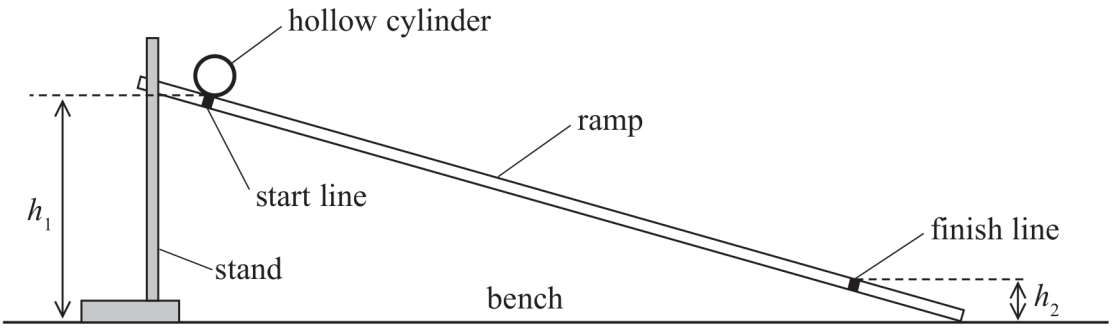
4 A student used the apparatus shown to investigate the time taken for a hollow cylinder to roll down a ramp.



(a) (i) The student measured the height h_1 of the start line from the bench using a metre rule.

State two precautions she should take to ensure the measurement is as accurate as possible.

(2)

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(ii) The student measured the height h_2 of the finish line. She recorded the difference in height Δh between the start line and finish line as 65 mm ± 1 mm.

Explain why the uncertainty in Δh is 1 mm.

(2)

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(b) The student placed the cylinder on the start line and released it. She immediately started a stopwatch and measured the time t for the cylinder to roll to the finish line. She repeated the measurements several times as shown.

t/s	2.10	1.86	1.94	1.89

(i) Calculate the mean value of t and its uncertainty.

(2)

Mean value of t = ... ± .....

(ii) The student made the ramp less steep by reducing the value of h_1.

Explain how this might improve the measurement of t.

(2)

(c) Two students each carried out this procedure for another value of Δh. They recorded the following times for the same value of Δh.

Student	t/s				Mean t/s
A	2.45	2.50	2.38	2.41	2.44
B	2.48	2.45	2.43	2.40	2.44

Compare the accuracy and precision of the data that each student collected.

(4)

(d) The relationship between t and the acceleration of free fall g is given by

$$t^2 = \frac{4s^2}{g\Delta h}$$

where s is the distance along the ramp between the start line and the finish line.

The student recorded the following values.

$t = 2.44\,\text{s} \pm 0.04\,\text{s}$
$s = 80.0\,\text{cm} \pm 0.1\,\text{cm}$
$\Delta h = 43\,\text{mm} \pm 1\,\text{mm}$

(i) Determine a value for g.

(2)

$g =$ .....

(ii) Determine the percentage uncertainty in the value of g.

(2)

Percentage uncertainty = ...

(iii) Deduce whether the value of g is accurate.

(2)

(Total for Question 4 = 18 marks)