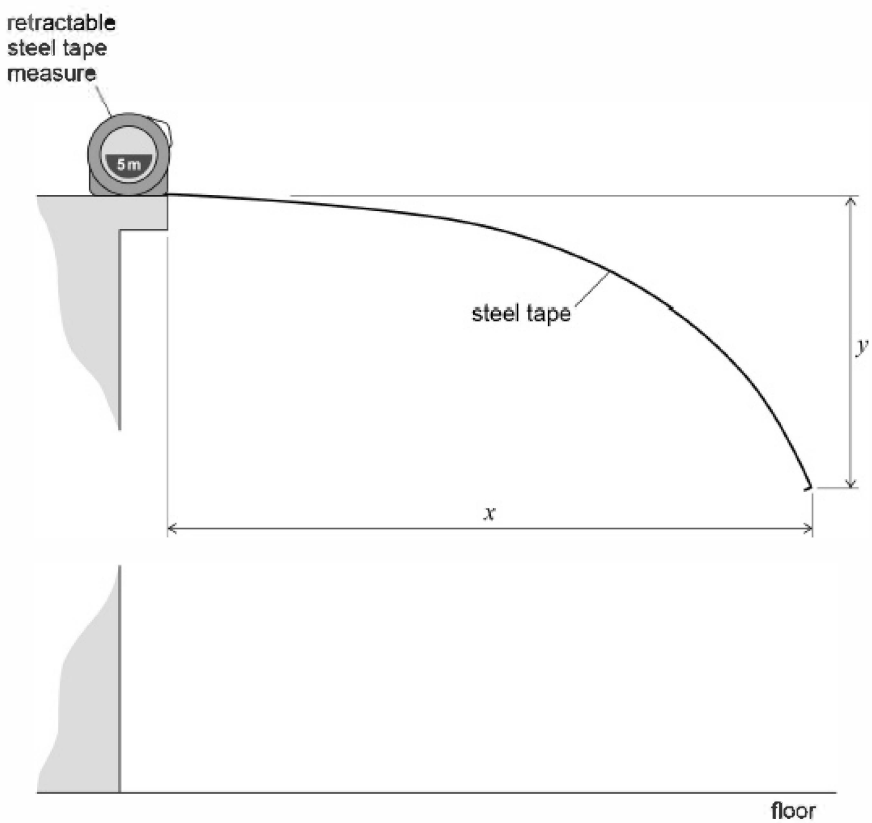
1 This question is about an experiment with a retractable steel tape measure.

The tape measure is placed at the edge of the bench and about 1 m of the steel tape is extended so that it overhangs the bench.

The tape is then locked in this position to stop it from retracting.

A student measures the dimensions x and y, the horizontal and vertical displacements of the free end of the tape, as shown in **Figure 1**.

Figure 1



(a) Describe a suitable procedure the student could use to measure *y*.
You may add detail to **Figure 1** to illustrate your answer.

clamp a meter rule next to the tape measure that extends horizontally. Use another rule at the end to measure the drop. A set square could be used to ensure a right angle, or a piece of string with a mass to ensure vertical line to measure against

(2)

(b) By changing the extension of the tape, the student obtains further values of *x* and *y*.

These data are shown in the table.

x / cm	*y* / cm
132.4	61.2
116.8	33.7
105.1	24.3
94.5	15.6
84.3	11.0
73.2	5.7

Suggest why the student chose to make **all** measurements of *x* greater than 70 cm

perhaps the rule didn't have enough mass until 70cm to cause it to bend more likely though that the student felt the measurement was too small compared to the uncertainty in the reading leading to too large a percentage error in the reading.

(1)

(c) The data from the experiment suggest that $y = Ax^n$ where n is an integer and A is a constant.

These data are used to plot the graph in **Figure 2**.

Determine n using **Figure 2**.

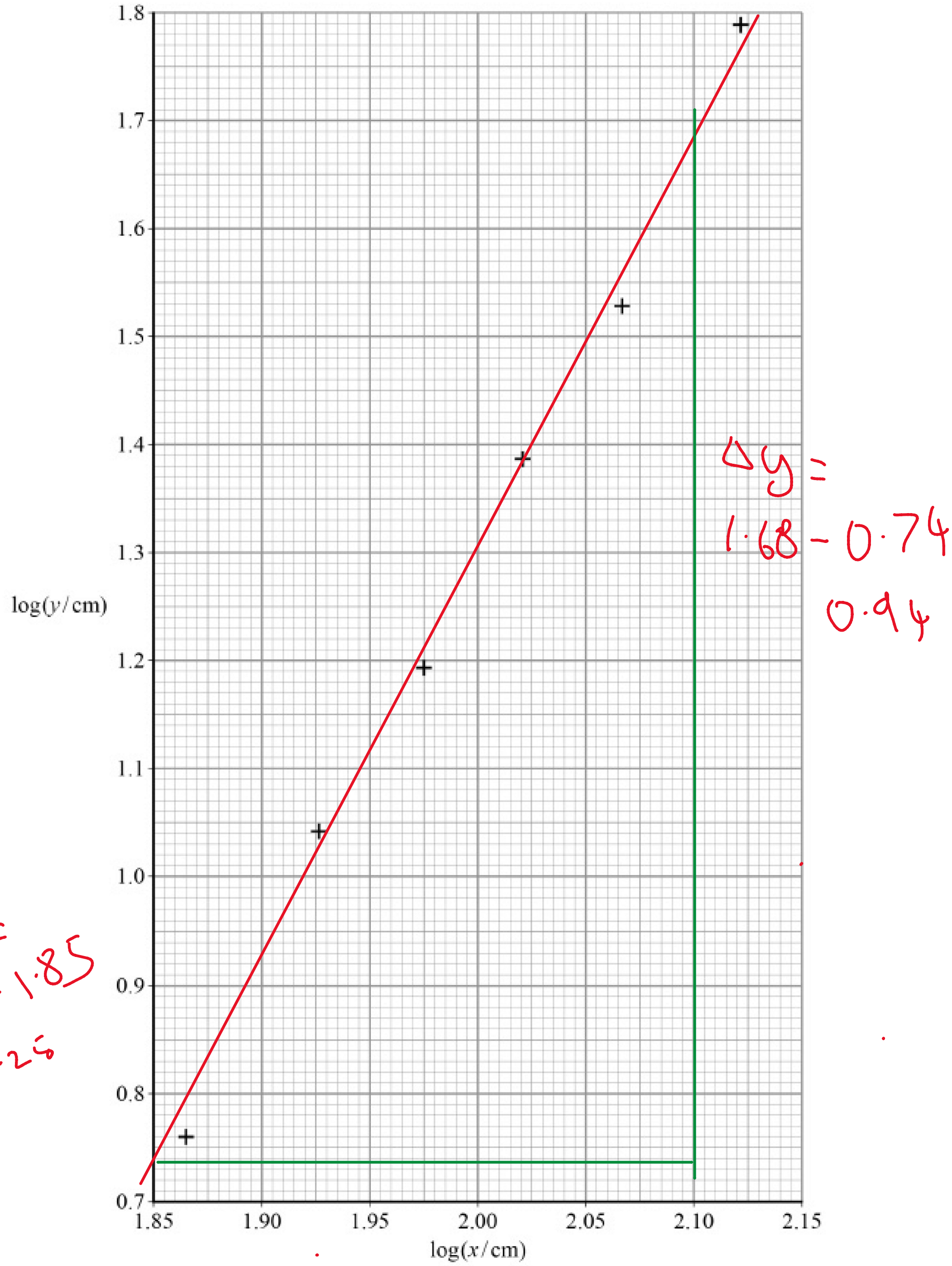
$y = Ax^n \Rightarrow \log y = \log A - n x$

So n = gradient = 3.76

n = 4

integer

Figure 2


log(y / cm)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
1.85
1.90
1.95
2.00
2.05
2.10
2.15
log(x / cm)
Δy =
1.68 − 0.74
0.94
Δx =
2.10 − 1.85
= 0.25

(3)

(d) Explain how the numerical value of A can be obtained from **Figure 2**.

$y = Ax^n \Rightarrow \log y = \log A - n \log x$

so y intercept = $\log A$

from $y = mx + c$

(3)

(e) Estimate the order of magnitude of A.
You should use data for x and y from any **one** row in the table above.
Give your answer with an appropriate unit.

$y = Ax^n \Rightarrow A = \frac{y}{x^n}$ $\quad n = 4$

$x = 94.5$

$y = 15.6$ $\quad A = \frac{15.6}{(94.5)^4} \approx 2.0 \times 10^{-7}$ (s.f.)

order of magnitude of A = -7, 10^{-7} unit cm^{-3}

(3)
(Total 12 marks)

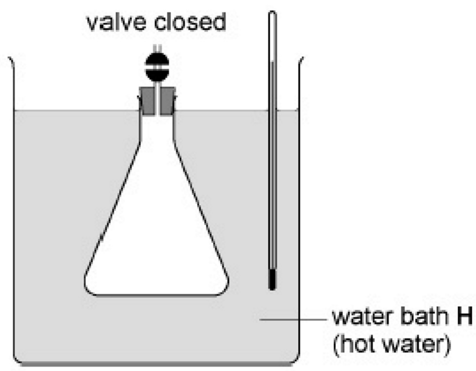
units are $\frac{cm}{cm^4} = cm^{-3}$

2 This question is about an experiment to estimate absolute zero.

Figures 1a to 1d show the stages in the procedure carried out by a student.

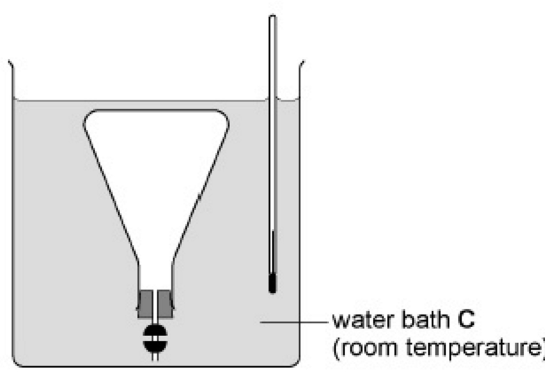
An empty flask fitted with a tube and an open valve is placed in water bath **H** containing hot water. The air inside the flask is allowed to come into thermal equilibrium with the water. The valve is then closed, trapping a certain volume of air, as shown in **Figure 1a**.

Figure 1a



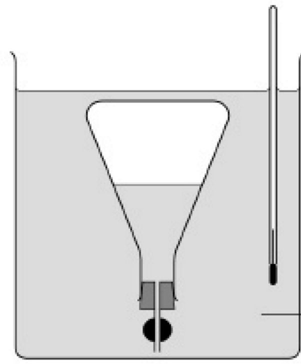
The flask is inverted and placed in water bath **C** in which the water is at room temperature. The air inside the flask is again allowed to come into thermal equilibrium with the water, as shown in **Figure 1b**.

Figure 1b



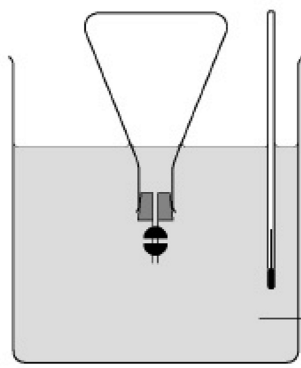
The valve is opened and some water enters the flask, as shown in **Figure 1c**.

Figure 1c



The depth of the inverted flask is adjusted until the level of water inside the flask is the same as the level in the water bath.
The valve is then closed, trapping the air and the water inside the flask, as shown in **Figure 1d**.

Figure 1d



(a) Explain why the volume of the air in the flask in **Figure 1c** is less than the volume of the air in the flask in **Figure 1d**.

Pressure in 1C is higher due to water column being deeper, ∴ since pV = const, the V must be less in 1C

(2)

(b) Explain why Charles's Law can be applied to compare the air in the flask in **Figure 1a** with the air in the flask in **Figure 1d**.

$V = kT$ Pressure has remained constant as has mass of gas

(2)

(c) The flask is removed from water bath **C** and the valve and stopper are removed.

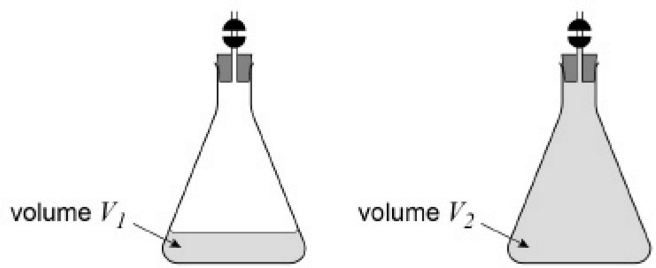
The volume of the water in the flask is V_1

The flask is then completely refilled with water and the valve and stopper replaced.

The volume of the water now in the flask is V_2

The volumes V_1 and V_2 are shown by the shaded parts in **Figure 2**.

Figure 2



Explain how V_1 and V_2 can be determined.

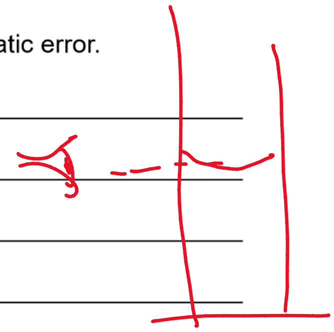
In your answer you should

- identify a suitable measuring instrument
- explain a suitable procedure to eliminate possible systematic error.

measuring cylinder

read from bottom

of miniscus



(3)

(d) Plot on **Figure 3** points to show the volume V and the temperature θ of the air in the flask when

- the flask is as shown in **Figure 1a**
- the flask is as shown in **Figure 1d**.

$V = kT$ ← use °C not K ∴ want to find absolute zero

The temperature of the hot water bath is 86 °C

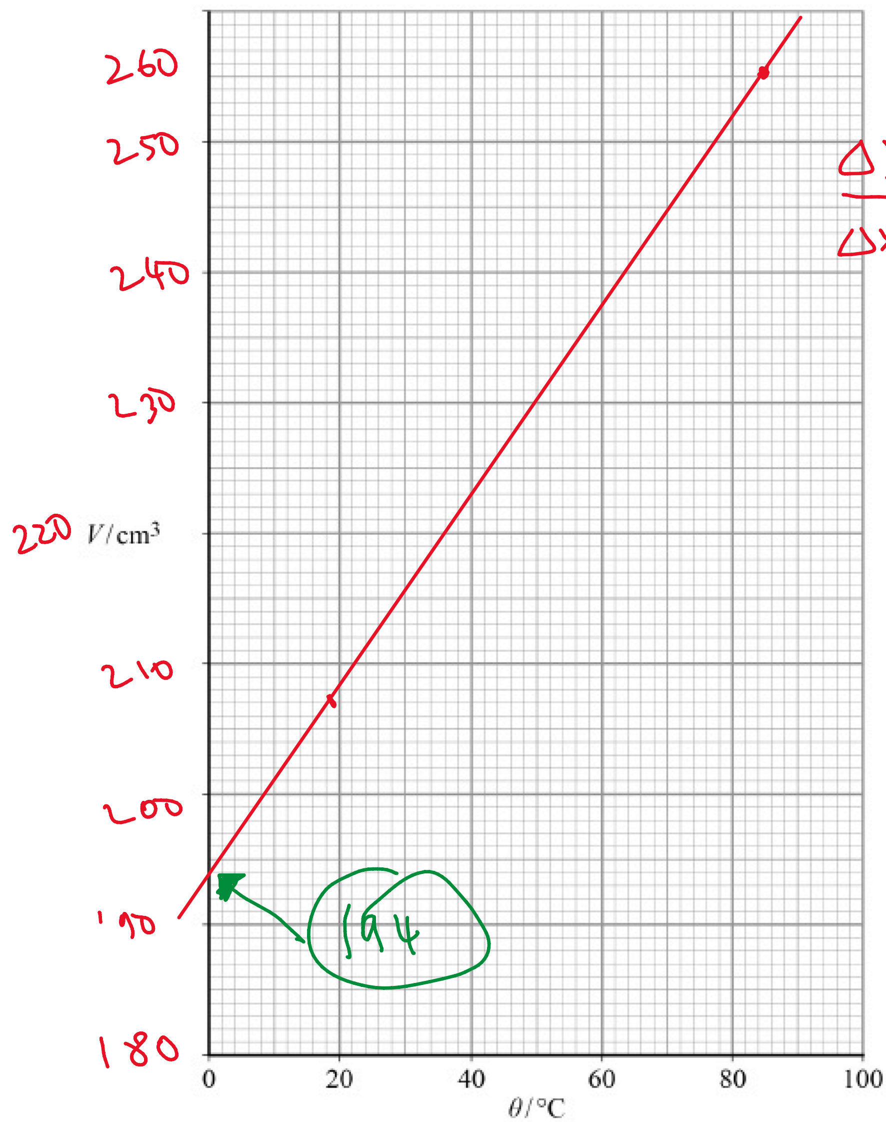
Room temperature is 19 °C

$V_1 = 48\ \text{cm}^3$ – vol of gas $= 255 - 48 = 207$

$V_2 = 255\ \text{cm}^3$

(19, 207)
(86, 255)

Figure 3



$\frac{\Delta y}{\Delta x} = \frac{255-207}{86-19}$

$= 0.72$ (2sf)

(3)

(e) Add a best fit line to your graph in **Figure 3** to show how V should vary with θ according to Charles's Law.

(1)

(f) Determine the value of absolute zero in °C using your graph in **Figure 3**.

$y = mx + c$ $m = 0.72$ $c = 194$

$V = 0.72T + 194$

set $V = 0 \Rightarrow 0 = 0.72T + 194$

$\Rightarrow \frac{-194}{0.72} = T$

value of absolute zero = -269.4 °C

(3)

or -270°C

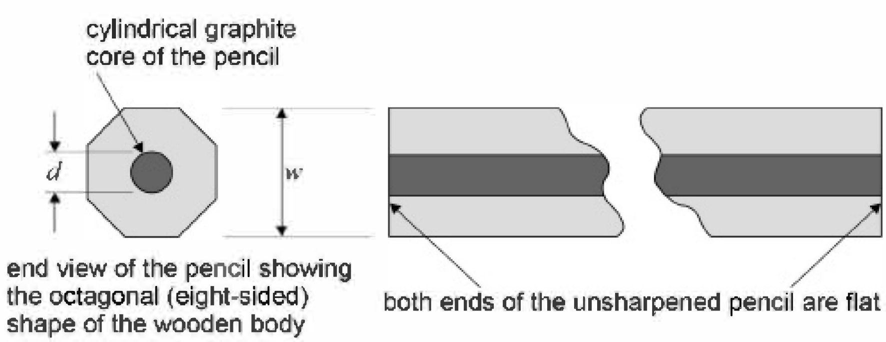
(Total 14 marks)

258

3 A pencil, unsharpened at both ends, has a cylindrical graphite core of uniform diameter d surrounded by an octagonal (eight-sided) wooden body.

Figure 1 shows an end view and a cross-sectional slice along the length of the pencil.

Figure 1



(a) A student used a micrometer to measure the width w at several points along the length of the pencil.

Explain why the student used this procedure to determine a value for w.

gets a mean, reduce uncertainties by identifying anomolous readings

(1)

(b) The student's results are shown in the table.

w_1 / mm	w_2 / mm	w_3 / mm	w_4 / mm	w_5 / mm
7.23	7.10	7.06	7.20	7.16

Determine the percentage uncertainty in the result the student obtains for w.

range = 7.23 − 7.06 = 0.17

mean = 7.15 ∴ $7.15 \pm \frac{0.17}{2}$ ← 0.085

$\frac{0.085}{7.15} \times 100$

percentage uncertainty = 1.19 (3 sf) %

(2)

(c) The cross-sectional area A of the end of the pencil is given by

$$A = 0.83\, w^2$$

2 s.f.

The volume of the cylindrical core is known to be 9.0% of the volume of the unsharpened pencil.
The cylindrical core of the graphite has a diameter d.

Determine d.

$w = 7.15\text{ mm}$

$V_{whole} = A \times L$

$V_g = \pi\left(\frac{d}{2}\right)^2 \times L$

$V_g = 0.09 V_w$

$0.09 \times A \cancel{L} = \frac{\pi d^2}{4} \cancel{L}$

$\sqrt{\frac{0.09 \times A \times 4}{\pi}} =$

d = 2.2 mm

(2)

(d) A student investigates the rate at which a similar pencil wears away through use.

The student measures the length of the pencil using a sliding vernier scale placed alongside a fixed scale. The fixed scale has a precision of 1 mm.

Figure 2 shows the vernier scale in the zero position.

Figure 3 shows the pencil (which is now sharpened) placed next to the fixed scale.

The position of the vernier scale is adjusted so that the length of the pencil can be read.

Read and record the length of the pencil shown in **Figure 3**.

length of pencil = 85.3 mm

(1)

(e) The pencil is then removed from the scale and is used to draw 20 lines on a sheet of paper. Each line has a length 25 cm.

The pencil is then replaced next to the fixed scale and the vernier scale adjusted so the new length of the pencil can be read, as shown in **Figure 4**.

Read and record the new length of the pencil shown in **Figure 4**.

new length of pencil = 83.8 mm

(1)

(f) $L_{1/2}$ is the length of the line that could be drawn which would cause the original length of the pencil to be halved.

Calculate $L_{1/2}$.

Ignore any decrease in length as a result of sharpening the pencil.

original length $\rightarrow$ 85.3 − 83.8 = 1.5mm   20 lines lengths 25cm = 5 m

So 1.5mm is used drawing 5m.

$L_{\frac{1}{2}} = \frac{85.3}{2} = 42.65mm$ $\Rightarrow L_{\frac{1}{2}} = \frac{42.65mm}{1.5} \times 5$

$L_{1/2}$ = 142.17 m

(2)

So 142 (3 sf)

Figure 2

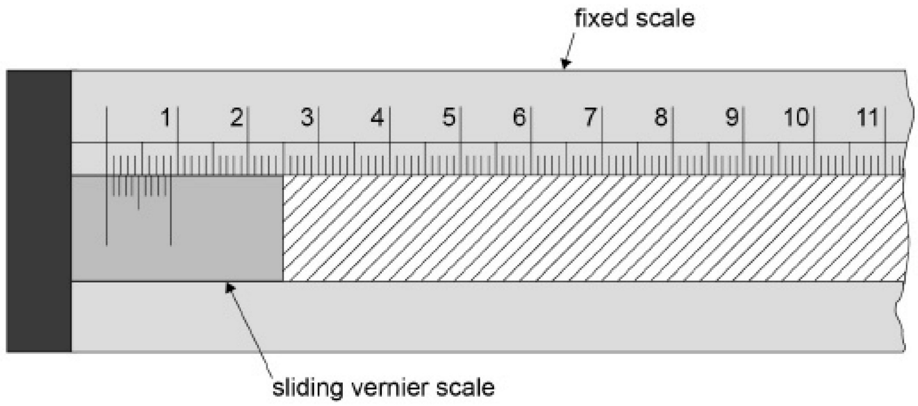


Figure 3

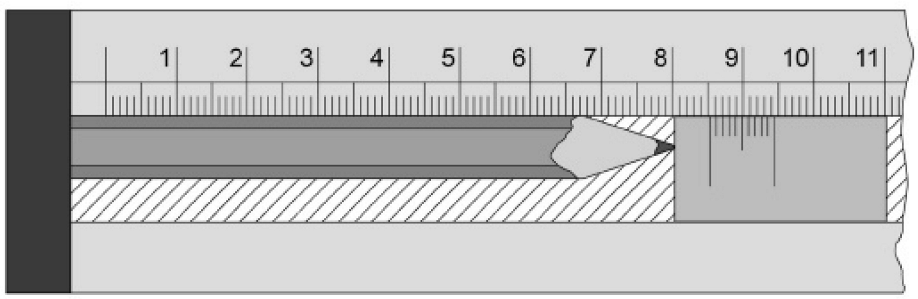
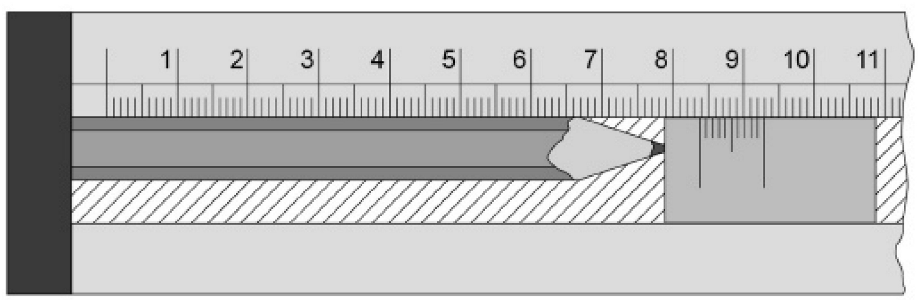


Figure 4



(Total 9 marks)