SAT PHYSICS

PHYSICAL QUANTITIES AND UNITS

PHYSICS

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PHYSICALS QUANTITIES AND UNITS

Learning outcomes
Candidates should be able to:

1.1 Physical quantities a) understand that all physical quantities consist of a numerical magnitude and a unit
b) make reasonable estimates of physical quantities included within the syllabus

1.2 SI units
a) recall the following SI base quantities and their units: mass (kg), length(m), time (s), current (A), temperature (K), **amount of substance** (**mol**)
b) express derived units as products or quotients of the SI base units and use the named units listed in this syllabus as appropriate
c) use SI base units to check the homogeneity of physical equations
d) 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)
e) understand and use the conventions for labelling graph axes and table columns as set out in the ASE publication *Signs*, *Symbols and Systematics* (*The ASE Companion to 16–19 Science*, 2000)

1.3 The Avogadro constant
a) understand that the Avogadro constant *N*A is the number of atoms in 0.012 kg of carbon-12
b) use molar quantities where one mole of any substance is the amount containing a number of particles equal to the Avogadro constant *N*A

1.4 Scalars and vectors
a) distinguish between scalar and vector quantities and give examples of each
b) add and subtract coplanar vectors
c) represent a vector as two perpendicular components

PHYSICALS QUANTITIES AND UNITS

SI Units

Base Quantities and Base Units

Base quantities	SI units	Symbols
Mass	kilogram	kg
Length	metre	m
Time	second	s
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Electric current	ampere	A
Luminous intensity	candela	cd

Some Examples of Derived Quantities and their Units

Derived quantities	Defining equations	Base quantities used	Derived units
Area	length × breadth	length	m^2
Volume	length × breadth × height	length	m^3
Speed	rate of change of distance	length, time	$m\ s^{-1}$
Acceleration	rate of change of velocity	length, time	$m\ s^{-2}$
Force	mass × acceleration	mass, length, time	$kg\ m\ s^{-2}$ or N
Momentum	mass × velocity	mass, length, time	$kg\ m\ s^{-1}$
Work	force × distance	mass, length, time	$kg\ m^2\ s^{-2}$ or J

DIMENSIONS OF PHYSICAL QUANTITIES

Symbols used to denote dimensions

The dimensions of the base quantities like mass, length, time, temperature, amount of substance, current can be denoted by capital letters M, L, T, θ, N and A respectively.

Prefixes for Multiples of SI Units

Multiplication Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

EXERCISE 1.1

1. Which one of the following units is a derived unit ?
   a. candela b. mole c. second d. kelvin e. volt
2. What is the correct definition of velocity ?
   a. displacement per unit time
   b. distance travelled in unit time
   c. distance travelled per unit time
   d. speed in a particular direction
3. The relationship between four physical quantities x, p, q and t is given by : x = p + qt , where t is the time in seconds. If q has the units ms^{-1} then p must have the units.
   a. ms^{-1} b. ms^{-2} c. m s d. m e. ms^{-3}
4. The force of attraction F between two particles of masses m_1 and m_2 situated a distance r apart is given by $F = G\dfrac{m_1.m_2}{r^2}$; the gravitational constant G has the SI unit.
   a. $Nm^{-2}kg^{-2}$ c. ms^{-2} e. $J.m.kg^{-1}$
   b. $m^3kg^{-1}s^{-2}$ d. m^2kg^{-2}
5. The amount of energy E in joule emitted by a black body is given by the equation : $E = \sigma\, t\, A\, T^4$, where t, A, T represent time in s, area in m^2 and temperature in K respectively. Determine the unit of the constant σ .
   a. $J\ s\ m^{-1}\ K^{-4}$ c. $J\ s^{-1}\ m\ K^{-4}$ e. $J\ s^{-1}\ m^{-2}\ K^{-4}$
   b. $J\ s\ m^{-2}\ K^{-4}$ d. $J\ s^{-1}\ m^{-1}\ K^{-4}$
6. The energy of a photon of light of frequency f is given by h.f , where h is the planck constant. What are the base units of h ?
   a. $kg\ m\ s^{-1}$ c. $kg\ m^2\ s^{-2}$ e. $kg\ m^{-1}\ s^2$
   b. $kg\ m^2\ s^{-1}$ d. $kg\ m^2\ s^{-3}$
7. The base units of the SI system include those of mass, kg ; length, m ; time, s ; electric current, A. Which base units would be needed to express the SI unit of potential difference (the volt) ?
   a. kg and A only c. s and A only e. kg, m, s and A
   b. m and A only d. m, s and A

8. The experimental measurement of the heat capacity C of a solid as a function of temperature T is to be fitted to the expression

$$C = \alpha T + \beta T^3$$

What are possible units of α and β ?

	α	β
a.	J	$J\ K^{-2}$
b.	$J\ K^2$	J
c.	J K	$J\ K^3$
d.	$J\ K^{-2}$	$J\ K^{-4}$
e.	J	J

9. The equation $P + av^2 = b$ is dimensionally correct, P and v represent pressure and velocity respectively. The unit of a is similar to that of.

a. Mass c. Density e. Area
b. Volume d. Force

EXERCISE 1.2

1. Suppose we are told that the acceleration **a** of a particle moving with uniform speed **v** in a circle of radius **r** is proportional to some power of r, say $\mathbf{r^n}$, and some power of v, say $\mathbf{v^m}$, we write this acceleration $\mathbf{a = k\ r^n\ v^m}$ where k is a dimensionless constant. Determine the values of n and m ?

a. – 2 and 1 c. – 1 and 2 e. 1 and – 1
b. 1 and 2 d. 2 and 1

2. Which expression could be correct for the velocity v of ocean waves in terms of ρ the density of sea-water, g the acceleration of free fall, h the depth of the ocean and λ the wavelength ?

a. $\sqrt{g\lambda}$ b. $\sqrt{\frac{g}{h}}$ c. $\sqrt{\rho g h}$ d. $\sqrt{\frac{g}{\rho}}$ e. $\sqrt{\frac{g}{\lambda}}$

3. Gravitational energy per unit mass V is given by the equation $V = \frac{-GM}{R}$ where G, M, R represent gravitational constant, mass of planet and radius of planet resprectively. The dimensions of G are.

a. $M\ L^2\ T$ c. $M^{-1}\ L^2\ T^{-1}$ e. $M^{-1}\ L^{-3}\ T^{-1}$
b. $M\ L^3\ T^{-2}$ d. $M^{-1}\ L^3\ T^{-2}$

4. The mass M of gas escaping in a short time t through a small hole of area A in the wall of a gas Cylinder is given by $\frac{M}{t} = CP^{\alpha}\rho^{\beta}A^{\gamma}$ where C is constant, and P and ρ are the pressure and density of the gas. Determined the values of the constant α, β and γ

a. $\frac{1}{2}, \frac{1}{2}, 1$ c. $\frac{1}{2}, -\frac{1}{2}, -1$ e. $\frac{1}{2}, \frac{1}{2}, -1$
b. $\frac{1}{2}, 1, \frac{1}{2}$ d. $-\frac{1}{2}, \frac{1}{2}, 1$

5. Pressure in a gas filled container is given by the equation : $P = \frac{\alpha + t^2}{\beta h}$ where "α" and "β" are constants, " t " is temperature and " h " is the height. Find the dimension of ratio "$\frac{\alpha}{\beta}$".

a. θ^2 c. $M T^{-2}$ e. $M^{-1} T^2 \theta^2$
b. $M L T^{-2}$ d. $M L^{-1} T^{-2}$

6. It is observed that the velocity ' v ' of a liquid leaving a nozzle depends upon the pressure drop ' p ' and the density ' ρ '. The relationship between them is of the form …..

a. $v = C\left(\frac{\rho}{p}\right)^{\frac{1}{2}}$ d. $v = C\left(\frac{p}{\rho}\right)$
b. $v = C\left(\frac{\rho}{p}\right)$ e. $v = C\, p\, \rho$
c. $v = C\left(\frac{p}{\rho}\right)^{\frac{1}{2}}$

7. How many nanometers are in a kilometer ?

a. 10^{-9} c. 10^{-12} e. 10^{27}
b. 10^{9} d. 10^{12}

8. Given the following equations :

(1) $v = \dfrac{A.x.\rho}{\eta}$ (3) $v = \dfrac{C.\eta}{x.\rho}$

(2) $v = \dfrac{B.x.\eta}{\rho}$ (4) $v = \dfrac{D.x}{\eta.\rho}$

Where v, x, ρ, η represent the speed of an object, width of the object, density of liquid, coefficient of viscosity of liquid (unit : kg m^{-1} s^{-1}) while A, B, C are dimensionless constants. Determine which equation (s) is / are dimensionally correct.

a. (1) b. (2) c. (3) d. (4) e. (1) dan (2)

9. It is observed that the frequency of oscillation of a guitar string ‘ f ‘depends upon the mass ‘ m ‘, the length ‘ l ‘ and tension ‘ F ‘. The relationship between them is …..

a. $f = C\left(\dfrac{F}{ml}\right)$

b. $f = C\left(\dfrac{F}{ml}\right)^{\frac{1}{2}}$

c. $f = C\left(\dfrac{Fl}{m}\right)$

d. $f = C\left(\dfrac{Fl}{m}\right)^{\frac{1}{2}}$

e. $f = C\left(\dfrac{Fm}{l}\right)$

10. The theory of gas flow through small diameter tubes at low pressures is an important consideration of high vacuum technique. One equation which occurs in the theory is $Q = \dfrac{kr^3(P_1 - P_2)}{l}\sqrt{\dfrac{M}{RT}}$

Where k is a number without units, r is the radius of the tube, P_1 dan P_2 are the pressures at each end of the tube of length l, M is the molar mass of the gas (unit : kg mol^{-1}), R is the molar gas constant (unit : J $K^{-1}mol^{-1}$) and T is the temperature. What are the dimensions of Q ?

a. M T^{-3} c. M T^{-1} e. M T^{-5}

b. M T^{-2} d. M T^{-4}

EXERCISE 1.3

1. The frequency (n) of a tuning fork depends upon the length (l) of its prong, the density (d) and Young's modulus (Y) of its material. Using dimensional consideration, find a relation of n in terms of l, d and Y ?
2. The period of revolution (T) of a planet moving round the sun in a circular orbit depends up on the radius (r) of the orbit, mass (M) of the sun and gravitational constant (G) Using dimensional considerations, obtain Kepler's third law (the law of periods) of planetary motion ?
3. The time period T of oscillation of a gas bubble from an explosion under water is proportional to $p^a\ d^b\ E^c$, where p is the static pressure, d is the density of water and E is total energy of explosion. Find the value of a, b, and c ?
4. Convert

a. 30 km h^{-1} to m s^{-1}	e. 4 GHz = ...KHz
b. 400 nm to µm	f. 5 Mg = ... μ g
c. 0.01 m^2 to mm^2	g. 2,8 g/cm^3 =........kg/m^3
d. 120 000 min^{-1} to s^{-1}	h. 72 km/jam = ...m/s

5. The dimensions of quantities P and Q are MLT^{-2} and L^2 respectively. What are the base units of the quantity X, which is defined as X = P/Q ?
6. The magnetic flux density B of a magnetic field is defined as the magnetic force per unit length of a straight thin conductor per unit current flowing in the conductor. Determine the base units of B.
7. Current is the rate of flow of charge. A voltage of 1 volt across two points is equal to the energy of 1 J per unit charge. Determine the base units of volt.
8. The electric field strength E is defined as the electric force per unit charge.The magnetic flux density B is defined as the magnetic force per unit length of a conductor and per unit current carried by the conductor. Show that the units of the ratio E/B are similiar to those of speed.

9, A sphere of radius r moves at speed v in a viscous fluid. The sphere is acted on by a viscous force F which is given by F = krv .Determine the dimension of k.

10. A wire of mass m and length l is stretched so that the tension in the wire is F. When the wire vibrates in a transverse manner, the speed of the transverse waves travelling along the wire is v. Using the method of dimensional analysis, determine an expression for v in terms of F, m and l.

MEASUREMENT TECHNIQUES

1 (a) **Experimental Errors**

(i) **Systematic Errors**: They are errors where repeated measurements taken under the same conditions yield the same error both in magnitude and sign.

(ii) Its value changes in a predictable manner depending on the conditions.

(b) **Random Errors**: Errors with different magnitudes and signs in repeated measurements.

2 Actual Uncertainty

The actual uncertainly in the scale reading (or pointer reading) of an instrument is generally taken as half the smallest graduation.

3 Fractional and percentage errors

(a) The fractional error of $R = \dfrac{\Delta R}{R}$

(b) The percentage error of $R = \dfrac{\Delta R}{R} \times 100\%$

4 Consequential Uncertainties

Given $R_1 = 51.2 \pm 0.1$; $R_2 = 30.1 \pm 0.1$

(a) **Addition**

$$R = R_1 + R_2 = 81.3 \pm \Delta R$$

where $\Delta R = \Delta R_1 + \Delta R_2 = 0.2$

(b) **Subtraction**

$$R = R_1 - R_2 = (51.2 - 30.1) \pm \Delta R$$
$$= 21.1 \pm \Delta R$$

where $\Delta R = \Delta R_1 + \Delta R_2 = 0.2$

(c) **Product**

$$R = R_1 \times R_2 = (51.2 \times 30.1) \pm \Delta R$$
$$= 1\,541.12 \pm \Delta R$$

where $\dfrac{\Delta R}{R} = \dfrac{\Delta R_1}{R_1} + \dfrac{\Delta R_2}{R_2}$ or

$$\Delta R = \frac{0.1}{51.2} + \frac{0.1}{30.1} \quad (1\,541.12)$$
$$= [0.002 + 0.003](1\,541.12) = 7.71$$

(d) **Quotient**

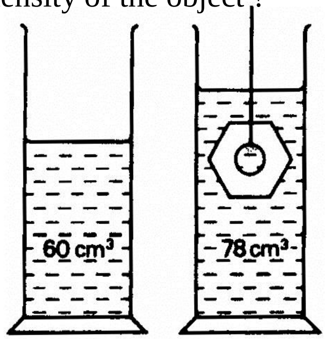
$$R = \frac{R_1}{R_2} = \frac{51.2}{30.1} \pm \Delta R$$
$$= 1.70 \pm \Delta R$$

where $\dfrac{\Delta R}{R} = \dfrac{\Delta R_1}{R_1} + \dfrac{\Delta R_2}{R_2}$ or

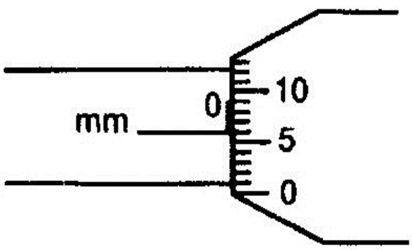
$$\Delta R = \frac{0.1}{51.2} + \frac{0.1}{30.1} \quad (1.70)$$
$$= [0.002 + 0.003](1.70) = 0.0085 = 0.01$$

EXERCISE 1.4

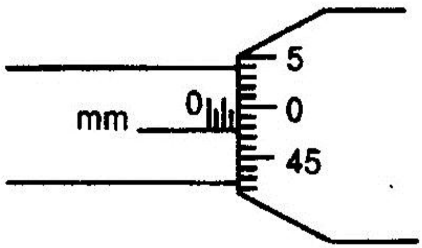
1. The measuring cylinder on the left contains 60 cm^3 of water. When a metal object is lowered into the water so that it is completely below the surface, the reading goes up to 78 cm^3. The mass of the object is 128 g.
   What is the density of the object ?
   a. 0.6 g/cm^3
   b. 1.6 g/cm^3
   c. 2.1 g/cm^3
   d. 7.1 g/cm^3
   e. 18.0 g/cm^3



2. The diameter of a steel ball is measured using a micrometer screw gauge. A student takes an initial zero reading and then a reading of the diameter. The diagrams show enlargements of the screw gauge readings. What is the diameter of the ball ?



zero reading



diameter reading

   a. 3.48 mm   c. 1.98 mm   e. 1.42 mm
   b. 2.04 mm   d. 1.92 mm

3. A student obtained the following readings for the diameter of a wire: 1.42 mm, 1.38 mm, 1.41 mm, 1.39 mm. How should he write its value in his experimental report?
   a. 1.40 mm   c. Between 1.38 mm and 1.42 mm   e. 1.41 mm
   b. 1.398 mm   d. (1.40 ± 0.02) mm

4. The time taken for a free-falling body to reach the earth's surface from a tower is measured as (3.0 ± 0.1) s. Find the height of the tower given that the free-fall acceleration is taken to be 10 ms^{-2}

a. (45 ± 3) m c. (45 ± 3.5) m e. (45 ± 4) m
b. (45 ± 5) m d. (45 ± 0.5) m

5. In an experiment, a plastic tube with an external diameter d_1 was measured at (54 ± 2) mm while its internal diameter d_2 was measured at (37 ± 1) mm. The maximum percentage error for the quantity ($d_1 - d_2$) is

a. 20% c. 4% e. 0.6%
b. 18% d. 5%

6. The density of a steel ball bearing is obtained by dividing its mass with its volume.The percentage error of the measurements were for

Mass : 2%
Diameter : 3%

The maximum percentage error in the density of the ball is

a. 9% c. 13% e. 20%
b. 11% d. 15%

DAFTAR PUSTAKA :

- Cheong Foon Choong, Pre U STPM Physics, Pearson Longman Publisher
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