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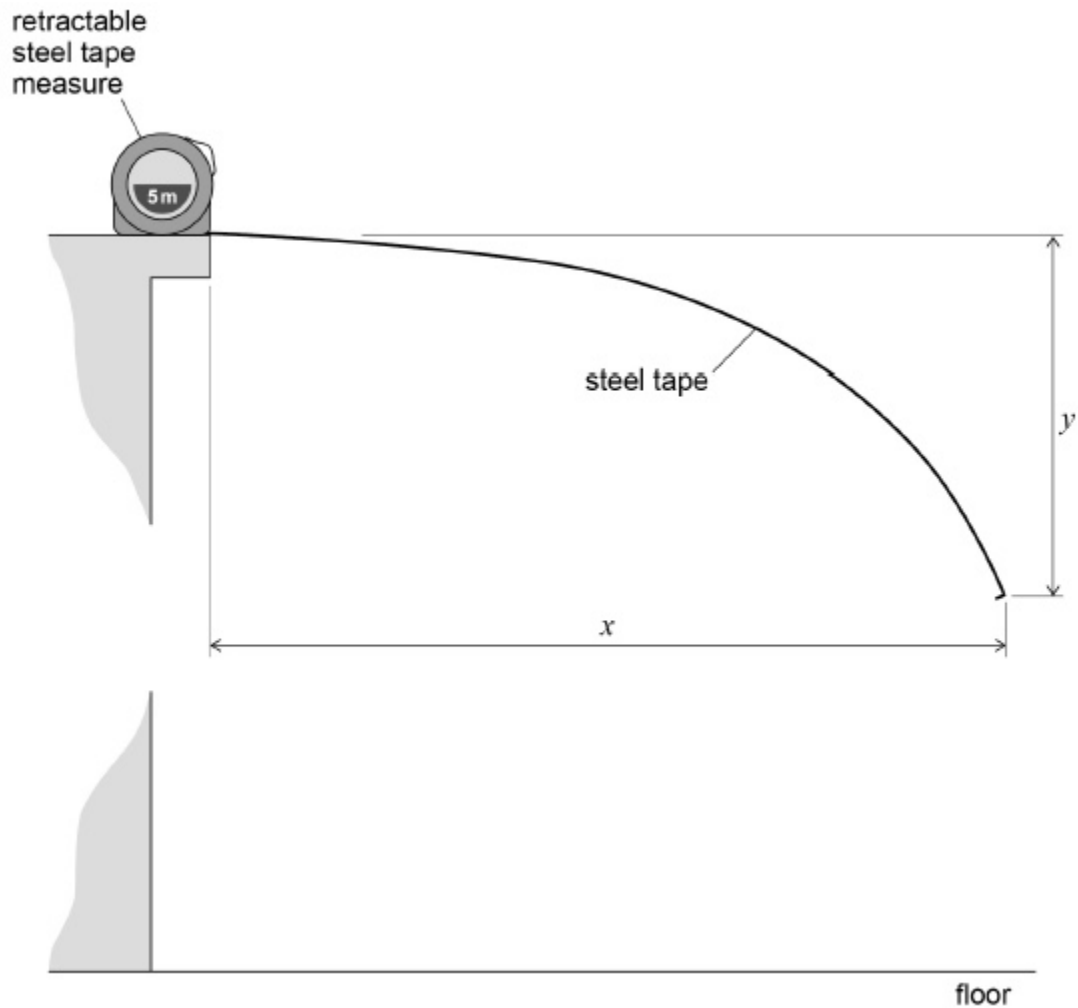
(a) Describe a suitable procedure the student could use to measure y.
You may add detail to **Figure 1** to illustrate your answer.

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_____

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(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
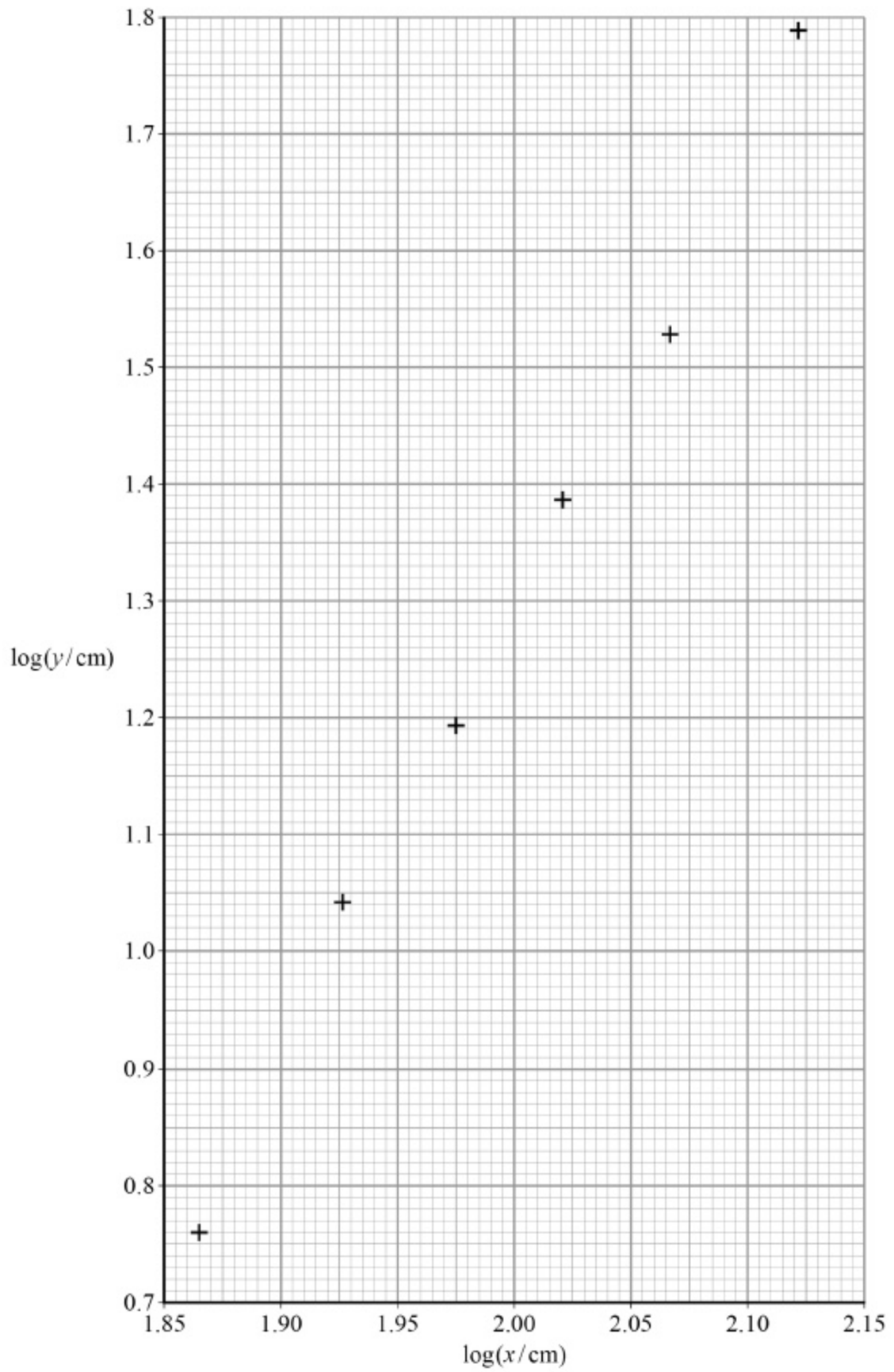
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(1)

(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**.

$n =$ _____

Figure 2

(3)

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

_____

_____

_____

_____

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_____

(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.

order of magnitude of A = _____ unit _____

(3)
(Total 12 marks)

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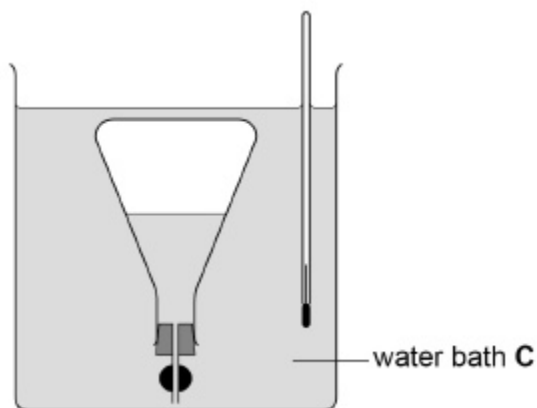
Figure 1a
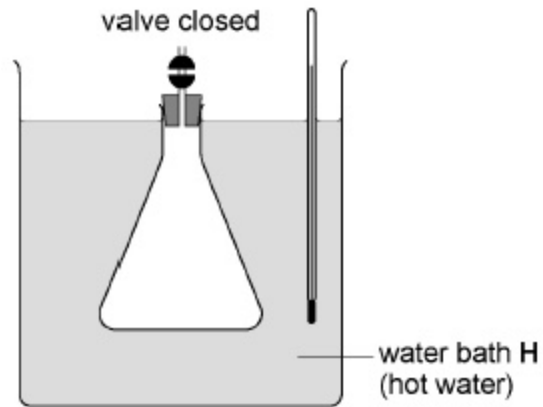
The flask is inverted and placed in water bath **C** in which the water is at room temperature. The air inside the flask is again allowed to come into thermal equilibrium with the water, as shown in **Figure 1b**.

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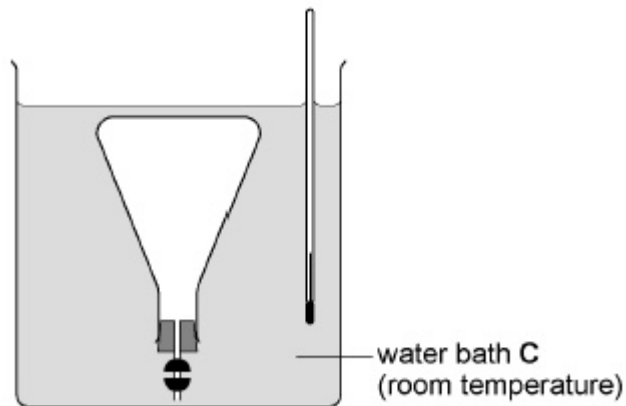
The valve is opened and some water enters the flask, as shown in **Figure 1c**.
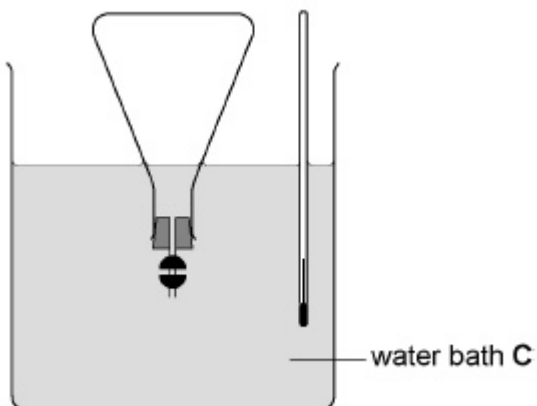
Figure 1c

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**.

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_____

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_____

(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**.

_____

_____

_____

_____

(2)

(c)   The flask is removed from water bath **C** and the valve and stopper are removed.
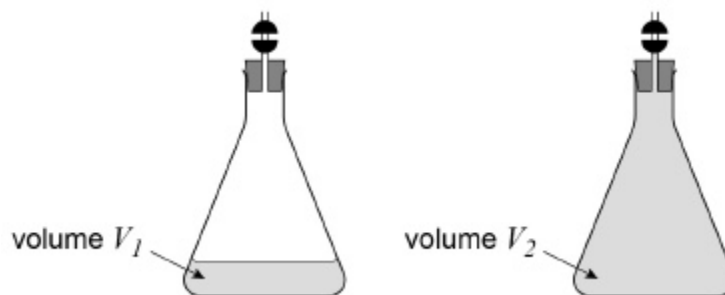
The volume of the water in the flask is V_1

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.

_____

_____

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(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**
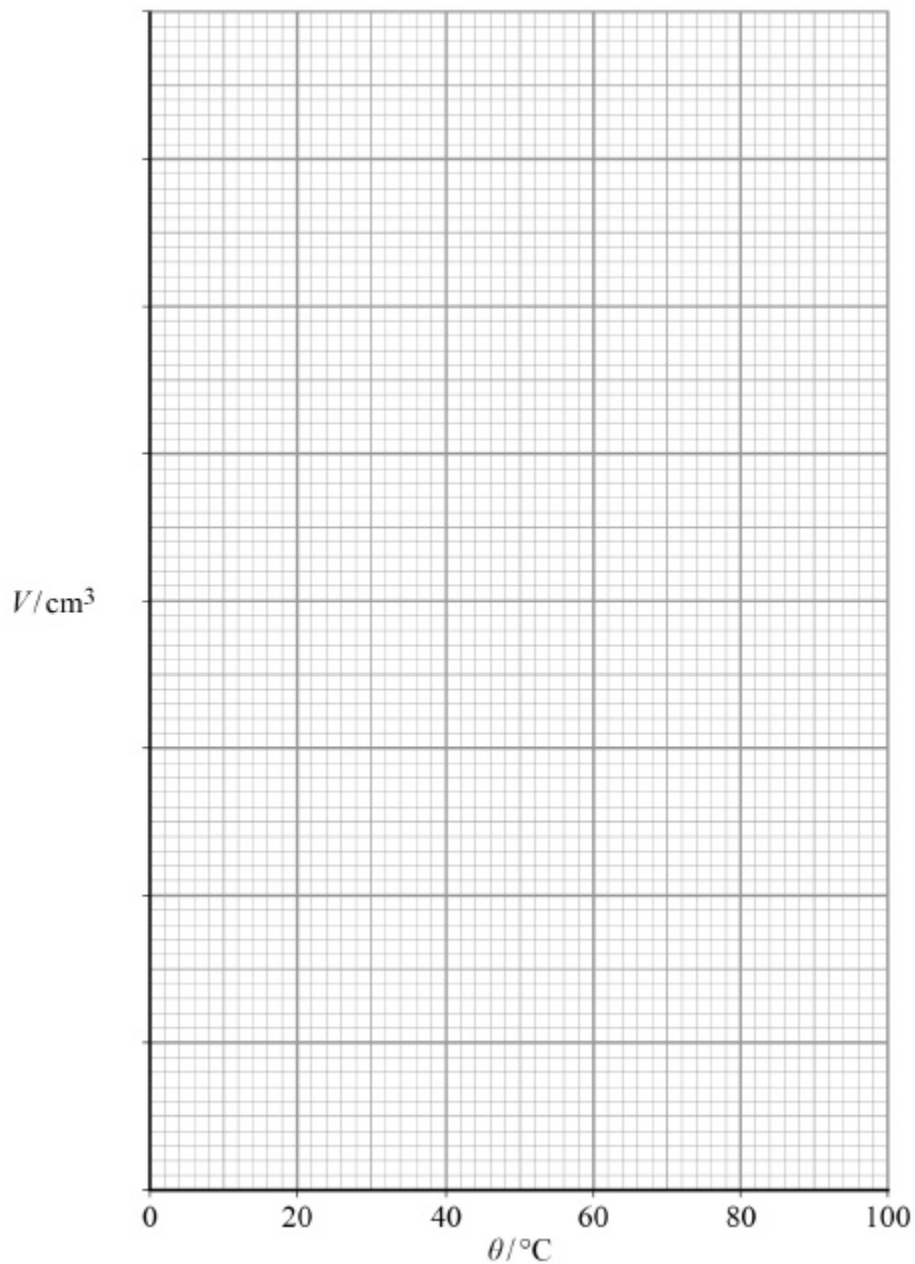   •   the flask is as shown in **Figure 1d**.

The temperature of the hot water bath is 86 °C

Room temperature is 19 °C

$V_1 = 48$ cm^3

$V_2 = 255$ cm^3

Figure 3

$V/$cm^3

0 20 40 60 80 100

$\theta/°C$

(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**.

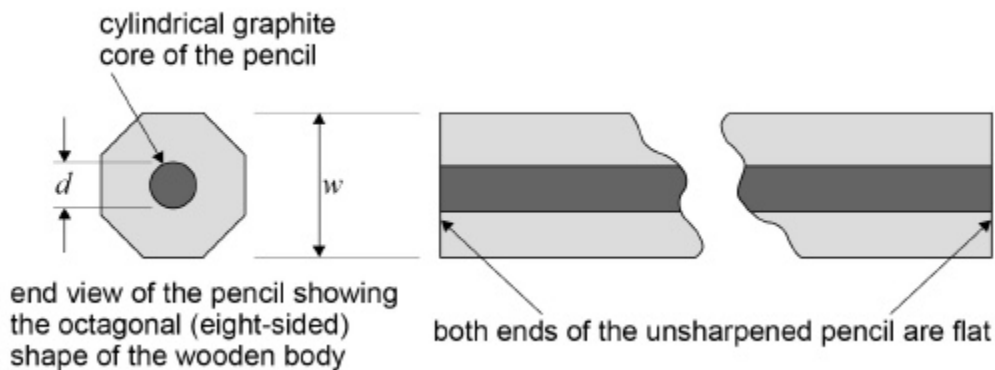value of absolute zero = _____ °C

(3)

(Total 14 marks)

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

cylindrical graphite core of the pencil

d w

end view of the pencil showing the octagonal (eight-sided) shape of the wooden body

both ends of the unsharpened pencil are flat

(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.

_____

_____

_____

_____

_____

(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.

percentage uncertainty = _____ %

(2)

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

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

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.

$d =$ _____ 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 = _____ 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 = _____ 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.

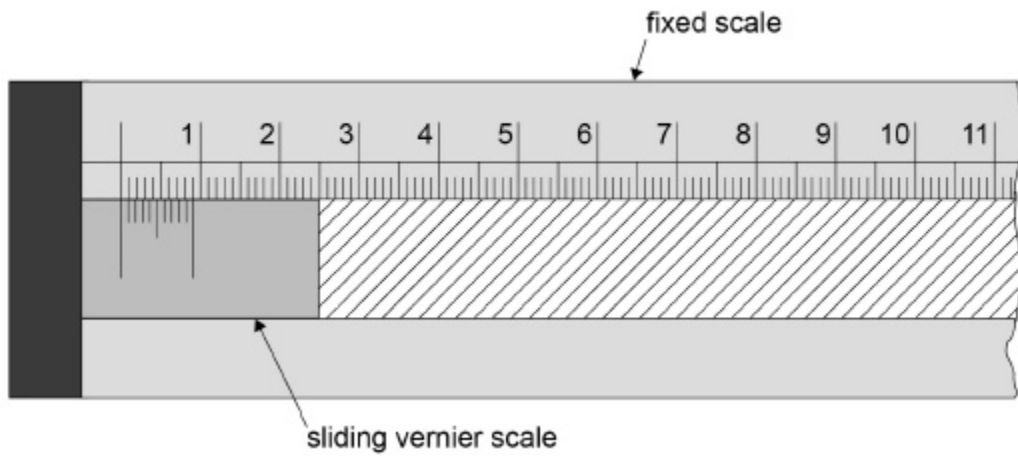Calculate $L_{1/2}$.

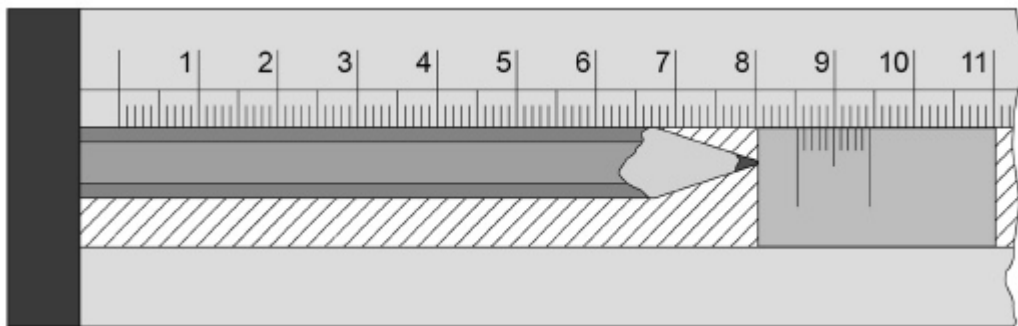Ignore any decrease in length as a result of sharpening the pencil.

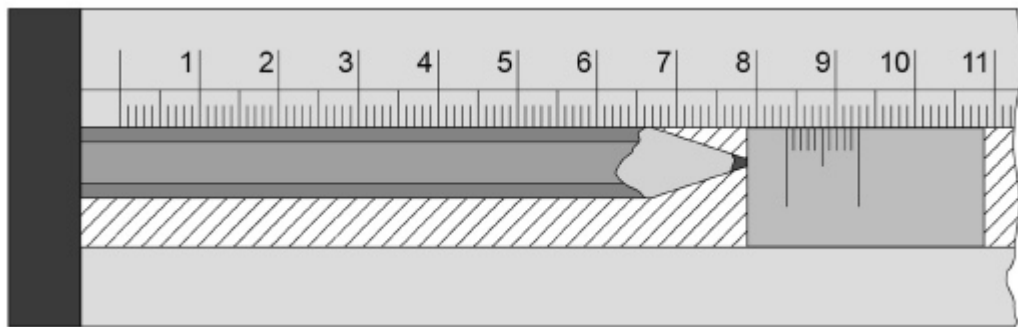$L_{1/2} =$ _____ m

(2)

Figure 2

fixed scale

sliding vernier scale

Figure 3

Figure 4

(Total 9 marks)