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Maximum launch velocity = ...

(c) The launch velocity was measured using a light gate and data logger. This produced a smaller value for the launch velocity than that calculated in (b).

Give a reason why this method produced a smaller value for the launch velocity.

(1)

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(Total for question = 14 marks)

Q24.

Which of the following is a correct statement?

☐ **A** charge is a base quantity

☐ **B** velocity is a base quantity

☐ **C** mass is a derived quantity

☐ **D** resistance is a derived quantity

(Total for question = 1 mark)

Q25.

Which of the following best describes the newton as used in physical measurements?

☐ **A** base quantity

☐ **B** base unit

☐ **C** derived quantity

☐ **D** derived unit

(Total for question = 1 mark)

Q26.

Which of the following is a base SI unit?

☐ **A** ampere
☐ **B** coulomb
☐ **C** joule
☐ **D** newton

(Total for question = 1 mark)

Q27.

Which of the following is the unit for tension expressed in SI base units?

(1)

- ☐ **A** N
- ☐ **B** N s
- ☐ **C** kg m s^{-1}
- ☐ **D** kg m s^{-2}

(Total for question = 1 mark)

Q28.

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)

Q29.

Read the passage and answer the question below.

© Reuters

The Solar Impulse 2 is a solar-powered plane that completed a round the world trip in 2016 without using fossil fuels.

The wings are covered in thin solar panels, keeping the total mass of the plane and pilot at 1600 kg. The need to reduce the weight limits the efficiency of the solar panels to 23%. However, in daylight, these panels generate enough energy to run the four 7.5 kW electric motors that keep the plane airborne and to fully charge the batteries that power the plane during the night. The batteries take about 6 hours to fully charge.

In daylight the plane flies at a height of 8500 m to harness the most sunlight, and at night descends to 1500 m. This descent makes use of the gravitational potential energy gained during the day to help the plane get through the night.
(Source: www.solarimpulse.com)

Comment on how projects such as the Solar Impulse 2 might be of benefit to society at large.

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(Total for question = 1 mark)

Q30.

In an investigation to determine the Young modulus of a material in the form of a wire, a tensile force of 14 N was applied to the wire. The length of the wire was 2.0 m. The diameter of the wire was 2.5 mm. The length of the wire increased by 0.20%.

Explain why the wire chosen should be as long as possible.

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(Total for question = 2 marks)

Q31.

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)

Q32.

The resistivity of a metal is an important property of wire used in an electric circuit.

A student carried out an experiment to determine the resistivity of a type of wire.
He used a micrometer to measure the diameter *d* of the wire.

(Source: © Viktor Chursin/Shutterstock)

He recorded the following values.

d_1 / mm	d_2 / mm	d_3 / mm	d_4 / mm
1.40	1.44	1.42	1.41

(i) Calculate the percentage uncertainty in the mean diameter of the wire.

(3)

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% uncertainty in mean diameter of wire = ...

(ii) The student used an ohmmeter to measure the resistance *R* of a 1.65 m length of the wire.

He looked up the resistivity values of some materials.

Material	Titanium	Constantan	Stainless Steel
Resistivity / $10^{-7}\,\Omega\,m$	4.2	4.7	6.9

Identify the material of the wire.
$R = 0.72\ \Omega$

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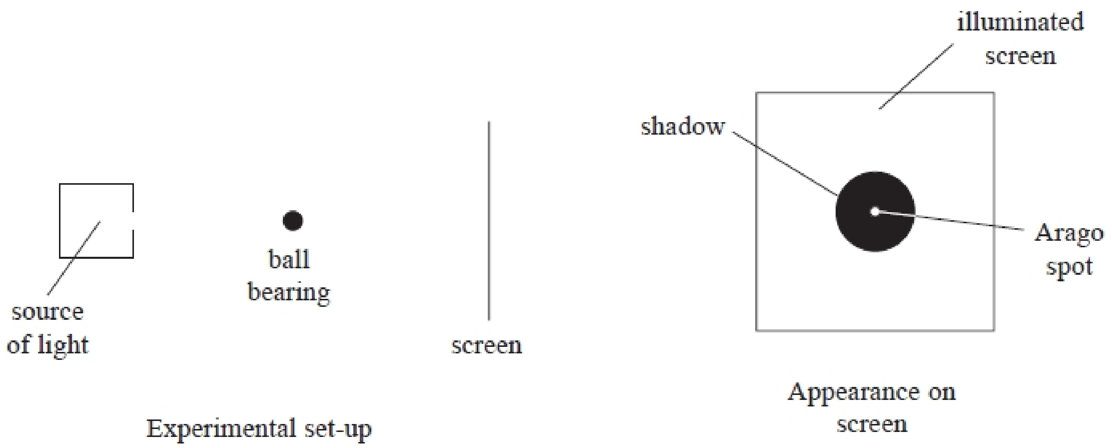
(Total for question = 6 marks)

Q33.

The diagram shows a coherent beam of light incident on a metal ball bearing.



The ball bearing shown in the experimental set-up has a diameter of about 1 cm.

Describe how the diameter could be measured accurately.

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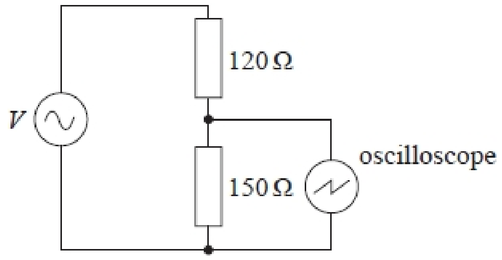
(Total for question = 2 marks)

Q34.

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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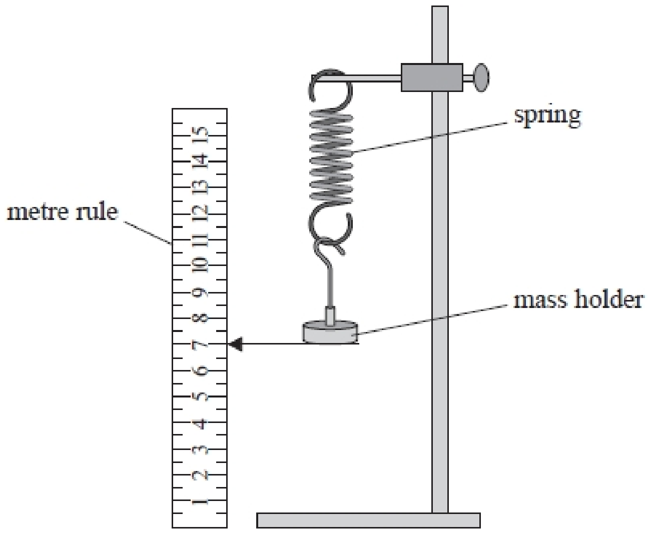
(Total for question = 3 marks)

Q35.

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.

(2)

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(Total for question = 2 marks)

Q36.

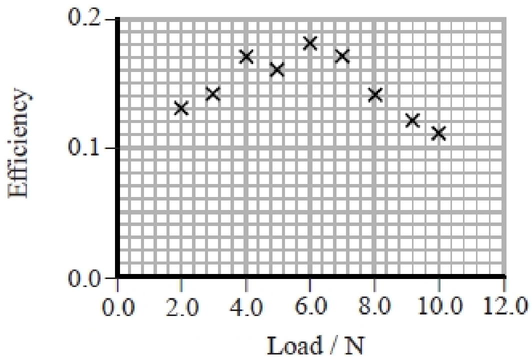
A student investigates how the efficiency of an electric motor being used to raise a load varies with the weight of the load.

The time taken for the motor to lift a load from the floor to the maximum height was measured using a stopwatch. The load was varied by adding weights, each marked '1.00 N'.

The spreadsheet shows the student's results (columns A to E) and calculation (column F).

	A	B	C	D	E	F
1	load /N	current / A	potential difference / V	time / s	change in height / m	efficiency
2	2.00	1.8	4.6	1.52	0.825	0.13
3	3.00	1.9	4.4	2.05	0.825	0.14
4	4.00	2.1	4.3	2.19	0.825	0.17
5	5.00	2.3	5.1	2.26	0.825	0.16
6	6.00	2.5	4.5	2.48	0.825	0.18
7	7.00	3.1	5.2	2.17	0.825	0.17
8	8.00	3.7	4.8	2.68	0.825	0.14
9	9.00	3.9	4.8	3.36	0.825	0.12
10	10.00	4.2	4.7	3.72	0.825	0.11

The student uses the spreadsheet to plot a graph.



The student concludes that 'the efficiency of the motor increases with the weight of the load up to a maximum when the load is 6.00 N'.

Critcise the student's investigation and conclusion.

(5)

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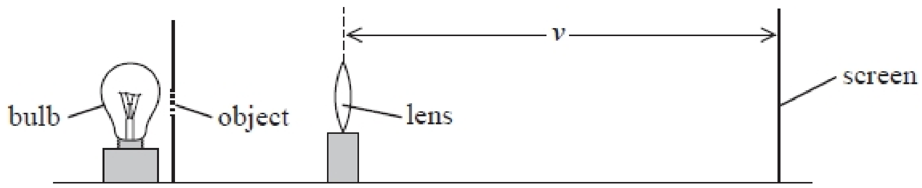
(Total for question = 5 marks)

Q37.

A student carried out an experiment to determine the focal length of a converging lens. The student used a bulb to illuminate an object as shown. The converging lens produced an image of the object on a screen. The student adjusted the position of the screen until the image was in focus.

He repeated the procedure for different distances between the object and the lens. The distance *v* from the lens to the screen was measured for each lens position.



The student measured the height h_o of the object and the height h_i of the corresponding image on the screen for each lens position. The magnification *m* was calculated.

To determine the focal length *f* of the lens the student used the equation

$$m = \frac{v}{f} - 1$$

Explain why a graph of *m* on the y-axis and *v* on the x-axis should be a straight line.

(2)

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(Total for question = 2 marks)

Q38.

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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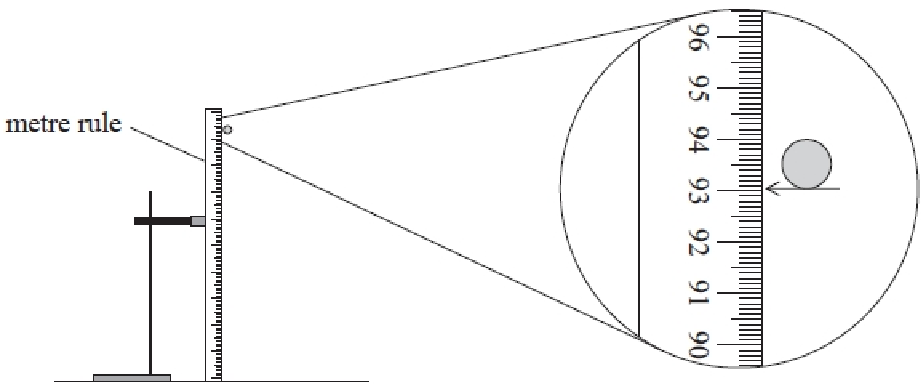
(Total for question = 2 marks)

Q39.

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 (☒).

A student carried out an experiment to determine the acceleration of free fall. The initial height of a ball bearing was measured using a metre rule.



What is the best estimate of the percentage uncertainty in the measurement of height?

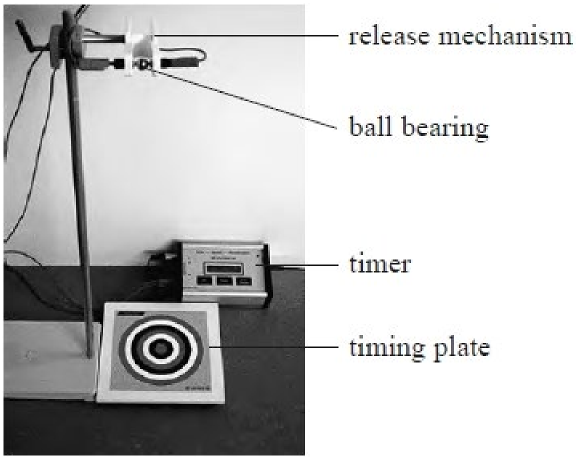
☐ **A** ±0.001%
☐ **B** ±0.01%
☐ **C** ±0.1%
☐ **D** ±1%

(Total for question = 1 mark)

Q40.

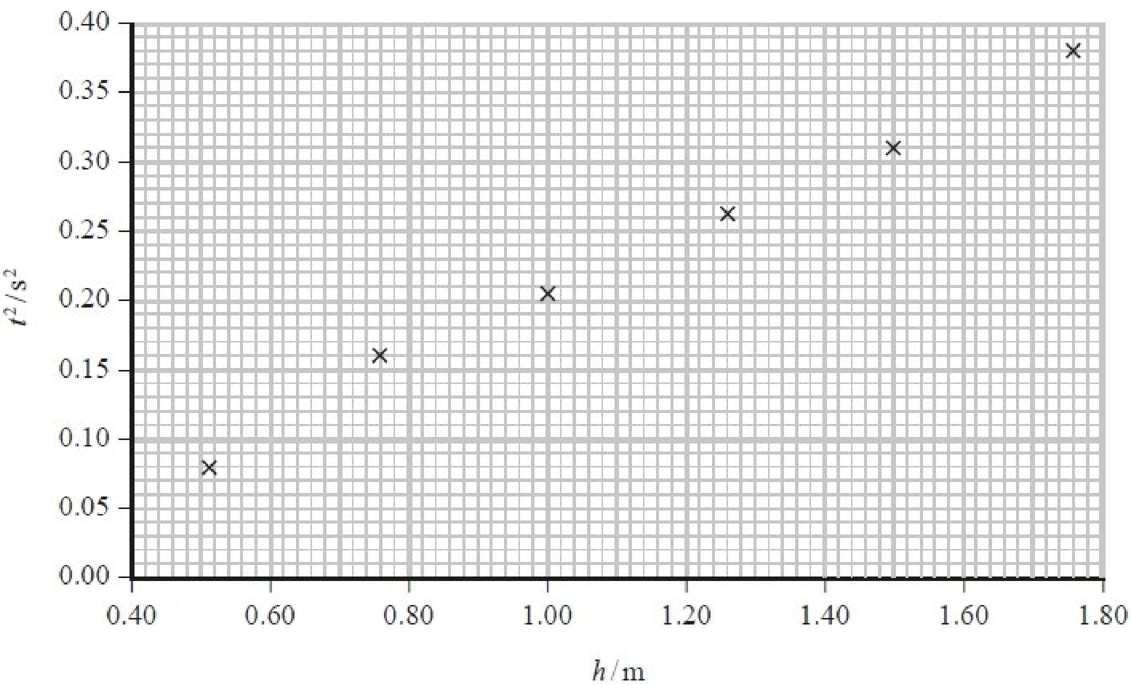
A student carried out an experiment to determine the acceleration of free-fall *g* using the apparatus shown in the photograph.

A ball bearing was released from a measured height *h* and a timer automatically started. On hitting a timing plate, the ball bearing stopped the timer and the time *t* was displayed on the timer. This was repeated for different values of *h*.



The uncertainty in *t* was ± 3%. The uncertainty in *h* was ± 1%.

The student plotted a graph of t^2 against *h* and used it to determine a value for *g*.



The student concluded that her value for *g* was consistent with the accepted value.

Comment on the student's conclusion. Your answer should include a calculation of *g* from the student's data.

You may assume that the percentage uncertainty in your value of *g* is the same as if the value were calculated from just one pair of readings.

(5)

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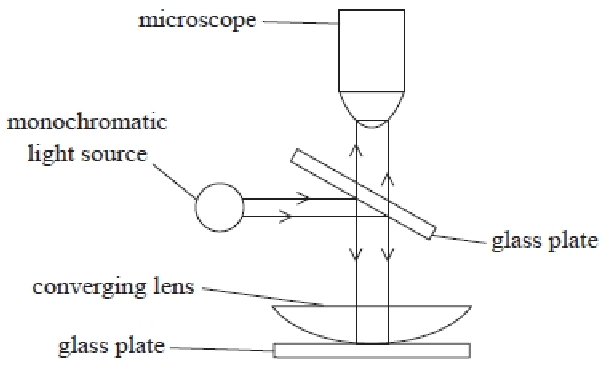
(Total for question = 5 marks)

Q41.

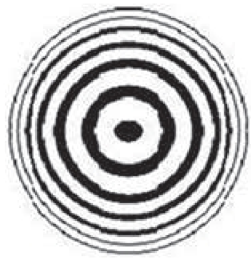
A method to determine the wavelength of light using a converging lens was first proposed by Sir Isaac Newton.

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)

Q42.

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)

(Total for question = 9 marks)

Q43.

A mobile phone is powered by a lithium-ion battery. The information shown is taken from the battery.

3.82 V
6.91 W h

(i) The watt-hour (W h) is an alternative unit for energy.

Show that the maximum energy that can be stored by the battery is about 25kJ. 1 W h = 3600J

(1)

(ii) Calculate the maximum charge that the battery can provide.

(2)

Maximum charge = ...

(iii) The mobile phone 'runs out of charge'.

Calculate the minimum time taken, in hours, for the battery to fully recharge.
charging current = 0.90 A

(3)

....

....

....

Minimum time = ... hours

(Total for question = 6 marks)

Q44.

A series of experiments was carried out in the 1970s to investigate the structure of protons using the linac at Stanford, USA.

An electron leaves the accelerator with a momentum of 20 GeV / c.

(i) Explain, with reference to base units, why GeV / c can be used as a unit of momentum.

(2)

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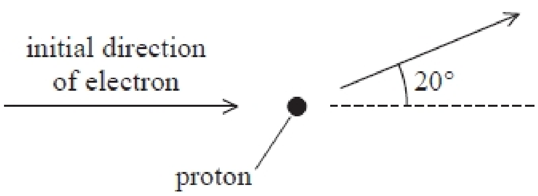
(ii) An electron with initial momentum 20 GeV / c collides with a stationary proton. After the collision the electron is deflected by an angle of 20° as shown and its momentum is 9.1 GeV / c. The momentum of the proton after the collision is 11.9 GeV / c.



Deduce whether the law of conservation of momentum is obeyed.

(3)

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(iii) The collisions between electrons and the protons in these experiments are sometimes inelastic.

State what is meant by an inelastic collision.

(1)

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(Total for question = 6 marks)

Q45.

A student modelled the behaviour of a circuit containing a cell of emf 1.5 V with internal resistance 3.0 Ω, using a spreadsheet. In this model the cell is connected across a resistor. The student used the model to investigate how the power *P* dissipated by the resistor varies with its resistance *R*.

	A	B	C
1	R / Ω	Current / A	P / W
2	0.5	0.43	0.09
3	1.0	0.38	0.14
4	1.5	0.33	0.17
5	2.0	0.30	0.18
6	2.5	0.27	0.19
7	3.0	0.25	0.19
8	3.5	0.23	0.19
9	4.0	0.21	0.18
10	4.5	0.20	0.18

The student concluded that the power dissipated by the resistor is a maximum when *R* is between 2.5 Ω and 3.5 Ω.

Explain how this spreadsheet could be improved so that this maximum can be located more precisely.

(2)

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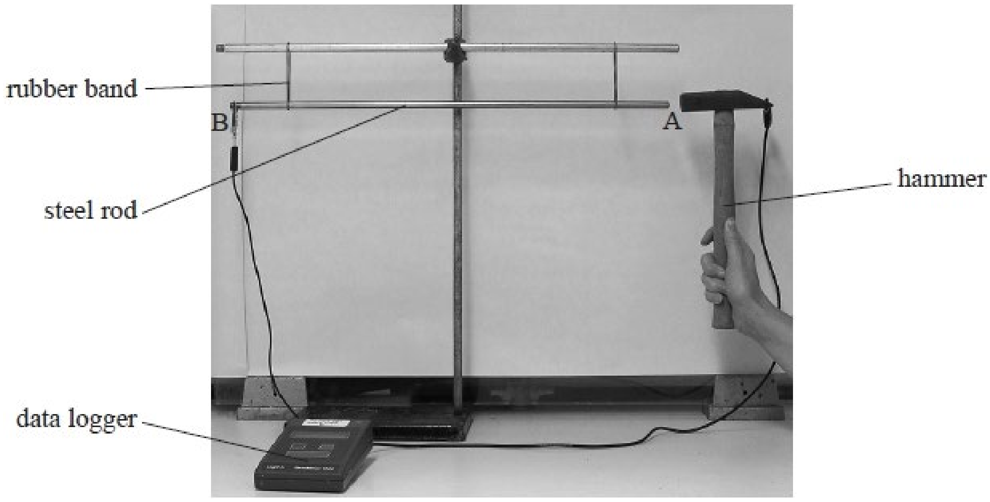
(Total for question = 2 marks)

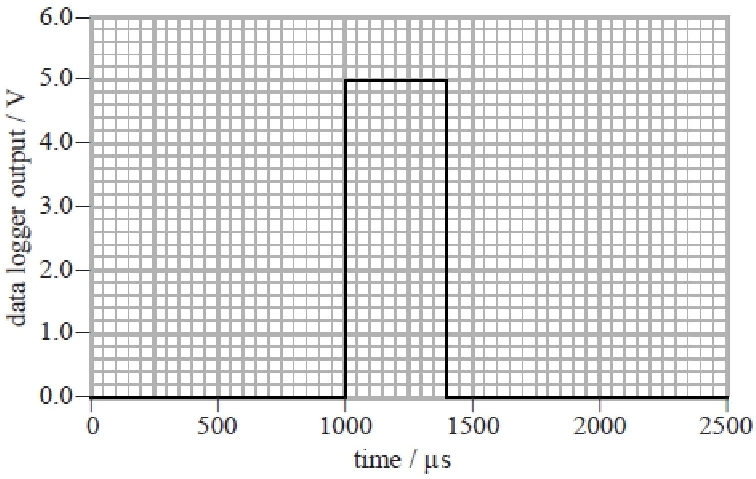
Q46.

A teacher is demonstrating how to measure the speed of sound in a steel rod. The equipment comprises a hanging steel rod and a hammer connected to a data logger as shown.



The rod is tapped at A with the hammer. A compression pulse travels to B and is reflected back. When the reflection reaches A the hammer loses contact with the rod.
Whilst the hammer is in contact with the rod the output from a 5 V supply is recorded by the data logger.

The graph shows the output from the data logger for one hammer tap.



Explain why a data logger is appropriate for this demonstration.

(2)

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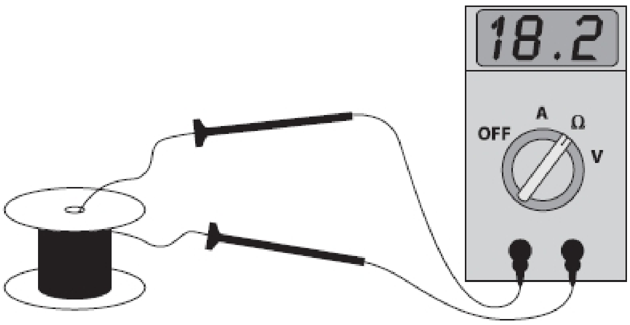
(Total for question = 2 marks)

Q47.

A student carried out an experiment to determine the resistivity of nichrome wire.

He used an ohmmeter to measure the resistance of a length of nichrome wire as shown.



The diameter of the wire was measured as 0.27 mm ± 0.01 mm.
The length of the wire was measured as 1.25 m ± 0.05 m.

Determine which of the three measurements introduces the greatest uncertainty into the value for the resistivity.

Your answer should include calculations.

(4)

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(Total for question = 4 marks)

Q48.

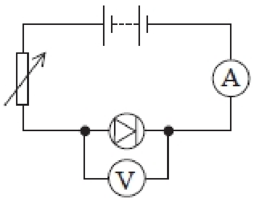
Which of the following is the SI base unit for the Planck constant?

- ☐ **A** N m^{-1} s^{-1}
- ☐ **B** N m s
- ☐ **C** kg m^{2} s^{-1}
- ☐ **D** kg m^{-2} s

(Total for question = 1 mark)

Q49.

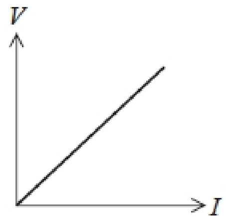
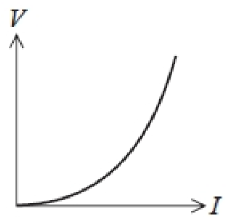
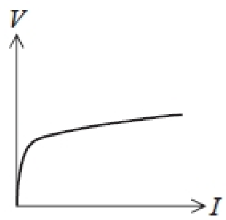
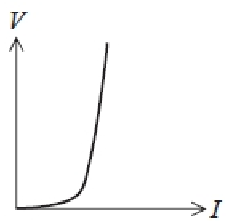
A student carried out an experiment to investigate the current-potential difference characteristics of a diode using the circuit below.



He plotted the graph of potential difference *V* on the *y*-axis against the corresponding current *I* on the *x*-axis.

Which graph would be obtained by the student?

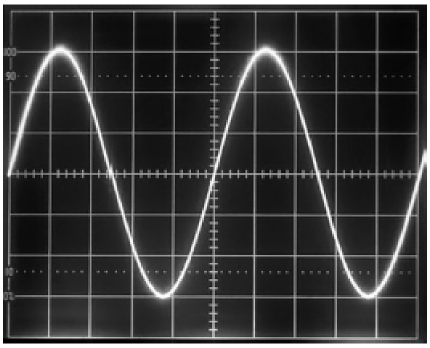
(1)

☐ **A**	
☐ **B**	
☐ **C**	
☐ **D**	

(Total for question = 1 mark)

Q50.

In an investigation to determine the speed of sound in air, a student sets up an oscilloscope to display the waveform of a sound wave as shown.



The timebase is set to 25 μs / division.

The student sets the timebase on the oscilloscope to a lower value per division.

Describe any changes to the appearance of the waveform on the screen.

(1)

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(Total for question = 1 mark)

Mark Scheme – Working as a Physicist

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
	B		1

Q2.

Question Number	Answer	Mark
	C	1

Q3.

Question Number	Answer	Mark
	D $kgm^2s^{-3}A^{-1}$	1
	Incorrect Answers: A – correct units but J and C are not base units B – correct units but J is not a base unit C – correct units but C is not a base unit	

Q4.

Question Number	Answer	Mark
	D power $kg\ m^2\ s^{-3}$	1
	Incorrect Answers: A – Coulombs is not an SI base unit B – Incorrect, as the unit for charge in SI base units is A s C – $J\ s^{-1}$ is not in SI base units	

Q5.

Question Number	Answer	Mark
	C $kg\ m^2\ s^{-3}\ A^{-2}$	1
	Incorrect Answers: A – Ω is not a base unit B – V is not a base unit D – C is not a base unit	

Q6.

Question Number	Answer	Additional Guidance	Mark
	D is the only correct answer	A is incorrect because coulombs is a derived unit and amperes is a base unit B is incorrect because joules is a derived unit C is incorrect because newtons is a derived unit and kilograms is a base unit	**1**

Q7.

Question Number	Answer	Mark
	B length	1
	Incorrect Answers: **A** energy is a derived quantity **C** speed is a derived quantity **D** velocity is a derived quantity	

Q8.

Question Number	Acceptable answer	Additional guidance	Mark
	A	The only correct answer is A because a real image is produced at a distance of 30 cm from the lens B is not the correct answer because the object distance is less than the focal length so the image is virtual C is not the correct answer because diverging lenses produce virtual images with real objects D is not the correct answer because diverging lenses produce virtual images with real objects	**1**

Q9.

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

Q10.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Time a number of (complete) oscillations and divide this time by the number of (complete) oscillations • This increases the total time recorded **Or** this reduces the effect of reaction time (Dependent on MP1) • Time from the mid-point of the oscillation • Use a marker to identify the mid-point of the oscillation **Or** pendulum is travelling fastest at the mid-point • Each method reduces the (percentage) uncertainty (in the value for *T*)	**(1)** **(1)** **(1)** **(1)** **(1)**	Allow: MP1:Use a light gate with a data logger **Or** video oscillation and play back frame by frame MP2: this reduces the effect of reaction time (Dependent on MP1) MP3: accept equilibrium point for mid-point MP5: can't be awarded on its own.	5

Q11.

Question Number	Acceptable Answer		Additional Guidance	
(i)	• Wear safety glasses (to protect eyes from breaking wire) **Or** wear suitable footwear (to protect feet from falling masses) **Or** place sand tray under masses (to catch them if they fall)			1
Question Number	**Acceptable Answer**		**Additional Guidance**	
(ii)	• $\lambda = 2L$ substituted into $v = f\lambda$ • v substituted into $v = \sqrt{\frac{T}{\mu}}$ • Correct re-arrangement into $y = mx + c$ format	(1) (1) (1)	$v = f\lambda$ and $\lambda = 2L$ so $v = 2fL$ $v = \sqrt{\frac{T}{\mu}}$, so $4f^2L^2 = \frac{T}{\mu}$ $L^2 = \left(\frac{T}{4\mu}\right) \cdot \frac{1}{f^2}$, so gradient is $\frac{T}{4\mu}$	3
(iii)	• Gradient calculated • Use of gradient = $\frac{T}{4\mu}$ • $\mu = 1.8$ (g m^{-1}) • SWG consistent with their calculated value of μ (24 swg)	(1) (1) (1) (1)	Example of calculation gradient = $\frac{(0.043 - 0)\text{m}^2}{(15.0 - 0.0) \times 10^{-6}\text{s}^2} = 2.87 \times 10^3 \text{m}^2\text{s}^{-2}$ $\mu = \frac{2.1 \text{ kg} \times 9.81 \text{ m s}^{-2}}{4 \times 2.87 \times 10^3 \text{m}^2\text{s}^{-2}} = 1.79 \times 10^{-3} \text{ kg m}^{-1}$ $\therefore \mu = 1.79 \text{ g m}^{-1}$	4

Q12.

Question Number	Acceptable Answer	Additional Guidance	
(i)	An explanation that makes reference to the following points: **Either** • Take readings in different positions/orientations along the wire (and calculate a mean) (1) • As wire diameter may not be uniform (1) OR • Check (and correct for) for zero error (1) • Zero error reduces the accuracy of the measurement Or Zero error moves the value away from the true value (1)	Accept: use ratchet to close up micrometer to avoid squashing the wire MP2 accept cross section for diameter MP2: accept to reduce the effect of random error MP2 accept systematic error not changed by repeat measurements	2

Q13.

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

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Accuracy relates to how close the measurement is to the true value **(1)** **OR** accuracy depends on the way in which the measurement is made **(1)** • Callipers reduce random/measurement errors in determining the value, giving a lower uncertainty in the measurement than that for a metre rule **(1)** • so scientist B has not made a more accurate measurement he has made a measurement with lower uncertainty **(1)**	This refers to digital, dial or vernier callipers but if reference to a compass style callipers MP2 would become: The callipers would reduce parallax errors due to movement and MP 3 becomes a more accurate measurement because it is closer to a true value	**3**

Q15.

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**

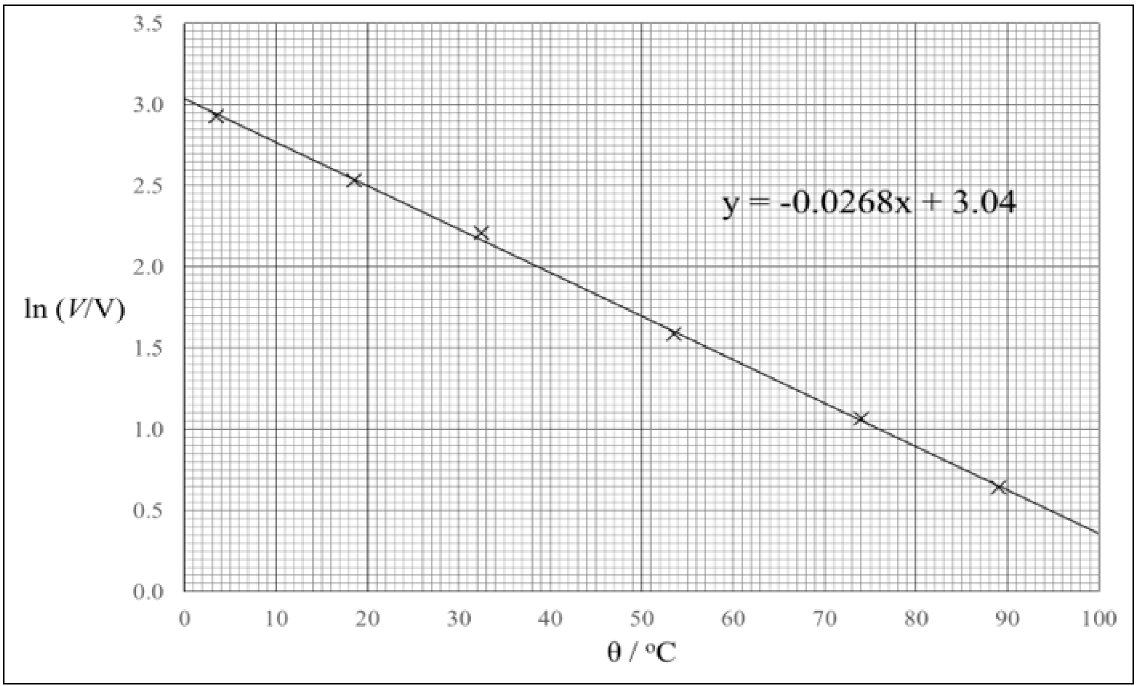
Q16.

Question Number	Acceptable Answer		Additional Guidance	
(i)	An explanation that makes reference to the following points: • Shows expansion $\ln(V) = \ln(V_0) - b\theta$ • Compares with $y = mx + c$ and shows that m is $(-)b$	(1) (1)		2

Question Number	Acceptable Answer		Additional Guidance	
(ii)	• Ln values correct and to 2 or 3 decimal places • Labels and unit • Scales • Plots • Line of best fit	(1) (1) (1) (1) (1)	see table below	5

θ /°C	V /V	ln (V/V)	ln (V/V)
89.0	1.9	0.642	0.64
74.0	2.9	1.065	1.06
53.5	4.9	1.589	1.59
32.5	9.1	2.208	2.21
18.5	12.6	2.534	2.53
3.5	18.7	2.929	2.93

(iii)	• Gradient determined using large triangle • b in range (0.026 → 0.028) °C^{-1} to 2 or 3 sf with unit • Inverse ln of intercept determined • V_0 in range (19 → 22) V	(1) (1) (1) (1)	MP2: unit can be K^{-1} Example of calculation: $\text{gradient} = \frac{(3.04 - 0.35)}{(0 - 100)} = -0.027\ {}_{\circ}\text{C}_{-1}$ $VV_0 = ee^{3.0}$ V = 20.1 V	4



Q17.

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**

Q18.

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 Example of calculation $l_m = \frac{85.5+86.0+85.5}{3} = 85.7\text{ cm}$	**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 Example of calculation $T = 2\pi\sqrt{\frac{\ell}{g}}$ $= 2\pi \times \sqrt{\frac{0.857\text{ m}}{9.81\text{ m s}^{-2}}} = 1.86\text{ s}$	**2**

Q19.

Question Number	Acceptable Answer	Additional Guidance	
(i)	• Mean time calculated (1) • Use of $s = ut$ (1) • $u = 0.039$ (m s^{-1}) (1)	Credit individual velocities and then mean velocity being calculated Example of calculation $t_{av} = \frac{6.40 + 6.35 + 6.36 + 6.38)\text{ s}}{4} = 6.37\text{ s}$ $u = \frac{0.25\text{ m}}{6.37\text{ s}} = 3.92 \times 10^{-2}\text{ m s}^{-1}$	**3**
(ii)	• Use of $\eta = \frac{2r^2 g(\rho_B - \rho_H)}{9v}$ (1) • $\eta = 10.8$ (Pa s), so it is honey A (1)	Show that value gives 10.5 Pa s 10.7 Pa s if 0.0392 m s^{-1} used Allow ecf from (i) Example of calculation $\eta = \frac{2 \times (5.50 \times 10^{-3})^2 \times 9.81\text{ m s}^{-2} \times (7750 - 1360)\text{ kg m}^3}{9 \times 3.9 \times 10^{-2}\text{ m s}^{-1}}$ $\therefore \eta = 10.8\text{ Pa s}$	**2**

Q20.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• He should have moved the microphone over more inphase positions (to determine multiple wavelengths) **(1)** • This would reduce the uncertainty in the value (for *d)* (dependent upon MP1) **(1)**	**Alternative:** MP1: move microphone between antiphase positions MP2: as it is easier to judge when waves are in antiphase (peak corresponds to a trough)	**2**

Q21.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Comment that a straight line graph through the origin (up to 5 N) is consistent with Hookes law / $F \propto x$ (1) • Comment that indicates that the max extended length 400 mm is not covered by the student's results (1) • Use of $\Delta E_{el} = \frac{1}{2}F\Delta x$ **and** $F = k\Delta x$ with $\Delta x = 0.4$ m **Or** Use of $\Delta E_{el} = \frac{1}{2}F\Delta x$ using extrapolated readings from graph (1) • Candidate's calculated energy value compared with 1.6 J and valid conclusion given (1) **Either** • Use of %U to determine the range in *k* (manufacturer's) (1) • Comparison of values for *k* with conclusion consistent with candidates calculated value (1) **Or** • Calculates % difference between candidate's calculated value for *k* and 21 N m^{-1} (1) • Comparison of calculated % difference with 5% and conclusion made (1)	<u>Example of calculation</u> $k = 21 \pm 1.05 = 19.95 - 22.05$ N m^{-1} $F = k\Delta x = 20$ N m^{-1} × 0.4 m = 8.0 N $\Delta E_{el}(\text{max}) = \frac{1}{2} \times 8.0$ N × 0.4 m = 1.6 J	**6**

Q22.

Question Number	Acceptable Answers		Additional guidance	Mark
(a)	• Sound travels as a longitudinal wave **Or** in a series of compressions and rarefactions • With oscillations/vibrations of (air) particles/molecules parallel to the direction of energy transfer	(1) (1)	Accept: Direction of energy transfer **Or** propagation of the wave **Or** direction of wave travel/motion	2

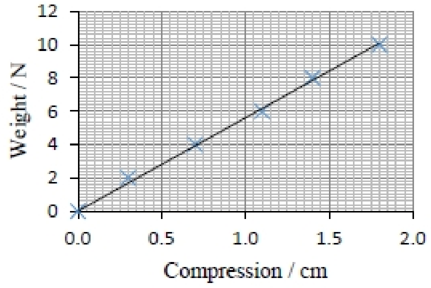
Question Number	Acceptable Answers		Additional guidance	Mark
(b)(i)	• the idea that there is a wide variation in the first two readings	(1)		1

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(ii)	• uses $\frac{\text{half the range of values}}{\text{mean value}}$ • percentage uncertainty = 8.5%	(1) (1)	Example of Calculation $\frac{0.5 \times (0.51\text{ s} - 0.43\text{ s})}{0.47\text{ s}} \times 100\% = 8.5\%$ Accept calculations based on $\frac{\text{range of values}}{\text{mean value}}$ (17%)	2

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(iii)	• attempt to calculate Δv • $\Delta v = 7.4\text{ m s}^{-1}$ or 8.0 m s^{-1}	(1) (1)	Example of Calculation $\frac{160\text{ m}}{0.46\text{ s}} - \frac{160\text{ m}}{0.47\text{ s}} = 7.4\text{ m s}^{-1}$ Use of 80 m (Δv =3.7) scores MP1 only	2

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(iv)	Max 2: • insufficient number of results • identifies one other variable to take into account • difference (in t or v) could be due to human reaction times • uncertainty in results may account for the difference	(1) (1) (1) (1)	Do not accept take readings over more days MP2 examples:wind speed/direction, humidity, air pressure MP3 do not credit human error	2

Q23.

Question Number	Acceptable answers		Additional guidance	Mark
(a)(i)	Processing of data to calculate change in length Axes with labels & units (accept force for weight) Scales Plots Line of best fit	(1) (1) (1) (1) (1)	 **MP2**: only award for a graph of weight against compression. Units may be in m or cm for compression. Allow paper to be landscape **MP3**: scales only in 1,2,4,5 and must cover at least half of paper **MP4**: a 2 mm square tolerance, check all points	5

Weight/ N	Compression/ cm
0.00	0.0
2.00	0.3
4.00	0.7
6.00	1.1
8.00	1.4
10.00	1.8

Question Number	Acceptable answers		Additional guidance	Mark
(a)(ii)	• States that best fit line is through the origin	(1)	If plunger position plotted in (a)(i) then only MP2 may be awarded for attempt at gradient	4
	• So it fits Hooke's law because extension is proportional to force	(1)		
	• Uses corresponding values from best fit line from (a)(i) to determine gradient	(1)	**MP3**: values selected from at least half way along line or a triangle using over half the line is used	
	• Spring constant = 10.0 N / 0.0176 m = 568 (N m^{-1}) (which, 1 s.f., is the stated answer)	(1)	**MP4**: conditional on MP3 and allow any value that rounds to 1 sf as 600	

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Use of $\Delta F = k\Delta x$	(1)	<u>Example of calculation</u> $\Delta F = k\Delta x$ = 610 N m^{-1} × 0.054 m = 32.94 N $\Delta E_{el} = ½ F\Delta x$ = ½ × 32.94 N × 0.054 m = 0.90 J $E_k = ½ mv^2$ so 0.90 J = ½ × (0.0041 + 0.0354) kg × v^2 v = 6.75 m s^{-1}	4
	• Use of $\Delta E_{el} = ½ F\Delta x$	(1)		
	• Use of $E_k = ½ mv^2$	(1)		
	• v = 6.7 m s^{-1} to 6.8 m s^{-1}	(1)		

Question Number	Acceptable answers	Additional guidance	Mark
(c)	Work may be done against friction (by the spring/marble) **Or** KE is gained by the spring **Or** GPE gained by the piston **and** marble **Or** the light gate must be above the launch position so the marble is already accelerating downwards **Or** statement of friction between two specified parts in launch system **(1)**		1

Q24.

Question Number	Acceptable Answer	Additional Guidance	Mark
	D		1

Q25.

Question Number	Answer	Mark
	D – derived unit	1
	Incorrect Answers: A – not a base quantity B – not a base unit C – not a derived quantity	

Q26.

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

Q27.

Question Number	Acceptable Answer	Additional Guidance	Mark
	D kg m s^{-2}		**1**

Q28.

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**

Q29.

Question Number	Acceptable Answers	Additional guidance	Mark
	Max 1 (1) • Develops new technologies • Develops alternative energy sources • Raises public awareness • Secures funding for other projects		**1**

Q30.

Question Number	Acceptable Answers	Additional guidance	Mark
	• (The longer the wire) the larger the extension (for a given force) (1) • (So) smaller percentage uncertainty (in measurement of extension) (1)		**2**

Q31.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Use of half resolution to calculate % uncertainty • % uncertainty in V = 3 × % uncertainty in r • % uncertainty in ρ = (% uncertainty in m + % uncertainty in V) • Use of % uncertainty to calculate upper value of density • Upper value of density 2596 (kg m^{-3}) [2616 (kg m^{-3}) if "show that" value used] • Glass is in the range and Quartz isn't, so it may not be genuine 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)	(1) (1) (1) (1) (1) (1)	% 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 ρ = (3 × 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

Q32.

Question Number	Answer	Additional Guidance	Mark
(i)	• Calculation of mean (1) • Use of half range **Or** maximum difference from the mean (1) • % uncertainty = 1.4% (1)	Example of calculation $\bar{d} = \frac{(1.40+1.44+1.42+1.41)\text{ mm}}{4}$ $=1.42\text{ mm}$ $\%U = \frac{(1.44-1.40)\text{ mm}/2}{1.42\text{ mm}} \times 100\%$ $=1.41\%$	3
(ii)	• Use of $A = \pi r^2$ (1) • Use of $R = \frac{\rho l}{A}$ (1) • $\rho = 6.9 \times 10^{-7}$ (Ω m), so wire is made from stainless steel (1)	Example of calculation $A = \pi \left(\frac{1.42 \times 10^{-3}\text{m}}{2}\right)^2 =$ $1.58 \times 10^{-6}\text{ m}^2$ $\rho = \frac{0.72\ \Omega \times 1.58 \times 10^{-6}\text{ m}^2}{1.65\text{ m}} =$ $6.9 \times 10^{-7}\ \Omega\text{ m}$	3

Q33.

Question Number	Acceptable answers	Additional guidance	Mark
	• (Vernier) callipers **Or** travelling microscope **Or** micrometer (1) • Measure diameter in different places and calculate mean (1)		2

Q34.

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

Q35.

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

Q36.

Question Number	Acceptable answers	Additional guidance	Mark
	Max 5 • The time is too short to be measured by a stop watch **Or** there is reaction time. (1) • Another variable could have been controlled (1) • Repeats should have been taken and a mean calculated (1) • Identifies that there is an anomaly (at about 5 N) that has not been checked/repeated (1) • Smaller weight intervals (around 6 N) to identify the maximum **Or** plot/take more data points around 6 N. (1) • Don't know where the maximum is so can't make a judgement that there is a maximum efficiency at 6 N (1) • The conclusion ignores the decline after 6 N (so is incomplete) (1)	MP2 need to specify a variable e.g. current or p.d.	5

Q37.

Question Number	Answer	Additional Guidance	Mark
	• Comparison with $y = mx + c$ **(1)** • Gradient is $1/f$ and constant [allow reference to m for "gradient"] **(1)**	$m = \frac{v}{f} - 1$ $m = \frac{1}{f}v - 1$	2

Q38.

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

Q39.

Question Number	Answer	Mark
	C ± 0.1 %	1
	Incorrect Answers: A – the calculation has not been multiplied by 100 to give the % uncertainty i.e. $\frac{0.1}{93} = 0.001$ B – the uncertainty in mm has not been converted to cm and the calculation has not been multiplied by 100 i.e. $\frac{1}{93} = 0.01$ D – the uncertainty in mm has not been converted to cm i.e. $\frac{1}{93} \times 100 = 1$	

Q40.

Question Number	Acceptable answers	Additional guidance	Mark
	• calculation of gradient of the graph (1) • Use of $s = ½ at^2$ to obtain value for g (1) • Total uncertainty = 7 % (1) • Calculation of % difference **Or** Range of calculated g (1) • Judgment on accuracy of experiment with reason (1)	MP2: use of $\frac{2}{\text{gradient}}$ MP3: percentage uncertainty = 3 % + 3 % + 1 % MP5: e.g. comparison of total uncertainty with % difference **Or** comparison of calculated range with 9.81 m s^{-2} <u>Example of calculation</u> Gradient = $\frac{0.385\ \text{s}^2 - 0.06\ \text{s}^2}{1.8\ \text{m} - 0.4\text{m}} = 0.232\ \text{s}^2$ m^{-1} $g = \frac{2}{0.232\ \text{s}^2\ \text{m}^{-1}} = 8.67\ \text{m s}^{-2}$ Percentage difference=$\left(\frac{9.81\ \text{m s}^{-2} - 8.67\ \text{m s}^{-2}}{9.81\ \text{m s}^{-2}}\right) \times 100 =$ 12 %	5

Q41.

<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 ($\log_e$)
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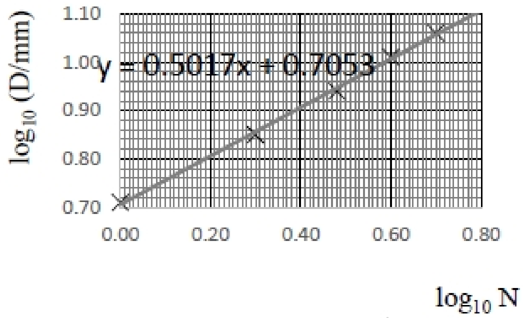
<tr><td>0.710</td><td>0.000</td></tr>
<tr><td>0.850</td><td>0.301</td></tr>
<tr><td>0.940</td><td>0.477</td></tr>
<tr><td>1.01</td><td>0.602</td></tr>
<tr><td>1.06</td><td>0.699</td></tr>
</table>
<table>
<tr><th>ln (D/mm)</th><th>ln N</th></tr>
<tr><td>1.64</td><td>0.000</td></tr>
<tr><td>1.96</td><td>0.693</td></tr>
<tr><td>2.16</td><td>1.10</td></tr>
<tr><td>2.33</td><td>1.39</td></tr>
<tr><td>2.44</td><td>1.61</td></tr>
</table>


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

Q42.

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> % uncertainty= $\frac{0.005\text{ mm}}{2.52\text{ mm}} \times 100\ \% = 0.20\ \%$	
(iii)	• % uncertainty = 1.6 % (1)	<u>Example of calculation:</u> % 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> $V = 0.866\ m \times \frac{\pi(2.52\times10^{-3})^2}{4} = 4.32\times 10^{-6}\ m^3$ $\rho = \frac{3.20\times10^{-2}\text{ kg}}{4.32\times10^{-6}\text{m}^3} = 7400\text{ kg m}^{-3}$ Uncertainty in ρ = $\pm(7400\text{ kg m}^{-3} \times \frac{2.7}{100})$ = 200 kg m^{-3}	4

Q43.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	Use of 3600 × W h to give energy stored = 24 900 (J) (1)	<u>Example of calculation</u> 6.91 W h = 6.91 × 3600 s = 24 876 J	1

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• Use of $V = W/Q$ (1) • Q = 6510 C (1)	<u>Example of calculation</u> $Q = \frac{24\,876\text{ J}}{3.82\text{ V}} = 6512\text{ C}$ (ecf for calculated energy from (a)(i)) (show that value gives Q = 6545 C)	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• Use of $Q = It$ **Or** $W = VIt$ **(1)** • Use of $\frac{\text{time in seconds}}{3600}$ **(1)** • $t = 2.0$ (h) **(1)**	Example of calculation $t = \frac{6512\text{ C}}{0.9\text{ A}} = 7235.6$ s $t = \frac{7235.6\text{ s}}{3600} = 2.01$ h (ecf for calculated charge from (a)(i)) (show that value gives $t = 2.02$ h)	3

Q44.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• units eV (energy) base units: kg m^2 s^{-2} **Or** base units of momentum: kg m s^{-1} **(1)** • divide energy by units of speed (c) m s^{-1} gives kg m s^{-1} which are units of momentum Or multiply units of momentum by speed (c) m s^{-1} to give units of energy kg m^2 s^{-2} **(1)**		2
(ii)	• resolves a y-component or x-component of electron momentum **(1)** • applies momentum conservation in x-direction or y-direction **(1)** • comparison of total momentum after **Or** momentum of proton after plus comment **(1)** Alternative: • draws a vector triangle • Uses cosine rule • Calculates angle from three sides = 20.4°	Example of calculation $p_y = 9.1\text{ (GeV/c)}\sin 20 = 3.1\text{ GeV/c}$ $p_x = 9.1\text{ (GeV/c)}\cos 20 = 8.55\text{ GeV/c}$ p_x of proton $= 20\text{ (GeV/c)} - 8.55\text{ (GeV/c)} = 11.45$ G $p_{proton} = \sqrt{3.1^2 + 11.45^2}$ $= 11.86$ GeV/c Alternative: p_y $= 9.1\text{ (GeV/c)}\sin 20 = 3.1\text{ GeV/c}$=11.9($\emptyset = 15.2$ So total p after = 11.9 GeV/c cos 15.2 + 9.1 (GeV/c)cos20 = 11.5 + 8.55 = 20.05 GeV/c	3
(iii)	• (total) kinetic energy not conserved **(1)**		1

Q45.

Question Number	Acceptable Answer	Additional guidance	Mark
	• use smaller increments for resistance (1) • around area of peak (1)		2

Q46.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following: • The time interval is very short (1) • the idea of a high sample rate (with the datalogger) (1) **Or** (Percentage) uncertainty in measurement would be small (when using the datalogger).	MP2 examples: time interval between measurements is small Many recordings/sec	2

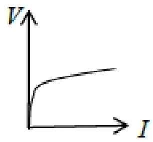
Q47.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• The measurement of resistance has an uncertainty of 0.6 % (1) • The measurement of the length has an uncertainty of 4 % (1) • The measurement of the diameter has an uncertainty of 4 % (1) • The % uncertainty in diameter is doubled giving the greatest amount of uncertainty into the value for the resistivity (1)	MP1 accept use of 0.05 giving 0.3 % <u>Example of calculation:</u> Uncertainty in $R = \frac{0.1\,\Omega}{18.2\,\Omega} \times 100\% = 0.55\%$ Uncertainty in $L = \frac{0.05\,\text{m}}{1.25\,\text{m}} \times 100\% = 4.0\%$ Uncertainty in $d = \frac{0.01\,\text{m}}{0.27\,\text{m}} \times 100\% = 3.7\%$	4

Q48.

Question Number	Answer	Mark
	C kg m^2 s^{-1}	**1**
	Incorrect Answers: **A** – N is not an SI base unit and incorrect arrangement **B** – N is not an SI base unit **D** – incorrect arrangement	

Q49.

Question Number	Acceptable Answer	Additional Guidance	Mark
	C 		1

Q50.

Question Number	Answer	Additional Guidance	Mark
	• Fewer waves/cycles on screen (1)	Accept wavelength increases	1