(D) ANSWERS OF CONCEPTUAL QUESTIONS

C1. A quantity which is used in explanation of some physical phenomenon and which can be measured directly or indirectly is called a physical quantity.

Example: Force, mass, length, temperature, electric current, charge, pressure, density, volume, kinetic energy, etc.

C2. A reference standard used for measurement of a physical quantity is called a **unit.** It is arbitrarily chosen but internationally accepted. For example, metre is a unit of length, second is a unit of time, kilogram is unit of mass, newton is unit of force, pascal is unit of pressure, joule is unit of energy, etc.

C3. Fundamental or base quantities are those physical quantities which cannot be interrelated. At present, seven such quantities are known. These are (i) length, (ii) mass, (iii) time, (iv) electric current, (v) thermodynamic temperature, (vi) luminous intensity and (vii) amount of substance.

C4. The units defined for measurement of fundamental or base quantities are called fundamental or base units. At present seven fundamental units are defined. These are (i) metre, (ii) kilogram, (iii) second, (iv) ampere, (v) kelvin, (vi) candela and (vii) mole.

C5. Since the number of physical quantities is very large, it is not convenient to define independent unit for each physical quantity. If done so, it will be very difficult to remember all of them. Therefore, minimum number of independent physical quantities are chosen for defining base units. The units of other physical quantities are then expressed in terms of the base units.

C6. The physical quantities other than the fundamental quantities are called derived quantities. Example: speed, acceleration, pressure, volume, kinetic energy, density, momentum, torque, etc.

C7. The units of derived quantities are called derived units. The derived units are obtained from the base units. Example: metre per second; metre per second square; newton per metre square; metre cube; joule; kg per metre cube; kilogram metre per second, newton metre.

C8. A system of units is a complete set of units which include the base units and derived units. Example: SI system of units; MKS system of units.

C9. The SI units system is the International System of Units of measurement devised around seven base units and the convenience of the number ten.

The SI units are divided into two classes - base units and derived units.

There are seven base units, each representing, by convention, different kinds of physical quantities. These SI base units and their physical quantities are:

(i) metre for length,
(ii) kilogram for mass,
(iii) second for time,
(iv) ampere for electric current,
(v) kelvin for temperature,
(vi) candela for luminous intensity,
(vii) mole for the amount of substance.

There are a large number of derived units.

Five of these along with the names of associated physical quantity are:

(i) pascal for pressure,

(ii) newton for force,

(iii) m/s for speed,

(iv) m^3 for volume,

(v) joule for energy.

Advantages of SI units:

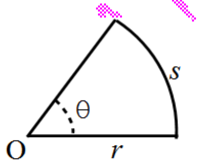
(i) SI units use decimal system. Therefore, conversions within the system are simple and convenient.

(ii) It is a coherent system. That is all derived units can be obtained by multiplying and dividing, the base (fundamental) units.

(iii) It is not static, units are created and definitions are modified through international agreement.

(iv) It is internationally accepted, both in everyday commerce and in science.

C10. (a) The plane angle θ is defined as the ratio of length of arc *s* to the radius *r* (See Fig.(a))



$$\theta = \frac{s}{r}$$

Fig.(a)

(b) The solid angle dΩ is defined as the ratio of the intercepted area *dA* of the spherical surface, described about the apex O as the centre, to the square of its radius *r*, as shown in Fig.(b).

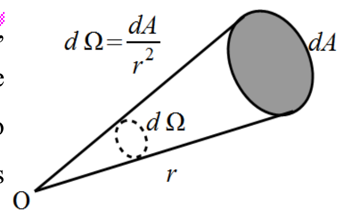


Fig.(b)

The unit for plane angle is radian with the symbol rad and the unit for the solid angle is steradian with the symbol sr.

C11. The numerical measure (*n*) of a physical quantity is inversely proportional to the size of the unit (*u*), that is,

$$n \propto \frac{1}{u} \quad ,$$

or $$n\,u = \text{constant} \quad .$$

C12. (i) Yes, the numerical measure change when the unit is changed,

$$n_2 u_2 = n_1 u_1 \quad .$$

(ii) No, the magnitude $n\,u = \text{constant}$ for a given specified physical quantity.

C13. The unit metre is defined as equal to the length of the path travelled by light in vacuum during a time interval of

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of a second.

C14. The unit kilogram is defined as the mass equal to the mass of the international prototype of the kilogram. Prototype kilogram is a platinum-iridium(90% Pt-10%Ir) cylinder, 39 mm high and 39 mm in diameter.

C15. The unit second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom. This definition refers to a caesium atom at rest at a temperature of 0 K.

C16. The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

C17. The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12.

C18. For convenience, different units are used for same physical quantity lying in a wide range. For example diameter of an atom is measured in nanometers or angstrom, while diameter of a tennis ball is measured in centimeter. Similarly atomic masses are measured in atomic mass units, while grocery masses are measured in kilograms, or grams.

C19. Because in mechanics, all other physical quantities can be expressed in terms of the base quantities, length, mass and time.

C20. (a) Planck's constant, universal gravitational constant, Boltzmann constant, Stefan's constant, etc.
(b) Reynolds number, fine structure constant.

C21. No. The length, mass and time are taken as fundamental physical quantities by international agreement. Other sets could be (a) force, length and time, (b) energy, length and time, (c) momentum area and time.
(see Numerical Questions)

C22. (i) m/s , (ii) rad/s^2 , (iii) N m , (iv) kg m / s.

C23. (i) newton (N), (ii) joule (J) (iii) volt (V), (iv) pascal (Pa), (v) ohm (Ω), (vi) steradian (sr), (vii) coulomb (C), (viii) hertz (Hz), (ix) watt (W).

C24. From Fig.1, we can make statements, like
(I) The weight of man is large (in comparison to weight of cat)
(II) The weight of man is small (in comparison to weight of elephant)

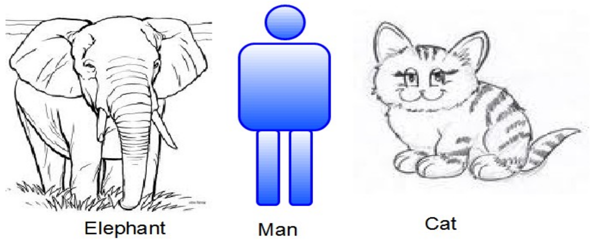


Fig.1

Similarly form Fig.2, we can make statements like
(III) The length of the ant is large (in comparison to length of DNA)
(IV) Length of ant is small (in comparison to length of a python).

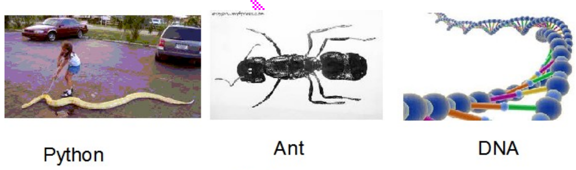


Fig.2

Therefore, we conclude that "To call a dimensional quantity 'large' or 'small' is meaningless without specifying a standard for comparison".

Therefore, some of the statements should be rephrased:
(a) atoms are very small objects in comparison to the objects we use in daily life.
(b) a jet plane moves with great speed in comparison to speeds used for travel on land.
(c) the mass of Jupiter is very large compared to earth satellites.
(d) the air inside this room contains a large number of molecules compared to the number of molecules in the air we breath.
(e) a proton is much more massive than an electron. (statement O.K.)
(f) the speed of sound is much smaller than the speed of light.(statement O.K.)

C25.

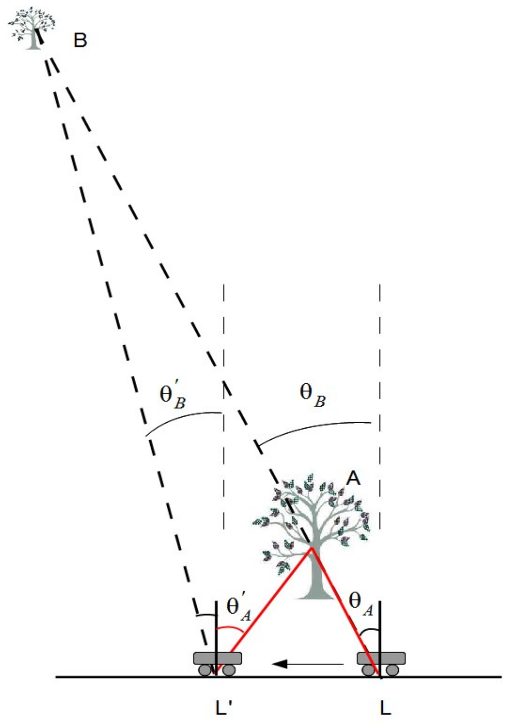


Fig.C25

The figure shows two trees A and B. A is near and B is far off. At a certain location L, let the two trees appear in line ($\theta_A = \theta_B$) to an observer in a moving vehicle (as shown in Fig.C25). When the moving observer arrives at location L', the angular positions have changed to θ'_A and θ'_B . For the near object change in angle is large and has reversed in sign, while for the far off object change in angular position is small. Thus nearby tree seems to move rapidly in a direction opposite to the observer's motion, but the distant tree seems to move with the observer.

Thus, in summary, when one is moving, the angular change is less for distant objects than nearer objects. As s result, the distant objects seem to move along with the observer, but the nearer objects in opposite.

C26. (b) and (d)

parsec and light year, both are units of distance.

1 parsec = the distance at which 1 *A (astronomical unit)* subtends 1 arc sec

and

1 ly = distance traveled by light in one year.

(Comment: The unit light year is now in the category of disapproved (rejected) units.)

C27. Different units are used for the same physical quantity because the order of magnitude for the physical quantity for different objects may differ greatly. For example, if we consider the masses of atoms, these are of the order of $10^{-27}\,\text{kg}$; masses of objects used in daily life are of the order of tens to 100s of kg; while masses of astronomical bodies (say stars) are of the order of $10^{30}\,\text{kg}$. Another example, if we consider the distances between atoms in a crystalline solid, these are of the order of angstrom (Å); the distances involved in daily life are in km ranges; while the astronomical distances are in parsec ranges.

C28. Ratio of volume of an atom and the volume of a nucleus is

$$= \left(\frac{r_{\text{atom}}}{r_{\text{nucleus}}}\right)^3 = \left(\frac{10^{-10}}{10^{-15}}\right)^3 = \left(10^5\right)^3 ,$$

$$= 10^{15} .$$

C29. Arc length = radius × angle

$$= 31 \times \frac{3.14}{6} = 16.2\,\text{cm} .$$

C30. By definition,

$$\text{solid angle} = \frac{\text{area}}{\text{distance}^2} .$$

Therefore,

$$\Omega=\frac{1}{5^2}=\frac{1}{25}=4\times10^{-2}\,\mathrm{sr}\quad.$$

C31. $1\,\mathrm{u}=1.66\times10^{-27}\,\mathrm{kg}\quad.$

$$1\,u=\frac{Mass\ of\ ^{12}C\ atom}{12}\quad.$$

C32. The length, mass and time are chosen as base quantities in mechanics, because all other physical quantities appearing in mechanics can be expressed in terms of length, mass and time through simple relations.

C33. Let in the new system of units, the length, mass and time units are: $\mathrm{kg_N}$, $\mathrm{m_N}$ and $\mathrm{s_N}$. It is given that

$$1\,\mathrm{kg}_N=\alpha\ \mathrm{kg}\quad,$$

$$1\,\mathrm{m}_N=\beta\ \mathrm{m}\quad,$$

$$1\,\mathrm{s}_N=\gamma\ \mathrm{s}\quad.$$

Therefore,

$$1\ \mathrm{J}=1\,\mathrm{kg}\cdot\mathrm{m}^2\cdot\mathrm{s}^{-2}\quad,$$

or $$=(\frac{1}{\alpha}\ \mathrm{kg_N})\cdot(\frac{1}{\beta^2}\mathrm{m_N^2})\cdot(\gamma^2\ \mathrm{s_N^{-2}})\quad,$$

or $$1\,\mathrm{J}=\left(\frac{\gamma^2}{\alpha\beta^2}\right)\mathrm{kg_N}\cdot\mathrm{m_N^2}\cdot\mathrm{s_N^{-2}}\quad,$$

or $$1\,\mathrm{J}=\left(\frac{\gamma^2}{\alpha\beta^2}\right)\mathrm{J_N}\quad.$$

Therefore,

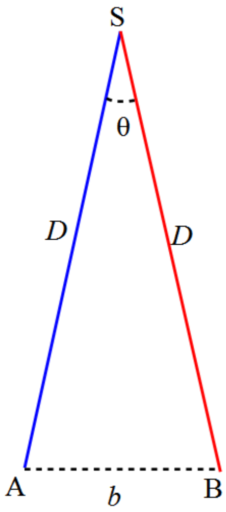
$$5\,\mathrm{J}=5\left(\frac{\gamma^2}{\alpha\beta^2}\right)\mathrm{J_N}\quad.$$

C34. Mass spectrograph.

(Comment: There are many kinds of mass spectrograph. One such is Bainbridge mass spectrograph).

C35. Parallax is an apparent displacement of an object viewed along two different lines of sight, and is measured by the angle or semi-angle of inclination between those two lines.

C36. Let a planet S is far away, at a distance D from the Earth. To measure D by the parallax method, we observe it from two different positions(observatories) A and B on the Earth, separated by distance AB = b at the same time as shown in Fig.



We measure the angle between the two directions along which the planet is viewed at these two points.

The $\angle ASB=\theta$ in the Fig. is the parallax angle.

As the planet is very far away,

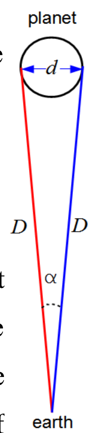
$$\frac{b}{D}\ll1$$

and, therefore, θ is very small. Then we approximately take AB as an arc of length b of a circle with center at S and the distance D as the radius (D = AS = BS) so that

$$\mathrm{AB}=b=D\,\theta$$

where θ is in radians. Thus the distance of the distant planet is

$$D=\frac{b}{\theta}\quad.$$



C37. Let the diameter of the planet is d. Let the angular size of the planet (the angle subtended by d at the earth)is α. The distance of the planet is D. Then from the geometry of Fig. shown below,

$$d = \alpha D \quad . \qquad (1)$$

The angle α can be measured from the same location on the earth. It is the angle between the two directions when two diametrically opposite points of the planet are viewed through a telescope. If D is first determined by parallax method, then diameter d of the planet can be determined using by using Eq.(1).

C38. In order to estimate the molecular size, first a mono-molecular layer of oleic acid is formed on the water surface. For this, we dissolve $1\,\text{cm}^3$ of oleic acid in alcohol to make a solution of $20\,\text{cm}^3$. Then we take $1\,\text{cm}^3$ of this solution and dilute it to $20\,\text{cm}^3$, using alcohol. So, the concentration of the solution is equal to

$$\left(\frac{1}{20\times 20}\right)\text{cm}^3$$

of oleic acid per cm^3 of solution. Next we lightly sprinkle some lycopodium powder on the surface of water in a large trough and we put one drop of this solution in the water. The oleic acid drop spreads into a thin, large and roughly circular film. Let us drop n drops in the water. These quickly spread into a circular patch. We measure the diameter of the thin film to get area A of the patch. Suppose, volume of one drop is V (cm^3) (estimated independently). Then volume of n drops is

$$n V\,\text{cm}^3$$

The amount of oleic acid in this volume is

$$n V\left(\frac{1}{20\times 20}\right)\text{cm}^3 \quad .$$

Let the thickness of the film is t, then

$$t = \frac{\text{volume of the oleic acid circular patch}}{\text{area } A \text{ of the patch}} \quad ,$$

or $$t = \frac{nV}{A}\left(\frac{1}{20\times 20}\right) \quad \text{cm} \quad ,$$

where V is in cm^3 and A is in cm^2. If we assume that the film has mono-molecular thickness, then this t is the size or diameter of a molecule of oleic acid. The value of this thickness comes out to be of the order of $10^{-9}\,\text{m}$.

C39. Time = distance / speed

$$t = \frac{10^{25}}{3\times 10^{8}} = 3.3\times 10^{16}\,\text{s} \quad .$$

The order of the time taken is $10^{16}\,\text{s}$, and the order of magnitude is 16.

C40. The precision (least count) of the various time measuring devices are as follows:

(a) Wall clock (with second's hand) = 1 second

(b) A stop watch = 0.1 second

(c) A digital watch = 0.01 second

(d) An atomic clock = 10^{-12} second.

Thus an atomic clock is the most precise time measuring device.

C41. (I) Error: The difference between the true value of the quantity and the individual measurement value is called the error of the measurement.

(II) Mean absolute error: The mean absolute error of value of a physical quantity, *a,* is defined as the arithmetic mean of all absolute errors. That is

$$\Delta a_{\text{mean}} = \sum_{i=1}^{n} \frac{|\Delta a_i|}{n} \quad ,$$

where $|\Delta a_i|$ is the absolute error in the i^{th} measurement.

(III) Relative error: The relative error is the ratio of the mean absolute error Δa_{mean} to the mean value a_{mean} of the quantity measured.

$$\text{Relative error} = \frac{\Delta a_{\text{mean}}}{a_{\text{mean}}} \quad .$$

(IV) Percentage error: Percentage error is the relative error expressed in percent.

$$\text{Percentage error} = \frac{\Delta a_{\text{mean}}}{a_{\text{mean}}} \times 100\,\% \quad .$$

C42. The systematic errors are those errors that tend to be in one direction, either positive or negative. Some sources of systematic errors are:

(a) Instrumental errors that arise from the errors due to imperfect design or calibration of the measuring instrument, zero error in the instrument.

(b) Imperfection in experimental technique or procedure.

(c) Personal errors that arise due to an individual's bias, lack of proper setting of the apparatus or individual's carelessness in taking observations without observing proper precautions

C43. (I) The random errors are those errors, which occur irregularly and hence are random with respect to sign and size. These can arise due to random and unpredictable fluctuations in experimental conditions and personal (unbiased) errors by the observer taking readings.

(II) The least count error is the error associated with the resolution of the instrument.

C44. Systematic errors can be minimized by improving experimental techniques, selecting better instruments and removing personal bias as far as possible.

For a given set-up, these errors are estimated to a certain extent and necessary corrections applied to the readings.

C45. The probability of occurrence of positive and negative random errors is the same. As a result random errors are reduced when measurements are repeated a large number of times.

C46. (I) When two quantities are added or subtracted, the absolute error in the final result is the sum of the absolute errors in the individual quantities.

(II) When two quantities are multiplied or divided, the relative error in the result is the sum of the relative errors in the individual quantities.

C47. Then the relative error in Z is

$$\frac{\Delta Z}{Z} = \text{p}\frac{\Delta A}{A} + \text{q}\frac{\Delta B}{B} + \text{r}\frac{\Delta C}{C} \quad .$$

C48. (c) 4

C49. (a) 1, (b) 3, (c) 4, (d) 4, (e) 4, (f) 5

C50. (d) 639

C51. (d) 1.64 and 6.74.

C52. (c) .

Justification: From the given information, we note that the least count of

(a) vernier callipers is:

$$\text{L.C.} = \frac{1\text{ mm}}{20} = 0.05\text{ mm} \quad .$$

(b) screw gauge is:

$$\text{L.C.} = \frac{1\text{ mm}}{100} = 0.01\text{ mm} \quad .$$

(c) optical instrument is:

L.C ≈ 550 nm (mean wavelength)

(assuming range of visible light = 400 nm to 700 nm).

Since the least count of the optical instrument is the smallest for the given instruments, therefore, amongst the given instrument, optical instrument is the most precise.

C53. The thread is wound on the metre scale with turns as close as possible (but not overlapping). The thickness l of the n turns of the thread is measured. Then, the thickness of the thread is

$$\text{thickness of thread} = \frac{l}{n} \ .$$

C54. No, it is not possible to increase the accuracy of the screw gauge arbitrarily by increasing the number of divisions on the circular scale.

To increase the number of divisions, one has to increase the radius of the circular plate. This increases the weight of the circular plate which in turn increases the wear and tear of threads on the screw which controls the pitch. The instrument becomes cumbersome.

C55. The random errors are reduced when the measurements are repeated a large number of times. The arithmetic mean approaches the true value. Therefore, a set of 100 measurements is expected to yield a more reliable estimate than a set of 5 measurements only.

C56. The ideal gas law requires

$$pV = NkT \ .$$

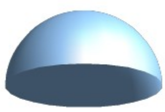
Here, $V = 4\times 3.5\times 1.5 = 21\,\text{m}^3$.

Therefore, substituting relevant data, we find

$$N = \frac{pV}{kT} = \frac{10^5\times 21}{1.38\times 10^{-23}\times 300} = 5.1\times 10^{26} \ .$$

C57. The surface area of hemisphere is

$$A = 2\pi r^2.$$



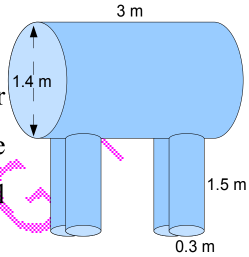
If the number of hairs per unit area is n, then, the total number of hairs on the head is

$$N = A\,n$$

Substituting values, we get

$$\begin{aligned} N &= 2\times 3.14\times 10^2(\text{cm}^2)\times 2(\text{mm}^{-2}) \\ &= 6.28\times 100\times(10^2\,\text{mm}^2)\times 2(\text{mm}^{-2}) \ , \\ &= 12.56\times 10^4 \end{aligned}$$

or $N \approx 10^5$.



C58. The volume of a cylinder is $V = \pi r^2 l$. Therefore, the volume of the elephant model is

$$\begin{aligned} V &= \pi\left(\left(\frac{1.4}{2}\right)^2\times 3 + 4\left(\left(\frac{0.3}{2}\right)^2\times 1.5\right)\right) \\ &= 3.14\times(0.49\times 3 + 4\times 0.0225\times 1.5) \ , \\ &= 3.14\times(1.47 + 0.135) \end{aligned}$$

or $V = 5.04\,\text{m}^3$.

The density of water is $\rho = 1000\ \text{kg/m}^3$. Therefore, the mass of the elephant is

$$\begin{aligned} M &= \rho V = 5.04\times 1000\,\text{kg} \\ &\approx 5\times 10^3\ \text{kg} \end{aligned} \ .$$

Alternative method (more accurate):

Put the elephant onto a boat. Measure the displacement by looking at the water-line, and record this mark. Remove the elephant. Add known weights to the boat (i.e 20 kg weights) until the water level reaches that of the elephant. Then, count and calculate the weights. This should be a better estimate of the weight of the elephant (within ± 20 kg weight).

C59. The dimensions of a physical quantity are the powers (or exponents) to which the base quantities are raised to represent that quantity.

C60. (a) The dimensional formula of a given physical quantity is the expression which shows how and which of the base quantities represent the dimensions of that physical quantity.

(b) The dimensional equation of a physical quantity is an equation obtained by equating the physical quantity with its dimensional formula.

C61. Dimensional analysis can be used for (a) checking the dimensional consistency of an equation relating physical quantities; (b) deducing relation amongst physical quantities; and (c) converting the numerical measure of a physical quantity from one system of units to another system of units.

C62. The principle of homogeneity of dimensions states that the final dimensions on the left hand side of an equation should be equal to the final dimensions on the right hand side of that equation.

C63. The limitations of dimensional analysis are:

(i) The method of dimensional analysis gives no information about any dimensional constant and any numerical factor appearing in equation.

(ii) If a physical quantity depends on more than three variables, then methods of dimensional analysis can not be used.

(iii) If a physical quantity involves trigonometric functions or logarithmic functions, such as $y = A\sin(\omega t)$, $T = (\log_e 2)/\lambda$, then the dimensional analysis can not be used for deducing relation among physical quantities.

(iv) The methods of dimensional analysis can not be used to establish relations involving addition or subtraction of two or more terms (e.g., $s = ut + \frac{1}{2}at^2$).

(v) If a relation contains an unknown dimensional constant, then the methods of dimensional analysis fails.

C64. (c) tension and surface tension.

Reason: Tension has dimensions of force, namely, $[\mathrm{M\,L\,T^{-2}}]$, while that of the surface tension has dimensions of force per unit length, namely, $[\mathrm{M\,T^{-2}}]$.

C65. The dimensions of pressure are: $[\mathrm{M\,L^{-1}T^{-2}}]$. Consider the dimensions of the given quantities:

(a) $[force/area] = [\mathrm{M\,L\,T^{-2}}]/[\mathrm{L^2}] = [\mathrm{M\,L^{-1}T^{-2}}]$.

(b) $[energy/volume] = [\mathrm{M\,L^2T^{-2}}]/[\mathrm{L^3}] = [\mathrm{M\,L^{-1}T^{-2}}]$.

(c) $[energy/area] = [\mathrm{M\,L^2\,T^{-2}}]/[\mathrm{L^2}] = [\mathrm{M\,T^{-2}}]$.

(d) $[force/volume] = [\mathrm{M\,L\,T^{-2}}]/[\mathrm{L^3}] = [\mathrm{M\,L^{-2}T^{-2}}]$.

Thus (a) and (b) are dimensionally equivalent to force.

C66. Since different powers of θ are added to get $f(\theta)$, θ should be dimensionless. If θ had dimensions than θ , θ^2 , θ^3 etc. will have different dimensions. Then the expression for $f(\theta)$ will not follow the principle of homogeneity of dimensions.

C67. The situation is illustrated in Fig. The solid angle,

$$\Omega = \frac{\pi R_m^2}{r_{Em}^2} = \frac{\pi R_S^2}{r_{ES}^2} ,$$

or $$\frac{R_S}{R_m} = \frac{r_{ES}}{r_{Em}} .$$

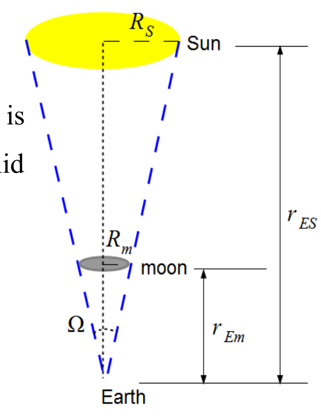


Fig.ACQ67

C68. (a) (i) plane angel, (ii) solid angle

(b) (i) relative density, (ii) relative permittivity

(c) (i) Planck's constant, (ii) gravitational constant

(d) (i) Raynold number, (ii) fine structure constant.

C69. The dimensional equation for energy can be written as

$$[E]=[\mathrm{M\,L^2\,T^{-2}}] \quad . \qquad (1)$$

The dimensional formula for momentum (*P*), and area (*A*) are, respectively,

$$[\mathrm{P}]=[\mathrm{M\,L\,T^{-1}}] \quad \text{and} \quad [\mathrm{A}]=[\mathrm{L^2}] \qquad (2)$$

Therefore, we may rewrite Eq.(1) as,

$$[E]=[(\mathrm{M\,L\,T^{-1}})([\mathrm{L^2}])^{1/2}(\mathrm{T^{-1}})] \quad .$$

Using (2) in the above, we get

$$[E]=[\mathrm{P^1\,A^{1/2}\,T^{-1}}] \quad .$$

Therefore, the correct answer is (d).

C70. Physical quantities having different dimensions can not be added or subtracted, but these can be multiplied or divided. Therefore, (a) and (e) cannot give any meaningful quantity.

Comments:

In case of (b) if the product PQ leads to a quantity having dimensions of R than PQ – R would be meaningful.

In case of (c), it always leads to some physical quantity.

In case of (d), it will lead to a meaningful quantity if the product PR has the same dimensions as those of Q^2.

C71. The dimensional formula for the various given possibilities are:

(a) $$\text{linear impulse}=F\,\Delta t=[\mathrm{M\,L\,T^{-2}\,T}] =[\mathrm{M\,L\,T^{-1}}] \quad ,$$

(b) $$\text{angular impulse}=\tau\,\Delta t=[\mathrm{M\,L^2\,T^{-2}}][\mathrm{T}] =[\mathrm{M\,L^2\,T^{-1}}]$$

(c) $$\text{Linear momentum}=m\,v=[\mathrm{M}][\mathrm{L\,T^{-1}}] =[\mathrm{M\,L\,T^{-1}}]$$

(d) $$\text{Angular momentum}=m\,v\,r=[\mathrm{M}][\mathrm{L\,T^{-1}}][\mathrm{L}] =[\mathrm{M\,L^2\,T^{-1}}] \quad .$$

The dimensions of the Planck's constant are:

$$[h]=[\frac{E}{\nu}]=\frac{[\mathrm{M\,L^2\,T^{-2}}]}{[\mathrm{T^{-1}}]}=[\mathrm{M\,L^2\,T^{-1}}] \quad .$$

Comparing with (a) to (d) above, we note that the dimensions of the Planck's constant are the same as those of (b) angular impulse and (d) angular momentum.

C72. The dimensions of *h* and *c* are;

$$[h]=[\mathrm{M^1\,L^2\,T^{-1}}] \quad , \quad [c]=[\mathrm{L^1\,T^{-1}}] \quad .$$

The dimensions of (a) m_e , (b) G , (c) e and (d) m_p are, respectively,

(a) $[m_e]=[\mathrm{M^1\,L^0\,T^0}]$,

(b) $[G]=[\mathrm{M^{-1}\,L^3\,T^{-2}}]$,

(c) $[e]=[\mathrm{M^0\,L^0\,T^1\,A^1}]$, and

(d) $[m_p]=[\mathrm{M^1\,L^0\,T^0}]$

The physical quantity *e* has dimensions of electric current (independent from length, mass and time). Therefore, it can not be combined with *h* and *c* to get L or M or T.

Therefore, the third physical quantity (in addition to the two *h* and *c*) which can be chosen for expressing length, mass and time, could be (a) m_e , (b) G and (d) m_p .

Comment: Note that the combinations

$$\frac{h}{mc} \quad \text{and} \quad \sqrt{\frac{hG}{c^3}}$$

have dimensions of length; the combinations

$$m \quad \text{and} \quad \sqrt{\frac{hc}{G}}$$

have dimensions of mass; and the combinations

$$\frac{h}{mc^2} \quad \text{and} \quad \sqrt{\frac{hG}{c^5}}$$

have dimensions of time.

C73. The argument of the trigonometric function should be dimensionless. Therefore, the dimensional formula

(a) for ω should be $[T^{-1}]$, and

(b) for k should be $[L^{-1}]$.

C74. $1\,\text{N/m}^2 = 10^5\,\text{dyne}/10^4\,\text{cm}^2 = 10\,\text{dyne/cm}^2$.

Therefore,

$$1.9\times10^{11}\,\text{N/m}^2 = 1.9\times10^{12}\,\text{dyne/cm}^2 \ .$$

the correct answer is (c).

C75. It is given that

$$1\,\text{N}_{new} = 100\,\text{N} \ ,$$

$$1\,\text{m}_{new} = 10\,\text{m} \ ,$$

$$1\,\text{s}_{new} = 100\,\text{s} \ .$$

Let $1\,\text{kg}_{new} = n\,\text{kg}$.

w know that the dimensions of force are

$$[F] = [\text{M}^1\text{L}^1\text{T}^{-2}] \ .$$

If n_1 and n_2 numerical measures, respectively, in new units and the SI units, then

$$n_1[\text{M}_1\text{L}_1\text{T}_1^{-2}] = n_2[\text{M}_2\text{L}_2\text{T}_2^{-2}] \ ,$$

or $$1\,[\text{kg}_{new}\,\text{m}_{new}\,\text{s}_{new}^{-2}] = 100\,[\text{kg}\,\text{m}\,\text{s}^{-2}] \ ,$$

or $$1\,\text{kg}_{new} = 100\times\text{kg}\times\frac{\text{m}}{\text{m}_{new}}\times\left(\frac{\text{s}}{\text{s}_{new}}\right)^{-2} \ ,$$

or $$1\,\text{kg}_{new} = 100\times\text{kg}\times\frac{1}{10}\times\left(10^{-2}\right)^{-2} \ ,$$

or $$1\,\text{kg}_{new} = 10^5\,\text{kg} \ .$$