1. Physical Quantities and Units

1.3 Errors and uncertainties

Paper 2

Question Paper

1 **(b)** A square solar panel with sides of length 1300 mm is shown in Fig. 1.1.

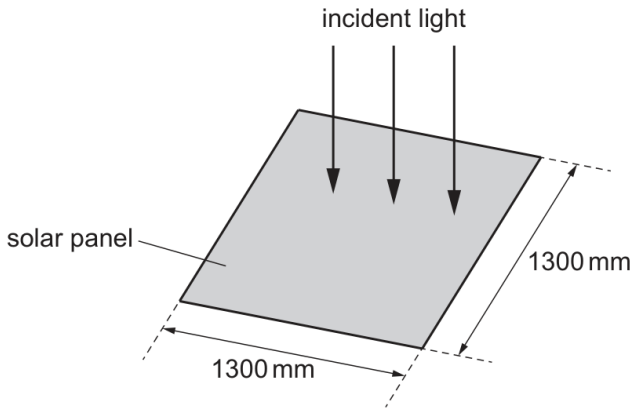


Fig. 1.1 (not to scale)

Light is incident normally on the solar panel.

(ii) The percentage uncertainty in the incident power is ± 3%.
The uncertainty in the length of each side is ± 5 mm.

Calculate the percentage uncertainty in the intensity of the light.

percentage uncertainty = ... % [2]

2 **(b)** Fig. 1.1 shows a cuboidal glass block.

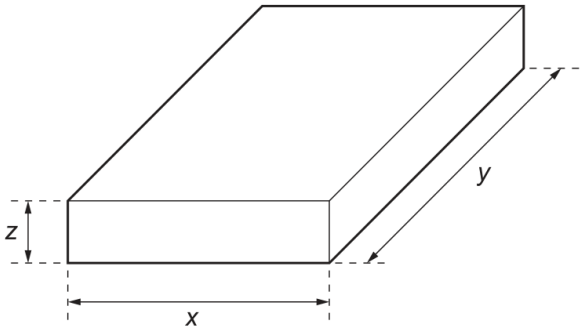


Fig. 1.1 (not to scale)

A student measures the mass m of the block and the side lengths x, y and z. The measurements are shown in Table 1.1.

Table 1.1

quantity	measurement
m	(0.243 ± 0.001) kg
x	(5.41 ± 0.01) cm
y	(11.09 ± 0.01) cm
z	(1.62 ± 0.01) cm

(ii) Calculate the percentage uncertainty in the density.

percentage uncertainty = ...% [3]

(c) The true value of the density of the glass is different from the answer in **(b)(i)** because of a systematic error in the measurements.

Suggest **one** possible cause of this systematic error.

.....

.....

..... [1]

3 **(b)** A horizontal pipe has length L and a circular cross-section of radius R. A liquid of density ρ flows through the pipe. The mass m of liquid flowing through the pipe in time t is given by

$$m = \frac{\pi(p_2 - p_1)R^4\rho t}{8kL}$$

where p_1 and p_2 are the pressures at the ends of the pipe and k is a constant.

(c) An experiment is performed to determine the value of k by measuring the values of the other quantities in the equation in **(b)**.

The values of L and R each have a percentage uncertainty of 2%.

State and explain, quantitatively, which of these two quantities contributes more to the percentage uncertainty in the calculated value of k.

.....

.....

..... [1]

4 **(b)** The radius of a small sphere is determined from a measurement of the volume of the sphere. The sphere is submerged in water, displacing some of the water into a measuring cylinder as shown in Fig. 1.1.

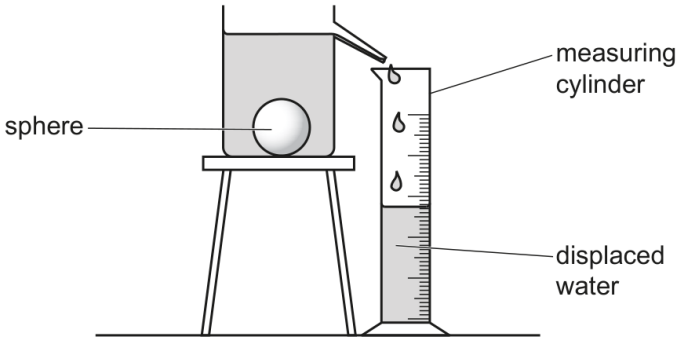


Fig. 1.1 (not to scale)

The measured volume of displaced water is $(28.0 \pm 0.5)\,cm^3$.

Calculate:

(i) the radius, in cm, of the sphere

radius = ... cm [1]

(ii) the percentage uncertainty in the radius of the sphere.

percentage uncertainty = ... % [2]

5 **(b)** Fig. 1.1 shows a horizontal beam clamped at one end with a block attached to the other end.

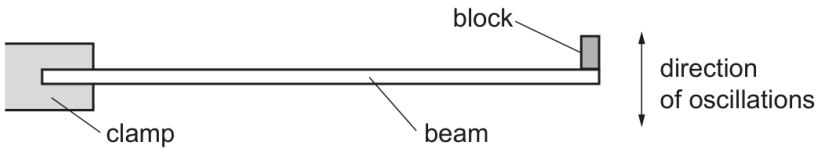


Fig. 1.1

The block is made to oscillate vertically.

The Young modulus E of the material of the beam is given by

$$E = \frac{kM}{T^2}$$

where M is the mass of the block,
T is the period of the oscillations
and k is a constant.

A student determines the values and percentage uncertainties of k, M and T.
Table 1.1 lists the percentage uncertainties.

Table 1.1

quantity	percentage uncertainty
k	±2.1%
M	±0.6%
T	±1.5%

The student uses the values of k, M and T to calculate the value of E as 8.245×10^9 Pa.

(i) Calculate the percentage uncertainty in the value of E.

percentage uncertainty = ... % [2]

(ii) Use your answer in **(b)(i)** to determine the value of E, with its absolute uncertainty, to an appropriate number of significant figures.

E = (..... ± .....) × 10^9 Pa [2]

6 **(b)** A set of experimental measurements is described as precise and not accurate.

State what is meant by:

(i) precise

.....

..... [1]

(ii) not accurate.

.....

..... [1]

(c) An object of mass m travels with speed v in a circle of radius r. The force F acting on the object is given by

$$F = \frac{mv^2}{r}.$$

The percentage uncertainties of three of the quantities are given in Table 1.1.

Table 1.1

quantity	percentage uncertainty
F	±3%
m	±4%
r	±5%

The value of v is determined from F, m and r.

(i) Calculate the percentage uncertainty in v.

percentage uncertainty = ... % [2]

(ii) The value of v is $15.0\,m\,s^{-1}$.

Calculate the absolute uncertainty in v.

absolute uncertainty = ... $m\,s^{-1}$ [1]

7 **(c)** The maximum useful output power P of a car travelling on a horizontal road is given by

$$P = v^3 b$$

where v is the maximum speed of the car and b is a constant.

For the car,

$P = 84\,\text{kW} \pm 5\%$
and $b = 0.56 \pm 7\%$ in SI units.

(i) Calculate the value of v.

$v =$ ..... m s^{-1} [2]

(ii) Determine the absolute uncertainty in the value of v.

absolute uncertainty = ... m s^{-1} [2]

8 **(b)** Fig. 1.1 shows a solid pyramid with a square base.

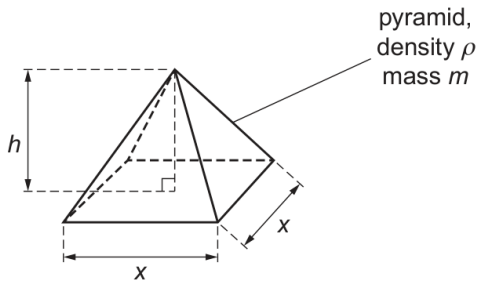


Fig. 1.1

The mass m of the pyramid is given by

$$m = \frac{1}{3}\rho h x^2$$

where ρ is the density of the material of the pyramid,
h is the height, and
x is the length of each side of the base.

Measurements are taken as shown in Table 1.1.

Table 1.1

quantity	measurement	percentage uncertainty
m	19.5 g	±2%
x	4.0 cm	±5%
h	4.8 cm	±4%

(i) Calculate the absolute uncertainty in length x.

absolute uncertainty = ... cm [1]

(ii) The density ρ is calculated from the measurements in Table 1.1.

Determine the percentage uncertainty in the calculated value of ρ.

percentage uncertainty = ... % [2]

9 **(b)** A smooth pebble, made from uniform rock, has the shape of an elongated sphere as shown in Fig. 1.1.

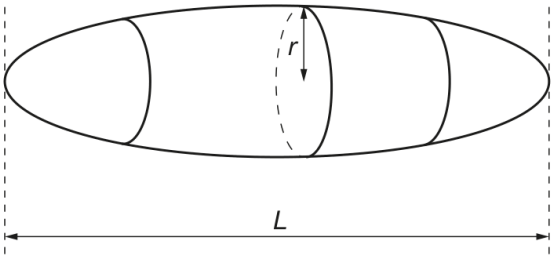


Fig. 1.1

The length of the pebble is L. The cross-section of the pebble, in the plane perpendicular to L, is circular with a maximum radius r.

A student investigating the density of the rock makes measurements to determine the values of L, r and the mass M of the pebble as follows:

$$L = (0.1242 \pm 0.0001)\,\text{m}$$
$$r = (0.0420 \pm 0.0004)\,\text{m}$$
$$M = (1.072 \pm 0.001)\,\text{kg}.$$

(i) State the name of a measuring instrument suitable for making this measurement of L.

..... [1]

(ii) Determine the percentage uncertainty in the measurement of r.

percentage uncertainty = ... % [1]

(c) The density ρ of the rock from which the pebble in **(b)** is composed is given by

$$\rho = \frac{Mr^n}{kL}$$

where n is an integer and k is a constant, with no units, that is equal to 2.094.

(ii) Calculate the percentage uncertainty in ρ.

percentage uncertainty = ... % [3]

(iii) Determine ρ with its absolute uncertainty. Give your values to the appropriate number of significant figures.

ρ = (..... ± .....) kg m^{-3} [3]

10 (c) The potential difference V between the two ends of a uniform metal wire is given by

$$V = \frac{4\rho LI}{\pi d^2}$$

where d is the diameter of the wire,
I is the current in the wire,
L is the length of the wire,
and ρ is the resistivity of the metal.

For a particular wire, the percentage uncertainties in the values of some of the above quantities are listed in Table 1.2.

Table 1.2

quantity	percentage uncertainty
d	±3.0%
I	±2.0%
L	±2.5%
V	±3.5%

The quantities listed in Table 1.2 have values that are used to calculate ρ as $4.1 \times 10^{-7}\,\Omega\,\text{m}$.

For this value of ρ, calculate:

(i) the percentage uncertainty

percentage uncertainty = ...% [2]

(ii) the absolute uncertainty.

absolute uncertainty = ... Ω m [1]

11 (b) (ii) Measurements of a constant current in a wire are taken using an analogue ammeter.

For these measurements, describe one possible cause of:

1. a random error

.....

.....

2. a systematic error.

.....

.....

[2]

12 (b) (i) A school experiment is performed on a metal wire to determine the Young modulus of the metal. A force is applied to one end of the wire which is fixed at the other end. The variation of the force F with extension x of the wire is shown in Fig. 4.1.

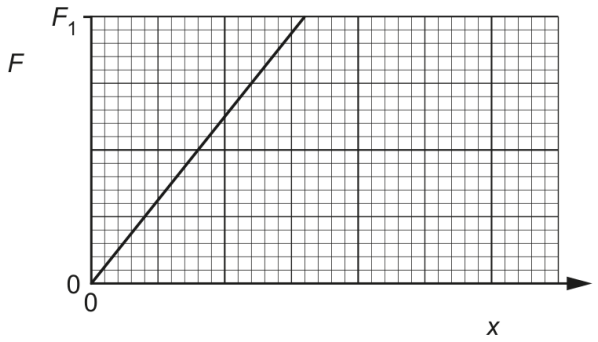


Fig. 4.1

The maximum force applied to the wire is F_1.

The gradient of the graph line in Fig. 4.1 is G. The wire has initial length L and cross-sectional area A.

Determine an expression, in terms of A, G and L, for the Young modulus E of the metal.

$E =$ ..... [2]

(iv) Each student in the class performs the experiment in **(b)(i)**. The teacher describes the values of the Young modulus calculated by the students as having high accuracy and low precision.

Explain what is meant by *low precision*.

.....

..... [1]

13 (b) The speed v of a sound wave through a gas of pressure P and density ρ is given by the equation

$$v = \sqrt{\frac{kP}{\rho}}$$

where k is a constant that has no units.

An experiment is performed to determine the value of k. The data from the experiment are shown in Fig. 1.1.

quantity	value	uncertainty
v	$3.3 \times 10^2\,\text{m s}^{-1}$	± 3%
P	$9.9 \times 10^4\,\text{Pa}$	± 2%
ρ	$1.29\,\text{kg m}^{-3}$	± 4%

Fig. 1.1

(i) Use data from Fig. 1.1 to calculate k.

k = ... [2]

(ii) Use your answer in **(b)(i)** and data from Fig. 1.1 to determine the value of k, with its absolute uncertainty, to an appropriate number of significant figures.

k = ... ± ..... [3]

14 **(a)** The diameter d of a cylinder is measured as 0.0125 m ± 1.6%.

Calculate the absolute uncertainty in this measurement.

absolute uncertainty = ... m [1]

(b) The cylinder in **(a)** stands on a horizontal surface. The pressure p exerted on the surface by the cylinder is given by

$$p = \frac{4W}{\pi d^2}.$$

The measured weight W of the cylinder is 0.38 N ± 2.8%.

(ii) Determine the absolute uncertainty in the value of p.

absolute uncertainty = ... $\mathrm{N\,m^{-2}}$ [2]

15 (b) The period T of the oscillations of a mass m suspended from a spring is given by

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

where k is the spring constant of the spring.

The manufacturer of a spring states that it has a spring constant of $25\,\text{N m}^{-1} \pm 8\%$. A mass of $200 \times 10^{-3}\,\text{kg} \pm 4 \times 10^{-3}\,\text{kg}$ is suspended from the end of the spring and then made to oscillate.

(i) Calculate the period T of the oscillations.

$T =$ ..... s [1]

(ii) Determine the value of T, with its absolute uncertainty, to an appropriate number of significant figures.

$T =$ ..... ± ..... s [3]