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AS Level 9702

PHYSICS

TOPICAL PAPER 2

2016-2023

All Variants / All Topics

With Mark Scheme

Cambridge 2023-2025 Syllabus

Arranged Sub-Topic Wise

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Content for Paper 2 Topical

All that I am

Or Hope to Be,

I Owe to My

Angel Mother

Abdul Hakeem

Syllabus Content

1 Physical quantities and units

1.1 Physical quantities

Candidates should be able to:

1 understand that all physical quantities consist of a numerical magnitude and a unit

2 make reasonable estimates of physical quantities included within the syllabus

1.2 SI units

Candidates should be able to:

1 recall the following SI base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K)

2 express derived units as products or quotients of the SI base units and use the derived units for quantities listed in this syllabus as appropriate

3 use SI base units to check the homogeneity of physical equations

4 recall and use the following prefixes and their symbols to indicate decimal submultiples or multiples of both base and derived units: pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T)

1.3 Errors and uncertainties

Candidates should be able to:

1 understand and explain the effects of systematic errors (including zero errors) and random errors in measurements

2 understand the distinction between precision and accuracy

3 assess the uncertainty in a derived quantity by simple addition of absolute or percentage uncertainties

1.4 Scalars and vectors

Candidates should be able to:

1 understand the difference between scalar and vector quantities and give examples of scalar and vector quantities included in the syllabus

2 add and subtract coplanar vectors

3 represent a vector as two perpendicular components

1.1 Physical Quantities

2022

9702/22/F/M/22/Q1

1 A sphere of radius 2.1 mm falls with terminal (constant) velocity through a liquid, as shown in Fig. 1.1.

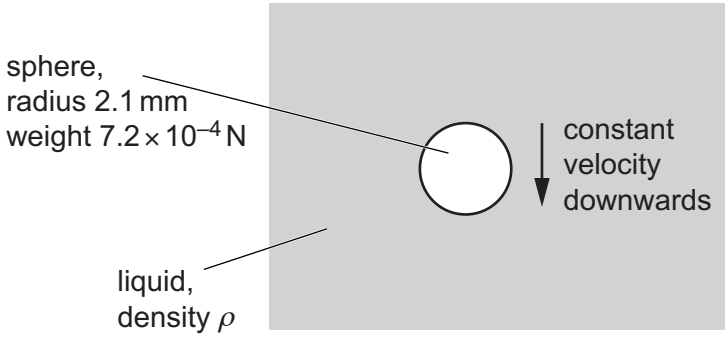

Fig. 1.1

Three forces act on the moving sphere. The weight of the sphere is 7.2×10^{-4} N and the upthrust acting on it is 4.8×10^{-4} N. The viscous force F_V acting on the sphere is given by

$$F_V = krv$$

where r is the radius of the sphere, v is its velocity and k is a constant. The value of k in SI units is 17.

(a) Determine the SI base units of k.

SI base units ..... [2]

(b) Use the value of the upthrust acting on the sphere to calculate the density ρ of the liquid.

ρ = ... kg m^{-3} [3]

(c) **(i)** On the sphere in Fig. 1.1, draw three arrows to show the directions of the weight *W*, the upthrust *U* and the viscous force F_V. Label these arrows *W*, *U* and F_V respectively. [1]

(ii) Determine the magnitude of the terminal (constant) velocity of the sphere.

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

2021

2 **(a)** State what is meant by *work done*. **9702/23/O/N/21/Q2**

.....

..... [1]

(b) Use your answer in **(a)** to show that the SI base units of energy are $kg\,m^2\,s^{-2}$.

[1]

(c) A metal rod is heated at one end so that thermal energy flows to the other end. The thermal energy *E* that flows through the rod in time *t* is given by

$$E = \frac{cA(T_1 - T_2)t}{L}$$

where *A* is the cross-sectional area of the rod,
T_1 and T_2 are the temperatures of the ends of the rod,
L is the length of the rod,
and *c* is a constant.

Determine the SI base units of *c*.

SI base units ..... [3]

2015

3 Underline all the scalar quantities in the list below. **9702/23/M/J/15/Q1/d**

acceleration energy momentum power weight

[1]

1.2 SI Units

2023

1 (a) (i) Define pressure. **9702/22/M/J/23/Q1**

.....

..... [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]

---

2 **(a)** **(i)** Define power. **9702/21/M/J/23/Q1**

.....

..... [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]

2019

3 **(a)** Distinguish between vector and scalar quantities. **9702/22/O/N/19/Q1**

.....

.....

..... [2]

(b) The electric field strength E at a distance x from an isolated point charge Q is given by the equation

$$E = \frac{Q}{x^2 b}$$

where b is a constant.

(i) Use the definition of electric field strength to show that E has SI base units of kg m A^{-1} s^{-3}.

[2]

(ii) Use the units for E given in **(b)(i)** to determine the SI base units of b.

SI base units of b ..... [2]

4 **(a)** **(i)** Define *resistance*. **9702/23/M/J/19/Q1**

.....

.....[1]

(ii) A potential difference of 0.60 V is applied across a resistor of resistance 4.0 GΩ.

Calculate the current, in pA, in the resistor.

current = ... pA [2]

(b) The energy E transferred when charge Q moves through an electrical component is given by the equation

$$E = QV$$

where V is the potential difference across the component.

Use the equation to determine the SI base units of potential difference.

SI base units ..... [3]

2018

5 **(a)** Define *force*. **9702/22/M/J/18/Q1**

.....[1]

(b) State the SI base units of force.

.....[1]

(c) The force F between two point charges is given by $F = \dfrac{Q_1 Q_2}{4\pi r^2 \varepsilon}$

where Q_1 and Q_2 are the charges,
r is the distance between the charges,
ε is a constant that depends on the medium between the charges.

Use the above expression to determine the base units of ε.

base units .....[2]

2017

6 **(a)** **(i)** Define *power*. **9702/23/O/N/17/Q1**

.....

.....[1]

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

[1]

(b) All bodies radiate energy. The power P radiated by a body is given by

$$P = kAT^4$$

where T is the thermodynamic temperature of the body,
A is the surface area of the body
and k is a constant.

(i) Determine the SI base units of k.

base units .....[2]

(ii) On Fig. 1.1, sketch the variation with T^2 of P. The quantity A remains constant.

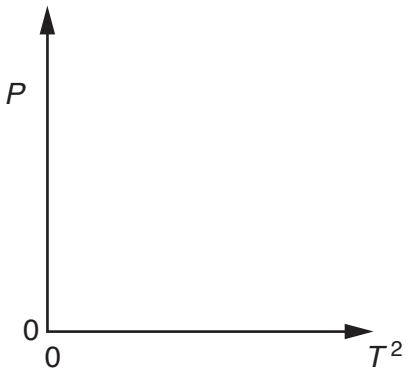

Fig. 1.1

[1]

9702/21/O/N/17/Q1 (a)

7 The drag force F_D acting on a sphere moving through a fluid is given by the expression

$$F_D = K\rho v^2$$

where K is a constant,
ρ is the density of the fluid
and v is the speed of the sphere.

Determine the SI base units of K.

base units .....[3]

---

8 **(a)** State two SI base units other than kilogram, metre and second. **9702/22/M/J/17/Q1**

1. .....

2. .....

[1]

(b) Determine the SI base units of resistivity.

base units .....[3]

2016

9 (a) (i) Define *pressure*. **9702/22/O/N/16/Q1**

.....

.....[1]

(ii) Show that the SI base units of pressure are $kg\,m^{-1}\,s^{-2}$.

[1]

(b) Gas flows through the narrow end (nozzle) of a pipe. Under certain conditions, the mass m of gas that flows through the nozzle in a short time t is given by

$$\frac{m}{t} = kC\sqrt{\rho P}$$

where k is a constant with no units,
C is a quantity that depends on the nozzle size,
ρ is the density of the gas arriving at the nozzle,
P is the pressure of the gas arriving at the nozzle.

Determine the base units of C.

base units .....[3]

1.3 Errors and Uncertainties

2023

1 **(a)** Underline **all** the SI base units in the following list. **9702/22/F/M/23/Q1**

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]

2022

9702/23/O/N/22/Q1

2 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]

---

3 **(a)** State what is meant by work done. **9702/22/O/N/22/Q1**

.....

..... [1]

(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 kW ± 5%
and b = 0.56 ± 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]

9702/21/O/N/22/Q1

4 **(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]

9702/23/M/J/22/Q1

5 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]

---

6 **(a)** In the following list, underline all units that are SI base units. **9702/22/M/J/22/Q1**

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.

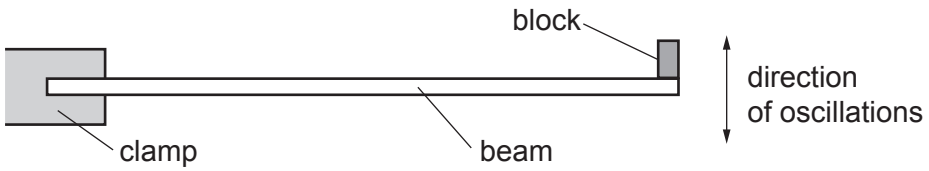

Fig. 1.1

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.

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]

2021

9702/22/O/N/21/Q1

7 **(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]

8 **(a)** Define *density*. **9702/21/O/N/21/Q1**

.....

..... [1]

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

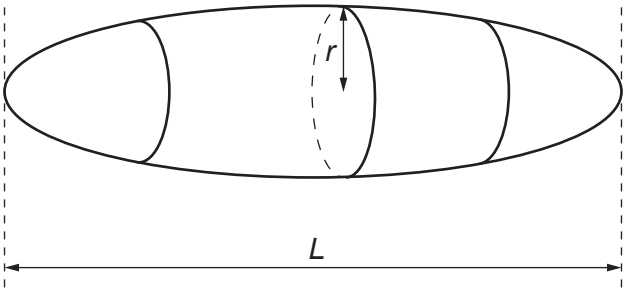

Fig. 1.1

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]

9 **(a)** Define *density*. **9702/21/M/J/21/Q1**

.....

..... [1]

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

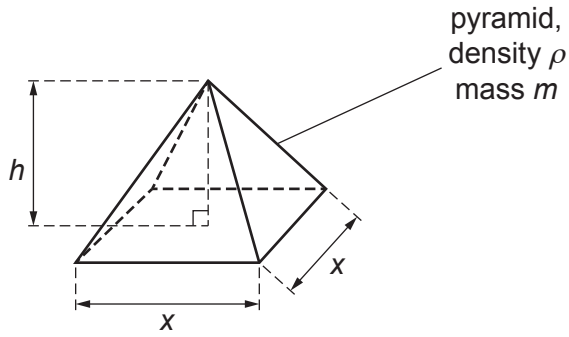

Fig. 1.1

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]

2020

10 **(a)** An electromagnetic wave has a wavelength of 85 μm. **9702/23/O/N/20/Q1**

(i) State the wavelength, in m, of the wave.

wavelength = ... m [1]

(ii) Calculate the frequency, in THz, of the wave.

frequency = ... THz [2]

(iii) State the name of the region of the electromagnetic spectrum that contains this wave.

..... [1]

(b) The current I in a coil of wire produces a magnetic field. The energy E stored in the magnetic field is given by

$$E = \frac{I^2 L}{2}$$

where L is a constant.

The manufacturer of the coil states that the value of L, in SI base units, is $7.5 \times 10^{-6} \pm 5\%$. The current I in the coil is measured as (0.50 ± 0.02) A.

The values of L and I are used to calculate E.

Determine the percentage uncertainty in the value of E.

percentage uncertainty = ... % [2]

9702/21/M/J/20/Q1

11 **(a)** Use an expression for work done, in terms of force, to show that the SI base units of energy are $kg\,m^2\,s^{-2}$.

[2]

(b) **(i)** The energy E stored in an electrical component is given by

$$E = \frac{Q^2}{2C}$$

where Q is charge and C is a constant.

Use this equation and the information in **(a)** to determine the SI base units of C.

SI base units ..... [2]

(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]