Name: _____

Topic 1: Working as a Physicist Part 2

Date:

Time:

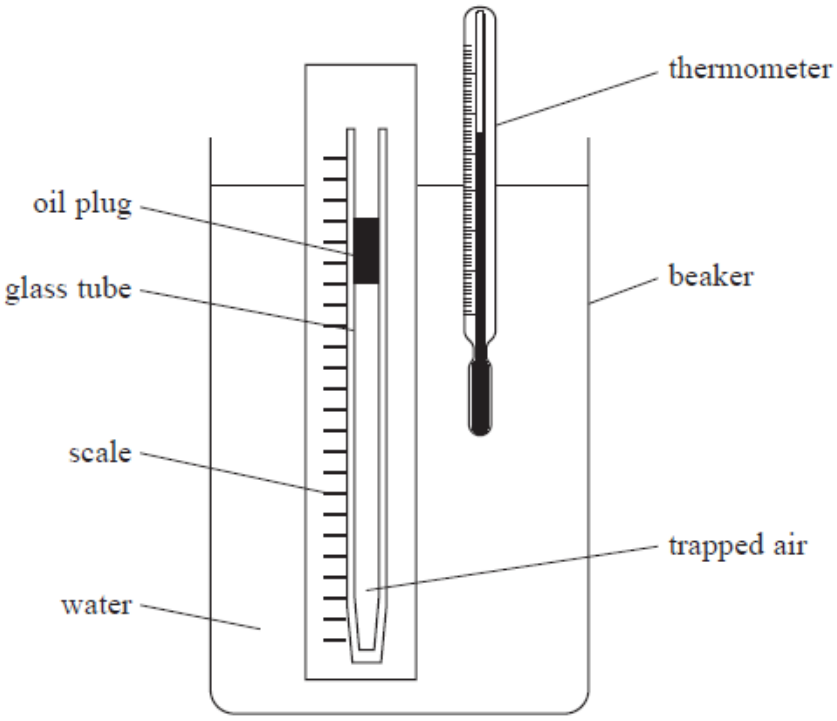
Total marks available:

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

(i) Criticise the student's results.

(3)

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(ii) Explain two possible sources of error in this investigation.

(4)

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(iii) Describe two improvements that would increase the accuracy of measurements obtained in this investigation.

(2)

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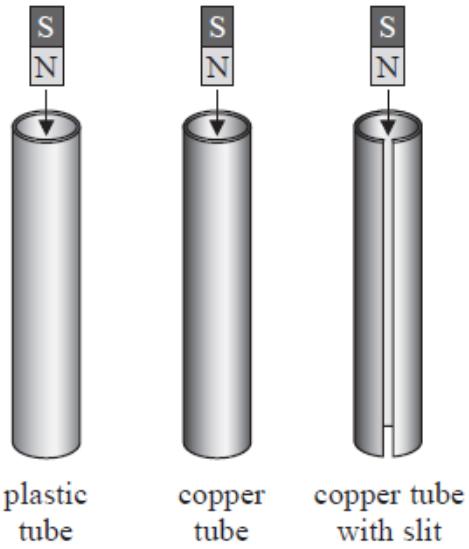
(Total for question = 9 marks)

Q2.

A teacher carries out a demonstration to illustrate the laws of electromagnetic induction.
She uses three tubes of identical dimensions. One is made of plastic, one copper and one copper with a slit cut into its length.



(a) The teacher releases a magnet from rest at the top of the plastic tube and it takes 0.45 s to fall through the tube.
Calculate the average acceleration of the magnet as it falls through the tube.

length of tube = 0.75 m

(2)

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Average acceleration = ...

*(b) The teacher suggests that the magnet would take longer to fall through the copper tube as a consequence of the laws of electromagnetic induction.

Assess the validity of this suggestion.

(6)

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(c) Before the teacher releases the magnet through the copper tube with a slit along its length, she asks the class to consider how the time taken will compare with the time for the other copper tube. The class predicts that the time will be the same.

Explain, using electromagnetic induction, whether this prediction is correct.

(3)

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(d) The times for the magnets to fall through the tubes were measured manually using an electronic timer.

Explain how suitable this is as a means of recording these times.

(2)

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(Total for question = 13 marks)

Q3.

In 2015 the Messenger spacecraft crashed into the surface of the planet Mercury after four years in orbit observing the surface of Mercury.

Messenger's orbit was highly elliptical, varying between 200 km and 15 000 km above the surface of Mercury. Messenger completed one full orbit every 12 hours.

mass of Messenger spacecraft = 565 kg
mass of planet Mercury = 3.30×10^{23} kg
radius of planet Mercury = 2430 km

It has been suggested that the same orbital period of about 12 hours could have been achieved if Messenger was in a circular orbit 7690 km above the surface of Mercury.

(i) Determine whether this suggestion is correct.

(4)

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(ii) The elliptical orbit chosen had advantages over this circular orbit.

Explain **one** advantage.

(2)

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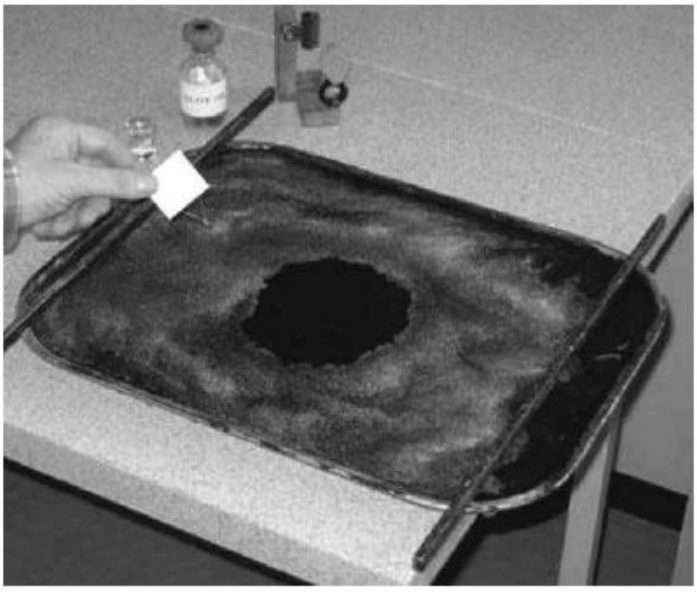
(Total for question = 6 marks)

Q4.

When a drop of oil is placed on the surface of water it spreads out to form a thin film 1 molecule thick. A student uses this phenomenon to determine the size of an oil molecule.

She dips a wire loop into the oil so that a small, spherical oil drop forms. She uses a millimetre scale to measure the diameter of this oil drop.

The student fills a tray with water and scatters a fine powder on the water surface. The oil drop is placed on the water surface and spreads out to form a thin film, approximately circular, as shown in the photograph.



The student uses a metre rule to measure the diameter of the circular thin film.
She records the following measurements:

diameter of oil drop = 0.5 mm
diameter of thin film = 250 mm

The student now equates the volume of oil as a drop to the volume of the film.

Evaluate the student's method and suggest refinements that would improve the accuracy of determining the size of the molecule.

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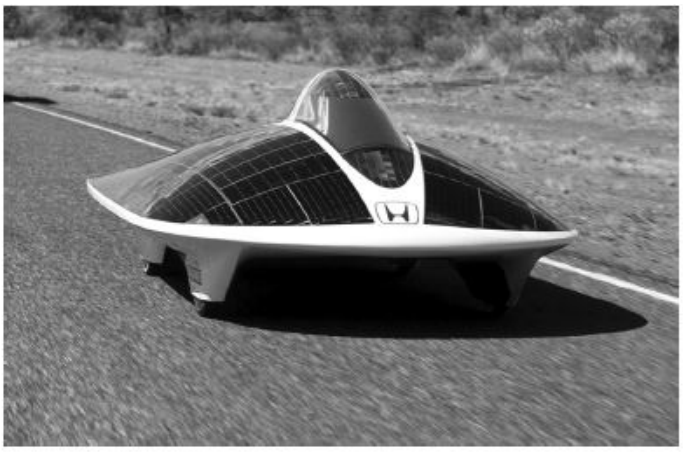
(Total for question = 6 marks)

Q5.

The world solar challenge is set every two years, in Australia. The challenge is to complete a three thousand kilometre route with a vehicle powered only by the Sun.

Vehicles have their surfaces fitted with solar panels, as shown in the photograph.



(Source: © LAURENT DOUEK/LOOK AT SCIENCES/SCIENCE PHOTO LIBRARY)

Solar power alone would not be suitable for a family car because it is not sunny all the time.

Give two further reasons why solar power alone would not be suitable.

(2)

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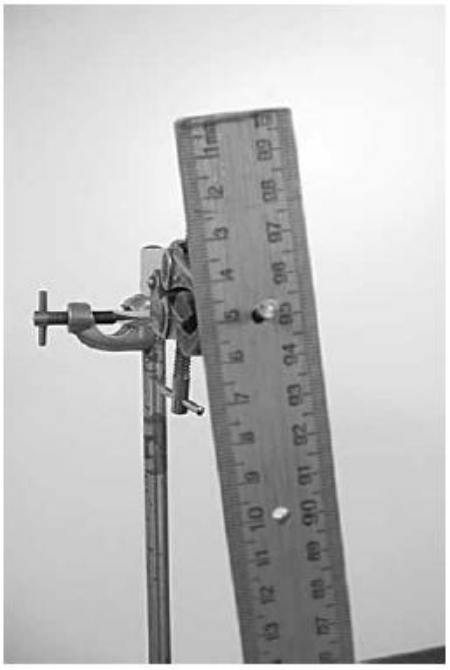
(Total for question = 2 marks)

Q6.

A metre rule has a small hole drilled at the 5 cm mark. The rule is hung on a horizontal pin passing through the hole.



The rule is rotated through a small angle and released. It then oscillates about the pin as a pendulum with a time period *T*.

(i) Describe how to use a stopwatch to determine a value for *T*.

(2)

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(ii) State **two** reasons why repeating the readings will improve the results for *T*.

(2)

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(Total for question = 4 marks)

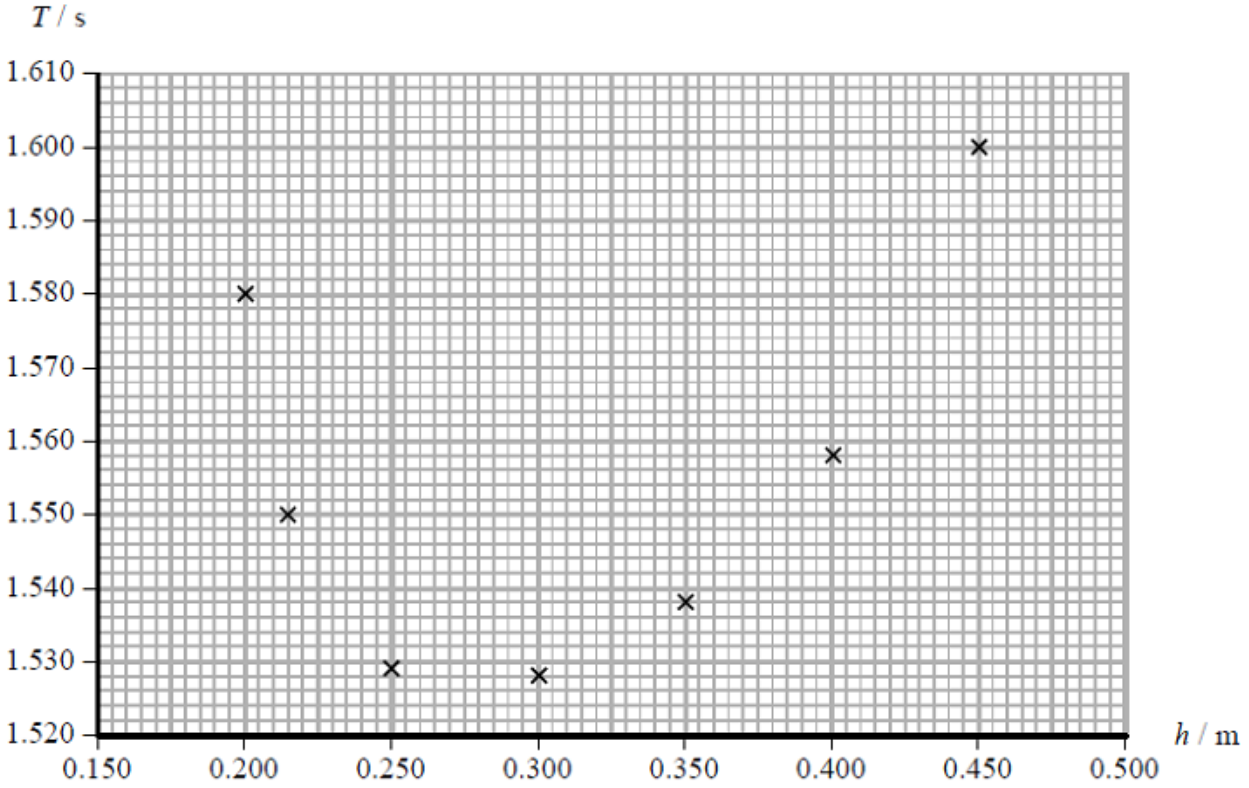
Q7.

A metre rule has a small hole drilled at the 5 cm mark. The rule is hung on a horizontal pin passing through the hole.

(a) There are six more holes drilled at intervals down the rule. The rule is hung from each hole and the distance *h* from the pin to the 50 cm mark is recorded.

T is determined for each value of *h* and a graph of *T* against *h* is plotted.

h/m	T/s
0.450	1.601
0.400	1.558
0.350	1.538
0.300	1.528
0.250	1.529
0.215	1.550
0.200	1.580



(i) Draw a line of best fit on the graph.

(1)

(ii) Use your line to determine the value of h that would produce the smallest value of T.

Record these values.

(2)

h = ... T = ...

(b) The graph of T against h does **not** produce a straight line.

The variables T and h are related by

$T^2h = 4\pi^2h^2/g + C$

where C is a constant.

Describe a graphical method to determine a value for C and state the unit for C.

(3)

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(Total for question = 6 marks)

Q8.

The photograph shows a tea cup on a saucer.

A student notices that walking with this sort of tea cup when it is filled with tea is particularly difficult to do without spilling it.

While walking, the tea starts to oscillate from side to side in the cup, rapidly increasing in amplitude and spilling over the edge.

The student develops the hypothesis that spillage occurs most when the frequency of the steps taken by a person matches the natural frequency of oscillation of tea in the cup.

*(i) Devise an experiment to investigate the hypothesis.

(6)

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(ii) Describe how the measurements taken will be used to come to a conclusion.

(3)

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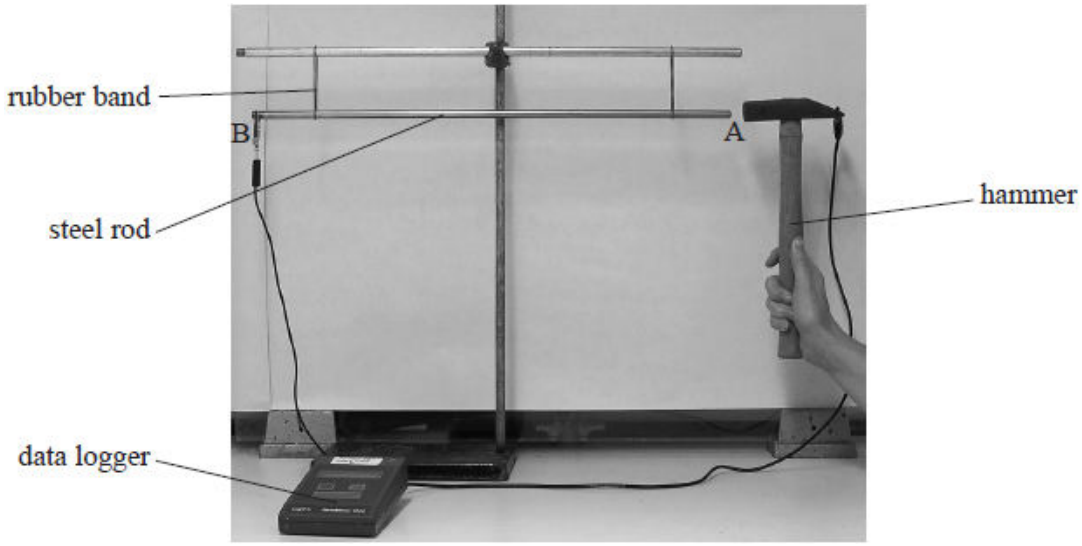
(Total for question = 9 marks)

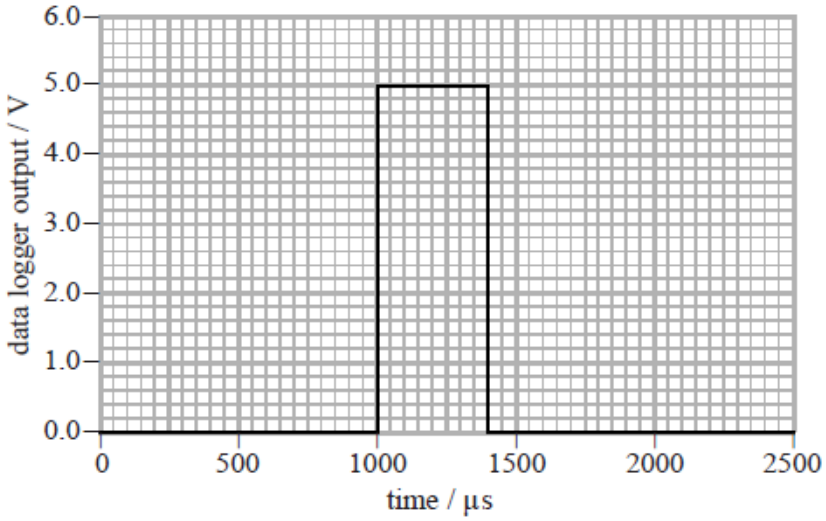
Q9.

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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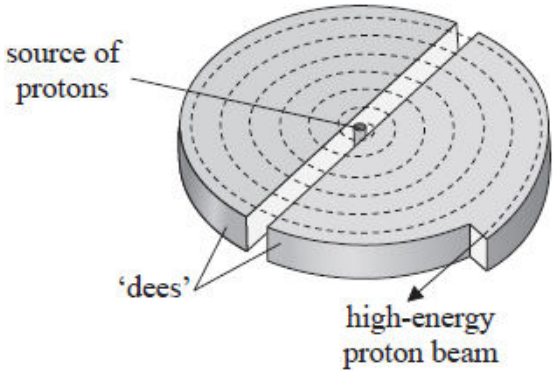
(Total for question = 2 marks)

Q10.

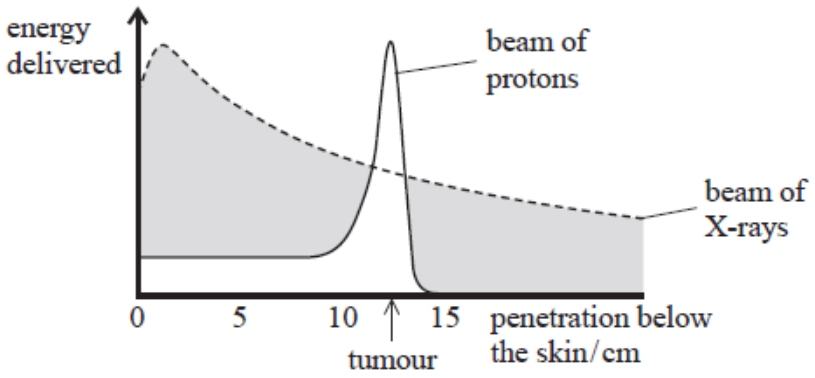
Proton beam therapy is being introduced in the UK as a new cancer treatment.

A beam of protons is accelerated by a cyclotron to an energy of 23 MeV and is then focused onto a tumour.



Conventional treatment may use X-rays to deliver energy to a tumour.

The graph shows the variation of energy delivered with penetration below the skin for a beam of protons and a beam of X-rays.



Deduce why the beam of protons could be a more effective treatment for tumours than a beam of X-rays.

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(Total for question = 2 marks)

Q11.

The joule can be expressed in SI base units as

☒ **A** kg m s^{-2}

☒ **B** kg m^2 s^{-1}

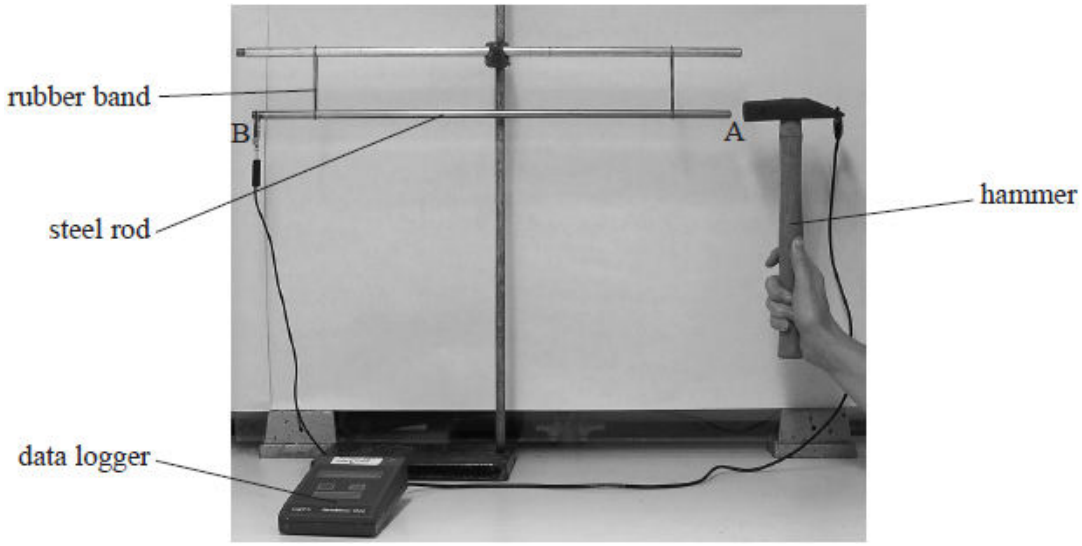
☒ **C** kg m^2 s

☒ **D** kg m^2 s^{-2}

(Total for question = 1 mark)

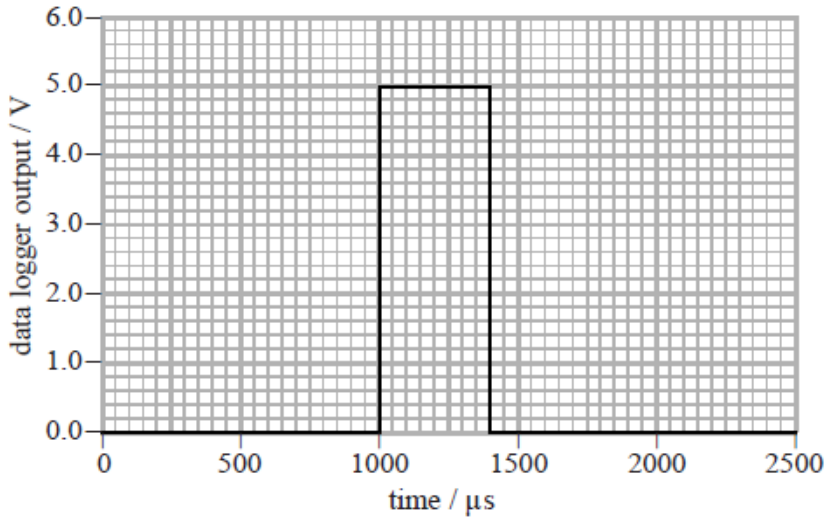
Q12.

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.



(i) Use the graph to show that the speed of the pulse in the rod is about 6000 m s^{-1}.

length of steel rod = 1.18 m

(3)

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(ii) The speed of sound v in the rod depends on the Young modulus E and the density ρ of the material of the rod as given by the equation

$$v = \sqrt{\frac{E}{\rho}}$$

Calculate the Young modulus of steel.

ρ_{steel} = 7850 kg m^{-3}

(2)

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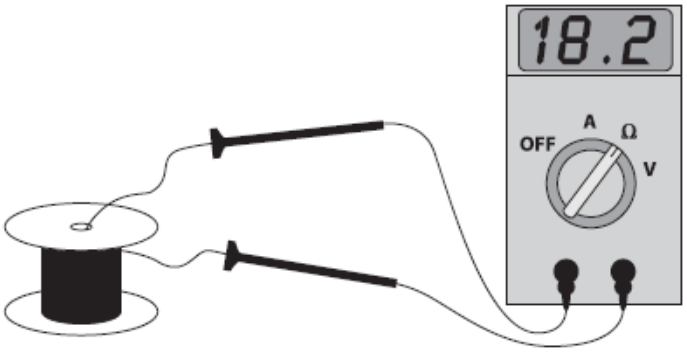
Young modulus of steel = ...

(Total for question = 5 marks)

Q13.

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.

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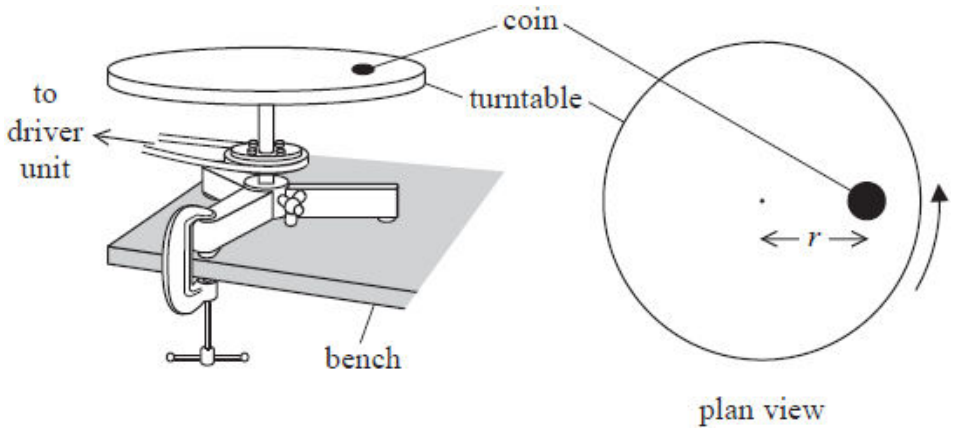
(Total for question = 4 marks)

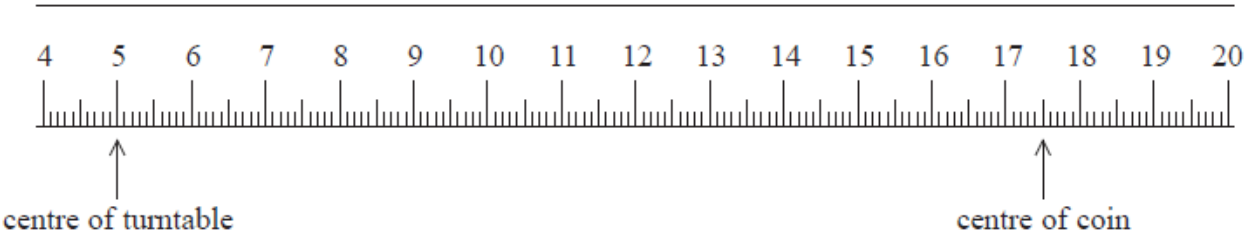
Q14.

A student was investigating the forces involved in circular motion.

He placed a small coin on a horizontal turntable as shown. The turntable was connected to a driver unit so that it could be rotated at a constant rate.



The student measured the distance *r* between the centre of the turntable and the centre of the coin, with a metre rule as shown.



Explain why the percentage uncertainty in the value of *r* is about 1%.
Your answer should include a calculation.

(3)

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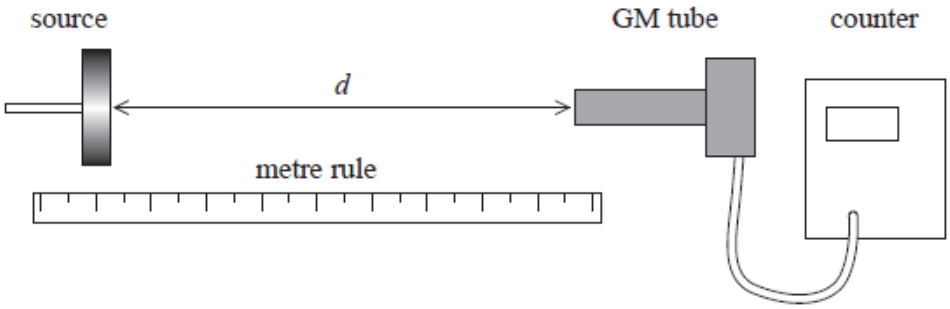
(Total for question = 3 marks)

Q15.

A student investigated the way in which gamma radiation spreads out from a source.
He placed a cobalt-60 source in a source holder and set up a Geiger-Müller (GM) tube a short distance *d* away. He connected the GM tube to a counter as shown.



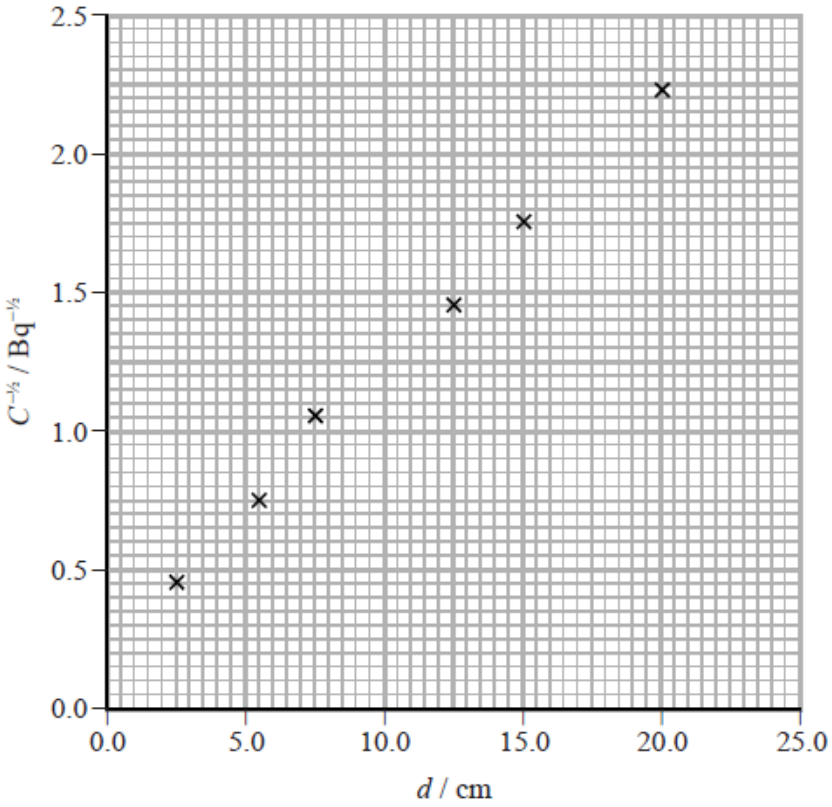
The student recorded the count for 2 minutes.

The variation in the intensity of gamma radiation with distance from a point source should obey an inverse square law. If this is the case, then the count rate *C* should vary with *d* according to the equation

$$C = \frac{K}{4\pi d^2}$$

where K is a constant.

The student plotted $\frac{1}{\sqrt{C}}$ against d and obtained the following graph.



(i) Draw a line of best fit on the graph.

(1)

(ii) The student concluded that the graph was consistent with the gamma radiation intensity obeying an inverse square law.

Discuss the extent to which the data obtained supports the student's conclusion.

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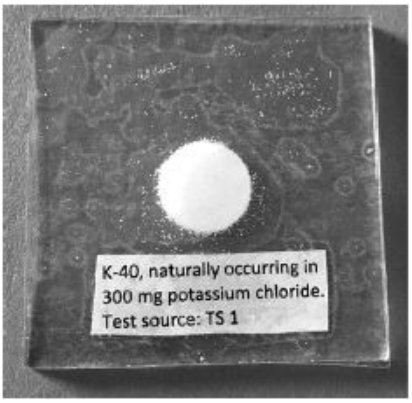
(Total for question = 5 marks)

Q16.

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.

A teacher makes some measurements using the potassium chloride test source to determine whether a Geiger-Müller tube is sufficiently efficient at detecting β radiation.

(i) The potassium chloride sample has a mass of 300 mg.

Show that the number of nuclei of potassium-40 in the sample is about 3×10^{17}.

number of potassium nuclei in 1 g of potassium chloride = 8.1×10^{21}

(2)

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(ii) Show that the activity of this sample is about 5 Bq.

half-life of potassium-40 = 1.25×10^9 years

(3)

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(iii) With no sample in front of the Geiger-Müller tube, a count rate of 15 counts per minute is recorded. When the potassium chloride test sample is placed next to the Geiger-Müller tube 176 counts are recorded in a period of 10 minutes.

A detector is considered efficient if it detects at least 7.5% of beta emissions from the source.

Determine whether this Geiger-Müller tube can be considered efficient.

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(iv) Explain a possible reason why only a low proportion of the decays are detected.

(2)

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(Total for question = 10 marks)

Q17.

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

Give two reasons why a measurement may have an uncertainty.

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(Total for question = 2 marks)

Q18.

A student investigated the rate at which a hot liquid transfers thermal energy to the surroundings. He placed hot water in a Pyrex beaker and measured the temperature of the water using a liquid-in-glass thermometer.

He obtained the following data for the temperature θ of the water at times t. He measured t using a stopwatch.

t / s	θ / °C		
0	95		
120	87		
240	81		
360	76		
480	71		

temperature of surroundings = 23 °C

Theory suggests that a liquid transfers internal energy to the surroundings at a rate proportional to the temperature difference $\Delta\theta$ between the liquid and the surroundings.

This leads to the expression

$$\Delta\theta = \Delta\theta_0 e^{-bt}$$

where b is a constant and $\Delta\theta_0$ is the initial temperature difference.

(a) Explain why a graph of ln $\Delta\theta$ against t should be a straight line.

(2)

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(Total for question = 2 marks)

Q19.

The photograph shows the containers of two radioactive sources kept in a school.

The sources are tested every year and a record of the activity of the sources has to be kept.

The school has incomplete records. The table shows the test entries for cobalt for 2015 and for a year X, which is the year the source was purchased.

Year	Background: counts in 60 s	Source: counts in 60 s
X	22	12227
2015	15	322

The school records show that sources were purchased in 1980, 1987 and 1995, but there is no record of which source was purchased in which year.

(i) Determine the age of the cobalt source in order to establish in which year the school purchased this source.

half-life of Co 60 = 5.3 years

(5)

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Year = ...

(ii) Explain a factor that may affect the reliability of this date.

(2)

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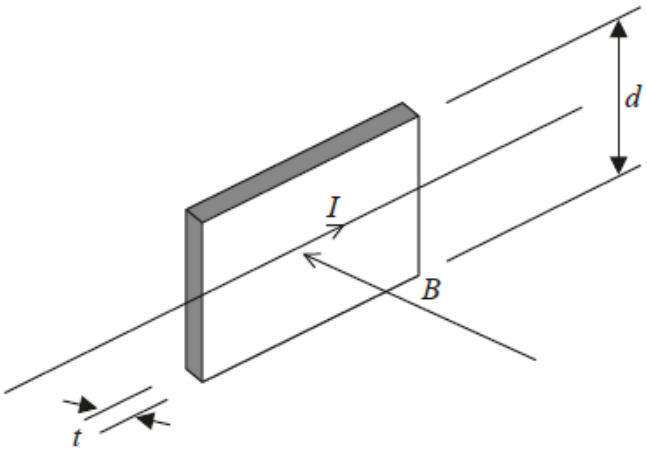
Q20.

Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's surface by measuring the Earth's magnetic flux density.

A current *I* and a magnetic field of flux density *B* are applied to a slice of semiconductor as shown. The slice has thickness *t* and depth *d*.



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage V_{HALL} develops.

Show that the units are the same on each side of the equation

$$V_{HALL} = \frac{BI}{nte}$$

(3)

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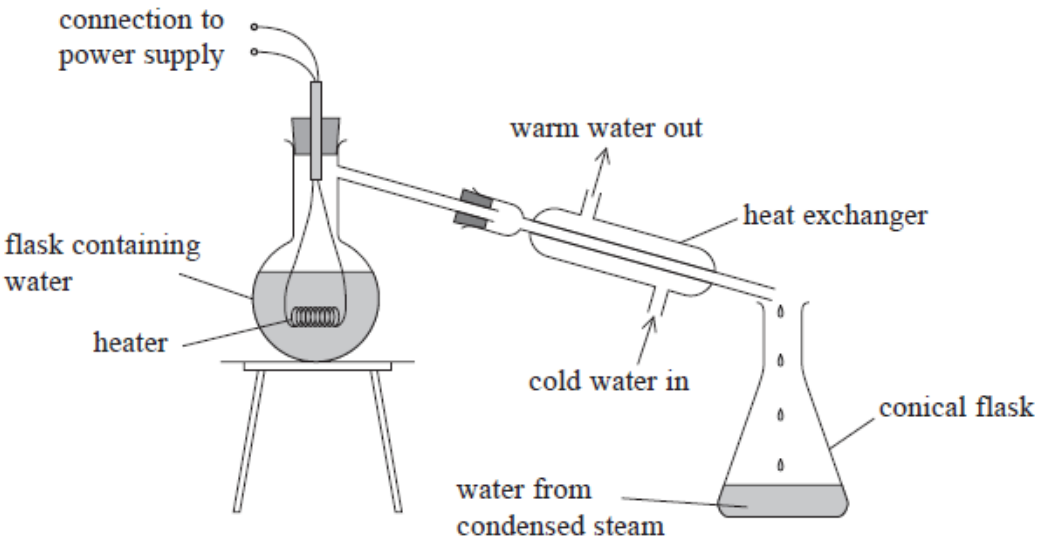
(Total for question = 3 marks)

Q21.

The apparatus shown can be used to determine a value for the specific latent heat of vaporisation of water.



(a) In one experiment the current in the heater was 8.20 A, and the potential difference across the heater was 230 V.

(i) Show that the power of the heater was about 2 kW.

(2)

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(ii) There was 0.655 kg of water in the flask at an initial temperature of 22.5 °C.
The heater was switched on, and the water in the flask was heated to boiling point.

Calculate the minimum time taken for the water to be heated to 100.0 °C.

specific heat capacity of water = 4190 J kg^{-1} K^{-1}

(3)

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Minimum time taken for water to be heated = ...

(b) The heater was left on and water continued to boil in the flask. The water was allowed to boil for a few minutes. The conical flask was then placed under the heat exchanger and water was collected in it.

(i) Give a reason why the water was left boiling for a few minutes before the conical flask was put in place.

(1)

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(ii) Water with a mass of 95.0 g was collected in a time of 125 s.

Calculate the rate of energy transfer in the heat exchanger.

specific latent heat of vaporisation of water = 2.26×10^6 J kg^{-1}

(3)

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Rate of energy transfer in the heat exchanger = ...

(iii) Discuss your answers to (a)(i) and (b)(ii).

(3)

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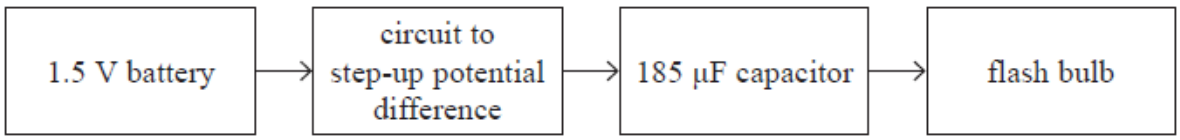
(Total for question = 12 marks)

Q22.

* Cameras usually have an inbuilt flash bulb that can be used to take photographs in poor light conditions. As a photograph is taken, the bulb should be able to produce a bright flash of light for up to 4 ms.

A capacitor can be used along with a battery as a power supply for the flash bulb. The flow diagram shows a possible arrangement.



Comment on the suitability of using this capacitor arrangement as a power supply rather than connecting the bulb directly to the battery.

A typical flash bulb has a resistance of 6 Ω.

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(Total for question = 6 marks)

Q23.

(a) A magnetic field can be measured with a device called a Hall probe. The probe is connected to a voltmeter. When the probe is placed at right angles to a magnetic field, a potential

difference is recorded on the voltmeter. The potential difference increases with increasing magnetic flux density.

A wire carries a constant current. A Hall probe is used to investigate how the magnetic flux density produced by the wire varies with distance from the wire.

The potential difference V was recorded for a range of distances r.

r/cm	V/V
1.0	0.725
1.5	0.483
2.0	0.363
2.5	0.29
3.0	0.242
3.5	0.21

(i) Criticise these results.

(2)

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(ii) It is suggested that V and r are related by the equation

$$V = \frac{k}{r}$$

where k is a constant.

(1) Determine by calculation whether this suggestion is valid.

(2)

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(2) A graph of

$\frac{1}{V}$ is plotted against r.

State how the graph would indicate that the equation is correct.

(1)

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(b) The Hall probe can be replaced with a small coil of wire which is connected to a sensitive voltmeter. The plane of the coil is at right angles to the magnetic field produced by the current-carrying wire.

(i) Explain, with reference to Faraday's law, why the voltmeter reading would be zero.

(2)

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(ii) State **three** different ways in which an e.m.f. could be induced in this coil.

(3)

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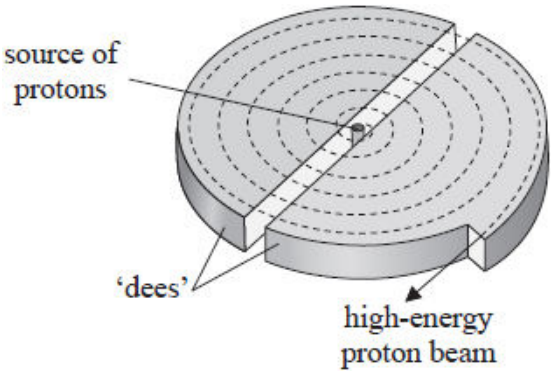
(Total for question = 10 marks)

Q24.

Proton beam therapy is being introduced in the UK as a new cancer treatment.

A beam of protons is accelerated by a cyclotron to an energy of 23 MeV and is then focused onto a tumour.



Developing new cancer treatments is expensive.

Give two possible reasons why money should be provided for the development of this new cancer treatment.

(2)

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(Total for question = 2 marks)

Q25.

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

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

A student determined the length of steel used to make the spring by using vernier calipers to measure the width *w* of the spring.

The length of wire *l* on each loop is given by $l = \pi w$

The student obtained the following values for *w*.

w / mm	15.3	15.2	15.4	15.3

(i) Calculate *l*.

(3)

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.....

l = ...

(ii) Estimate the percentage uncertainty in your value for *l*.

(2)

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.....

% uncertainty in *l* = ...

(iii) Calculate the total length *L* of wire used to make the spring.

(2)

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.....

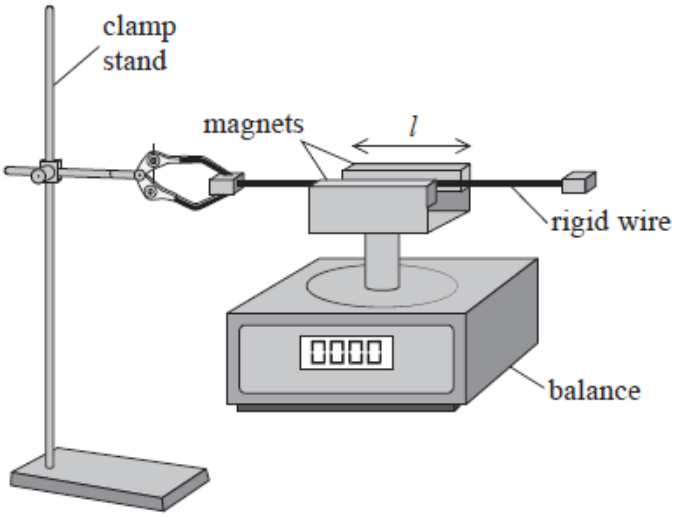
.....

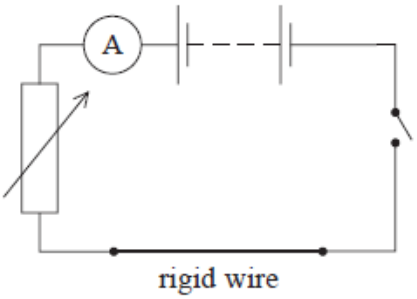
L = ...

(Total for question = 7 marks)

Q26.

A student set up the apparatus shown. A length of rigid wire was held horizontally by a clamp in a uniform magnetic field of flux density *B*.
The circuit connected to the rigid wire is also shown.





With the switch open, the balance was set to zero. When the switch was closed a current *I* in the circuit was recorded by the ammeter and the reading on the balance increased.

The student wrote the following statement

"The balance could read to the nearest 0.01 g, which makes my values for the magnetic force both accurate and precise."

Comment on this statement.

(3)

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(Total for question = 3 marks)

Q27.

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 unit of magnetic flux?

☒ **A** $N\ C^{-1}$

☒ **B** $T\ m^{-2}$

☒ **C** $V\ s$

☒ **D** $Wb\ m^{2}$

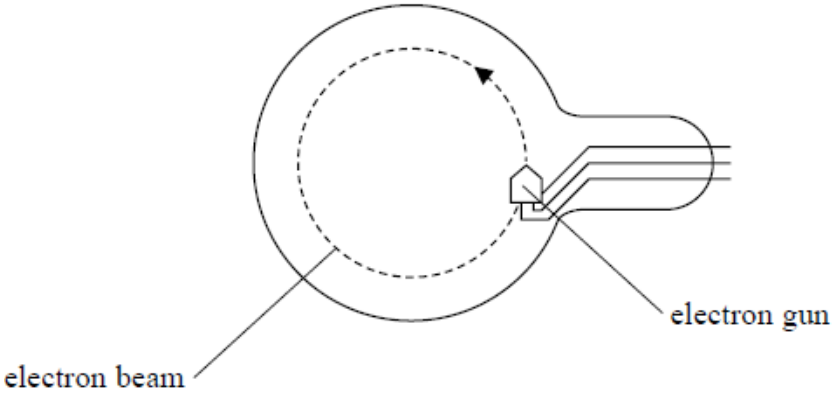
(Total for question = 1 mark)

Q28.

An electron beam tube can be used to demonstrate the deflection of electrons in a uniform magnetic field. The tube contains a very low pressure gas so that electron paths can be seen.

(Source: http://www.klingereducational.com/images/products/thumbs/555571.jpg)

Electrons are emitted from the electron gun travelling vertically upwards into a region of uniform horizontal magnetic flux density.



The magnetic flux density is varied while the speed of the electrons remains constant. The following data is obtained.

Radius/cm	Magnetic flux density/mT	
8.0	0.63	
9.5	0.52	
11.0	0.46	

Theory suggests that the radius of the electron path is inversely proportional to the magnetic flux density.

Analyse the data and comment on this suggestion, you may use the table to show any calculated values.

(4)

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(Total for question = 4 marks)

Q29.

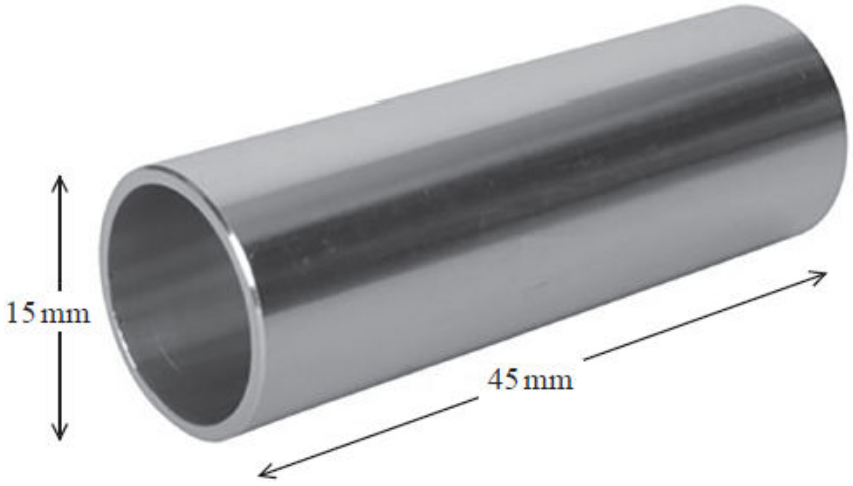
Select the row of the table that correctly identifies a derived unit and a base unit.

	Derived unit	Base unit
☒ A	ampere	joule
☒ B	coulomb	kilogram
☒ C	joule	coulomb
☒ D	kilogram	ampere

(Total for question = 1 mark)

Q30.

An engineer was checking the dimensions of a steel tube. The tube had a length of about 45 mm and an external diameter of about 15 mm as shown.



She used a digital micrometer to measure the diameter of the tube. Before taking the reading she closed the jaws of the micrometer to check for a zero error.

The engineer determined the length of the tube using the micrometer. The reading on the micrometer scale was 45.043 mm. She recorded the reading as 45.0 mm. State why recording a reading of 45.043 mm could not be justified.

(1)

.....

.....

.....

(Total for question = 1 mark)

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	**MAX 3** • There is an inconsistent number of decimal places (1) • No evidence of repeats (1) • Range is too small (1) • Not enough readings between 24 °C and 60 °C (1) • Four (pairs of) readings are not enough (1)		3
(ii)	An explanation that makes reference to the following points: • The (trapped) air may not have been at the temperature of the water (1) • Because water temperature may not be uniform **Or** because transfer of thermal energy through the glass takes time (1) • The volume of the (trapped) air column may not be proportional to the length of the column (1) • Because the bore of the glass tube may not have been uniform (1) • The temperature / length may be read incorrectly (1) • Because there may be a parallax error when reading the temperature or length of the trapped air column (1)	Mark any two pairs	4

(iii)	**Any two from:** • Stir water in beaker (1) • Use digital thermometer **Or** temp sensor & data logger (1) • Put thermometer close to tube (1) • Let tube reach thermal equilibrium before taking readings (1) • Use thermostatically controlled water bath (1) • Take reading in line with scale (1)		**2**

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• use of $s = ut + \frac{1}{2}at^2$ (1) • a = 7.4 m s^{-2} (1)	Example of calculation: $s = ut + \frac{1}{2}at^2 \quad \therefore a = \frac{2 \times 0.75\text{m}}{(0.45\text{s})^2} = 7.41\text{ms}^{-2}$	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
* **(b)**	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5 - 4 / 3 3 - 2 / 2	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	

1	1
0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning	
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	(1) (1) (1)
Answer is partially structured with some linkages and lines of reasoning	1	(1)
Answer has no linkages between	0	(1)

	points and is unstructured		

Indicative content:

- when the magnet falls there is a rate of change of magnetic flux linked with the tube
- the change in flux linkage for the copper tube induces an emf (Faraday's law)
- the induced emf causes a current to flow in the tube
- the induced emf (and current) are in such a direction as the oppose the change in flux linkage (Lenz's law)
- a force is exerted on the magnet opposing its motion
- plastic is not a conductor so no current is induced, shorter time to fall through the tube so teacher is correct

(6)

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)	An explanation that makes reference to the following:			
	• the slit will limit the size of the induced current	(1)		
	• hence a smaller force will oppose the motion of the magnet	(1)		
	• so the time taken to fall will be less	(1)		**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(d)	An explanation that makes reference to the following: • manual timing will be affected by reaction time (1) • the shorter the time being measured the greater the effect that reaction time will have (1)		**(2)**

Q3.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• use of $F = Gm_1m_2/r^2$ **and** use of $F = mr\omega^2$ **Or** use of $F = Gm_1m_2/r^2$ **and** use of $F = mv^2/r$	(1)	MP3 and 4 - for force and angular velocity, both approaches required Example of calculation $T^2 = 4\pi^2r^3 / G\,m_1$	4
	• use of $T = 2\pi/\omega$ **Or** use of $T = 2\pi r/v$	(1)	$T^2 = 4\pi^2 \times (2\,430\,000\text{ m} + 7\,690\,000\text{ m})^3 / 6.67 \times 10^{-11}\text{ N m}^2\text{ kg}^{-2} \times 3.30 \times 10^{23}\text{ kg}$	
	• $T = 12$ hours **Or** $F = 120$ N by gravitational approach and centripetal force approach **Or** $\omega = 1.45 \times 10^{-4}$ radians s^{-1} by gravitational approach and circular motion approach **Or** height of orbit = 7700 km	(1)	$T = 43115$ s = 11.98 hours	
	• Comparative statement consistent with their value(s)	(1)		
(ii)	**Max 2** • Allows satellite to get (much) closer to surface	(1)	For each, the second marking point is dependent on the first. Award second marking point for other sensible advantages	2
	• So more detailed photographs/scans possible	(1)		
	OR			
	• Allows satellite to spend time further from the surface	(1)		
	• So prevents exposure to prolonged heat from planet damaging probe	(1)		
	OR			
	• Satellite varies distance from surface	(1)		
	• So it can take wide-angle and close-up pictures of the planet	(1)		

Q4.

Question number	Acceptable answers	Additional guidance	Mark
	• Diameter is only half a division on the scale **(1) OR** diameter is measured to only 1 sf **(1)** • Hence there is a large percentage uncertainty in measurement of diameter of oil drop **(1)** • Since the volume of the drop is calculated by taking (diameter)^3, the percentage uncertainty in volume becomes very large (3 × % uncertainty in diameter) **(1)** • Suggestion for improvement: use a larger oil drop, use a (vernier) scale capable of reading to nearest 0.1 mm, project image of droplet to larger size **(1)** • Drop will not spread out as an exactly circular area, so diameter reading may be inaccurate **(1)** • Suggestion for improvement: the diameter of spread-out oil drop should be taken a number of times across a number of different directions and a mean calculated **(1)**	Allow for identification of any other valid problems and improvements based on good physics, for example place metre rule across tray so that it is close to the surface.	**6**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	Max 2 • normal car would have much more mass **(1)** • too much area of solar cell needed so impractical **(1)** • going uphill would need far more power **(1)**		**2**

Q6.

Question number	Acceptable answers	Additional guidance	Mark
(i)	A description that makes reference to the following points: • Record nT (where n is at least 5) **(1)** • Divide measurement by n **(1)**		**2**
(ii)	• Anomalies can be spotted **(1)** • Reduce the effect of random error **(1)**		**2**

Q7.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• BFL is smooth and thin with a definite minimum and minimum is in range 0.26 m – 0.28 m **(1)**		1
(ii)	• Values read correctly from candidate's line **(1)** • h to 3 sig fig **and** T to 4 sf **(1)**	Values from their curve to within 1 small square with no unit penalty.	2
	A description that makes reference to the following points: • Plot $T^2 h$ against h^2 **(1)** • C is intercept on $T^2 h$ axis **(1)** **OR** C is the value of $T^2 h$ when h^2 is zero **(1)** • Unit is m s^2 **(1)**		3

Q8.

Question number	Acceptable answers	Additional guidance	Mark
(i)*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5–4 / 3 3–2 / 2 1 / 1 0 / 0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	6

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>(i)* (continued)</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.
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<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table></td><td></td><td></td></tr>
</table>

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>(i)* (continued)</td><td>Indicative content
• Determine the natural frequency by displacing the tea in the cup and measuring the time for oscillations
• Time (5 to 10 or ‘suitable number’ if test run mentioned) full oscillations and divide by the number
• Carry the tea for a known volume of tea for fixed number of steps at a steady pace
• Determine the frequency of the gait
• Measure the quantity of tea remaining
• Repeat for other walking paces</td><td></td><td></td></tr>
<tr><td>(ii)</td><td>A description that makes reference to the following points:
• Plot volume of remaining tea against walking frequency (1)
• Determine whether there is a relationship between step frequency and spillage (1)
• If there is, determine whether maximum spillage occurs at or near the natural frequency (1)</td><td></td><td>3</td></tr>
</table>

Q9.

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**

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	For the proton beam • Proton beam deposits more energy in tumour than the X-rays **(1)** • Proton beam results in less energy absorbed by surrounding tissue compared to X-rays **(1)**	Accept converse statement for both marks related to X-rays	**2**

Q11.

Question number	Acceptable answers	Additional guidance	Mark
	D		**1**

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Correct time(s) read from graph **(1)** • Use of $v = \frac{s}{t}$ **(1)** • $v = 5900\ (\text{m s}^{-1})$ **(1)**	Example of calculation: $t = (1400 - 1000) \times 10^{-6}$ s $v = \frac{2L}{t} = \frac{2 \times 1.18\ \text{m}}{400 \times 10^{-6}\ \text{s}} = 5900\ \text{m s}^{-1}$	**3**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• Substitution into $E = v^2\rho$ ecf from (b)(i) (1) • $E = 2.7 \times 10^{11}$ Pa (1)	MP2 accept N m^{-2} for units 'show that value' gives $E = 2.8 \times 10^{11}$ Pa Example of calculation: $E = v^2\rho = (5900\,\text{m s}^{-1})^2 \times 7850\,\text{kg m}^{-3}$ $\therefore E = 2.73 \times 10^{11}\,\text{Pa}$	2

Q13.

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 % Example of calculation: 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

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • Uncertainty in each reading = 0.05 cm (1) • Uncertainty in r is 2 × uncertainty in each reading (1) • Hence percentage uncertainty = 0.8 % (1)	Example of calculation: % uncertainty= $\frac{0.1\text{ cm}}{(17.5\text{-}5.0)\text{ cm}} \times 100\,\% = 0.8\,\%$ Accept statement that uncertainty in r = 0.1 cm for MP2	3

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Mean straight line with positive intercept on the y-axis (1)		1

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• $C = \frac{K}{4\pi d^2}$ used to show $\frac{1}{\sqrt{C}} \propto d$ (1) **Or** identifies gradient as $\sqrt{\frac{4\pi}{K}}$ which is constant • Since graph is a straight line, data is consistent with this (1) • However, line doesn't pass through the origin (1) • This indicates a <u>systematic</u> error in measuring the distance (1)		4

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of ratio of atoms and atoms per g (1) • Number of nuclei = 2.9×10^{17} (1)	$N = 0.3\text{ g} \times 8.1 \times 10^{21}\text{ g}^{-1} \times 0.012/100$ $= 2.9 \times 10^{17}$	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• use of $\ln 2 = \lambda t_{1/2}$ (1) • use of activity = λN (ecf from (b)(i)) (1) • activity = 5.1 (Bq) (use of show that value gives 5.3 Bq) (1)	$\ln 2 = \lambda \times 1.25 \times 10^9$ years $= \lambda \times (1.25 \times 10^9 \times 365 \times 24 \times 60 \times 60)$ s $\lambda = 1.76 \times 10^{-17}\text{ s}^{-1}$ $A = 1.76 \times 10^{-17}\text{ s}^{-1} \times 2.9 \times 10^{17}$ = 5.1 Bq	3

Question Number	Acceptable answers	Additional guidance	Mark
(iii)	• use of count rate = (counts – background counts) / time (1) • calculates percentage of activity from (b)(ii) **Or** applies 7.5% to activity from (b)(ii) (1) • Comparative statement consistent with their values (1)	**MP3** can only be awarded if Activity from (ii) is used. A clear comparison with the corresponding value must be made e.g. percentage = 0.8 % which is < 7.5 % so not efficient **Or** detects 176 but should detect 379 counts in 10 min, so not efficient **Or** should detect a rate of at least 0.63 Bq, so not efficient Example of calculation Recorded count rate = (176 - 150) ÷ 600 s = 0.04 Bq 0.04 Bq × 100 ÷ 5.1 Bq = 0.78 % (ecf from (b)(ii) for MP3)	3

Question Number	Acceptable answers	Additional guidance	Mark
(iv)	**Max two from** • emissions are in all directions (1) • some emitted particles may be absorbed by the material in the sample (1) • some emitted particles may be absorbed by the window (1) • some emitted particles pass (right) through detector (1)		2

Q17.

Question Number		Additional Guidance	Mark
	Any **two** valid reasons that relate to • the instrument being used to make the measurement (1) • the way in which the measurement is made (1) • the quantity measured not being constant	Examples: resolution of instrument, zero error, parallax error, reaction time Vague statements that there will be random errors or there might be systematic errors not acceptable.	2

Q18.

Question Number	Acceptable Answer		Additional Guidance	
	An explanation that makes reference to the following points: • Shows expansion $\ln \Delta\theta = \ln \Delta\theta_0 - bt$ • Compares with $y = mx + c$ and states that the gradient is b (which is constant)	(1) (1)		2

Q19.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• subtracts background from counts in 60 s	(1)	Example of calculation: 12227 - 22 = 12205 322 - 15 = 307	
	• use of half life × λ = ln 2	(1)	307 = 12205 × $e^{-\ln 2t/5.3\ y}$ ln 307 = ln 12205 - ln2 × t / 5.3 y t = 28 years Year = 2015 - 28 = 1987	
	• use of $A = A_0\ e^{-\lambda t}$	(1)		
	• correct logarithmic conversion	(1)		
	• year = 1987	(1)		**(5)**

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	An explanation that makes reference to one of the following pairs: • if the measurement in 2015 were at a larger distance than X, the count rate would be less (1) • the source would appear to be older than it really is (1) <u>OR</u> • 307 is a relatively small count (1) • the equations apply for large numbers of decays therefore you cannot be sure of the accuracy of the age (1) <u>OR</u> • if the sensitivity of the GM tube were greater in 2015, the count rate would be larger (1) • the source would appear to be younger than it really is (1)	Allow reverse arguments	**(2)**

Q20.

Question Number	Acceptable answers	Additional guidance	Mark
	• Uses V = J/C **Or** V = Nm/C **Or** V = Wb s^{-1} **(1)** • Use of T = N/Cms^{-1} **Or** T = N/Am **Or** T = Wb m^{-2} **Or** Sub of $B=F/IL$ and cancels I's **(1)** • Uses units of n = m^{-3} and completes agreement **(1)** Alternative with base units: • Uses base unit of force = kg m s^{-2} **Or** base unit of energy = kg m^2 s^{-2} **(1)** • Uses base unit of charge = A s **Or** uses A = Cs^{-1} **Or** Sub of $B=F/IL$ and cancel I's or A's **(1)** • Uses base units of n = m^{-3} and completes agreement **(1)**	Example of unit simplification: J/C should equal $\frac{N}{Am} \times A \div m^{-3}Cm$ $= \frac{Nm}{C} = \frac{J}{C}$	**(3)**

Q21.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• Use of $P = VI$ **(1)** • P = 1900 W (1.9 kW) **(1)**	Example of calculation P=230 V × 8.20 A = 1890 W	**2**
(a)(ii)	• Use of $\Delta E = mc\Delta\vartheta$ • Use of $P = \frac{\Delta E}{\Delta t}$ **(1)** • Δt = 112 s or 113 s [106 s or 107 s if show that value used] **(1)** ECF from (a)(i) **(1)**	Example of calculation $\Delta E = 0.655\ \text{kg} \times 4190\ \text{J kg}^{-1}\text{K}^{-1} \times (100 - 22.5)\text{K}$ $\Delta E = 2.13 \times 10^5\ \text{J}$ $\Delta t = \frac{2.13 \times 10^5 \text{J}}{1890\ \text{W}} = 112.5\ \text{s}$	**3**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• After a short time of boiling in the flask, all the apparatus would be at 100 °C. **Or** so energy is not being used to heat up the flask **Or** so steam won't condense in the flask (1)		1
(b)(ii)	• Use of $\Delta E = mL$ (1) • Use of $P = \frac{\Delta E}{\Delta t}$ (1) • 1720 W (1.72 kW) (1)	Example of calculation $\frac{\Delta m}{\Delta t} = \frac{95 \times 10^{-3}\ \text{kg}}{125\ \text{s}}$ $= 7.6 \times 10^{-4}\ \text{kg s}^{-1}$ $\frac{\Delta E}{\Delta t} = 7.6 \times 10^{-4}\ \text{kg s}^{-1}$ $\times 2.26$ $\times 10^{6}\ \text{J kg}^{-1}$ $P = 1720\ \text{J s}^{-1}$	3
(b)(iii)	• Comparison of answer to (a)(i) with answer to (b)(ii) (1) • Not all of the energy from the heater is used to turn water from liquid state into vapour (1) **Or** energy is being used to heat the heat exchanger (1) **Or** not all the steam condenses in the heat exchanger • Some energy is transferred to the surroundings	e.g. rate at which thermal energy is supplied to the water in the flask is greater than rate at which thermal energy is removed from the water in the heat exchanger. If answer for (b)(ii) is bigger than 2 kW,1 mark for correct comparison can be scored.	3

Q22.

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5 - 4</td><td>3</td></tr>
<tr><td>3 - 2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td>
<td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td>
<td></td>
</tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

(6)

Indicative content

- the capacitor can be charged to a higher p.d. than that of the battery
- storing larger amount of energy on capacitor as predicted by $E = \frac{1}{2} CV^2$
- with a low resistance in the bulb the capacitor discharges rapidly
- this produces enough power, $P = W/t$ to produce the flash
- use of $T = RC$ to estimate a value for T (1 ms)
- comparison of time constant with 4 ms

Example of calculation:

$T = 6\ \Omega \times 185\ \mu\text{F} = 1.1\ \text{ms}$

Accept $5T > 4\ \text{ms}$

Q23.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Mark</th></tr>
<tr><td>(a)(i)</td><td>Max 2
Inconsistent number of significant figures or decimal places
Or results recorded to different precision /resolution (1)
No repeat readings (1)
More readings needed up to <u>1.5</u> cm (1)</td><td>2</td></tr>
<tr><td>(a)(ii)(1)</td><td>Attempt to use Vr= constant (1)
Correctly finds two values of Vr from values in table and makes comment
Or uses Vr value with another r or V to confirm corresponding value and makes comment (1)

<u>Example of calculation</u>

<table>
<tr><th>r/cm</th><th>V/V</th><th>rV/ cmV</th></tr>
<tr><td>1.0</td><td>0.725</td><td>0.725</td></tr>
<tr><td>1.5</td><td>0.483</td><td>0.725</td></tr>
<tr><td>2.0</td><td>0.363</td><td>0.726</td></tr>
<tr><td>2.5</td><td>0.29</td><td>0.725</td></tr>
<tr><td>3.0</td><td>0.242</td><td>0.726</td></tr>
<tr><td>3.5</td><td>0.21</td><td>0.735</td></tr>
</table></td><td>2</td></tr>
<tr><td>(a)(ii)(2)</td><td>The graph would be a straight line graph through the origin. (1)
(accept a sketch of a straight line graph going through the origin graph)</td><td>1</td></tr>
<tr><td>(b)(i)</td><td>An e.m.f. is (induced) when there is a changing (magnetic) field/flux. (1)

Because the <u>current</u> is constant there is a constant magnetic field. Or Because the <u>current</u> is constant there isn't a changing magnetic field. (1)</td><td>2</td></tr>
<tr><td>(b)(ii)</td><td>
Movement of either the coil or the wire (1)
Use an alternating current/signal/supply/AC (1)
Switch the current on/off Or change current e.g. use of variable resistor (1)</td><td>3</td></tr>
<tr><td></td><td>Total for question</td><td>10</td></tr>
</table>

Q24.

Question Number	Acceptable answers	Additional guidance	Mark
	Any two from: • Cost of treatment reduced in the long-term (1) • Better chances of success compared with previous treatment (1) • Fewer side effects compared to previous **Or** patient recover more quickly (1)		2

Q25.

Question Number	Acceptable Answer	Additional Guidance Whole question to be clipped together to allow full ECF	Mark
(i)	• Calculation of mean value (1) • Use of $l = \pi w$ (1) • l= 48.1 mm (3 sf) (1)	Example of calculation: $w = \frac{(15.3+15.2+15.4+15.3)}{4} = 15.3$ mm $l = \pi \times 15.3$ mm$= 48.1$ mm	3
(ii)	• Calculation of half range **Or** greatest deviation from mean (1) • % uncertainty = 0.7 % **Allow ECF from (a)(i)** (1)	Example of calculation: Half range value $= \frac{15.4 \text{ mm} - 15.2 \text{ mm}}{2} = 0.1$ mm $\therefore$ % uncertainty$= \frac{0.1 \text{ mm}}{15.3 \text{ mm}} \times 100\ \% = 0.65\ \%$	2
(iii)	• Use of $L = Nl$ with N = 16 **or** 18 (1) • L = 866 mm [0.866 m] **Allow ECF from (a)(i)** (1)	Example of calculation: $L = 18 \times 48.1$ mm $= 866$ mm	2

Q26.

Question Number	Acceptable Answer	Additional Guidance	Mark
	MAX 3 A comment that makes reference to the following points: (1) • High precision means a small spread of values (1) • High accuracy means close to the true value (1) • The student is actually referring to the resolution of the balance (1) • (The student should have stated) there was a low uncertainty in the value of the force **Or** a high resolution doesn't guarantee accuracy/precision		3

Q27.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A is not correct as this is a unit of electric field strength B is not correct as units T m^2 could be used as a unit of flux D is not correct as Wb is a unit of flux		**1**

Q28.

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td></td><td>• Calculates B x r (1)
• Calculate the percentage uncertainty (1)
• Suitable comment on difference from expectation (1)
• Weak conclusion because only three readings (1) OR no repeats (1) OR limited range (1)</td><td>Example of calculation:
%U = (0.06/5.01) x 100% = 1.2%
<table><tr><td>Radius /cm</td><td>Magnetic flux density/mT</td><td></td></tr><tr><td>8.0</td><td>0.63</td><td>5.04</td></tr><tr><td>9.5</td><td>0.52</td><td>4.94</td></tr><tr><td>11.0</td><td>0.46</td><td>5.06</td></tr></table></td><td>4</td></tr>
</table>

Q29.

Question Number	Acceptable Answer	Additional guidance	Mark
	B	coulomb, kilogram	**(1)**

Q30.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• There will be variations in positioning the (jaws of the) micrometer. **Or** There will be variations in the length of the tube (at different points around the circumference of the tube) **(1)**	(Accept any reasonable practical physics alternative)	1