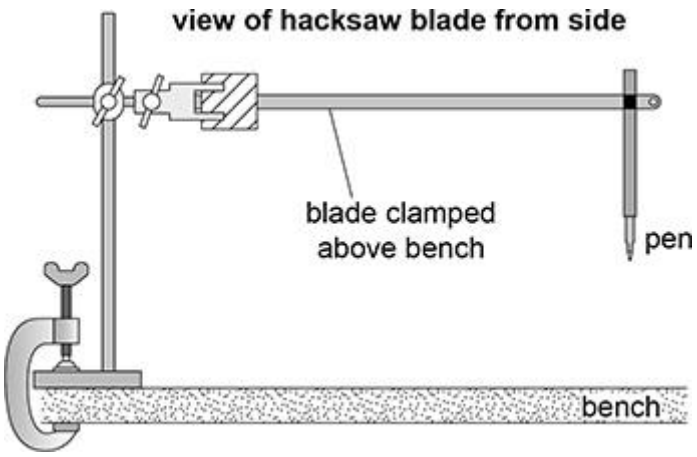
Q1.

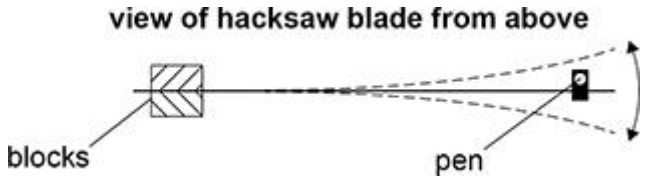
A hacksaw blade is a thin flexible strip of metal.
Figure 1 shows a blade clamped between two blocks above a horizontal bench.
A pen is attached to the free end of the blade.

Figure 1



The free end of the blade is displaced and released.
The blade oscillates in a horizontal plane as shown in **Figure 2**.

Figure 2



The time for each oscillation is T.

(a) The table below shows repeated measurements of $60T$.

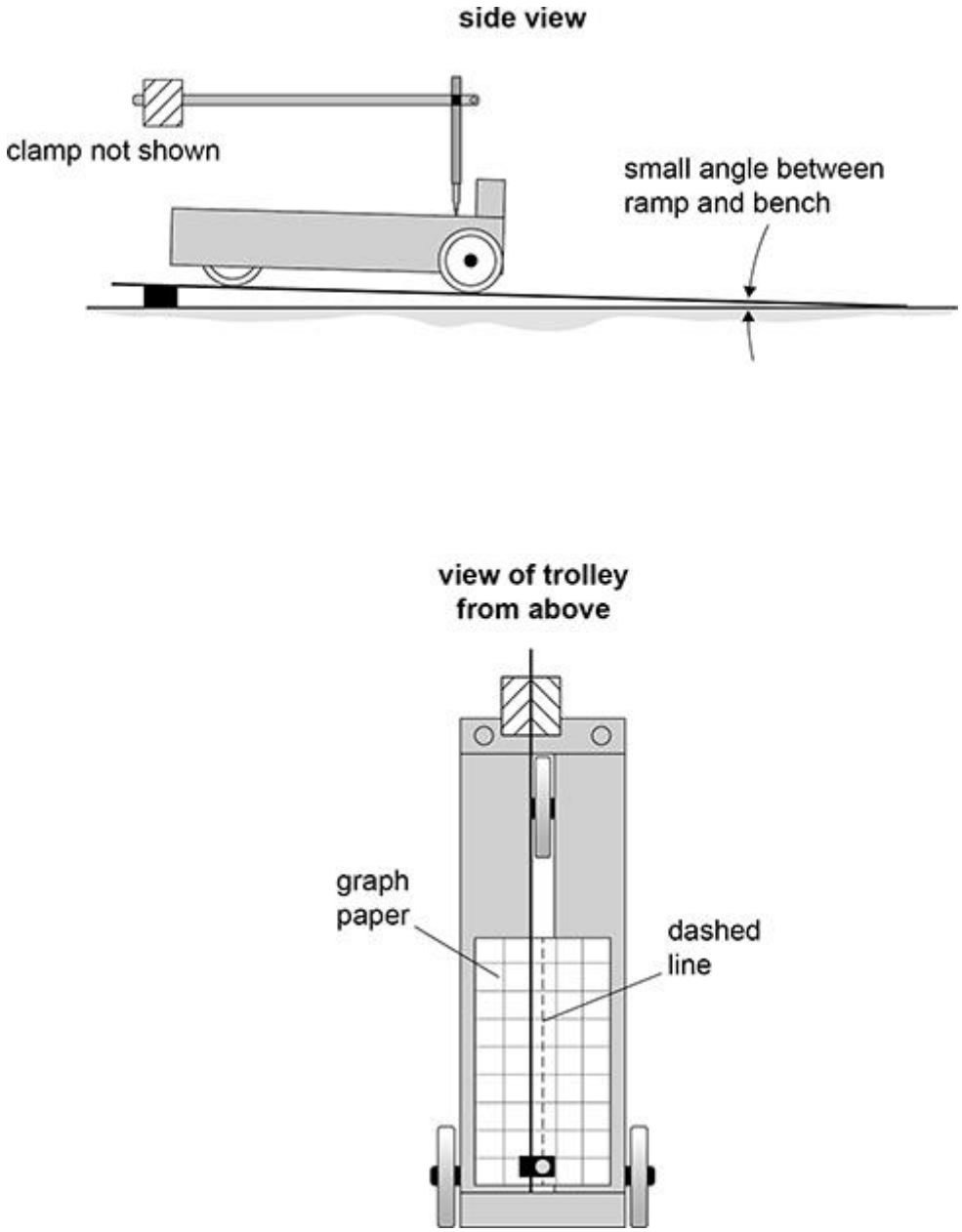
Measurements of $60T$ / s			
25.20	25.05	24.97	25.10

Show that T is about 0.42 s.

(1)

Figure 3 shows a trolley placed on a ramp that is inclined at a small angle to the bench.
A piece of graph paper is fixed to the upper surface of the trolley.
The blade and pen are positioned so that the tip of the pen rests on the graph paper.
The dashed line shows the rest position of the pen.

Figure 3



The free end of the blade is displaced as shown in **Figure 4a**.
The blade and the trolley are then both released at the same moment.
The blade oscillates horizontally.
The pen remains in contact with the graph paper as the trolley moves.
Figures 4b and **4c** show the trolley as it moves down the ramp with uniform acceleration.

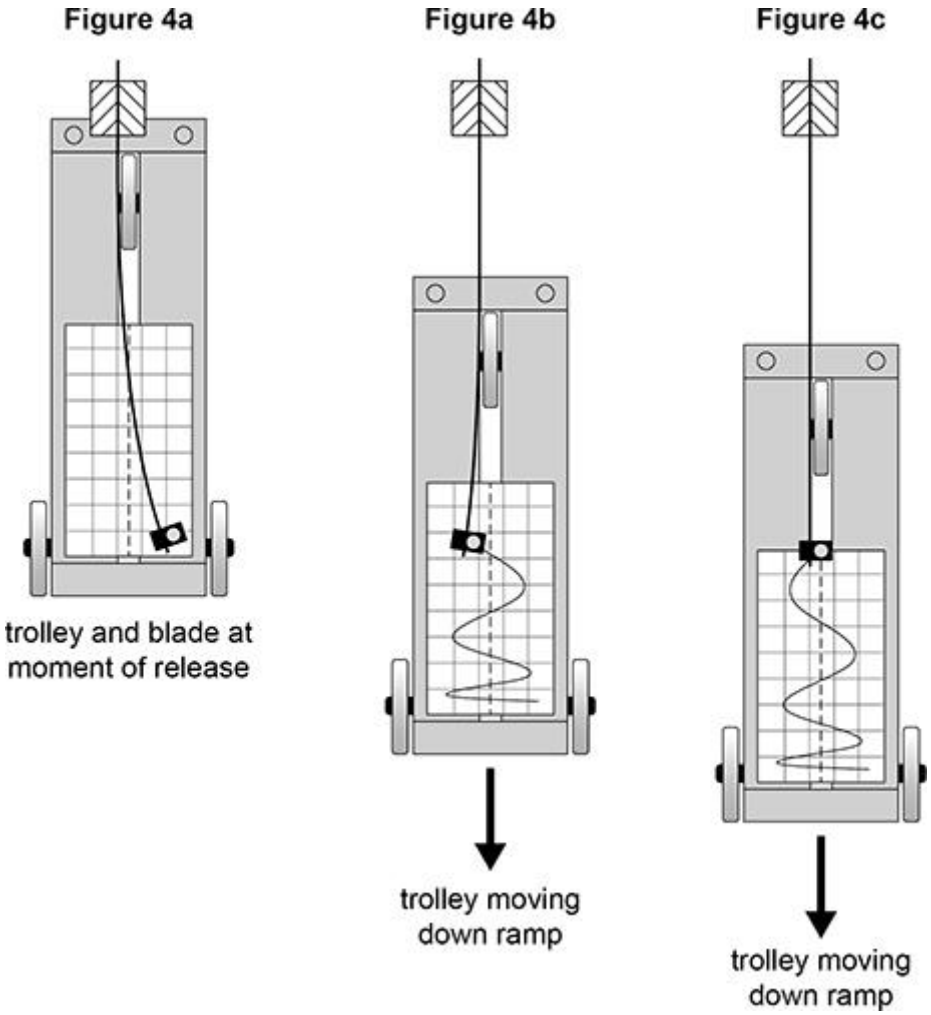
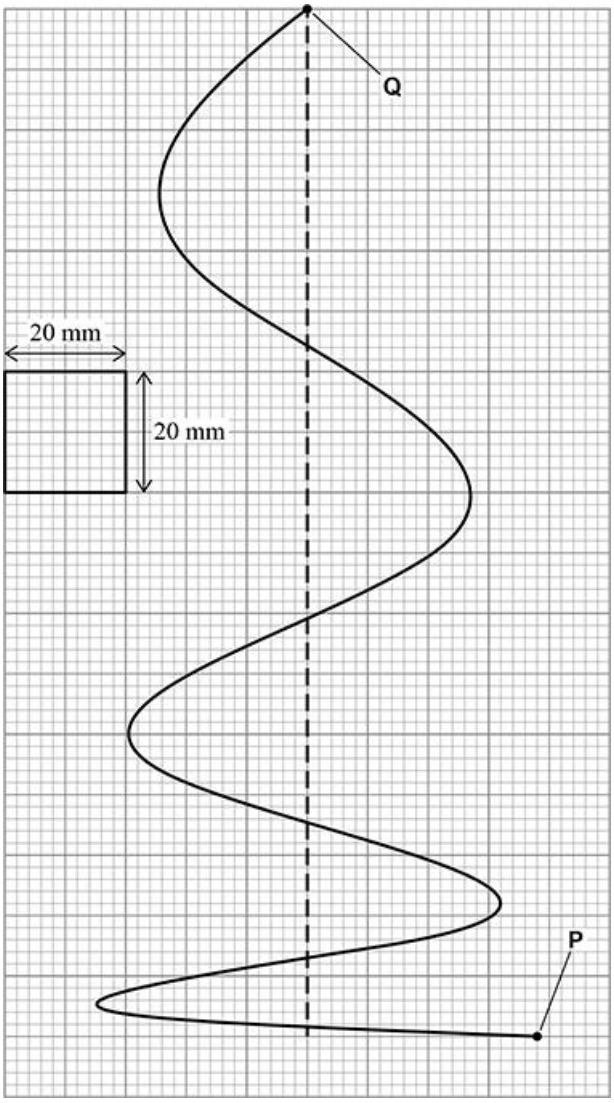


Figure 5 shows the graph paper.
Points **P** and **Q** mark the start and end of the continuous line drawn by the pen after the trolley is released.

Figure 5



T_{PQ} is the time for the pen to draw the line from **P** to **Q**.
s is the displacement of the trolley during T_{PQ}.

(b) Determine T_{PQ}.
Assume that the time for each full oscillation of the blade is 0.42 s.

T_{PQ} = _____ s

(2)

(c) Determine s.
The scale of the graph paper is shown on **Figure 5**.

s = _____ m

(1)

(d) Determine the acceleration a of the trolley.

a = _____ m s^{-2}

(2)

(e) A teacher suggests that the absolute uncertainty in s is ±2 mm.

Explain why this is a valid suggestion.

_____

_____

_____

_____

_____

(2)

(f) The percentage uncertainty in T_{PQ} is 0.46%.

Determine the percentage uncertainty in your result for a.

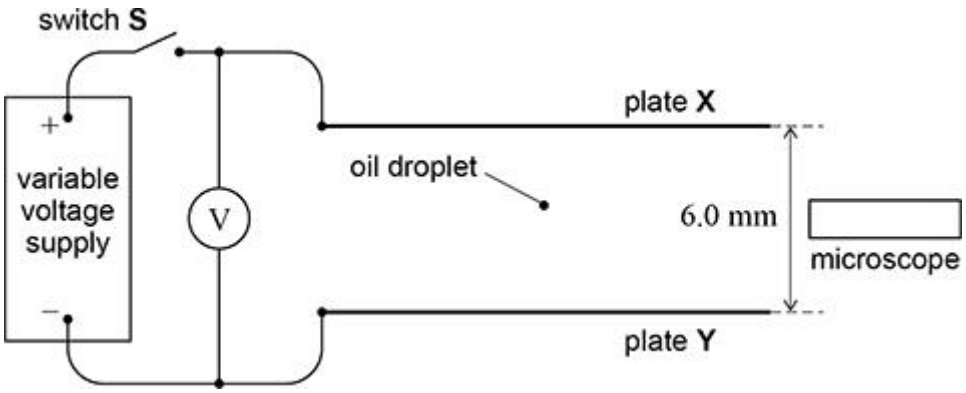
percentage uncertainty = _____ %

(2)

(Total 10 marks)

Q2.

(a) The figure below shows a cross-sectional view of the arrangement that Millikan used to determine the charge on the electron.



Millikan's initial step was to determine the radius of the oil droplet.

Explain how Millikan used this apparatus to determine the radius of the oil droplet.

In your answer you should:

- describe the procedure used, the measurements taken and any additional data required
- describe how the radius was determined from the measurements
- state the physical principles and assumptions involved in the determination of the radius.

(6)

(b) On one occasion, the radius of a droplet was determined to be 1.20×10^{-6} m.
When the droplet was stationary, the voltmeter reading was 467 V.

Show that the charge on the droplet was approximately 8×10^{-19} C.

density of oil = 880 $\mathrm{kg\ m^{-3}}$

(3)

(c) The table below shows the percentage uncertainty in each quantity.

Quantity	Percentage uncertainty
radius of oil droplet	4%
density of oil	1%
gravitational field strength	0.1%
potential difference	0.2%
distance between the plates	2%

Show that the absolute uncertainty in your answer to part (b) is approximately $\pm 1 \times 10^{-19}$ C.
Go on to discuss whether this uncertainty allows your answer to part (b) to be used to support the quantisation of electric charge.

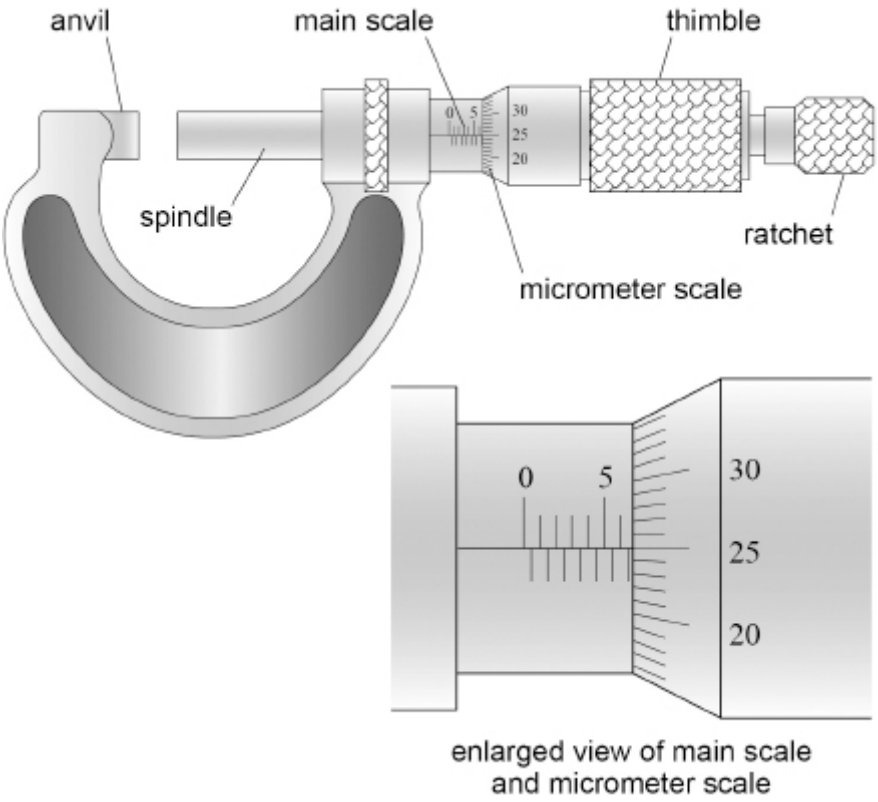
(3)

(Total 12 marks)

Q3.

(a) **Figure 1** shows a micrometer screw gauge.

Figure 1



What is the reading on the micrometer?

Tick ✓ **one** box.

6.25 ☐

6.75 ☐

7.25 ☐

8.25 ☐

(1)

(b) A metal wire of diameter d is held in the gap between the anvil and the spindle.
Just before the reading of d is taken, the gap is closed using the ratchet and not the thimble.

Explain why the gap is closed in this way.

_____

_____

_____

(1)

(c) The mass per unit length μ of the metal wire is given by

$$\mu = \frac{\pi \rho d^2}{4}$$

where ρ is the density of the metal.

Values of d and μ are used to calculate ρ.

The percentage uncertainty in d is 1.2%.
The percentage uncertainty in μ is 2.0%.

Calculate the percentage uncertainty in the result for ρ.

percentage uncertainty = _____ %

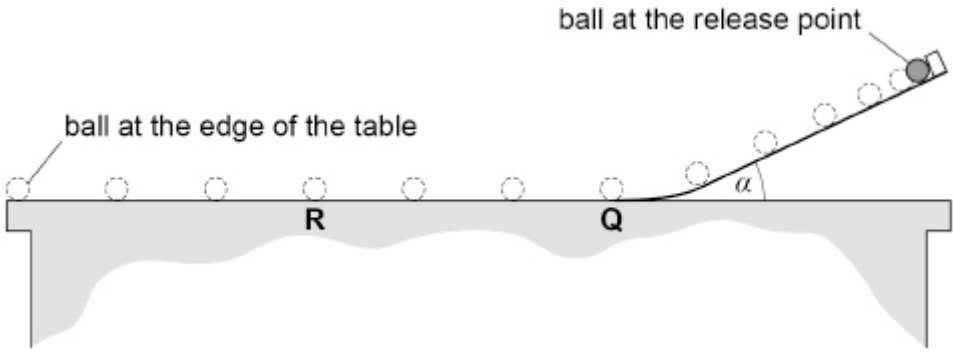
(2)

(Total 4 marks)

Q4.

A ball is released from rest and then continues to roll at a constant velocity across a horizontal table, as shown in **Figure 4**.

Figure 4



The bottom of the track is fixed to the table at point **Q**.
The angle between the straight part of the track and the table is α.
A marker is placed at **R**, a point midway between **Q** and the edge of the table.

The student uses a stopwatch to measure the time t for the ball to roll from **Q** to **R**.

(a) Explain why increasing the distance **QR** will reduce the percentage uncertainty in t.

_____

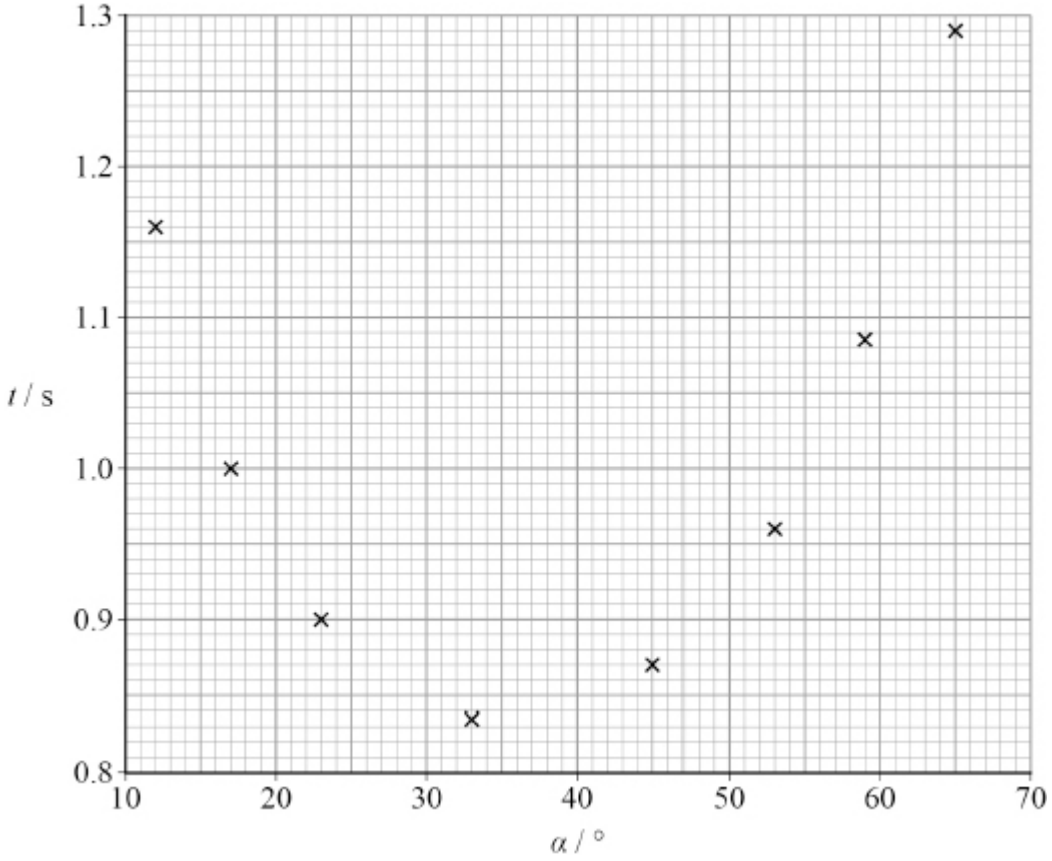
_____

_____

(1)

(b) **Figure 5** shows values of t for different values of α.

Figure 5



At a particular value of α the ball rolls from **Q** to **R** at its maximum velocity.

Explain how the student should use **Figure 5** to determine this value of α. Go on to suggest what further readings should be taken to reduce the uncertainty in this value of α.

(2)

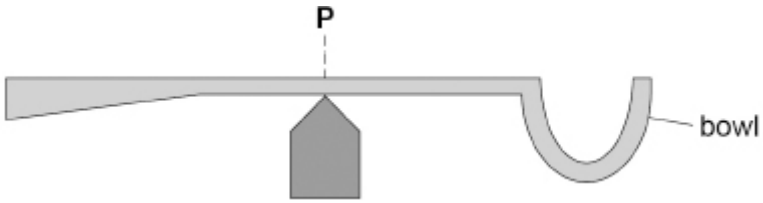
(Total 3 marks)

Q5.

Figure 1 shows a spoon used to measure the mass of food.

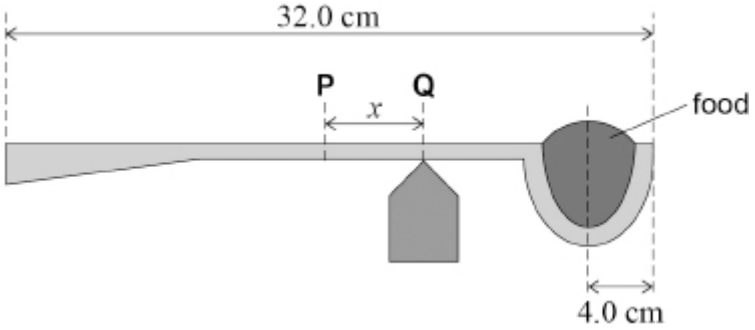
The empty spoon balances when a pivot is placed under a point **P** halfway along the spoon.

Figure 1



The spoon tilts when food of mass M is placed in the bowl. The spoon is rebalanced by moving the pivot a distance x to the right of **P**. The new position of the pivot is under point **Q** in **Figure 2**.

Figure 2



The total length of the spoon is 32.0 cm. The weight of the food acts through a line at a distance of 4.0 cm from the right-hand edge of the spoon.

(a) Explain why the spoon in **Figure 2** is balanced when the pivot is at **Q**.

_____

_____

_____

_____

(2)

(b) The empty spoon has mass m.

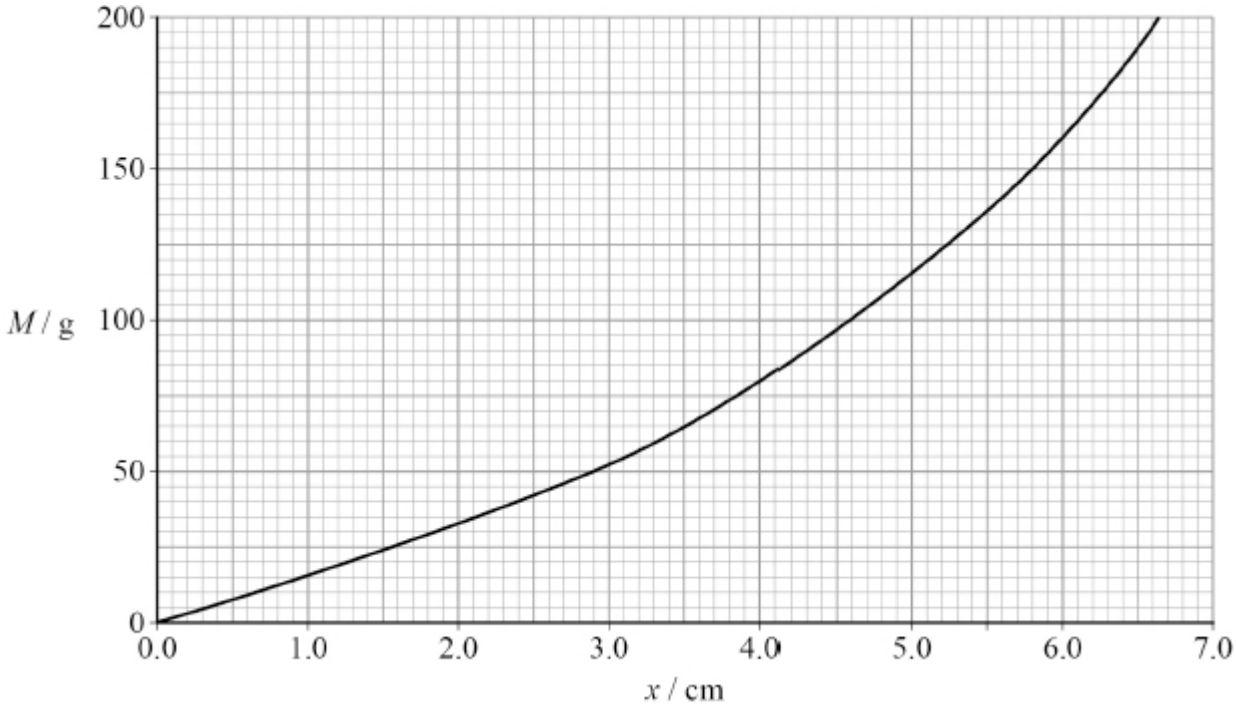
Show that, for the arrangement in **Figure 2**,

$$\frac{m}{M} = \frac{(12.0 - x)}{x}$$

(2)

(c) **Figure 3** shows how x varies with M.

Figure 3



Determine, using **Figure 3**, the weight of the empty spoon.

weight = _____ N

(3)

(d) A scale, in grams, is marked on the spoon between **P** and the bowl. **Figure 3** is used to calibrate this scale in intervals of 25 g.

M can be measured by balancing the spoon. The value is read from the point of the scale directly above the pivot.

State and explain how the uncertainty in the value read from the scale changes as M increases.

_____

_____

_____

_____

_____

_____

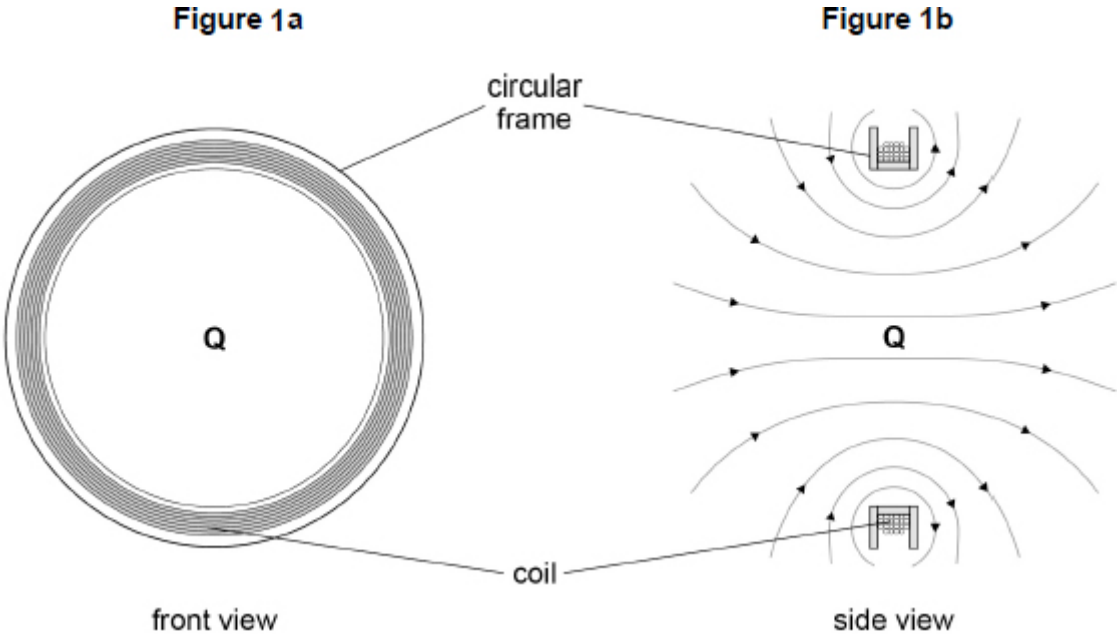
(3)

(Total 10 marks)

Q6.

Figure 1 shows the front view of a vertical coil mounted on a circular frame.

Figure 1 is a side view showing a section through the frame and coil.
A constant direct current in the coil produces magnetic flux represented by the magnetic field lines on this diagram.



Point **Q** is at the centre of the coil.

A sensor placed at **Q** detects B_H, the horizontal component of the magnetic flux density.

The effect of the Earth's magnetic field at **Q** is negligible.

(a) Discuss whether a search coil is a suitable sensor to detect B_H.

_____

_____

_____

_____

_____

_____

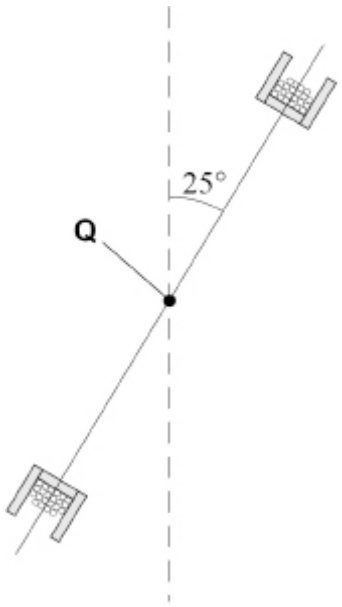
_____

(2)

B_H is measured at **Q** with the coil vertical.

The coil is now rotated about **Q** through 25° as shown in **Figure 2**.
The current in the coil does not change.

Figure 2



A new measurement of B_H is made with the coil fixed in this new position.

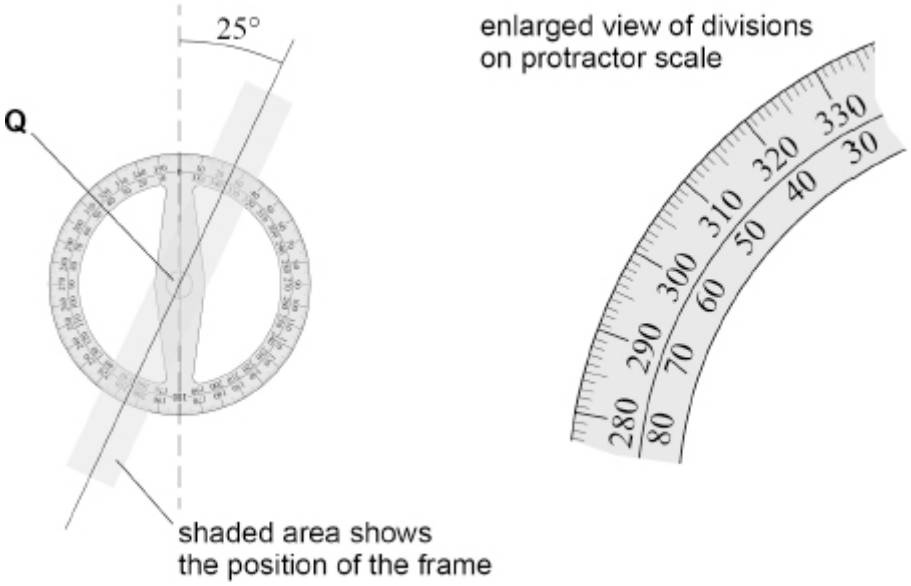
(b) Determine the percentage change in B_H produced by this rotation of the coil.
Show your working.

percentage change = _____ %

(2)

(c) **Figure 3** shows a protractor being used to measure the angle through which the coil is rotated.

Figure 3



Estimate the percentage uncertainty in this result.
Justify your answer.

percentage uncertainty = _____ %

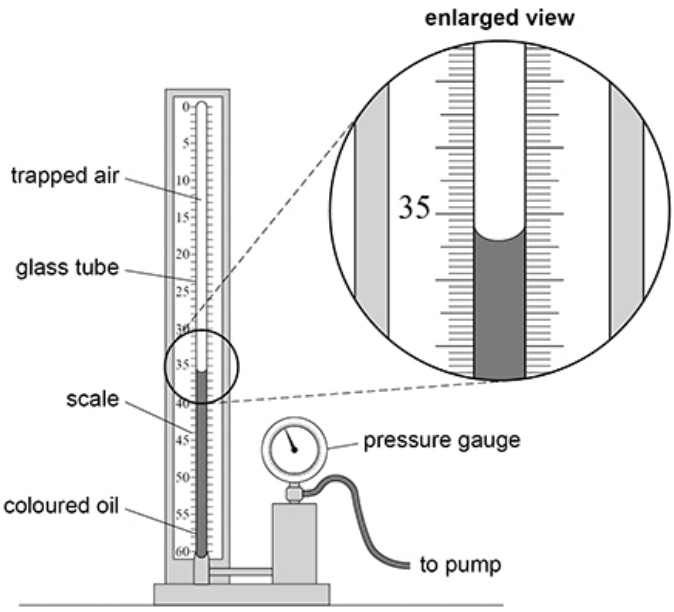
(3)

(Total 7 marks)

Q7.

Figure 4 shows apparatus used in schools to investigate Boyle's law.

Figure 4



A fixed mass of air is trapped above some coloured oil inside a glass tube, closed at the top.
A pump applies pressure to the oil and the air.
The trapped air is compressed and its pressure p is read from the pressure gauge.

(a) A scale, marked in 0.2 cm^3 intervals, is used to measure the volume V of the air.
A student says that the reading for V shown in **Figure 4** is 35.4 cm^3.

State:

- the error the student has made
- the correct reading, in cm^3, of the volume.

_____

_____

_____

_____

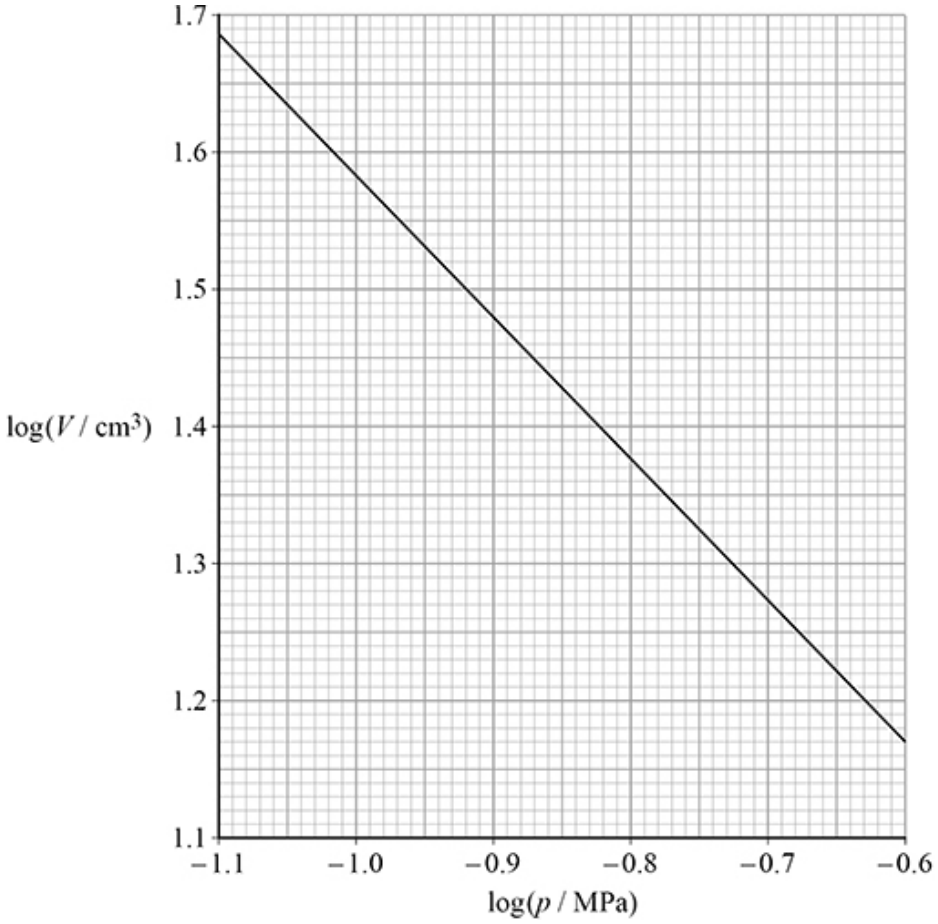
_____

volume = _____ cm^3

(2)

(b) **Figure 5** shows data obtained using the apparatus in **Figure 4**.

Figure 5



Explain why the gradient of the graph in **Figure 5** confirms that the air obeys Boyle's law.

(3)

(c) The largest pressure that can be read from the pressure gauge is 3.4×10^5 Pa.

Determine, using **Figure 5**, the volume *V* corresponding to this pressure.

V = _____ cm^3

(3)

(d) State **one** property of the air that must not change during the experiment. Go on to suggest how this can be achieved.

_____

_____

_____

_____

_____

(2)

(Total 10 marks)