O'ZBEKISTON RESPUBLIKASI OLIY VA O'RTA MAXSUS TA'LIM VAZIRLIGI
Al-Xorazmiy nomidagi Urganch Davlat Universiteti
"Umuminjenerlik fanlari" kafedrasi

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PHYSICS PART I

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Physics Part I - Metodik qo`llanma. Kutliev U.O., Matnazarov A.R., Aminov U.A., Kurbanov M.K. Urganch, UrDU, 2015. – 60 b.

Mazkur o`quv qo`llanma «Fizika» yo`nalishi bo`yicha tahsil oluvchi talabalarni fizikaning mexanika qismida ishlatiladigan asosiy tarif va tushunchalarni ingliz tilida ishlatilishi bilan tanishtiradi.

Bu metodik qo`llanma "Fizika" yo`nalishi bakalavriat talabalari, o'qituvchilar va kasb –hunar kollejlari talabalari uchun mo`ljallangan.

Al-Xorazmiy nomidagi Urganch davlat universiteti ilmiy–uslubiy kengashi 2015 yil № qaroriga ko`ra chop etildi.

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MUNDARIJA

SO`Z BOSHI

Davlatimiz rahbarining 2012-yil 10-dekabrda qabul qilingan “Chet tillarni o‘rganish tizimini yanada takomillashtirish chora-tadbirlari to‘g‘risida”gi qarori bu boradagi ishlar samaradorligini oshirish va uni yangi bosqichga olib chiqishda muhim omil bo‘lmoqda.

Mazkur qaror bilan ta’lim tizimining barcha bosqichlarida chet tillarni o‘rganishni kengaytirish chora-tadbirlari dasturi tasdiqlandi. 2013-2014 o‘quv yilidan boshlab oily ta’lim muassalarida ko’pgina fanlarni chet tillarni uzluksiz o‘qitish joriy etildi. Shuningdek, o‘qitishning barcha bosqichlarida ushbu ta’limning izchilligi ta’minlandi. Bugungi 2014-2015 o‘quv yilidan boshlab talabalar safiga yangi qabul qilingan talabalar butunlay yangi davlat ta’lim standartlari asosida fanlarni ko’p qismini ingliz tilda o’rganishadi. Shuning uchun talabalari va o‘qituvchilari uchun chet tillar bo‘yicha yangi darsliklar va o‘quv-uslubiy qo‘llanmalar nashr etish nazarda tutilgan. Xozirda talabalar uchun ingliz tili bo‘yicha darsliklar yangicha shakl va mazmunda, zamonaviy audio-video materiallari bilan ishlab chiqilmoqda. Akademik litsey va kasb-hunar kollejlari, oliy ta’limning bakalavriat va magistratura bosqichi uchun takomillashtirilgan darsliklar yaratilmoqdi. Oliy o‘quv yurtining eksperimental guruhlarida ingliz tili o‘qituvchilarini tayyorlash va malakasini oshirish bo‘yicha izchil ishlar bajarilmoqda.

Ushbu o’quv-uslibiy qo’llanmada oily o’quv yurtlarida o’qitiladigan fizika fanining mexanika qismida ishlatiladigan asosiy tushunchalarning inglizcha ifodalanishi keltirilgan. Ushbu qo’llanma bu yo’nalishda qilingan ilk ishlardan biri xisoblanadi.

INTRODUSING

Unit: The standard quantity is known as a unit.

Magnitude: The number of times, as a standard quantity is known as the "magnitude" of the physical quantity.

Fundamental Quantity: A physical quantity which is independent of any other quantity is a fundamental quantity.

Fundamental unit: The unit of a physical quantity which is independent of any other quantity is called a fundamental unit.

Complementary Fundamental Units: Units of angle (degrees) and solid angle.

Derived quantities: The physical quantities which can be derived from other physical quantities are called derived quantities.

All other quantities except the fundamental quantities are derivable. The units of these quantities are also derivable from the fundamental units and are called derived units.

Derived units: The units of physical quantities which can be expressed in terms of fundamental units are called derived units.

For example area, pressure, density and speed are derived quantities and their units-square metre, Pascal, kilogram metre^{-3} and metre second^{-1} are derived from the fundamental units.

SYSTEMS OF UNITS

To measure the fundamental quantities length, mass and time, there are three standardised systems of units They are:

(1) CGS (Metric), (2) FPS (British) and (3) MKS System.

Their units are as shown in the table below:

System	**Length**	**Mass**	**Time**
1. F.PS	foot	pound	second
2. CGS	centimetre	gram	second
3. MKS	metre	kilogram	second

Fundamental Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Thermodynamic temperature	kelvin	K
Illuminating power (Luminous intensity)	candela	cd
Strength of electric current	ampere	A
Quatity of matter	mole	mol
Plane angle	radian	rad
Solid angle	steradian	sr

Symbol for Kelvin temperature is K, but not ^{o}K.

1. C.G.S. System: In this system, the unit of length is centimetre; the unit is mass of gram, and the unit of time is second.

2. F.P.S. System: In the F.P.S. system, the unit of length is foot, the unit of mass is pound and the unit of time is second.

3. M.K.S. System: In this system, the unit of length is metre, the unit of mass is kilogram and the unit of time is second.

Coherent system of units: A coherent system of units is a system based on a certain set of basic (or fundamental) units from which all derived units may be obtained by simple multiplication or division without introducing any numerical factors. S.I. system of units is a coherent system of units for all types of physical quantities.

S.I. Units: S.I. unit is the short name of "System International System of Units". It is an extension of M.K.S. system.

PHYSICAL WORLD AND MEASUREMENTS

Following are given definitions of some S.I. units of measurements which are used in day to day activities in physical world.

1. Metre: Metre is 1,650, 763.73 times the wavelength of the orange light in vacuum emitted by $_{36}K^{86}$ (Krypton) in the transition $2p_{10}$ to $5d_5$.

Or

Metre is 1 in 299,792,458the part of the distance travelled by light in vacuum in 1 second.

Sub-units of Metre:

1 metre (m) = 100 centimetres (cm)

1 metre = 1000 millimetres (mm)

1 metre = 10 decimetres (dm)

The Multiple Units of a Metre are:

10 metres = 1 decametre (dm)

10 decametres = 1 hectometre (hm)

10 hectometres = 1 kilometre (km)

NOTE

1 km = 1000 m = 10^3 m

1 hm = 100 m = 10^2 m

1 cm = 10 mm = 10^{-1} m

2. Kilogram: Kilogram is the mass of a platinum-irridium alloy cylinder kept at Sevres, near Paris.

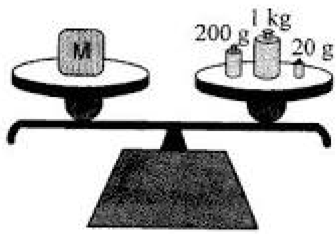
Multiples and Submultiples of Kilogram:

1 tonne (t) = 1000 kg

1 kg = 1000 grams (g)

1 g = 1000 milligrams (mg)

1 g = 1000,000 micrograms (μg)



3. Second: One second is the time taken by 9,192,631,770 cycles of the radiation from the hyperfine transition in caesium-133 atom, when unperturbed by external fields.

4. Kelvin: This is 1/273.16 of the temperature at the triple point of water measured on thermodynamic scale.

5. Candela: Candela is the luminous intensity in a direction normal to the surface of $1/6 \times 10^5$ m^2 of a black body at the temperature of freezing platinum at a pressure of 101.325 Newton per square metre.

6. Ampere : Ampere is the current which, when flowing is each of two parallel conductors of infinite length and negligible cross-section and placed one metre apart in vacuum, causes each conductor to experience a force exactly 2×10^{-7} Newton per metre length.

7. Mole: Mole is the amount of substance of a system that contains as many elementary entities as there are atoms in 0,012 kg of carbon – 12.

8. Radian: Radian is the angle subtended at the centre of a circle by an arc whose length is equal to the radius.

$$2\pi \text{ radian} = 360°$$

$$1 \text{ radian} = \frac{360}{2\pi} = 57° \; 17' \; 44''$$

9. Steradian: The solid angle subtended at the centre of the sphere of radius 1 metre by its surface of area 1 square metre.

Multiplication factors of units: The multiples end sub-multiples of a unit are written by adding suitable multiplication factor as prefix to the unit. The names and symbols of various multiplication factors are shown in the table below:

Multiplication factors	**Name**	**Symbol**
10^{18}	Exa	E
10^{15}	Peta	P
10^{12}	Tera	T
10^{9}	Giga	G
10^{6}	Mega	M
10^{3}	Kilo	K
10^{2}	hecto	h
10	deca	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

(1) The multiplication factors 10^{-2}, 10^{-1}, 10 and 10^{-2} are avoided as far as possible. It is preferable to express quantity as a coefficient of 10^3. For example instead of writing 2.2×10^2, it is preferable to write $0, 22 \times 10^3$.

(2) Compound multiplication factors should be avoided 5×10^{12} should be written as 5 T but not as 5 GK.

UNITS NAMED AFTER SCIENTISTS

Quantity	Unit	Symbol
Force	newton	N
Energy	joule	J
Power	watt	W
Pressure	pascal	Pa
Frequency	hertz	Hz
Electric potential	volt	V
Electric charge	coulomb	C
Capacitanse	farad	F
Magnetic flux	weber	Wb
Electromagnetic induction	henry	H
Electric resistance	ohm	Ω
Luminous flux	lumen	Lm

DIMENSION ANALYSIS

Dimensional formula: The expression showing the powers to which the fundamental units are to be raised to obtain one unit of derived quantity is called the dimensional formula of that quantity.

Dimensional equation: The equation between unit of a physical quantity and its dimensional formula is called the dimensional equation e.g.,

$$\text{Pressure } P = \frac{Force}{Area} = \frac{(M^1L^{-2})}{(L^2)} = [M^1L^{-1}T^{-2}].$$

Dimensions: The dimensions of a physical quantity are the powers to which the fundamental units are raised to obtain one unit of that quantity.

Dimensionless quantities: All physical quantities need not have dimension. Angle, ratio (Proportionality constant) and number do not have dimension e.g., strain, specific gravity (relative density), refractive index, trigonometrically ratios, exponential functions etc, do not have dimensions.

Principle of homogeneity of dimensions: The physical quantities having the same dimensions may be either added or subtracted or equated e.g.,

(i) v = u - at : In this equation **at** is added to u because **at** and **u** have same dimensions (LT^{-1}).

(ii) v = u - gt : In this equation **gt** is subtracted from u because **gt** and **u** have same dimensions (LT^{-1}).

(iii) V = gt : In this equation **gt** is equated to **v** because **gt** and **v** have same dimensions (LT^{-1}).

DIMENSIONS OF SOME PHYSCAL QUANTITIES

1. Velocity and speed: Velocity is the displacement per second. Speed is the distance travelled in one second.

$$v = \frac{\text{displacement}}{\text{time}} \quad \text{and speed} = \frac{\text{distance}}{\text{time}}.$$

Velocity or speed $\quad v = \frac{L}{T} = [LT^{-1}]$

So dimensions of length is +1 and of time is -1 in velocity and speed.

2. Acceleration: It is defined as the rate of change of velocity.

$$a = \frac{V}{t} = (\frac{LT^{-1}}{T}) = [LT^{-2}]$$

3. Force: Force = mass × acceleration = m × a

$$F = (M) \times (LT^{-2}) = [MLT^{-2}]$$

So, dimension of mass is 1 and that of lenght is +1 and that of time is -2 in force.

4. Work or energy: W = force × displacement = F × s

$$W = (MLT^{-2}) \times (L) = [ML^2T^{-2}]$$

5. Power : $P = \frac{\text{Work}}{\text{Time}} = \frac{W}{t} = \frac{Fxs}{t} = \frac{mass}{t} \quad P = \frac{ML}{T^2}\frac{L}{T} = [ML^2T^{-3}]$

6. Pressure: $\frac{\text{force}}{\text{area}} = \frac{F}{A}$ P = $\frac{MLT^{-2}}{L^2}$ = [$MLT^{-1}T^{-2}$]

7. Gravitational constant: According to Newton's universal law of gravitation,

$$F = \frac{Gm_1m_2}{r^2}$$

or $$G = \frac{Fr^2}{m_1m_2}$$

$$G = \frac{MLT^{-2}L^2}{M^2} = [M^{-1}L^3T^{-2}]$$

8. Momentum: mass × velocity : = M × $\frac{L}{T}$ = [MLT^{-1}]

9. Acceleration due to gravity: g= $4\pi \left(\frac{I}{T^2}\right) = \frac{L}{T^2}$ =[LT^{-2}]

10. Kinetic energy (K.I): $\frac{1}{2}$ × mass × velocity^2

$E_k = \frac{1}{2}mv^2 = M\frac{L}{T}x\frac{L}{T}$ = [ML^2T^{-2}]

11. Potential energy (P.I): mass × g × height= m g h

$E_p = \frac{ML}{T^2}xL$ = [ML^2T^{-2}]

12. Coeffeicient of friction (μ): $\frac{\text{frictional force}}{\text{normal reaction}} = \frac{MLT^{-2}}{MLT^{-2}}$ =[M°L°T°]

Coefficient of friction has no dimensions.

13. Impulse: force × time= mass × acceleration × time = M × $\frac{L}{T^2}$ = [MLT^{-1}]

= same as momentum.

14. Angular displacement:

$$\varphi = \frac{\text{arc}}{\text{radius}} = \frac{L}{L} = \text{number}$$

15. Angular velocity:

$$\beta = \frac{\text{angular displacement}}{\text{time}} = \frac{\varphi}{\text{t}} = [T^{-1}]$$

16. Angular acceleration:

$$\omega = \frac{\text{angular velocity}}{\text{time}} = \frac{T^{-1}}{T} = \left[T^{-2}\right]$$

17. Moment of a force or Torque or moment of a couple: force × distance.

$$M = \frac{ML}{T^2} x\, L = \left[M^1 L^2 T^{-2}\right]$$

18. Young's modules: $Y = \frac{Mgl}{\pi r^2 e}$

$$Y = \frac{\text{Stress}}{\text{Strain}} = \left(\frac{(F/A)}{\frac{\Delta L}{L}}\right) = \frac{(MLT^{-2}/L^2)}{(L/L)} = \left[ML^{-1}T^{-2}\right]$$

19. Stress: $\frac{force}{area} = \frac{ML}{T^2} \text{ x } \frac{1}{L^2} = [M^1L^{-1}T^{-2}]$; same as pressure.

20. Angular momentum or moment of momentum L : r × mv = LM$\frac{L}{T}$= $[ML^2T^{-2}]$

21. Surface tension: $\frac{force}{length} = \frac{ML}{T^2} \cdot \frac{1}{L} = [M^1L^{\circ}T^{-2}]$

22. Coefficient of viscosity (η) : $\frac{F}{A(\frac{dv}{dx})} = \frac{MLT^{-2}}{L^2(\frac{LT^{-1}}{L})} = \frac{ML}{T^2} \cdot \frac{1}{L^2} \cdot \frac{LT}{L} = [ML^{-1}T^{-1}]$

23. Frequency n or υ : $\frac{1}{Time}$ = 1/T= $[T^{-1}]$

24. Planck's constant: Radiation energy = Planck's constant × frequency

E = hv

$h = \frac{E}{v} = \frac{ML^2T^{-2}}{T^{-1}} = ML^2T^{-1}$; same as Angular Momentum.

25. Moment of inertia: Moment of inertia = mass × $(\text{length})^2 = [ML^2]$

$I = [ML^2]$

26. Heat: Heat is a form of energy. $Q = [ML^2T^{-2})$

27. Thermal capacity: The amount of heat energy required by a body for unit rise of temperature.

Thermal capacity, H = $\frac{dQ}{dT} = \frac{ML^2T^{-2}}{K} = \left[ML^2T^{-2}K^{-1}\right]$

28. Specific heat: Thermal capacity for unit mass of the body.

$$C = \frac{H}{m} = \frac{1}{m} \cdot \frac{dQ}{dT} = \frac{ML^2T^{-2}K^{-1}}{M} = [M^\circ L^2T^{-2}K^{-1})$$

29. Latent heat: Heat absorbed per unit mass during change of state

$$L = \frac{Q}{m} = \frac{ML^2T^{-2}}{M} = [L^2T^{-2}]$$

30. Coefficient of thermal conductivity K_0 :

$$Q = \frac{K_0A(\theta_2 - \theta_1)t}{d}$$

$$K_0 = \frac{Qd}{A(\theta_2 - \theta_1)t} = \frac{ML^2T^{-2}L}{L^2KT} = [MLT^{-3}K^{-1}]$$

DIMENSIONS OF SOME ELECTRICAL AND MAGNETIC QUANTITIES

In some cases, the dimensions of electrical and magnetic quantities are expressed in terms of the dimensions of charge. The dimensions of some quantities are as follows:

Electric charge, q : strength of current x time

$= [AT] = [M^\circ L^\circ T^1A^1]$

Electric potential = $ML^2T^{-2}Q^{-1}$

Current density = $L^{-2}T^{-1}Q$

Electric dipole moment = LQ

Electric flux = $ML^3T^{-2}Q^{-1}$

Electric field strength = $MLT^{-2}Q^{-1}$

Electromotive force = $ML^2T^{-2}Q^{-1}$

Permeability (μ_0) = MLQ^{-2}

Permittivity (ε_0) = $M^{-1}L^{-3}T^2Q^2$

Magnetic induction = $MT^{-1}Q^{-1}$

Magnetic flux = $ML^2T^{-1}Q^{-1}$

Magnetisation = $L^{-1}T^{-1}Q$

Magnetic field strength = $L^{-1}T^{-1}Q$

Magnetic dipole moment = $L^2T^{-1}Q$

Capacitance = $M^{-1}L^{-2}T^2Q^2$

Inductance = ML^2Q^{-2}

Receptivity = $ML^3T^{-1}Q^{-2}$

Uses of dimensional equations: The chief uses to which dimensional equations can be put are:

(a) **Conversion of one system of units into another:** If the dimensional equation of a physical quantity is know, we can find its numerical value when changing from one system of units to another. If there is a physical quantity say q, whose dimensions in mass, length and time are a, b, c respectively. Then the dimensional formula of this quantity is $[M^aL^bT^c]$. If its numerical value is n_1, when the fundamental units are M^1, L^1 and T^1, then

$$q = n_1 [M_1^a L_1^b T_1^c] \qquad (1)$$

and if n_2 is its numerical value in another system of fundamental units M^2, L^2 and T^2 respectively, then

$$q = n_2 [M_2^a L_2^b T_2^c] \qquad (2)$$

From equations (1) and (2), we get

$$n^1 [M_1^a L_1^b T_1^c] = n_2 [M_2^a L_2^b T_2^c]$$

$$\text{or } n_2 = n_1 \left(\frac{M_1}{M_2}\right)^a \left(\frac{L_1}{L_2}\right)^b \left(\frac{T_1}{T_2}\right)^c \qquad (3)$$

(b) **Checking the results arrived at:** This depends upon the principle of homogeneity of dimensions, according to which the dimensions of all the terms on the two sides of an equation must be the same.

(c) **Deriving a correct relationship between physical quantities:** We can deduce the relationships between different physical quantities by using the method of dimensions, provided the factors on which the given physical quantities are know.

Limits of dimensional method: The proportionality constant in an equation cannot be obtained by dimensional method.

This method cannot be applied to equations involving trigonometrically or exponential functions.

If any side of an equation is the sum of some quantities, dimensional method cannot be used to derive the formula.

If an equation involves more than three fundamental quantities, it is difficult to apply dimensional method.

ERROR ANALYSIS

Accuracy: Accuracy of a measurement is defined as the closeness of the measured value to the true value.

Precision: The closeness of the measured values of repeated measurements of a physical quantity by an instrument is called precision.

Mistakes: The fault in the measurement or observation is called mistake.

Errors: The inaccuracy and imprecision in a measurement without mistakes is called error.

Or

The difference between the measured value and the true value as per standard without mistakes is called the error.

Systematic Errors: The errors due to a definite cause and which follow a particular rule are called systematic errors.

Least Count (LC): The least count of a screw gauge is the smallest distance that can be measured accurately with it.

Finding the least count: The least count of screw gauge is found by using the following relation:

$$\text{L.C.} = \frac{\text{Pitch of the screw}}{\text{Number of divisions on CS}}$$

If p = 1 mm and three are 100 divisions on the circular scale, then

L.C. 1/100 = 0.01 mm =0.001 cm

Least count error: This is an error due to resolution of instrument. Using a metre scale the minimum distance that can be measured accurately is 0.1 cm. This minimum distance is called least count. Let a distance be measured by a scale as 6.7 cm. The true value may be just greater or less than 6.7 cm. The deviation in the measurement cannot go beyond the minimum measurable value which is 0.1 cm So the error is 0.1 cm and this is the least count error. Similarly, if the minimum distance that can be measured (least count) by a screw gauge is 0.01 mm, the error is 0.01 mm.

Pitch: The pitch (p) of a screw is the distance between any two consecutive threads.

The pitch is also the distance moved by the tip of the screw when its head is given one complete rotation.

Finding the pitch: The pitch of a screw is found by giving its head at least ten rotations and then finding the distance travelled by the tip of the screw. The distance, divided by 10, is the pitch of the screw.

Zero error: This is an instrument error. The error due to improper designing and construction is called the instrument error. The zero error in a screw gauge be +0.02 mm. The correction for an observation becomes -0.02mm. The diameter of a rod is measured as 10.02 mm by this screw gauge. The value after correction becomes 10.02 – 0.02 which is 10.00 mm. In every measurement with this instrument, this error of +0.02 mm creeps in.

Positive zero-error: When the movable jaw is brought in contact with the fixed jaw and the zero of the venire scale is on the right of the zero of main scale, then the zero error is positive and the correction is negative. This means that the 'value' of the zero error should be 'subtracted from the final reading.

Negative zero-error: When the movable jaw is brought in contact with the fixed jaw and the zero of the venire scale is on the left of the zero of the main scale, then the zero error is negative and the correction is positive. This means that the 'value' of the zero-error should be 'added to the final reading.

Theoretical error: The error due to the approximations in deriving the theoretical error. In the derivation of the formula for the time period of a simple pendulum it is approximated as sin θ = o for smaller values of 'θ'. When the amplitude of the pendulum is 3°, the error that creeps in is about 0.02%. Its amplitude is more, the error is more.

Parallax error: This is a personal error. The errors due to the limitations of the human senses are called personal errors. An observer may consistently read the observed value either high or low by keeping his view inclined. So an error is introduced. Parallax error is such error under some conditions.

Random errors: The errors which are not systematic and caused by the uncontrolled disturbances which influence the physical quantity and instrument are called the random errors.

Error due to line voltage changes: The uncontrolled disturbances in the line voltage fluctuations cause the change in the reading of an electrical instrument. This error can be minimised by using a stabilizer.

Backlash error: In an instrument which works on the principle of screw, three is always an allowance between the screw and nut. This causes an error called 'backlash error'. This error appears in screw gauge, speedometer and travelling microscope. The error may be positive or negative depending on direction of motion of the screw.

Gross errors: The errors due to faulty adjustment or improper usage of the instrument are called gross errors.

Average: The measure of central tendency is called gross average.

Median: When all the values in the set of observations are arranged in either INS creasing or decreasing order, the mid value is called the median.

Mode: When a particular value is repeatedly occurring in the set of the observations it is called mode. It is also called "most probable" value. It is a position average.

Arithmetic mean: Let there be 'n' observations which are x_1, x_2, ... x_n. The arithmetic mean is represented by $\bar{x}$.

The arithmetic mean

$$\bar{x} = \frac{x_1 + x_2 + ... + x_n}{n} = \frac{\Sigma x}{n}.$$

Absolute deviation (d_n) : The difference between the measured value (x_n) and the arithmetic mean ($\bar{x}$).

The mean deviation: The arithmetic mean of deviations of the individual values from the average of the observations.

Significant figures: The digits required to express a physical quantity accurately are called significant figures. Following set of rules will help in finding the significant figures.

(1) Power of ten do not form significant figures e.g. 9.1 x 10^{-27} has only two significant figures.

(2) The number of zeroes appearing to the left in a digit is not counted in significant figures e.g. 0.0008 has only one significant figure.

(3) The zeroes appearing in between the digits and also at the right end are counted as significant figures e.g. 1.906 and 1.90 have got 4 and 3 significant figures respectively.

(4) The number of significant figures does not change even if the decimal point is shifted to different positions e.g. 1.234, 12.34, 1234 all have 4 significant figures.

(5) **Rounding off of a digit:** A digit can be converted into a significant digit by rounding off the last digit in the second and third decimal place. If the number happens to be more than 5, then the number prior to it is increased by 1 but if it is less than 5, then the number prior to it remains unchanged e.g. 1.49 = 1.5 and 1.44 = 1.4. Further, if the number to be rounded off happens to be 5, then number prior to it is increased by one if it is odd but it remains the same if it is even e.g. 1.35 = 1.4 and 1.45 =1.4.

FORMULAI

If Δx is the deviation from true value x, it is absolute error.

$\frac{\Delta x}{x}$ Is absolute error.

$\frac{\Delta x}{x}*100\%$ is percentage error.

If Δx and Δy are the deviations in x and y then

(a) Absolutely error in addition (x+y) is Δx + Δy

Relative error is $\frac{\Delta x + \Delta y}{x + y}$

Percentage of error is $\frac{\Delta x + \Delta y}{x + y}*100\%$

(b) Absolutely error in subtraction (x-y) is Δx + Δy

Relative error is $\frac{\Delta x + \Delta y}{x - y}$

Percentage of error is $\frac{\Delta x + \Delta y}{x - y}*100\%$

(c) Absolutely error in product (x*y) is(x Δy + yΔx)

Relative error is $\frac{\Delta x}{x} + \frac{\Delta y}{y}$

Percentage of error is $(\frac{\Delta x}{x} + \frac{\Delta y}{y})*100\%$

(d) Relative error in division x/y is $\frac{\Delta x}{x} + \frac{\Delta y}{y}$

Percentage of error is $(\frac{\Delta x}{x} + \frac{\Delta y}{y})*100\%$

(e) Relative error in x^n is $n\frac{\Delta x}{x}$

Percentage of error is $n\frac{\Delta x}{x}*100\%$

(f) Percentage of error in $\frac{x^n}{y^m}$ is $\left(n\frac{dx}{x}+m\frac{dy}{y}\right)*100\%$

(g) The percentage of error in $x^{\frac{1}{n}}$ is $\frac{1}{n}\frac{\Delta x}{x}*100\%$

DESCRIPTION OF MOTION IN ONE DIMENSION

Mechanics: Mechanics is a branch of physical science dealing with the behaviour of matter under the action of forces.

Classical mechanics comprises three principle branches:

(1) Kinematics (2) Dynamics (3) Static's.

Kinematics: Kinematics is the study of the mechanical motion of bodies, without regard for the cause of motion like forces, interacting bodies etc.

Rest: if an object does not change its position with regard to its surroundings with the passage of time, it is said to be at rest.

Motion: An object is said to be in motion if it changes its position with regard to its surroundings with the passage of time.

Point object: In general, whenever the motion of an object involves changes of position by distances much greater than its size, we can without much error neglect its size and think of it as a point-like object.

Origin: In any process involving change, we must be able to assign times to the various events that occur. For this purpose, some instant of time must be chosen as the origin and be assigned the value zero of time. This is called origin of representation of time.

Unit: The unit of time may be second, minute or hour as per convenience.

Position co-ordinate: At each time t, the position of our moving object is given by a real number written as X(t), positive or negative or zero. This is called the position co-ordinate.

Distance: The total lengths of actual path covered by the moving body. It is scalar has no direction and is expressed in metres.

Displacement: The distance travelled by the moving body in a specified direction. It is also the shortest distance between initial and final positions of a body. It is a vector having both magnitude as well as direction. The magnitude of the displacement is never more than the distance.

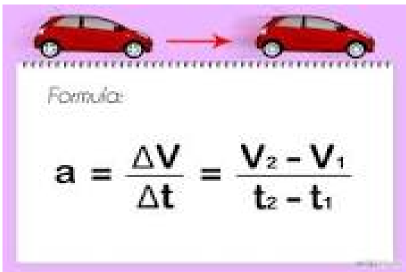
The motion: The motion is said to be one dimensional if it takes place on a straight line path and can be described with the help of only one space coordinate.

The speed is defined as the distance covered by the body per second or the rate of change of distance with time. It is a scalar quantity.

Average speed: The ratio of the total distance covered at the total time taken.

Average velocity: Average velocity is defined as the total displacement divided by total time in a particular direction.

Acceleration: Acceleration is defined as the rate of change of velocity with time. It is a vector quantity and expressed in m/s^{-2} . Increase in velocity per second is acceleration while decrease is **retardation.** The acceleration is uniform it is velocity changes by equal amounts in equal intervals of time. It is variable if it changes by unequal amounts in equal intervals of time.



Acceleration due to gravity (G): The acceleration of a freely falling body due to earth's attraction is called acceleration due to gravity.

Motion under gravity: If a body falls under gravity then all the equations of motion are applicable to such motion. The only difference that **'a'** (acceleration) is to be replaced by **'g'** (acceleration to be gravity).

If this body is moving up, then **g** is negative and if the body is falling then **g** is positive.

When a body attains maximum height, then at this point it is final velocity becomes zero.

The following points are to be remembered for the body in vertical motion:

(i) The maximum height attained by **a** body = $\dfrac{u^2}{2g}$

(ii) The time taken to reach the highest points = the time taken reach the points from where it is projected = $\dfrac{u}{g}$

(iii) The total time taken by a body in going to the maximum height and falling back to the projected point $\dfrac{2u}{g}$.

(iv) When a body strikes the same point from where it was projected, the velocity became the same as that of the velocity of projection.

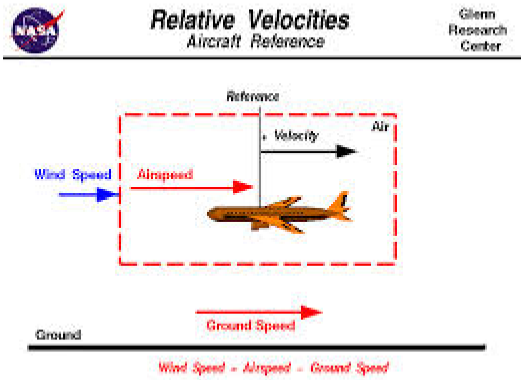
Velocity: The rate of change of displacement with regard to time of an object is called the velocity of the object. It may also be defined as the speed of the object in a particular direction. It is a vector quantity. It is units and dimensions are same as that of speed.

Uniform velocity: An object is said to be moving with uniform velocity, if it undergoes equal displacement in equal intervals of time, however small these intervals may be.

Variable velocity: An object is said to be moving with variable velocity, if either speed or its direction of motion or both change with time.

Instantaneous velocity: The velocity of an object at a particular instant of time or at a particular point of its path is called the **instantaneous velocity** of the object.

Relative velocity: It is defined as the velocity of an object relative to another object which may be stationary or moving.



Average acceleration: It is measured by the ratio of change in velocity in a time interval to the length of time interval.

Instantaneous acceleration: It is the acceleration at any instant and is defined as the limiting value of the average acceleration when the time interval Δt becomes very small.

Uniform acceleration: If the velocity changes in magnitude of an object are equal intervals of time, it is said to be moving with a **uniform acceleration**.

Variable acceleration: If an object moves in such a way that its velocity changes in magnitude and are unequal in equal intervals of time. It is said to be moving with a v**ariable acceleration**.

Maximum height of ascent (projection): It is the maximum height to which the body rises.

Time of ascent: It is the time in which the body reaches the highest point.

Time of descent: It is the time in which the body falls from the highest point to that from which it was projected upwards.

Projectile: A body projected into air with some velocity at angle (other than 90°) with the horizontal is called a **projective** or a body which moves in a to dimensional plane in the gravitational field of earth is called a **projectile**.

Time of flight: The time interval between the time of projection and the time when the projectile passes the same horizontal plane through the point of projection is called the **time of flight**.

Range of projectile: The minimum horizontal distance travelled by the projectile from the point of projection during the time of flight is called its **flight**.

Quantity	**CGS**	SI
1. Displacement (s)	cm	m
2. Velocity or speed (v)	cms^{-1}	ms^{-1}
3. Acceleration or retardation (a)	cms^{-2}	ms^{-2}
4. Acceleration due to gravity (g)	cms^{-2} (980 cms^{-2})	ms^{-2} (9.8 ms^{-2})

FORMULAE

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 - u^2 = 2as$$

$$s_n = u = a\left(n - \frac{1}{2}\right)$$

$$x = (u \cos \theta)\, t$$

and $$y = (u \sin \theta)\, t - \frac{1}{2}gt^2$$

$$\text{Time of flight, } T = \frac{2u \sin \theta}{g}$$

$$\text{Range, } R = \left(\frac{u^2\, 2\theta}{g}\right)$$

$$\text{Maximum height, } h = \frac{(u^2 \sin^2 \theta)}{2g}$$

Velocity of A with respect to B, $v_a - v_b$ when A and B are moving in the same direction.

Velocity of B with respect to A, $v_b - v_a$ when A and B are moving in the same direction.

Velocity of A with regard to B $v_a - (-v_b) = v_a + v_b$ when A and B are moving in opposite directions.

Velocity of B with regard to A = $-v_b - v_a = -(v_a = v_b)$ when A and B are moving in opposite directions.

When A and B are moving in perpendicular directions, the magnitude of relative velocity, Or = $Or_1 = \sqrt{v_a^2 + v_b^2}$

Direction 'θ' with A, $\tan \theta = (v_b/v_a)$

Direction 'θ' with B, $\tan \theta = (v_a/v_b)$

DESCRIPTION OF MOTION IN TWO AND THREE DIRECTIONS

Scalar Quantity: A quantity which has only magnitude but no direction.

Vector Quantity: A quantity which has both magnitude and direction.

Graphical Represent of Vectors: A vector is represented by an arrow. The length of the arrow is proportional to the magnitude of the vector and its orientation gives the direction of the vector.

Equality of Vectors: The vectors of the same physical quantity are equal if they are of the same magnitude and have the same direction.

Addition of Vectors: Let $\vec{A}$ and $\vec{B}$ be two vectors to be added. Now choose any point P and draw $\overrightarrow{PQ} = \vec{A}$ and $\overrightarrow{QR} = \vec{B}$ such that the terminus of $\overrightarrow{PQ}$ is the origin of $\overrightarrow{QR}$. Now $\overrightarrow{PR} = \vec{C}$ is said to be the sum of A and B.

Commutation Law: In addition of two vectors, the order of addition makes no difference. This is called commutative law.

Associative Law: Suppose there are three vectors $\vec{A},\ \vec{B},$ and $\vec{C}.$ If we first add A and B and then add C, we get the same result as that obtained by adding $\vec{A}$ to the sum $\left(\vec{B} + \vec{C}\right)$.

Subtraction of Vectors: To subtract vector $\vec{B}$ from vector $\vec{A}$, $(-\vec{B})$ vector obtained by reversing the direction of $\vec{B}$ is added to $\vec{A}$. Thus $\vec{R} = \vec{A} + (-\vec{B}) = \vec{A} - \vec{B}$. The vector Subtraction does not obey commutative law though it obeys associative law i.e. $\vec{A} + (\vec{B} - \vec{C}) = (\vec{A} + \vec{B}) - \vec{C}$ also the resultant vector.

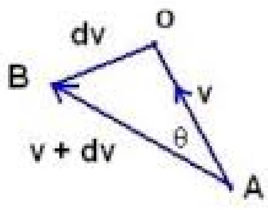
$\mathrm{I\,R\,I} = \sqrt{A^2 + B^2 - 2\,AB\cos\theta}.$

Thus $\left|\vec{A} + \vec{B}\right| = \left|\vec{A} - \vec{B}\right|$ if $\theta = 90°$ and $\mathrm{I\,R\,I} = \sqrt{A^2 + B^2}.$

Distributive Law: The distributive law of algebra is applicable in multiplication of vectors by a scalar. This means $(n + m)\ \vec{P} = n\ \vec{P} + m\ \vec{P}$ and $(\vec{P} + \vec{Q}) = m\ \vec{P} + m\ \vec{Q}$.

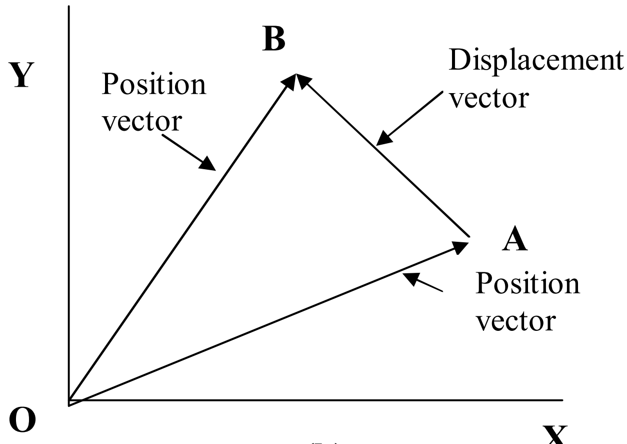
Parallelogram Law of Vectors: If two vectors are represented by two adjacent sides of parallelogram drawn from a point, then their resultant is given by the diagonal passing through the same point.

Triangle Law of Vectors: If two vectors (velocities, accelerations, forces etc.) are represented in magnitude and direction by the sides of a triangle taken in order, the resultant or vector sum is represented in magnitude and direction by the third side of the triangle taken in the reverse order.



Polygon Law: If a number of vectors are represented in magnitude and direction by sides of a polygon taken in order, the resultant is represented in magnitude and direction by the reverse order.

Displacement Vector: If an object changes its position from a point A to B [Fig. b], then the vector will tail at A and tip at B and AB is the displacement vector. It may be noted that in its actual motion the object may not have travelled along the straight line A to B at all.



(b)

Negative Vectors: The negative vectors is defined as another vector having the same length but drawn in opposite directions. The negative vector of $\vec{A}$ is represented -$\vec{A}$. The two vectors have equal magnitudes but their directions are opposite.

Null Vector or Zero Vectors: A vector whose origin and terminus are the same is called a null vector.

Unit Vector: A vector having unit magnitude is called a unit vector.

Collinear Vectors: Vectors which act along the parallel lines are called collinear vectors. Magnitude of collinear vector may or may not be equal.

Co-initial Vectors: Vectors are said to be co-initial if they originate from a common initial point.

The dot or Scalar Product of two Vectors: It is equal to the product of their magnitudes and cosine of the angle between them.

The Cross or Vector Product of two Vectors: It is equal to the product of their magnitude and the sine of the inclined angle and its direction is perpendicular to the plane of the two vectors given by the right hand thumb rule.

FORMULAE

Rectangular components A = C cos θ; B = C sin θ

R = $\sqrt{(u^2 + v^2 + 2\,uv\cos\theta)}$ and tan $\alpha = \frac{v\sin\theta}{u + v\cos\theta}$

When θ = 0°, R = u + v when θ = 90°, R = $\sqrt{u^2 + v^2}$. When θ = 180°, R = u – v or v – u

Motion of boat in a river: sin θ = (v/u)

Dot product of two vectors: $\vec{A} \cdot \vec{B}$ = AB cos θ

Cross – products: $\vec{A} \times \vec{B}$ = AB sin θ

Moment of a force about a point or Torque: $\vec{\tau} = \vec{r} \times \vec{F}$ = rF sin θ

v = $\vec{\omega} \times \vec{r} = r\omega \sin\theta \, \vec{n}$

LAW OF MOTION

Dynamics: It is the branch of mechanics which studies the relation between motion and its cause, that is, ‘force’. The relation between force and motion is governed by the three fundamental laws gives by Sir Isaac Newton (1686 A.D.).

Particle Dynamics: The study of relation between the force and the effect it produces particularly on motion is called particle dynamics.

Newton's First Law of Motion: It states that everybody continues in its state of rest or of uniform motion in a straight line unless compelled by some external force to etc otherwise.

Newton's Second Law of Motion: It a state that rate of change of momentum of a body is directly proportional to applied force and take place in the direction of force.

Newton's Third Law of Motion: It states that to every action, there is equal and opposite reaction.

Collision: The strong physical interaction among the bodies involving the change of moment a.

Elastic collision: A collision in which both K.E. and momentum are conserved.

Semi- elastic or Inelastic Collision: A collision in which only momentum is conserved.

Impulse: The product of the force and time of application.

The change in momentum is the measure of impulse.

Force: It is a push or pull which produces or tends to produce the motion in a body at rest, stops and tends to stop the body in motion, increases or decreases the magnitude of velocity of the moving body or changes the direction of moving body.

The Gravitational Force: It is the force of attraction between two objects due to their masses. It has following properties:

(i) It obeys inverse square law.

(ii) It is a long range force i.e., it extends up to infinity.

(iii) It is the weakest force operating in nature.

(iv) It is always attractive in nature.

(v) It is a central force and hence a conservative force.

Electromagnetic Force: The force between two charges is called electromagnetic force, while the force between two magnetic poles is called magnetic force. A moving charge produces magnetic field. Further, a charged particle moving in a magnetic field (not parallel to the direction of motion of charged particle) experiences as a force. The branch of physics which deals with theory of electricity and magnetism is called electromagnetism and electric and magnetic forces are two facts of electromagnetic force. It has following properties:

(i) It obeys inverse square law.

(ii) It is long range force.

(iii) The photon is the field particle of electromagnetic force.

(iv) It is stronger than weak force.

(v) It is central and conservative force.

Weak force: It is the force which acts between two elementary particles. It is weaker than electrostatic force but stronger than gravitational force.

Strange force: It is a force of nuclear region. Because of this force even protons attract each other inside the nucleus. It has following properties:

(i) It varies inversely with some higher power of distance.

(ii) It is a short range force ($=10^{-14}$ m).

(iii) The π- meson is its attractive force.

(iv) It is basically an attractive force.

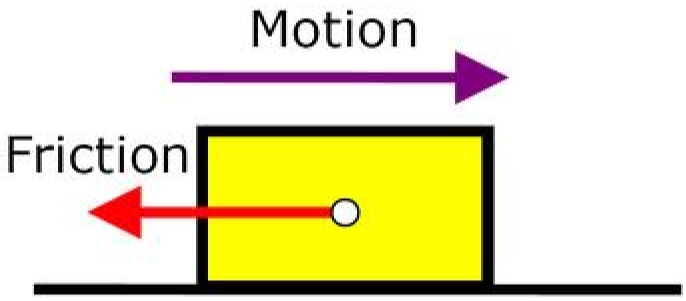
(v) It is the strongest force operating in nature.

Equilibrium of concurrent forces: A number of forces acting at the same point are called **equilibrium of concurrent forces.**

Momentum: It is defined as the total quantity of motion contained in the body.

Conservation of linear momentum: It states that in the absence of external force, the momentum of the system remains constant.

Friction: It is an opposing or retarding force which automatically comes into play when a body slides or rolls on the surface of another. This force is always tangential to the surface in contact and acts in a direction opposite to that of the motion of the body.



Static friction: It is the force of friction acting on the body, when it is in rest position inspite of the fact that some force is being applied on it.

Limiting friction: It may be defined as the force of friction which comes into play when a body just slides over the surface of another body.

Dynamic or kinetic friction: The force of friction which comes into play when a body is in a state of steady motion on the surface of another body. Value of dynamic friction for two bodies is constant and does not change with the change in velocity. Moreover, value of sliding (dynamic) friction is always less than the limiting friction.

Angle of friction: It is defined as the angle which the resultant of limiting friction and normal reaction makes with the normal reaction.

Angle of repose: The angle of inclination of the plane that it makes with the horizontal, at which the slipping of the body just takes place is known as the angle of repose.

Rolling friction: When a body rolls or tends to roll over the surface of another body, the friction in body is called rolling friction.

Normal reaction: When one body rests on another, the force acting on the bottom surface of the upper body is called the normal reaction because it is perpendicular to the bottom surface.

The coefficient of friction between two surfaces in the ratio of the frictional force to the normal reaction.

1. Friction opposes relative motion between two surfaces in contact and is always parallel to the surfaces in contact.

2. Friction depends on the nature of two surfaces in contact i.e. nature of

materials, surface films, lubrication of surfaces, temperature and the impurities between the two surfaces.

3. Friction is independent of the area of contact between the two surfaces.

4. Limiting value of friction is directly proportional to the normal reaction of the body.

The coefficient of static friction between two surfaces: It is the ratio of maximum force of static friction to the normal reaction.

The coefficient of kinetic friction between two surfaces: It is the ratio of the force of kinetic friction to the normal reaction, when they are in relative motion.

Coefficient of friction: The coefficient of friction between two surfaces in the ratio of the limiting value of frictional force to the normal reaction.

Friction is a necessary evil: It is due to existence of friction that we can walk on the ground, trains can run on rail track. Buses can ply on the road. Motion can be transmitted from a motor to machinery by means of gears and conveyor belts. Brakes could not be applied in the absence of friction.

Friction-an evil: Large amount of work done on the machine is used up in overcoming friction which reduces the efficiency of machine. The energy wasted in overcoming friction appears in the form of heat and causes lot of damage to machine components.

Methods to reduce friction: (i) Polishing (ii) Lubrication (iii) Using ball bearings (iv) By using antifriction materials (v) Streamlining of bodies.

Coefficient of restitution: The coefficient of restitution between two bodies in a collision is defined as the ratio of the relative velocity of their separation after collision to the relative velocity of their approach before collision.

A Frame of reference: A coordinate system relative to which the state of rest or the state of motion of a body can be described or relative to which the measurement of an event can be expressed is called a frame of reference.

Inertial frame of reference: An imaginary coordinate system which is at rest or in uniform motion and where Newton’s laws of motion are valid.

Non-inertial frame of reference: An imaginary coordinate system which is in rotation in uniform acceleration where Newton's laws of motion are invalid.

FORMULAE

$m_1u_1+m_2u_2 = m_1v_1+m_2v_2$

$\frac{1}{2}m_1u_1^2+\frac{1}{2}m_2u_2^2=\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2$

$v_1 = \frac{m_1-m_2}{m_1+m_2}u_2 + \frac{2m}{m_1+m_2}u_2 \;\}$

For an elastic collision

$v_2=\frac{2m_1}{m_1+m_2}u_1 += \frac{m_2-m_1}{m_1+m_2}u_2 \;\}$

For an elastic collision

When two bodies moving in opposite directions collides elastically

$v_1 = \frac{m_1-m_2}{m_1+m_2}u_1 - \frac{2m_2}{m_1+m_2}u_{2;}$

$v_2=\frac{2m_1}{m_1+m_2}u_1 += \frac{m_2-m_1}{m_1+m_2}u_2$

$e = \frac{v_2-v_1}{u_1-u_2}$

$h_n = e^{2n}h$

$v_n = e^nv$

μ_k or $\mu_s = \tan\theta = \frac{F}{R}$

$F = mg(\sin\theta - \mu_k\cos\theta)$ when the body slides down or about to slide.

$F = mg(\sin\theta - \mu_k\cos\theta)$ when the body moves up with uniform velocity.

$a = g\sin\theta$ for a body moving down a smooth inclined plane.

$a = -g\sin\theta$ for a body moving down a smooth inclined plane.

$a = g(\sin\theta - \mu_k\cos\theta)$ for a body moving down a smooth inclined plane.

$a = \frac{P-mg(\sin\theta+\mu_k\,\mathrm{cus}\,\theta)}{m}$ for a body moving up a rough inclined plane under the action of applied force, P.

Frictional force × unif rm velocity = power developed.

UNITS OF PHYSICAL QUANTITIES

Quantity	CGS system	SI system
Mass (m)	gm	kg
Momentum (p)	gm cm s^{-1} dyne-sec	kg m s^{-1} N-s
Force (F)	dyne	Newton (N)
Impulse (L)	dyne-sec gm cm sec^{-1}	N s or kg m s^{-1}
Work (W)	erg	joule (J)
Power (P)	erg sec^{-1}	Watt (W)
Energy (E)	erg	joule (J)

WORK - POWER AND ENERGY

Work: Work is said to be done only when a force produces motion. Work done in moving a body is equal to the force exerted on the body and the distance moved by the body in the direction of force.

Positive work: When a body moves in the direction of force, the work done by the force is said to be positive.

Negative work: When a body moves in the direction opposite to force, the work done by the force is negative.

Power: The time rate at which works is done is called power or work done per second is called power.

Energy: The capacity to do work is called energy.

Potential energy (P.E.): Potential energy is the energy possessed by a body by virtue of its position or state or condition or configuration.

Kinetic energy: Kinetic energy is the energy possessed by a body by virtue of its motion.

Work- energy theorem: The work done by a resultant force acting on a particle is always equal to the change in the kinetic energy of the particle.

Principle of conservation of energy: It states that the energy can neither be created nor can be destroyed but can only be converted from one form to another.

Internal energy: An object possessed internal energy because of its temperature.

Heat energy: An object possesses heat energy due to the disorderly motion of its molecules. The heat energy is also related to internal energy of the object.

Light energy: Light is a form of energy. It is light energy that enables us to see the object around us. In fact, without light energy, we are as good as blind.

Light is often found to be necessary for chemical reactions. For example, in photographic action, photosynthesis, photoelectric effect, light is absolutely necessary.

Sound energy: It is sound energy which makes it possible for hearing speech. When sound waves strike the eardrum (diaphragm), it begins to vibrate and makes hearing possible.

Sound is evidently a form of energy because the glass-panes of doors and windows are shattered due to an explosion nearby or vibrate due to sound produced by a low flying plane.

Chemical energy: An object possessed chemical energy because of chemical binding of its atoms.

Electrical energy: When has to be done in order to move an electric charge from one point to another in an electric field or for the transverse motion of a current carrying conductor inside a magnetic field. The work done appears as the electrical energy of the system.

Magnetic energy: When a magnet is placed near a piece of iron, the is piece of iron attracted towards the magnet or a magnet can attract or repel another magnet.

The energy of a magnetic field can be used to produce an electric current in a conductor (electromagnetic induction).

Nuclear energy: The nucleus of an atom possesses energy which can be used for various purposes such as power generation in a nuclear reaction.

Nuclear fission: It is possible to split the nucleus of a body atom into nuclei of smaller masses. This process is called nuclear fission.

In this process, the masses of the end products are slightly less than the original masses. The difference in the original masses and the masses of the end products are converted in energy. This is because mass and energy are interconvertible.

The apparent loss of mass can be accounted for by using Einstein's mass energy relation, $E = mc^2$, where C is the velocity of light (in vacuum).

According to this relation, the loss of mass (m) is converted into energy (E), which is known as the nuclear energy.

Nuclear fusion: The reverse process of fission, namely, fusion of lighter nuclei to from heavy nucleus is also possible. In the process of fusion, there is also a release of energy which is more than the energy released during fusion. This energy released is known as thermo-nuclear energy.

Transformation of energy: Conversion of one form of energy into another is called transformation of energy. In nature, there is continuous conversion of different forms of energies. In our daily life, we convert the available form of energy into suitable form of energy. This is illustrated by the following examples:

1) Conversion of potential energy into kinetic (electrical) energy: Water is stored in a dam at a high level. It possesses potential energy. When this water is allowed to fall then this P.E. is converted into the K.E. of water which can be utilised for various purposes. For example, when the jets of this water stream are made to fall on the blades of a turbine, then the turbine begins to rotate at a high speed. This K.E. of turbine is converted into electrical energy.

2) Conversion of mechanical energy into electrical energy: To convert mechanical energy into electrical energy, a rectangular coil is rotated at a high speed in a uniform magnetic field. This gives rise to a potential difference between the ends of a coil. This is used for supplying an electrical current for practical purposes. This is principle of a generator or a a dynamo.

3) Conversion of electrical energy into heat and light energy: When an electric current is passed through the filament of a bulb, the electrical energy is first converted into heat as it becomes red not and then it emits light.

4) Conversion of chemical energy into electrical energy: When an electric cell is used, it converts the chemical energy into electrical energy which supplies a continuous current. However, when a cell is being charged, a current is passed through it. This means that the reverse effect takes place, that is, the electrical energy is converted into chemical energy.

In an electric motor, the reverse effect takes place. When an electric current is passed through the coil of an electric motor, the coil begins to rotate at a high speed in the uniform magnetic field, thus, converting electrical energy into mechanical energy.

5) Conversion of electrical energy into sound energy: When we ring the door-bell, the electrical energy is converted into sound. Similarly, a loud speaker converts electrical energy into sound.

Dissipation of energy: Consider a bullet fired into a target. The entire energy of the bullet is lost. This energy is converted into heat and sound. This energy can not be further unutilised in practice. We say that the energy of the body is "dissipated".

Similarly, if an object hits the ground, it is entire (initial) potential energy is wasted in the forum of sound and heat, which is eventually diffused in the atmosphere. Thus, the entire useful energy is dissipated.

Mass-energy equivalence: According to Einstein, matter and energy are inter convertible. The energy associated with a mass m is given by

$$E= mc^2$$

where c is the speed of light in vacuum and given by $3\times10^8 m/c^{-1}$.

Work done by a variable force: A force whose magnitude may keep on varying but direction is always same is called a **variable force**.

Erg: Erg is the amount of work done when a force of one dyne moves a body through a distance of one centimetre in its own direction.

$$1Erg= 1dyne \times 1sm$$

Joule: Joule is the amount of work done when a force of 1 Newton moves a body through a distance of 1 metre in its own direction.

1 Joule= 1 Newton × 1 metre= 1Nm= 10^5 dyne × 100sm= 10^7dyne x sm

1 Joule= 10^7 Erg

Watt: When work is done at the rate of 1 Joule per second, the power is said to be 1 watt.

$$1Watt = \frac{1Joule}{1\sec ond} \qquad \left(1W = \frac{1J}{1c}\right)$$

1 kilowatt (KW) = 10 ^{3}W

1 megawatt (MW) = 10^8 W

1 Horse power (HP) 746 W

Note: Kilowatt is the unit of power, but Kilowatt-hour (KWH) is the unit of energy, where

1. KWH = 1 KW × 1 hour = 1000 W × 3600 s = 1000 $\frac{J}{s}$ s 3600 s

1KWH = 36 × 10^5 J

FORMULAE

Work done =$\vec{F}$. $\vec{S}$ = FS cos θ .Here 'θ' is the angle between the force and displacement.

Power = $\frac{work}{time}$

Potential energy = mgh

Kinetic energy = $\frac{1}{2}$ mv^2

$\frac{1}{2}$ mv^2 - $\frac{1}{2}$ mu^2 = work done.

$\frac{p^2}{2\,\text{m}}$ = E. Here p is the momentum and E is the energy.

P = $\frac{W}{t}$ = $\frac{Fs}{t}$

$P = F \times v$ ($v = \frac{s}{t}$ = average speed).

ROTATIONAL MOTION

Centre of mass: The centre of mass of a system of particles (or a rigid body) is that point lying within the boundary of system where the entire mass appears to be concentrated.

Characteristics of the centre of mass: Centre of mass is a point such that the mass of the system ($M = M_1 + M_2$) multiplied by the acceleration ($d^2 / \vec{R}\, dt^2$) of the centre of mass of a system gives the resultant of all the forces acting on the system.

The centre of mass of a system of two particles lies in between them on the line joining the particles.

In case, the two masses are equal, that is $M_1 = M_2$ then:

$$\vec{R}_{cm} = \frac{M_1 \vec{r}_1 + M_2 \vec{r}_2}{M_1 + M_2} = \frac{\vec{r}_1 + r_2}{2}$$

So, for particles of equal masses the centre of mass is located at the mean position vector of the particles.

There may or may not exist actual mass at the centre of mass. A hypothetical mass equal to the mass of the system can be supposed to exist at the centre of mass to describe the motion of the system under the influence of external and internal forces.

The centre of mass of the system depends upon the masses of the constituent particles and their respective position vectors. it is independent of the forces acting on the system.

In symmetrical bodies in which the distribution of mass is homogeneous the centre of mass coincides with geometrical centre.

The position of centre of mass remains unchanged in rotatory motion while it changes in translatory motion.

If the origin coincides with the centre of mass then sum of the moments of the masses of the system about the centre of mass is zero.

The position of the centre of mass is independent of the coordinate system chosen.

The position of centre of mass depends upon the shape of the body and hence on the distribution of mass e.g. for a disc the centre of mass will be within the material of the disc while for a ring it will lie outside the material of the ring.

Centre of gravity: Centre of gravity of a body is the point fixed relative to the body, through which the weight of the body always acts in whatever position the body may be placed.

DISTINCTION BETWEEN CENTRES OF MASS AND CENTRE OF GRAVITY

Centre of mass	**Centre of gravity**
1. Centre of mass of a body is the point with respect to the body at which if a force is applied, the body undergoes translatory motion.	1. The centre of gravity of a body is the point fixed relative to the body through which the weight of the body always acts.
2. It refers to mass of the body.	2. It refers to weight acting on all particles of the body.
3. In the case of ordinary small and regular bodies the of mass and the centre of gravity coincide.	3. In the case of a very large body over different parts of which the acceleration due to gravity is different, the centre of mass and centre of gravity do not coincide.

Translation motion: If the motion of the body is represented by any one of the body is translational.

System: A collection of particles, interacting with one another is called a system.

Centre of mass or the C-frame of reference: A frame of reference carried by the centre of mass of an isolated system of articles (i.e. a system not subjected to an external force) is called the ‘centre of mass’ or the C-frame of reference.

Centre of mass of a rigid body: The centre of mass of a rigid body is a fixed point and it does not change when external forces are applied on the rigid body.

The centre of mass of a rigid body depends upon the shape of the body and the way how the mass of a body is distributed throughout its volume.

Centre of mass can lie outside the rigid body e.g.

The centre of mass of a circular ring is at its geometrical centre.

CENTRE OF MASS OF RIGID BODIES OF REGULAR SHAPES

NO.	Shape	Position of centre of mass
1.	Uniform rod (Metre-rod)	Middle point of rod.
2.	Circular disc	Centre of disc.
3.	Circular ring	Centre of ring.
4.	Solid or hollow sphere	Centre of sphere.
5.	Uniform cylinder	Middle point of the axis of cylinder.
6.	Cuboids	Point of intersection of diagonals.
7.	Triangular lamina	Point of intersection of meridians.
8.	Cone (solid)	On the line joining the apex to the centre of the base at a distance $\frac{1}{4}$th of the length of line from base.

Moment of inertia: It is the property of a body by virtue of which it is unable to change its state of rest or of uniform rotation about an axis by itself.

Circular motion: When a particle moves in a circular path with constant speed such hat the magnitude of its velocity remains constant while the direction of velocity changes continuously, the motion is said to be uniform circular motion.

Angular displacement: The angle through which the radius vector rotates in a given time is called angular displacement.

Direction: The direction of angular displacement vector and the sense of rotation are related to each other and is given by Right Hand Rule which states that if the fingers of the right hand curl round the axis of ration in the direction of rotation, then the thumb represents the direction of angular displacement vector. The length of the arrow gives the magnitude I dθ I.

Angular velocity: The rate of angular displacement of a body is called angular velocity.

Relation between angular velocity, time period and frequency: We know that in one complete revolution a revolving body describes an angle of 2π radian in time T. According to definition of angular velocity (ω), it is defined as the angle described about a fixed point per unit time.

$$\omega = \frac{2\pi}{T}$$

Further, $\frac{1}{T}$ = v, hence

$$\omega = 2\pi \times \frac{1}{T} = 2\pi v$$

Relation between angular velocity and linear velocity:

$$\omega = \frac{\theta}{t} = \frac{l}{r\,.\,t}$$

Where l = length of the arc traced out in time t by moving body.

But l/t = v = linear velocity

$$v = r\omega$$

Angular acceleration: The rate of change of angular velocity of a body is called angular acceleration.

Instantaneous angular acceleration (a): It is defined as the limit of the ratio $\frac{\Delta\omega}{\Delta t}$ as Δt tends to zero.

i.e. $a = \underset{\Delta t \to 0}{\text{Lt.}} \frac{\Delta\omega}{\Delta t} = \frac{d\omega}{dt}$

The units of a are radian/s^2 (rad/s^2) or degree/s^2.

For small change in velocity $\overrightarrow{d\omega}$ is vector and hence $\vec{a}$ is vector.

Centripetal force: It is defined as the force required to move a body with a uniform speed along a circular path. It acts on the body along the radius and towards the centre of the circle.

Rigid body: The body which does not undergo any change in its shape and volume by the application of force is called a rigid body.

Rotatory motion: A body is said to be in rotatory motion if every particle moves in a circular path about a fixed point on a line which is called the axis of rotation.

Axis of rotation: The locus of the centres of circular paths of the particles in a rotating body is called the **axis of rotation**.

Translator motion: A rigid body is said to execute translator motion if it moved bodily from one place to another in such away that all it constituent particles suffer same displacement.

Coplanar forces: When the lines of action of the forces lie in one plane, they are called **coplanar forces**.

Parallel force: When the lines of action of a number of forces acting on a rigid body are parallel, they are called **parallel forces**.

Equilibrium: When a number of forces act on a rigid body, it has neither translator nor rotatory motion, it is said to be in **equilibrium**.

The moment of a force a bout a point is the turning effect of the force a bout the point and is measured by the product of the force and the perpendicular distance of the point from the line of action of the force.

Couple: A pair of equal, unlike, parallel and non- collinear forces acting on a rigid body is called a **couple**.

Moment of a couple: The moment of a couple is equal to the product of one of the forces and the perpendicular distance between the lines of action of the forces. The moment of a couple is "torque"**.** It is a vector. It is direction is perpendicular to plane of rotation given by the right hand rule.

Laws of parallel forces: (a) The sum of the forces, acting in one direction is equal to the sum of the forces acting in the opposite direction.

(b) The sum of the clockwise moments about a point in a body is equal to the sum of the anticlockwise moments about the same point.

Moment of inertia: The moment of inertia of a rigid body about a given axis is the sum of the products of the mass of each particle and the square of its distance from the axis of rotation that make up the body.

Radius of gyration (K): Radius of gyration is the distance of the point from the axis of rotation of a body at which it's whole mass M appears to be concentrated so that MK^2 becomes equal to the moment of inertia of the body about that axis.

Similarity between mass and moment of inertia: The moment of inertia in rotatory motion is just similar to mass in translator motion. This can be clearly seen from the following table:

Translator motion	**Rotatory motion**
1. Linear velocity, $v = \frac{ds}{dt}$	1. Angular velocity, $\omega = \frac{d\theta}{dt}$
2. Linear acceleration, $a = \frac{d^2s}{dt^2}$	2. Angular acceleration, $a = \frac{d^2\theta}{dt^2}$
3. Force, F = ma	3. Moment of a force or torque, $\tau = 1a$
4. Kinetic energy = $\frac{1}{2}mv^2$	4. Rotation K.E. = $\frac{1}{2}1\omega^2$
5. Linear momentum = mv	5. Angular momentum = lω

Parallel axes theorem: The moment of inertia of a rigid body about an axis is equal to the sum of the moment of inertia about a parallel axis passing through the centre of mass and the product of its mass and square of the distance between the two axes.

Perpendicular axes theorem: The sum of the moments of inertia of a plane lamina about any two perpendicular axes in its plane is equal to its moment of inertia about an axis perpendicular to the plane and passing through the point of intersection of the first two axes.

Angular momentum: The moment of particle about a point is called the angular momentum about the point.

Conservation of angular momentum: The angular momentum about an axis of a rotating body or system of bodies is constant, if no external couple (torque) acts about that axis.

ANALOGY BETWEEN TRANSLATIONAL AND ROTATIONAL QUANTITIES

Quantities	**Translation**	**Rotational**
Displacement	s	θ
Velocity	$v = \frac{ds}{dt}$	$\omega = \frac{d\theta}{dt}$
Acceleration	mass, m	Moment of inertia, I
Momentum	p = mv	Angular momentum = lω = mvr
Impulse	Ft	Angular impulse = τt
Work done	Fs	τθ
Kinetic energy	$\frac{1}{2}mv^2$	$\frac{1}{2}l\omega^2$
Power	Fv	τω
Newton's second law	F = ma	$\tau = 1a$
Equilibrium condition	$\sum F = 0$	$\sum \tau = 0$

FORMULAE

Coordinates of centre of mass

$$x_{cm} = \frac{\sum m_i x_i}{\sum m_i};\ y_{cm} = \frac{\sum m_i y_i}{\sum m_i};\ z_{cm} = \frac{\sum m_i z_i}{\sum m_i}$$

$F_{ext} = F_{cm} = Ma_{cm}$

Coordinates of velocity of C.M. $V_{cm} = \frac{\sum m_i v_i}{\sum m_i}$

Coordinates of acceleration of C.M $a_{cm} = \frac{\sum m_i a_i}{\sum m_i}$

$$v = r\omega$$

Torque or moment of a force $\vec{r} \times \vec{F}$

$$I = \sum m.r^2 = MK^2$$

$$I = I_g + Mr^2$$

$$I_z = I_x + I_y$$

Thin rod about the axis perpendicular to length passing through

(a) Mid-point $I = MI^2/12$

(b) About one end $I = \frac{ML^2}{3}$

Circular ring: Axis through centre and perpendicular to its plane $I = Mr^2$

Circular disc or cylinder:

(a) Axis through centre and perpendicular to its plane $I = MI^2/2$

(b) About the diameter $I = MI^2/4$

Cylindrical rod: (a) about the axis passing through centre and perpendicular to it.

$$I = M\left(\frac{R^2}{4} + \frac{l2}{12}\right)$$

(b) About its axis $l = MR^2/2$

Rectangular lamina in xy plane: $l_x = \frac{MI^2}{12l}$ $l_y = \frac{Mb^2}{12}$, $l_z = \frac{M}{12}(l^2 + b^2)$

Angular momentum $L = l\omega$

Torque $\tau = la = \frac{dL}{dt}$

K.E. of pure rotation $= \frac{1}{2} l\omega^2$

Kinetic energy $= \frac{L^2}{2l}$

K.E. of rolling body = = $\frac{1}{2} I\omega^2 + \frac{1}{2}$ Mv^2

Acceleration of a body rolling down a smooth inclined plane $\sqrt{\frac{g \sin \theta}{1+\frac{K^2}{R^2}}}$

Velocity at the bottom of inclined plane $\sqrt{\frac{2 gh}{1+\frac{K^2}{R^2}}}$

GRAVITY AND GRAVITATION

Law of universal gravitation: The gravitational force of attraction between two bodies is directly proportional to the product of their (inertia) masses and inversely proportional to the square of the distance between their centres. This force acts along the line joining the centres of the two bodies.

KEPLER'S LAWS

(1) Every planet revolves round the sun in an elliptical orbit with the sun at one of its foci.

(2) The line joining the planet to the sun sweeps equal areas in equal intervals of time.

(3) The square of the time for one revolution of the planet round the sun is directly proportional to the cube of the semi major axis of its elliptical orbit.

Newton's law of gravitation: Every particle of matter in the universe attracts every other particle with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

Gravitational constant: The universal gravitation constant is numerically equal to the force of attraction between two unit masses separated by unit distance.

Gravity: If one of the bodies is earth of mass M and radius R then the force of attraction or a body of mass m placed at its surface is called the force of gravity.

Mass and density of earth: The mass of earth is given by,

M = $\frac{gR^2}{G}$ = 5.98 X 10^{24} kg

Density of earth, $p = \frac{3g}{4\pi GR}$

Acceleration due to gravity: When a body falls freely under the action of force of gravity, this force produces acceleration in the body which is called acceleration due to gravity and is denoted by 'g'.

Variation of acceleration due to gravity: The value of 'g' varies from place to place on the surface of earth due to

1. Effect of altitude.
2. Effect of depth.
3. Effect of latitude.

Weight of the body: The space surrounding a particle in which gravitational force can be experienced is called gravitational field.

Strength of gravitational field: It is defined as the force experienced by a unit mass placed in the gravitational field of mass M.

Gravitational potential: The gravitational potential at a point in the gravitational field is defined as the work done in taking a unit mass from infinity to that point.

Gravitational potential energy: The work done in bringing a body from infinity to a point in the gravitational field is called the gravitational potential energy at that point.

Relation between gravitational intensity and gravitational potential: The gravitational intensity is the negative space rate of change of gravitational potential or in other words the negative potential gradient gives the gravitational intensity. Mathematically,

$$I = \left(\frac{dv}{dr}\right)$$

Take off velocity: The ake-off velocity of a rocket is the velocity required by it to leave the launching pad. Its value is about 2 km s^{-1}.

Orbital velocity: The speed of a satellite in its orbit is called orbital velocity.

Escape velocity: The minimum velocity with which a body should be projected to overcome the earth's gravitational field is called the escape velocity. Its value is about 11.2 km.

Parking or stationary orbit: The orbit of the artificial satellite, in which its period of revolution is equal to the period of rotation of earth is called parking orbit.

Satellite: A satellite is a body revolving round a bigger body, usually a planet.

Geostationary satellite: A satellite revolving around equator in an orbit such that its period of revolution is exactly 24 hours (equal to that of earth) is known as geostationary satellite.

Uses of satellites: Artificial satellites are used (a) to study the atmospheric changes. (b) For telecommunication and television and radio transmission. (c) to study the shape and size of earth. (d) To locate mineral deposits on the earth. (e) For spying purposes. (f) To study the chemical reactions, biological processes in weightless conditions etc.

FORMULAE

$F = G\, m_1\, m_2/r^2$

$g = G\, M/R^2$

$D = 3\, g/4\pi RG$

The orbital velocity of a projected body, $v_o = \sqrt{gR} = \sqrt{GM/R}$

The escape velocity from a planet, $v_a = \sqrt{2\,gR} = \sqrt{2\,GM/R}$

The orbital angular velocity, $\omega = \sqrt{g/R}$

SATELLITE REVOLVING IN ORBIT OF RADIUS $R_o = (R + h)$

Orbital velocity:

(i) $v = \sqrt{\frac{GM}{R_o}}$ (ii) $v = \sqrt{g\frac{R^2}{R_o}}$ (iii) $v = \frac{2\pi R_o}{T}$

Angular velocity:

(i) $\omega = \sqrt{\frac{GM}{R_0^3}}$ (ii) $\omega = \sqrt{\frac{gR^2}{R_0^3}}$

Time period:

(i) $T = 2\pi\sqrt{\frac{R_0^3}{GM}}$ (ii) $T = 2\pi\sqrt{\frac{R_0^3}{gR^2}}$

SATELLITE REVOLVING CLOSE TO THE SURFACE OF PLANET (R_0 +R)

(i) $v = \sqrt{\frac{GM}{R}}$ (ii) $v = \sqrt{gR}$ (iii) $v = \frac{2\pi R}{T}$

Angular velocity:

(i) $\omega = \sqrt{\frac{GM}{R^2}}$ (ii) $\omega = \sqrt{\frac{g}{R}}$

Time period:

(i) $T = 2\pi\sqrt{\frac{R^3}{GM}}$ (ii) $T\ 2\pi\sqrt{\frac{R}{g}}$

PROPERTIES OF MATTER

ELASTICITY

Elasticity: The property of a body by virtue of which it resists deformation force and regains its original shape when deformation force is removed is called elasticity.

Deformation force: The force which changes or tries to change the shape or size of a body without moving it as a whole is called deforming force.

Elastic bodies: A body which regains its original shape when the deformation force is removed is called elastic body.

Inelastic or plastic bodies: A body which cannot regain its original shape when the deformation force is removed is called a plastic body (or inelastic body).

Stress: The restoring force per unit area developed inside the body is called stress.

Strain: The change produced per unit magnitude of a body is called strain.

Elastic limit: The maximum value of stress within which the body completely regains its original condition when deformation force is removed is called elastic limit.

Hooke's law: It states that within elastic limits stress is directly proportional to the strain.

$$\text{Stress} \propto \text{Strain}$$

or $$\text{Stress} = E \times \text{strain}.$$

where E is the constant of proportionality known as modulus of elasticity. It depends upon different types of strain and nature of material.

Modulus of elasticity: The modulus of elasticity of a body is the magnitude of stress to be applied to produce unit strain.

Longitudinal strain (linear or tensile strain): When an external force is applied to a rod along its length the fractional change in its length is called longitudinal strain.

Shearing or tangential strain: When simultaneous compression and extension in mutually perpendicular directions take place in a body, the change of shape it undergoes is called shearing strain.

Volume or bulk strain: It is the change in volume per unit volume.

Young's modulus (Y): Within the elastic limit of a body, the ratio of longitudinal stress to the longitudinal strain is called the Young's modulus of elasticity.

Rigidity modulus (n): Within the elastic limit of a body, the ratio of tangential stress to the shearing strain is called the rigidity modulus of elasticity.

Bulk modulus (k): Within the elastic limit of a body, the ratio of volumetric stress to bulk strain is called bulk modulus of elasticity.

Compressibility: The reciprocal of the modulus is called compressibility.

Elastic fatigue: The state of temporary loss of elastic nature of a body due to continuous strain is called elastic fatigue.

Poisson's ratio: The ratio of lateral contraction strain to the longitudinal elongation strain of a body is called Poisson's ratio.

Strain-energy: The potential energy stored in a body when strained is called strain-energy.

Couple per unit angular twist or torsional rigidity: The couple required to twist a rod or a wire clamped at one end through one radian is given by

$$c = \frac{\pi \eta r^4}{2l}$$

where r is the radius and l is length of the wire and η is the coefficient of rigidity of the material.

Energy density: It is the energy stored in a wire per unit volume when stretched longitudinally by applying a force at its free end. It is given by

$$\text{Energy density } U = \frac{1}{2} \text{ stress} \times \text{strain} = \frac{1}{2} \cdot \frac{F}{A} \times \frac{l}{L} = \frac{1}{2} \text{ Y} \times (\text{strain})^2$$

$$= \frac{1}{2} (\text{stress})^2 \times \frac{1}{Y}.$$

ELASTIC CONSTANTS

Substance	Elastic modull			Poisson's
	Y (Giga	n Pascal	K GP)	σ
1.Aluminimum	70.5	26.7	76.6	0.34
2.Copper	123	45.0	135	0.35
3.Brass	110	35.0	106	0.3 to 0.4
4.Nickel	202	77.0	176	0.30
5.Cast Iron	100 to 130	35-53	95	0.23 to 0.31
6.Steel	195-206	79-89		0.25 to 0.33

SURFACE TENSION

Surface tension: The force acting per unit length of an imaginary line drawn on the surface of a liquid, normal to it, is called the surface tension of the liquid.

Cohesive force: The force of attraction between the molecules of the same substance.

Adhesive force: The force of attraction between the molecules of different substances.

Angle of contact: It is the angle made by the tangent drawn to the lquid surface at the point of contact and the surface of the glass plate, the angle measured inside the liquid.

Excess of pressure: The pressure on the concave side of the surface is always greater than the pressure on the convex side. The difference pressure P is given by

$$p = 2T\left(\frac{1}{r_1}+\frac{1}{r_2}\right)$$

In case of spherical soap bubble

$$r_1 = r_2 = r$$

$$p = \frac{4T}{r}$$

For liquid drop and air bubble in a liquid $p = \frac{2T}{r}$

Capillarity: The property of rise or depression of a liquid due to surface tension in a capillary tube.

Surface energy: Energy per unit area of the liquid surface is called surface energy. It is numerically equal to surface tension.

Units: The surface energy is expressed as J/m^2 in S.I. system.

The surface energy can be expressed in following cases:

(i) The work done in forming a soap bubble of radius R is $8 \pi R^2 T$.

(ii) The work done in breaking a big drop of radius R into n drops of equal radii $W = 4 \pi R^2 T [n^{1/3} - 1]$.

(iii) The energy liberated in combining n equal drops of radius r each to form a big drop of radius R.

$$W = 4 \pi R^2 T [n^{1/3-1}]$$

(iv) The surface energy = T x Δ A, where T = S.I. and Δ A = Increase in area.

VISCOSITY

Viscosity: The property of a fluid by virtue of which it offers a resistance to relative motion between its different layers.

Streamline flow: If the velocity at any point in the flow is independent of time it is called steady or streamline flow.

Laminar flow: If the streamlines are parallel, the flow is called laminar flow.

The streamline flow in a tube is laminar flow.

Critical velocity: Minimum velocity at which the flow changes from laminar to turbulent state is called critical velocity of that liquid.

Stoke's law: When a small, spherical, rigid body falls through an extended column of viscous liquid under gravity, its motion is opposed by a force $F = 6\pi\eta rv$, where r = radius; v = velocity.

Terminal velocity: As the velocity of the falling body increases, the viscous drag on it also increases. A stage comes, when the viscous drag is equal to the weight of the body, so the net downward force on the body reduces to zero. After this stage, the body falls down with a constant velocity, called the terminal velocity. If a spherical body of material of density p falls through a viscous liquid of density'd', then terminal velocity is given by

$$v_o = \frac{2}{9}\frac{r^2(p-d)g}{\eta}$$

If $p >$ d, v_o is + ve; If $p =$ d, v_o =0; If $p <$ d, v_a is - ve and body rises up.

Streamline and turbulent motion: The flow of fluid (liquid or gas) in which all particles of the fluid passing though a point follow the same path, is called streamline motion. If they move at random we called it turbulent motion.

Velocity of efflux: The velocity of efflux of a liquid through an orifice is equal to that which a body would acquire in falling freely from the free surface of liquid. This velocity is given by

$v = \sqrt{2gh}$, where h = height of the orifice below free surface.

Horizontal range: If R is the horizontal range for the liquid falling, then it can be shown that

$$R = \sqrt{2h\,(H - h)}$$

For horizontal range to be maximum, we have $\frac{dR}{dh} = 0$

or $\frac{d}{dh}\,(2hH - 2h^2)^{1/2} = 0$; which gives h = H/2.

Coefficient of viscosity: The coefficient of viscosity of a liquid is the tangential force per unit area required to maintain unit velocity gradient normal to the direction of flow.

Poise: The coefficient of viscosity of liquid is one poise if a force of 1 dyne is required to maintain unit velocity gradient between two layers, each of area 1 square centimetre.

Decapoise: In SI system, the unit of viscosity is called poiseuille or decapoise. If A = $1m^2$, dv = 1 m s^{-1} dx = 1 m or dv/dx = $1s^{-1}$, F = 1N, then $\eta = 1$ poiseuille of decapoise. Hence, the coefficient of viscosity is said to be, poiseuille, if a viscous (backward) drag of 1N exists between two layers each of area $1m^2$ and having a velocity gradient of 1 s^{-1} between them.

1 decapoise = 1 Nsm^{-2} = kg m^{-1} s^{-1}.

Reynolds number: When a liquid flows through a pipe or closed channel, the expression for its critical velocity is given by

$$v_c = \frac{K\eta}{pr}$$

Here 'η' is the coefficient of viscosity of liquid 'η', 'p' its density and 'r' is the radius of the pipe. K is a constant called Reynolds number.

Principle of continuity: When an incompressible and non-viscous liquid flows in a tube of non-uniform cross-section in streamline motion, the product of velocity of liquid and are of cross-section at all points of the tube remains constant.

$A_1 V_1 = A_2 V_2 = \dots =$ Constant.

Equation of continuity: According to this the velocity of the liquid is inversely proportional to the area of cross-section.

Buoyancy: When a body is immersed in a fluid at rest, the bottom surface experiences greater pressure than the top surface of the body because the pressure depends on depth. So the body experiences a resultant force acting vertically upwards. This upward force is called ‘buoyant force’ or ‘buoyancy’.

Pressure energy: The work done in keeping an elementary mass of a fluid at a point against the pressure existing at that point in the fluid is called ‘Pressure energy’.

Bernoulli’s theorem: The sum of the pressure energy, kinetic energy and potential energy at any point in a steady flow of a fluid is constant.

Venturimeter: It is a device to measure the speed of flow of a fluid.

Turbulent flow: If the velocity of the flow is greater than critical velocity, it is called turbulent flow.

If the velocity at a point in a flow changes with time (dependent on time), It is called turbulent flow.

The ideal fluid: It is incompressible, irrotational and non-viscous.

KINETIC THEORY OF GASES

Assumptions: (i) Every gas is composed of small particles called molecules. The volume of the molecule is negligible in comparison to the volume of the gas.

(ii) Molecules are perfectly elastic and rigid. They move along straight lines in all possible directions. The direction of motion is changed on collision among

(iii) The pressure of the gas s due to the collision of the molecules among themselves or with the walls of the containing vessel.

(iv) The collision among the two molecules is perfectly elastic. There is no force of attraction or repulsion among the molecules.

(v) The time taken by the molecules for collision is negligible in comparison to the time taken by the molecules travelling the straight path.

(vi) The distance travelled by a molecule in two consecutive collisions is called the 'free path'. The average of these free paths is called 'mean free path'.

Expression for pressure: The pressure of the gas P is given by the relation-

$$P = \frac{1}{3}\frac{mn}{V}\bar{c}^2 = \frac{1}{3}p\,\bar{c}^2 = \frac{2}{3}\left(\frac{1}{2}p\,\bar{c}^2\right) = \frac{2}{3}E$$

Where mn = mass of the gas; V = volume of the gas; p = density of the gas and $\bar{c}$ = root mean square velocity (R.M.S. velocity) of the molecules.

Average velocity:

$$\bar{c} = \frac{(C_1 + C_2 + C_3 + ... + C_n}{n}$$

Where C_1, C_2, C_3 ... C_n are the respective velocities of n different molecules.

Mean square velocity:

$$(\bar{c})^2 = \frac{(C_1^2 + C_2^2 + ... + C_n^2}{n}$$

Average velocity: C = 0.921 $\bar{c}$

Maximum velocity = $\sqrt{\frac{2}{3}}$ **x** $\bar{c}$ = 0.817 $\bar{c}$

Expression for R.M.S. velocity: $\bar{c} = \sqrt{\frac{3P}{p}} = \sqrt{\frac{3RT}{M}}$

Hence, $C \propto \sqrt{T}$

At T = 0 K, $\bar{c}$ = 0.

If at the temperatures T, K and T_2 K, the respective R.M.S. velocities are $\bar{c}_1$ and $\bar{c}_2$, then

$$\frac{\bar{c}_1}{\bar{c}_2} = \sqrt{\frac{T_1}{T_2}}$$

If the molecular weights of the two gases are M_1 and, then the ratio of their R.M.S. velocities is given by the relation –

$$\frac{\bar{c}_1}{\bar{c}_2} = \sqrt{\frac{M_1}{M_2}}$$

If m is the mass of a gas molecule, then

$$\bar{c} = \sqrt{\frac{3KT}{m}}$$

where K = Boltzmann's constant = 1.38 x 10^{-23} J/K

Kinetic interpretation of temperature

For the point of view of kinetic theory, the mean kinetic energy of a molecule can be regarded as a measure of the temperature of the gas i.e,

$$\text{K.E.} = \frac{1}{2}m\bar{c}^2 = \frac{3}{2}\text{KT} = \frac{3}{2}\frac{R}{N}\text{T}$$

$$\text{K.E.} \propto \text{T}$$

Gas laws:

(1) Boyle's law: Temperature remaining constant, the pressure of a given mass of a gas is inversely proportional to its volume i.e.

$$P \propto \frac{1}{V}$$

(For given mass of a gas at constant temperature)

or PV = a constant

(2) Charles's law: Pressure remaining constant, the volume of the given mass of a gas is directly proportional to the absolute temperature of the gas i.e.,

$$V \propto T$$

(For given mass of a gas at constant pressure)

(3) gas equation: For an ideal gas (perfect gas) –

PV = RT (R = Universal gas constant)

In an ideal gas, there is no force of attraction or repulsion among the molecules.

(4) Avogadro's law: Equal volume of all gases under similar conditions of temperature and pressures contains equal number of molecules.

At NTP (sometimes referred as STP) the volume of one gram mole of every gas has the volume 22.4 litres (22400 cc).

At NTP 22.4 litres of every gas contains 6.02 x 10^{23} number of molecules. This number is called 'Avogadro's number'.

(5) Graham's law of diffusion: Under similar conditions of temperature and pressure, the rate of diffusion of a gas is inversely proportional to the square root of their molecular weights i.e.,

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

(6) Dalton's law of partial pressure: The gases which do not react with each other, if enclosed in a vessel, the total pressure P will be the sum of the pressures exerted by each gas, provided they are at the same temperatures i.e.,

$P = P_1 + P_2 + P_3 + \ldots$

(7) For one mol of a gas at STP, the value of $\frac{PV}{T}$ is equal to 'universal gas constant R'. Its value is same for all the gases irrespective of their nature.

R = 8.31 J/K-mol = 8.31 x 10^7 erg/K-mol = 2 cal/K-mol (approx.) = 0.082 atom-litre/K-mol

R = KN = 1.38 x 10^{-23} x 6.02 x 10^{23} + 8.31 J/K-mol

FORMULAE

ELASTICITY

$$Y = \frac{Fl}{Ae} = \frac{Mgl}{\pi T^2 e}$$

Work done per unit volume = $\frac{1}{2}$ stress x strain

Total work

done = $\frac{1}{2}$ stress x strain x volume

Heat produced when the wire breaks is given by

W = JQ = JMCt.

where J is the mechanical equivalent of heat and W = strain energy at the time of breakage, C = specific heat (heat units) and t is the rise of temperature.

$$n = \frac{F}{A\theta} = \frac{Fl}{A\Delta l}$$

$$n = \frac{360Mgrl}{\pi^2 a^4 a}$$

$$K = \frac{PV}{\Delta V}$$

$$\sigma = \frac{Y}{2n} - 1$$

SURFACE TENSION

$$T = \frac{rhdg}{2\cos\theta}$$

When $\theta = 0°$, $T = \frac{rhdg}{2}$

$$T = \frac{\text{potential energy}}{area} = \frac{W}{A} \text{ or } W = TA$$

Excess pressure

(i) For soap bubble, $P_1 = \frac{4T}{r}$

(ii) For liquid drop, $P_2 = \frac{2T}{r}$

VISCOSITY

$$F = \eta A \left(\frac{dv}{dx}\right)$$

$$\eta = \frac{\pi Pr^4}{8lv} = \frac{\pi hdgr^4 t}{8lv}$$

When n, r and l are the same, the ratio of the coefficient of viscosity is

$$\eta_1/\eta_2 = V_2/V_1$$

When n, r and l are the same, the ratio of the coefficient of viscosity is

$$h_1/h_2 = p_1/p_2$$

$$\frac{h_1}{h_2} = \frac{p_1}{p_2}$$

When h, l, v and r the same

$$\eta_1/\eta_2 = d_1t_1/d_2t_2$$

$$a_1v_1 = a_2v_2.$$

K.E. of unit mass $\frac{1}{2}v^2$ and K.E. per unit volume $\frac{1}{2}\ p\,v^2$.

Pressure energy per unit mass $\frac{P}{p}$ and per unit volume is P.

$$\frac{P}{p} + \frac{1}{2}v^2 + gh = \text{constant}$$

For a horizontal tube of variable cross sections, the pressure difference is

$$(P_1 - P_2) = \frac{1}{2}\ p\,(v_2^2 - v_1^2)$$

Efflux velocity $v = \sqrt{2gh}$ (Torricelli's theorem).

Adabiyotlar

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