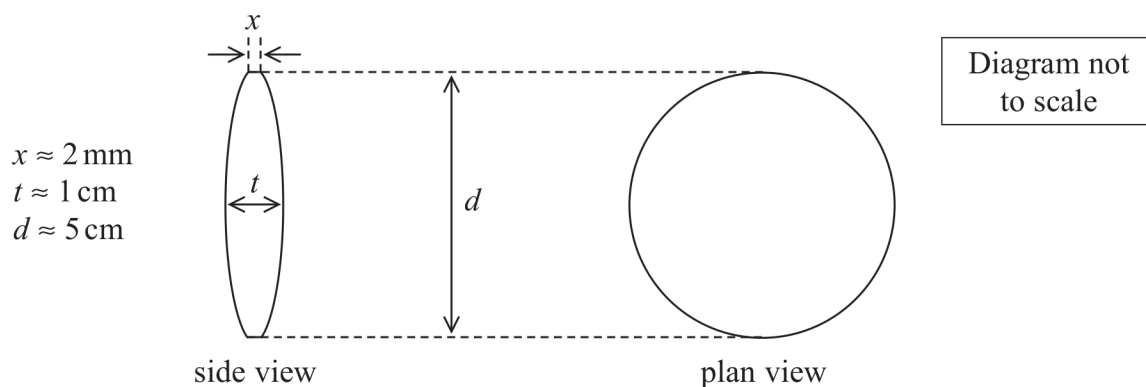4 A student measured some dimensions of a thick, circular lens. The diagram shows approximate values of these dimensions.

$x \approx 2\,mm$
$t \approx 1\,cm$
$d \approx 5\,cm$

side view   plan view

Diagram not to scale

(a) (i) The student had a set of Vernier calipers and a micrometer screw gauge, as shown in the photograph.

State, with a reason, which of these measuring instruments she should use to measure the diameter d of the lens.

(1)

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(ii) The student recorded the following values of d, measured at different points across the lens.

$$5.10\,\text{cm} \qquad 5.11\,\text{cm} \qquad 5.10\,\text{cm}$$

She concluded that because her measurements were precise, they must be accurate.

Explain why this conclusion may not be justified.

(2)

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(b) The student measured the thickness x of the edge of the lens using the micrometer screw gauge.

She recorded the following measurements.

x/mm				
2.11	2.10	2.13	2.14	2.11

Calculate the mean value of x in mm and its uncertainty.

(2)

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Mean value of x = ... mm   ± .... mm

(c) The refractive index n of the material of the lens can be determined using

$$n = 1 + \frac{d^2 + (t - x)^2}{8f(t - x)}$$

where f is the focal length of the lens.

(i) Determine the value of n.

   $d = 5.10 \, \text{cm} \pm 0.01 \, \text{cm}$

   $t = 8.30 \, \text{mm} \pm 0.01 \, \text{mm}$

   $f = 9.8 \, \text{cm} \pm 0.3 \, \text{cm}$

(2)

$n =$ ....

(ii) Show that the percentage uncertainty in $(t - x)$ is approximately 0.5%.

(2)

(iii) Show that the uncertainty in $d^2 + (t - x)^2$ is approximately 0.11 cm.

(4)

(iv) The table shows data for some materials used to make lenses.

Material	Pyrex	Crown glass	Flint glass
Refractive index	1.47	1.52	1.66

Deduce whether this lens could be made from one of these materials.

(3)

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(Total for Question 4 = 16 marks)