APPLIED PHYSICS

Semester-I

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RATIONALE

Applied physics includes the study of a large number of diverse topics all related to things that go on in the world around us. It aims to give an understanding of this world both by observation and by prediction of the way in which objects will behave. Concrete use of physical principles and analysis in various fields of engineering and technology are given prominence in the course content.

Note: Teachers should give examples of engineering/technology applications of various concepts and principles in each topic so that students are able to appreciate learning of these concepts and principles. In all contents, SI units should be followed. Working in different sets of units can be taught through relevant software.

LEARNING OUTCOMES

After undergoing this subject, the students will be able to:

- Identify physical quantities, parameters and select their units for use in engineering solutions
- Write unit and dimensions of different physical quantities
- Use equipment like-vernier calliper, screw gauge, spherometer
- Represent physical quantities as scalar and vector
- Understand basic laws of motion
- Analyse and design banking of road
- Define work, energy and power, their SI units,solve simple numerical problems based on these
- State law of conservation of energy
- Identify forms of energy, its conversion from one form to another
- Describe surface tension phenomenon, its SI unit, applications, effectof temperature on surface tension
- Describe viscosity of liquid, its unit
- Define stress and strain, modulus of elasticity, State Hooke’s law
- Measure temperature on different scales (Celsius, Kelvin, Fahrenheitetc.)

- Distinguish between conduction, convection and radiation

1. Unit and Dimensions

1.1 Definition of Physics, physical quantities- fundamental and derived

1.2 Units: fundamental and derived

1.3 System of units: CGS, FPS, MKS, SI

1.4 Dimension, dimensional formulae and SI units of physical quantities-distance, displacement, area, volume, density, velocity, acceleration, linear momentum, force, impulse, work, power, energy, pressure, surface tension, stress, strain)

1.5 Dimensional equations, principle of homogeneity of dimensional equation

1.6 Application of dimensional analysis: checking the correctness of physical equation, conversion of system of unit (force, work, acceleration)

2. Force and Motion

2.1 Scalar and vector quantities– definition and examples, representation of vector, types of vector (unit vector, position vector, co-initial vector, collinear vector, co-planar vector)

2.2 Vector algebra- addition of vectors, Triangle &Parallelogram law (statement and formula only),

2.3 Scalar and vectorproduct (statement and formula only)

2.4 Force and its units, resolution of force (statement and formula only)

2.5 Newton's laws of motion (statement and examples)

2.6 Linear momentum, Law of conservation of linear momentum (statement and examples), Impulse

2.7 **Circular motion**: definition of angular displacement, angular velocity, angular acceleration, frequency, time period; Relation between linear and angular velocity, centripetal and centrifugal forces (definition and formula only), application of centripetal force in banking of road

2.8 **Rotational motion:** definition with examples

2.9 Definition of torque, angular momentum, moment of inertia and its physical significance

3. Work, Power and Energy

3.1 Work- definition, symbol, formula and SI unit, types of work (zero work, positive work and negative work) with example

3.2 Friction– definition and its simple daily life applications

3.3 Power- definition, formula and units

3.4 Energy- definition and its SI unit, examples of transformation of energy.

3.5 Kinetic energy- definition, examples, formulaand its derivation

3.6 Potential energy- definition, examples, formulaand its derivation

3.7 Law of conservation of mechanical energy for freely falling bodies (withderivation)
3.8 Simple numerical problems based on formula ofPower and Energy

4. Properties of Matter

4.1 Elasticity and plasticity- definition, deforming force, restoring force, example of elastic and plastic body
4.2 Definition of stress and strain, Hooke's law, modulus of elasticity
4.3 Pressure- definition, atmospheric pressure, gauge pressure, absolute pressure, Pascal's law
4.4 Surface tension- definition, SI unit, applications of surface tension, effect of temperature on surface tension
4.5 Viscosity: definition, unit, examples, effect of temperature on viscosity

5. Heat and Temperature

5.1 Definition of heat and temperature (on the basis of kinetic theory)
5.2 Difference between heat and temperature
5.3 Principle and working of mercury thermometer
5.4 Modes of transfer of heat- conduction, convection and radiation with examples.
5.5 Properties of heat radiation
5.6 Different scales of temperature and their relationship

LIST OFPRACTICALS(08 experiments are compulsory)

1. Familiarization of measurement instruments and their parts (for example - verniercalliper, screw gauge, spherometer, travelling microscope etc.), and taking a reading. (compulsory to all students)
2. To find diameter ofsolidcylinder using avernier calliper
3. Tofindinternaldiameteranddepthofabeakerusingavernier calliperandhencefind its volume.
4. To find the diameter ofwireusingscrewgauge
5. To find thickness of paper usingscrewgauge.
6. To determinethe thickness of glass strip usingaspherometer
7. To determine radius of curvature of a given spherical surface by a spherometer.
8. To verifyparallelogram law of force
9. To determinetheatmosphericpressure ataplaceusingFortin's Barometer
10. To determine forceconstant of springusingHooke's law
11. Measuring room temperature with the help of thermometer and its conversion in different scale.

INSTRUCTIONAL STATREGY

Teacher may use various teaching aids like models, charts,graphs and experimental kits etc. for imparting effective instructions in the subject. Students need to be exposed to use of different sets of units and conversion from one unit type to another. Software may be used to solve problems involving conversion of units. The teacher should explain about field applications before teaching the basics of mechanics, work, power and energy, rotational motion, properties of matter etc. to develop proper understanding of the physical phenomenon. Use of demonstration can make the subject interesting and develop scientific temper in the students.

MEANSOFASSESSMENT

- Assignments and quiz/class tests and end-term written tests, model/prototype
- Actual laboratory and practical work, exercises and viva-voce

RECOMMENDED BOOKS

1. Text Book of Physics for Class XI(Part-I, Part-II); N.C.E.R.T., Delhi
2. AppliedPhysics,Vol.IandVol.IIbyDr.HHLal;TTTIPublications,TataMcGraw Hill, Delhi
3. Applied Physics - I by AS Vasudeva; Modern Publishers, Jalandhar.
4. Applied Physics - I by R ABanwait; Eagle Prakashan, Jalandhar.
5. e-books/e-tools/relevant software to be used as recommended by AICTE/ HSBTE/ NITTTR.
6. Practical Physics, by C. L. Arora, S Chand Publication

Websites forReference:

http://swayam.gov.in

Chapter 1
UNITS AND DIMENSIONS

Learning objective: After going through this chapter, students will be able to;

- *Understand physical quantities, fundamental and derived;*
- *Describe different systems of units;*
- *Define dimensions and formulate dimensional formulae;*
- *Write dimensional equations and apply these to verify various formulations.*

1.1 DEFINITION OF PHYSICS AND PHYSICAL QUANTITIES

Physics: *Physics is the branch of science, which deals with the study of nature and natural phenomena*. The subject matter of physics includes heat, light, sound, electricity, magnetism and the structure of atoms.

For designing a law of physics, a scientific method is followed which includes the verifications with experiments. The physics, attempts are made to measure the quantities with the best accuracy. Thus, physics can also be defined as **science of measurement**.

Applied Physics is the application of the Physics to help human beings and solving their problem, it is usually considered as a bridge between Physics & Engineering.

Physical Quantities: *All quantities that can be measured are called physical quantities.*
For example: Distance, Speed, Mass, Force etc.

Types of Physical Quantity:
Fundamental Quantity: *The quantity which is independent of other physical quantities*. In mechanics, mass, length and time are called fundamental quantities.
Derived Quantity: *The quantity which is derived from the fundamental quantities is a derived quantity*. For example, area, speed etc.

1.2 UNITS: FUNDAMENTAL AND DERIVED UNITS

Measurement: In our daily life, we need to express and compare the magnitude of different quantities; this can be done only by measuring them.

Measurement is the comparison of an unknown physical quantity with a known fixed physical quantity.

Unit: The known fixed physical quantity is called unit.

or

The quantity used as standard for measurement is called unit.

For example, when we say that length of the class room is 8 metre, we compare the length of class room with standard quantity of length called metre.

$$\boxed{Q = nu}$$

Physical Quantity = Numerical value × unit

Q = Physical Quantity

n = Numerical value

u = Standard unit

e.g.Mass of stool = 15 kg

Mass = Physical quantity

15 = Numerical value

kg = Standard unit

Means mass of stool is 15 times of known quantity i.e. kg.

Characteristics of Standard Unit: A unit selected for measuring a physical quantity should have the following properties

(i) It should be well defined i.e. its concept should be clear.

(ii) It should not change with change in physical conditions like temperature, pressure, stress etc.

(iii) It should be suitable in size; neither too large nor too small.

(iv) It should not change with place or time.

(v) It should be reproducible.

(vi) It should be internationally accepted.

Classification of Units: Units can be classified into two categories.

Fundamental units:*Units of fundamental physical quantities are called Fundamental units***.**

Physical Quantity	Fundamental unit
Mass	kg, gram, pound
Length	metre, centimetre, foot
Time	second

Derived units: *the units of derived physical quantity are called as derived units*.

For exampleunits of area, speed etc.

Area = Length × Breadth

$= \text{Length} \times \text{Length}$

$= (\text{Length})^2$

Speed $= \text{Distance} / \text{Time}$

$= \text{Length} / \text{Time}$

1.3 SYSTEMS OF UNITS: CGS, FPS, MKS, SI

For measurement of physical quantities, the following systems are commonly used:-

(i) **C.G.S system**:In this system, the unit of length,mass and time are centimetre, gram and second, respectively.

(ii) **F.P.S system**: In this system, the unit of length, mass and time are foot, pound and second, respectively.

(iii) **M.K.S**: In this system, the unit of length, mass and time are metre, kilogram and second, respectively.

(iv) **S.I System**: This system is an improved and extended version of M.K.S system of units. It is called international system of unit.

With the development of science & technology, the three fundamental quantities like mass, length & time were not sufficient as many other quantities like electric current, heat etc. were introduced. Therefore, more fundamental units in addition to the units of mass, length and time are required.

Thus, MKS system was modified with addition of four other fundamental quantities and two supplementary quantities.

Table of Fundamental Units

Sr. No.	Name of Physical Quantity	Unit	Symbol
1	Length	metre	m
2	Mass	kilogram	kg
3	Time	second	s
4	Temperature	kelvin	K
5	Electric Current	ampere	A
6	Luminous Intensity	candela	cd
7	Quantity of Matter	mole	mol

Table of Supplementary unit

Sr. No	Name of Physical Quantity	Unit	Symbol
1	Plane angle	radian	rad
2	Solid angle	steradian	sr

Advantage of S.I. system:

(i) It is coherent system of unit i.e. the derived units of a physical quantity are easily obtained by multiplication or division of fundamental units.

(ii) It is a rational system of units i.e. it uses only one unit for one physical quantity e.g. joule (J) is unit for all types of energies (heat, light, mechanical).

(iii) It is metric system of units i.e. it's multiples & submultiples can be expressed in power of 10.

(iv) It gives due representation to all branches of physics.

Definition of Basic and Supplementary Units of S.I. system

1. **Metre** (m): one metre is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second.

2. **Kilogram** (kg): one kilogram is the mass of the platinum-iridium prototype which wasapproved by the ConférenceGénérale des Poids et Mesures, held in Paris in1889, and kept by the Bureau International des Poids et Mesures.

3. **Second** (s): one second is the duration of 9192631770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of Cesium-133 atom.

4. **Ampere** (A) : The ampere is the intensity of a constant current which, if maintained in two straightparallel conductors of infinite length, of negligible circular cross-section, andplaced 1 metre apart in vacuum, would produce between these conductors aforce equal to 2×10^{-7}newton per metre of length.

5. **Kelvin** (K): Kelvin is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

6. **Candela** (cd): The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

7. **Mole** (mol): 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.

Supplementary units:

1. **Radian (rad):** It is supplementary unit of plane angle. It is the plane angle subtended at the centre of a circle by an arc of the circle equal to the radius of the circle. It is denoted by θ.

$$\theta = l / r; l \text{ is length of the arc and } r \text{ is radius of the circle}$$

2. **Steradian (sr):** It is supplementary unit of solid angle. It is the angle subtended at the centre of a sphere by a surface area of the sphere having magnitude equal to the square of the radius of the sphere. It is denoted by Ω.

$$\Omega = \Delta s / r^2$$

SOME IMPORTANT ABBREVIATIONS

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

Some Important Units of Length:

1 micron = 10^{-6} m = 10^{-4} cm
1 angstrom = 1Å = 10^{-10} m = 10^{-8} cm
1 fermi = 1 fm = 10^{-15} m
1 Light year = 1 ly = 9.46 x 10^{15}m
1 Parsec = 1pc = 3.26 light year

Some conversion factor of mass:

1 kilogram = 2.2046 pound
1 pound = 453.6 gram
1 kilogram = 1000 gram
1 milligram = 1/1000 gram = 10^{-3} gram
1 centigram = 1/100 gram = 10^{-2} gram
1 decigram = 1/10 gram
1 quintal = 100 kg
1 metric ton = 1000 kilogram

1.4 DEFINITION OF DIMENSIONS

<u>Dimensions:</u> The powers, to which the fundamental units of mass (M), length (L) and time (T) are raised, which include their nature and not their magnitude are called dimensions of a physical quantity.

For example Area = Length x Breadth

$= [L^1] \times [L^1] = [L^2] = [M^0L^2T^0]$

Here the powers (0, 2, 0) of fundamental units are called dimensions of area in mass, length and time respectively.

e.g.Density = mass/volume

$= [M^1]/[L^3]$

$= [M^1L^{-3}T^0]$

1.5 DIMENSIONAL FORMULAE AND SI UNITS OF PHYSICAL QUANTITIES

Dimensional Formula: An expression along with power of mass, length & time which indicates how physical quantity depends upon fundamental physical quantity.

e.g.Speed = Distance/Time

$= [L^1]/[T^1] = [M^0L^1T^{-1}]$

It tells us that speed depends upon L & T and it does not depend upon M.

Dimensional Equation: An equation obtained by equating the physical quantity with its dimensional formula is called dimensional equation.

e.g. the dimensional equation of area, density & velocity are given as under-

Area = $[M^0L^2T^0]$

Density = $[M^1L^{-3}T^0]$

Velocity = $[M^0L^1T^{-1}]$

Dimensional formula & SI unit of Physical Quantities

Sr. No.	**Physical Quantity**	**Mathematical Formula**	**Dimensional formula**	**S.I unit**
1	Force	Mass × Acceleration	$[M^1L^1T^{-2}]$	newton (N)
2	Work	Force × Distance	$[M^1L^2T^{-2}]$	joule (J)
3	Power	Work / Time	$[M^1L^2T^{-3}]$	watt (W)
4	Energy (all form)	Stored work	$[M^1L^2T^{-2}]$	joule (J)
5	Pressure, Stress	Force/Area	$[M^1L^{-1}T^{-2}]$	Nm^{-2}
6	Momentum	Mass × Velocity	$[M^1L^1T^{-1}]$	$kgms^{-1}$
7	Moment of force	Force × Distance	$[M^1L^2T^{-2}]$	Nm
8	Impulse	Force × Time	$[M^1L^1T^{-1}]$	Ns
9	Strain	Change in dimension / Original dimension	$[M^0L^0T^0]$	No unit
10	Modulus of elasticity	Stress / Strain	$[M^1L^{-1}T^{-2}]$	Nm^{-2}
11	Surface energy	Energy / Area	$[M^1L^0T^{-2}]$	joule/m^2
12	Surface Tension	Force / Length	$[M^1L^0T^{-2}]$	N/m
13	Co-efficient of viscosity	Force × Distance/ Area × Velocity	$[M^1L^{-1}T^{-1}]$	N/m^2
14	Moment of inertia	Mass × (radius of gyration)^2	$[M^1L^2T^0]$	kg-m^2
15	Angular Velocity	Angle / Time	$[M^0L^0T^{-1}]$	rad per sec
16	Frequency	1/Time period	$[M^0L^0T^{-1}]$	hertz (Hz)
17	Area	Length × Breadth	$[M^0L^2T^0]$	m^2
18	Volume	Length × Breadth × Height	$[M^0L^3T^0]$	m^3
19	Density	Mass/ Volume	$[M^1L^{-3}T^0]$	kg/m^3
20	Speed or velocity	Distance/ Time	$[M^0L^1T^{-1}]$	m/s
21	Acceleration	Velocity/Time	$[M^0L^1T^{-2}]$	m/s^2
22	Pressure	Force/Area	$[M^1L^{-1}T^{-2}]$	N/m^2

Classification of Physical Quantities on the basis of dimensional analysis

1. **Dimensional Constant**: These are the physical quantities which possess dimensions and have constant (fixed) value.

e.g. Planck's constant, gas constant, universal gravitational constant etc.

2. **Dimensional Variable**: These are the physical quantities which possess dimensions but do not have fixed value.

e.g. velocity, acceleration, force etc.

3. **Dimensionless Constant**: These are the physical quantities which do not possess dimensions but have constant (fixed) value.

e.g. e, π, numbers like 1, 2, 3, 4, 5, etc.

4. **Dimensionless Variable**: These are the physical quantities which do not possess dimensions and have variable value.

e.g. angle, strain, specific gravity etc.

Example1 Derive the dimensional formula of following Quantity & write down their dimensions.

(i) Density (ii) Power

(iii) Co-efficient of viscosity (iv) Angle

Sol. (i) Density = mass/volume

$=[M^1]/[L^3] = [M^1L^{-3}T^0]$

(ii) Power = Work/Time

=Force x Distance/Time

$=[M^1L^1T^{-2}] \times [L^1]/[T^1]$

$=[M^1L^2T^{-3}]$

(iii) Co-efficient of viscosity = $\dfrac{\text{Force x Distance}}{\text{Area x Velocity}}$

$$\frac{\text{Mass x Acceleration x Distance x time}}{\text{length x length x Displacement}}$$

$=[M^1] \times [L^1T^{-2}] \times [L^1]\ [T^1]/[L^2] \times [L^1]$

$=[M^1L^{-1}T^{-1}]$

(v) Angle = arc (length)/radius (length)

$= [L^1]/[L^1]$

$=[M^0L^0T^0]$ = No dimension

Example2 Explain which of the following pair of physical quantities have the same dimension:
(i) Work &Power (ii) Stress & Pressure (iii) Momentum &Impulse

Sol. (i) Dimension of work = force x distance = $[M^1L^2T^{-2}]$
Dimension of power = work / time = $[M^1L^2T^{-3}]$
Work and Power have not the same dimensions.

(ii) Dimension of stress = force / area = $[M^1L^1T^{-2}]/[L^2] = [M^1L^{-1}T^{-2}]$
Dimension of pressure = force / area = $[M^1L^1T^{-2}]/[L^2] = [M^1L^{-1}T^{-2}]$
Stress and pressure have the same dimension.

(iii) Dimension of momentum = mass x velocity= $[M^1L^1T^{-1}]$
Dimension of impulse = force x time =$[M^1L^1T^{-1}]$
Momentum and impulse have the same dimension.

PRINCIPLE OF HOMOGENEITY OF DIMENSIONS

It states that *the dimensions of all the terms on both sides of an equation must be the same*. According to the principle of homogeneity, the comparison, addition & subtraction of all physical quantities is possible only if they are of the same nature i.e., they have the same dimensions.

If the power of M, L and T on two sides of the given equation are same, then the physical equation is correct otherwise not. Therefore, this principle is very helpful to check the correctness of a physical equation.

Example: A physical relation must be dimensionally homogeneous, i.e., all the terms on both sides of the equation must have the same dimensions.

In the equation, $S = ut + ½ at^2$

The length (S) has been equated to velocity (u) & time (t), which at first seems to be meaningless, but if this equation is dimensionally homogeneous, i.e., the dimensions of all the terms on both sides are the same, then it has physical meaning.

Now, dimensions of various quantities in the equation are:

Distance, $S = [L^1]$
Velocity, $u = [L^1T^{-1}]$
Time, $t = [T^1]$
Acceleration, $a = [L^1T^{-2}]$
½ is a constant and has no dimensions.
Thus, the dimensions of the term on L.H.S. is $S=[L^1]$ and
Dimensions of terms on R.H.S=

$$ut + ½ at^2 = [L^1T^{-1}]\,[T^1] + [L^1T^{-2}]\,[T^2] = [L^1] + [L^1]$$

Here, the dimensions of all the terms on both sides of the equation are the same. Therefore, the equation is dimensionally homogeneous.

1.6 DIMENSIONAL EQUATIONS, APPLICATIONS OF DIMENSIONAL EQUATIONS

Dimensional Analysis: A careful examination of the dimensions of various quantities involved in a physical relation is called dimensional analysis. The analysis of the dimensions of a physical quantity is of great help to us in a number of ways as discussed under the uses of dimensional equations.

Uses of dimensional equation: The principle of homogeneity & dimensional analysis has put to the following uses:

(i) Checking the correctness of physical equation.

(ii) To convert a physical quantity from one system of units into another.

(iii) To derive relation among various physical quantities.

1. **To check the correctness of Physical relations**: According to principle of Homogeneity of dimensions, a physical relation or equation is correct, if the dimensions of all the terms on both sides of the equation are the same. If the dimension of even one term differs from those of others, the equation is not correct.

Example 3 Check the correctness of the following formulae by dimensional analysis.

(i) $F = mv^2/r$ (ii) $t = 2\pi\sqrt{l/g}$

Where all the letters have their usual meanings

Sol. $\boldsymbol{F = mv^2/r}$

Dimensions of the term on L.H.S

Force, $F = [M^1L^1T^{-2}]$

Dimensions of the term on R.H.S

$\boldsymbol{mv^2/r} = [M^1][L^1T^{-1}]^2 / [L]$

$=[M^1L^2T^{-2}]/ [L]$

$=[M^1L^1T^{-2}]$

The dimensions of the term on the L.H.S are equal to the dimensions of the term on R.H.S. Therefore, the relation is correct.

(ii) $t = 2\pi\sqrt{l/g}$

Here, Dimension of term on L.H.S

$t = [T^1] = [M^0L^0T^1]$

Dimensions of terms on R.H.S

Dimension of length = $[L^1]$

Dimension of g (acc. due to gravity) = $[L^1T^{-2}]$

2π being constant have no dimensions.

Hence, the dimensions of terms $t = 2\pi\sqrt{l/g}$ on R.H.S

$$= (L^1/ L^1T^{-2}])^{1/2} = [T^1] = [M^0L^0T^1]$$

Thus, the dimensions of the terms on both sides of the relation are the same i.e., $[M^0L^0T^1]$.Therefore, the relation is correct.

Example 4 Check the correctness of the following equation on the basis of dimensional analysis, $v = \sqrt{\frac{E}{d}}$. Here v is the velocity of sound, E is the elasticity and d is the density of the medium.

Sol. Here, Dimension of the term on L.H.S

$$v = [M^0L^1T^{-1}]$$

Dimension of elasticity, $E = [M^1L^{-1}T^{-2}]$

& Dimension of density, $d = [M^1L^{-3}T^0]$

Therefore, dimensions of the terms on R.H.S

$$v = \sqrt{\frac{E}{d}} = [M^1L^{-1}T^{-2}/ M^1L^{-1}T^{-2}]^{1/2} = [M^0L^1T^{-1}]$$

Thus, dimensions on both sides are the same, hence the equation is correct.

Example 5 Using Principle of Homogeneity of dimensions, check the correctness of equation, $h = 2Td /rg\cos\theta$.

Sol. The given formula is, $h = 2Td /rg\cos\theta$.

Dimension of term on L.H.S

Height (h) = $[M^0L^1T^0]$

Dimensions of terms on R.H.S

T= surface tension = $[M^1L^0T^{-2}]$

d= density = $[M^1L^{-3}T^0]$

r =radius = $[M^0L^1T^0]$

g=acc. due to gravity = $[M^0L^1T^{-2}]$

$\cos\theta = [M^0L^0T^0]$ = no dimensions

So, the dimensions of $2Td/rg\cos\theta = [M^1L^0T^{-2}] \times [M^1L^{-3}T^0] / [M^0L^1T^0] \times [M^0L^1T^{-2}]$

$= [M^2L^{-5}T^0]$

Dimensions of terms on L.H.S are not equal to dimensions on R.H.S. Hence, formula is not correct.

Example 6 Check the accuracy of the following relations:

(i) $E = mgh + ½\ mv^2$; (ii) $v^3-u^2 = 2as^2$.

Sol. (i)$E = mgh + ½\ mv^2$

Here, dimensions of the term on L.H.S.

Energy, $E = [M^1L^2T^{-2}]$

Dimensions of the terms on R.H.S,

Dimensions of the term, $mgh = [M] \times [LT^{-2}] \times [L] = [M^1L^2T^{-2}]$

Dimensions of the term, $\frac{1}{2} mv^2 = [M] \times [LT^{-1}]^2 = [M^1L^2T^{-2}]$

Thus, dimensions of all the terms on both sides of the relation are same; therefore, the relation is correct.

(ii)The given relation is,

$$v^3 - u^2 = 2as^2$$

Dimensions of the terms on L.H.S

$v^3 = [M^0] \times [LT^{-1}]^3 = [M^0L^3T^{-3}]$

$u^2 = [M^0] \times [LT^{-1}]^2 = [M^0L^2T^{-2}]$

Dimensions of the terms on R.H.S

$2as^2 = [M^0] \times [LT^{-2}] \times [L]^2 = [M^0L^3T^{-2}]$

Substituting the dimensions in the relations, $v^3 - u^2 = 2as^2$

We get, $[M^0L^3T^{-3}] - [M^0L^2T^{-2}] = [M^0L^3T^{-2}]$

The dimensions of all the terms on both sides are not same; therefore, the relation is not correct.

Example 7 The velocity of a particle is given in terms of time t by the equation

$$v = at + \frac{b}{t+c}$$

What are the dimensions of a, b and c?

Sol. Dimensional formula for L.H.S

$V = [L^1T^{-1}]$

In the R.H.S dimensional formula of at

$[T] = [L^1T^{-1}]$

$a = [LT^{-1}] / [T^{-1}] = [L^1T^{-2}]$

t +c = time, c has dimensions of time and hence is added in t.

Dimensions of t + c is [T]

Now, $\frac{b}{t+c} = v$

$b = v(t + c) = [LT^{-1}] [T] = [L]$

There dimensions of $a = [L^1T^{-2}]$, dimensions of b = [L] and that of c = [T]

Example 8 In the gas equation $(P + a/v^2)(v - b) = RT$, where T is the absolute temperature, P is pressure and v is volume of gas. What are dimensions of a and b?

Sol. Like quantities are added or subtracted from each other i.e.

$(P + a/v^2)$ has dimensions of pressure $= [M^1L^{-1}T^{-2}]$

Hence, a/v^2 will be dimensions of pressure = $[M^1L^{-1}T^{-2}]$

$a = [M^1L^{-1}T^{-2}]\ [\text{volume}]^2 = [M^1L^{-1}T^{-2}]\ [L^3]^2$

$a = [M^1L^{-1}T^{-2}]\ [L^6] = [M^1L^5T^{-2}]$

Dimensions of a = $[ML^5T^{-2}]$

$(v - b)$ have dimensions of volume i.e.,

b will have dimensions of volume i.e., $[L^3]$

or $[M^0L^3T^0]$

2. To convert a physical quantity from one system of units into another.

Physical quantity can be expressed as

$$Q = nu$$

Let n_1u_1 represent the numerical value and unit of a physical quantity in one system and n_2u_2 in the other system.

If for a physical quantity Q; $M_1L_1T_1$ be the fundamental unit in one system and $M_2L_2T_2$ be fundamental unit of the other system and dimensions in mass, length and time in each system can be respectively a,b,c.

$$u_1 = [\ M_1^aL_1^bT_1^c]$$
$$u_2 = [\ M_2^aL_2^bT_2^c]$$

As we know

$$n_1u_1 = n_2u_2$$
$$n_2 = n_1u_1/u_2$$
$$n_2 = n_1\frac{\left[M_1^aL_1^bT_1^c\right]}{\left[M_2^aL_2^bT_2^c\right]}$$
$$n_2 = n_1\left[\left(\frac{M_1}{M_2}\right)^a\left(\frac{L_1}{L_2}\right)^b\left(\frac{T_1}{T_2}\right)^c\right]$$

While applying the above relations the system of unit as first system in which numerical value of physical quantity is given and the other as second system

Thus knowing $[M_1L_1T_1]$, $[M_2L_2T_2]$ a, b, c and n_1, we can calculate n_2.

Example 9 Convert a force of 1 newton to dyne.

Sol. To convert the force from MKS system to CGS system, we need the equation

$$Q = n_1u_1 = n_2u_2$$

Thus $n_2 = \dfrac{n_1u_1}{u_2}$

Here $n_1 = 1$, $u_1 = 1N$, $u_2 = \text{dyne}$

$$n_2 = n_1\frac{\left[M_1L_1T_1^{-2}\right]}{\left[M_2L_2T_2^{-2}\right]}$$

$$n_2 = n_1\left(\frac{M_1}{M_2}\right)\left(\frac{L_1}{L_2}\right)\left(\frac{T_1}{T_2}\right)^{-2}$$

$$n_2 = n_1\left(\frac{kg}{gm}\right)\left(\frac{m}{cm}\right)\left(\frac{s}{s}\right)^{-2}$$

$$n_2 = n_1\left(\frac{1000gm}{gm}\right)\left(\frac{100cm}{cm}\right)\left(\frac{s}{s}\right)^{-2}$$

$$n_2 = 1(1000)(100)$$

$$n_2 = 10^5$$

Thus **1N=** 10^5 **dynes**.

Example 10 Convert work of 1 erg into joule.

Sol: Here we need to convert work from CGS system to MKS system

Thus in the equation

$$n_2 = \frac{n_1 u_1}{u_2}$$

n_1=1

u_1=erg (CGS unit of work)

u_2=joule (SI unit of work)

$$n_2 = \frac{n_1 u_1}{u_2}$$

$$n_2 = n_1 \frac{M_1 L_1^2 T_1^{-2}}{M_2 L_2^2 T_2^{-2}}$$

$$n_2 = n_1\left(\frac{M_1}{M_2}\right)\left(\frac{L_1}{L_2}\right)^2\left(\frac{T_1}{T_2}\right)^{-2}$$

$$n_2 = n_1\left(\frac{gm}{kg}\right)\left(\frac{cm}{m}\right)^2\left(\frac{s}{s}\right)^{-2}$$

$$n_2 = n_1\left(\frac{gm}{1000gm}\right)\left(\frac{cm}{100cm}\right)^2\left(\frac{s}{s}\right)^{-2}$$

$$n_2 = 1(10^{-3})(10^{-2})^2 \quad n_2 = 10^{-7}$$

Thus, **1 erg=** 10^{-7} **joule**.

Example 11 Convert acceleration of 5m/s^2 to cm/s^2.

Solution Here we need to convert work from MKS system to CGS system.

Thus in the equation

$$n_2 = \frac{n_1 u_1}{u_2}$$

$n_1 = 1$

u_1 = m/s^2 (SI unit of acceleration)

u_2 = cm/s^2 (CGS unit of acceleration)

$$n_2 = \frac{n_1 u_1}{u_2}$$

$$n_2 = n_1 \frac{L_1 T_1^{-2}}{L_2 T_2^{-2}}$$

$$n_2 = n_1 \left(\frac{L_1}{L_2}\right)\left(\frac{T_1}{T_2}\right)^{-2}$$

$$n_2 = n_1 \left(\frac{m}{cm}\right)^1 \left(\frac{s}{s}\right)^{-2}$$

$$n_2 = n_1 \left(\frac{100cm}{cm}\right)\left(\frac{s}{s}\right)^{-2}$$

$$n_2 = 5(100) \quad n_2 = 500$$

EXERCISES

Multiple Choice Questions

Q1) Dimensional formula of Acceleration is:

a) $M^1L^1T^{-1}$
b) $M^0L^1T^{-2}$
c) $M^1L^2T^1$
d) $M^0L^0T^3$

Q2 Full form of FPS is given as

a) Mass, Kilogram, Second
b) Foot, Pound, Second
c) Force, Power, Sound
d) Second, Pound, Foot

Q3 SI system of units is also known as

a) International system of units
b) Intelligent system
c) Integrated system
d) none

Q4) Which is not a system of units?

a) FPS
b) MKS

c) SI
d) MLT

Q5) SI unit of temperature is_______

a) Celsius
b) Fahrenheit
c) Kelvin
d) Reumer

Q6 Pascal is the SI unit of

a) Force
b) Pressure
c) Work
d) Power

Q7) The quantity which has same dimension as that of energy is

a) Work
b) Power
c) Force
d) Stress

Q8) $M^1L^2T^{-3}$ is the dimensional formula of

a) Force
b) Work
c) Power
d) Velocity

Q9) Which of the following is not a derived unit

a) Mole
b) Joule
c) Newton
d) m/s

Q10) The fundamental unit which is common in FPS and CGS system is

a) Foot
b) Gram
c) Pound
d) second

Answers: 1 (b), 2 (b), 3 (a), 4 (d), 5 (c), 6(b), 7 (a), 8 (c), 9 (a), 10 (d)

Fill in the blanks:

1. The dimensional formula for coefficient of friction is ……………..
2. The dimensional formula for Modulus of elasticity is ……………..
3. 10^5 fermi is equal to ……………..angstrom.
4. The unit of angular velocity is…………………….

5. The unit for measuring the luminous intensity is ………………..
6. The displacement of particle moving along x-axis with respect to time is $x=at+bt^2-ct^3$. The dimension of c is ……………..
7. Dimensional formula of Strain is ______.
8. Full form of MKS is __________.
9. The dimensional formula of work is__________.
10. S.I. unit stress is_______
11. Dimensional formula for force is _____________
12. The unit for measuring the luminous intensity is ___________
13. A quantity which has same dimension as pressure is _____________
14. The displacement of particle moving along x-axis with respect to time is $x=at+bt^2-ct^3$. The dimension of c is __________
15. ___________is a dimensionless quantity.
16. SI unit of electric current is__________

Short Answer Questions

1. Define Physics.
2. Define physical quantity.
3. Differentiate between fundamental and derived unit.
4. Write full form of the following system of units
   (i) CGS (ii)FPS (iii)MKS
5. Write definition of Dimensions.
6. What is the suitable unit for measuring distance between sun and earth?
7. Write the dimensional formula of the following physical quantity -
   (i) Momentum (ii) Power (iii) Surface Tension (iv) Strain v) density
8. State principle of Homogeneity of Dimensions.
9. Write the S.I & C.G.S units of the following physical quantities-
   (a) Force (b) Work

Long Answer Questions

1. Check the correctness of the relation λ = h /mv; where λ is wavelength, h- Planck's constant, m is mass of the particle and v - velocity of the particle.
2. Explain different types of system of units.
3. Convert 1 dyne to newton.
4. Check the correctness of the following relation by using method of dimensions
   (i) $v = u + at$
   (ii) $F = mv / r^2$
   (iii) $v^2 – u^2 = 2as$
5. Convert an acceleration of 100 m/s^2 into km/h^2.

Chapter 2
FORCE AND MOTION

Learning objective: After going through this chapter, students will be able to

- *Understand scalar and vector quantities, addition of vectors, scalar and vector products etc.*
- *State and apply Newton's laws of motion.*
- *Describe linear momentum, circular motion, application of centripetal force.*

2.1 SCALAR AND VECTOR QUANTITIES

Scalar Quantities:

Scalar quantities are those quantities which have only magnitude but no direction.

Examples**:** Mass, length, density, volume, energy, temperature, distance, speed, electric charge, current, electric potential etc.

Vector Quantities:

Vector quantities are those quantities which are having both magnitude as well as direction.

Examples**:** Displacement, velocity, acceleration, force, electric intensity, magnetic intensity etc.

Representation of Vector: A vector is represented by a straight line with an arrow head. Here, the length of the line represents the magnitude and arrow head gives the direction of vector.

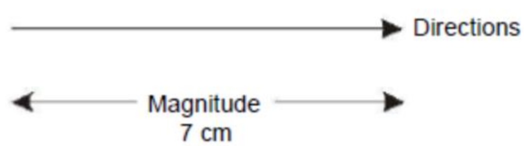


Figure:2.1

Types of Vectors

Negative Vectors: The negative of a vector is defined as another vector having same magnitude but opposite in direction.

i. e.any vector $\vec{A}$ and its negative vector $[-\vec{A}]$ are shown in Fig.2.2.

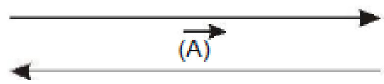


Figure:2.2

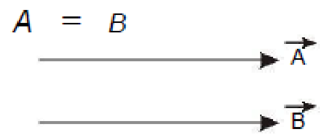


Figure:2.3

Equal Vector: Two or more vectors are said to be equal, if they have same magnitude and same direction. If $\vec{A}$ and $\vec{B}$ are two equal vectors then

Unit Vector: A vector divided by its magnitude is called a unit vector. It has a magnitude one unit and direction same as the direction of given vector. It is denoted by $\hat{A}$ (A cap).

$$\hat{A} = \frac{\vec{A}}{A}$$

Collinear Vectors: Two or more vectors having equal or unequal magnitudes, but having same direction are called collinear vectors

Figure:2.4

Zero Vector: A vector having zero magnitude and arbitrary direction (be not fixed) is called zero vector. It is denoted by O.

Co-initial Vector: are two or more vectors which have the same initial point. Vector OA and OB are co-initial vector here.

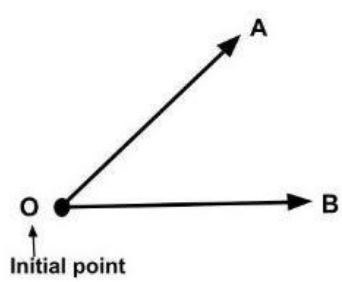


Figure:2.5

Co-Planner Vector: the vectors which lie on the same plane, in a three-dimensional space. These are vectors which are parallel to the same plane.

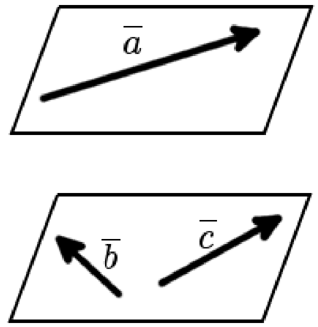


Figure: 2.6

Position Vector: straight line having one end fixed to a body and the other end is used to describe the position of the point relative to the body. E.g. "OP" is shown as position vector in fig.

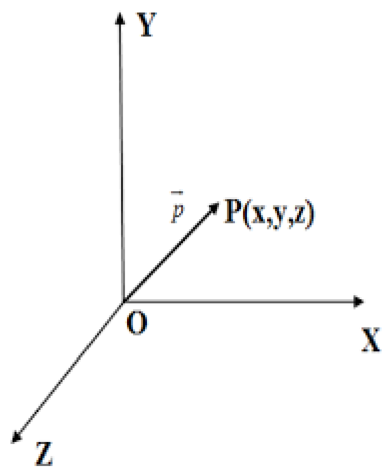


Figure: 2.7

2.2 LAWS OF ADDITION OF VECTORS

(i) Triangle law of vector addition.

It two vectors can be represented in magnitude and direction by the two sides of a triangle taken in the same order, then the resultant is represented in magnitude and direction, by third side of the triangle taken in the opposite order (Fig. 2.8).

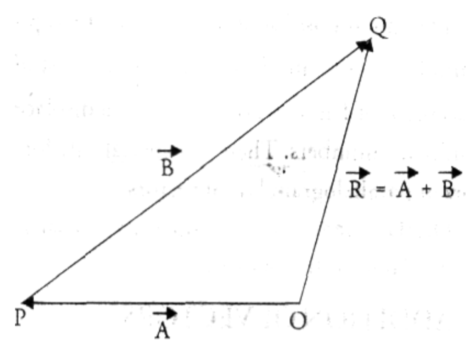


Figure: 2.8

Magnitude of the resultant is given by

$$R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$$

And direction of the resultant is given by

$$\tan\beta = \frac{B\sin\theta}{A + B\cos\theta}$$

(ii) Parallelogram (||gm) law of vectors addition:

It states that if two vectors, acting simultaneously at a point, can have represented both in magnitude and direction by the two adjacent sides of a parallelogram, the resultant is represented by the diagonal of the parallelogram passing through that point (Fig. 2.9).

Magnitude of the resultant is given by

$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

And direction of the resultant is given by

$$\tan\phi = \frac{Q\sin\theta}{P + Q\cos\theta}$$

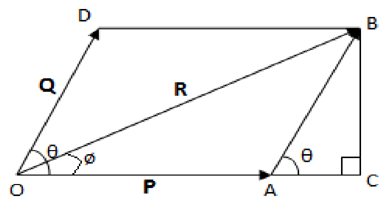


Figure:2.9

2.3 SCALAR AND VECTOR PRODUCT

Multiplication of Vectors

(i) Scalar (or dot) Product:of two vectors is defined as the product of magnitude of two vectors and the cosine of the smaller angle between them. The dot product of vectors $\vec{A}$ and $\vec{B}$can be represented as

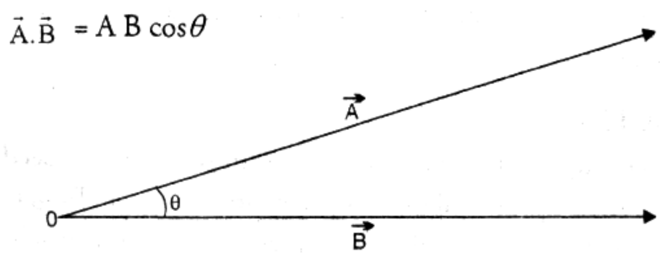


Figure:2.10

(ii) Vector (or Cross) Product: of two vectors is defined as a vector having a magnitude equal to the product of the magnitudes of the two vectors and the sine of the angle between them and is in the direction perpendicular to the plane containing the two vectors.

Thus, the vector product of two vectors A and B is equal to

$$\vec{A} \times \vec{B} = AB\sin\theta\,\hat{n}$$

2.4 DEFINITION OF DISTANCE, DISPLACEMENT, SPEED, VELOCITY, ACCELERATION

Distance: *The path covered byan object during it motion is called distance.* Distance is a scalar quantity. SI unit is metre (m).

Displacement: *The shortest distance between the two points is called displacement.* It is a vector quantity.

SI unit is metre.

Dimension formula: [L]

Speed: *The rate of change of distance is called speed. Speed is a scalar quantity.*

$$speed = \frac{\text{distance}}{\text{time}}$$

Unit: ms^{-1}.

Linear Velocity: *The time rate of change of displacement.*

$$v = \frac{change\ in\ displacement}{time}$$

Units of Velocity: ms^{-1}

Dimension formula = $[M^0L^1T^{-1}]$

Acceleration: *The change in velocity per unit time.* i.e. the time rate of change of velocity.

$$a = \frac{Change\ in\ velocity}{time}$$

If the velocity increases with time, the acceleration 'a' is positive. If the velocity decreases with time, the acceleration 'a' is negative. Negative acceleration is also known as retardation.

Units of acceleration:

C.G.S. unit is cm/s^2 (cms^{-2}) and the SI unit is m/s^2 (ms^{-2}).

Dimension formula = $[M^0L^1T^{-2}]$

FORCE

Force: Force is an agent that produces acceleration in the body on which it acts.

Or

*It is a push or a pull which change or tends to change the position of the body at rest or in uniform motion.*Force is a vector quantity.

For example,

(i) To move a football, we have to exert a push i.e., kick on the football

(ii) To stop football or a body moving with same velocity, we have to apply push in a direction opposite to the direction of the body.

SI unit is newton.

Dimension formula: $[MLT^{-2}]$

Concept of Resolution of a Force

The phenomenon of breaking a given force into two or more forces in different directions is known as resolution of force. The forces obtained on splitting the given force are called components of the given force.

If these are at right angles to each other, then these components are called rectangular components.

Let a force F be represented by a line OP. Let OB (or F_x) is component of F along x-axis and OC (or F_y) is component along y-axis (Fig. 2.11).

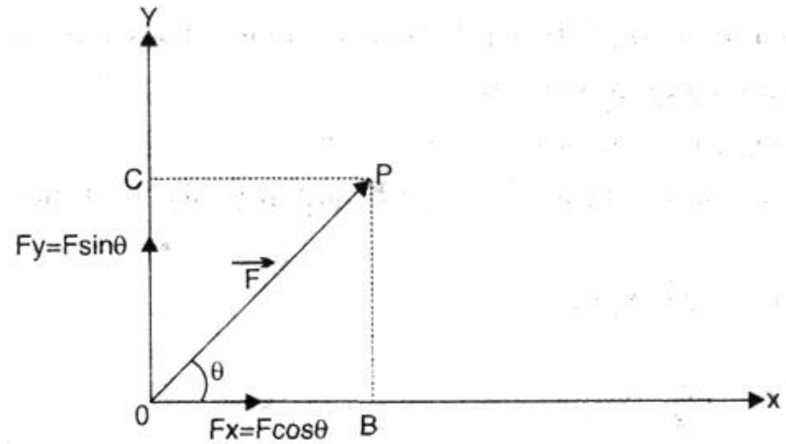


Figure:2.11

Let force F makes an angle θ with x-axis.

In Δ OPB

$$\sin\theta = \frac{OB}{OP}$$

or

$$PB = OP \sin\theta$$

$$F_y = F \sin\theta$$

$$\cos\theta = \frac{OB}{OP}$$

$$OB = OP \cos\theta$$

$$F_x = F \cos\theta$$

$$\text{Vector}\vec{F} = \vec{F}_x + \vec{F}_y$$

So, resultant: $F = \sqrt{F_x^2 + F_y^2}$

2.5 NEWTON'S LAWS OF MOTION

Sir Isaac Newton gave three fundamental laws. These laws are called Newton's laws of motion. These are

Newton's First Law: *It states that everybody continues in its state of rest or of uniform motion in a straight line until some external force is applied on it.*

For example, the book lying on a table will not move at its own. It does not change its position from the state of rest until no external force is applied on it.

Newton's Second law: *The rate of change of momentum of a body is directly proportional to the applied force and the change takes place in the direction of force applied.*

Or

Acceleration produced in a body is directly proportional to force applied.

Let us consider a body of mass m is moving with a velocity u. Let a force F be applied so that its
velocity changes from u to v in t second.

Initial momentum $= mu$

Final momentum after time t second $= mv$

Total change in momentum $= mv-mu$.

Thus, the rate of change of momentum will be

$$\frac{mv - mu}{t}$$

From Newton's second law

$$F \propto \frac{mv-mu}{t} \text{ or } F \propto \frac{m(v-m)}{t}$$

$$\text{but } \frac{v-u}{t} = \frac{\textit{Change in velocity}}{\textit{time}} = \text{acceleration(a)}$$

Hence, we have

$$F \propto ma$$

or $$F = k\,ma$$

Where k is constant of proportionality, for convenience let k = 1.

Then **F = ma**

Units of force:

One **dyne** is that much force which produces an acceleration of $1 cm/s^2$ in a mass of 1 gm.

$$1 \text{ dyne} = 1gm \times 1\ cm/s^2$$
$$= 1gm\ cm\ s^{-2}$$

One **newton**is that much force which produces an acceleration of $1\ m/s^2$ in a mass of 1kg.

Using $F = ma$

$1N = 1kg \times 1m/s^2$

or $= 1kgm/s^2$

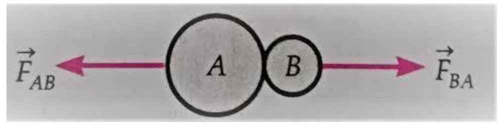
$$IN = 1000gm \times 100\ cm/s^2 = 10^5 \text{ dyne}$$

Newton's Third law:it state that *to every action there is an equal and opposite reaction* or *action and reaction are equal and opposite*.

When a body exerts a force on another body, the other body also exerts an equal force on the first body but in opposite direction.

From Newton's third law these forces always occur in pairs. If two bodies A and B applies force on each other, then

F_{AB} (force on A by B) = $-F_{BA}$ (force on B by A)



2.6LINEAR MOMENTUM, CONSERVATION OF MOMENTUM, IMPULSE

Linear Momentum (*p*): *The quantity of motion contained in the body is linear momentum*. It is given by product of mass and the velocity of the body. It is a vector and its direction is the same as the direction of the velocity.

Let m be the mass and v is the velocity of a body at some instant, then its linear momentum is given by$p = mv$

Example, a fast-moving cricket ball has more momentum in it than a slow moving one. But a slow-moving heavy roller has more momentum than a fast cricket ball.

Units of momentum:

The SI unit is kg m/s i.e. $kgms^{-1}$

Dimension formula = $[M^1L^1T^{-1}]$

Law of conservation of Momentum

It states that if external force acting on a system of bodies is zero then the total linear momentum of a system always remains constant. As we know from newton's second law of motion

$$F=\frac{dp}{dt}$$

i.e. If F=0

Thus, $F=\frac{dp}{dt}=0$

Hence, p (momentum) is constant.

Application of law of conservation of momentum

Recoil of the Gun: When a bullet is fired with a gun the bullet moves in forward direction and gun is recoiled/pushed backwards. Let

m = mass of bullet

u = velocity of bullet

M = mass of gun

V = velocity of gun

The gun and bullet form an isolated system, so the total momentum of gun and bullet before firing = 0

Total momentum of gun and bullet after firing$=mu+MV$

Using law of conservation of momentum

$$0 = m.u+M.v$$

$$MV = -mu$$

$$V = \frac{-mu}{M}$$

This is the expression for recoil velocity of gun.

Here negative sign shows that motion of the gun is in opposite direction to that of the bullet. Also, velocity of gun is inversely proportional to its mass. Lesser the mass, larger will be the recoil velocity of the gun.

Impulse

Impulse is defined as the total change in momentum produced by the impulsive force.

OR

Impulse may be defined as the product of force and time and is equal to the total change in momentum of the body.

$F.t = p_2 - p_1$ = total change in momentum

Example: A kick given to a football or blow made with hammer.

SI unit: Ns

2.7 CIRCULAR MOTION

The motion of a body in a circle of fixed radius is called circular motion.

For example, the motion of a stone tied to a string when whirled in the air is a circular motion.

Angular Displacement (θ): T*he angle subtended by a body while moving in a circle* is called angular displacement.

Consider a body moves in a circle, starting from A to B so that ∠BOA is called angular displacement

The SI unit of angular displacement is radian (rad.)

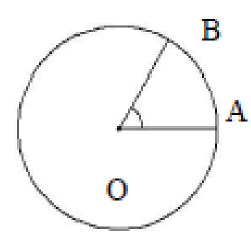


Figure: 2.12

Angular Velocity: Angular velocity of a body moving in a circle is the *rate of change of angular displacement with time*. It is denoted by ω (omega)

If θ is the angular displacement in time t then

$$\omega = \frac{\theta}{t}$$

SI unit of angular velocity is rad/s

Time Period: *Time taken by a body moving in a circle to complete one cycle* is called time period. It is denoted by T

Frequency (*n*): *The number of cycles completed by a body in one second* is called frequency.It is reciprocal of time period; $n = \frac{1}{T}$

Angular Acceleration: *The time rate of change of angular velocity of a body*.

It is denoted by α. Let angular velocity of a body moving in a circle change from ω_1 to ω_2 in time *t*, then

$$\alpha = \frac{\omega_1 - \omega_2}{t}$$

SI unit of 'α' is rad/s^2

Relationship between linear and angular velocity

Consider a body moving in a circle of radius *r* Let it start from A and reaches to B after time t, so that ∠BOA = θ (Fig. 2.9).Now

$$angle = \frac{arc}{radius}$$

$$\theta = \frac{AB}{OA} = \frac{S}{r}$$

$$S = r\theta$$

Dividing both sides by time (t), we get

$$\frac{S}{t} = r\frac{\theta}{t}$$

Here $\frac{s}{t} = v$ is linear velocity

And $\frac{\theta}{t} = \omega$ is angular velocity

Hence $\boxed{v = r\omega}$

CENTRIPETAL AND CENTRIFUGAL FORCES

Centripetal Force: The force acting along the radius towards the centre of circle to keep a body moving with uniform speed in a circular path is called centripetal force. It is denoted by F_C.

$$F_c = \frac{mv^2}{r}$$

For example, a stone tied at one end of a string whose other end is held in hand, when round in the air, the centripetal force is supplied by the tension in the string.

Centrifugal Force:

A body moving in circle with uniform speed experience a force in a direction away from the centre of the circle. This force is called centrifugal force.

For example, cream is separated from milk by using centrifugal force. When milk is rotated in cream separator, cream particles in the milk being lighter, experience less centrifugal force.

APPLICATION OF CENTRIPETAL FORCE IN BANKING OF ROADS

Banking of Roads: While travelling on a road, you must have noticed that *the outer edge of circular road is slightly raised above as compared to the inner edge of road. This is called banking of roads (Fig. 2.13).*

Angle of Banking: The angle through which the outer edge of circular road is raised above the inner edge of circular roads is called angle of banking.

Application of centripetal force in banking of roads

Let m = mass of vehicle
r=radius of circular road
v=uniform speed (velocity) of vehicle
θ = angle of banking

At the body two forces act.Figure 2.10

(i) Weight (mg) of vehicle vertically downwards.

(ii) Normal reaction (R).

R makes an angle θ and resolves the forces into two components

(i) $R\sin\theta$ towards the centre
(ii) $R\cos\theta$ vertically upwards and balance by weight of (mg) vehicle

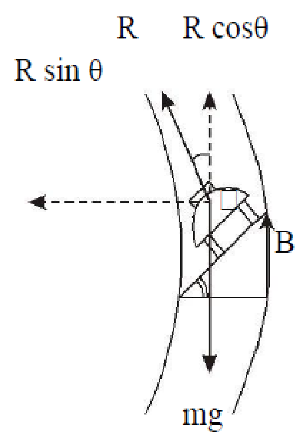


Figure:2.13

$R\sin\theta$provides the necessary centripetal force ($\frac{mv^2}{r}$)

$$R\sin\theta = \frac{mv^2}{r} \qquad \text{- - - - - (1)}$$

and $$R\cos\theta = mg \qquad \text{- - - - -(2)}$$

Divide equation 1 by 2

$$\frac{R\sin\theta}{R\cos\theta} = \frac{\frac{mv^2}{r}}{mg}$$

$$\tan\theta = \frac{v^2}{rg}$$

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

2.8 ROTATIONAL MOTION

The *rotation of a body about fixed axis* is called Rotational motion. For example,

(i) Motion of a wheel about its axis

(ii) Rotation of earth about its axis.

2.9 DEFINITION OF TORQUE AND ANGULAR MOMENTUM

Torque (τ)

It is measured as the product of magnitude of force and perpendicular distance of the line of action of force from the axis of rotation.

It is denoted by τ,

$$\vec{\tau} = \vec{F} \text{x} \vec{r}$$

Where F is external force and r is perpendicular distance.

Unit: newton (N)

Dimension Formula: $[M^1L^2T^{-2}]$

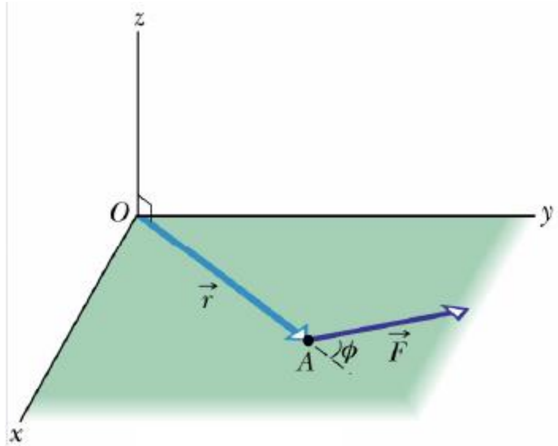


Figure: 2.14

Angular Momentum (L)

Angular momentum of a rotating body about its axis of rotation is *the algebraic sum of the linear momentum of its particles about the axis*. It is denoted by L. It is vector quantity.

L = momentum × perpendicular distance

$L = p \times r$

or $L = mvr$

Unit: Kg m^2/sec

Dimensional Formula = $[ML^2T^{-1}]$

MOMENT OF INERTIA AND ITS PHYSICAL SIGNIFICANCE

Moment of Inertia of a rotating body about an axis is defined as *the sum of the product of the mass of various particles constituting the body and square of respective perpendicular distance of different particles of the body from the axis of rotation*.

Expression for the Moment of Inertia:

Let us consider a rigid body of mass M having n number of particles revolving about any axis. Let m_1, m_2, m_3 ..., m_n be the masses of particles at distance r_1, r_2, r_3... r_n from the axis of rotation respectively (Fig. 4.2).

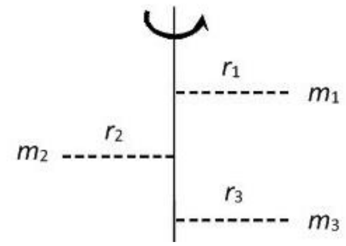


Figure: 2.15

Moment of Inertia of whole body

$$I = m_1r_1^2 + m_2r_2^2 + ... m_nr_n^2$$

or $$I = \sum_{i=1}^{n} m_i r_i^2$$

Physical Significance of Moment of Inertia

It is totally analogous to the concept of inertial mass. Moment of inertia plays the same role in rotational motion as that of mass in translational motion. In rotational motion, a body, which is free to rotate about a given axis, opposes any change in state of rotation. Moment of Inertia of a body depends on the distribution of mass in a body with respect to the axis of rotation.

Example 1. What torque will produce an acceleration of 2 rad/s^2 in a body if moment of inertia is 500 kg m^2?

Sol. Here, I = 500 kg m^2

α = 2 rad/s^2

Now, torque $\tau = I \times \alpha$

$= 500$ kgm$^2 \times 2$ rad/s^2 = 1000 kg m^{2}s^{-2}

= 1000 Nm or J

Example2. An engine is rotating at the rate of 1500 rev. per minute. Find its angular velocity.

Sol. Here, Revolution per minute of engine, n= 1500

Angular velocity $\omega = 2\pi n$

Or $$\omega = 2 \times \frac{22}{7} \times \frac{1500}{60}$$

$$\omega = 157.1 \text{ rad/s}$$

Example 3. How large a torque is needed to accelerate a wheel, for which I = 2 kgm^2, from rest to 30 r.p.s in 20 seconds?

Sol. Here, Moment of inertia, I = 2 kgm^2

R.P.S after 20 sec, $n = 30$

Initial velocity, $\omega_1 = 0$

Final velocity, $\omega_2 = 2 \times \pi \times 30 = 188.4$ rad/s.

Angular acceleration = $\dfrac{\omega_2 - \omega_1}{t} = \dfrac{188.4 - 0}{20}$ = 9.43 rad/s^2.

Now, torque, $\tau = I \times \alpha$

$= 2 \text{ kg m}^2 \times 9.43 \text{ rad/s}^2$

$= 18.86$ Nm or J

Example 4. If a point on the rim of wheel 4 m in diameter has a linear velocity of 16 m/ s, find the angular velocity of wheel in rad/sec.

Sol. Radius of wheel (R) $= \dfrac{\text{Diameter}}{2} = \dfrac{4}{2} = 2$ m

From the relation $v = r\omega$

$$\omega = \frac{v}{r} = \frac{16}{2} = 8 \text{ rad/s.}$$

Angular velocity of wheel is 8 rad/s.

* * * * *

EXERCISES

Q1) SI unit of force is

a) Joule
b) Newton
c) dyne
d) Pascal

Q2) Identify the vector quantity

a) Time
b) Work
c) Heat
d) Angular momentum

Q3) Newton's second law is also known as

a) Law of inertia
b) Law of action
c) Gravitational law
d) Real law of motion

Q4) Swimming is possible on account of Newton's

a) First law of motion
b) Third law of motion
c) Second law of motion
d) Law of gravitation

Q5) The rate of change of momentum is proportional to

a) Force
b) Impulse

c) Acceleration
d) None of them

Q6) To rotate a body, we need
a) Torque
b) Momentum
c) Velocity
d) None of them

Q7) Momentum has same dimension as that of
a) Force
b) Pressure
c) Impulse
d) None of the above

Q8) The maximum possible number of rectangular components of a vector are

a) 2
b) 3
c) 4
d) 5

Q9) The acceleration of the particle performing uniform circular motion is
a) 1
b) 0
c) Maximum
d) Minimum

Answers: 1 (b), 2 (d), 3 (d), 4 (b), 5 (a), 6(a), 7 (c), 8 (b), 9 (b)

Fill in the blanks:

1. Force is ______ a quantity.
2. Time is a ______ quantity
3. Dimensional formula of velocity is ____.
4. Recoil of gun is an example of conservation of ______.
5. Formula for angular momentum is ____________.
6. The unit of angular velocity is_____________
7. Torque has same dimensional formula as that of ____________.
8. Centripetal force always acts _____________ the centre of the circle.
9. Railway tracks are banked at the curves so that the necessary ____________force may be obtained from the horizontal component of the reaction on the train.
10. The angle through which the outer edge of a circular road is raised above its inner edge is called ____________
11. A force which acts for a small time and also varies with time is called___________
12. The formula for radius of gyration is________________

Short Answer Type Questions

1. State and explain laws of vector addition.
2. Explain resolution of a vector.
3. How is impulse related to linear momentum?
4. Define circular motion. Give examples.
5. Define banking of roads.
3. Define scalar and vector quantities with examples.
4. Define resolution and composition of forces.
5. Define impulse.
6. Why does a gun recoil when a bullet is fired?
7. Differentiate between centripetal and centrifugal forces.
8. An artificial satellite takes 90 minutes to complete its revolution around the earth. Calculate the angular speed of satellite. [Ans. 2700 rad/sec]
9. Define Force. Give its units.
10. Define Triangle law of vector addition.
11. State parallelogram law of vector addition.
12. Define torque.
13. Define rotational inertia or moment of inertia. Give its SI unit.
14. Define radius of gyration and give its SI units.

Long Answer Type Questions

1. Explain Newton's Law of Motion.
2. Explain Banking of Roads.
3. State law of conservation of momentum.
4. Derive relationship between linear and angular velocity.
5. Define radius of gyration and derive its expression.
6. Define moment of inertia. Derive its expression and explain its physical significance.

Chapter 3

WORK, POWER AND ENERGY

Learning objective: After going through this chapter, students will be able to;

- *Understand work, energy and power, their units and dimensions.*
- *Describe different types of energies and energy conservation.*
- *Solve relevant numerical problems*

3.1 WORK (DEFINITION, SYMBOL, FORMULA AND SI UNITS)

Work: *is said to be done when the force applied on a body displaces it through certain distance in the direction of applied force.*

$$Work = \text{Force} \times \text{Displacement}$$

In vector form, it is written as $\vec{F} \cdot \vec{S} = FS\cos\theta$

It is measured as the product of the magnitude of force and the distance covered by the body in the direction of the force. It is a scalar quantity.

Unit: SI unit of work is joule (J). In CGS system, unit of work is erg.

$1J = 10^7$ergs Dimension

of work = $[M^1L^2T^{-2}]$

POSITIVE, NEGATIVE AND ZERO WORK

Positive work- If the angle between force and displacement vector is less than 90^0, then work done is said to be positive. For example-in case of push or pull of an object, work done is positive.

Negative work- If the angle between force and displacement vector is 180^0, then work done is negative as force acts opposite to displacement. For example, work done by frictional force is negative as it opposes the motion.

Zero work-If the angle between force and displacement vector is 90^0, then their dot product is zero and hence work done is zero. For example, if a coolie moves with a load on his head, then work done is zero as the force acts downward and displacement is in horizontal direction.

Example1. What work is done in dragging a block 10 m horizontally when a 50 N force is applied by a rope making an angle of 30° with the ground?

Sol. Here, $F = 50$ N, $S = 10$ m, $\theta = 30$

$$W = FS\cos\theta$$

$$W = 50 \times 10 \times \cos 30°$$

$$W = 50 \text{x} 10 \text{x} \sqrt{3/2}$$

= 612.4 J

Example2. A man weighing 50 kg supports a body of 25 kg on head. What is the work done when he moves a distance of 20 m?

Sol. Total mass = 50 + 25 = 75 kg

$\theta = 90°$

Distance = 20 m

W = FS × 0 (Cos 90° = 0)

W = 0

Thus, work done is zero.

Example3. A man weighing 50 kg carries a load of 10 kg on his head. Find the work done when he goes (i) 15 m vertically up (ii) 15 m on a levelled path on the ground.

Sol. Mass of the man, m_1= 50 kg

Mass carried by a man, m_2 = 10 kg

Total mass $M = m_1 + m_2 = 50 + 10 = 60$ kg.

When the man goes vertically up,

Height through which he rises, h = 15 m

W = mgh = 60 × 9.8 × 15 = 8820 J

When the man goes on a levelled path on the ground

W= FS Cosθ

As θ =90°, therefore, Cos 90°= 0

Hence W= F×S×0 =0

3.2 FRICTION– DEFINITION AND ITS SIMPLE DAILY LIFE APPLICATIONS

It is that opposing force which comes into play when a body tends to slide or actually sliding over the surface of another body.

The surface of a solid body is never perfectly smooth. Even a surface which appears smooth to the naked eye, when highly magnified, shows considerable roughness. Thus when a body B is placed over another body A, the irregularities of the two surfaces get interlocked as shown in Fig. 3.1- To remove this interlocking, we have to apply a force. Thus when two bodies are in contact and one moves or tends to move over the other, thereis always a force which opposes the motion. Such resistance to motion is called friction.

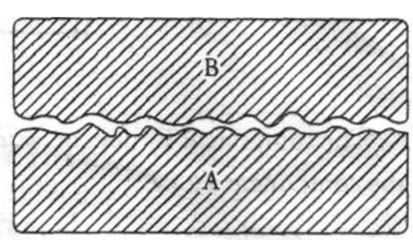
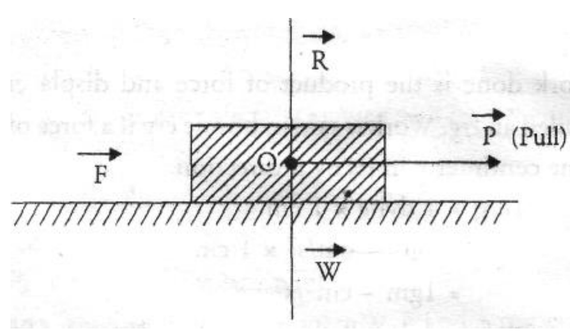


Figure:3.1

LAWS OF FRICTION

The following are the four laws of limiting friction:



1. The force of friction always acts in a direction opposite to the direction of motion.
2. The force of limiting friction (F) is directly proportional to the normal reaction (R)between the two surfaces in contact i.e. F α R.
3. The force of limiting friction depends upon the material and nature of the surfaces incontact.
4. The force of limiting friction is independent of the apparent area of contact, so long as normal reaction between the two bodies in contact remains the same.

COEFFICIENT OF FRICTION

We know that F a R

or $F = \mu R$

$$\mu = \frac{F}{R}$$

Here μ (mu) is a constant of proportionality and is called the co-efficient of friction.

Thus, co-efficient of friction for any pair of surfaces in contact is equal to the ratio of the limiting friction and the normal reaction. Since it is a pure ratio, has got no units and its value depends upon the nature of the surfaces in contact. Further, μ is always less than unity and is never equal to zero.

Daily Life Examples

1. Driving of a vehicle on a surface
2. Applying brakes to stop a moving vehicle
3. Skating
4. Walking on the road
5. Writing on notebook/ blackboard
6. Flying of aeroplanes
7. Drilling a nail into wall
8. Sliding on a garden slide
9. Lighting a matchstick
10. Dusting a foot mat/ carpet by beating it with a stick

3.3 POWER (DEFINITION, FORMULA AND UNITS)

Power is defined as the *rate at which work is done* by a force. T*he work done per unit time* is also called power.

If a body do work W in time t, then power is $P = \dfrac{W}{t}$

Units of Power: SI unit of power is watt (W)

$$1W = \frac{1J}{1s}$$

Power is said to be 1 W, if 1 J work is done in 1 s.

Bigger units of power are:

kilowatt (kW)	$= 10^3$W
Megawatt (MW)	$= 10^6$ W
Horse power (hp)	= 746 W

Dimension of power $= [M^1 L^2 T^{-3}]$

3.4 ENERGY

Energy of a body is defined as *the capacity of the body to do the work*. Like work, energy is also a scalar quantity.

Unit: SI system –joule (J), CGS system - erg

Dimensional Formula: $[ML^2 T^{-2}]$.

Transformation of Energy

The phenomenon of changing energy from one form to another form is called transformation of energy. For example-

- In a heat engine, heat energy changes into mechanical energy
- In an electric bulb, the electric energy changes into light energy.
- In an electric heater, the electric energy changes into heat energy.
- In a fan, the electric energy changes into mechanical energy which rotates the fan.
- In the sun, mass changes into radiant energy.
- In an electric motor, the electric energy is converted into mechanical energy.
- In burning of coal, oil etc., chemical energy changes into heat and light energy.
- In a dam, potential energy of water changes into kinetic energy, then K.E rotates the turbine which produces the electric energy.
- In an electric bell, electric energy changes into sound energy.
- In a generator, mechanical energy is converted into the electric energy.

3.5KINETIC ENERGY (FORMULA, EXAMPLES AND ITS DERIVATION)

Kinetic Energy (K.E.): the *energy possessed by the body by virtue of its motions* is called kinetic energy.

For example (*i*) running water (*ii*) Moving bullet.

Expression for Kinetic Energy

Consider F is the force acting on the body at rest (*i.e.*, $u = 0$), then it moves in the direction of force to distance (s).

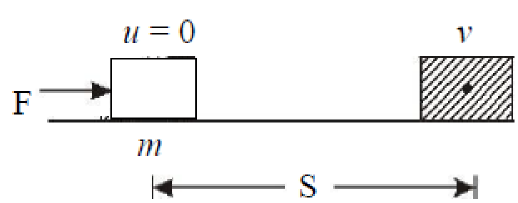


Figure:3.1

Let v be the final velocity.

Using relation $$v^2 - u^2 = 2aS$$

$$\frac{v^2 - u^2}{2S} = a$$

$$\frac{v^2 - 0}{2S} = a$$

$$\frac{v^2}{2S} = a \qquad \text{--------------(1)}$$

Now, work done, $W = FS$

or $W = maS$ (using F $= ma$) ------------- (2)

By equation (1) and (2)

$$W = m.\frac{v^2}{2S}.S$$

or $W = \frac{1}{2}mv^2$

This work done is stored in the body as kinetic energy. So kinetic energy possessed by the body is (K.E.) $= \frac{1}{2}mv^2$

3.6 POTENTIAL ENERGY

Potential Energy (P.E.): *theenergy possessed by the body by virtue of its position is called potential energy.* Example

(*i*)Water stored in a dam

(*ii*)Mango hanging on the branch of a tree

Expression for Potential Energy (P.E)

It is defined as the energy possessed by the body by virtue of its position above the surface of earth.

$W = FS$

Work done $=$ Force $\times$ height

$= mg \times h = mgh$

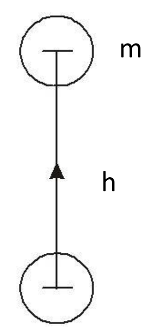


Figure:3.2

This work done is stored in the form of gravitational potential energy.

Hence Potential energy $= mgh$.

3.7 LAW OF CONSERVATION OF ENERGY

Energy can neither be created nor be destroyed but can be converted from one form to another.

CONSERVATION OF MECHANICAL ENERGY OF A FREE FALLING BODY

Let us consider K.E., P.E. and total energy of a body of mass m falling freely under gravity from a height *h* from the surface of ground.

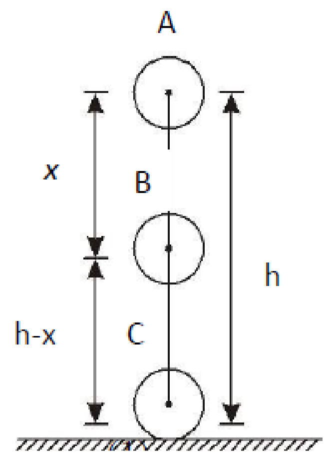


Figure:3.3

According to Fig. 3.3

At position A:

Initial velocity of body (u) = 0

K.E = $\frac{1}{2}mv^2$

P. E. = mgh

Total Energy =K.E + P.E

=0 + mgh

=$\boldsymbol{mgh}$ ------------- (1)

At position B

Potential energy=$mg(h-x)$

Velocity at point B= u

From equation of motion K.E. = $\frac{1}{2}mu^2$

As $V^2 - U^2 = 2aS$

Hence $u^2 - 0^2 = 2gx$

or $u^2 = 2gx$

Putting this value we get, KE= $\frac{1}{2}m(2gx)$

or K.E. = mgx

Total Energy =K.E + P.E

=$mgx + mg(h-x)$

=mgh --------(2)

At position C

Potential energy = 0(as h = 0)

Velocity at Point B= v

From equation of motion K.E. = $\frac{1}{2}mv^2$

As $V^2 - U^2 = 2aS$

Hence $v^2 - 0^2 = 2gh$

or $v^2 = 2gh$

Putting this value we get KE= $\frac{1}{2}m(2gh)$

or K.E. = mgh

Total Energy =K.E + P.E

$=mgh + 0$

$=mgh$ ---------(3)

From equations (1), (2) and (3), it is clear that total mechanical energy of freely falling body at all the positions is same and hence remains conserved.

Example 4 A spring extended by 20 mm possesses a P.E. of 10 J. What will be P.E., if the extension of spring becomes 30 mm?

Sol. $h = 20 \text{ mm} = 20 \times 10^{-3}\text{m}$

$g = 9.8 \text{ ms}^{-2}$, m =?

P.E $=mgh = 10\text{J}$

i.e., $m \times 9.8 \times 20 \times 10^{-3} = 10 \text{ J}$

$$m = \frac{10}{9.8\text{x}20\text{x}10^{-3}}$$

m =51.02 kg

When extension is 30 mm *i.e.*, 30×10^{-3} m, then

$P.E = mgh$

$= 51.02 \times 9.8 \times 3 \times 10^{-3} = 15.0 \text{ J}$

Example 5 A man weighing 65 kg lifts a mass of 45 kg to the top of a building 10 metres high in 12second. Find;

(i) Total work done by him. The power developed by him.

Solution Mass of the man, $m_1 = 65$ kg

Mass lifted $m_2 = 45$ kg

Height through which raised $h = 10$ m

Time taken $t = 12$ seconds.

(*i*) Total work done by the man, W = mgh

$=110 \times 9.81 \times 10 = 10791.0\text{J}$

(ii) Power developed $P = \frac{\text{W}}{\text{t}} = \frac{10791\text{J}}{12s} = 899.25 \text{ W}$

* * * * * *

EXERCISES

Multiple Choice Question

Q.1 SI unit of power is ______

a) Newton
b) Watt
c) Erg
d) None

Q2) One horse power in terms of watt is

a) 7.46
b) 746
c) 74.6
d) 7460

Q3) Moment of inertia is analogy as term to_______ in linear momentum.

a) Mass
b) Momentum
c) Intertia
d) None

Q4) Running water possess___________

a) Kinetic energy
b) Potential energy
c) Electrical energy
d) Thermal energy

Q5) If velocity of a body doubles, then its kinetic energy gets

a) Doubled
b) Halved
c) 4 times
d) Does not change

Q6) SI unit of electrical energy is

a) joule
b) volt
c) watt
d) kwh

Q7)When a string is stretched, its potential energy

a) Increases
b) Decreases
c) does not change
d) none of the above

Q8)The formula for power is

a) P=F.S

b) P=F.V
c) P=F.t
d) P=F/t

Answers: 1 (b), 2 (b), 3 (a), 4 (a), 5 (c), 6(d), 7 (d), 8 (b)

Fill in the blanks:

1. There are two bodies X and Y with equal kinetic energy but different masses m and 4m respectively. The ratio of their linear momentum is……
2. When a spring is stretched, its potential energy …………
3. 1 kWH= …….J
4. SI unit of work is ……………
5. Formula of Kinetic Energy is ______.
6. Formula of Potential Energy is ______.
7. The sum of kinetic and potential energy is called ____________
8. When an object goes up its potential energy ____________
9. Coolie is an example of ______work.
10. Work is force multiplied by _______________in the direction of force.
11. Kinetic energy is energy possessed by a body by virtue of its___________.
12. Potential energy is energy possessed by a body by virtue of its___________.
13. ____________ is the rate of doing work
14. 1joule =______ergs

Short Answer Type Questions

1. Define potential energy, Derive expression for gravitational potential energy.
2. Define work and write its unit.
3. Define power. Give it S.I unit and dimensions.
4. Explain transformation of energy.
5. A person walking on a horizontal road with a load on his head does not work. Explain.
6. Give some examples of transformation of energy.

Long Answer Type Questions

1. State and explain the law of conservation of energy for free falling body.
2. Define kinetic energy with examples. Obtain an expression for kinetic energy of body moving with uniform speed.

Chapter4

PROPERTIES OF MATTER

Learning objective: After going through this chapter, students will be able to;

- *Understandelasticity, deforming force, restoring force etc.*
- *Define stress, strain, Hook's law, modulus of elasticity, pressureetc..*
- *Describe surface tension,viscosity and effect of temperature on these.*
- *Understand fluid motion and nature of flow.*

4.1 DEFINITION OF ELASTICITY, DEFORMING FORCE, RESTORING FORCE, EXAMPLE OF ELASTIC AND PLASTIC BODY

Elasticity:It is the property of solid materials to return to their original shape and size after removal of deforming force.

Deforming Forces: The forces which bring the change in configuration of the body are called deforming forces.

Restoring Force: It is a force exerted on a body or a system that tends to move it towards an equilibrium state.

Elastic Body: It is the body that returns to its original shape after a deformation.Examples are Golf ball, Soccer ball, Rubber band etc.

Plastic Body: It is the body that do not return to its original shape after a deformation.Examples are Polyethylene, Polypropylene, Polystyrene and Polyvinyl Chloride (PVC).

4.2 DEFINITION OF STRESS AND STRAIN WITH THEIR TYPES

Stress:*It* is *defined* as *the restoring force per unit area* of a material.Stress is of two types:

1. **Normal Stress**: If deforming force acts normal (perpendicular) to the surface of the body then the stress is normal stress.

2. **Tangential Stress:**If deforming force acts tangentially to the surface of the body then the stress is tangential stress.

Strain: It is defined as *the ratio of change in configuration to the original configuration*, when a deforming force is applied to a body. The strain is of three types:

(i) Longitudinal strain:

If the deforming force produces a change in length only, the strain produced is called longitudinal strain or tensile strain. It is defined as *the ratio of change in length to the original length*.

$$\text{Longitudinal strain} = \frac{\text{Change in length}(\Delta l)}{\text{original length}(l)}$$

(ii) **Volumetric strain**: It is defined as *the ratio of the change in volume to the original volume*.

$$\text{Volumetric strain} = \frac{\text{Change in volume}(\Delta \text{V})}{\text{original volume}(\text{V})}$$

(iii) Shearing strain:

It is defined as *the ratio of lateral displacement of a surface under the tangential force to the perpendicular distance between surfaces*

$$\text{Shearing strain} = \frac{\text{Lateral Displacement}}{\text{Distance between surfaces}}$$

$$= \frac{\Delta L}{L} = \tan \Phi$$

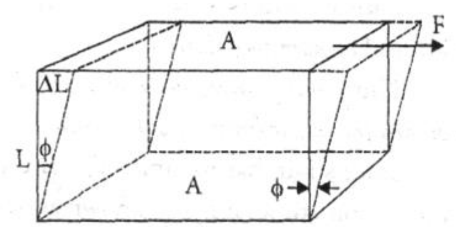


Figure: 4.1

The shearing strain is also defined as the angle in radian through which a plane perpendicular to the fixed surface of a rectangular block gets turned under the effect to tangential force.

Units of strain:

Strain is a ratio of two similar physical quantities, it is unitlessand dimensionless.

HOOK'S LAW, MODULUS OF ELASTICITY

Hook's law: *Within elastic limits, the stress and strain are proportional to each other*.

Thus, Stress $\propto$ Strain

Stress = E $\times$ Strain

Where E is the proportionality constant and is known as modulus of elasticity.

Modulus of Elasticity: *The ratio of stress and strain is always constant and called as modulus of elasticity*.

Young's Modulus(Y): *The ratio of normal stress to the longitudinal strain is defined as Young's modulus* and is denoted by the symbol Y.

$$Y = \frac{F/A}{\Delta l/l} = \frac{F \times l}{A \times \Delta l}$$

The unit of Young's modulus is the same as that of stress i.e., Nm^{-2} or pascal(Pa)

Bulk Modulus (K): *The ratio of normal (hydraulic) stress to the volumetric strain is called bulk modulus*. It is denoted by symbol K.

$$K = \frac{F/A}{\Delta V/V} = \frac{F \times V}{A \times \Delta V}$$

SI unit of bulk modulus is the same as that of pressure i.e., Nm^{-2} or Pa

Shear Modulus or Modulus of rigidity (η): *The ratio of shearing stress to the corresponding shearing strain* is called the shear modulus of the material and is represented by η. It is also called the modulus of rigidity.

$$\eta = \frac{\text{Tangential stress}}{\text{Shear strain}}$$

$$\eta = \frac{F/A}{\Delta L/L} = \frac{F \times L}{A \times \Delta L}$$

The SI unit of shear modulus is Nm^{-2} or Pa.

4.3 PRESSURE

It is defined as the force acting per unit area over the surface of a body.

$$P = \frac{F}{A}$$

SI unit is Nm^{-2} or Pa

ATMOSPHERIC PRESSURE

The atmosphere exerts pressure on the earth's surface. This pressure is known as atmospheric pressure. The atmospheric pressure at any point is numerically equal to the weight of an air column of unit cross-sectional area from that point to the top of the atmosphere.

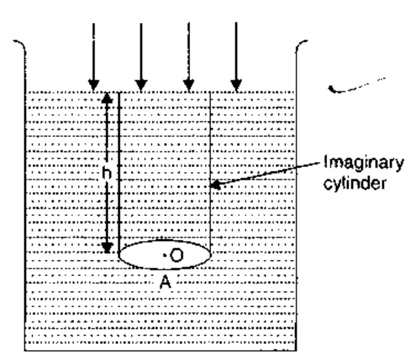
Atmospheric pressure = 1.013×10^6 dyne/cm^2

or = 1.013×10^5 N/m^2 (Pa)

ABSOLUTE PRESSURE

The total pressure at any point inside a liquid is called absolute pressure. The total pressure at a point A is equal to the sum of the atmospheric pressure at the surface of liquid and the pressure due to liquid column of height h at A.

Total pressure $P_A = P_0 + hdg$



Where P_0 = atmospheric pressure.

Hence absolute pressure= atmospheric pressure + hdg

Figure: 4.2

GAUGE PRESSURE:

The difference of absolute pressure and atmospheric pressure is called gauge pressure e.g. Pressuremeasured in car tyre is called gauge pressure.

i.e. gauge pressure = Absolute pressure - atm. pressure

$= P_A - P_0 =$ hdg

Pascal Law: *A change in the pressure applied to an enclosed incompressible fluid is transmitted undiminished to every portion of the fluid and to the walls of its container*.

Or *it states that liquid enclosed in a vessel exerts equal pressure in all the directions*.

4.4 SURFACE TENSION

The property of a liquid due to which its free surface behaves like stretched membrane and acquires minimum surface area. It is given by force per unit length.

$$T = \frac{F}{l}$$

Surface tension allows insects (usually denser than water) to float and stride on a water *surface.*

SI unit is N/m.

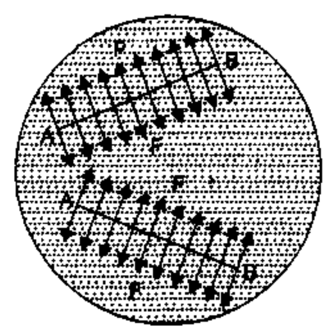


Figure: 4.3

Applications of surface tension in daily life

It plays an important role in many applications in our daily life.

- Washing clothes
- Cleaning
- Cosmetics
- Lubricants in machines
- Spreading of ink, colours
- Wetting of a surface
- Action of surfactants
- Paints, insecticides
- Creating fuel-spray in automobile engines
- Passing of liquid in porous media
- Spherical shape of water droplets.

Effect of Temperature on Surface Tension

In general, *surface tension decreases* when *temperature increases* and vice versa. This is because cohesive forces decrease with an increase of molecular thermal activity. The influence of the surrounding environment is due to the adhesive action liquid molecules have at the interface.

4.5 VISCOSITY

The property of liquid due to which it opposes the relative motion between its layers. It is also known as liquid friction.

SI *unit of viscosity* is pascal-second (Pas) and cgs unit is poise.

Daily life uses

- **Lubrication in vehicles.**
- Some viscous fluids add texture to foods; honey, for example, is quite viscous and can change the "mouth feel" of a dish.
- Lubricants that are too viscous can jam and clog pipelines. Lubricants that are too thin provide too little protection for moving parts.
- Brake Oil
- Super Glue
- Paint

Effect of Temperature on Viscosity

In liquids the source for viscosity is considered to be atomic bonding. As we understand that, with the increase of temperature the bonds break and make the molecule free to move. So, we can conclude that the ***viscosity decreases as the temperature increases and vice versa***.

In gases, due to the lack of cohesion, the source of viscosity is the collision of molecules. Here, ***as the temperature increases the viscosity increases and vice versa***. This is because the gas molecules utilize the given thermal energy in increasing its kinetic energy that makes them random and therefore resulting in more the number of collisions.

****

EXERCISES

1. S.I. unit of stress is
   (A) Newton (B) Newton/m^2
   (C) Joule (D) None of the above
2. Ratio of Normal stress to the longitudinal strain is called
   (A) Bulk modulus (B) modulus of rigidity
   (C)Hook's law (D) Young's modulus
3. Change in length per unit original length is called
   (A) Longitudinal strain (B) Volumetric strain
   (C) Normal stress (D) None of above
4. Force per unit area is called
   (A) Strain (B) Pressure (C) Viscosity (D) Surface Tension
5. Difference between absolute pressure and atmospheric pressure is called______
   (A) Stress (B) Strain (C) Gauge Pressure (D) None
6. Atmospheric pressure is measured by_________
   (A) Barometer (B)Manometer (C)Thermometer (D)None
7. Pascal is the unit of
   (A) Force (B)Work (C)Pressure (D)Energy
8. Ratio of stress to the strain is called
   (A) Normal Stress (B) Modulus of Elasticity
   (C) Volumetric Stress (D) None of the above.
9. Which of the following has no units
   (A) Stress (B) Pressure (C) Strain (D) All of these
10. Pressure is defined as Force per unit
   (A) Length (B) Volume (C) Mass (D) Area.
11. Small Rain drops are spherical due to
   (A) Viscosity (B)Surface Tension (C) Density (D) Gravity.
12. Force per unit length is called_________
   (A) Surface Tension (B) Pressure (C) Strain (D) None of these
13. According to Hooks Law stress is directly proportional to.
   (A) Strain (B) Length (C) Volume (D) Area.
14. Soaps are based on the application of
   (A) Viscosity (B) Elasticity (C) Surface Tension (D) All of above.
15. S. I. unit of surface Tension is
   (A) N/M^2 (B) N/M (C) J/sec (D) None of above
16. Viscosity of any liquid increase with
   (A) Increase in temperature (B) Decrease in temperature
   (C) Increase in Pressure (D) None of above

Answers (MCQ): 1(B), 2 (D), 3 (A) , 4 (B), 5 (C), 6 (A), 7 (C), 8 (B), 9 (C), 10 (D), 11 (B), 12 (A), 13 (A), 14 (C), 15 (B), 16 (B)

Fill in the blanks

1. *Stress*is *defined* as the ………………. per unit area of a material.
2. ……………………is the ratio of change in dimensions to the original dimensions.
3. For small deformations the stress and strain are proportional to each other. This is called …………………
4. *Pressure*is *defined* as the force per unit ………………. over the surface of a body.
5. A change in the pressure applied to an enclosed incompressible fluid is transmitted undiminished to every portion of the fluid to the walls of its container. It is called………………….
6. The property of solid materials to return to their original shape and size after the removal of deforming forces *is called* ....
7. Surface tension of a liquid______________ with rise in Temperature. (Increase)
8. Small insects can walk on the surface of water due to________. (surface Tension)
9. Newton/$m^2$is the S.I. unit of _____________ (Stress)
10. Force due to which a body regains its original shape and size is called________. (Restoring Force)
11. Atmospheric Pressure is measured by_____________. (Barometer)
12. Change in length per unit original length is called __________ . (Longitudinal Strain)
13. S.I. unit of surface tension is _________. Newton/m
14. Newton/m^2 is equal to one Pascal (T/F)
15. Absolute Pressure is the total pressure at any point inside a liquid. (T/F)
16. Which is more viscous honey or oil? Honey

Short Answer Type Questions

1. Define elasticity.
2. Defineviscosity.
3. Define turbulent flow.
4. Define surface tension.
5. What is Young's modulus of elasticity?
6. State and explain Hooks Law.
7. State and explain Pascal's Law.
8. What is the effect of temperature on surface tension?
9. What is the effect of temperature on viscosity?
10. Give any five applications of surface tension.
11. Write difference between elastic and plastic bodies.

Long Answer Type Questions

1. Explain different kind of modulus of elasticity.
2. Definesurface tension. Give formula, units and applications of surface tension.
3. Explain streamline flow, laminar flow and turbulent flow.
4. Explain different types of stress.
5. Explain Young’s modulus of elasticity and its units.

Chapter5

HEAT AND TEMPERATURE

Learning Objectives:*After going through this chapter, the students will be able to:*

- *Define heat and temperature; understand the difference between heat and temperature;*
- *Describe principles of measuring temperature and different temperature scales,*
- *Enlist properties of heat radiations and various modes of transfer of heat.*

5.1 HEAT AND TEMPERATURE

All objects are made of atoms or molecules. These molecules are always in some form of motion (linear, vibrational or rotational) and possess kinetic energy by virtue of their motion. The hotter an object is, faster will be the motion *of the* molecules inside it and hence more will be its kinetic energy. H*eat* of an object is the total energy of all the individual molecules of which the given object is made. It is a form of thermal energy. When the object is heated, its thermal energy increases, means its molecules begin to move more violently. *Temperature,*on theother hand, is a measure *of the average heat or thermal* energy *of the* molecules *in a* substance.

Heat is the form of energy which produces the sensation of warmth or coldness.

The cgsunit of heat is the calorie (cal) - *defined as the amount of heat required to raise the temperature of 1g of water through 1°C.*The S.I. unit of heat energy is the joule (J) The relation between these two units is:

$$1 \text{ cal} = 4.18 \text{ J.}$$

Heat on the basis of kinetic theory: According to the kinetic theory, heat of a body is total kinetic energy of all its molecules.If a body have '*n*' number of molecule having mass *m* and velocities v_1, v_2, v_3, --------, v_n respectively, then

Total heat energy in the body (H) = Sum of kinetic energy of all molecules

$$H = K\left(\frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 + \frac{1}{2}mv_3^2 + ... + \frac{1}{2}mv_n^2\right)$$; where K is thermal constant.

When the body is heated, the kinetic energy of each molecule inside it increases due to increase in their velocity. This results in the increase of total kinetic energy of the body and in turn represents total heat of the body.

Temperature

Temperature is the degree of hotness or coldness of the body. It is the average kinetic energy of all the molecules of which the given body is made and is given by the expression;

$$T = \frac{K\left(\frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 + \frac{1}{2}mv_3^2 + ... + \frac{1}{2}mv_n^2\right)}{n}$$

Units of temperature are; fahrenheit(^{o}F), celsius(^{o}C) and kelvin (K). Kelvin is the S.I. unitof temperature.

5.2 DIFFERENCE BETWEEN HEAT AND TEMPERATURE:

Heat	Temperature
Heat is energy that is transferred from one body to another as the result of a difference in temperature	Temperature is a measure of degree of hotness or coldness
It is total kinetic energy of all the molecules	It is average kinetic energy of all the molecules
It depends on quantity of matter	It does not depend on quantity of matter
It is form of energy (Thermal)	It is measure of energy
S.I. unit is joule	S.I. unit is kelvin

5.3 PRINCIPLES OF MEASUREMENT OF TEMPERATURE:

Measurement of temperature depends on the principle that *properties (physical/electrical/chemical) of material changes with change in temperature*. A device that utilizes a change in property of matter to measure temperature is known as thermometer. Temperature is a principle parameter that needs to be monitored and controlled in most engineering applications such as heating, cooling, drying and storage. Temperature can be measured via a diverse array of sensors. All of them infer temperature by sensing some change in a physical characteristic; be it a thermal expansion, thermoelectricity, electrical resistance or thermal radiation. There are four basic types of thermometers, each working on a different principle:

1. Mechanical (liquid-in-glass, bimetallic strips, bulb & capillary, pressure type etc.)
2. Thermo-electric (Thermocouples)
3. Thermo-resistive (RTDs and thermistors)
4. Radiative (Infrared and optical pyrometers).

Each produces a different scale of temperature which can be related to one another. Commonly used thermometers are mercury thermometer, platinum resistance thermometer, thermo-electric and pyrometers. Liquid thermometers can measure temperature upto 300^{o}C. Resistance thermometers can go upto 1200^{o}C while thermo-electrics are used for measuring temperature as high as 3000^{o}C. For still higher temperatures pyrometers (very hot furnaces) are used.

MERCURY THERMOMETER (PRINCIPLE AND WORKING)

The working principle of a mercury thermometer is the expansion of matter on heating

In a mercury thermometer, a glass tube is filled with mercury and a standard temperature scale is marked on the tube. With changes in temperature, the mercury expands and contracts, and the temperature can be read from the scale.

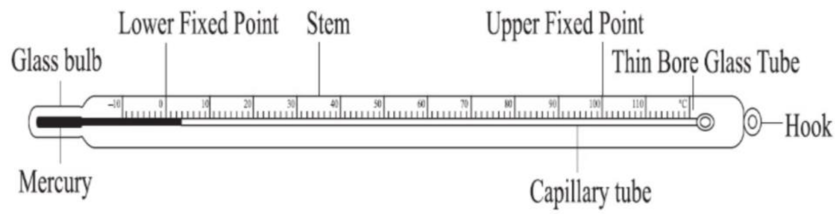


Figure 5.1: Mercury Thermometer

Uses of a mercury thermometer

- It is used for determining the body, liquid and vapor temperature.
- It is used in power plants and piping.
- It is used in Bakeries and for candy making.
- It is used in heating and cooling equipment, etc.

6.4 MODES OF TRANSFER OF HEAT

When two bodies having different temperatures are brought close together, the heat flows from body at higher temperature to body at lower temperature. Heat may also flow from one portion of body to another portion because of temperature difference. The process is called transfer of heat. There are three modes by which heat is transferred from one place to another. These are named as conduction, convention and radiations.

(i)Conduction: It is defined as that mode of transfer of heat in which *the heat travels from particle to particle* in contact, along the direction of fall of temperature *without any net displacement of the particles.*

For example, if one end of a long metal rod (iron or brass) is heated, after some time other end of rod also become hot. This is due to the transfer of heat energy from hot atoms to the nearby atoms. When two bodies have different temperatures and are brought into contact, they exchange heat energy and tend to equalize the temperature. The bodies are said to be in *thermal equilibrium*. This is the mode of heat transfer in solids.

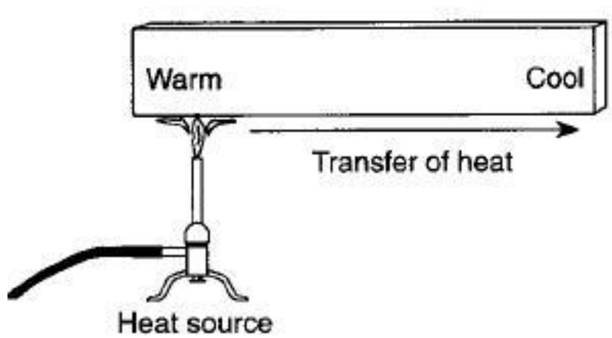


Figure 5.2: Conduction

ii) Convection: The process of transmission of heat in which *heat is transferred from one point to another by the physical movement of the heated particles* is called convection.

For example,if a liquid in a vessel is heated by placing a burner below the vessel, after some time the top surface of liquid also become warm. This is because the speed of atoms or molecules increases when liquid or gases are heated. The molecule having more kinetic energy rise upward and carry heat with them.Liquids and gases transfer heat by convection.Examples areheating of water, cooling of transformers, see breeze, heating of rooms by heater etc.

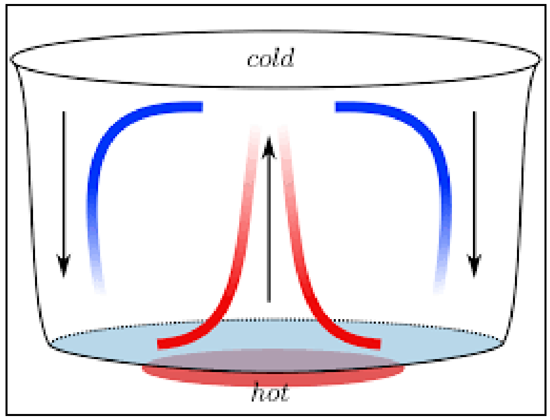


Figure 5.3: Convection

(iii) Radiation:The process of heat transfer in which*heat is transmitted from one place to another in the form of Infra-Red radiation, without heating the intervening medium is called radiation.*

Thermal radiations are the energy emitted by a body in the form of radiations on account of its temperature and travel with the velocity of light. We receive heat from sun by radiation process. All the bodies around us do emit these radiations. These radiations are the electromagnetic waves.

5.5 PROPERTIES OF HEAT RADIATIONS

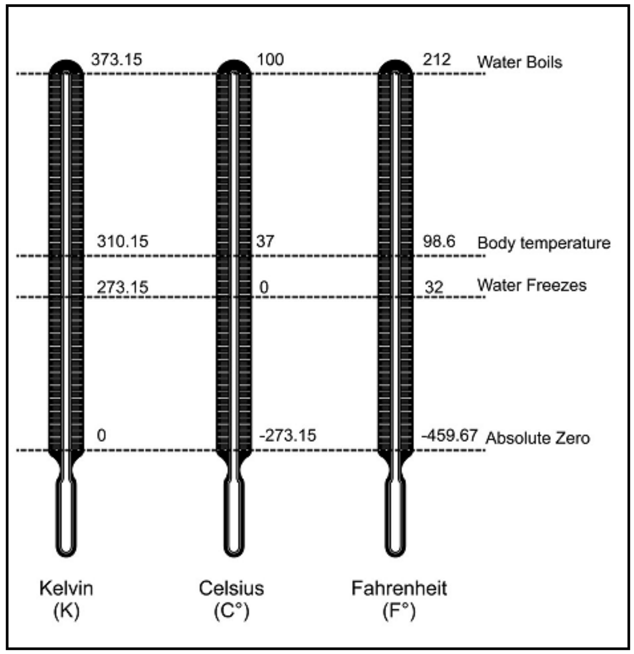
1. They do not require a medium for their propagation.
2. Heat radiations travel in straight line.
3. Heat radiations do not heat the intervening medium.
4. Heat radiations are electromagnetic waves.
5. They travel with a velocity 3×10^8 m/s in vacuum.
6. They undergo reflection, refraction, interference, diffraction and polarization.
7. They obey inverse square law.

5.6 DIFFERENT SCALES OF TEMPERATURE AND THEIR RELATIONSHIP

In general, there are three scales of temperature measurement. The scales are usually defined by two fixed points; temperature at which water freezes and the boiling point of water as defined at sea level and standard atmospheric pressure.

a) **Fahrenheit Scale:** It was given by physicist Daniel Gabriel Fahrenheit in 1724. It uses the degree fahrenheit (symbol: °F) as the unit. On this scale, freezing point of water is taken as the lower fixed point (32°F) and boiling point of water is taken as upper fixed point (212°F). The interval between two points is divided into 180 equal parts. Each division is 1^{o} F.

This scale is used for clinical and meteorological purpose.



b). **Celsius Scale**: This scale was given by Anders Celsius in 1742. On this scale, freezing point of water is taken as the lower fixed point (marked 0°C) and boiling point of water is taken as upper fixed point (marked 100°C). The interval between two points is divided into 100 equal parts. Each division is 1^{o}C.

This scale is used for common scientific, clinical, meteorological and technological work.

c). **Kelvin Scale:** This scale defines the SI base unit of temperature with symbol K. On this scale freezing point of water is taken as the lower fixed point (273K) and boiling point of water is taken as upper fixed point (373K). The interval between two points is divided into 100 equal parts. Each division is 1K.

On scale $1^{o}C = 1$ K

This is the natural scale of temperature also called the ***absolute temperature scale***. The scale is based on ideal gas thermometer.

Figure 5.4Temperature scales

RELATION AMONG THE SCALES OF TEMPERATURE

Temperature of a body can be converted from one scale to the other.

Let, L = lower reference point (freezing point)

H = upper reference point (boiling point)

T = temperature read on the given scale.

Now $\dfrac{T-L}{H-L}$ = Relative temperature w.r.t. both reference point.

Let us take a body whose temperature is determined by three different thermometers giving readings in ^{o}C, ^{o}F and K respectively.

Let $T_1 = C$ = Temperature in ^{o}C, $L_1 = 0°C$ $H_1 = 100°C$

$T_2 = F$ = Temperature in^{o}F, $L_2 = 32°F$ $H_2 = 212°F$

T_3 = K = Temperature Kelvin, L_3 =273 K H_3 = 373K

We can write,

$$\left(\frac{T_1 - L_1}{H_1 - L_1}\right) = \left(\frac{T_2 - L_2}{H_2 - L_2}\right) = \left(\frac{T_3 - L_3}{H_3 - L_3}\right)$$

$$\left(\frac{C - 0}{100 - 0}\right) = \left(\frac{F - 32}{212 - 32}\right) = \left(\frac{K - 273}{373 - 273}\right)$$

$$\frac{C}{100} = \frac{F - 32}{180} = \frac{K - 273}{100}$$

$$\boxed{\frac{C}{5} = \frac{F - 32}{9} = \frac{K - 273}{5}}$$

* * * * * *

EXERCISES

Multiple Choice Questions

1. Two Bodies are solid to be in thermal equilibrium if they have the same
   a) Temperature b) Amount of Heat
   c) Specific Heat d) Thermal Capacity.
2. If temperature of a body is 40˚C, its value on Fahrenheit scale is
   a) 96˚F b) 100˚F c) 104˚F d) 72˚F.
3. Value of 0˚6 on Kelvin scale is -------
   a) 273K b)-273K c) 283 K d)none of the above.
4. Temperature of a body measures the
   a) Amount of heat contained in a body
   b) Degree of hotness or coldness of a body
   c) Kinetic energy of molecules
   d) None of the above
5. Absolute Zero means temperature on Kelvin scale is--------
   a) 0 K b) 273K c) -273K d) None
6. On Celsius scale Boiling temp. of water is
   a) 200˚C b) 100˚C c) 150˚C d) 273˚C
7. Velocity of heat radiation in vaccum is_______
   a) 3×10^{8}m/sec b) 3×10^{10} m/sec
   c) 3×10^{6} m/sec d) Both A and B
8. S. I. Unit of Heat energy is
   a) Erg b) Joule c) Joule/Sec d) None
9. Temp of a body is the
   a) Total Kinetic energy b) Average kinetic energy
   c) Degree of Hotness d) Bothb and c
10. Value of 50˚C on reumer scale is
    a) 40˚R b) 50˚R c) 25˚ R d) None.
11. In conduction method transfer of heat is due to
    a) Vibration of molecule b) Motion of molecules
    c) Displacement of molecules d) All of above
12. Hot gasses coming out from chimney are example of
    a) Conduction method b) Convection method
    c) Radiation d) all of above
13. Example of conduction process is
    a) Tradition of vehicles b) Heating of liquids
    c) Cooking utensils d) None of these
14. Which of the following is not a mode of heat transfer
    a) Conduction b) radiation c) Reverberation d) Convection
15. Lower Fixed point on Kelvin scale is

a) 273K b) 373K c) 173K d) None

16. Mercury thermometer is based upon the Principle
    a) Expansion of solids b) Expansion of liquids
    c) Resistance d) Expansion of gases

Answers: 1 (a), 2 (b), 3 (a), 4 (b), 5 (a), 6(b), 7 (d), 8 (b), 9 (d), 10 (a), 11 (a), 12 (b), 13 (c), 14 (c), 15 (a), 16(b)

Fill in the blanks and true/false

i. *Heat* of an object is the …………………. (total/average) energy of all the molecular motions inside that object.
ii. *Temperature* is a measure *of the* …………………. energy *ofthe* molecules.
iii. Transfer of heat from a fluid to a solid surface or within a fluid is called............ .
iv. Matter that is at finite temperature emits energy in space in the form of electromagnetic waves. The process is known as ……………....
v. Heat radiation travels at the same speed as sound. (True/False).
vi. The Kelvin scale is an absolute scale. (True/ False)
vii. Heat radiations cannot travel through a vacuum. (True / False)
viii. *Air conditioner is an example of radiation. (True / False)*
ix. Heat is a cause whose effect is____________. (Temperature)
x. Transfer of Heat without actual motion of molecules is called ______________.(Conduction)
xi. Degree of Hotness or coldness of a body is called ______________. (Temperature)
xii. S.I. unit of temperature is _______________.(Kelvin)
xiii. Heat waves always travel in __________.(Straight Ling)
xiv. Heat flows from a body at ________ temperature to a body at ___________temperature. (higher to lower).
xv. Average kinetic energy of molecules of a body is called_______.(Temperature)
xvi. Name any one mode of transfer of heat. (Conduction, Convection , Radiation)
xvii. Heat from sun reaches to earth by which method ,.(Radiation)

Short Answer Questions

1. Define heat. Give SI unit of heat.
2. Define temperature. Give SI unit of temperature.
3. What are heat radiations? Whether these travel in straight line or not?
4. What is principle of measurement of temperature?
5. Give two examples of convection.
6. Define the process of conduction in metals.
7. Give relationship between celsiusand fahrenheitscales of temperature.
8. Temperature of a patient is 40^{o}C. What will be the corresponding temperature on Fahrenheit scale?

Long Answer Questions

1) Explain heat and temperature on basis of kinetic theory.
2) Describe principle of temperature measurements and name two such devices.
3) Describe with example different modes of transfer of heat.
4) Explain different scales of temperature and establish relationship between them.
5) Give any five properties of heat radiations.

Subject: Applied Physics (180013)

Assignment – 1 (Section A)

Q1: Each Question carries 2 marks.

i. Write the SI unit of force, work, energy, pressure and momentum.
ii. Write dimensional formula of distance, displacement, density, force, stress, work, momentum, velocity, strain, acceleration, impulse, surface tension, coefficient of viscosity.
iii. 1 newton =______dynes.
iv. State the principle of homogeneity
v. Write cgs units of length, mass and time.
vi. Write two advantages of SI units over the earlier systems.
vii. Give limitations of method of dimensions.
viii. Name the fundamental quantities and write their units.
ix. State triangle law and parallelogram law of vector addition.
x. What is relation between linear and angular velocity?
xi. Define velocity and acceleration
xii. Define Impulse with example.

1. Covert 1 joule into erg using dimension analysis. (4)
2. Define vector and scalar quantity, giving examples in each case. (4)
3. Define the terms vector product and scalar product. Write formula. (4)
4. Define force. What is meant by resolution of force? (4)
5. Define momentum. State conservation of liner momentum. (4)
6. Define centripetal and centrifugal force. Write formula (4)
7. State Newton's three laws of motion with example (4)
8. Define angular displacement, angular velocity, angular acceleration, frequency and time period. (8)
9. Define banking of road. Derive an expression for banking of road. (8)

Subject: Applied Physics (180013)

Assignment – II (Section B)

Q1: Each Question carries 2 marks.

i. Define power. Write its unit.
ii. Define energy and write its unit.
iii. Define potential energy.
iv. Define work. Give unit of work
v. Define stress. Give its SI units.
vi. State Hooks law.
vii. Define elasticity. Give 2 example of elastic material.
viii. Define restoring force and deforming force.
ix. Give four example of transformation of Energy.
x. Define pressure and write its unit.
xi. Define streamline and turbulent flow.
xii. What is effect of temperature on surface tension?
xiii. What is physical significance of moment of inertia?
xiv. Define torque with example.
xv. What is Pascal law?

1. State kinetic energy. Find the expression for it. (4)
2. Define strain. Explain its types. (4)
3. Define radius of gyration. Derive expression for it. (4)
4. Define angular momentum. What is conservation of angular momentum? (4)
5. Define moment of inertia with example. (4)
6. Define surface tension and give its unit. Write three applications of surface tension? (4)
7. Define viscosity. What is the effect of temperature on viscosity?. (4)
8. State principle of conservation of energy and prove it for freely falling body. (8)
9. Explain Young's, bulk and shear modulus of elasticity. (8)

Subject: Applied Physics (180013) **Set -1**

Sample paper (Section C)

MM: 60

Section A: objective types question. All questions are compulsory. (1X10=10)

Question 1

i. SI unit of temperature is …………………..

ii. Heat is transferred in solids by the mode of ……………….

iii. SI unit of specific resistance is ………………..

Section B: Very short answer type questions. Attempt any five questions. (5X2=10)

Question 2

a) Define convection.

b) Define electric power. Give its SI unit.

Section C: Short answer type questions. Attempt any six questions. (6X4=24)

3. Write any four principles of measurement of temperature?

i. SI unit of temperature is ______________.

3. What is difference between heat and temperature?
4. Name different scales for measuring temperature. Give relation among the scales of temperature.