Name: ____

Topic 1: Working as a Physicist Part 3

Date:

Time:

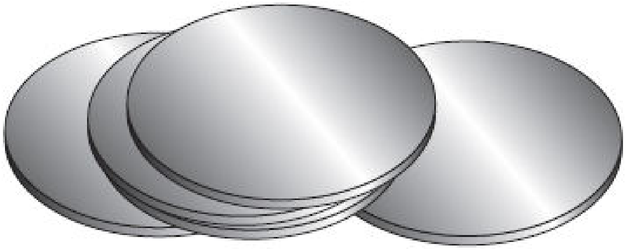
Total marks available:

Total marks achieved: ______

Questions

Q1.

A student is investigating the properties of steel. He has fifty steel discs available.



Each disc has a diameter $d \approx 1.3$ cm and a thickness $t \approx 2$ mm.

State a suitable measuring instrument that could be used with a single disc to measure t.

(1)

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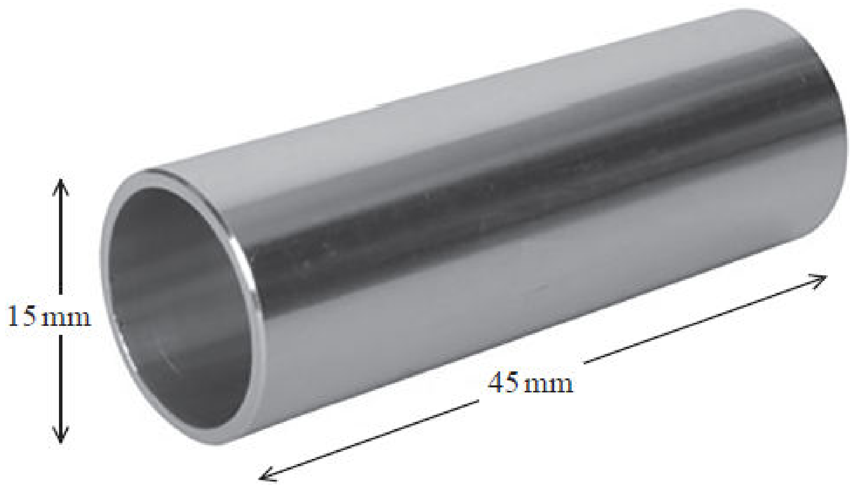
(Total for question = 1 mark)

Q2.

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.

Describe the procedure she should follow to determine an accurate value for the external diameter of the tube.

(3)

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(Total for question = 3 marks)

Q3.

A student released a ping pong ball in front of a metre rule and used a phone camera to record the motion of the ball as it fell. The phone camera captures 60 images per second, which may be played back one image at a time.

This experiment could have been attempted using a stopwatch to measure the time as the ping pong ball fell.

Explain an advantage of using a phone camera rather than a stopwatch.

(2)

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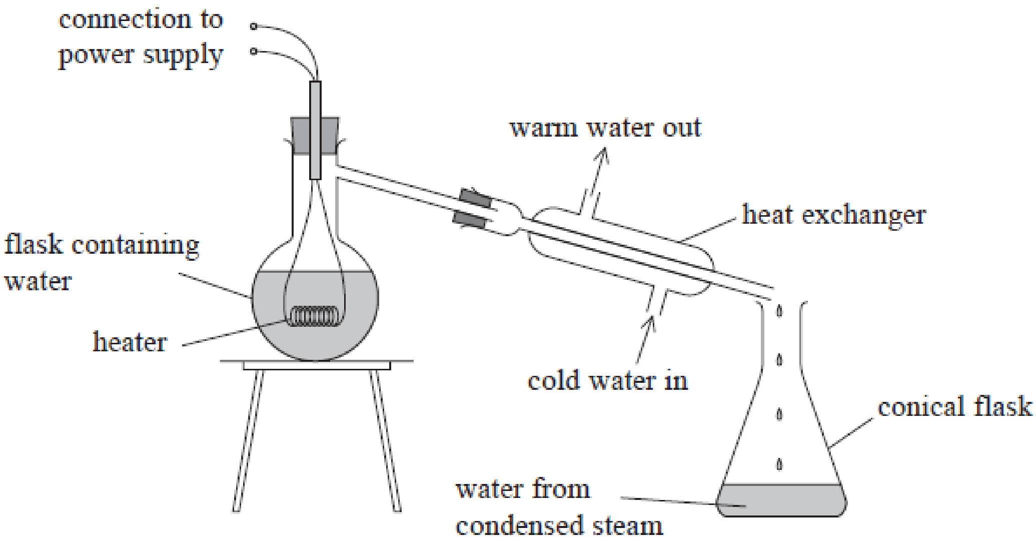
(Total for question = 2 marks)

Q4.

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



State how the apparatus could be modified to minimise the effect of a significant source of error.

(1)

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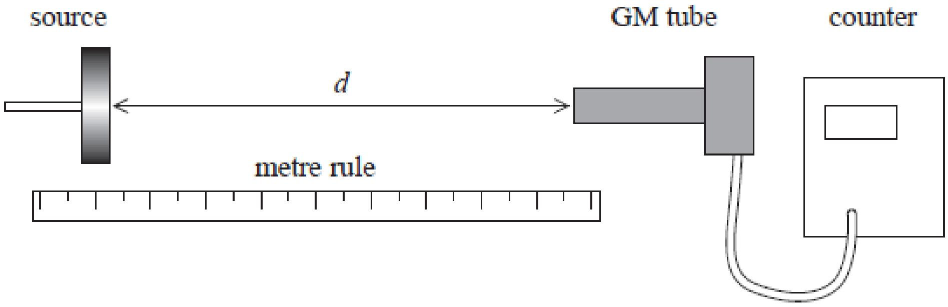
(Total for question = 1 mark)

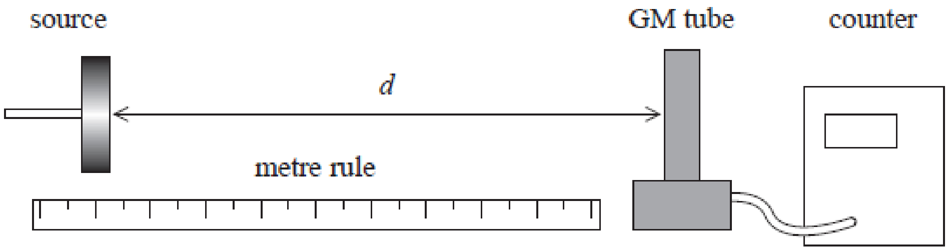
Q5.

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.

His teacher turned the GM tube through 90° so that the side of the tube faced the source as shown below.



(i) Explain why this arrangement could lead to more accurate data.

(2)

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(ii) Explain another modification to the experimental method which would improve the accuracy of the data.

(2)

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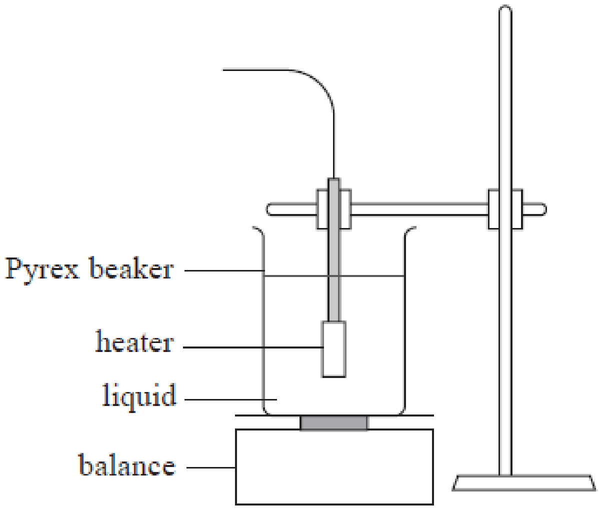
(Total for question = 4 marks)

Q6.

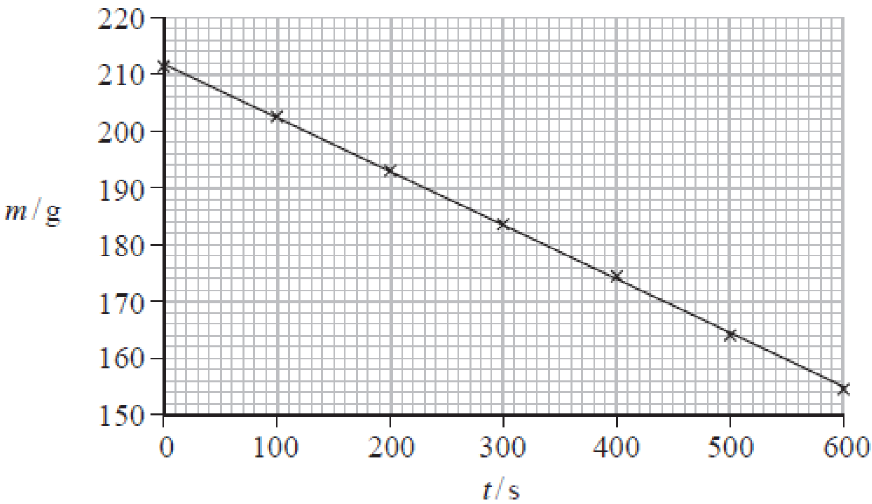
A student determined the latent heat of vaporisation of a liquid using an electrical heater to boil the liquid in a Pyrex beaker.

The apparatus used is shown below.



She connected the heater into a circuit and took measurements of the potential difference *V* and the current *I* for the heater.

The student monitored the mass of the beaker and the liquid *m* over the time *t* for which the liquid was boiling. Her results are plotted on the graph.



The student used her graph to determine a value for the latent heat of the liquid in the beaker. She concluded that the liquid was pure water.

Liquid	Latent heat of vaporisation / MJ kg^{-1}
Pure water	2.26
Weak salt water solution	2.10
Strong salt water solution	2.00

The student's conclusion was

V = 20.5 *V*

I = 10.5 A

Explain how this method might be modified to improve the accuracy of the student's conclusion.

(2)

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(Total for question = 2 marks)

Q7.

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.

The student suggested that the experiment would have been more accurate if a temperature sensor and data logger had been used to collect the data.

Assess the validity of the student's suggestion.

(4)

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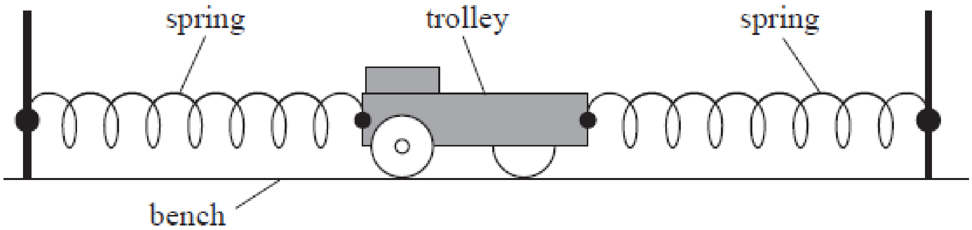
(Total for question = 4 marks)

Q8.

A trolley is attached to the ends of two springs as shown. When displaced from its equilibrium position, the trolley moves with simple harmonic motion.



Another student suggests that a more accurate value for *T* could be obtained by using a position sensor and data logger.

Comment on this suggestion.

(1)

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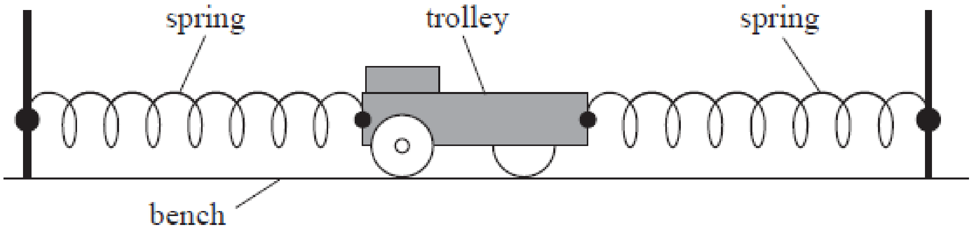
(Total for question = 1 mark)

Q9.

A trolley is attached to the ends of two springs as shown. When displaced from its equilibrium position, the trolley moves with simple harmonic motion.



A student has a stopwatch and metre rule available.

(i) Explain the procedure that the student should follow to make an accurate determination of the time period *T* of the trolley.

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(ii) Describe how the student should use her value of *T* to determine the maximum speed of the trolley.

(3)

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(Total for question = 9 marks)

Q10. On 1st November 2006, the former Russian spy Alexander Litvinenko fell ill. Twenty one days later he died from the radiation effects of polonium-210. Experts suggest that as little as 0.89 μg of polonium-210 would be enough to kill, although Mr Litvinenko's death was linked to a much larger dose of the radioactive isotope. Traces of the isotope were later found in washrooms at five locations around London visited by the Russian.

Polonium-210 has a half life of 138 days.

(a) (i) In a 0.89 μg sample of polonium-210 there are 2.54×10^{15} atoms of polonium. Show that the decay constant for polonium-210 is about $6 \times 10^{-8}\ s^{-1}$, and hence calculate the activity of a sample of this size.

(4)

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Activity = ...

(ii) Calculate the fraction of polonium-210 nuclei that have decayed after a time of 21 days.

(3)

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Fraction decayed = ...

(b) Polonium-210 emits alpha particles. Explain why polonium-210 is virtually harmless unless it is taken into the body.

(2)

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(c) (i) Complete the equation below for the decay of polonium.

(2)

$$^{210}_{84}\text{Po} \rightarrow \, ^{\cdots\cdots}_{\cdots\cdots}\text{Pb} + \, ^{\cdots\cdots}_{\cdots\cdots}\alpha$$

(ii) State why the Pb nuclei would recoil from the alpha particles emitted during the decay.

(1)

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(d) Radioactive decay is said to occur spontaneously and randomly. Explain what is meant by spontaneous and random in this context.

(2)

Spontaneous

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Random

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(e) Suggest why traces of the isotope were found in locations visited by the Russian.

(2)

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(Total for Question = 16 marks)

Q11.

Positron emission tomography (PET) is a nuclear medicine imaging technique. Pairs of gamma rays, produced when positrons from a radioisotope annihilate with electrons, are detected to form the image.

Radioisotopes used in PET scanning are typically isotopes with short half-lives such as carbon-11. Carbon-11 has a half-life of 1220 s and decays by positron emission to stable boron-11. Positrons are the antiparticles to electrons.

(a) Explain what is meant by a radioactive atom.

(2)

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(b) Complete the equation for the decay of carbon-11.

$$^{11}_{6}\text{C} \rightarrow {}^{\dots}_{\dots}\text{B} + {}^{\dots}_{\dots}\text{e}^{+} + {}^{0}_{0}\nu_e$$

(2)

(c) Calculate the energy in joules released in a positron decay of carbon-11.

	Mass / MeV/c^2
positron	0.511
carbon	10 253.6
boron	10 252.2

(3)

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Energy = ... J

(d) Explain why carbon-11 is a relatively safe radioisotope to use within the body.

(2)

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(e) A patient was injected intravenously with a radioactive compound containing carbon-11 with an activity of 1.58×10^6 Bq.

The sample was prepared 3600 s before it was administered to the patient.

Calculate the activity of the sample when it was prepared.

(4)

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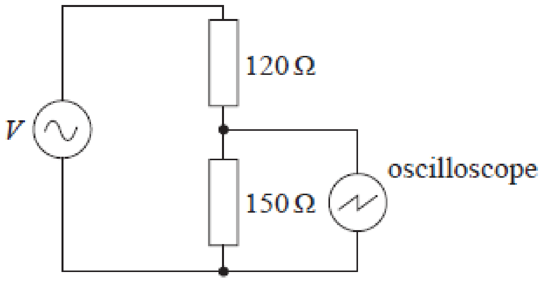
Activity of the sample = ...

(Total for Question = 13 marks)

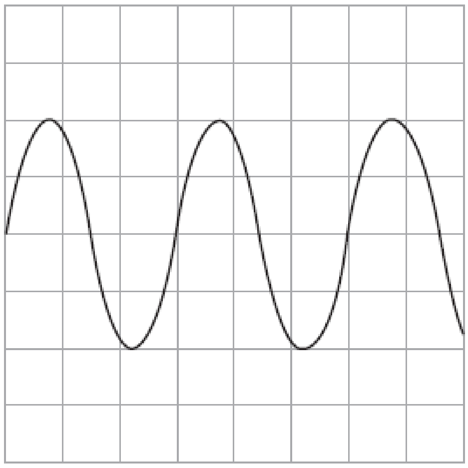
Q12.

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.



The trace obtained on the oscilloscope is shown below.



(i) Determine the peak p.d. across the 150 Ω resistor.

y-sensitivity of oscilloscope = 2.0 V per division

(2)

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Peak p.d. across 150 Ω resistor = ...

(ii) Calculate the root mean square (r.m.s.) value of the current in the circuit.

(3)

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r.m.s. value of current = ...

(iii) Calculate the power dissipated in the circuit.

(3)

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Power dissipated in circuit = ...

(Total for question = 8 marks)

Q13.

Infrared cameras are used to create images that show the infrared radiation emitted by objects.

The photographs show the same scene taken first with an ordinary camera and then with an infrared camera.

Deduce whether the objects shown in the photographs would be expected to have peak emissions at infrared wavelengths. Your answer should include a calculation.

(4)

longest wavelength of visible red light ≈ 700 nm

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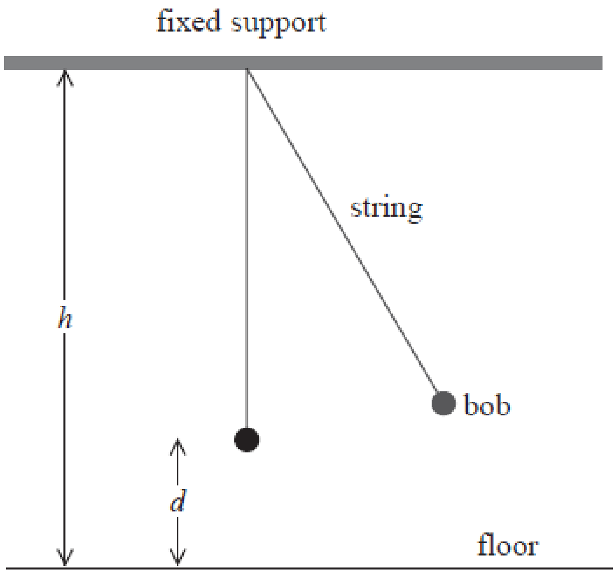
(Total for question = 4 marks)

Q14.

A student carried out an experiment with a pendulum hung from a fixed support. The fixed support was a distance *h* above floor level as shown.



As the student was unable to measure the length of the pendulum directly, she measured the distance *d* from the bob to the floor.

To determine the period *T* of the pendulum, the student used the following method:

- release the bob from its highest position and start a stopwatch
- stop the stopwatch when the bob reaches the same position again.

Criticise the student's method for measuring the period.

(2)

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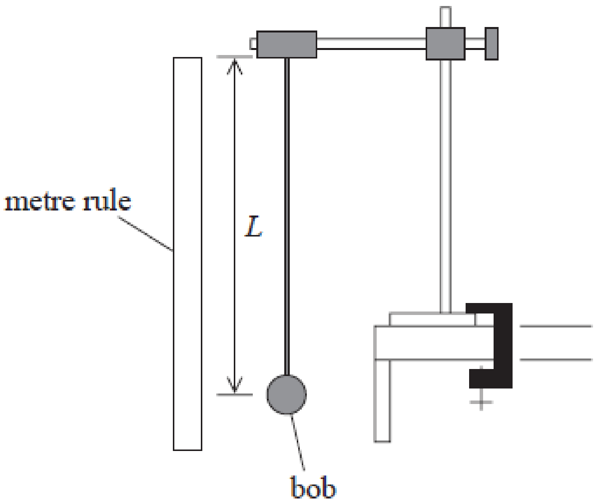
(Total for question = 2 marks)

Q15.

A student set up a "seconds pendulum". This is a simple pendulum for which the time taken to move from the bob's highest position on one side to its highest position on the opposite side is 1.00 s.



(a) Calculate the length *L* required for the pendulum to be a "seconds pendulum".

(2)

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L = ...

(b) The student set the pendulum into oscillation. She used a stopwatch to check the accuracy of the pendulum's period *T*.

Describe the procedure the student should have used to obtain an accurate value for *T*.

(2)

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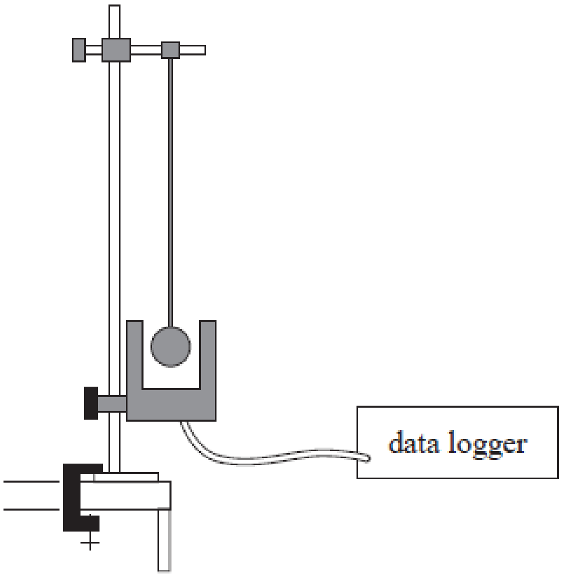
(c) Another student suggested that the uncertainty in the measurement of the time period of the pendulum could be reduced by using a light gate and a data logger. The data logger would record the time between successive interruptions of the light beam. Both the data logger and the stopwatch have a resolution of 0.01 s.



Comment on the student's suggestion of using a data logger rather than a stopwatch.

(4)

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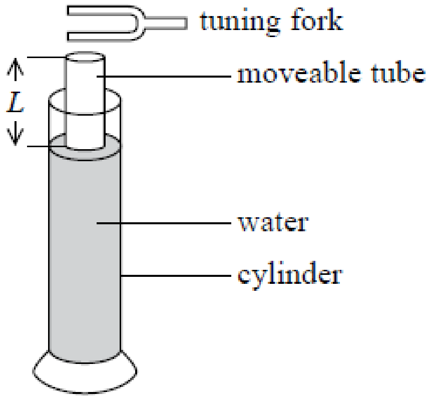
(Total for question = 8 marks)

Q16.

A set of tuning forks is used to find a value for the speed of sound in air.
A tuning fork is struck and then held near to the end of an air column formed by a moveable tube. The moveable tube is used to adjust the length, L, of the air column until a standing wave is set up in the tube and the loudest sound is heard. The experiment is repeated for a number of different tuning forks.



The following results are obtained by a student.

Fork frequency / Hz	Length, L / cm	Speed of sound / m s^{-1}
256	31.9	327
320	25.6	328
512	16.1	330

Student A says "These results show that the speed of sound increases as the frequency of the sound increases".

Student B says "The speed of sound should be the same for each frequency".

By estimating the uncertainties in these results, conclude which of these statements is valid.

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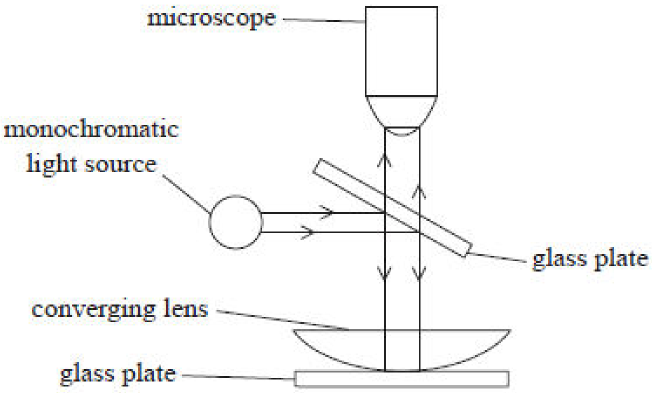
(Total for question = 4 marks)

Q17.

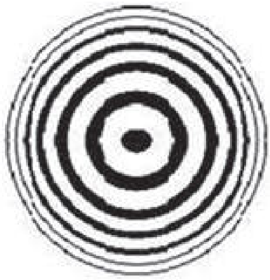
A method to determine the wavelength of light using a converging lens was first proposed by Sir Isaac Newton.

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 table below shows the readings from which the diameter of the first dark circle was calculated.

Position of left-hand side of circle / mm	Position of right-hand side of circle / mm	Diameter / mm
54.79	49.66	5.13

(i) Use these readings to estimate the percentage uncertainty in the diameter due to the resolution of the instrument.

(2)

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Percentage uncertainty = ...

(ii) State why the actual percentage uncertainty would have been greater than the value calculated in (i).

(1)

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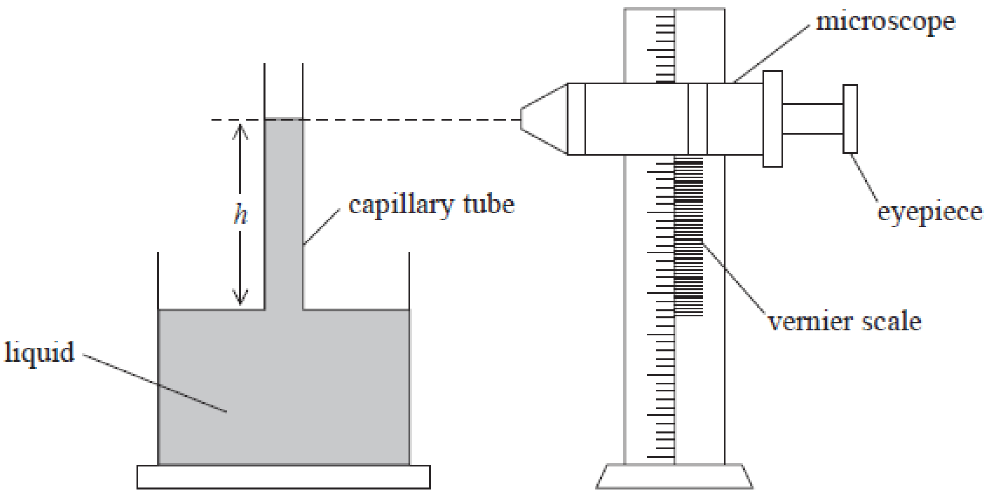
(Total for question = 3 marks)

Q18.

A student measured the height *h* of a liquid column in a capillary tube. She used a travelling microscope to make measurements of the positions of the top and bottom of the liquid column.

The travelling microscope consists of a simple microscope that can be moved vertically along a vernier scale.



The student used a capillary tube with an internal radius *r* equal to 0.10 mm and recorded the following readings from the vernier scale.

Bottom of liquid column / cm	Top of liquid column / cm
12.00	27.10

(i) State the uncertainty in each of these readings.

(1)

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(ii) Calculate the percentage uncertainty in the student's value of *h*.

(2)

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Percentage uncertainty in *h* = ...

(iii) The student repeated the measurement of *h* for capillary tubes of different radii.

The table shows the student's final data.

r / mm	1/*r*	*h* / cm
0.09	11.1	16.56
0.10	10.0	15.1
0.12	8.3	12.6
0.15	6.7	10.33

Criticise the student's recording of the data.

(2)

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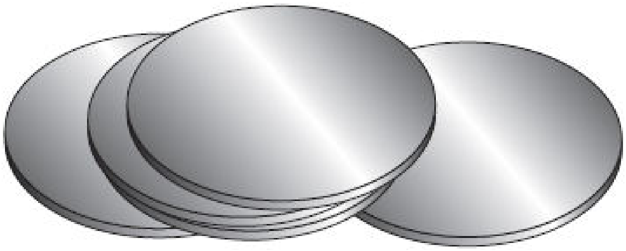
(Total for question = 5 marks)

Q19.

A student is investigating the properties of steel. He has fifty steel discs available.



Each disc has a diameter $d \approx 1.3$ cm and a thickness $t \approx 2$ mm.

A balance which can measure mass with a resolution of 0.2 g is available.

Determine the minimum number of discs that should be placed on the balance together if the percentage uncertainty in the measurement of the mass is to be less than 0.5%.

(4)

density of steel = 7900 kg m^{-3}

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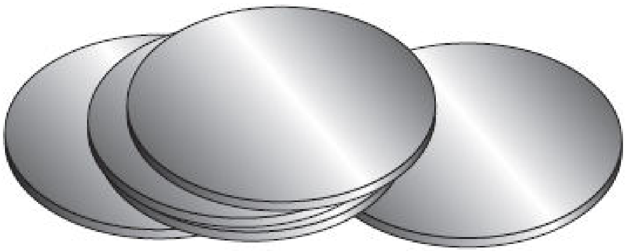
Minimum number of discs = ...

(Total for question = 4 marks)

Q20.

A student is investigating the properties of steel. He has fifty steel discs available.



Each disc has a diameter $d \approx 1.3$ cm and a thickness $t \approx 2$ mm.

The measured uncertainty in *d* is ±0.1 mm and the measured uncertainty for *t* is ±0.05 mm.

Determine the percentage uncertainty in the calculated volume of the disc.

(3)

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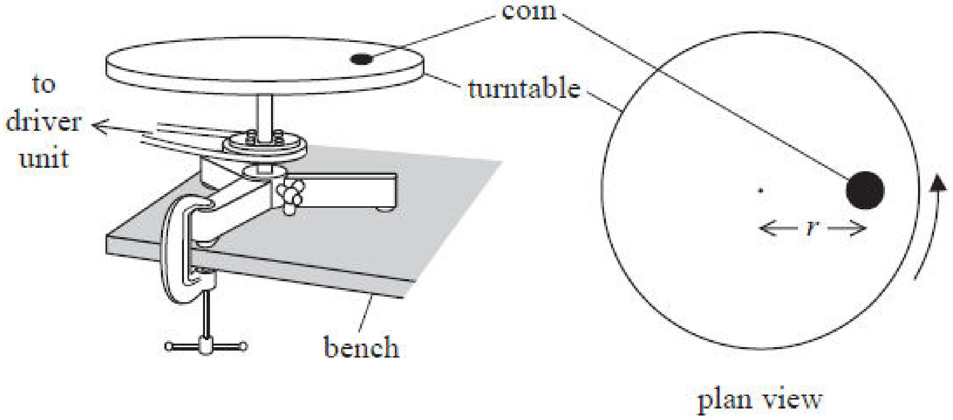
Percentage uncertainty in volume = ...

(Total for question = 3 marks)

Q21.

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 switched on the driver unit and increased the rate of rotation until the coin slid off the turntable. He read the angular velocity ω of the turntable from a digital display on the driver unit. He then replaced the coin in the original position on the turntable and repeated the procedure.

His results are shown.

ω / rad s^{-1}				
0.125	0.112	0.118	0.123	0.116

(i) The student used the results to calculate a mean value of ω.

State the purpose of calculating a mean.

(1)

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(ii) Calculate the percentage uncertainty in the mean value of ω.

(3)

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Percentage uncertainty = ...

(iii) The student used ω and r to calculate the centripetal acceleration of the coin at the instant it started to slide.

Calculate the percentage uncertainty in this centripetal acceleration.

(3)

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Percentage uncertainty = ...

(Total for question = 7 marks)

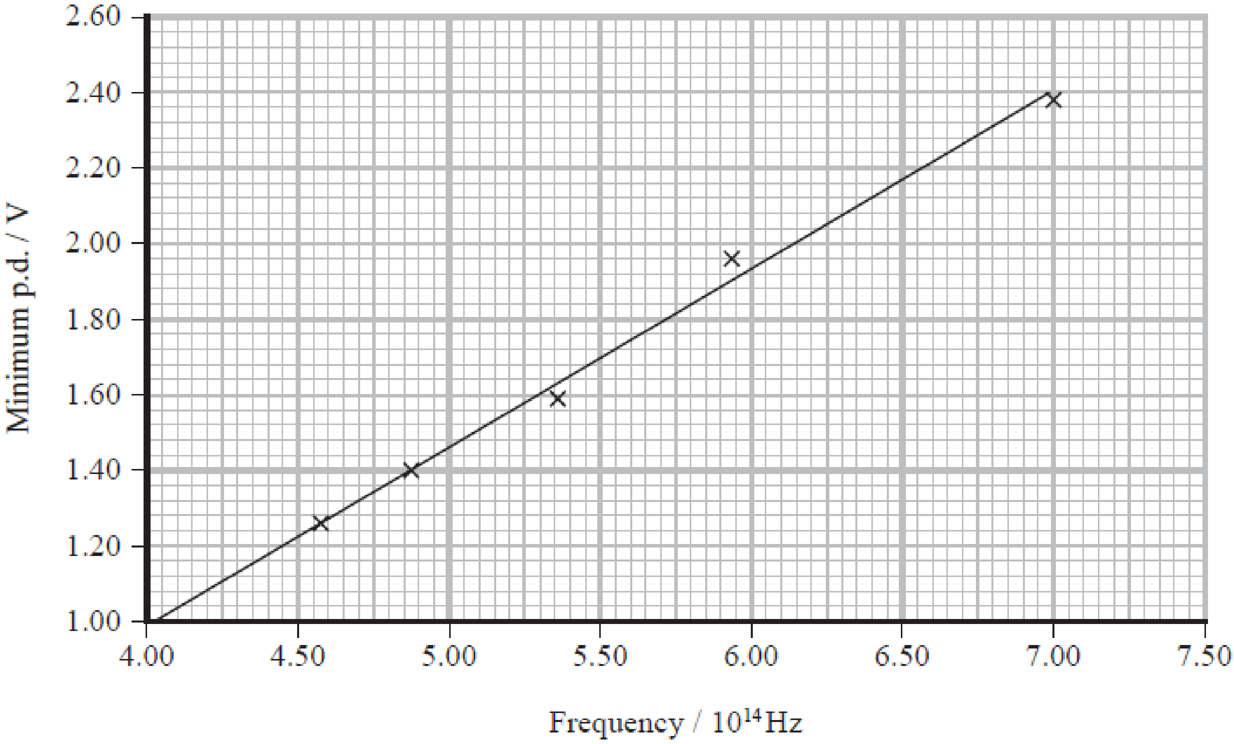
Q22.

The Planck constant can be determined in a school laboratory using light emitting diodes (LEDs).

An LED emits light when the potential difference (p.d.) across it is large enough to transfer sufficient energy to an electron to result in the emission of a photon.
The electron must have energy greater than or equal to the photon energy.

The minimum p.d. required to produce light from LEDs emitting different frequencies was measured by increasing the p.d. from zero until light was first seen.

The graph shows the results.



There are two problems with using LEDs to determine the Planck constant:

- when the p.d. is increased and the LED first emits light it is difficult to see
- the LEDs do not emit a single frequency but also light of frequencies slightly above and below the recorded frequency.

Discuss the extent to which these problems are consistent with obtaining a result from this graph for the Planck constant which is higher than the accepted value.

(3)

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(Total for question = 3 marks)

Q23.

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.

(i) Plot a graph of ln $\Delta\theta$ against t on the grid below.

Use the columns provided in the table to show any processed data.

(5)

(ii) Determine the value of *b*.

(3)

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b = ...

(Total for question = 8 marks)

Q24.

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

The school is required to make a safety inspection of the sources every year.

(i) Explain how the sources can be tested to ensure that each source is in the correct container.

(4)

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(ii) Explain a safety precaution that must be applied during this procedure.

(2)

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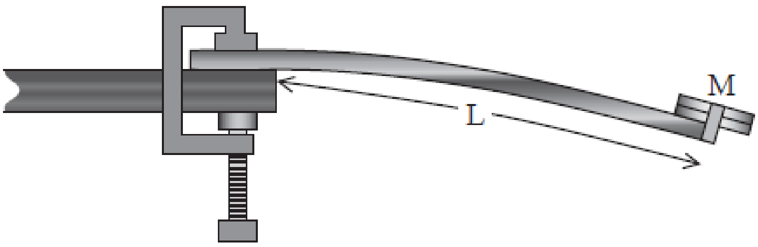
Q25.

A metre rule clamped at one end is an example of a cantilever. The diagram shows an arrangement of a cantilever where a mass *M* is attached to the end of a metre rule and the rule clamped with a free length *L*.



When *M* is displaced, the period of oscillation *T* of the cantilever is related to *L* and the Young modulus *E* of the material of the metre rule by the following equation:

$$T^2 = \frac{KML^3}{E}$$

where *K* is a constant.

A student uses this arrangement to compare the Young modulus values for two metre rules. The metre rules have identical dimensions, but are made from different types of wood.

(a) One of the metre rules is set into oscillation, and the time for 20 oscillations is measured with an electronic stopwatch. This is repeated twice with the same metre rule. The same procedure is carried out for the second metre rule, using an identical mass and free length.

(i) Explain why a pointer placed at the equilibrium position of the end of the metre rule would help the student to obtain repeatable data.

(2)

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(ii) The student collects the following data.

	Time for 20 oscillations t_1 / s	Time for 20 oscillations t_2 / s	Time for 20 oscillations t_3 / s
Metre rule 1	19.3	19.1	19.3
Metre rule 2	21.3	21.5	21.5

Use this data to calculate a value for the ratio E_2/E_1 of the Young modulus values of the two metre rules.

(3)

....

....

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....

E_2/E_1 = ...

(b) The student intends to use a graphical method to determine a value for the Young modulus of one of the metre rules. She decides that she will vary the free length L and measure the time period for each length.

(i) State what variables she should plot.

(1)

y-axis

....

x-axis

....

(ii) Explain how the student can use her graph to determine the Young modulus of the rule. You may assume that she has been provided with the value of K.

(2)

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(c) Explain what the student could do to reduce the uncertainty in her measurement of the time period.

(2)

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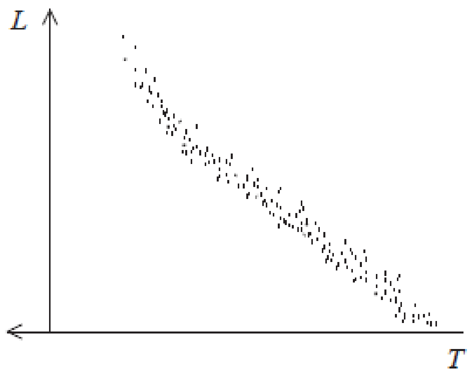
....

(Total for question = 10 marks)

Q26.

A Hertzsprung-Russell (HR) diagram shows how the luminosity *L* depends on the surface temperature *T* for a group of stars.

The HR diagram below is for a young star cluster.



The HR diagram shows an approximately linear relationship for stars in this cluster.

(i) It is suggested that the relationship between luminosity *L* and surface temperature *T* is of the form

$$L = kT^n$$

where *k* and *n* are constants.

Explain why a graph of log *L* against log *T* would give a straight line.

(2)

....

....

....

....

(ii) The table shows data for stars in this cluster.

L / L_{Sun}	T / K		
39.5	10 600		
545	16 400		
20 600	26 800		
535 000	44 900		
1 770 000	53 300		

Plot a graph of log *L* against log *T* on the grid below. Use the columns provided to show any processed data.

(5)

(iii) Determine a value for *n*.

(2)

....

....

....

n = ...

(Total for question = 9 marks)

Q27.

A converging lens has a focal length of less than 20 cm. The lens can be used to produce real images of an illuminated object. You are required to investigate how the image distance from the lens depends upon the object distance from the lens. Your method should lead to a graphical method to determine the focal length of the lens.

(a) Describe how you would obtain the data.

(4)

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(b) Explain how you would use your results to determine a value for the focal length of the lens.

(3)

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(Total for question = 7 marks)

Q28.

A student is carrying out an experiment to determine a value for the acceleration due to gravity *g*. He drops a ball from various heights, which he measured with a metre rule.
The ball has a built in timer which starts when the ball is released and stops when the ball hits the ground.

The student starts by releasing the ball from a height of 1.00 m and measures the time taken for the ball to fall. He repeats this twice.

t_1 /s	t_2 /s	t_3 /s
0.45	0.51	0.43

(a) Use the student's data to calculate a value for *g*.

(3)

....

....

....

....

....

g = ...

(b) Estimate the percentage uncertainty in your value for *g*.

(3)

....

....

....

....

....

Percentage uncertainty = ...

(c) The student then measured the time interval for the ball to fall from a 3.00 m height. Explain how this would improve the value obtained for *g*.

(2)

....

....

....

....

....

(Total for question = 8 marks)

Q29.

Smartphones have built-in cameras. A lens on one side of the smartphone is used to form an image on sensors on the opposite side.

A smartphone camera is able to form clear images of objects at distances from the camera between 4.5 cm and infinity.

(a) Sketch a ray diagram to show the formation of a real image for an object close to the phone.

The diagram is not expected to be to scale.

(4)

(b) Estimate the thickness of a smartphone and use this value to determine the power of a lens that could be used to form a clear image for an object that is 4.5 cm away from the lens.

(3)

....

....

....

....

Power = ...

(Total for question = 7 marks)

Q30.

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 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)

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
	Micrometer (screw gauge) (1)	Accept digital calipers	1

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• (Take readings at) different places/positions (1) • (Take readings at) different orientations/angles (1) • Calculate a mean/average value (1)		3

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • With a phone camera there won't be reaction time errors (when starting and stopping the stopwatch) **Or** with a phone camera the recording can be replayed (a number of times) (1) • So the uncertainty in the measured times will be reduced **Or** this may lead to a more accurate value/time/velocity (1)		2

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• By lagging the flask (to reduce energy transfer to the surroundings) (1)		1

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	**Either** • The GM-tube has a low efficiency for γ-ray detection (1) **Or** there is an increased area exposed to γ-rays • (So) placing the tube side on to the radiation would increase the count rate (1) **Or** • The γ-radiation could be detected anywhere inside the GM-tube (1) • So placing the tube side on to the radiation would reduce the uncertainty in the distance measurement (1)	For low efficiency, accept GM tube poor at detecting γ-rays.	2

Question Number	Acceptable Answer		Additional Guidance	Mark
(ii)	• Record the count (at least) twice and then determine an average count rate **Or** record the count for a much longer time	(1)		
	• This reduces the effect of (random) errors in the measurement of the count rate	(1)		2

Q6.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Use lagging to insulate the container from the surroundings	(1)	Accept "to minimise heat loss to the surroundings"	
	• So that a greater proportion of the energy supplied is used to boil the liquid	(1)		
	Or			
	• Use a heater with a higher electrical power	(1)		
	• So that a shorter time is needed to boil the liquid	(1)		2

Q7.

Question Number	Acceptable Answer		Additional Guidance	
	MAX 3 from • Dataloggers are useful when data changes over a very short (or very long) time scale • Dataloggers are useful when a number of quantities are being measured simultaneously • A comment on the time between temperature readings in this experiment. • It takes longer for the liquid in glass thermometer to respond to temperature changes than the temperature sensor • There may be parallax error in reading from the liquid in glass thermometer • Conclusion consistent with discussion of suitability of using a data logger	(1) (1) (1) (1) (1) (1)		4

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• (The sensor and data logger) eliminates reaction time **Or** data logger will not necessarily record the time with any greater resolution (1)		1

Q9.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • Time n oscillations and divide by n, where n is a large number • Increasing the time (measured) reduces the uncertainty (in T) • Repeat timing and calculate a mean • Use a (fiducial) marker to indicate the reference position • Use equilibrium position as reference position • The trolley is moving fastest at this point so the uncertainty in starting/stopping the stopwatch is least	(1) (1) (1) (1) (1) (1)	Where $n \geq 5$ For equilibrium allow centre/undisplaced	6
(ii)	• Use $\omega = 2\pi/T$ (to calculate a value for ω) **Or** use $\omega = 2\pi f$ with $f = 1/T$ • Measure the maximum displacement of the trolley from the equilibrium position (with the metre rule) • Use $v_{max} = \omega A$ (to calculate a value for the maximum velocity of the trolley)	(1) (1) (1)	For equilibrium allow centre/undisplaced [accept initial displacement for maximum displacement]	3

Q10.

Question Number	Answer		Mark
(a)(i)	Use of $\lambda t_{1/2} = \ln 2$ $\lambda = 5.8 \times 10^{-8}$ (s^{-1}) Use of $\frac{\Delta N}{\Delta t} = -\lambda N$ $\frac{\Delta N}{\Delta t} = (-)1.5 \times 10^{8}$ Bq [accept s^{-1} **Or** counts s^{-1}] <u>Example of calculation</u> $\lambda = \frac{0.693}{(138 \times 24 \times 3600)s} = 5.81 \times 10^{-8} s^{-1}$ $\frac{\Delta N}{\Delta t} = -5.81 \times 10^{-8} s^{-1} \times 2.54 \times 10^{15} = -1.48 \times 10^{8}$ Bq	(1) (1) (1) (1)	**4**
(a)(ii)	Use of $N = N_0 e^{-\lambda t}$ Fraction of nuclei remaining = 0.90 10% of nuclei have decayed [accept 0.1 **Or** 1/10] <u>Example of calculation</u> t = 21 × 24 × 3600 s = 1 814 400 s $\frac{N}{N_0} = e^{-5.81 \times 10^{-8} s^{-1} \times 1.81 \times 10^{6} s}$ $\frac{N}{N_0} = e^{-0.105} = 0.900$ Fraction decayed = 1- 0.9 = 0.1	(1) (1) (1)	**3**

(b)	Idea that α-particles are not able to penetrate the (dead layer of) skin (from outside the body) Damage/danger if energy is transferred to cells/DNA **Or** damage/danger to cells/DNA due to ionisation	(1) (1)	**2**
(c)(i)	$^{210}_{84}Po \rightarrow ^{206}_{82}Pb + ^{4}_{2}\alpha$ Top line correct Bottom line correct	(1) (1)	**2**
(c)(ii)	So that momentum is conserved	(1)	**1**
(d)	Spontaneous means that the decay cannot be influenced by any external factors. Random means that we cannot identify which atom/nucleus will (be the next to) decay **Or** we cannot identify when an individual atom/nucleus will decay **Or** we cannot state exactly how many atoms/nuclei will decay in a set time **Or** we can only estimate the fraction of the total number that will decay in the next time interval	(1) (1)	**2**

(e)	Idea that traces of the isotope will be excreted from the body (and deposited in the surroundings) (1) Idea that the half life is long enough for the activity to be detectable for a long time (1)	**2**
	Total for question	**16**

Q11.

Question Number	Answer	Mark
(a)	A radioactive atom has an unstable nucleus **(1)** which emits α, β, or γ radiation [at least one of α β γ named] **(1)**	**2**
(b)	$C \rightarrow {}^{11}_{5}B + {}^{0}_{1}e^{+} + \nu_e$ Top line correct **(1)** Bottom line correct **(1)**	**2**
(c)	Attempt at mass diference calculation **(1)** Attempt at conversion from (M)eV to J **(1)** $\Delta E = 1.4 \times 10^{-13}$ (J) **(1)** <u>Example of calculation:</u> ΔE= 10 253.6 – 10252.2-0.5 = 0.889 MeV ΔE= 0.889 MeV × 1.6×10^{-13} J MeV^{-1} = 1.42×10^{-13} J	**3**
(d)	The idea that the sample will not produce radiation for very long (because carbon-11 has a relatively short half-life) **(1)** β particles are not very ionising **Or** positrons are not very ionising **Or** boron is safe in small amounts **(1)**	**2**
(e)	Use of $\lambda t_{1/2} = \ln 2$ **(1)** ($\lambda = 5.68 \times 10^{-4}\ s^{-1}$) Use of $A = A_0 e^{-\lambda t}$ **(1)** Use $A = 1.58 \times 10^6$ Bq in $A = A_0 e^{-\lambda t}$ **(1)** $A_0 = 1.2 \times 10^7$ Bq **(1)** <u>Example of calculation:</u> $\lambda = \frac{0.693}{1220\ s} = 5.68 \times 10^{-4}\ s^{-1}$ $1.58 \times 10^6\ Bq = A_0 e^{-5.68\times10^{-4}\ s^{-1} \times 60\times60\ s}$ $A_0 = 1.22 \times 10^7$ Bq	**4**
	Total for question	**13**

Q12.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• Use of *y*-sensitivity value • $V_0 = 4.0$ V	(1) (1)	Example of calculation: $V_0 = 2 \times 2.0\,V = 4.0$ V	2
(ii)	• Use of $I = \frac{V}{R}$ • Use of $I_{rms} = \frac{I_0}{\sqrt{2}}$ **Or** use of $V_{rms} = \frac{V_0}{\sqrt{2}}$ • $I_{rms} = 0.019$ A ECF from(i)	(1) (1) (1)	Example of calculation $I_0 = \frac{4.0\text{ V}}{150\ \Omega} = 0.0267$ A $I_{rms} = \frac{0.0267\text{ A}}{\sqrt{2}} = 0.0189$ A	3
(iii)	• Use of $R = R_1 + R_2$ • Use of $P = I^2R$ (or other valid power equation) • $P = 0.096$ W ECF from(i) and (ii)	(1) (1) (1)	Example of calculation: $R = 150\ \Omega + 120\ \Omega = 270\ \Omega$ $P = I^2R$ $= (0.019\text{ A})^2$ $\times 270\ \Omega = 0.0964$ A	3

Q13.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K • … with sensible temperature expressed in Kelvin • E.g. $\lambda_{max} = 9.89 \times 10^{-6}$ m for 293 K • Value is greater than max wavelength of red light so is in IR region **Or** (if starting from 700 nm) • Use of $\lambda_{max}T = 2.898 \times 10^{-3}$ m K • $T = 4100$ K • Comparison with stated sensible temperature (°C or K) • Temperature is too high so wavelength greater than max wavelength of red light so is in IR region	(1) (1) (1) (1)	Example of calculation $\lambda_{max}T = 2.898 \times 10^{-3}$ m K $\lambda_{max} = 2.898 \times 10^{-3}$ m K / 293 K $\lambda_{max} = 9.89 \times 10^{-6}$ m MP4 consistent with calculation	4

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	Any **TWO** from: • Should have used (a fiducial mark as) a reference point **(1)** • Should have timed from the equilibrium position of the bob **Or** Shouldn't time from the maximum displaced position of the bob **(1)** • Only timed one oscillation **Or** should have times more than one oscillation **(1)** • Should have allowed the pendulum to swing to and fro a few times before starting to time (as the first swing may be different from the others) **(1)**	Accept centre/vertical/undisplaced position for equilibrium position	2

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• Use of $T = 2\pi\sqrt{\frac{L}{g}}$ **(1)** • $L = 0.994$ m **(1)**	Example of calculation: $L = \frac{(2.00\,\text{s})^2 \times 9.81\,\text{m}\,\text{s}^{-2}}{4\pi^2} = 0.994\,\text{m}$	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	A description that makes reference to the following points: • Record nT (where n is at least 5) **and** divide by n (to find T) **(1)** • Time oscillations from equilibrium position of bob using a (fiducial) marker **Or** repeats timings for multiple oscillations and calculate mean **(1)**		2

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	• Using the stopwatch there would be reaction time (1) • The uncertainty in the measurement of the time is larger with the stopwatch than with the data logger. (1) • Timing multiple swings (with stopwatch) reduces %U (1) • Light gates are difficult to use with a pendulum bob. (1)	MP2 dependent on MP1	4

Q16.

Question number	Acceptable answers	Additional guidance	Mark
	• Sensible estimate of uncertainties from readings given **(1)** • Adds percentage uncertainties **(1)** • Hence calculates uncertainty in speed **(1)** • Candidate's conclusion must be supported by their estimate of the uncertainties **(1)**	Example of calculation: %U in L is (0.1/25.6) x 100 % = 0.4 % %U in F is (1/320) x 100 % = 0.3 % %U in speed is 0.7 % 328 x 0.007 = 2 Speed = 328 ± 2 All three results are within the calculated uncertainty so concludes student B is correct	4

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• absolute uncertainty in position × 2 (1) • % uncertainty = 0.2 % (1)	Example of calculation Absolute uncertainty = 2 × 0.005 mm = 0.01 mm $\therefore \%\text{ uncertainty} = \frac{0.01\text{ mm}}{5.13\text{ mm}} \times 100\% = 0.2\,\%$	2
(ii)	• The edges of the dark circle are not clearly defined (1)	Accept: the rings are not perfect circles	1

Q18.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• (±) 0.005 cm	(1)		1
(ii)	• Use of 2 × uncertainty • 0.07 % [1 or 2 sf] ECF answer from (a)(i)	(1) (1)	Example of calculation % uncertainty in h = $\frac{2 \times 0.005\text{cm}}{(27.10 - 12.00\text{cm})} \times 100\%$ % uncertainty in h = 0.066 %	2
(iii)	MAX 2 • No units given for $1/r$ in table • $1/r$ recorded to more significant figures than r • h recorded to an inconsistent number of decimal places • raw data for h not shown	(1) (1) (1) (1)		2

Q19.

Question Number	Acceptable Answer		Additional Guidance	Mark
	Use of $V = \pi r^2 t$ Use of $\rho = \frac{m}{V}$ to find m Use of 0.5% to find total mass needed Number of discs = 10	(1) (1) (1) (1)	Example of calculation $V = \pi r^2 t = \pi \left(\frac{1.3 \times 10^{-2}\text{ m}}{2}\right)^2 \times 2 \times 10^{-3}\text{m}$ $\therefore V = 2.65 \times 10^{-7}\text{m}^3$ $m = \rho V = 7900\text{ kg m}^{-3} \times 2.65 \times 10^{-7}\text{m}^3$ $\therefore m = 2.10 \times 10^{-3}\text{kg}$ $\frac{0.1\text{ g}}{M} = 0.5\%$ $\therefore M = \frac{0.1\text{ g}}{0.5/100} = 20\text{ g}$ $\therefore$ number of discs$= \frac{20\text{ g}}{2.10\text{ g}} = 9.5$	4

Q20.

Question Number	Acceptable Answer	Additional Guidance	Mark
	% uncertainty calculated for d or t (1) % uncertainty calculated for cross sectional area (1) Uncertainty in volume = (±) 4% [accept 4.0%] (1)	Example of calculation uncertainty in $d = \frac{0.1\text{ mm}}{13\text{ mm}} \times 100\% = 0.77\%$ ∴ uncertainty in A = 2 × 0.77% = 1.5% uncertainty in $t = \frac{0.05\text{ mm}}{2\text{ mm}} \times 100\% = 2.5\%$ ∴ uncertainty in V = 1.5% + 2.5% = 4.0 %	3

Q21.

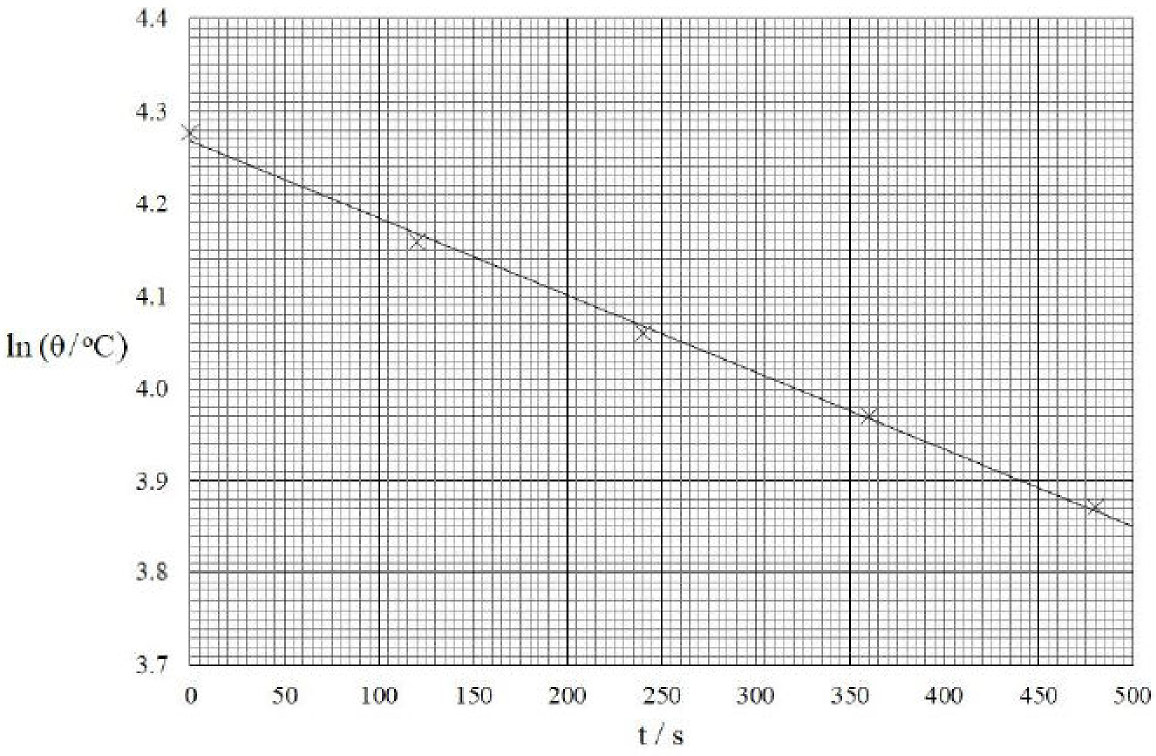
Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• To reduce the effect of random errors (1)		1
(ii)	• Use of data to calculate mean value (1) • Use of half range **Or** Use of greatest deviation from mean (1) • % uncertainty in range 5 % to 6% consistent with student's working (1 or 2 SF) (1)	Example of calculation: $\omega_{av} = \frac{(0.112+0.116+0.118+0.123+0.125)}{5}$ $= 0.119\text{ rad s}^{-1}$ Half range value $= \frac{0.125\text{ mm} - 0.112\text{ mm}}{2} = 0.0065$ ∴ % uncertainty$= \frac{0.0065\text{ mm}}{0.119\text{ mm}} \times 100\ \% = 5.5\ \%$ Use of greatest deviation from mean gives 5.9 %	3
(iii)	• % uncertainty in ω is doubled (1) • Add % uncertainty in r (1) • % uncertainty = 11 % to 13% consistent with student's working (2 or 3 SF)(ecf from (b)(ii)) (1)	Don't penalise sf in both (ii) **and** (iii) Example of calculation: % uncertainty = 5% + 5% + 1% = 11%	3

Q22.

Question Number	Acceptable answers	Additional guidance	Mark
	• (Faint and difficult to see, so may not be seen at the correct p.d. and) recorded p.d. could be too high (1) • (Range of frequencies could mean light is seen before the light at the stated frequency and) recorded p.d. could be too low (1) • Discussion of these points, e.g. opposite effects, could cancel or could be systematic errors and not affect gradient (1)		3

Q23.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th></th><th>Additional Guidance</th><th></th></tr>
<tr><td>(i)</td><td>• ln values correct (at least 2 dec.places)
• Labels and unit
• Scales
• Plots
• Line of best fit</td><td>(1)
(1)
(1)
(1)
(1)</td><td>
<table>
<tr><th>Δθ / °C</th><th>ln (Δθ / °C)</th></tr>
<tr><td>72</td><td>4.277</td></tr>
<tr><td>64</td><td>4.159</td></tr>
<tr><td>58</td><td>4.060</td></tr>
<tr><td>53</td><td>3.970</td></tr>
<tr><td>48</td><td>3.871</td></tr>
</table>
</td><td>5</td></tr>
<tr><td>(ii)</td><td>• Determines gradient using large triangle
• $b = 8 \times 10^{-4} \rightarrow 9 \times 10^{-4}$ (2 or 3 sf)
• Units s^{-1}</td><td>(1)
(1)
(1)</td><td>Example of calculation:
$m = \frac{4.27 - 3.85}{(0 - 500)\ s}$
$= 8.4 \times 10^{-4}\ s^{-1}$</td><td>3</td></tr>
</table>



Q24.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	An explanation that makes reference to the following:			
	• use a GM tube and counter to measure the number of counts in a known time	(1)	Answers may refer to the use of a ratemeter instead of a counter	
	• place a piece of aluminium a few mm thick between the source and the detector	(1)		
	• α and β will not penetrate aluminium but γ will	(1)		
	• so the source that is unchanged is Co 60 and the one with a decreased count is Ra 226	(1)		

	<u>OR</u> use a GM tube and counter to measure the number of counts in a known time • place a strong magnet near the source (1) • α and β will be deviated but γ will not (1) • so the source that is unchanged is Co 60 and the one with a decreased count is Ra 226 (1)		**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	An explanation that makes reference to a precaution and the reason for it • make sure the source remains at a distance of at least 30 cm from your body to minimise exposure (1) <u>OR</u> make sure the source is always pointed away from you to minimise exposure (1) <u>OR</u> only use one source at a time to minimise exposure (1) • the sources emit ionising radiation which can be harmful to your cells (1)		**(2)**

Q25.

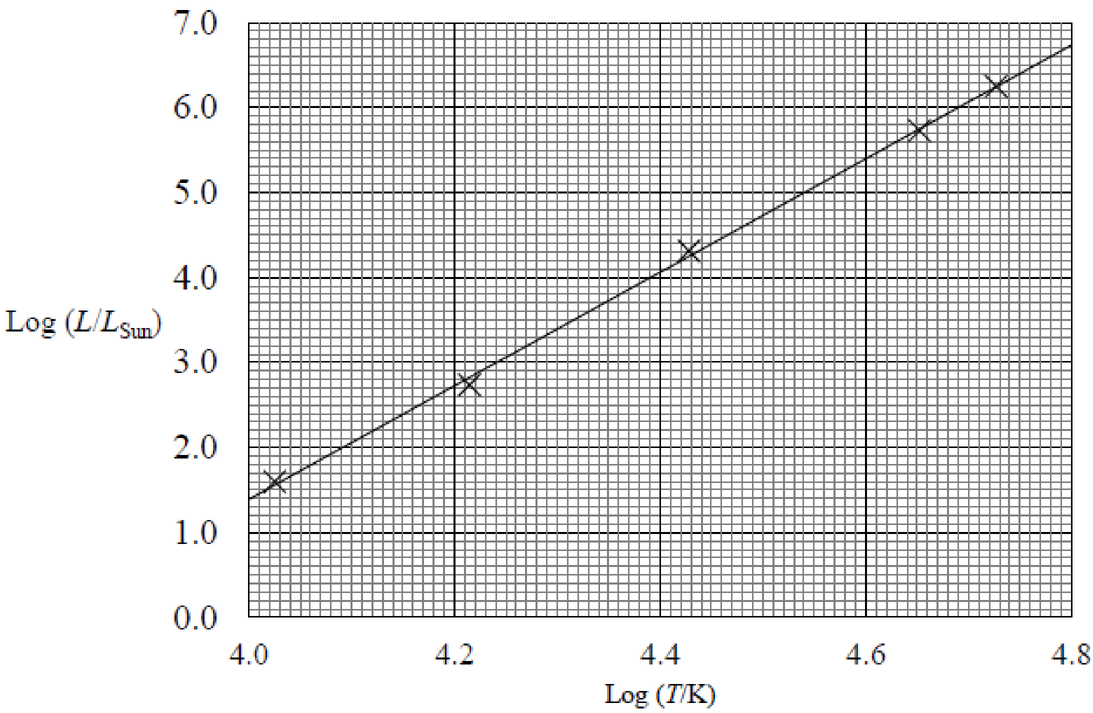
Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• reference point so that reliable timings can be made (1) • end of metre rule will be travelling fastest at its equilibrium position (so uncertainty is determining when rule is at this position is least) (1)		**(2)**
(a)(ii)	• calculate average time period for each ruler [T_1 = 0.962 s, T_2 = 1.072 s] (1) • use of $T^2 \propto \frac{ML^3}{E}$ (1) • $\frac{E_2}{E_1} = 0.80$ (1)	Example of calculation: $T_1 = \frac{19.3\text{s} + 19.1\text{s} + 19.3\text{s}}{60} = 0.962\text{s}$ $T_2 = \frac{21.3\text{s} + 21.5\text{s} + 21.5\text{s}}{60} = 1.07\text{s}$ $T^2 \propto \frac{ML^3}{E} \therefore \frac{E_1}{E_2} = \frac{T_2^2}{T_1^2}$ $\frac{E_2}{E_1} = \frac{T_1^2}{T_2^2} = \left(\frac{0.962\text{s}}{1.07\text{s}}\right)^2 = 0.804$	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	T^2 on y-axis and L^3on x-axis (or vice versa)		**(1)**
(b)(ii)	An explanation that makes reference to the following: • $T^2 = \frac{KML^3}{E}$, so gradient will be $\frac{KM}{E}$(if T^2 plotted against L^3) (1) • $\therefore E = \frac{KM}{\text{gradient}}$, if *K* is known *E* can be determined (1)	If axes reversed in (b)(i), gradient = *E*/*KM* for full credit	**(2)**

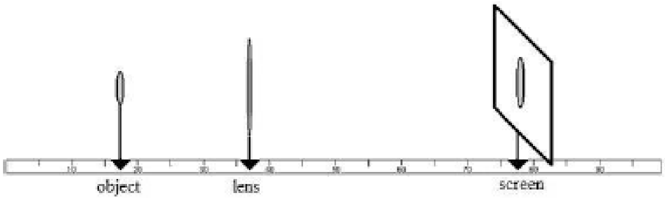
Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	An explanation that makes reference to the following: • time a larger number of oscillations (1) • as the greater the total time the smaller the % uncertainty (1)		**(2)**

Q26.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • Shows expansion $\log L = n \log T + \log k$ • Compares with $y = mx + c$ and states that gradient is n	(1) (1)		2
(ii)	• Log values correct and to 2 or 3 d.p. • Graph axes labelled with quantities and units • Scales • Plots • Line of best fit	(1) (1) (1) (1) (1)	Log (L/L_{Sun}) / Log (T/K): 1.597 / 4.025 2.736 / 4.215 4.314 / 4.428 5.728 / 4.652 6.248 / 4.727	5
(iii)	• Determines gradient using large triangle • n = 6.68 to 2 or 3 SF (accept answers in range 6.6 → 6.9)	(1) (1)		2



Q27.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• diagram with illuminated object, lens, screen and metre rule (1) • lens position adjusted until clear image located on screen (1) • object, image distances calculated from metre rule readings (1) • procedure repeated for at least 4 other positions of the lens (1)	Example of Diagram:  Example of calculation: $\frac{1}{u} = -\frac{1}{v} + \frac{1}{f}$ $y = mx + c$	**(4)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	• 1/*v* plotted against 1/*u* and intercept(s) of line read off (1) • lens equation compared with equation of a straight line (1) • f = 1/intercept (1)	Question 5 to be marked holistically	**(3)**

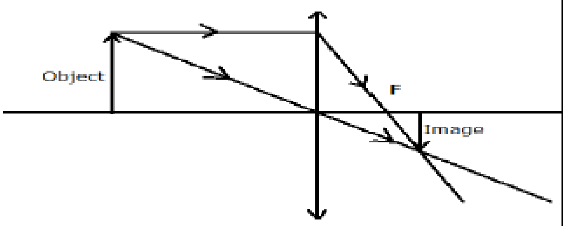
Q28.

Question Number	Acceptable Answer		Additional Guidance	Mark
(a)	• calculates mean value of time • use of $s = ut + \frac{1}{2}at^2$ • a = 9.5 m s^{-2} to 2/3 sf	(1) (1) (1)	<u>Example of calculation:</u> Average time, t_{av} = (0.45 s +0.51 s + 0.43 s)/3 = 0.46 s $s = ut + \frac{1}{2}at^2 \quad \therefore a = \frac{2 \times 1.00\,\text{m}}{(0.46\,\text{s})^2} = 9.45\,\text{m s}^{-2}$	**(3)**

Question Number	Acceptable Answer		Additional Guidance	Mark
(b)	• calculates % uncertainty in t using range / half-range **Or** calculates uncertainty in s using precision of instrument • doubles uncertainty in t • uncertainty in a = 18 %	(1) (1) (1)	<u>Example of calculation:</u> Uncertainty in t = (0.04/0.46) × 100% = 8.7 % Uncertainty in t^2 = 2 × 8.7 % = 17.4 % Uncertainty in s = (0.01/1.00)× 100 % = 1 % Uncertainty in g = 18.4 %	**(3)**

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)	• % uncertainty in t would decrease • longer times identified as key factor in reducing uncertainty in value obtained for *g*	(1) (1)		**(2)**

Q29.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of a correct ray (1) • use of second correct ray (1) • indicates image formed where rays cross (1) • image drawn is real, inverted and diminished (1)	Correct rays are: Ray through the principal focus and parallel to the principal axis Ray parallel to principal axis then through the principal focus Ray through the optical centre of the lens Example of diagram: 	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• use of $1/f = 1/v + 1/u$ for u estimate 4 – 10 mm (1) • use of $P = 1/f$ (1) • P = (120 D to 230 D) (1)	Example of calculation: Assuming the thickness of 8 mm: $1/f = 1/0.008 + 1/0.045$ $P = 1/f$ P = 147 D Full credit for any thicknesses in range 4 – 10 mm	**(3)**

Q30.

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**