Answer ALL questions in the spaces provided.

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

(a) Describe what physicists mean by the terms accuracy and precision.

(2)

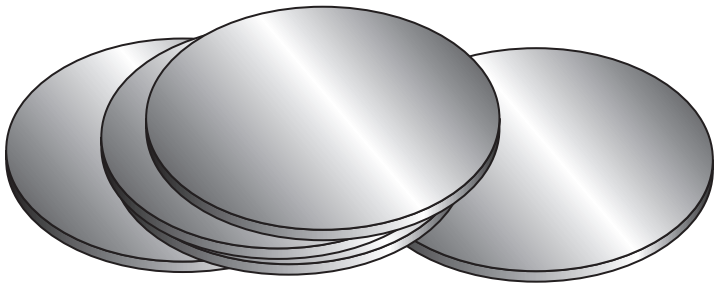
(b) The temperature of the air in a room is measured using a mercury-in-glass thermometer.

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

(2)

(Total for Question 1 = 4 marks)

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

(1)

(b) 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}

Minimum number of discs = ...

(c) The measured uncertainty in d is ±0.1 mm and the measured uncertainty for t is ±0.05 mm.

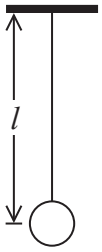
Determine the percentage uncertainty in the calculated volume of the disc.

(3)

Percentage uncertainty in volume = ...

(Total for Question 3 = 8 marks)

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



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

l / cm			
l_1	l_2	l_3	l_4
85.5	86.0	87.5	85.5

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

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

(i) Calculate a more accurate value for l_m.

(2)

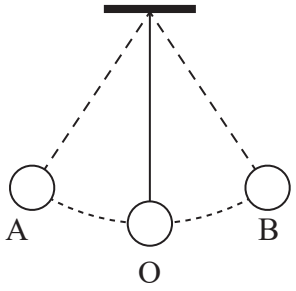
l_m = ...

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

(2)

Time period of oscillations = ...

(b) She sets the pendulum into oscillations with small amplitude and uses a stopwatch to determine the time period.



The student releases the pendulum at A and simultaneously starts the stopwatch. She measures the time taken for 5 oscillations and divides the value by 5. She repeats the procedure twice and calculates a mean time period.

Explain two modifications to the student's method that would improve the value obtained for the time period.

(4)

.....

.....

.....

.....

.....

.....

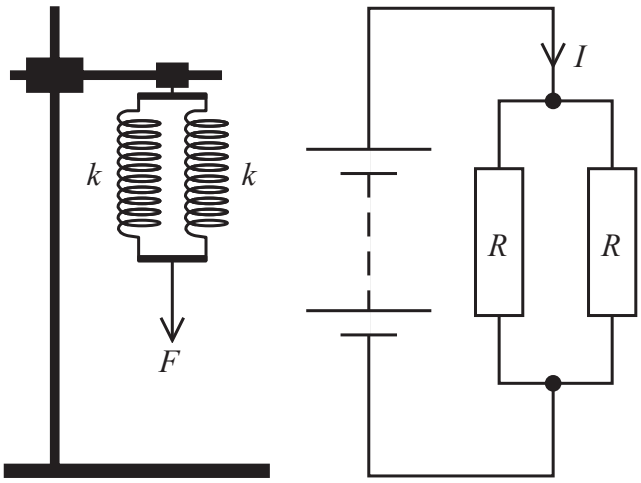
.....

.....

(Total for Question 5 = 8 marks)

6 A student is experimenting with different combinations of springs and recalls that in physics it is often possible to model different physical situations in similar ways.

The student suggests that a parallel combination of springs could be a model for a parallel combination of resistors in a circuit.



(a) Derive an expression for the effective resistance R_{eff} of two resistors R_1 and R_2 connected in parallel in a circuit.

(3)

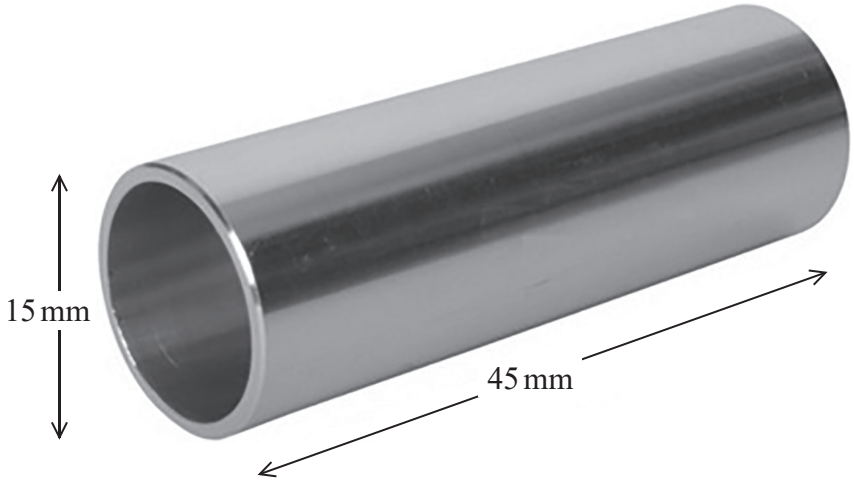
(b) Assess the validity of the student's suggestion by considering the effective stiffness of two identical springs in parallel.

(6)

(Total for Question 6 = 9 marks)

Answer ALL questions in the spaces provided.

1 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.

(a) State the type of error she avoided by doing this.

(1)

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

(3)

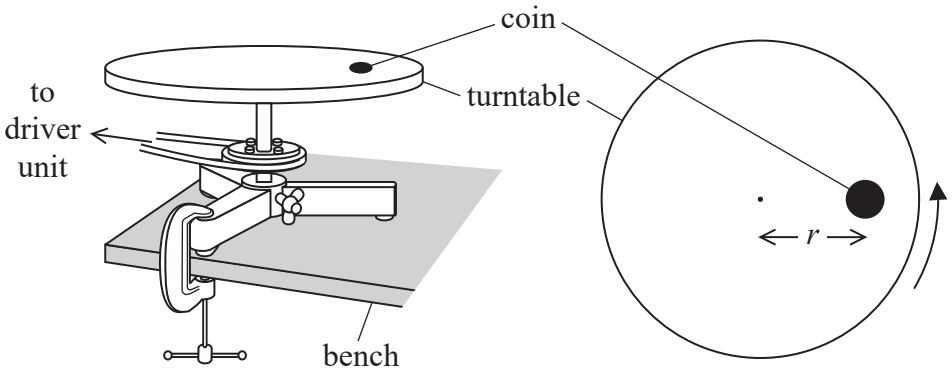
(c) The engineer determined the length of the tube using the micrometer. The reading on the micrometer scale was 45.043 mm. She recorded the reading as 45.0 mm.
State why recording a reading of 45.043 mm could not be justified.

(1)

(Total for Question 1 = 5 marks)

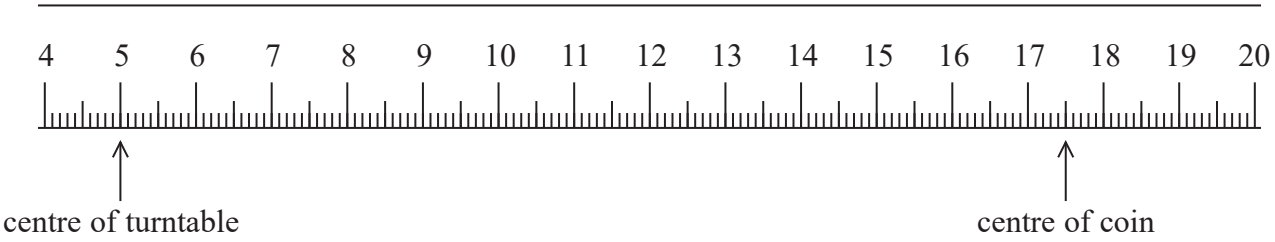
3 A student was investigating the forces involved in circular motion.

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.



plan view

(a) 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)

(b) 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)

.....

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

(3)

.....

.....

.....

.....

.....

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)

.....

.....

.....

.....

Percentage uncertainty = ...

(c) The student repeated the procedure with different values of r.

Explain how the value of ω at which the coin started to slide varied as r increased.

(3)

.....

.....

.....

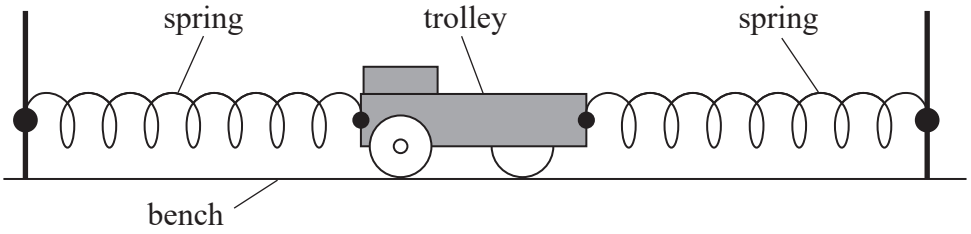
.....

.....

.....

(Total for Question 3 = 13 marks)

7 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) 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.

(6)

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

(3)

(b) 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)

(c) The student displaces the trolley a greater distance from the equilibrium position, so the amplitude of oscillation is doubled. The trolley still moves with simple harmonic motion.

Explain how the maximum kinetic energy of the trolley will change.

(3)

(Total for Question 7 = 13 marks)

9 The Beaufort scale is used to describe wind intensity. On this scale the average wind speed v increases with the Beaufort scale value B.

The relationship between v and B is given by

$$v = kB^p$$

where k and p are constants.

(a) Explain why a graph of $\log v$ against $\log B$ should give a straight line.

(2)

.....

.....

.....

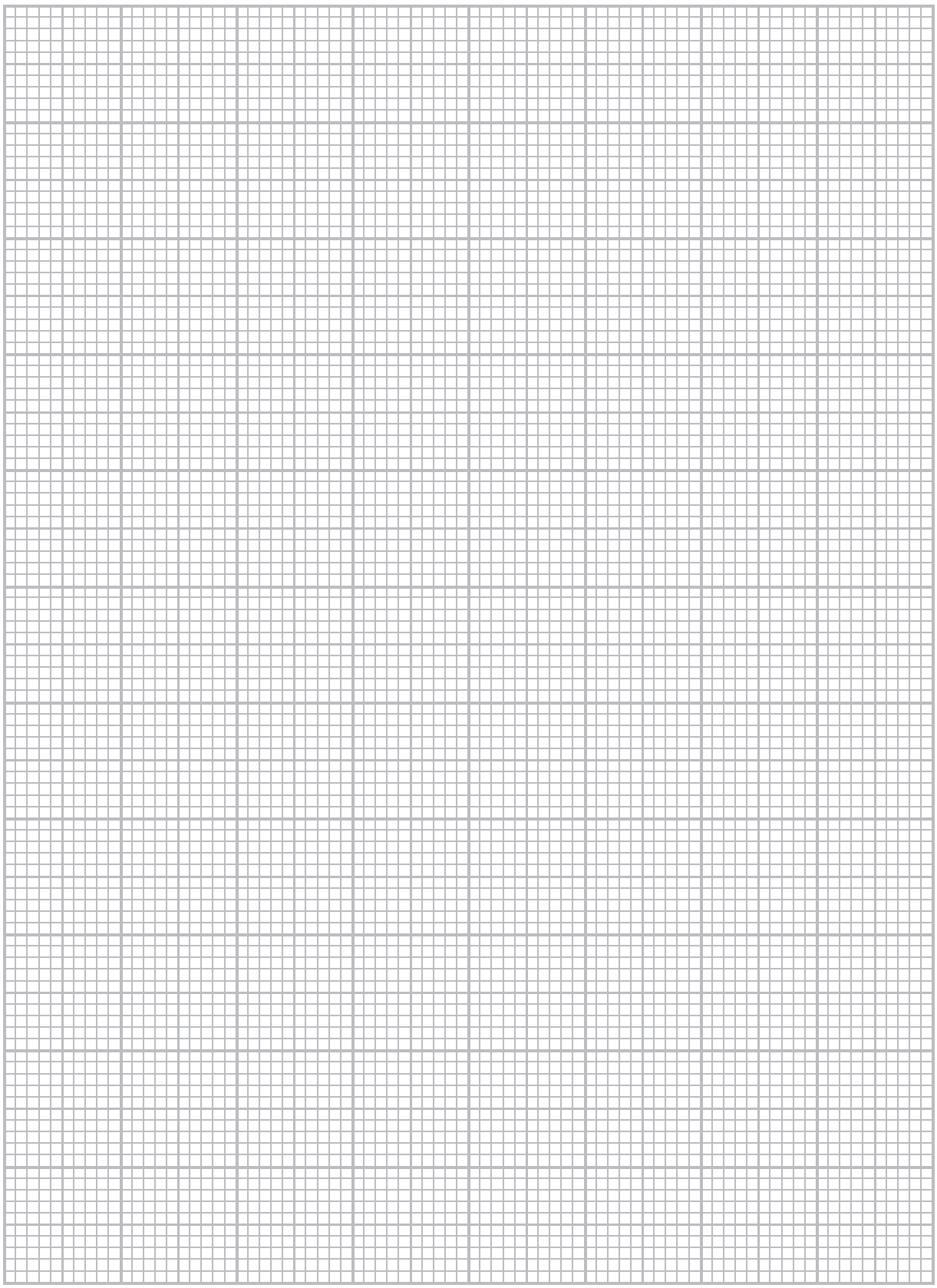
.....

(b) The table gives some values of v and corresponding values of B.

v / m s^{-1}	B		
2.00	1		
10.0	3		
21.5	5		
36.0	7		
50.5	9		
68.0	11		

(i) Plot a graph of $\log v$ against $\log B$ on the grid opposite.
Use the columns provided to show any processed data.

(5)



(ii) Determine the values of p and k.

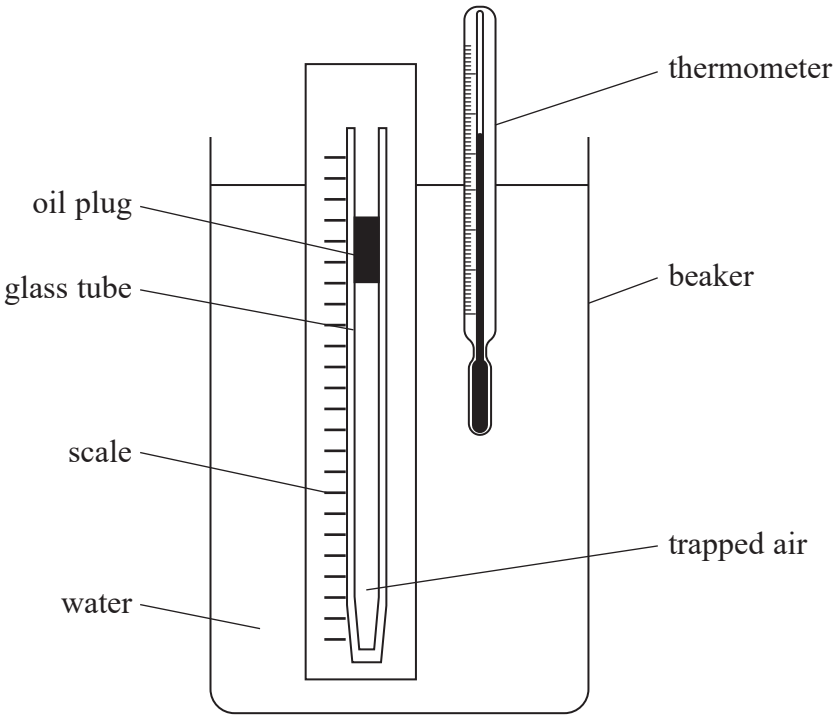
(3)

$p =$ .....

$k =$ .....

(Total for Question 9 = 10 marks)

11 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

(a) (i) Criticise the student's results.

(3)

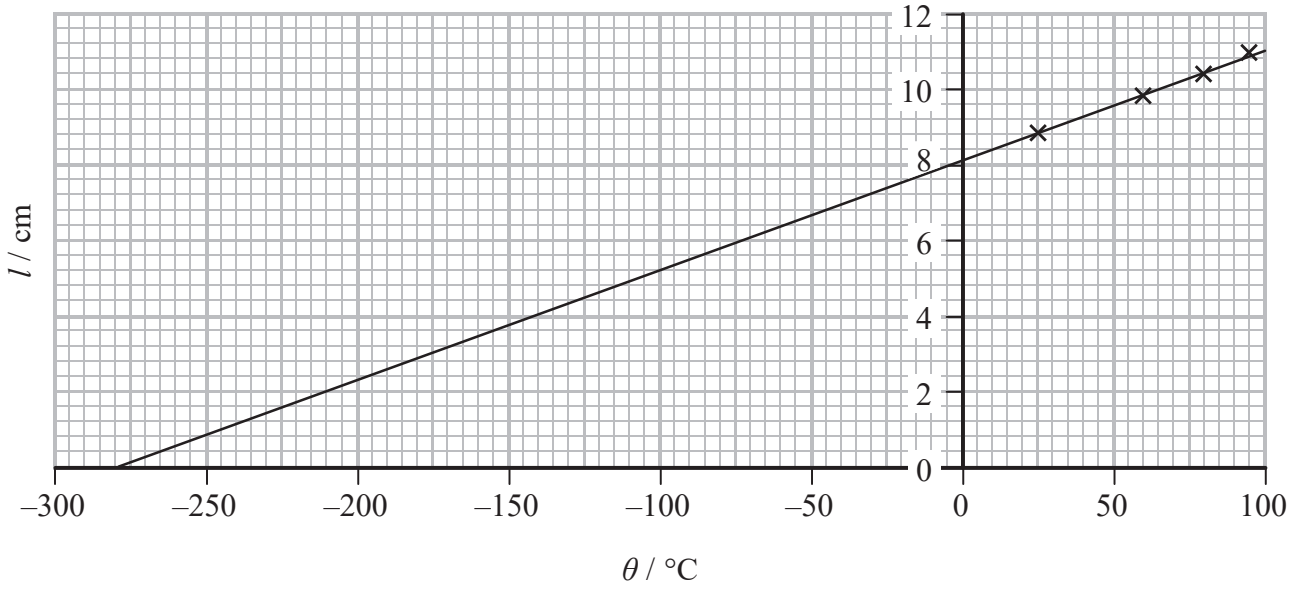
(ii) Explain two possible sources of error in this investigation.

(4)

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

(2)

(b) The student plotted a graph of l against θ as shown.



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

(3)

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

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

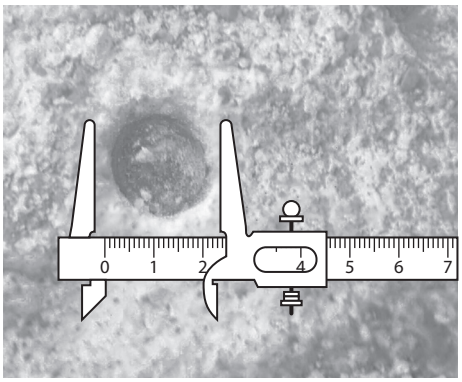
Discuss the student's conclusion.

(4)

(Total for Question 11 = 16 marks)

12 Impact craters are formed when meteorites strike the surface of a planet. A student investigated some factors that might influence the formation of impact craters. He did this by dropping spheres of modelling clay into a tray of sand.

The diameter of the crater produced by each sphere was measured using vernier calipers as shown.



This process was repeated for spheres of different diameters.

(a) In one test, the spheres were dropped from the same height.

Determine the factor by which the kinetic energy of the sphere just before impact increases when the sphere diameter is increased from 2.0 cm to 4.0 cm.

(3)

Factor = ...

*(b) The student also dropped the spheres from different heights. His results are shown in the table.

Drop height / m	Sphere diameter / cm	Crater diameter / cm
0.30	2.0	3.6
	4.0	7.0
	6.0	6.8
0.60	2.0	4.8
	4.0	7.5
	6.0	7.3
0.90	2.0	5.6
	4.0	8.0
	6.0	8.3

The student wrote the following conclusion:

"The greater the drop height, the greater the diameter of the crater formed when a sphere hits the sand. This is because the impact velocity increases as the drop height is increased. As the speed of the sphere increases the diameter of the crater formed also increases. Also, the bigger the sphere the bigger the crater."

Assess the validity of the student's conclusion.

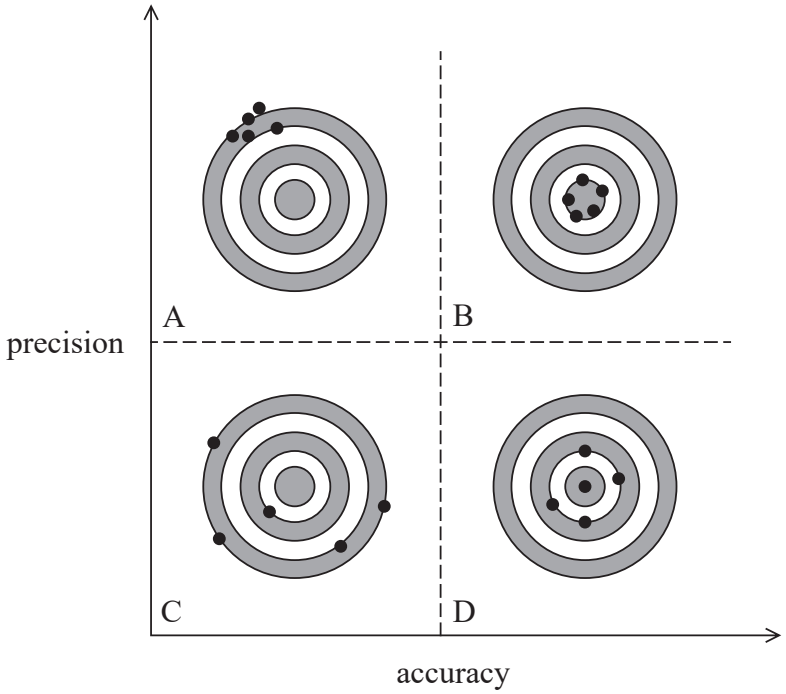
(6)

(Total for Question 12 = 9 marks)

TOTAL FOR PAPER = 120 MARKS

Answer ALL questions in the spaces provided.

1 A teacher is explaining the differences between accuracy and precision to her students. She draws the following diagram, which shows different degrees of accuracy and precision. The circles represent targets A, B, C and D and the dots represent arrows hitting the targets.



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

(4)

(Total for Question 1 = 4 marks)

2 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.

(a) The ball was dropped from a height such that it reached its terminal velocity as it passed the metre rule.

(i) Explain how the terminal velocity of the ball could be determined using the phone camera recording.

(4)

(ii) Explain how a systematic error could affect the value obtained for the terminal velocity.

(2)

(b) 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)

(Total for Question 2 = 8 marks)

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

(a) The mean diameter of the crystal ball was measured to be 5.06 cm and the mass of the crystal ball was measured to be 175 g.

Show that the density of the material of the crystal ball is about 2600 kg m^{-3}.

(3)

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

The table gives the densities of clarified quartz and glass.

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

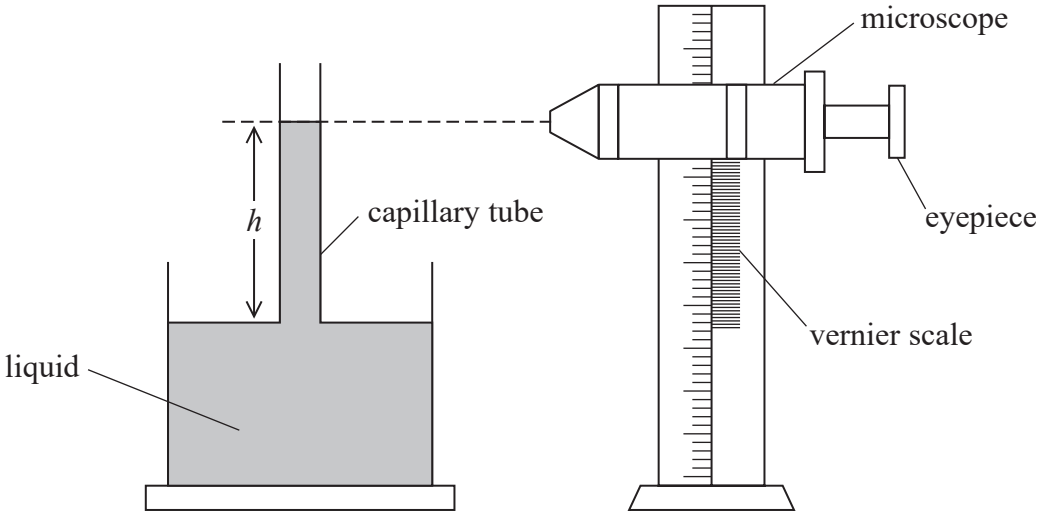
Determine whether the crystal ball was genuine.

(6)

(Total for Question 3 = 9 marks)

5 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.



(a) 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)

.....

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

(2)

.....

.....

.....

.....

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)

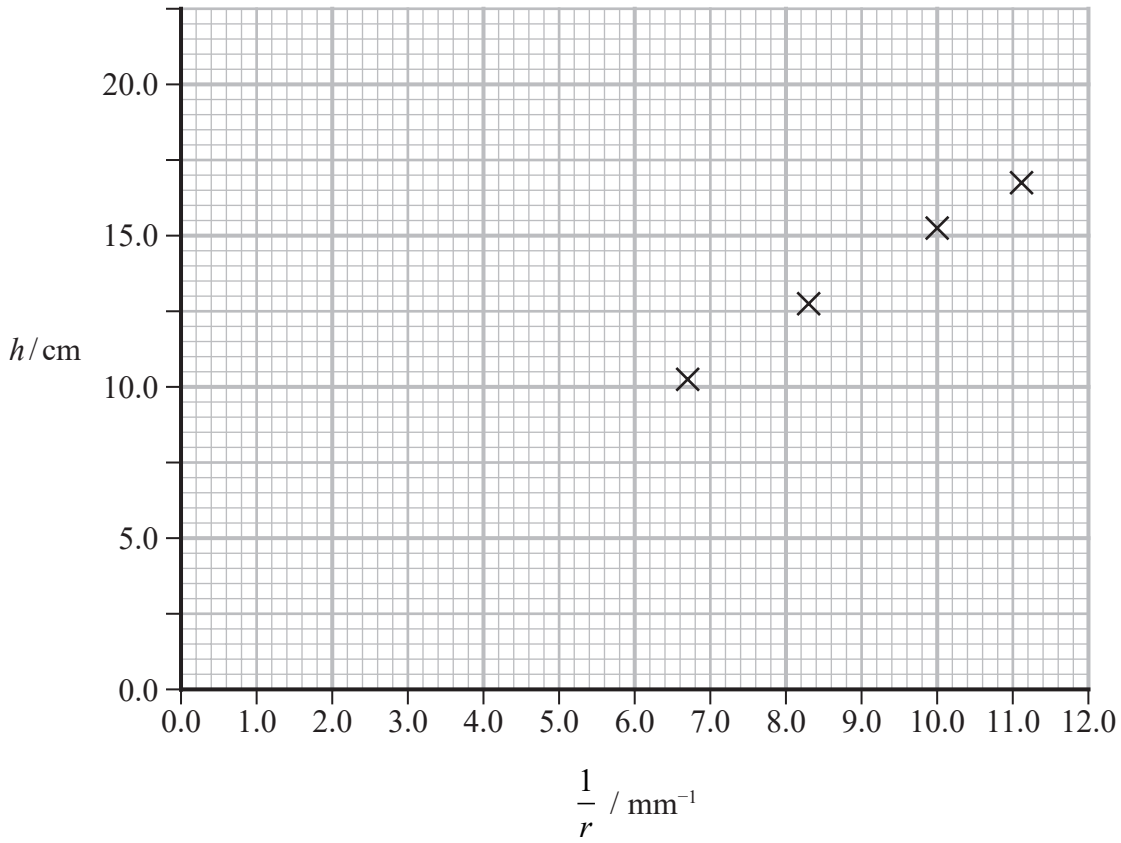
.....

.....

.....

.....

(b) The student plotted the following graph.



(i) Determine the height of the liquid column that the student could expect for a tube with an internal radius of 0.11 mm.

(3)

Height of liquid column = ...

(ii) In her notes it stated that

$$h = \frac{k}{r} \qquad \text{where } k \text{ is constant}$$

Assess the extent to which the student's data supports this relationship.

(4)

(Total for Question 5 = 12 marks)

2 A student was given a box of identical glass microscope slides and asked to determine the density of the glass. She used a micrometer to measure the thickness of one of the slides. She repeated this measurement twice in different places and calculated a mean value for the thickness. The thickness of each slide was approximately 1 mm.

(a) Explain how she should have measured the thickness of the slides in order to minimise the percentage uncertainty.

(2)

(b) In her report she wrote

"My value for the mass of the glass slides was precise, because I measured the mass using an electronic balance which was accurate to the nearest 0.01g. I reduced the effect of random error by repeating the measurement several times."

Comment on this statement.

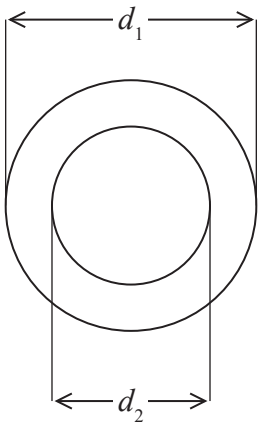
(4)

(Total for Question 2 = 6 marks)

11 The photograph shows some metal washers. A student carried out an experiment to determine the density of the metal the washers are made from.

(Source: © NJH Photography/Shutterstock)

Each washer has a diameter d_1 of about 4.5 cm. The internal diameter d_2 of each washer is about 2.5 cm. Each washer has a thickness t of about 4 mm.



(a) The student used a half metre rule to make measurements of a washer.

Comment on the student's choice of measuring instrument.

(3)

(b) The student measured t for each of the five washers and then calculated a mean value.

Explain how the student could modify her method to obtain a more accurate mean value for t.

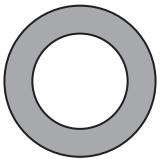
(3)

(c) The student obtained the following mean values.

$d_1 = 4.52\,\text{cm} \pm 0.02\,\text{cm}$

$d_2 = 2.53\,\text{cm} \pm 0.02\,\text{cm}$

She calculated the area A of a washer indicated by the shaded section below.



She used the formula $A = \frac{\pi}{4}(d_1 + d_2)(d_1 - d_2)$

(i) Show that the percentage uncertainty in her value for the area of a washer is about 3%.

(4)

(ii) The student obtained the following values of t for each of the five washers.

t / mm	4.3	4.2	4.1	3.9	4.0

The table shows the density of iron and steel.

Metal	Iron	Steel
Density / g cm^{-3}	6.9	7.9

Deduce whether the washers are made from iron or steel.

mean mass of a washer = 32.0 g

The uncertainty in the mass is negligible.

(6)

(Total for Question 11 = 16 marks)

TOTAL FOR PAPER = 120 MARKS