CAMBRIDGE INTERNATIONAL AS & A LEVEL • PHYSICS 9702

Topical Questions

Unit 1: Unit and Measurement

Past Papers 2021 – 2025

QUESTION PAPER 24 Questions

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Question 1

(a) Define *density*.

.....

..... [1]

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

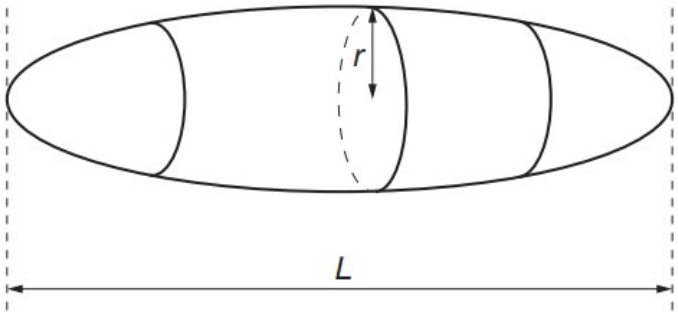

Fig. 1.1

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.

(i) Use SI base units to show that n is equal to –2.

[2]

(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]

[Total: 11]

Question 2

(a) A unit may be stated with a prefix that represents a power-of-ten multiple or submultiple.

Complete Table 1.1 to show the name and symbol of each prefix and the corresponding power-of-ten multiple or submultiple.

Table 1.1

prefix	power-of-ten multiple or submultiple
kilo (k)	10^3
tera (T)	
( )	10^{-12}

[2]

(b) In the following list, underline all the units that are SI base units.

ampere coulomb metre newton [1]

(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 $4.1 \times 10^{-7}\,\Omega\,m$.

For this value of ρ, calculate:

(i) the percentage uncertainty

percentage uncertainty = ...% [2]

(ii) the absolute uncertainty.

absolute uncertainty = ... Ω m [1]

[Total: 6]

Question 3

(a) Define *density*.

.....

..... [1]

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

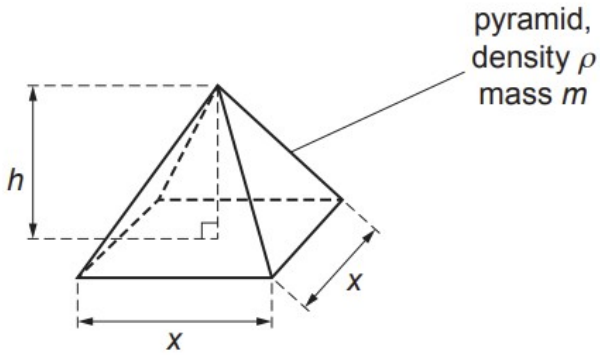

Fig. 1.1

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]

(c) The square base of the pyramid in **(b)** rests on the horizontal surface of a bench.

Use data from Table 1.1 to calculate the average pressure of the pyramid on the surface of the bench. The uncertainty in your answer is not required.

pressure = ... Pa [3]

[Total: 7]

Question 4

(a) A property of a vector quantity, that is not a property of a scalar quantity, is direction. For example, velocity has direction but speed does not.

(i) State **two** other scalar quantities and **two** other vector quantities.

scalar quantities: ..... and .....

vector quantities: ..... and .....

[2]

(ii) State **two** properties that are possessed by both scalar and vector physical quantities.

1. .....

2. .....

[2]

(b) A ship at sea is travelling with a velocity of $13\,m\,s^{-1}$ in a direction 35° east of north in still water, as shown in Fig. 1.1.

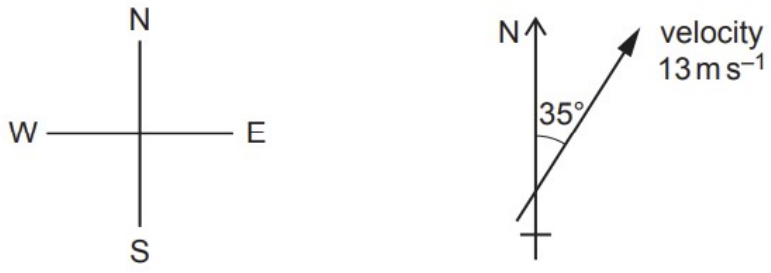

Fig. 1.1

(i) Determine the magnitudes of the components of the velocity of the ship in the north and the east directions.

north component of velocity = ... $m\,s^{-1}$

east component of velocity = ... $m\,s^{-1}$

[2]

(ii) The ship now experiences a tidal current. The water in the sea moves with a velocity of $2.7\,m\,s^{-1}$ to the west.

Calculate the resultant velocity component of the ship in the east direction.

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

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to determine the magnitude of the resultant velocity of the ship.

magnitude of resultant velocity = ... $m\,s^{-1}$ [2]

(iv) Use your answers in **(b)(i)** and **(b)(ii)** to determine the angle between north and the resultant velocity of the ship.

angle = ...° [2]

[Total: 11]

Question 5

(a) The results of the α-particle scattering experiment provide evidence for the structure of the atom.

Result 1: The vast majority of the α-particles pass straight through the metal foil or are deviated by small angles.

Result 2: A very small minority of α-particles is scattered through angles greater than 90°.

State what may be inferred (deduced) from:

(i) result 1

.....

..... [1]

(ii) result 2.

.....

.....

..... [2]

(b) A radioactive decay sequence contains four nuclei, P, Q, R and S, as shown.

$$^{218}_{84}\text{P} \rightarrow {}^{214}_{82}\text{Q} \rightarrow {}^{214}_{83}\text{R} \rightarrow \text{S}$$

Nucleus S is an isotope of nucleus P.

(i) Determine the proton number and the nucleon number of nucleus S.

proton number = ...

nucleon number = ...
[2]

(ii) The quark composition of a nucleon in Q changes as Q decays to form R.

Describe this change to the quark composition of the nucleon.

.....

..... [1]

[Total: 6]

Question 6

(a) The boxes in Fig. 1.1 contain terms on the left-hand side and examples of these terms on the right-hand side.

Draw a line between each term on the left and the correct example on the right.

base quantity	coulomb
base unit	electric current
derived quantity	force
derived unit	kilogram

Fig. 1.1

[2]

(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]

[Total: 7]

Question 7

(b) Use the answer to **(a)** to determine the SI base units of power.

SI base units ..... [2]

(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]

Question 8

The rate of flow Q of a liquid along a narrow pipe of length L and radius r is given by

$$Q = \frac{\alpha r^4}{L}$$

where α is a constant.

An experiment is carried out to determine the value of α. The data from the experiment are shown in Table 1.1.

Table 1.1

quantity	value	percentage uncertainty
Q	$2.72 \times 10^{-8}\,m^3\,s^{-1}$	±3%
r	$7.1 \times 10^{-5}\,m$	±2%
L	$2.5 \times 10^{-2}\,m$	±4%

(a) Use information in Table 1.1 to show that the SI base unit of α is s^{-1}.

[1]

(b) Show that the percentage uncertainty in α is 15%.

[1]

(c) Calculate α with its absolute uncertainty. Give your answer to an appropriate number of significant figures.

α = (..... ± .....) × $10^7\ s^{-1}$ [3]

[Total: 5]

Question 9

(a) In the following list, underline all units that are SI base units.

ampere degree Celsius kilogram newton [1]

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

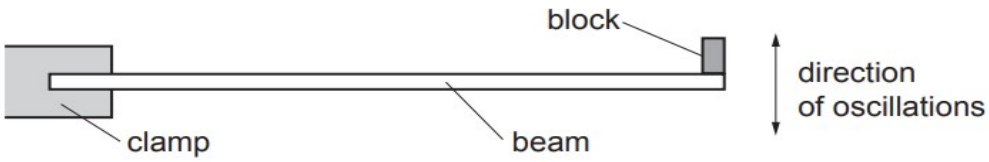

Fig. 1.1

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.

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]

[Total: 5]

Question 10

A solid metal sphere has a diameter of (3.42 ± 0.02) cm and a mass of (67 ± 2) g.

(a) Calculate the density, in g cm^{-3}, of the metal.

density = ... g cm^{-3} [3]

(b) Determine the percentage uncertainty in the density.

percentage uncertainty = ...% [2]

[Total: 5]

Question 11

(a) Compare scalar and vector quantities.

.....

.....

..... [2]

(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.

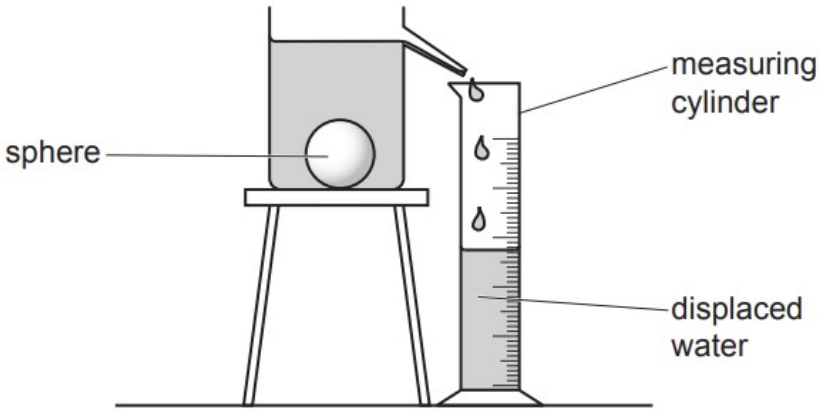

Fig. 1.1 (not to scale)

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]

[Total: 5]

Question 12

(a) Table 1.1 lists some physical quantities. Complete the table by placing a tick (✓) next to the scalar quantities.

Table 1.1

acceleration	
charge	
momentum	
power	
upthrust	

[1]

(b) A uniform cylinder has diameter D, length L and mass M.
The density ρ of the cylinder is given by

$$\rho = \frac{4M}{\pi D^2 L}.$$

Table 1.2 shows the data obtained from an experiment to determine the density of the cylinder.

Table 1.2

quantity	measurement	percentage uncertainty
D	(26.2 ± 0.1) mm	.....%
L	(162 ± 1) mm	.....%
M	(247 ± 1) g	0.4%

(i) Calculate the percentage uncertainties in D and L. Write your answers in Table 1.2.

[1]

(ii) Calculate the density of the cylinder. Give your answer to three significant figures.

density = ... $kg\,m^{-3}$ [2]

(iii) Calculate the percentage uncertainty in the density.

percentage uncertainty = ...% [2]

[Total: 6]

Question 13

(a) (i) Define power.

.....

..... [1]

(ii) Use the definition of power to show that the SI base units of power are $kg\,m^2\,s^{-3}$.

[1]

(b) The intensity I of a sound wave moving through a gas is given by

$$I = f^2A^2vk$$

where f is the frequency of the wave,
A is the amplitude of the wave,
v is the speed of the wave
and k is a constant that depends on the gas.

Determine the SI base units of k.

SI base units ..... [3]

[Total: 5]

Question 14

(a) (i) Define pressure.

.....

..... [1]

(ii) Use the answer to **(a)(i)** to show that the SI base units of pressure are $kg\,m^{-1}\,s^{-2}$.

[1]

(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.

Determine the SI base units of k.

SI base units ..... [3]

(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]

[Total: 6]

Question 15

(a) Underline **all** the SI base units in the following list.

ampere coulomb current kelvin newton [1]

(b) A toy car moves in a horizontal straight line. The displacement s of the car is given by the equation

$$s = \frac{v^2}{2a}$$

where a is the acceleration of the car and v is its final velocity.

State **two** conditions that apply to the motion of the car in order for the above equation to be valid.

1 .....

2 .....

[2]

(c) An experiment is performed to determine the acceleration of the car in **(b)**. The following measurements are obtained:

$s = 3.89\,\text{m} \pm 0.5\%$
$v = 2.75\,\text{m s}^{-1} \pm 0.8\%$.

(i) Calculate the acceleration a of the car.

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

(ii) Determine the percentage uncertainty, to two significant figures, in a.

percentage uncertainty = ...% [2]

(iii) Use your answers in **(c)(i)** and **(c)(ii)** to determine the absolute uncertainty in the calculated value of *a*.

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

[Total: 7]

Question 16

(a) Define density.

.....

..... [1]

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

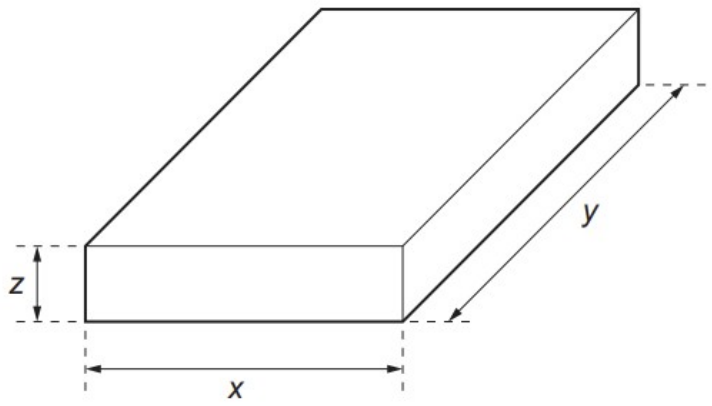

Fig. 1.1 (not to scale)

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

(i) Determine the density of the glass.

density = ... $kg\,m^{-3}$ [2]

(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]

[Total: 7]

Question 17

(a) State what is meant by a vector quantity.

.....

..... [1]

(b) A sphere falls vertically through a liquid that has density 830 kg m^{-3}. The sphere has radius r and constant velocity v, as shown in Fig. 1.1.

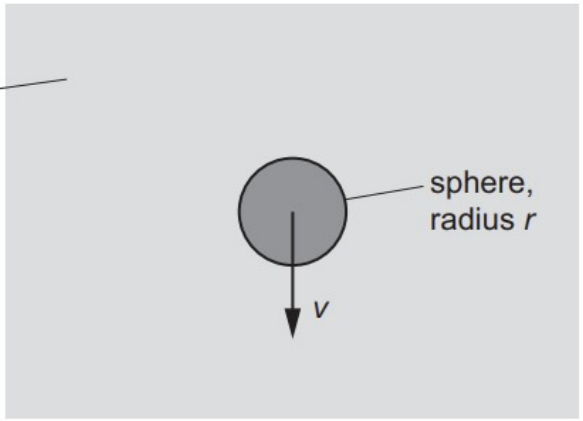

Fig. 1.1

(i) The drag force D acting on the sphere is given by

$$D = 6\pi r\eta v$$

where η is a property of the liquid.

Determine the SI base units of η.

SI base units ..... [3]

(ii) State an equation showing the relationship between the magnitudes of the weight *W*, drag force *D* and upthrust *U* acting on the sphere.

..... [1]

Question 18

The drag force F_D acting on an object falling through air is given by

$$F_D = \frac{1}{2} C\rho A v^2$$

where A is the cross-sectional area of the object,
v is the velocity of the object in the air,
ρ is the density of the air and
C is a constant called the drag coefficient.

(a) Use SI base units to show that the drag coefficient has no units.

[3]

Question 19

(a) The list below shows some SI quantities.

Underline the quantity that is **not** an SI base quantity.

charge current length time [1]

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

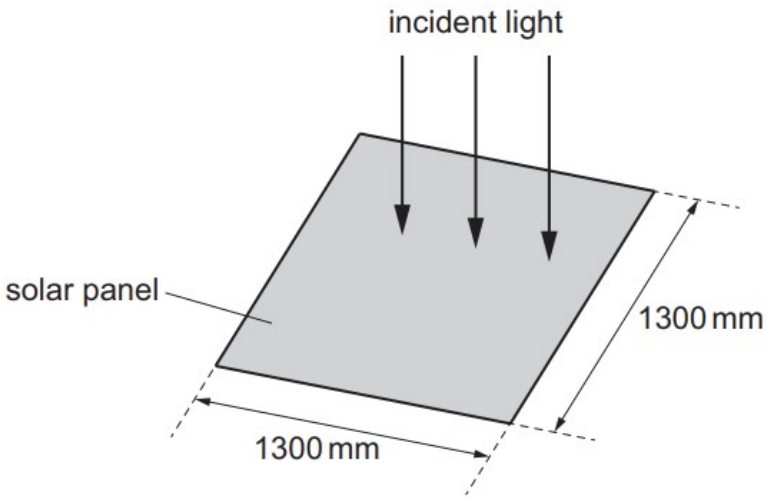

Fig. 1.1 (not to scale)

Light is incident normally on the solar panel.

(i) The power of the light incident on the solar panel is 750 W.

Calculate the intensity of the light.

intensity = ... $W\,m^{-2}$ [3]

(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]

(iii) The useful power output of the solar panel is 160 W.

Calculate the percentage efficiency of the solar panel.

efficiency = ... % [1]

(iv) Another square solar panel is placed so that light of the same intensity is incident normally on it. The new panel has shorter sides than the original panel. The new panel has the same power output as the original panel.

State and explain whether the efficiency of the new panel is greater than, less than or the same as the efficiency of the original panel.

.....

.....

.....

.....

..... [3]

[Total: 10]

Question 20

The drag force F_D acting on a sphere falling through a liquid is given by

$$F_D = 6\pi\eta r v$$

where r is the radius of the sphere,
v is the speed of the sphere in the liquid and
η is a property of the liquid called the viscosity.

(a) Show that the SI base units of viscosity are $\text{kg m}^{-1}\text{ s}^{-1}$.

[2]

(b) The sphere has a radius of 3.0 cm and is falling vertically downwards at a terminal velocity of $2.0\,\text{m s}^{-1}$ through the liquid. The drag force acting on the sphere is 0.096 N.

Calculate the viscosity of the liquid.

viscosity = ... $\text{kg m}^{-1}\text{ s}^{-1}$ [2]

Question 21

(a) Table 1.1 lists some SI quantities. Complete the table by indicating with a tick (✓) which rows are SI base quantities.

Table 1.1

quantity	base quantity
current	
energy	
force	
mass	

[1]

(b) Use the definition of power to determine its SI base units.

SI base units ..... [2]

(c) A light meter is used to measure the intensity of light in a classroom. Daylight is incident normally on the sensor of the meter. The sensor has an area of $2.2\,cm^2$. The reading on the meter is $950\,W\,m^{-2}$.

Calculate the power of the daylight incident on the sensor.

power = ... W [3]

[Total: 6]

Question 22

1 Scientists are investigating the variation in air pressure at different locations on a mountain.

(a) The scientists take measurements of several physical quantities at each location.

Complete Table 1.1 by stating the SI base unit for each quantity and identifying with a tick (✓) whether each quantity is a scalar or a vector. Use the space for any working.

Table 1.1

quantity measured	SI base unit	scalar	vector
air temperature			
air pressure			

[2]

(b) (i) At one location, the density of the air is $1.1\,\text{kg}\,\text{m}^{-3}$. A spherical weather balloon is filled with a gas and released from rest. The balloon has radius 0.90 m.

Calculate the upthrust acting on the balloon when it is released.

upthrust = ... N [2]

(ii) Explain why an upthrust acts on the balloon.

.....

.....

.....

..... [2]

(iii) The balloon has weight 19 N.

Calculate the magnitude of the initial acceleration of the balloon.

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

(c) A quantity c relating to the motion of the balloon is calculated from three measured quantities k, F and v using the formula

$$c = \frac{2kF}{v^2}.$$

The percentage uncertainties in the measured quantities are given in Table 1.2.

Table 1.2

measured quantity	percentage uncertainty
k	5%
F	3%
v	4%

The calculated value of c is 1.8.

Determine the absolute uncertainty in c.

absolute uncertainty = ... [2]

[Total: 11]

Question 23

(a) Table 1.1 lists some physical quantities. Identify with ticks (✓) which quantities are vectors and which are scalars.

Table 1.1

quantity	scalar	vector
acceleration		
displacement		
gravitational potential energy		
speed		
temperature		

[2]

Question 24

(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 $8.7 \times 10^3 \text{ kg m}^{-3}$.

[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 $9.2 \times 10^3\,\text{kg}\,\text{m}^{-3} \pm 6\%$.

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

.....

.....

.....

..... [2]

[Total: 7]

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