2 Two quantities are measured.

$$L = 6.8 \pm 0.1\,\text{cm}$$

$$T = 2.42 \pm 0.08\,\text{s}$$

L and T are related to X by the equation shown.

$$X = \frac{4\pi^2 L}{T^2}$$

What is the calculated value and uncertainty of X?

A $45.8 \pm 0.2\,\text{cm s}^{-2}$

B $45.8 \pm 0.3\,\text{cm s}^{-2}$

C $46 \pm 2\,\text{cm s}^{-2}$

D $46 \pm 4\,\text{cm s}^{-2}$

2 What describes a set of data with a high precision?

A data measured using equipment with small scale divisions

B data that is close to the accepted value

C data with each value having a low uncertainty

D data with repeats that are close to each other

4 A ball is released from rest. The distance the ball falls and the time the ball takes to fall that distance are both measured.

The percentage uncertainty in the measured distance is negligible. The percentage uncertainty in the measured time is 4%.

The distance and the time are then used to calculate the acceleration of free fall.

Air resistance is negligible.

What is the percentage uncertainty in the calculated value of the acceleration of free fall?

A 2% **B** 4% **C** 8% **D** 16%

2 A steel rule can be read to the nearest millimetre. It is used to measure the length of a bar whose true length is 895 mm. Repeated measurements give the following readings.

length / mm 892, 891, 892, 891, 891, 892

Are the readings accurate and precise to within 1 mm?

	results are accurate to within 1 mm	results are precise to within 1 mm
A	no	no
B	no	yes
C	yes	no
D	yes	yes

3 A stone is released from rest and falls vertically to the ground.

The time taken to fall to the ground and the distance travelled are measured. The measurements are used to determine the acceleration of free fall.

The percentage uncertainty in the measured time is 0.05%. The percentage uncertainty in the measured distance fallen is 0.6%.

What is the percentage uncertainty in the calculated value of the acceleration of free fall?

A 0.5% **B** 0.7% **C** 1.1% **D** 1.3%

2 In this experiment, you will investigate the rolling of a plastic bottle.

(a) (i) You are provided with a plastic bottle with a cap, as shown in Fig. 2.1.

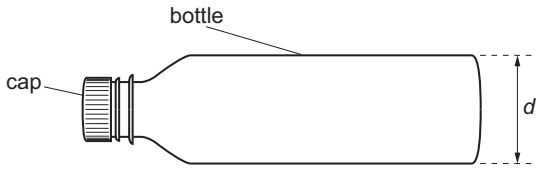

Fig. 2.1

The diameter of the base of the bottle is *d*.

Measure and record *d*.

d = ... [1]

(ii) Estimate the percentage uncertainty in your value of *d*. Show your working.

percentage uncertainty = ... % [1]

(b) • Set up the apparatus as shown in Fig. 2.2.

SIDE VIEW

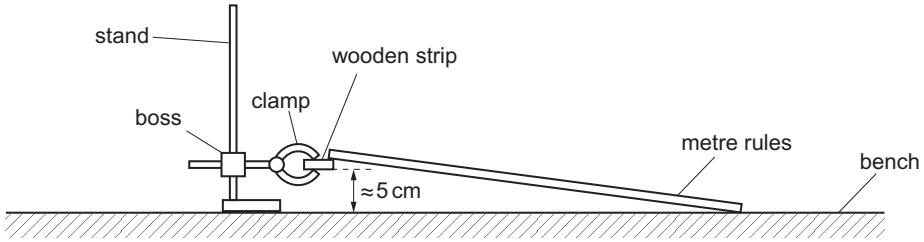

Fig. 2.2

• Adjust the two metre rules so that the rules are approximately parallel to each other, as shown in Fig. 2.3.

TOP VIEW

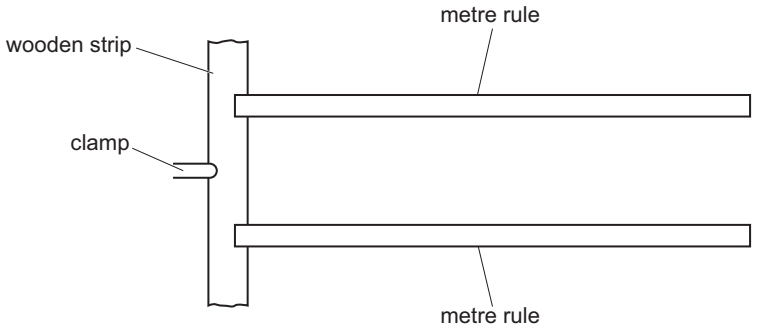

Fig. 2.3

• Pour all the water from the beaker into the bottle.

• Place the bottle on the two rules as shown in Fig. 2.4.

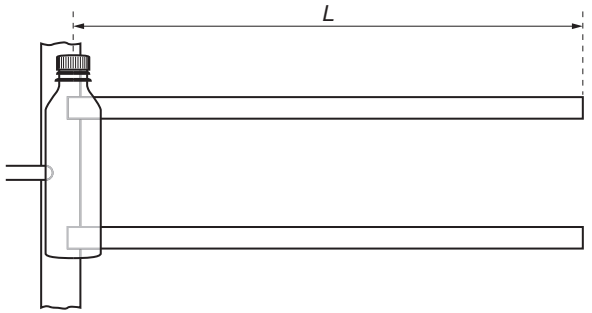

Fig. 2.4 (not to scale)

• Release the bottle. Adjust the rules so that the bottle rolls to the end of the rules.

• The distance that the bottle rolls on the rules is *L*, as shown in Fig. 2.4.

Measure and record *L*.

L = ... [1]

(c) (i) • Stand the bottle upright on the bench.

• The height of the water in the bottle is h, as shown in Fig. 2.5.

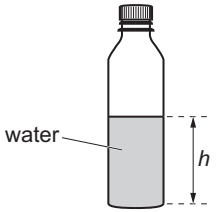

Fig. 2.5

Measure and record h.

h = ...

• The time for the bottle to roll distance L on the rules is t.

Take measurements to determine t.

t = ...
[3]

(ii) A value for the acceleration a of the bottle is given by

$$a = \frac{2L}{t^2}.$$

Calculate a.

a = ... [1]

(iii) Justify the number of significant figures that you have given for your value of a.

.....

.....

..... [1]

(d) • Pour approximately half the water from the bottle into the beaker.

• Repeat **(c)(i)** and **(c)(ii)**.

h = ...

t = ...

a = ...
[2]

(e) It is suggested that the relationship between a and h is

$$a = \frac{kd\sqrt{\pi h}}{2}$$

where k is a constant.

Using your data, calculate **two** values of k.

first value of k = ...

second value of k = ...
[1]

(f) It is suggested that the percentage uncertainty in the values of k is 15%.

Using this uncertainty, explain whether your results support the relationship in **(e)**.

.....

.....

.....

..... [1]

(g) (i) Describe **four** sources of uncertainty or limitations of the procedure for this experiment.

For any uncertainties in measurement that you describe, you should state the quantity being measured and a reason for the uncertainty.

1 .....

.....

2 .....

.....

3 .....

.....

4 .....

.....

[4]

(ii) Describe **four** improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1 .....

.....

2 .....

.....

3 .....

.....

4 .....

.....

[4]

[Total: 20]

2 Four students, **A**, **B**, **C** and **D**, have completed an experiment to determine the acceleration of free fall, *g*. Each student repeated the experiment three times. The determined values of *g* are shown in the table.

Which set of results has a high precision and a low accuracy?

	acceleration of free fall / m s^{-2}		
	experiment 1	experiment 2	experiment 3
A	7.2	9.4	8.3
B	9.5	9.8	10.2
C	9.8	9.8	9.9
D	10.1	10.2	10.1

3 The diameter of a ball is measured as (5.26 ± 0.02) cm.

What is the absolute uncertainty in the volume of the ball?

A 0.29 cm^3 **B** 0.87 cm^3 **C** 1.1 cm^3 **D** 7.0 cm^3

3 A student calculates the density of a solid steel cube in an experiment.

The measured mass is 975 g ± 10 g and the measured length of side is 50 mm ± 1 mm.

What is the density of the steel?

A 7.8 g cm^{-3} ± 3.0%

B 7.8 g cm^{-3} ± 7.0%

C 7.8 g cm^{-3} ± 11%

D 7.8 g cm^{-3} ± 13%

12 A student takes measurements to calculate the density of a liquid in a beaker.

The height of the liquid in the beaker is 0.20 m ± 2%.

The internal diameter of the beaker is 0.05 m ± 3%.

The mass of the liquid is 0.36 kg ± 10%.

What is the percentage uncertainty in the calculated density of the liquid?

A 2% **B** 5% **C** 15% **D** 18%

1 **(a)** Explain what is meant by the accuracy of a measured value.

.....

..... [1]

(b) Two solid cubes, A and B, are measured to determine the density of their materials.

Table 1.1 shows the measurements for cube A.

Table 1.1

quantity	measurement
length of side	(1.53 ± 0.01) cm
mass	(31.3 ± 0.5) g

(i) Show that the calculated density of the material of cube A is 8.7×10^3 kg m^{-3}.

[2]

(ii) Calculate the percentage uncertainty in the density of the material of cube A.

percentage uncertainty = ...% [2]

(iii) The density of the material of cube B is determined to be 9.2×10^3 kg m^{-3} ± 6%.

State and explain whether cube A and cube B could be made from the same material.

.....

.....

.....

..... [2]

[Total: 7]