

Units & Measurements

Very Short Answer Type Questions

1. Why do we have different units for the same physical quantity?
2. The radius of atom is of the order of 1 \AA and radius of nucleus is of the order of fermi. How many magnitudes higher is the volume of atom as compared to the volume of nucleus?
3. Name the device used for measuring the mass of atoms and molecules.
4. Express unified atomic mass unit in kg.
5. A function $f(\theta)$ is defined as:

$$f(\theta) = 1 - \theta + \frac{\theta^2}{2!} - \frac{\theta^3}{3!} + \frac{\theta^4}{4!} \dots$$

Why is it necessary for q to be a dimensionless quantity?

6. Why length, mass and time are chosen as base quantities in mechanics?

Short Answer Type Questions

1. (a) The earth-moon distance is about 60 earth radius. What will be the diameter of the earth (approximately in degrees) as seen from the moon?
(b) Moon is seen to be of $(\frac{1}{2})^\circ$ diameter from the earth. What must be the relative size compared to the earth?
(c) From parallax measurement, the sun is found to be at a distance of about 400 times the earth-moon distance. Estimate the ratio of sun-earth diameters.
2. Which of the following time measuring devices is most precise?
(a) A wall clock.
(b) A stop watch.
(c) A digital watch.
(d) An atomic clock.
Give reason for your answer.

3. The distance of a galaxy is of the order of 10^{25} m. Calculate the order of magnitude of time taken by light to reach us from the galaxy.
4. The vernier scale of a travelling microscope has 50 divisions which coincide with 49 main scale divisions. If each main scale division is 0.5 mm, calculate the minimum inaccuracy in the measurement of distance.
5. During a total solar eclipse the moon almost entirely covers the sphere of the sun. Write the relation between the distances and sizes of the sun and moon.
6. If the unit of force is 100 N, unit of length is 10 m and unit of time is 100 s, what is the unit of mass in this system of units?
7. Give an example of
 - (a) a physical quantity which has a unit but no dimensions.
 - (b) a physical quantity which has neither unit nor dimensions. (c) a constant which has a unit.
 - (d) a constant which has no unit.
8. Calculate the length of the arc of a circle of radius 31.0 cm which $\pi/6$ subtends an angle of at the centre.
9. Calculate the solid angle subtended by the periphery of an area of 1cm^2 at a point situated symmetrically at a distance of 5 cm from the area.
10. The displacement of a progressive wave is represented by $y = A \sin(\omega t - kx)$, where x is distance and t is time. Write the dimensional formula of (i) ω and (ii) k .
11. Time for 20 oscillations of a pendulum is measured as $t_1 = 39.6$ s; $t_2 = 39.9$ s; $t_3 = 39.5$ s. What is the precision in the measurements? What is the accuracy of the measurement?

Long Answer Type Questions

1. A new system of units is proposed in which unit of mass is α kg, unit of length β m and unit of time γ s. How much will 5 J measure in this new system?
2. The volume of a liquid flowing out per second of a pipe of length l and radius r is written by a student as

$$v = \frac{\pi P r^4}{8 \eta l}$$

where P is the pressure difference between the two ends of the pipe and η is coefficient of viscosity of the liquid having dimensional formula $ML^{-1} T^{-1}$. Check whether the equation is dimensionally correct.

3. A physical quantity X is related to four measurable quantities a, b, c and d as follows:

$$X = a^2 b^3 c^{5/2} d^{-2}.$$

The percentage error in the measurement of a, b, c and d are 1%, 2%, 3% and 4%, respectively. What is the percentage error in quantity X? If the value of X calculated on the basis of the above relation is 2.763, to what value should you round off the result.

4. In the expression $P = E l^2 m^{-5} G^{-2}$, E, m, l and G denote energy, mass, angular momentum and gravitational constant, respectively. Show that P is a dimensionless quantity.
5. If velocity of light c, Planck's constant h and gravitational constant G are taken as fundamental quantities then express mass, length and time in terms of dimensions of these quantities.
6. An artificial satellite is revolving around a planet of mass M and radius R, in a circular orbit of radius r. From Kepler's Third law about the period of a satellite around a common central body, square of the period of revolution T is proportional to the cube of the radius of the orbit r. Show using dimensional analysis, that

$$T = \frac{k}{R} \sqrt{\frac{r^3}{g}},$$

where k is a dimensionless constant and g is acceleration due to gravity.

7. In an experiment to estimate the size of a molecule of oleic acid 1 mL of oleic acid is dissolved in 19 mL of alcohol. Then 1 mL of this solution is diluted to 20 mL by adding alcohol. Now 1 drop of this diluted solution is placed on water in a shallow trough. The solution spreads over the surface of water forming one molecule thick layer. Now,

lycopodium powder is sprinkled evenly over the film and its diameter is measured.

Knowing the volume of the drop and area of the film we can calculate the thickness of the film which will give us the size of oleic acid molecule.

Read the passage carefully and answer the following questions:

- (a) Why do we dissolve oleic acid in alcohol?
- (b) What is the role of lycopodium powder?
- (c) What would be the volume of oleic acid in each mL of solution prepared?
- (d) How will you calculate the volume of n drops of this solution of oleic acid?
- (e) What will be the volume of oleic acid in one drop of this solution?

8. (a) How many astronomical units (A.U.) make 1 parsec?

(b) Consider a sunlike star at a distance of 2 parsecs. When it is seen through a telescope with 100 magnification, what should be the angular size of the star? Sun appears to be $(1/2)^\circ$ from the earth. Due to atmospheric fluctuations, eye can't resolve objects smaller than 1 arc minute.

(c) Mars has approximately half of the earth's diameter. When it is closest to the earth it is at about $1/2$ A.U. from the earth. Calculate what size it will appear when seen through the same telescope.

(Comment : This is to illustrate why a telescope can magnify planets but not stars.)

9. Einstein's mass – energy relation emerging out of his famous theory of relativity relates mass (m) to energy (E) as $E = mc^2$, where c is speed of light in vacuum. At the nuclear level, the magnitudes of energy are very small. The energy at nuclear level is usually measured in MeV, where $1 \text{ MeV} = 1.6 \times 10^{-13} \text{ J}$; the masses are measured in unified atomic mass unit (u) where $1u = 1.67 \times 10^{-27} \text{ kg}$.

(a) Show that the energy equivalent of 1 u is 931.5 MeV.

(b) A student writes the relation as $1 u = 931.5 \text{ MeV}$. The teacher points out that the relation is dimensionally incorrect. Write the correct relation.