1 The speed v of a transverse wave on a uniform string is given by the expression

$$v = \sqrt{\frac{Tl}{m}}$$

where T is the tension of the string, l is its length and m is its mass.

An experiment is conducted to determine the speed v of the wave. The measurements are shown in Table 1.1.

Table 1.1

quantity	measurement	uncertainty
T	1.8 N	0.1 N
l	126 cm	2 cm
m	5.1 g	0.2 g

(a) **(i)** Using the data in Table 1.1, determine the percentage uncertainty in the calculation of the speed v of the transverse wave.

percentage uncertainty = ... % [2]

(ii) Using your answer in **(a)(i)** and the data in Table 1.1, determine the value of v, with its absolute uncertainty, to an appropriate number of significant figures.

v = ... ± .... m s^{-1} [2]

1

(b) Another student used a different set-up to determine the value of v. His values of v are as follows:

$$20.6 \text{ m s}^{-1}, 21.1 \text{ m s}^{-1}, 20.4 \text{ m s}^{-1}$$

(i) With reference to the value of v obtained in **(a)(ii)**, comment on the accuracy of the values of v that the second student obtained.

....

.... [1]

(ii) State the type of error that is present in the measurements obtained by the second student.

Suggest a possible way to minimise or eliminate the error.

....

....

.... [2]

2 **(a)** Length, mass and temperature are all SI base quantities.

State two other SI base quantities.

1. ....

2. .... [2]

(b) A small frictionless trolley of mass m is attached to a fixed point A by means of a spring, as shown in Fig. 1.1.

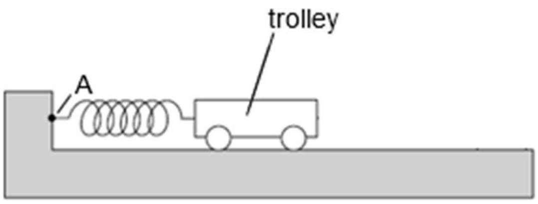

Fig. 1.1

The trolley is then displaced horizontally 5.0 cm and released.

The period T of the oscillations of the trolley is given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where k is the spring constant of the spring.

Data for the oscillation is shown in Fig. 1.2.

quantity	magnitude	uncertainty
k / N m^{-1}	25	± 8 %
m / kg	200×10^{-3}	± 2 %

Fig. 1.2

2 **(i)** Determine the period T of the oscillations, with its uncertainty. Give your answer to an appropriate number of significant figures.

T = ... ± .... s [4]

(ii) **1.** Derive an expression for total energy of the trolley in terms of T.

[2]

2. Calculate the total energy of the trolley using the period calculated in **b(i)**.

total energy = ……………………J [1]

3 Two groups of students performed similar experiments to measure the acceleration due to gravity *g*. Their results are shown in Fig. 1.1.

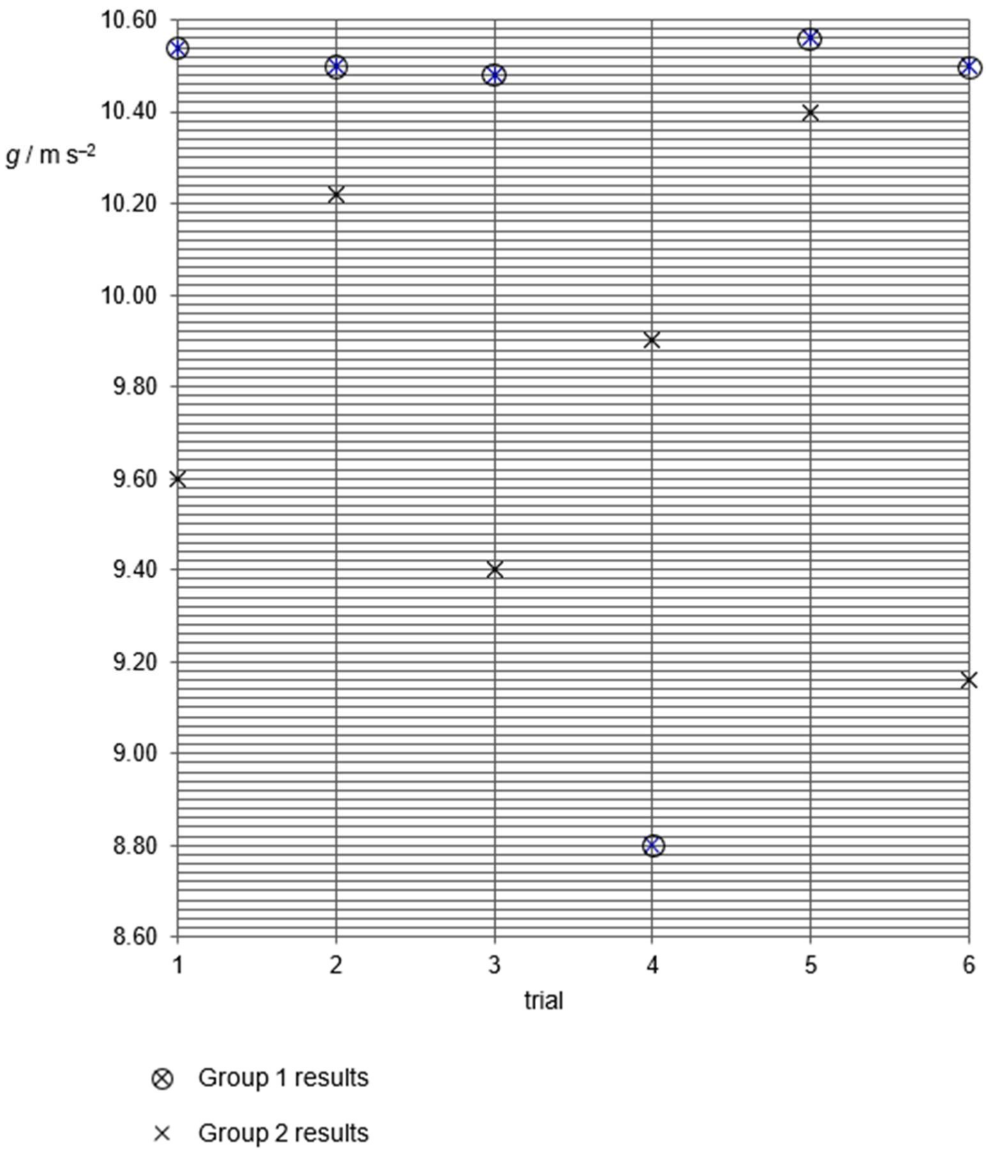

Fig. 1.1

3 The accepted value for *g* is 9.81 m s^{-2}.

Use Fig. 1.1 to answer the following questions. You should make calculations with clear working in support of your answer.

State and explain which group of results has

(a) larger *systematic* errors,

....

....

.... [2]

(b) larger *random* errors.

....

....

.... [2]

[Total: 4]

4 A beam is clamped at one end and an object X is attached to the other end of the beam, as shown in Fig. 1.1.

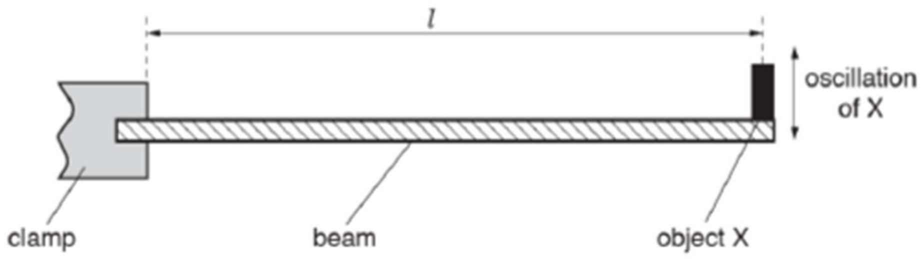

Fig. 1.1

The object X is made to oscillate vertically.

The time period T of the oscillations is given by

$$T = K\sqrt{\frac{Ml^3}{E}}$$

where M is the mass of X,
l is the length between the clamp and X,
E is the Young's modulus of the material of the beam and the unit is kg m^{-1} s^{-2}
and K is a constant.

(a) Determine the S.I. base units of K.

S.I. base units of K .... [2]

4 **(b)** Data in S.I. units for the oscillations of X are shown in Fig. 1.2.

quantity	value	uncertainty
T	0.45	± 2.0%
l	0.892	± 0.2%
M	0.2068	± 0.1%
K	1.48×10^5	± 1.5%

Fig. 1.2

Calculate E and its actual uncertainty.

E .... ± .... kg m^{-1} s^{-2} [4]

[Total :6]

5 The Poiseuille equation relating the volume flow rate $\frac{V}{t}$ of a fluid under laminar conditions through a horizontal tube of length L and internal radius r is

$$\frac{V}{t} = \frac{\pi p r^4}{8 \eta L}$$

where p is the pressure difference between the two ends of the tube and η is the viscosity of the fluid.

(a) Show that the SI base units for η is kg m^{-1} s^{-1}.

[2]

(b) In an experiment to determine η for water, a student recorded the following measurements in SI units, as shown in Table 1.1.

Table 1.1

quantity	magnitude in SI units	percentage uncertainty / %
$\frac{V}{t}$	1.0×10^{-6}	3
p	500	2
L	0.20	0.5

The internal diameter of the tube was measured and recorded as (0.200 ± 0.002) cm.

(i) Calculate the percentage uncertainty in the internal radius r of the tube.

percentage uncertainty = ... % [1]

5 **(ii)** Using the results in Table 1.1 and **(b)(i)**, determine η with its associated uncertainty. Give your answer to an appropriate number of significant figures.

η = ... ± .... kg m^{-1} s^{-1} [4]

(iii) State and explain which measured quantity has the greatest contribution to the uncertainty of η .

....

....

....[1]

[Total: 8]

6 A student takes measurements to determine the acceleration of a ball as it rolls down a slope. He uses the apparatus illustrated in Fig. 1.1.

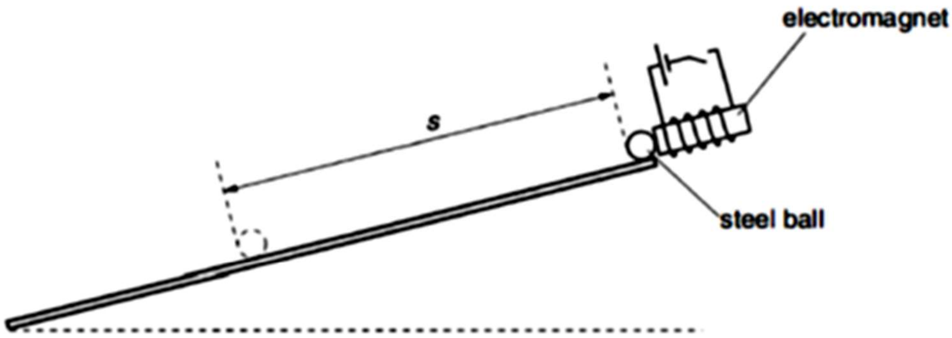

Fig. 1.1

The student measures the time t for the ball to roll a distance s down the slope after the ball has been released from the electromagnet.

The variation with t^2 of the distance s is shown in Fig. 1.2.

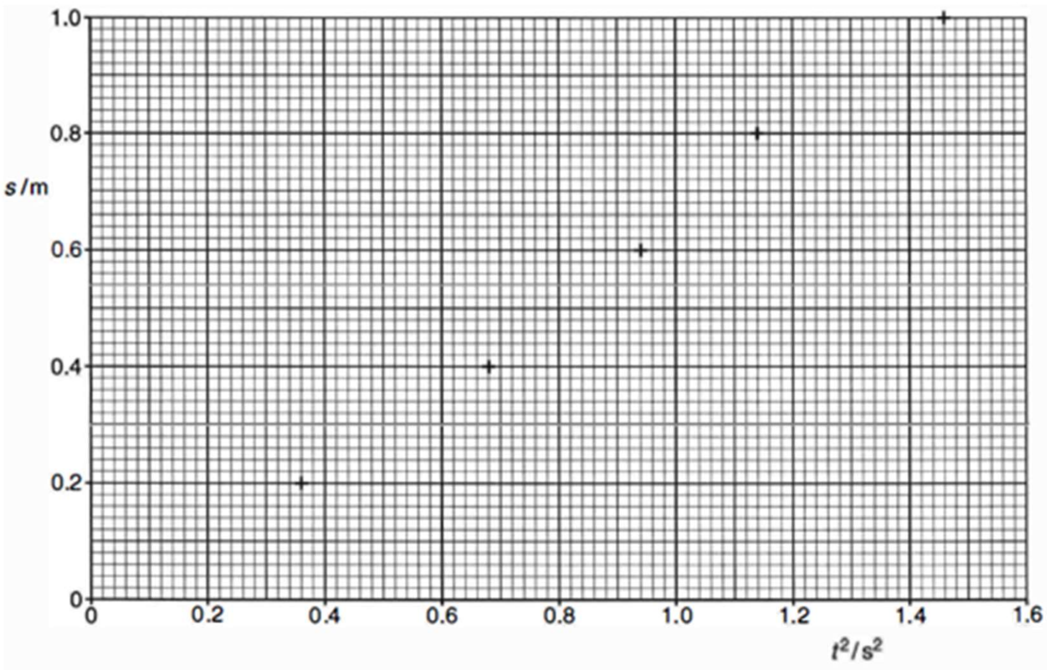

Fig. 1.2

6

(i) Use Fig. 1.2 to determine a value for the acceleration of the ball down the slope.

acceleration = ...m s^{-2} [5]

(ii) State the feature of the data shown in Fig. 1.2 that indicates the presence of

1. random error,

   ....

   ....

   .... [1]

2. systematic error.

   ....

   ....

   .... [1]

7 Experimental measurements of the gravitational constant G in different years are shown in the table.

Year	G / $m^3 kg^{-1} s^{-2}$
2000	$(6.674215 \pm 0.00009) \times 10^{-11}$
2007	$(6.67234 \pm 0.00014) \times 10^{-11}$
2009	$(6.67349 \pm 0.00017) \times 10^{-11}$

(a) State the year in which the measurement of G appears to be the most precise. Explain your answer.

....

.... [1]

(b) The value of G was determined in 2010 at the University of Zurich. The value was consistent with the value obtained in the 2007 experiment but was not consistent with the values from 2000 or 2009. The experimenter who obtained the value for G in 2010 thinks that there is probably a systematic error in each of the other two experiments.

(i) Explain what is meant by a *systematic error*.

....

.... [1]

(ii) Explain why the most precise result may not be the most accurate.

....

....

.... [2]

7 **(c)** In year 2009, experimental measurements were made of the mass of Earth, mass of Moon, and the gravitational force between Earth and Moon.

mass of Earth, M	$5.972 \times 10^{24} \pm 1\%$ kg
mass of Moon, m	$7.348 \times 10^{22} \pm 2\%$ kg
gravitational force between Earth and Moon, F	$(1.98 \pm 0.02) \times 10^{20}$ N

The distance between the centres of Earth and moon, R, is estimated to be around 3.844×10^{8} m.

Express R and its actual uncertainty ΔR. Show your working clearly.

$R \pm \Delta R$ = ... ± .... m [3]

8 A student set up the circuit shown in **Fig. 1.1** to determine the resistance R of a wire and hence the resistivity ρ of the metal of the wire.

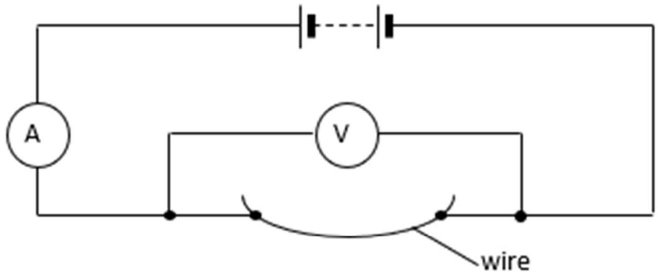

Fig. 1.1

The following readings were obtained for the experiment.

Reading of voltmeter $= 1.30 \pm 0.01$ V

Reading of ammeter $= 0.76 \pm 0.01$ A

Length L of wire $= 75.4 \pm 0.2$ cm

Diameter d of wire $= 0.54 \pm 0.02$ mm

(a) Calculate the percentage uncertainty of the resistance R from his measurements.

Percentage uncertainty = ... % [2]

8 **(b)** The resistivity ρ of the metal of the wire is given by the expression

$$\rho = \frac{\text{Resistance of wire} \times \text{Cross - sectional area of wire}}{\text{Length of wire}}.$$

Calculate, with its actual uncertainty, the value of the resistivity ρ of the metal of the wire.

resistivity = ... Ω m [5]

(c) A unit for resistivity is Ω m. Express this in base units.

[2]

(d) Suggest a method to reduce the percentage uncertainty of R calculated in **(a)**.

....

.... [1]