Measurements

For Examiner's Use

1 **(a)** State the difference between a scalar quantity and a vector quantity.

scalar: ....

....

vector: ....

.... [2]

(b) Two forces of magnitude 6.0 N and 8.0 N act at a point P. Both forces act away from point P and the angle between them is 40°.
Fig. 1.1 shows two lines at an angle of 40° to one another.

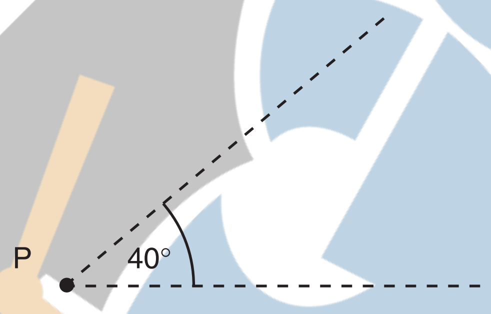

Fig. 1.1

On Fig. 1.1, draw a vector diagram to determine the magnitude of the resultant of the two forces.

magnitude of resultant = ... N [4]

For Examiner's Use

2 Make estimates of the following quantities.

(a) the speed of sound in air

speed = ... [1]

(b) the density of air at room temperature and pressure

density = ... [1]

(c) the mass of a protractor

mass = ... [1]

(d) the volume, in cm^3, of the head of an adult person

volume = ... cm^3 [1]

For Examiner's Use

3 **(a)** Derive the SI base unit of force.

SI base unit of force = ... [1]

(b) A spherical ball of radius r experiences a resistive force F due to the air as it moves through the air at speed v. The resistive force F is given by the expression

$$F = crv,$$

where c is a constant.

Derive the SI base unit of the constant c.

SI base unit of c = ... [1]

(c) The ball is dropped from rest through a height of 4.5 m.

(i) Assuming air resistance to be negligible, calculate the final speed of the ball.

speed = ... $m\,s^{-1}$ [2]

(ii) The ball has mass 15 g and radius 1.2 cm.

The numerical value of the constant *c* in the equation in **(b)** is equal to 3.2×10^{-4} when measured using the SI system of units.

Show quantitatively whether the assumption made in **(i)** is justified.

[3]

4 The uncalibrated scale and the pointer of a meter are shown in Fig. 1.1.

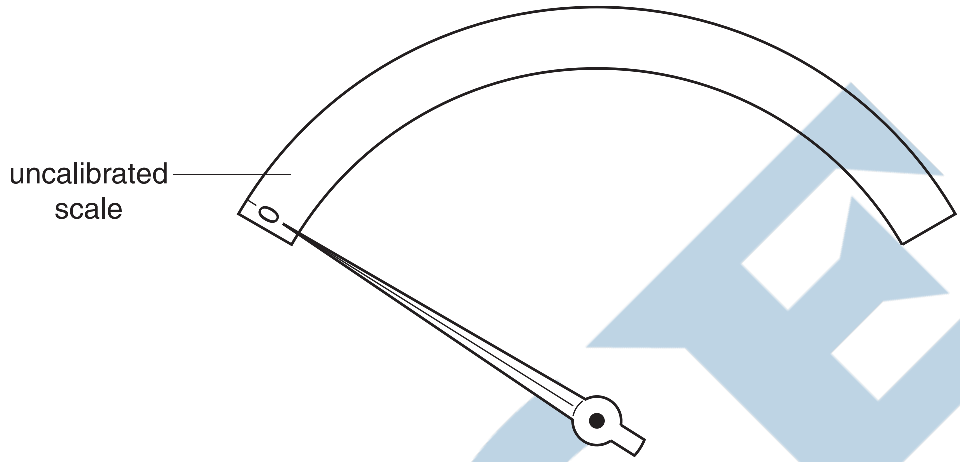

Fig. 1.1

The pointer is shown in the zero position.
The meter is to be used to indicate the volume of fuel in the tank of a car.
A known volume V of fuel is poured into the tank and the deflection θ of the pointer is noted.
Fig. 1.2 shows the variation with θ of V.

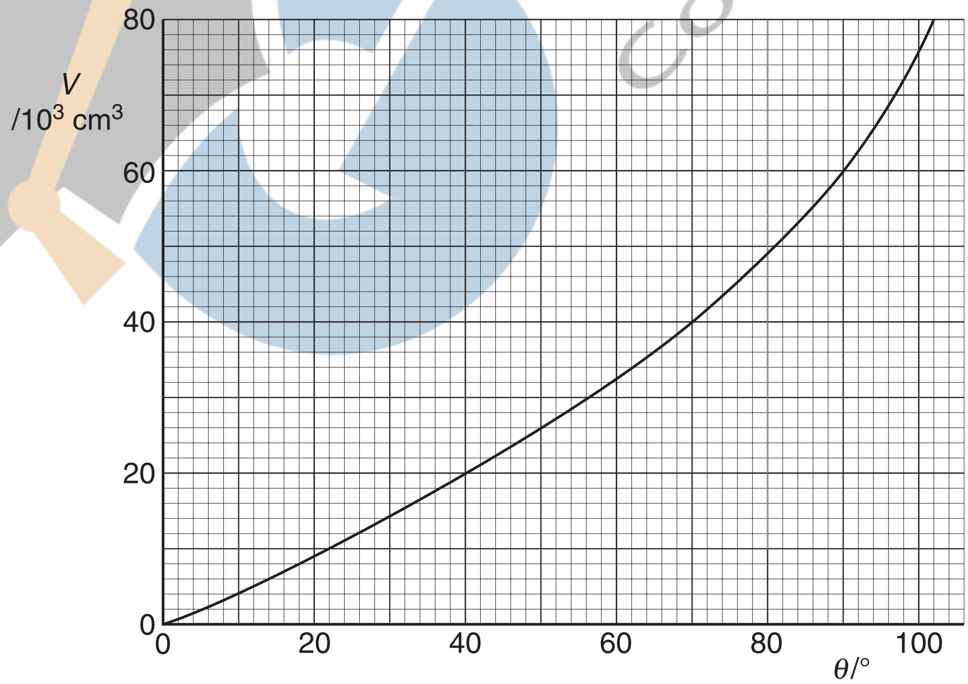

Fig. 1.2

For Examiner's Use

(a) On Fig. 1.1,

(i) calibrate the scale at 20×10^3 cm^3 intervals, [2]

(ii) mark a possible position for a volume of 1.0×10^5 cm^3. [1]

(b) Suggest one advantage of this scale, as compared with a uniform scale, for measuring fuel volumes in the tank of the car.

....

....[1]

For Examiner's Use

5 Make reasonable estimates of the following quantities.

(a) the frequency of an audible sound wave

frequency = ... Hz [1]

(b) the wavelength, in nm, of ultraviolet radiation

wavelength = ... nm [1]

(c) the mass of a plastic 30 cm ruler

mass = ... g [1]

(d) the density of air at atmospheric pressure

density = ... kg m^{-3} [1]

For Examiner's Use

6 **(a)** State the most appropriate instrument, or instruments, for the measurement of the following.

(i) the diameter of a wire of diameter about 1 mm

.... [1]

(ii) the resistance of a filament lamp

.... [1]

(iii) the peak value of an alternating voltage

.... [1]

(b) The mass of a cube of aluminium is found to be 580 g with an uncertainty in the measurement of 10 g. Each side of the cube has a length of (6.0 ± 0.1) cm.

Calculate the density of aluminium with its uncertainty. Express your answer to an appropriate number of significant figures.

density = ... ± .... g cm^{-3} [5]

7 A student determines the acceleration of free fall using the apparatus illustrated in Fig. 2.1.

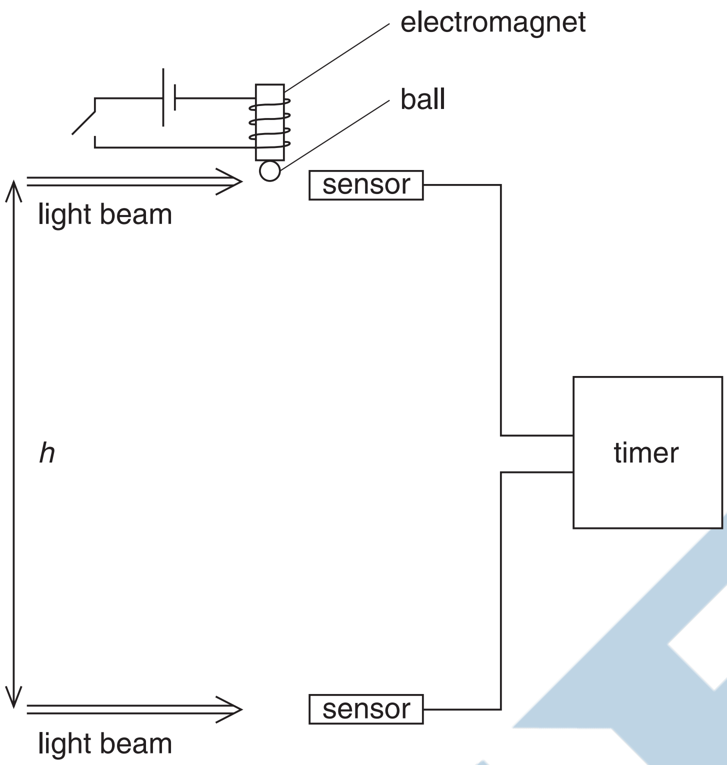

Fig. 2.1

A steel ball is held on an electromagnet. When the electromagnet is switched off, the ball immediately interrupts a beam of light and a timer is started. As the ball falls, it interrupts a second beam of light and the timer is stopped. The vertical distance h between the light beams and the time t recorded on the timer are noted. The procedure is repeated for different values of h. The student calculates values of t^2 and then plots the graph of Fig. 2.2.

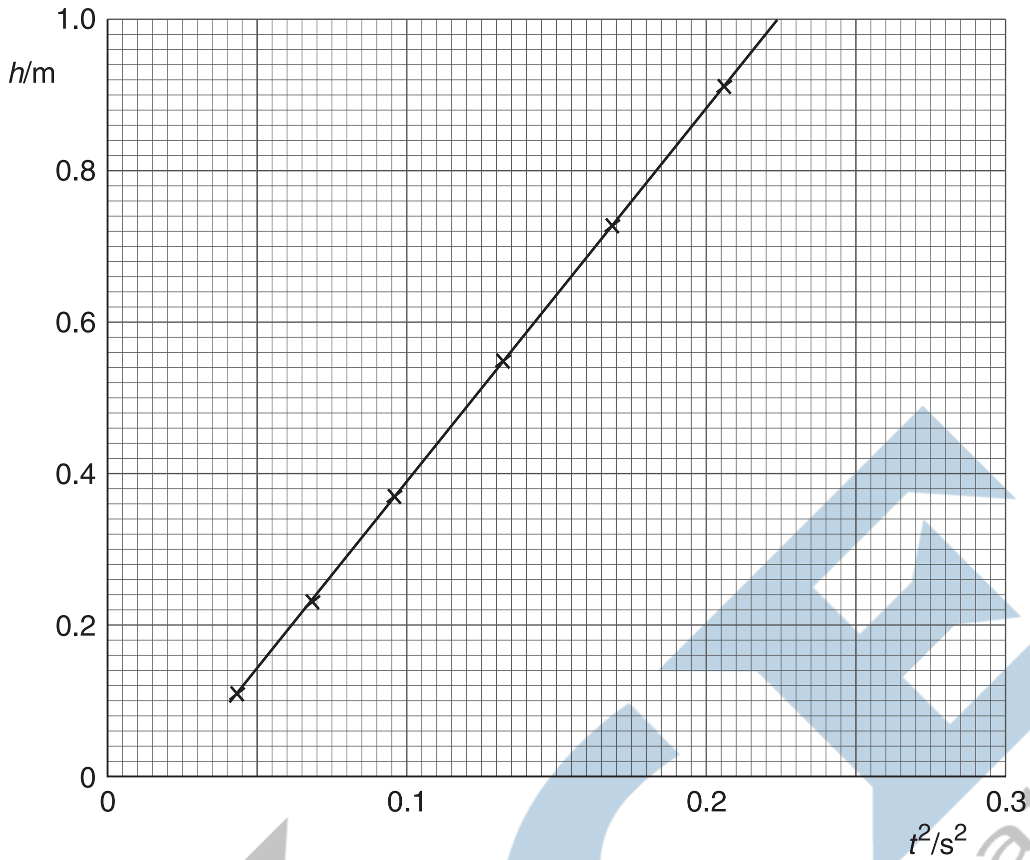

Fig. 2.2

(a) Use Fig. 2.2 to calculate a value for g, the acceleration of free fall of the ball. Explain your working.

g = ... $m\,s^{-2}$ [4]

(b) Identify one possible source of random error in the determination of g and suggest how this error may be reduced.

....

....

....[2]

8 **(a)** **(i)** Define *density*.

....

....

(ii) State the base units in which density is measured.

.... [2]

(b) The speed v of sound in a gas is given by the expression

$$v = \sqrt{\left(\frac{\gamma p}{\rho}\right)},$$

where p is the pressure of the gas of density ρ. γ is a constant.

Given that p has the base units of $\text{kg m}^{-1}\text{s}^{-2}$, show that the constant γ has no unit. [3]

9 A student uses a metre rule to measure the length of an elastic band before and after stretching it.

The lengths are recorded as

length of band before stretching, $L_0 = 50.0 \pm 0.1$ cm

length of band after stretching, $L_S = 51.6 \pm 0.1$ cm.

Determine

(a) the change in length $(L_S - L_0)$, quoting your answer with its uncertainty,

$(L_S - L_0)$ = ... cm [1]

(b) the fractional change in length, $\frac{(L_S - L_0)}{L_0}$,

fractional change = ... [1]

(c) the uncertainty in your answer in **(b)**.

uncertainty = ... [3]

For Examiner's Use

10 A student takes readings to measure the mean diameter of a wire using a micrometer screw gauge.

(a) Make suggestions, one in each case, that the student may adopt in order to

(i) reduce a systematic error in the readings,

....

....

(ii) allow for a wire of varying diameter along its length,

....

....

(iii) allow for a non-circular cross-section of the wire.

....

....
[3]

(b) The mean diameter of the wire is found to be 0.50 ± 0.02 mm. Calculate the percentage uncertainty in

(i) the diameter,

uncertainty = ... %

(ii) the area of cross-section of the wire.

uncertainty = ... %
[2]

For Examiner's Use

11 **(a)** **(i)** Define *pressure*.

....

.... [1]

(ii) State the units of pressure in base units.

.... [1]

(b) The pressure p at a depth h in an incompressible fluid of density ρ is given by

$$p = \rho g h,$$

where g is the acceleration of free fall.
Use base units to check the homogeneity of this equation.

....

....

....

.... [3]

12 (a) Distinguish between systematic errors and random errors.

systematic errors ....

....

random errors ....

.... [2]

(b) A cylinder of length *L* has a circular cross-section of radius *R*, as shown in Fig. 1.1.

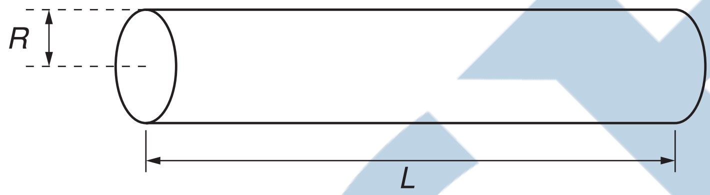

Fig. 1.1

The volume *V* of the cylinder is given by the expression

$$V = \pi R^2 L.$$

The volume and length of the cylinder are measured as

$V = 15.0 \pm 0.5\,\text{cm}^3$
$L = 20.0 \pm 0.1\,\text{cm}.$

Calculate the radius of the cylinder, with its uncertainty.

radius = ... ± .... cm [5]

For Examiner's Use

13 **(a)** The current in a wire is I. Charge Q passes one point in the wire in time t. State

(i) the relation between I, Q and t,

.... [1]

(ii) which of the quantities I, Q and t are base quantities.

....

.... [2]

(b) The current in the wire is due to electrons, each with charge q, that move with speed v along the wire. There are n of these electrons per unit volume.
For a wire having a cross-sectional area S, the current I is given by the equation

$$I = nSqv^k,$$

where k is a constant.

(i) State the units of I, n, S, q and v in terms of the base units.

I ....

n ....

S ....

q ....

v ....
[3]

(ii) By considering the homogeneity of the equation, determine the value of k.

k = ... [2]

14 The volume of fuel in the tank of a car is monitored using a meter as illustrated in Fig. 1.1.

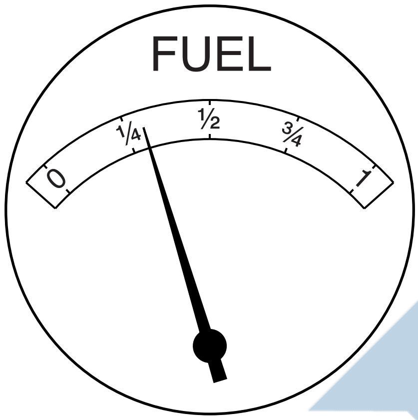

Fig. 1.1

The meter has an analogue scale. The meter reading for different volumes of fuel in the tank is shown in Fig. 1.2.

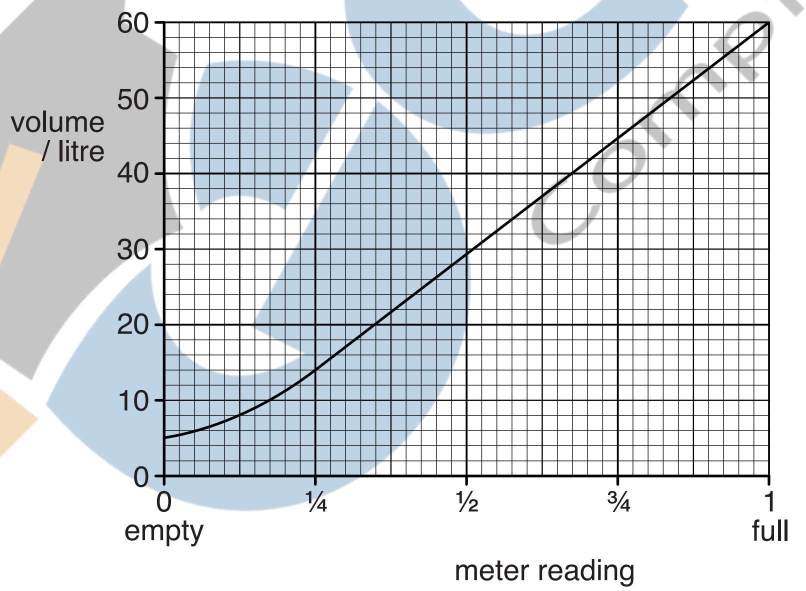

Fig. 1.2

The meter is calibrated in terms of the fraction of the tank that remains filled with fuel.

(a) The car uses 1.0 litre of fuel when travelling 14 km. The car starts a journey with a full tank of fuel.

(i) Calculate the volume of fuel remaining in the tank after a journey of 210 km.

volume = ... litres [2]

(ii) Use your answer to **(i)** and Fig. 1.2 to determine the change in the meter reading during the 210 km journey.

from *full* to .... [1]

(b) There is a systematic error in the meter.

(i) State the feature of Fig. 1.2 that indicates that there is a systematic error.

....

.... [1]

(ii) Suggest why, for this meter, it is an advantage to have this systematic error.

....

.... [1]

For Examiner's Use

15 A simple pendulum may be used to determine a value for the acceleration of free fall *g*. Measurements are made of the length *L* of the pendulum and the period *T* of oscillation.

The values obtained, with their uncertainties, are as shown.

$T = (1.93 \pm 0.03)\,\text{s}$
$L = (92 \pm 1)\,\text{cm}$

(a) Calculate the percentage uncertainty in the measurement of

(i) the period *T*,

uncertainty = ... % [1]

(ii) the length *L*.

uncertainty = ... % [1]

For Examiner's Use

(b) The relationship between T, L and g is given by

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

Using your answers in **(a)**, calculate the percentage uncertainty in the value of g.

uncertainty = ... % [1]

(c) The values of L and T are used to calculate a value of g as 9.751 m s^{-2}.

(i) By reference to the measurements of L and T, suggest why it would not be correct to quote the value of g as 9.751 m s^{-2}.

....

.... [1]

(ii) Use your answer in **(b)** to determine the absolute uncertainty in g.

Hence state the value of g, with its uncertainty, to an appropriate number of significant figures.

g = ... ± .... m s^{-2} [2]

16 A student has been asked to determine the linear acceleration of a toy car as it moves down a slope. He sets up the apparatus as shown in Fig. 3.1.

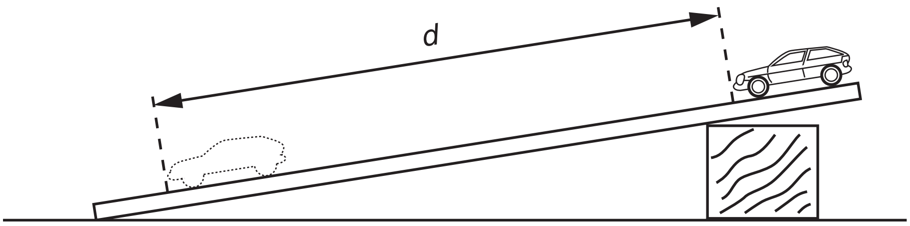

Fig. 3.1

The time *t* to move from rest through a distance *d* is found for different values of *d*. A graph of *d* (*y*-axis) is plotted against t^2 (*x*-axis) as shown in Fig. 3.2.

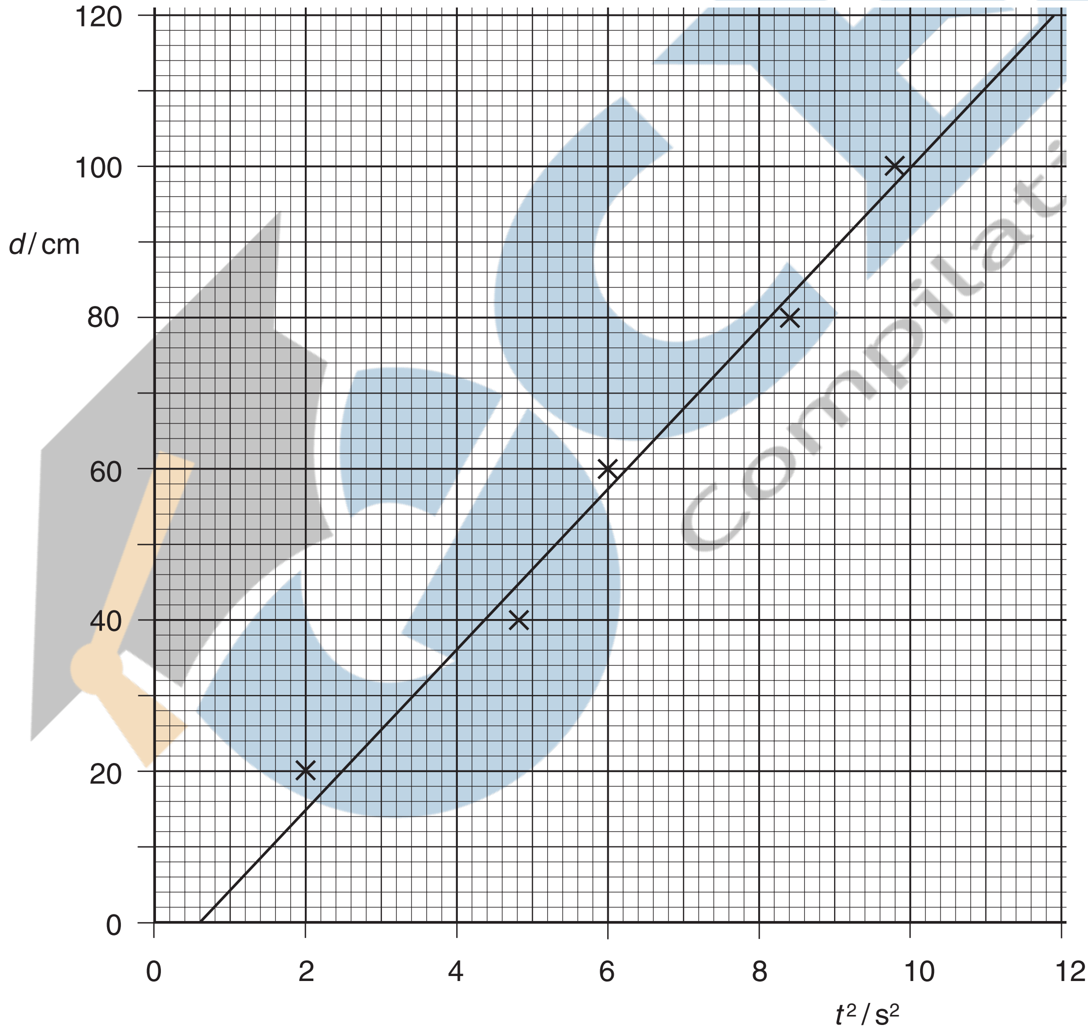

Fig. 3.2

For Examiner's Use

(a) Theory suggests that the graph is a straight line through the origin.
Name the feature on Fig. 3.2 that indicates the presence of

(i) random error,

....

(ii) systematic error.

....
[2]

(b) **(i)** Determine the gradient of the line of the graph in Fig. 3.2.

gradient = ... [2]

(ii) Use your answer to **(i)** to calculate the acceleration of the toy down the slope.
Explain your working.

acceleration = ... $m\,s^{-2}$ [3]

Answer **all** the questions in the spaces provided.

1 A unit is often expressed with a prefix. For example, the gram may be written with the prefix 'kilo' as the kilogram. The prefix represents a power-of-ten. In this case, the power-of-ten is 10^3.

Complete Fig. 1.1 to show each prefix with its symbol and power-of-ten.

prefix	symbol	power-of-ten
kilo	k	10^3
nano	n	....
centi	....	10^{-2}
....	M	10^6
....	T	10^{12}

Fig. 1.1

[4]

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 A metal wire has a cross-section of diameter approximately 0.8 mm.

(a) State what instrument should be used to measure the diameter of the wire.

.... [1]

(b) State how the instrument in **(a)** is

(i) checked so as to avoid a systematic error in the measurements,

....

.... [1]

(ii) used so as to reduce random errors.

....

....

.... [2]

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 A digital voltmeter with a three-digit display is used to measure the potential difference across a resistor. The manufacturers of the meter state that its accuracy is ±1% and ±1 digit.
The reading on the voltmeter is 2.05 V.

(a) For this reading, calculate, to the nearest digit,

(i) a change of 1% in the voltmeter reading,

change = ...V [1]

(ii) the maximum possible value of the potential difference across the resistor.

maximum value = ...V [1]

(b) The reading on the voltmeter has high precision. State and explain why the reading may not be accurate.

....

....

....[2]

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** Two of the SI base quantities are mass and time. State three other SI base quantities.

1. ....

2. ....

3. ....
[3]

(b) A sphere of radius r is moving at speed v through air of density ρ. The resistive force F acting on the sphere is given by the expression

$$F = Br^2 \rho v^k$$

where B and k are constants without units.

(i) State the SI base units of F, ρ and v.

F ....

ρ ....

v ....
[3]

(ii) Use base units to determine the value of k.

k = ... [2]

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** **(i)** Distinguish between vector quantities and scalar quantities.

....

....

.... [2]

(ii) State whether each of the following is a vector quantity or a scalar quantity.

1. temperature

.... [1]

2. acceleration of free fall

.... [1]

3. electrical resistance

.... [1]

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 Make estimates of the following quantities.

(a) the thickness of a sheet of paper

thickness = ... mm [1]

(b) the time for sound to travel 100 m in air

time = ... s [1]

(c) the weight of 1000 cm^3 of water

weight = ... N [1]

2 Briefly describe the structures of crystalline solids, polymers and amorphous materials.

crystalline solids ....

....

....

polymers ....

....

....

amorphous materials ....

....

....

[5]

Answer **all** the questions in the spaces provided.

1 **(a)** **(i)** Distinguish between vector quantities and scalar quantities.

....

....

.... [2]

(ii) State whether each of the following is a vector quantity or a scalar quantity.

1. temperature

.... [1]

2. acceleration of free fall

.... [1]

3. electrical resistance

.... [1]

For Examiner's Use

(b) A block of wood of weight 25 N is held stationary on a slope by means of a string, as shown in Fig. 1.1.

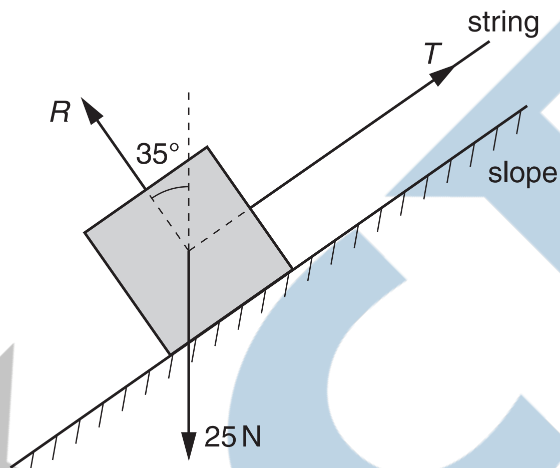

Fig. 1.1

The tension in the string is T and the slope pushes on the block with a force R that is normal to the slope.

Either by scale drawing on Fig. 1.1 or by calculation, determine the tension T in the string.

T = ... N [3]

For Examiner's Use

3 A loudspeaker produces a sound wave of constant frequency.

Outline how a cathode-ray oscilloscope (c.r.o.) may be used to determine this frequency.

....

....

....

....

.... [4]

For Examiner's Use

1 **(a)** For each of the following, tick [✓] one box to indicate whether the experimental technique would reduce random error, systematic error or neither. The first row has been completed as an example.

	random error	systematic error	neither
keeping your eye in line with the scale and the liquid level for a single reading of a thermometer		✓	
averaging many readings of the time taken for a ball to roll down a slope			
using a linear scale on an ammeter			
correcting for a non-zero reading when a micrometer screw gauge is closed			

[2]

(b) The measurement of a particular time interval is repeated many times. The readings are found to vary. The results are shown in Fig. 1.1.

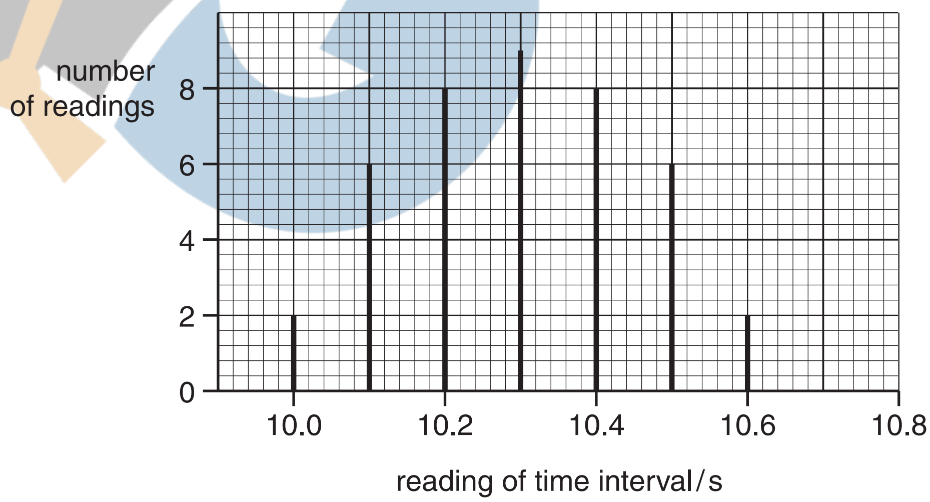

Fig. 1.1

The true value of the time interval is 10.1 s.

For Examiner's Use

(i) State how the readings on Fig. 1.1 show the presence of

1. a systematic error,

....

.... [1]

2. a random error.

....

.... [1]

(ii) State the expected changes to Fig. 1.1 for experimental measurements that are

1. more accurate,

....

.... [1]

2. more precise.

....

.... [1]

Answer **all** the questions in the spaces provided.

1 **(a)** Distinguish between *scalar* quantities and *vector* quantities.

....

....

.... [2]

(b) In the following list, underline **all** the scalar quantities.

acceleration   force   kinetic energy   mass   power   weight   [1]

(c) A stone is thrown with a horizontal velocity of $20\,m\,s^{-1}$ from the top of a cliff 15 m high. The path of the stone is shown in Fig. 1.1.

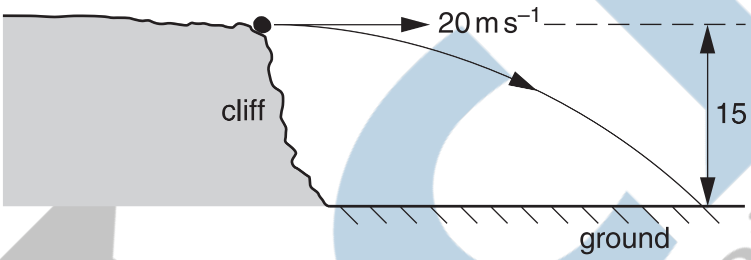

Fig. 1.1

Air resistance is negligible.

For this stone,

(i) calculate the time to fall 15 m,

time = ... s [2]

(ii) calculate the magnitude of the resultant velocity after falling 15 m,

resultant velocity = ... $m\,s^{-1}$ [3]

(iii) describe the difference between the displacement of the stone and the distance that it travels.

For Examiner's Use

....

....

.... [2]

[Turn over

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 Measurements made for a sample of metal wire are shown in Fig. 1.1.

quantity	measurement	uncertainty
length	1750 mm	± 3 mm
diameter	0.38 mm	± 0.01 mm
resistance	7.5 Ω	± 0.2 Ω

Fig. 1.1

(a) State the appropriate instruments used to make each of these measurements.

(i) length

.... [1]

(ii) diameter

.... [1]

(iii) resistance

.... [1]

(b) **(i)** Show that the resistivity of the metal is calculated to be 4.86×10^{-7} Ω m.

[2]

(ii) Calculate the uncertainty in the resistivity.

uncertainty = ± .... Ω m [4]

(c) Use the answers in **(b)** to express the resistivity with its uncertainty to the appropriate number of significant figures.

For Examiner's Use

resistivity = ... ± .... Ω m [1]

[Turn over

For Examiner's Use

2 **(a)** A sphere of radius R is moving through a fluid with constant speed v. There is a frictional force F acting on the sphere, which is given by the expression

$$F = 6\pi DRv$$

where D depends on the fluid.

(i) Show that the SI base units of the quantity D are $kg\,m^{-1}\,s^{-1}$.

[3]

(ii) A raindrop of radius 1.5 mm falls vertically in air at a velocity of $3.7\,m\,s^{-1}$. The value of D for air is $6.6 \times 10^{-4}\,kg\,m^{-1}\,s^{-1}$. The density of water is $1000\,kg\,m^{-3}$.

Calculate

1. the magnitude of the frictional force F,

F = ... N [1]

2. the acceleration of the raindrop.

acceleration = ... $m\,s^{-2}$ [3]

For Examiner's Use

(b) The variation with time *t* of the speed *v* of the raindrop in **(a)** is shown in Fig. 2.1.

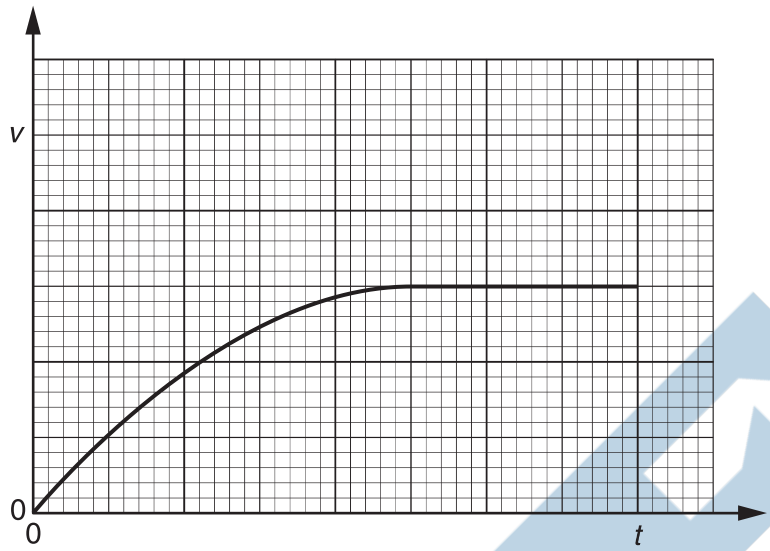

Fig. 2.1

(i) State the variation with time of the **acceleration** of the raindrop.

....

....

....

....

.... [3]

(ii) A second raindrop has a radius that is smaller than that given in **(a)**. On Fig. 2.1, sketch the variation of speed with time for this second raindrop. [2]