NCERT Maps

PHYSICS

(Class XI and XII)

Aakash

Medical

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Edition: 2021

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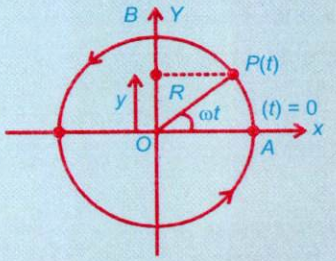
NCERT Maps

PHYSICS

Class XI



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Physical World

1 Chapter

1 SCIENCE

Systematic attempt to understand natural phenomena in as much detail and depth as possible, and use the knowledge so gained to predict, modify and control phenomena

2 SCIENTIFIC METHOD

The scientific method involves several interconnected steps:

- Systematic observations
- Controlled experiments,
- Qualitative and quantitative reasoning
- Mathematical modelling, prediction and verification or falsification of theories

3 HYPOTHESIS AND AXIOMS

- A hypothesis is a supposition without assuming that it is true.
- An axiom is a self-evident truth while a model is a theory proposed to explain observed phenomena.

4 PHYSICS

Study of the basic laws of nature and manifestation in different natural phenomenon

5 PRINCIPAL THRUSTS

Unification

To explain diverse physical phenomenon in terms of few concepts and laws.

Reduction

To derive the properties of a larger and a more complex problem or system into simpler constituents

6 PRINCIPAL DOMAINS

Macroscopic domain

Phenomenon at laboratory, terrestrial and celestial scale Mainly dealt by classical physics including mechanics, electrodynamics, optics and thermodynamics

Microscopic domain

Constitution and structure of matter at the minute scales of atoms and nuclei. Mainly dealt by quantum physics

8 NATURE OF PHYSICAL LAWS

- **Conservation of energy** : In an isolated system, total energy remains conserved.
- **Conservation of linear momentum** : In an isolated system, total linear momentum remains conserved.
- **Conservation of angular momentum** : In an isolated system, total angular momentum remains conserved.
- Symmetry of nature with respect to translation in time is equivalent to the law of conservation of energy
- Symmetry of the laws of nature with respect to translation in space gives rise to conservation of linear momentum
- Isotropy of space (no intrinsically preferred direction in space) underlies the law of conservation of angular momentum

7 FUNDAMENTAL FORCES IN NATURE

Strong nuclear force

- Acts between nucleons
- Short range (Nuclear size $\approx 10^{-15}$ m)
- Relative strength = 1
- Mediating particles are mesons

Electromagnetic force

- Force due to virtue of charges
- Both attractive and repulsive
- Range is infinite
- Relative strength = 10^{-2}
- Mediating particles are photons

Weak Nuclear Force

- Between some elementary particles particularly electron and neutrino
- Very short range ($\approx 10^{-16}$ m)
- Relative strength = 10^{-13}
- Mediating particles are bosons

Gravitational Force

- Force of attraction by virtue of mass
- Always attractive in nature
- It is weakest fundamental force
- Range is infinite
- Relative strength = 10^{-38}
- Mediating particle are graviton

Sharpen Your Understanding — NCERT Based MCQs

1. Natural sciences does not include [NCERT Pg. 2]
   (1) Physics
   (2) Chemistry
   (3) Biology
   (4) Social Science

2. Principal thrusts in Physics are [NCERT Pg. 2]
   (1) Unification
   (2) Reduction
   (3) Both (1) and (2)
   (4) None of the above

3. Attempt to explain diverse physical phenomenon in terms of a few concepts and laws is called [NCERT Pg. 2]
   (1) Unification
   (2) Reduction
   (3) Fusion
   (4) All of the above

4. Classical Physics mainly deals with [NCERT Pg. 3]
   (1) Microscopic phenomenon
   (2) Macroscopic phenomenon
   (3) Atomic phenomenon
   (4) Heisenberg's uncertainty principle

5. Among the following, choose the incorrect statement [NCERT Pg. 3]
   (1) The microscopic domain of physics deals with the constitution and structure of matter at the minute scales of atoms and nuclei
   (2) **Classical Physics deals mainly with macroscopic phenomena and includes subjects like Mechanics, Electrodynamics, Optics and Thermodynamics**
   (3) Both of the above
   (4) None of the above

6. Phenomenon of neutron induced fission of uranimum, which serves as a basis of nuclear power reactors and nuclear weapons, was discovered by [NCERT Pg. 5]
   (1) Hahn and Meitner (2) Einstein
   (3) Neils Bohr (4) Nicholas Tesla

7. Among the following, the scientists are matched with their major contribution or discovery. Which among the following is incorrectly matched? [NCERT Pg. 5]

A	Archimedes	Principle of Buoyancy
B	Christiaan Huygens	Wave Theory of Light
C	J.C.Bose	X-rays
D	Albert Einstein	Theory of Relativity

   (1) A
   (2) B
   (3) C
   (4) D

8. Among the following scientists, the one who is credited for the contribution to theory of condensed matter is [NCERT Pg. 6]
   (1) Ernest Orlando Lawrence
   (2) C.V. Raman
   (3) Ernest Rutherford
   (4) Lev Davidovich Landau

9. Full form of LASER is [NCERT Pg. 7]
   (1) Light amplification by shorted extraction of rays
   (2) Light amplification by stimulated emission of radiation
   (3) Long absorption of silent extraction of radiation
   (4) None of the above

10. Choose the incorrect statement among the following in relation to the electromagnetic waves. [NCERT Pg. 8]
   (1) Electromagnetic force do not require intervening medium
   (2) They act over large distances
   (3) Electromagnetic force is weaker than the gravitational forces
   (4) Electromagnetc forces may be attractive or repulsive

Thinking in Context

1. Newton, under a common law of gravitation, unified _____ and celestial domains. [NCERT Pg. 10]
2. Symmetry of nature with respect to translation in time is equivalent to law of conservation of _____. [NCERT Pg. 12]
3. Symmetry of nature with respect to translation in space is equivalent to law of conservation of _____ [NCERT Pg. 12]
4. J.J. Thomson is credited for his discovery of _____ [NCERT Pg. 5]
5. Hideki Yukawa is known for his contribution towards _____ forces [NCERT Pg. 6]
6. _____ was discovered by E.O. Lawrence [NCERT Pg. 6]
7. Isotropy of space (no intrinsically preferred direction in space) underlies the law of conservation of _____ [NCERT Pg. 12]
8. The laws of nature are _____ everywhere in the universe. [NCERT Pg. 12]
9. There are _____ fundamental forces in nature. [NCERT Pg. 10]
10. Fundamental forces which has shortest range is _____ force. [NCERT Pg. 9]

❑ ❑ ❑

Units and Measurements

2
Chapter

1 UNITS

Measurement of any physical quantity involves comparison with certain basic arbitrarily chosen internationally accepted reference called units.

Classification

Fundamental units	Derived units
Independent of each other	Expressed as combination of fundamental units

- A complete set of these units, both the base units and derived units is known as system of units.
- Old system of units: CGS, FPS and MKS system.
- In **CGS** fundamental units are centimeter, gram and second.
- In **FPS** fundamental units are foot, pound and second.
- In **MKS** fundamental units are meter, kilogram and second.

2 SI SYSTEM OF UNITS (INTERNATIONAL SYSTEM OF UNITS)

- Presently accepted internationally for measurement is SI system of units, revised in 2018. Certain rules to follow with standard symbols
- It is decimal system thus, conversion within system is easy and convenient
- It has 7 base unit and 2 supplementary units

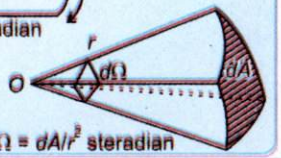
Base Units

S.N.	Quantity	Unit	Symbol
1.	Length	meter	m
2.	Mass	kilogram	kg
3.	Time	second	s
4.	Electric current	ampere	A
5.	Thermodynamic temperature	kelvin	K
6.	Amount of substance	mole	mol
7.	Luminous intensity	candela	cd

Supplementary Units

S.N.	Quantity	Unit	Symbol
1.	Plane angle	radian	rad
2.	Solid angle	steradian	sr

$d\theta = ds/r$ radian



$d\Omega = dA/r^2$ steradian

3 MEASUREMENT OF LENGTH

- Large distance is measured by parallax method.
- Parallax angle = $\frac{\text{Basis}}{\text{Distance}}$
- $1^\circ = 1.745 \times 10^{-2}$ rad
- $1'' = 4.85 \times 10^{-6}$ rad
- Measurement of very small distance like size of molecule uses, Optical microscope, Electronic microscope and Tunneling microscope
- 1 AU = 1.496×10^{11} m
- 1 ly = 9.46×10^{15} m
- 1 parsec = 3.08×10^{16} m
- Size of proton 10^{-15} m
- Radius of Earth 10^{7} m
- Distance to boundary of observable universe 10^{26} m

4 MEASUREMENT OF MASS

- SI unit is kilogram (kg)
- Unified atomic mass unit (u). It is used to measure mass of atoms and molecules
- 1 u = 1/12 × mass of one C-12 atom.
- 1 u = 1.66×10^{-27} kg
- Electron mass 10^{-30} kg
- Earth mass 10^{25} kg
- Observable universe 10^{55} kg

5 MEASUREMENT OF TIME

- Atomic standard of time: This is based on caesium clock, uncertainty gained overtime by caesium atomic clock is less than 1 part in 10^{13} (loss of 3 μs in one year)
- Time span of most unstable particle 10^{-24} s
- Travel time for light from nearest star 10^{8} s
- Age of universe 10^{17} s

6 ACCURACY and PRECISION

- Every measurement by any measuring instrument contains some uncertainty called error.
- Accuracy of a measurement is a measure of how close is the measured value to true value.
- Precision tells us to what resolution the quantity is measured.
- It is not necessary that more precise value is more accurate too.

7 ERRORS IN MEASUREMENT

Errors

- Systematic
  - Instrumental
  - Experimental
  - Personal
- Random

- Every measurement is approximate due to errors.
- Random errors occurs irregularly.
- Least count error is smallest value that can be measured by instrument (occurs within both systematic and random errors).
- Absolute error = $\frac{\Sigma(|a_i - a_{mean}|)}{n}$
- Relative error = $\frac{\Delta a_{mean}}{a_{mean}}$
- Percentage error = $\frac{\Delta a_{mean}}{a_{mean}} \times 100$

Combination of errors

Sum and difference	Product or Quotient
$\Delta Z = \Delta A + \Delta B$	$\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$

- If $X = \frac{A^a B^b}{C^c}$ then $\% \frac{\Delta X}{X} = a\left(\% \frac{\Delta A}{A}\right) + b\left(\% \frac{\Delta B}{B}\right) + c\left(\% \frac{\Delta C}{C}\right)$

8 SIGNIFICANT FIGURES

- Reliable digits plus first uncertain digit are known as significant digit.
- A choice of change of different units does not change number of significant digits.
- All non-zero digits are significant.
- All zero between two non-zero digits are significant.
- The terminal zeros in a number without a decimal point are not significant.
- The trailing zeros in a number with decimal point are significant.

Rules of Arithmatic Operations with Significant Figures

- Addition/Substraction: Final result contains as many decimal places as in number with least decimal places.
  e.g. 3.307 + 0.52 = 3.83
- Multiplication/Division: Result contains as many significant figures as in number with least number of significant figures.
  e.g. 4.11/1.2 = 3.4

Rounding off

- Preceding digit is raised by 1 if insignificant digit to be dropped is more than 5 and left unchanged of latter is less than 5.
- If insignificant digit is 5 then preceding digit is left unchanged if its even and uncreased by 1 if it is odd.

10 DIMENSIONAL FORMULAE AND SI UNITS OF VARIOUS PHYSICAL QUANTITIES

S. No.	Physical Quantity	Relation with other quantities	Dimensional Formula	SI Unit
1.	Gravitational constant 'G'	$\frac{\text{Force} \times (\text{distance})^2}{\text{Mass} \times \text{mass}}$	$\frac{[MLT^{-2}][L^2]}{M \times M} = [M^{-1}L^3T^{-2}]$	$N\,m^2\,kg^{-2}$
2.	Stress	$\frac{\text{Force}}{\text{Area}}$	$\frac{MLT^{-2}}{L^2} = [ML^{-1}T^{-2}]$	$N\,m^{-2}$
3.	Coefficient of elasticity	$\frac{\text{Stress}}{\text{Strain}}$	$\frac{ML^{-1}T^{-2}}{1} = [ML^{-1}T^{-2}]$	$N\,m^{-2}$
4.	Surface tension	$\frac{\text{Force}}{\text{Length}}$	$\frac{MLT^{-2}}{L} = MT^{-2} = [ML^0T^{-2}]$	$N\,m^{-1}$
5.	Coefficient of viscosity	$\frac{\text{Force} \times \text{distance}}{\text{Area} \times \text{velocity}}$	$\frac{MLT^{-2} \times L}{L^2 \times LT^{-1}} = [ML^{-1}T^{-1}]$	$N\,m^{-2}$ or Pa s or decapoise
6.	Planck's constant 'h'	$\frac{E}{\nu} = \frac{\text{Energy}}{\text{Frequency}}$	$\frac{ML^2T^{-2}}{T^{-1}} = [ML^2T^{-1}]$	J s
7.	Velocity gradient	$\frac{\text{Velocity}}{\text{Distance}}$	$\frac{LT^{-1}}{L} = T^{-1} = [M^0L^0T^{-1}]$	s^{-1}
8.	Pressure gradient	$\frac{\text{Pressure}}{\text{Distance}}$	$\frac{ML^{-1}T^{-2}}{L} = [ML^{-2}T^{-2}]$	$Pa\,m^{-1}$

9 DIMENSIONAL ANALYSIS

Dimensions

- Nature of physical quantity is determined by its dimension.
- The dimensions of physical quantity are powers to which base quantities are raised to represent it.
- The dimension of time in speed is –1.

Dimensional equation

- The expression which shows how and which of the base quantities represent the dimension of physical quantity is called dimensional formula.
- An equation is obtained by equating physical quantity with its dimensional formula.
- For example $[A] = [M^aL^bT^c]$

Homogeneity principle

Physical quantities represented by symbols on both sides of a mathematical equation must have same dimensions.

Applications

Checking dimensional consistency of equations

- It is based on homogeneity law. An equation is dimensionally correct if dimension of fundamental quantities of each term on left side of equation is equal to that on right hand side.

Deducing relations among physical quantities.

- We should know the dependence of physical quantity on other upto three physical quantities and product type of dependence

Limitations of Dimensional Analysis

- Dimensional analysis is useful in deducing relations among inter dependent physical quantities but dimensional constant can not be determined.
- It can test dimensional validity but not exact relationship between physical quantities having same dimensions.
- It does not distinguish between the physical quantities having same dimensions.

Sharpen Your Understanding — NCERT Based MCQs

1. Choose the correct option. [NCERT Pg. 22]

(1) A most precise measurement may be most accurate

(2) A most precise measurement will necessarily be most accurate

(3) A most precise measurement will be less accurate

(4) A most accurate measurement will necessarily be most precise

2. 1 metre is the length of path travelled by light in vacuum during a time interval of [NCERT Pg. 17]

(1) $\frac{1}{299,\ 972,\ 458}$ of a second

(2) $\frac{1}{299,\ 792,\ 548}$ of a second

(3) $\frac{1}{299,\ 792,\ 458}$ of a second

(4) $\frac{1}{299,\ 792,\ 854}$ of a second

3. The kelvin is the fraction [NCERT Pg. 17]

(1) $\frac{1}{273}$ of the thermodynamic temperature of triple point of water

(2) $\frac{1}{312}$ of the thermodynamic temperature of triple point of water

(3) $\frac{1}{273.16}$ of the thermodynamic temperature of triple point of water

(4) $\frac{1}{273}$ of the thermodynamic temperature of triple point of mercury

4. 1″ (second of arc) in radian is (approximately) [NCERT Pg. 19]

(1) 5.85×10^{-6} rad (2) 8.55×10^{-6} rad

(3) 5.85×10^{-5} rad (4) 4.85×10^{-6} rad

5. The diameter of sun is 1.39×10^{9} m. The distance of sun from earth is 1.496×10^{11} m. The angular diameter of sun is [NCERT Pg. 19]

(1) 1290″

(2) 9210″

(3) 2190′

(4) 1920″

6. The measured length of two rods are $l_1 = 30$ cm ± 0.5 cm and $l_2 = 20$ cm + 0.1 cm. The percentage error in difference of length of rods is [NCERT Pg. 26]

(1) 6%

(2) 4%

(3) 5%

(4) 3%

7. Two resistors of resistances $R_1 = 300 \pm 3$ ohm and $R_2 = 200 \pm 2$ ohm are connected in parallel. The equivalent resistance of parallel combination with error is [NCERT Pg. 37]

(1) [120 ± 1.8] ohm (2) [120 ± 1] ohm

(3) [120 ± 1.6] ohm (4) [120 ± 2.0] ohm

8. If percentage error in measurement of quantities A, B, C and D are 1%, 2%, 3% and 4% respectively, then percentage error in measurement of $z = \frac{A^2B^{1/2}}{C^{1/3}D^{1/4}}$ is [NCERT Pg. 27]

(1) 5%

(2) 4%

(3) 6%

(4) 8%

9. The number of insignificant zeros in 0.0048050 [NCERT Pg. 28]

(1) 1

(2) 2

(3) 3

(4) 4

10. The value of $(3.8 \times 10^3 + 3.5 \times 10^2)$ with regards to significant figure is [NCERT Pg. 30]

(1) 7.3×10^5 (2) 4.2×10^3

(3) 4.15×10^3 (4) 7.3×10^3

11. The value of gravitational constant is $G = 6.67 \times 10^{-11} \frac{N \times m^2}{kg^2}$. Suppose we employ a new system of units in which unit of mass is α kg, the unit of length β m and the unit of time is γ s. The value of gravitational constant in terms of new units is [NCERT Pg. 35]

(1) $6.67 \times 10^{-11}\ \alpha\ \beta^{-3}\ \gamma^{2}$

(2) $6.67 \times 10^{-11}\ \alpha^{-1}\ \beta^{3}\ \gamma^{-2}$

(3) $6.67 \times 10^{-11}\ \alpha\ \beta^{3}\ \gamma^{-2}$

(4) $6.67 \times 10^{-11}\ \alpha^{-1}\ \beta^{-3}\ \gamma^{2}$

12. In Cesium clock 1 second is the time in which cesium – 133 atom, vibrate between two hyperfine levels [NCERT Pg. 22]

(1) 9, 292, 631, 770 times

(2) 9, 192, 361, 770 times

(3) 9, 192, 136, 770 times

(4) 9, 192, 631, 770 times

13. Least count error belongs to the category of [NCERT Pg. 24]

(1) Random error only

(2) Systematic error only

(3) Neither systematic error nor-random error

(4) Systematic and random error both

14. A student measures the period of oscillation of a simple pendulum in successive measurements, the reading turn out to be 1.93 s, 1.99 s, 2.06 s, 2.08 s and 1.95 s. A more accurate way to write the measurement with error is [NCERT Pg. 25]

(1) (2.00 ± 0.05) s (2) (2.03 ± 0.06) s

(3) (2.0 ± 0.06) s (4) (2.03 ± 0.1) s

15. Each side of a cube is measured to be 6.372 m. The total surface area of cube with appropriate significant figures is [NCERT Pg. 32]

(1) 2.5×10^2 m^2 (2) 2×10^2 m^2

(3) 243.6 m^2 (4) 251.3207 m^2

16. Choose the correct statement [NCERT Pg. 33]

(1) A dimensionally correct equation need not be an actually correct equation

(2) A dimensionally correct equation may be an actually correct equation

(3) A dimensionally incorrect equation may be correct

(4) Both (1) and (2)

17. A famous relation in physics with many printing errors, relates the moving mass 'm' with rest mass for a moving object with speed v is printed as $m = \frac{n_0^2}{\sqrt{1-\frac{b}{c^2}}}$. The dimensional formula of n_0 and b are respectively (c is speed of light) [NCERT Pg. 36]

(1) [M], [LT^{-1}]

(2) [M], [L^{2}T^{-2}]

(3) [M$^{1/2}$], [L^{2}T^{-2}]

(4) [M$^{1/2}$], [LT^{-1}]

18. Parsec is a unit of [NCERT Pg. 21]

(1) Distance

(2) Velocity

(3) Time

(4) Angle

19. If the size of atom is in the range of 10^{-10} m to 10^{-9} m is scaled up to the tip of sharp pin (assume tip of pin to be in the range of 10^{-6} to 10^{-5} m). Roughly, size of nucleus is [NCERT Pg. 20]

(1) 0.1 Å

(2) 0.01 Å

(3) 0.001 Å

(4) 10 Å

20. In a screw gauge, each main scale division is 1 mm and there are 200 divisions on the circular scale. The least count of screw gauge is [NCERT Pg. 35]

(1) 0.05 mm

(2) 0.005 mm

(3) 0.05 cm

(4) 0.005 cm

Thinking in Context

1. The value of 1° is _____ rad. [NCERT Pg. 19]
2. The value of 2′ is _____ rad. [NCERT Pg. 19]
3. Speed is a _____ quantity. [NCERT Pg. 17]
4. 1 second is the duration of 9192631770 periods of radiation corresponding to the transition between two hyperfine level of ground state of the _____ atom. [NCERT Pg. 17]
5. The indirect method used to measure large distances is _____ method. [NCERT Pg. 18]
6. 1 parsec is the distance at which the average radius of _____ subtends an angle of _____. [NCERT Pg. 21]
7. 1 Fermi equals to ____ m. [NCERT Pg. 21]
8. The efficient caesium atomic clock are so accurate that uncertainty in time realisation as _____. [NCERT Pg. 22]
9. Least count is the _____ value that can be measured by the measuring instrument. [NCERT Pg. 24]
10. When two quantities are subtracted, the absolute error in the final result is the sum of _____ in the individual quantities. [NCERT Pg. 26]
11. When the two quantities are multiplied or divided, the relative error in the result is the sum of the _____ in the multipliers. [NCERT Pg. 26]
12. The result of a measurement should be reported in a way that indicates the _____ of measurement. [NCERT Pg. 27]
13. A choice of change of different units does not change the _____ of significant digits in a measurement. [NCERT Pg. 28]
14. In _____, the final result should be reported in least number of decimal places in used quantities. [NCERT Pg. 29]
15. The dimensions of a physical quantity are the _____ to which the base quantities are raised to represent that quantity. [NCERT Pg. 31]
16. The trailing zero(s) in a number with a decimal point are _____. [NCERT Pg. 28]
17. In _____, the final result should be reported in least number of significant figure as there in the original number. [NCERT Pg. 29]
18. The number of significant figures in 1.67×10^{-27} kg are _____. [NCERT Pg. 35]
19. $h \approx 6.6 \times 10^{-34} \text{kg}\frac{\text{m}^2}{\text{s}} =$ _____ $\text{g}\frac{\text{cm}^2}{\text{s}}$. [NCERT Pg. 35]
20. The value of $(4.2 \times 10^{-3} - 5.4 \times 10^{-4}) =$ _____. [NCERT Pg. 29]

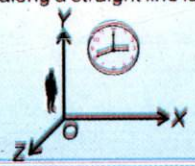
❑ ❑ ❑

Motion in a Straight Line

3
Chapter

1 FRAME OF REFERENCE

- A rectangular coordinate system consisting of three mutually perpendicular axes, along with a clock. The point of intersection of these three axes is called origin (O)
- If a body changes its position as time passes w.r.t. frame of reference, it is said to be in motion.
- Motion of objects along a straight line is called rectilinear motion.



2 DISTANCE AND DISPLACEMENT

- **Distance:** Actual path length in motion. During motion it is non-zero
- **Displacement:** The shortest path between initial and final position. Equal to change in position. May or may not be equal to path length travelled. It can be positive, negative or zero.

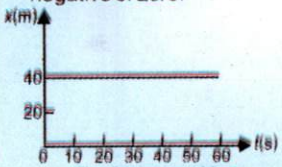


Fig: Stationary object

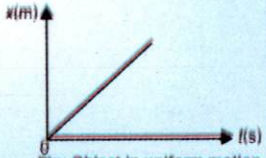


Fig: Object in uniform motion

3 SPEED

- The rate of distance covered with time is called speed.

$$v = \frac{\text{distance}}{\text{total time}} = \frac{\ell}{t}$$

Average Speed

$$v_{av} = \frac{\text{total distance}}{\text{total time}} = \frac{\text{total path length}}{\text{total time interval}}$$

Instantaneous speed

$$v = \lim_{\Delta t \to 0} \frac{\Delta \ell}{\Delta t} = \frac{d\ell}{dt}$$

4 VELOCITY

- The rate of change of position, It tells how fast position is changing with time and in what direction.

Average velocity

$$\vec{v}_{av} = \frac{\Delta \vec{x}}{\Delta t}$$

- SI units are $m\,s^{-1}$

Instantaneous velocity

$$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{x}}{\Delta t} = \frac{d\vec{x}}{dt}$$

- Slope of position time graph

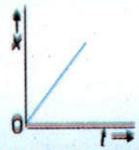


Fig: Moving with positive velocity

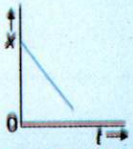


Fig: Moving with negative velocity

5 ACCELERATION

The time rate of change of velocity

Average Acceleration

$$\vec{a}_{av} = \frac{(v_2 - v_1)}{(t_2 - t_1)} = \frac{\Delta \vec{v}}{\Delta t}$$

Instantaneous Acceleration

$$\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$$

Uniform Acceleration

Equal change in velocity in equal intervals of time

Non-Uniform Acceleration

Acceleration changes with time

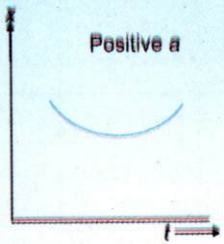


Fig: Positive acceleration

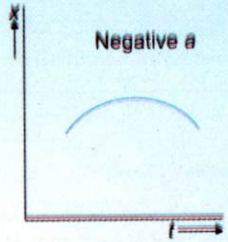


Fig: Negative acceleration

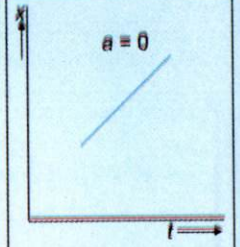


Fig: Zero acceleration

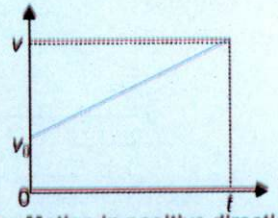


Fig: Motion in positive direction with positive acceleration

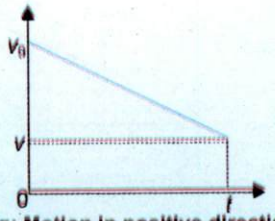


Fig: Motion in positive direction with negative acceleration

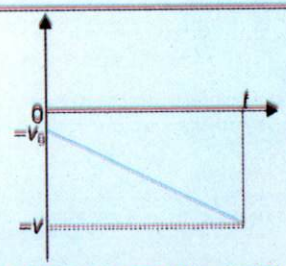
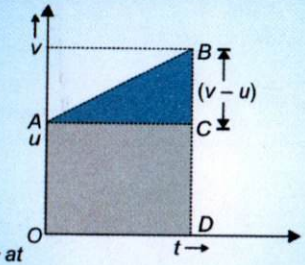


Fig: Motion in negative direction with negative acceleration

6 Kinematic Equations

- A mathematical treatment to describe the motion of a body in one-dimension.

For uniformly accelerated motion



- $v = u + at$
- $s = ut + \frac{1}{2}at^2 = \left(\frac{u+v}{2}\right)t$
- $v^2 = u^2 + 2as$
- $s_n = u + \frac{a}{2}(2n-1)$
- $\bar{v} = \frac{u+v}{2}$

7 FOR MOTION WITH VARIABLE ACCELERATION

- $\frac{dv}{dt} = a \Rightarrow v - u = \int a\,dt$
- $\frac{dx}{dt} = v \Rightarrow \Delta x = \int v\,dt$ (Area under $v-t$ curve)
- $\frac{v\,dv}{dx} = a$
- $\frac{d^2x}{dt^2} = a$

8 FOR MOTION UNDER GRAVITY

- A mathematical treatment to describe the motion of a body in one-dimension under free fall

Vertically downward motion

When object is released from $y = 0$

- $v = -gt$
- $y = -\frac{1}{2}gt^2$
- $v^2 = -2gy$

Vertically upward motion

$u \neq 0$, acceleration $a = -g$

- $v = u - gt$
- $S = ut - \frac{1}{2}gt^2$
- $v^2 = u^2 - 2gh$

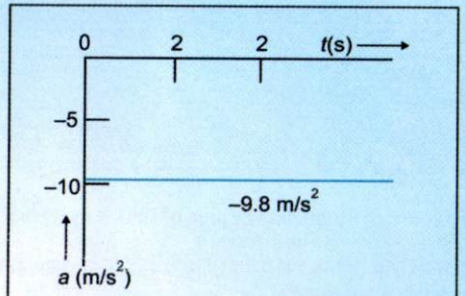


Fig: Variation of acceleration with time

- Distance travelled during equal intervals of time by a body falling freely from rest is in ratio 1 : 3 : 5 : 7 : 9 : 11 .. (Galileo's law)

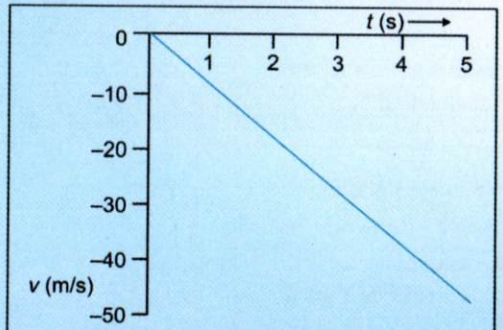


Fig: Variation of velocity with time

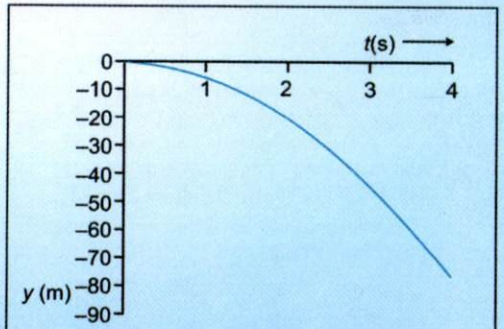


Fig: Variation of distance with time

9 Relative Velocity

- The velocity with which an object moves with respect to another object is called relative velocity.

$v_{AB} = (v_A - v_B)$

$v_{AB} = (v_A + (-v_B))$

$v_{BA} = (v_B - v_A)$

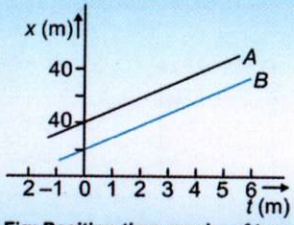


Fig: Position-time graphs of two objects with equal velocities

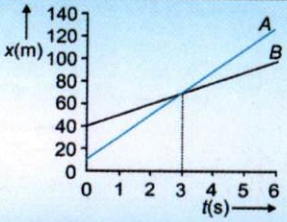


Fig: Position-time graphs of two objects with unequal velocities, showing the time of meeting

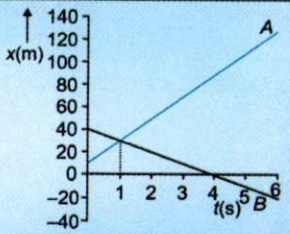


Fig: Position-time graphs of two objects with velocities in opposite directions, showing the time of meeting

Sharpen Your Understanding

1. Choose the correct statement [NCERT Pg. 42]

(1) Area under velocity-time graph gives the distance traveled

(2) Area under velocity-time graph gives the change in position

(3) Area under velocity-time graph gives average acceleration

(4) Area under velocity time graph gives change in acceleration

2. Choose the correct statement for one dimensional motion [NCERT Pg. 57]

(1) A constant speed in an interval must have non-zero acceleration in that interval

(2) With negative value of acceleration speed must decrease

(3) With negative value of acceleration speed may increase

(4) With positive value of acceleration speed must increase

3. A drunkard walking in a narrow lane takes 5 steps forward, 3 steps backward and then stay for 1 s and repeat the same process again and again. Each step is 1 m long and takes 1 s. The time taken by drunkard to fall in a pit 10 m away from start is [NCERT Pg. 56]

(1) 45 s (2) 27 s

(3) 30 s (4) 31 s

NCERT Based MCQs

4. The reaction time is the time interval in which a person [NCERT Pg. 51]

(1) Observe the things

(2) Think about the observations

(3) Observe the things and act

(4) Observe the things, think and act

5. A person driving a car with a speed of 72 km/h observes a boy crossing the road at a distance of 100 m from the car. Driver applies the brakes and retards the car with a retardation of 5 m/s^2 and is just able to avoid this accident. The reaction time of driver is [NCERT Pg. 51]

(1) 2.0 s

(2) 2.4 s

(3) 3.0 s

(4) 2. 8 s

6. In any realistic condition ($v - t$) and ($a - t$) graph cannot have sharp kinks at some points. This implies that [NCERT Pg. 47]

(1) Both velocity and acceleration can change abruptly at an instant

(2) Both velocity and acceleration cannot change abruptly at an instant

(3) Only velocity cannot change abruptly at an instant but acceleration can change

(4) Only acceleration cannot change abruptly at an instant but velocity can change

7. A ball is thrown vertically upward with a velocity of 20 m/s from the top of 160 m high building. The time taken by ball to hit the ground is [NCERT Pg. 48]

(1) 8 s (2) 10 s

(3) 4 s (4) 6 s

8. In which of the following cases an object can be considered as point object? [NCERT Pg. 55]

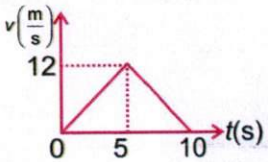
(1) Length of train in comparison to platform

(2) Length of engine in comparison to length of a small bridge

(3) A spinning cricket ball that turns sharply on hitting the pitch

(4) A railway carriage moving without jerks between two stations

9. The velocity time graph of a particle moving along a fixed direction is as shown in figure. The average velocity of particle between 5 s to 10 s is [NCERT Pg. 60]



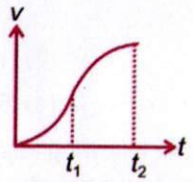
(1) 15.6 m/s

(2) 6.0 m/s

(3) 8.9 m/s

(4) 15.0 m/s

10. The velocity-time graph of a particle in one dimensional motion is as shown in figure. Which of the following relation is correct for describing the motion of particle over time interval t_1 to t_2? [NCERT Pg. 60]



(1) $v_{t_2}^2 = v_{t_1}^2 + 2a_{average}(t_2 - t_1)$

(2) $x_{t_2} = x_{t_1} + v_{average}(t_1 - t_2) + \frac{1}{2}a_{average}(t_2 - t_1)^2$

(3) $v_{t_2} = v_{t_1} + a(t_2 - t_1)$

(4) $a_{average} = \frac{v_{t_2} - v_{t_1}}{t_2 - t_1}$

11. A boy is standing on an open lift moving upwards with speed 10 m/s. The boy throws the ball with speed w.r.t. lift is 24.5 m/s. In how much time the ball returns to the hand of boy? (g = 10 m/s^2)

[NCERT Pg. 59]

(1) 10 s

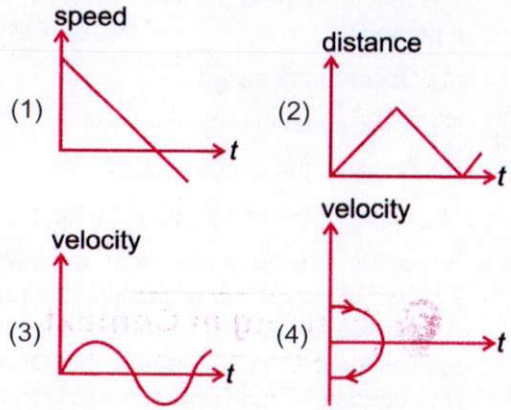
(2) 4.9 s

(3) 7.5 s

(4) 6 s

12. Which of the following graphs can represent one dimensional motion of a particle?

[NCERT Pg. 57]



13. A man walks on a straight road from his home to market 2.0 km away with a speed of 4.0 km/h. The stays in the market for 30 minute for purchasing and returns to home with a speed of 6 km/h. The magnitude of average speed of whole journey is

[NCERT Pg. 57]

(1) 4.0 km/h (2) 3.0 km/h

(3) 4.5 km/h (4) 3.5 km/h

14. Two trains P and Q of length 300 m and 500 m are moving on two parallel tracks each with a uniform speed of 72 km/h in the same direction, with Q ahead of P. The driver of train P decide to overtake train Q and accelerates by 2.0 m/s^2, if after 40 s the guard of P just brushes past the driver of Q, then the original distance between the trains is [NCERT Pg. 56]

(1) 450 m (2) 650 m

(3) 800 m (4) 1300 m

15. Two towns A and B are connected by a regular bus service with a bus leaving in either direction every T minutes. A man cycling with a speed of 20 km/h in the direction from A to B notices that a bus goes past him every 18 min in the direction of his motion and every 6 min in the opposite direction. The speed with which (assumed constant) buses ply on road is

[NCERT Pg. 56]

(1) 40 km/h

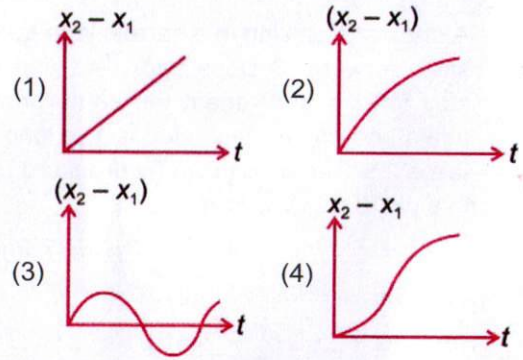
(2) 60 km/h

(3) 75 km/h

(4) 80 km/h

16. Two stones are thrown up from the edge of a cliff 300 m high with initial speed of 10 m/s and 20 m/s. Which of the following graph best represents the variation of relative position of second stone with respect to first stone till both the stones are in air? (neglect air resistance) g = 10 m/s^2

[NCERT Pg. 59]



17. Graphically derivative or differential coefficient means [NCERT Pg. 61]
(1) Angle made by the line joining two points on the curve with x-axis
(2) Slope of the tangent line at any point on the curve
(3) Area enclosed under the curve
(4) Both (1) and (3)

18. A police van moving on a highway with a speed of 30 km/h and a thief's car speeding away in same direction with speed is 192 km/h. Thief in the car fires bullet on police van. If muzzle speed of bullet is 150 m/s, then the speed with which bullet hits the w.r.t. police van is [NCERT Pg. 58]
(1) 145 m/s (2) 130 m/s
(3) 115 m/s (4) 105 m/s

19. The acceleration of a body starting from rest varies with time as $a = 2t + 3$, where t is in second. The speed of body at $t = 2$ s, is [NCERT Pg. 63]
(1) 10 m/s (2) 12 m/s
(3) 15 m/s (4) 18 m/s

20. The position of an object moving along x-axis is given by, $x = 10 + 15t + 5t^2$, where x is in meter and t is in second. The velocity of body at $t = 3$ s is [NCERT Pg. 45]
(1) 15 m/s (2) 30 m/s
(3) 40 m/s (4) 45 m/s

Thinking in Context

1. The study of motion of objects along a _____ called rectilinear motion. [NCERT Pg. 39]
2. In _____, we study ways to describe motion without going into the causes of motion. [NCERT Pg. 39]
3. A co-ordinate system along with a clock constitutes a _____ [NCERT Pg. 40]
4. Displacement has both _____ and _____ [NCERT Pg. 40]
5. The magnitude of displacement _____ equal to the distance traversed by an object. [NCERT Pg. 41]
6. The magnitude of average velocity in general is _____ than the average speed. [NCERT Pg. 43]
7. The velocity at an instant is defined as the limit of _____ as the time interval becomes _____ small [NCERT Pg. 43]
8. For uniform motion, velocity is same as the _____ at all instants. [NCERT Pg. 45]
9. Acceleration may result due to change in _____, a change in _____ or change in _____. [NCERT Pg. 46]
10. The area under velocity-time graph for any moving object represents the _____ over a given time interval. [NCERT Pg. 46]
11. The acceleration and velocity cannot change values abruptly at an instant. Changes are always _____. [NCERT Pg. 47]
12. Free fall is the case of motion with _____. [NCERT Pg. 49]
13. The _____ speed is always equal to magnitude of instantaneous velocity [NCERT Pg. 57]
14. On an $x - t$ graph, the average velocity over a time interval is the _____ connecting initial and final position corresponding to that interval [NCERT Pg. 53]
15. For uniform motion, acceleration-time graph is a straight line _____ to the time axis. [NCERT Pg. 53]
16. For uniform motion, position-time graph is having a _____ non-zero slope. [NCERT Pg. 53]
17. For uniform motion, velocity-time graph is a straight line _____ to the time axis. [NCERT Pg. 53]
18. For motion with _____ position-time is a parabola. [NCERT Pg. 54]
19. The sign of acceleration does not tell us whether the particle speed is _____ or _____. [NCERT Pg. 55]
20. The zero velocity of a particle at any instant does not necessarily imply zero _____ at that instant. [NCERT Pg. 55]

❑ ❑ ❑

Motion in a Plane

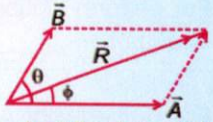
4
Chapter

1 SCALARS AND VECTORS

- **Scalar quantity:** It has only magnitude with proper unit. All base quantities are scalar. The rules combining scalars are rules of ordinary algebra.
- **Vector quantity:** It has both magnitude and direction and obeys the triangle law or parallelogram law of vector addition.
- **Equality of vector:** Two vectors $\vec{A}$ and $\vec{B}$ are said to be equal, if and only if, they have same magnitude and direction.
- **Multiplication of vector by real numbers:** If a vector $\vec{A}$ is multiplied by real number λ, then $A' = \lambda|\vec{A}|$
  if $\lambda > 0$, magnitude will change and direction remains same
  if $\lambda < 0$, magnitude changes λ times and direction gets reverse.
- **Parallelogram law of vector addition:** For two co-initial vectors represented by two adjacent sides of a parallelogram, the diagonal of a parallelogram passing through same point will be resultant.

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

$\tan\phi = \dfrac{B\sin\theta}{A + B\cos\theta}$

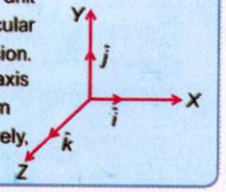


- **Subtraction of vector:** It can be defined as addition of a vector and negative of other vector.

$\vec{S} = \vec{A} - \vec{B}$

$\vec{S} = \vec{A} + (-\vec{B}) \Rightarrow |\vec{S}| = \sqrt{A^2 + B^2 - 2AB\cos\theta}$

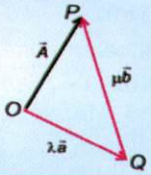
Unit Vectors: It is a vector of unit magnitude and points in a particular direction. It has no unit and dimension. Unit vectors along the x, y and z axis of a rectangular coordinate system represented by $\hat{i}$, $\hat{j}$ and $\hat{k}$ respectively, called basic unit vectors.



2 RESOLUTION OF VECTORS

$\vec{A} = \overline{OP} = \overline{OQ} + \overline{QP}$

$\vec{A} = \lambda\vec{a} + \mu\vec{b}$



3 RECTANGULAR COMPONENTS

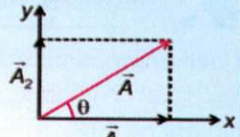
- $\vec{A} = \vec{A}_1 + \vec{A}_2$

$\vec{A} = A_x\hat{i} + A_y\hat{j}$

$\vec{A} = A\cos\theta\hat{i} + A\sin\theta\hat{j}$

$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$

$\tan\theta = \dfrac{A_y}{A_x}$, $\theta = \tan^{-1}\left(\dfrac{A_y}{A_x}\right)$

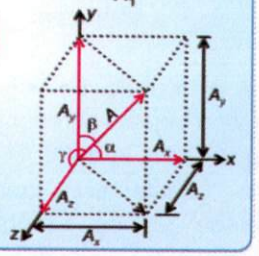


- Resolution in three. rectangular components

$A_x = A\cos\alpha$, $A_y = A\sin\alpha$

$A_z = A\cos\gamma$

$|\vec{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2}$



4 MOTION IN A PLANE

$\vec{r} = x\hat{i} + y\hat{j}$

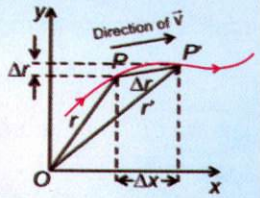
$\vec{r}' = x'\hat{i} + y'\hat{j}$

$\overline{\Delta r} = \vec{r}' - \vec{r}$

$\overline{\Delta r} = (x' - x)\hat{i} + (y' - y)\hat{j}$

$\vec{v}_{av} = \dfrac{\Delta\vec{r}}{\Delta t} = \vec{v}_x\hat{i} + \vec{v}_y\hat{j}$

Instantaneous velocity, $\vec{v} = \dfrac{d\vec{r}}{dt}$



- The direction of velocity at any point on path is tangent to path and in direction of motion.

5 MOTION IN A PLANE WITH CONSTANT ACCELERATION

- $\vec{v} = \vec{v}_o + \vec{a}t$
  $v_x = v_{ox} + a_x t$
  $v_y = v_{oy} + a_y t$
- $\vec{r} = \vec{r}_o + \vec{v}_o t + \frac{1}{2}\vec{a}t^2$, $x = x_o + v_{ox}t + \frac{1}{2}a_x t^2$
  $y = y_o + v_{oy}t + \frac{1}{2}a_y t^2$

6 RELATIVE VELOCITY IN TWO DIMENSIONS

The velocity of object A relative to B

$\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$

where $\vec{V}_A$ and $\vec{V}_B$ are velocities in the same frame.

Similarly, $\vec{V}_{BA} = \vec{V}_B - \vec{V}_A$

$\vec{V}_{AB} = -\vec{V}_{BA}$ and $|\vec{V}_{AB}| = |\vec{V}_{BA}|$

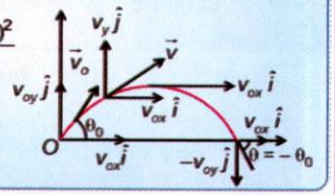
7 PROJECTILE MOTION

Equation of trajectory $y = x\tan\theta_0 - \dfrac{1}{2}\dfrac{gx^2}{v_o^2\cos^2\theta_0}$

This is equation of parabola.

- Time of flight $T_f = \dfrac{2v_o\sin\theta_0}{g}$
- Maximum height $h_m = \dfrac{(v_o\sin\theta_0)^2}{2g}$
- Horizontal range $R = \dfrac{v_o^2\sin 2\theta_0}{g}$

for R_{max}, $\theta = 45°$ $R_{max} = \dfrac{v_o^2}{g}$

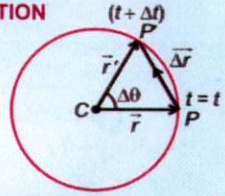


8 UNIFORM CIRCULAR MOTION

In uniform circular motion particle moves with constant speed.

- Angular displacement $\Delta\theta = \dfrac{\text{Arc } (PP')}{r}$
- Angular velocity $\omega = \dfrac{\Delta\theta}{\Delta t} = \dfrac{2\pi}{T} = 2\pi\nu$
- Linear speed $v = r\omega$
- Centripetal acceleration-Due to change in direction of velocity and is always directed towards centre.

$a = \dfrac{v^2}{r} = r\omega^2 = 4\pi^2\nu^2 r = v\omega$



Sharpen Your Understanding

NCERT Based MCQs

1. Two vectors are said to be equal, if [NCERT Pg. 66]
   (1) They have equal magnitude only
   (2) Same direction only
   (3) They have equal magnitude and same direction
   (4) They have unequal magnitude and same direction

2. A null vector has [NCERT Pg. 68]
   (1) Zero magnitude, specified direction
   (2) Zero magnitude, arbitrary direction
   (3) Non-zero magnitude, no direction
   (4) Non-zero magnitude, arbitrary direction

3. To a person moving with a speed of 5 m/s towards east, rain appears to be falling vertically downward with speed $5\sqrt{3}$ m/s. The actual velocity of rain is [NCERT Pg. 69]
   (1) 10 m/s at 30° with vertical
   (2) 20 m/s at 30° with vertical
   (3) 10 m/s at 60° with vertical
   (4) 20 m/s at 60° with vertical

4. A vector can be resolved [NCERT Pg. 70]
   (1) Only in two components
   (2) Only in three components
   (3) In any number of components
   (4) Either two or three components

5. The magnitude of component of a vector [NCERT Pg. 70]
   (1) Is always less than magnitude of vector
   (2) Is always equal to magnitude of vector
   (3) May be greater than magnitude of vector
   (4) Is always greater than magnitude of vector

6. A motor boat is racing towards north at 25 km/h and the water current in that region is 10 km/h in the direction of 60° east of south. The resultant velocity of the boat is nearly [NCERT Pg. 72]
   (1) 22 km/h
   (2) 12 km/h
   (3) 35 km/h
   (4) 26 km/h

7. In uniform circular motion, the centripetal acceleration is [NCERT Pg. 79]
   (1) Due to change in magnitude of velocity only
   (2) Due to change in direction of velocity only
   (3) Due to change in both magnitude and direction of velocity
   (4) Neither due to change in magnitude of velocity nor due to change in direction

8. In circular motion, the direction of angular velocity is [NCERT Pg. 80]
   (1) In the plane of circle
   (2) Perpendicular to plane of circle
   (3) In the direction of velocity
   (4) In the direction of acceleration

9. The shape of the trajectory of an object is determined by [NCERT Pg. 85]
   (1) Acceleration only
   (2) Velocity of projection only
   (3) Initial position and initial velocity only
   (4) Initial position, initial velocity and acceleration

10. Which of the following vector operation is meaningful? [NCERT Pg. 85]
    (1) Multiplication of any two vectors
    (2) Adding any two vectors
    (3) Adding a component of vector to the same vector
    (4) Both (2) and (3)

11. Which of the following quantities is/are vector? [NCERT Pg. 85]
    (1) Angular frequency
    (2) Angular velocity
    (3) Number of moles
    (4) Both (1) and (2)

12. Which of the following option is correct? [NCERT Pg. 86]

(1) Each component of a vector is always scalar

(2) Three vectors not lying in a plane can never add up to give null vector

(3) Two vectors of different magnitude can be add up to give null vector

(4) Minimum number of vectors to give null vector is five

13. A particle A is moving with velocity $(3\hat{i}+4\hat{j})$ m/s and particle B is moving with velocity $(-3\hat{i}-4\hat{j})$ m/s. The magnitude of velocity of B w.r.t A is [NCERT Pg. 76]

(1) 6 m/s

(2) 8 m/s

(3) 10 m/s

(4) 5 m/s

14. If two vectors $\vec{A}=a\hat{i}+6\hat{j}$ and $\vec{B}=b\hat{i}+c\hat{j}$ are equal then correct options for value of a, b and c is [NCERT Pg. 66]

(1) $a = b$

(2) $a = c$

(3) $c = 6$

(4) Both (1) and (3)

15. Equation of trajectory of projectile is $y=\sqrt{3}x-5x^2$. Then angle of projection with vertical is (Assume x-axis as horizontal and y-axis as vertical) [NCERT Pg. 78]

(1) 45°

(2) 30°

(3) 60°

(4) 53°

16. A projectile is projected with initial velocity $(10\hat{i}+20\hat{j})$ m/s from the ground. The velocity of the body just before hitting the ground is [NCERT Pg. 79]

(1) $10\hat{i}+20\hat{j}$

(2) $-10\hat{i}+20\hat{j}$

(3) $10\hat{i}-20\hat{j}$

(4) $-10\hat{i}-20\hat{j}$

17. The component of $(3\hat{i}+4\hat{j})$ in the direction of $(\hat{i}-\hat{j})$ is [NCERT Pg. 87]

(1) $\frac{\hat{j}-\hat{i}}{2}$

(2) $\frac{\hat{i}-\hat{j}}{2}$

(3) $\frac{1}{\sqrt{2}}(\hat{i}-\hat{j})$

(4) $\frac{1}{\sqrt{2}}(\hat{j}-\hat{i})$

18. The correct statement for a scalar quantity is [NCERT Pg. 87]

(1) It is conserved in a process

(2) It can never take negative values

(3) It does not vary from one point to another in space

(4) It has the same value for the observers with different orientations of axis

19. A man can swim with a speed of 5 km/h in still water. How long does he take to cross a river 1.0 km wide, if the river is flowing steadily at 3 km/h and he makes his strokes normal to the river current? [NCERT Pg. 86]

(1) 20 min

(2) 30 min

(3) 12 min

(4) 15 min

20. A particle starts from origin at $t = 0$ s with a velocity $4.0\ \hat{j}$ m/s and moves in x-y plane with a constant acceleration of $(6\hat{i}+4\hat{j})$ m/s^2. The time after which y-coordinate of particle will be 48 m, will be [NCERT Pg. 87]

(1) 6 s

(2) 4 s

(3) 8 s

(4) 5 s

Thinking in Context

1. The _____ of a vector is called its absolute value. [NCERT Pg. 66]

2. Addition and subtraction of scalars make sense only for quantities with _____ units. However, you can multiply and divide scalars of _____ units. [NCERT Pg. 66]

3. Displacing a vector parallel to itself leaves the vector unchanged. Such vectors are called _____. [NCERT Pg. 66]

4. Multiplying a vector $\vec{A}$ by a negative number λ gives a vector $\lambda\vec{A}$ whose direction is _____ to the direction of $\vec{A}$. [NCERT Pg. 67]

5. Vector addition follows _____ law and _____ law [NCERT Pg. 68]

6. On adding two equal and opposite vectors, resultant will be a _____. [NCERT Pg. 68]

7. A unit vector is a vector of _____ magnitude. It has no _____. [NCERT Pg. 70]

8. The sum of the squares of direction cosines of a vector is _____. [NCERT Pg. 71]

9. The instantaneous acceleration is the limiting value of _____ as the time interval approaches zero. [NCERT Pg. 74]

10. In two or three dimensions, velocity and acceleration vectors may have any angle between _____. [NCERT Pg. 75]

11. In one dimension, the velocity and acceleration may have angle _____ between them. [NCERT Pg. 75]

12. Motion in a plane can be treated as superposition of two separate simultaneous _____ motions along two perpendicular directions. [NCERT Pg. 76]

13. The resultant velocity is the _____ sum of two velocities. [NCERT Pg. 77]

14. Particle A is moving with velocity $\vec{v}_A$ and particle B is moving with velocity $\vec{v}_B$ in same direction then their relative velocity is given by the _____ of two velocities. [NCERT Pg. 77]

15. In uniform circular motion, magnitude of velocity and acceleration remains _____ [NCERT Pg. 81]

16. In projectile motion x-component of velocity _____ while y-component of velocity undergoes a _____. [NCERT Pg. 79]

17. In projectile motion if air resistance is considered then both x and y component of velocities undergoes a _____. [NCERT Pg. 79]

18. When an object follows a circular path at a _____ the motion is said to be uniform circular motion. [NCERT Pg. 79]

19. The shape of the trajectory of motion is not determined by the _____ alone, but also depends on initial conditions of motion. [NCERT Pg. 85]

20. In uniform circular motion, acceleration is directed along the _____ of circular path [NCERT Pg. 81]

❑ ❑ ❑

Laws of Motion

5
Chapter

1 NEWTON'S 1ST LAW

A body continues its state of rest or of motion until unless an external force is acted on it

Inertia of rest
The property of body due to which it cannot change its state of rest by itself.

Inertia of motion
The property of body due to which it cannot change its state of motion by itself.

Inertia of direction
The property due to which a body cannot change its direction of motion by itself.

2 NEWTON'S 2ND LAW

The rate of change of Linear momentum of a body is directly proportional to the external force applied on the body and takes place in the direction in which force acts

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

- The same force for the same time causes same change in momentum for different bodies.

Impulse
A large force acts for very short duration of time produces a finite change in momentum.
Product of force and time duration for which it acts is impulse.
Impulse $= F \times \Delta t = \Delta p$

Equilibrium of a particle

$\Sigma\vec{F} = 0 \Rightarrow \Sigma F_x = 0, \Sigma F_y = 0$ and $\Sigma F_z = 0$

Conservation of Liner Momentum
Total momentum of an isolated system of intracting particles is conserved if there is no external force acting on it.

$$\vec{p}_{initial} = \vec{p}_{final}$$

4 NON-INTERTIAL FRAME OF REFERENCE

Pseudo Force $\vec{F}_{pseudo} = -M\vec{a}_{frame}$

$$\vec{F}_{net} + \vec{F}_{pseudo} = M\vec{a}$$

3 NEWTON'S 3RD LAW

To every action there is always an equal and opposite reaction

$$\vec{F}_{AB} = -\vec{F}_{BA}$$

- Forces always occur in pairs. Force on body A by B is equal and opposite to force on body B by A.

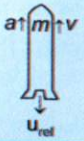
Some examples of Newton's 3rd Law
- Recoiling of Gun
- Rowing of boat
- When a man jumps from a boat, the boat moves backward
- It is difficult to walk on sand or ice.

Rocket Propulsion

- $a = \frac{u_{rel}}{m}\frac{dm}{dt} - g$

Thrust

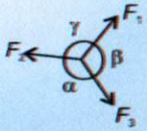
- $F = -u_{rel}\frac{dm}{dt}$



7 PROBLEM SOLVING TECHNIQUES IN MECHANICS

- Identify the unknown forces and accelerations
- Draw FBD of bodies in system
- Resolve forces into components
- Apply $\Sigma\vec{F} = 0$ in the direction of equilibrium
- Apply $\Sigma\vec{F} = M\vec{a}$ in the direction of accelerated motion
- Write constraint relations if exists.
- Solve the equations $\Sigma\vec{F} = 0$ and $\Sigma\vec{F} = M\vec{a}$
- For equilibrium of concurrent forces use sine rule

$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$



5 COMMON FORCES IN MECHANICS

Tension Force
- Restoring force in string is called tension.
- It is due to electromagnetic force
- Always acts away from the body
- It is a contact force.

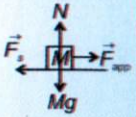
Weight
- It is equal to the gravitational pull *i.e.* $W = Mg$
- It is non-contact force.

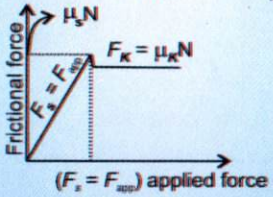
Normal Reaction
It is always perpendicular to the surface in contact.
- It is a contact force.

Spring Force
- $\vec{F} = -K\vec{x}$
- It is due to electromagnetic force
- It is a contact force.

Friction
It is the resistance offered to the relative motion between two bodies in contact
- It is parallel to surface of body in contact.

Type of Friction
- Static friction: $F_s = F_{applied}$
- Limiting friction $F_{lim} = \mu_s N$
- Kinetic friction $F_k = \mu_k N$





- Acceleration of body sliding down a rough inclined plane
  $a = g(\sin\theta - \mu\cos\theta)$
- Angle of friction: $\theta = \tan^{-1}(\mu_k)$
- Angle of repose: $\alpha = \tan^{-1}(\mu_s)$

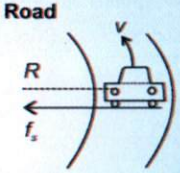
6 CIRCULAR MOTION

A body moving in a circular path is called circular motion.
$F_c = mv^2/R$ is called centripetal force.

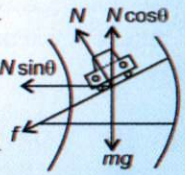
Uniform circular motion
- $a = a_c = \frac{v^2}{R} = R\omega^2$
- $a = a_c = v.\omega$

Non-uniform circular motion
- $\vec{a} = \vec{a}_T + \vec{a}_c$
- $a = \sqrt{a_T^2 + a_c^2}$

Motion of car on level Road
- $v_{max} = \sqrt{\mu_s Rg}$
- $\mu_{min} = \frac{v^2}{Rg}$
- $R_{min} = \frac{v^2}{\mu g}$

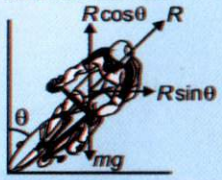


Motion of car on Banked Road
- $v_{max} = \sqrt{\frac{Rg(\mu_s + \tan\theta)}{(1 - \mu_s\tan\theta)}}$
- $v_{optimum} = \sqrt{Rg\tan\theta}$
- $v_{min} = \sqrt{\frac{Rg(\tan\theta - \mu_s)}{(1 + \mu_s\tan\theta)}}$



Bending of cyclist on a circular turn
- Angle of Bending

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



- Numerically: $\alpha = \theta$
- Kinetic friction is usually less than maximum value of static friction.

Sharpen Your Understanding

NCERT Based MCQs

1. A constant retarding force 100 N is applied to a body of mass 20 kg, moving initially with speed 20 m/s. How long does the body take to stop? [NCERT-I, XI Pg. 110]

(1) 2 s (2) 3 s

(3) 1 s (4) 4 s

2. A man of mass 60 kg stands on a weighing scale in a lift which is moving upward with a uniform speed of 10 m/s. The reading on the scale is. [NCERT-I, XI Pg. 110]

(1) Zero (2) 120 kg wt

(3) 60 kg wt (4) 90 kg wt

3. A rocket with a lift-off mass 10000 kg is blasted upwards with an initial acceleration of 2 m/s^2. The initial thrust of the blast is [NCERT-I, XI Pg. 110]

(1) 120 kN

(2) 80 kN

(3) 100 kN

(4) 140 kN

4. Consider the following statements

(a) Frictional force between block and contact surface depends on area of contact

(b) Frictional force may also act when there is no relative motion between the contact surfaces.

The correct statement is [NCERT-I, XI Pg. 110]

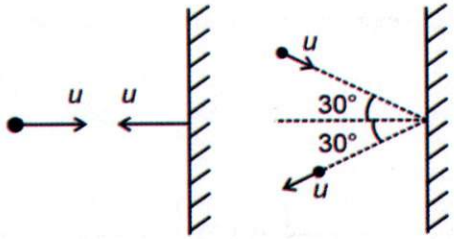
(1) (a) only

(2) (b) only

(3) (a) and (b) both

(4) Neither (a) nor (b)

5. Two identical billiard balls strike a rigid wall with same speed as shown in the figure. The ratio of magnitude of impulse imparted to the balls by the wall [NCERT-I, XI Pg. 98]



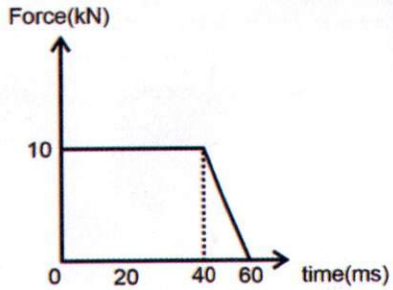
(1) $\frac{2}{\sqrt{3}}$

(2) $\frac{1}{\sqrt{3}}$

(3) $\frac{1}{2}$

(4) $\frac{1}{3}$

6. A force-time plot for a body is shown in the figure. The total change in momentum of the body is [NCERT-I, XI Pg. 98]



(1) 400 N s (2) 300 N s

(3) 500 N s (4) 200 N s

7. For a given surface, the normal reaction and frictional force are inclined at [NCERT-I, XI Pg. 101]

(1) 0° to each other

(2) 90° to each other

(3) 45° to each other

(4) $\tan^{-1}(\mu)$ to each other

8. A machine gun fires 10 bullets per second each with speed 200 m/s. If the mass of each bullet is 20 g, then the force required to keep the gun stationary is [NCERT-I, XI Pg. 98]

(1) 40 N

(2) 0.4 N

(3) 4 N

(4) 8 N

9. A mass of 2 kg rests on a horizontal plane. The plane is gradually inclined until at an angle $\theta = 30°$ with the horizontal, the mass just begins to slide. The coefficient of static friction between the block and the surface is [NCERT-I, XI Pg. 102]

(1) $\sqrt{3}$ (2) $\frac{1}{\sqrt{3}}$

(3) $\sqrt{2}$ (4) $\frac{1}{\sqrt{2}}$

10. A cyclist speeding at 5 m/s on a level road takes a sharp circular turn of radius 2.5 m without reducing the speed. The minimum value of coefficient of static friction between tyre and road such that cyclist does not slip is [NCERT-I, XI Pg. 105]

(1) 0.5

(2) 1.5

(3) 1.0

(4) 0.8

11. A truck starts from rest and accelerates uniformly with 5 m/s^2. The minimum value of coefficient of static friction between surface of truck and a box placed on it such that box does not slip back, will be [NCERT-I, XI Pg. 110]

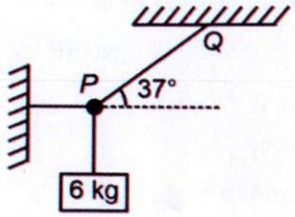
(1) 0.4

(2) 0.6

(3) 0.5

(4) 0.2

12. The tension in string PQ as shown in the figure is (g = 10 m/s^2)



[NCERT-I, XI Pg. 99]

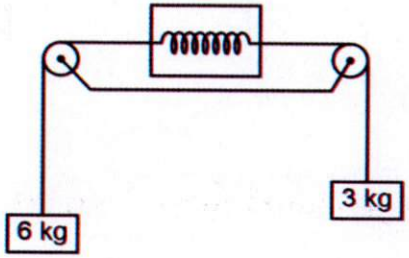
(1) 100 N

(2) 150 N

(3) 130 N

(4) 50 N

13. In the given figure, the reading of spring balance is (g = 10 m/s^2) [NCERT-I, XI Pg. 100]



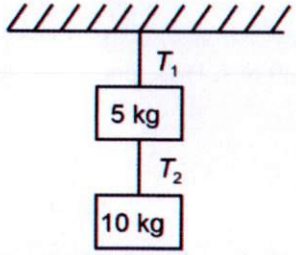
(1) 10 N

(2) 20 N

(3) 80 N

(4) 40 N

14. The ratio of tension T_1 and T_2, as shown in the figure is [NCERT-I, XI Pg. 100]



(1) $\frac{3}{2}$ (2) $\frac{1}{2}$

(3) $\frac{1}{3}$ (4) $\frac{4}{3}$

15. A car is moving on a curved road of radius R. The road is banked at an angle θ. The coefficient of friction between tyres of the car and road is μ. The minimum safe velocity on this road is [NCERT-I, XI Pg. 104]

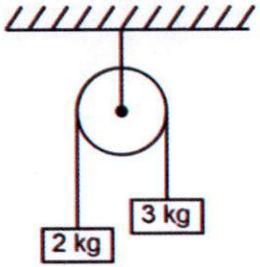
(1) $\sqrt{\frac{gR(\mu+\tan\theta)}{(1-\mu\tan\theta)}}$

(2) $\sqrt{\frac{gR(\tan\theta-\mu)}{(1+\mu\tan\theta)}}$

(3) $\sqrt{\frac{gR^2(\tan\theta-\mu)}{(1+\mu\tan\theta)}}$

(4) $\sqrt{\frac{gR(\tan\theta-\mu)}{(1-\mu\tan\theta)}}$

16. Two masses as shown in the figure are suspended from a smooth massless pulley. The acceleration of 3 kg mass, when system is released, will be [NCERT-I, XI Pg. 106]

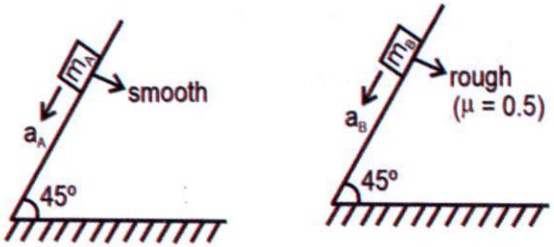


(1) 2.5 m/s^2 (2) 2.0 m/s^2
(3) 4.0 m/s^2 (4) 5.0 m/s^2

17. A body is acted upon by unbalanced forces, then body [NCERT-I, XI Pg. 95]

(1) Will be at rest
(2) Will keep moving with uniform speed
(3) Will accelerate
(4) Will be at rest if even number of forces will act

18. Two blocks *A* and *B* are released from rest on two inclined plane as shown in the figure.



The ratio of the accelerations (a_A / a_B) is

[NCERT-I, XI Pg. 102]

(1) 1
(2) 2
(3) 1.5
(4) 0.8

19. A 60 kg monkey, climbs on a rope which can withstand a maximum tension of 900 N. The case in which the rope will break if the monkey [NCERT-I, XI Pg. 113]

(1) Climbs up with acceleration of 6 m/s^2
(2) Climbs down with acceleration of 4 m/s^2
(3) Climbs up with uniform speed of 5 m/s
(4) Falls down the rope nearly freely under gravity

20. Which of the following is self adjusting force? [NCERT-I, XI Pg. 101]

(1) Static friction
(2) Limiting friction
(3) Kinetic friction
(4) All of these.

Thinking in Context

1. When horse starts suddenly, the rider falls backward due to inertia of _____.

[NCERT-I, XI Pg. 93]

2. An athlete runs some distance, before taking a long jump due to inertia of _____.

[NCERT-I, XI Pg. 93]

3. Suppose we are standing in a stationary bus and the driver starts the bus suddenly. Then we get thrown in _____ direction with a jerk

[NCERT-I, XI Pg. 93]

4. _____ of a body is defined to be the product of its mass and velocity.

[NCERT-I, XI Pg. 93]

5. The same force for same time causes the same _____ for different bodies

[NCERT-I, XI Pg. 94]

6. The rate of change of momentum of a body is _____ proportional to the applied force and takes place in the _____ in which the force acts. [NCERT-I, XI Pg. 94]

7. The product of force and _____, which is change in Linear momentum of body, is also called _____ [NCERT-I, XI Pg. 96]

8. In equation $\vec{F} = M\vec{a}$, any _____ forces in system are not included. [NCERT-I, XI Pg. 95]

9. The motion of a particle of mass m is described by $y = ut + \frac{1}{2}gt^2$. The force acting on the particle is _____. [NCERT-I, XI Pg. 96]

10. Action and Reaction forces acts on _____ bodies [NCERT-I, XI Pg. 97]

11. The total momentum of an isolated system of interacting particles is _____. [NCERT-I, XI Pg. 99]

12. A body is in translational equilibrium under three concurrent forces $\vec{F}_1, \vec{F}_2$ and $\vec{F}_3$, then $\vec{F}_1 + \vec{F}_2 + \vec{F}_2 =$ _____. [NCERT-I, XI Pg. 99]

13. Static friction opposes _____ motion [NCERT-I, XI Pg. 101]

14. The kinetic friction, like static friction in solids is found to be _____ of area of contact. [NCERT-I, XI Pg. 101]

15. Frictional force is the _____ of contact force which opposes the relative motion not the motion. [NCERT-I, XI Pg. 102]

16. We are able to walk because of the _____. [NCERT-I, XI Pg. 103]

17. The maximum velocity of car moving on a level circular road of radius R is _____ of mass of the car. [NCERT-I, XI Pg. 104]

18. A car is moving on circular banked road having inclination angle θ. If coefficient of static friction between road and tyre of car is μ_s, the maximum velocity of the car is _____. [NCERT-I, XI Pg. 105]

19. Impulse has the dimensional formula as _____. [NCERT-I, XI Pg. 108]

20. μ_s is the coefficient of static friction and μ_k is the coefficient of kinetic friction. It is found experimentally that μ_k is _____ than μ_s [NCERT-I, XI Pg. 108]

❑ ❑ ❑

Work, Energy and Power

6
Chapter

1 SCALAR PRODUCT

- Also called dot product
- $\vec{A}\cdot\vec{B} = AB\cos(\theta)$
- $\vec{A}\cdot\vec{B} = \vec{B}\cdot\vec{A}$
- $\vec{A}\cdot(\vec{B}+\vec{C}) = \vec{A}\cdot\vec{B} + \vec{A}\cdot\vec{C}$
- $\hat{i}\cdot\hat{i} = \hat{j}\cdot\hat{j} = \hat{k}\cdot\hat{k} = 1$
- $\hat{i}\cdot\hat{j} = \hat{j}\cdot\hat{k} = \hat{k}\cdot\hat{i} = 0$
- $(A_x\hat{i} + A_y\hat{j} + A_z\hat{k})\cdot(B_x\hat{i} + B_y\hat{j} + B_z\hat{k}) = A_xB_x + A_yB_y = A_zB_z$

2 WORK

- Scalar product of force and displacement is work.
- Work done by a force can be positive, negative or zero.
- Work done by gravity in horizontal displacement of object is zero.
- Work done by tension in pendulum bob is zero.
- Work done by spring elastic force during stretching or compressing is negative.
- Work can be done by a constant or variable force.

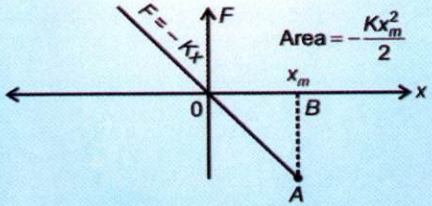
A. Constant force $W = \vec{F}\cdot\Delta\vec{r}$

B. Variable force $W = \int_{r_1}^{r_2} \vec{F}(r)\cdot d\vec{r}$

C. When force-displacement graph is given, Area under force-displacement curve gives work done by the force.

D. Work done in stretching a spring by distance Δl is

$W = \frac{1}{2}K(\Delta l)^2$



(Potential energy) $U = -W_S = \frac{1}{2}kx_m^2$

3 ENERGY

- Capability of an object to perform work is its energy.

Some common units of energy

Kilowatt hour	3.6×10^6 J
erg	10^{-7} J
Electron volt	1.6×10^{-19} J
Calorie	4.186 J

Mechanical energy is of two forms

Kinetic Energy

- Energy a body possesses by virtue of its motion.
- $KE = \frac{1}{2}mv^2$
- Its unit is joule
- Work is related to KE of body by theorem called work-energy theorem.

$$\Delta K = K_f - K_i = W = \int_{x_1}^{x_2} F(x)\,dx$$

- This theorem is in scalar form.
- Shape of graph between KE of a body and its speed is parabola.
- $(F_c + F_{nc})\Delta x = \Delta K$, when both forces are present

  F_c = Conservative forces

  F_{nc} = Non-conservative forces
- Kinetic energy of a body of fixed mass is directly proportional to square of its momentum.

$$K = \frac{P^2}{2m}$$

- Kinetic energy of fast moving air is used to generate electricity in wind mill.
- If two objects have same momentum, then the lighter has more kinetic energy and vice versa.
- Kinetic energy of fast flowing stream has been used to grind corn and now to generate hydro-electricity.

Potential Energy

- It is form of stored energy, by virtue of position or configuration of body.
- Notion of potential energy is applicable to class of conservative forces. Work done against such forces gets stored up as potential energy. When constraints are removed, this energy may appear as kinetic energy.
- Change in potential energy for a conservative force; ΔU is equal to negative of work done by the force
- $\Delta U = -\int_{\infty}^{r} \vec{F}\cdot d\vec{r}$
- A force is conservative if it is derived from a scalar quantity $U(x)$ by relation $F_x = -\frac{dU}{dx}$
- Work done by a conservative force depends only on initial and final points. Zero of potential energy is arbitrary.
- Work done by gravity depends on initial and final position only $U_h = mgh$ (Gravitational potential energy at height h)
- Potential energy of a stretched spring

$$U = \frac{Kx_m^2}{2}$$

K is spring constant. Spring is said to be stiff if K is high, x_m = extension of spring.

4 LAW OF CONSERVATION MECHANICAL ENERGY

- If conservative and non-conservative forces acts on a body then

$(F_c + F_{nc})\Delta x = \Delta K$

Now, $F_c \Delta x = -\Delta U$

$\Delta(K+U) = F_{nc}\Delta x$

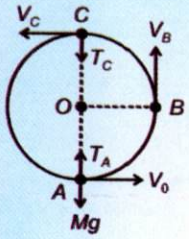
$\boxed{\Delta E = F_{nc}\Delta x}$

E = Total Mechanical Energy (Consequence of work energy theorem). If $F_{nc} = 0$ then $\boxed{\Delta E = 0}$

- Mechanical energy of a system is conserved if the forces doing work on it are conservative.

Conservative Forces	Non-conservative Forces
The work done by or against the force in moving a body depends only on initial and final position of the body and not on path followed in between.	The work done by or against the force in moving a body from one position to another depends on the path followed between the initial and final positions.

5 VERTICAL CIRCULAR MOTION



$T_A = \frac{MV_0^2}{L} + Mg$ and $E_A = \frac{1}{2}MV_0^2$

$E_C = \frac{1}{2}MV_C^2 + 2MgL$ = constant

$Mg = \frac{MV_C^2}{L}$ when string slackens (just completes loop)

$E_A = E_C = \frac{5}{2}MgL = \frac{MV_0^2}{2}$

$\therefore\ V_0 = \sqrt{5gL}$

Minimum speed at different locations to complete loop $V_C = \sqrt{gL}$

$V_B = \sqrt{3gL}$

$K_A : K_B : K_C = 5 : 3 : 1$

6 POWER

- Rate at which work is done is power.
- $P = \frac{dW}{dt} = F \cdot \frac{dr}{dt} = \vec{F} \cdot \vec{v}$
- Rate at which energy is transferred is power.
- Average power is ratio of total work to total time taken.
- $P_{av} = \frac{W}{t}$
- SI unit of power is watt.
- Another unit of power is horse power.

  [1 hp = 746 W]
- A machine which performs same amount of work over a shorter period of time has more power.

7 COLLISION

- Exchange of momentum between objects is consequence of collision, due to material impulsive forces. The laws of momentum and energy conservation are used in collision.
- Collision are classified as elastic and inelastic collision depending on nature of colliding bodies.
- In all collisions, total linear momentum of the systemis conserved. Initial momentum of system is equal to final momentum of the system.

COLLISION

PERFECT INELASTIC COLLISION

A collision in which two colliding particles move together (in one dimensions) after the collision is complete inelastic collision. Kinetic energy is always lost in such collisions. For m_1 moving at u_1 and m_2 at rest.

$v_f = \frac{m_1 u_1}{m_1 + m_2}$

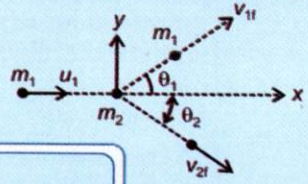
Loss in KE on collision

$\boxed{\Delta K = \frac{1}{2}\left(\frac{m_1 m_2}{m_1 + m_2}\right)(u_1)^2}$

INELASTIC

An intermediate collision case where the deformation is partly restored and some of initial kinetic energy is lost. Momentum of two colliding bodies before and after will remain conserved.

- In two dimension, inelastic collision if target at rest, two object don't move at right angles to each other (glancing collision) even when identical.



ELASTIC COLLISION

Both linear momentum and kinetic energy of system of colliding particles will remain conserved.

- In one dimensional collision with target initially at rest

$\boxed{v_{1f} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1}$

$\boxed{v_{2f} = \frac{2m_1 u_1}{m_1 + m_2}}$

- If two masses are equal and target is at rest

$\boxed{\begin{matrix} v_{1f} = 0 \\ v_{2f} = u_1 \end{matrix}}$

First one comes to rest and pushes off the second with its initial speed. Thus, velocities are exchanged

- If $m_2 >> m_1$

$\boxed{v_{1f} = -u_1 \text{ and } v_{2f} = 0}$

Heavier mass is undisturbed while lighter mass reverses its velocity.

- Fraction of kinetic energy lost by targetting body when target at rest

$f_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2$

and fraction of KE gained by target being at rest initially

$f_2 = \frac{4m_1 m_2}{(m_1 + m_2)^2}$

- When two equal masses undergo two dimensional elastic collision with one of them at rest, after collision they will move at right angles to each other.

Sharpen Your Understanding

1. What is the angle between force $\vec{F} = 3\hat{i} + 4\hat{j} - 5\hat{k}$ unit and displacement $\vec{S} = 4\hat{j} + 3\hat{k}$ unit? [NCERT Pg. 115]

(1) $\cos^{-1}\left(\frac{1}{5\sqrt{2}}\right)$ (2) $\cos^{-1}\left(\frac{1}{25\sqrt{2}}\right)$

(3) $\cos^{-1}\left(\frac{1}{5}\right)$ (4) $\cos^{-1}\left(\frac{1}{25}\right)$

2. A force F = 20 N acts on a object and displaces it from rest to speed of 10 m/s in its direction. What is displacement, if mass of object is 2 kg? [NCERT Pg. 119]

(1) 6 m (2) 5 m

(3) 12 m (4) 10 m

3. Raindrop is falling downwards under influence of gravity and opposing resistive force. Consider a drop of mass 5.00 g falling from height of 500 m and hits ground with speed of 70 m s^{-1}. What is work done by resistive force? [NCERT Pg. 136]

(1) –7.85 J (2) –9.50 J

(3) –12.75 J (4) –13.50 J

4. A cyclist comes to skidding stop in 6 m. During this process the force on cycle due to road is 120 N and is opposing the motion. How much work does road do on cycle? [NCERT Pg. 117]

(1) –720 J (2) –420 J

(3) 20 J (4) Zero

5. A shooter fires a bullet of mass 50 g with speed of 200 m s^{-1} on soft wood of thickness 2 cm. If bullet looses 80% of its kinetic energy and emerges out. What is emergent bullet speed? [NCERT Pg. 118]

(1) 89.4 m s^{-1} (2) 69.5 m s^{-1}

(3) 100 m s^{-1} (4) 20.0 m s^{-1}

6. A woman pushes a box on railway platform which has rough surface. She applies a force of 20 N over a distance of 5 m thereafter gets tired and applied force which reduces linearly to 10 N with distance. The total distance which box has been moved is 10 m. Work done during second displacement is [NCERT Pg. 119]

(1) 175 J (2) 19.5 J

(3) 75 J (4) 14.65 J

7. A block of mass m = 1 kg is moving on horizontal surface with speed of 4 m s^{-1} enters a rough patch ranging from x = 0.1 m to x = 1.6 m. The retarding force in this range is inversely proportional to x

$F = -\frac{1}{x}$ (0.1 < x < 1.6 m)

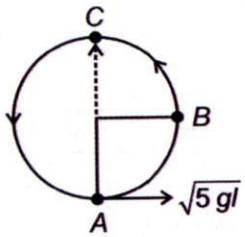
What is final kinetic energy of the body? [NCERT Pg. 120]

(1) 9.2 J (2) 7.3 J

(3) 6.84 J (4) 5.23 J

NCERT Based MCQs

8. A bob of mass m is suspended by light string of length l. At lowest position it is imparted a horizontal velocity $\sqrt{5gl}$ such that it just completes circular trajectory in vertical circle. What is ratio of its KE at B and C? [NCERT Pg. 122]



(1) 2 : 1 (2) 3 : 1

(3) 5 : 3 (4) 3 : 2

9. The potential energy of a body as a function of distance is given as $U(x) = (-6x^2 + 2x)$ J

The conservative force acting on body at x = 1 m will be [NCERT Pg. 124]

(1) 6 N (2) 8 N

(3) 10 N (4) 12 N

10. Consider the following statements.

A: Spring force is deformation dependent.

B: Work done by spring force depends on initial and final deformation. [NCERT Pg. 124]

(1) Both statements are true

(2) Both statements are false

(3) Only first statement is true

(4) Only second statement is true

11. A spring is executing motion about equilibrium position $x = 0$ where we take potential energy of spring to be zero. The spring is oscillating between $-x_m$ and $+x_m$ position with a mass m attached. During motion, maximum speed of spring will be

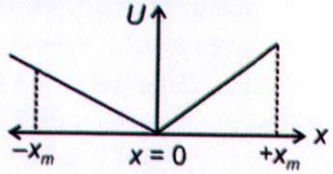
[NCERT Pg. 124]

(1) $2\sqrt{\frac{k}{m}}\,x_m$ (2) $\sqrt{\frac{k}{m}}\,x_m$

(3) $\sqrt{\frac{k}{2m}}\,x_m$ (4) $\sqrt{\frac{k}{m}}\left(\frac{x_m}{2}\right)$

12. The graph between potential energy (U) of a spring versus its position (x) is best shown by graph (equilibrium $x = 0$)

[NCERT Pg. 124]

(1)


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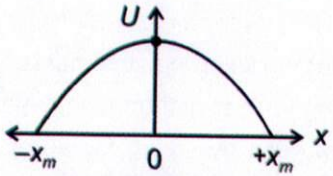

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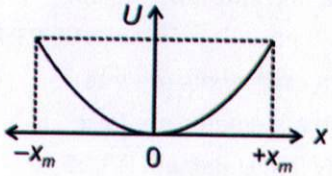

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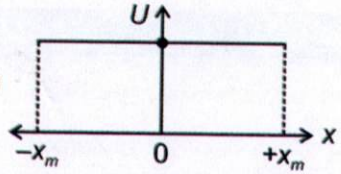


13. Consider a situation in which a car of mass 2000 kg moving with speed of 54 km/h on a smooth road and colliding with a horizontal mounted spring of spring constant 12.5×10^3 Nm^{-1}. What is maximum compression of spring?

[NCERT Pg. 124]

(1) 4 m (2) 6 m

(3) 8 m (4) 1 m

14. An elevator can carry a maximum load of 900 kg (elevator + passengers) is moving up with constant speed of 2 m s^{-1}. A constant frictional force of 5000 N opposes the motion. What minimum power is delivered by motor (in HP)?

[NCERT Pg. 128]

(1) 37.5 HP (2) 32.5 HP

(3) 42.5 HP (4) 50.2 HP

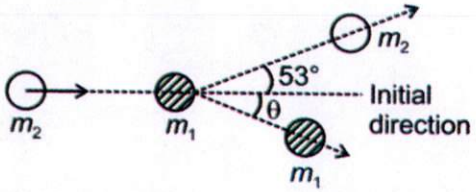
15. Two objects with mass $m_1 = 2$ kg and $m_2 = 3$ kg collides perfect inelastically. The particles were moving with speed of 10 m s^{-1} and zero respectively before collision. The loss of KE on collision is

[NCERT Pg. 131]

(1) 60 J (2) 40 J

(3) 100 J (4) 90 J

16. Consider a collision between two identical billiard balls with equal masses $m_1 = m_2 = m$. First ball was at rest and second hits it on edge. Second ball after hitting moves through an angle of 53° to initial direction. Assuming elastic collision, the angle through which first ball moves with initial line after collision is



[NCERT Pg. 131]

(1) 53° (2) 47°

(3) 37° (4) 90°

17. In a nuclear reactor, a neutron of high speed 10^4 m s^{-1} collides elastically with a light nuclei of deuterium (at rest). The collision results in loss of KE of neutron. What fraction of KE is lost by neutron?

[NCERT Pg. 130]

(1) $\frac{1}{4}$ (2) $\frac{2}{5}$

(3) $\frac{1}{9}$ (4) $\frac{2}{9}$

18. A bullet of mass 12 g and moving with horizontal speed of 100 m s^{-1} strikes a block of wood of mass 348 g and instantly comes to rest with respect to block. The block is suspended from ceiling by means of a thin wire. The height through which block rises is

[NCERT Pg. 137]

(1) 0.55 m (2) 0.88 m

(3) 0.77 m (4) 1.22 m

19. The blades of wind mill sweep out a circle of area $A = 2\ m^2$. The wind is flowing at velocity $v = 6\ m\ s^{-1}$ perpendicular to circle, the density of air is $1.2\ kg\ m^{-3}$. What is power generated? [NCERT Pg. 137]

(1) 160.8 W (2) 259.2 W
(3) 302.5 W (4) 239.2 W

20. An electron and a proton are detected in cosmic ray experiment. The electron has kinetic energy of 20 keV and proton has 50 keV. The ratio of speed of electron to proton is ($m_e = 9 \times 10^{-31}$ kg, $m_p = 1.6 \times 10^{-27}$ kg) [NCERT Pg. 136]

(1) 15.7 (2) 17.5
(3) 26.6 (4) 4.9

Thinking in Context

1. Work done by a force is defined as product of _____ in the direction of displacement and magnitude of its displacement. [NCERT Pg. 117

2. 1 kilowatt hour (kW h) is equal to _____ joule. [NCERT Pg. 117]

3. The _____ energy of fast flowing stream has been used to grind corn. [NCERT Pg. 118]

4. A graph shows variable force drawn on *Y*-axis and corresponding displacement on *X*-axis. The area under the curve is equal to _____ by force. [NCERT Pg. 119]

5. Work-Energy theorem is useful in variety of problems. It is an integral from of Newton's _____ law. [NCERT Pg. 119]

6. Potential energy is stored energy by virtue of _____ of body. [NCERT Pg. 120]

7. The notion of potential energy is applicable only to _____ forces where work done against the forces gets stored as energy. [NCERT Pg. 120

8. The dimensions of potential energy are _____ and unit is _____. [NCERT Pg. 120

9. The work done by conservative force depends only on the ends points and work done by this force in a closed path is _____. [NCERT Pg. 121]

10. Total mechanical energy of a system is conserved if the forces, doing work on it, are _____. [NCERT Pg. 121]

11. A bob is suspended by a light string and bob is given velocity at lowest position such that it completes semicircular trajectory in vertical plane. There are two external forces on bob, these are _____ and _____. [NCERT Pg. 122]

12. Work done by external pulling force on a spring is _____. [NCERT Pg. 124]

13. A moving car collides with a horizontal mounted spring and compresses it. In this case _____ energy of the car is converted entirely into _____ of the spring. [NCERT Pg. 125]

14. Not all forces are conservative, _____ for example is a non-conservative force. [NCERT Pg. 125]

15. The work done by friction on a body is not lost but is transferred as _____ energy. [NCERT Pg. 125]

16. In collision, the total _____ is conserved, but _____ of system is not necessarily conserved. [NCERT Pg. 129

17. A collision in which two particles move together after the collision is called _____ collision. [NCERT Pg. 129]

18. A collision in which deformation of colliding bodies is partly relieved and some of initial kinetic energy is lost is called _____ collision. [NCERT Pg. 129

19. The fraction of kinetic energy lost by targeting body hitting target at rest is _____ when both bodies have equal masses. [NCERT Pg. 131

20. When two equal masses undergo a glancing collision elastically with one of them at rest, after the collision, they will move at _____ to each other. [NCERT Pg. 132]

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System of Particles and Rotational Motion

7
Chapter

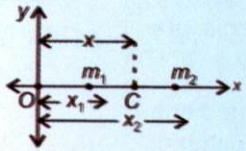
1 RIGID BODY

- Ideally a rigid body is a body with a perfectly definite and unchanging shape. The distances between all pairs of particles of such a body do not change.
- In pure translational motion at any instant of time all particles of the body have same velocity.
- The motion of rigid body which is pivoted or fixed is rotation. Every particle of the body moves in a circle.
- The motion of rigid body which is not pivoted or fixed in some way is either a pure translation or is combination of translation and rotation

2 CENTRE OF MASS

- COM is an imaginary point where mass of an extended body is assumed to be concentrated
- This concept is used to study indepedently translatory and rotatory motion under effect of external forces.
- The laws of motion which are applied to particles can be applied to large sized bodies by converting body into a particle at location of COM.
- **Centre of mass for two particle system**

$$\vec{R}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1 + m_2}$$



- For x and y plane

$$X_{cm} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2} \text{ and, } Y_{cm} = \frac{m_1y_1 + m_2y_2}{m_1 + m_2}$$

- For a system of n particles distributed in space,

$$X_{cm} = \frac{\sum m_ix_i}{M}, Y_{cm} = \frac{\sum m_iy_i}{M}, Z_{cm} = \frac{\sum m_iz_i}{M}$$

- **COM For Continous Mass**

If the body has continous distribution of mass (RING, DISC, ROD)

$$\boxed{\vec{R} = \frac{1}{M}\int \vec{r}dm} \quad M = \text{total mass of body}$$

The co-ordinates of COM of body,

$$X_{cm} = \frac{1}{M}\int xdm, Y_{cm} = \frac{1}{M}\int ydm, Z_{cm} = \frac{1}{M}\int zdm$$

- If we choose centre of mass at origin $\int \vec{r}dm = 0, \int xdm = \int ydm = \int zdm = 0$
- For homogeneous bodies of regular shape, centre of mass lies at geometric centre.

3 MOTION OF COM

$$M\vec{R} = \sum m_i\vec{r}_i$$

$$\therefore M\vec{V} = \sum m_i\vec{v}_i$$

- Velocity of COM of system

$$\boxed{\therefore \vec{V} = \frac{\sum m_i\vec{v}_i}{M}}$$

- Acceleration Of Com of System

$$\vec{A} \text{ or } \vec{a}_{cm} = \frac{\sum m_i\vec{a}_i}{M}$$

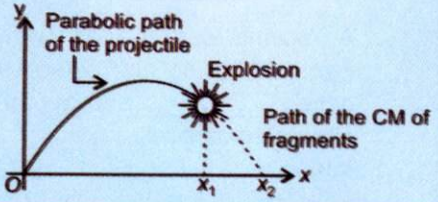
- Total mass of system of particles times the acceleration of its centre of mass is vector sum of all forces acting on system of particles.

$$M\vec{A} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ... + F_n$$

$$M\vec{A} = \vec{F}_{ext}$$

$$\boxed{\vec{A} = \frac{\vec{F}_{ext}}{M} = \frac{\text{Total external force}}{\text{Total mass of system}} = \frac{\sum m_i\vec{a}_i}{M}}$$

- Centre of mass of the system of particles moves as if all mass of a system was concentrated at centre of mass and all the external forces were applied at that point.
- A projectile following parabolic path explodes into fragments in mid air. The forces leading to explosion are internal, they contribute nothing to motion of COM. Total external force gravity acting on body is same before and after explosion. The COM under influence of external forces continue along same parabolic trajectory as it would have followed without explosion.



4 LINEAR MOMENTUM OF SYSTEM OF PARTICLES

- Velocity of COM for a system of n particles

$$\vec{P} = \vec{p}_1 + \vec{P}_2 + ...+ \vec{p}_n = m_1\vec{v}_1 + m_2\vec{v}_2 + ...+ m_n\vec{v}_n$$

$$\boxed{\vec{V} = \frac{m_1\vec{v}_1 + m_1\vec{v}_2 + ...+ m_n\vec{v}_n}{M}}$$

This is the velocity of centre of mass

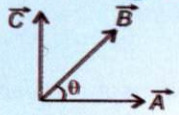
- Total linear momentum of system of particles is equal to the product of total mass of system and velocity of its centre of mass.
- When total external force acting on a system of particles is zero, total linear momentum of system is constant. The velocity of centre of mass remains constant.

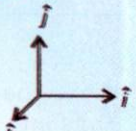
$$\vec{P} = m\vec{v}$$

$$\text{if } \vec{F}_{ext} \Rightarrow \frac{d\vec{P}}{dt} = 0 \quad \boxed{P = \text{constant}}$$

- If centre of mass was initially at rest, for no external force, centre of mass will remain at rest.

5 CROSS PRODUCT





- $\vec{C} = \vec{A} \times \vec{B}$

$|\vec{C}| = |\vec{A}||\vec{B}|\sin\theta$

θ is angle between $\vec{A}$ and $\vec{B}$

- Properties

$\vec{A} \times \vec{B} \neq \vec{B} \times \vec{A}$

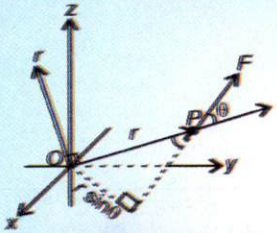
$\vec{A} \times \vec{B} = -(\vec{B} \times \vec{A})$

$\vec{A} \times \vec{A} = \vec{0}$

$\hat{i} \times \hat{i} = \vec{0}$
$\hat{j} \times \hat{j} = \vec{0}$
$\hat{k} \times \hat{k} = \vec{0}$
$\hat{i} \times \hat{j} = \hat{k}$
$\hat{j} \times \hat{k} = \hat{i}$
$\hat{k} \times \hat{i} = \hat{j}$
$\hat{j} \times \hat{i} = -\hat{k}$
$\hat{k} \times \hat{j} = -\hat{i}$
$\hat{j} \times \hat{k} = -\hat{i}$

6 MOMENT OF FORCE (TORQUE)

- Analogue of force in case of rotational motion is torque, which is turning effect of a force.
- $\vec{\tau} = \vec{r} \times \vec{F}$ when force acts on a particle whose position vector w.r.t. origin is $\vec{r}$.
- This is a vector quantity having SI units N m.
- Magnitude of torque



$\tau = rF\sin\theta$

$\tau = (r\sin\theta) \times F = r_{\perp}F$

$\tau = rF\sin\theta = rF_{\perp}$

$r_{\perp} = r\sin\theta$ = perpendicular distance of line of action of force from origin (axis of rotation) and $\vec{F}_{\perp}$ is component of $\vec{F}$ Perpendicular to $\vec{r}$.

- If direction of $\vec{r}$ and $\vec{F}$ are reversed, the direction of moment of force remains same.
- Couple : A pair of equal and opposite forces with different lines of action is known as a couple. A couple produces rotation without translation example : opening a bottle.

7 ANGULAR MOMENTUM

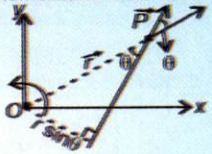
- It is referred as moment of linear momentum. For a particle,

$\boxed{\vec{L} = \vec{r} \times \vec{P}}$

The magnitude of angular momentum vector is $L = rp\sin\theta$

$L = r \times P\sin\theta = r \times P_{\perp}$

$L = r\sin\theta \times P = r_{\perp} \times P$



$r_{\perp} = (r\sin\theta)$ = is perpendicular distance of directional line of $\vec{P}$ from origin and

$P_{\perp}$ = component of P in the direction perpendicular to $\vec{r}$

- Angular momentum will be zero when $P = 0$ or particle is at origin or or line of P passes through origin.
- **Angular Momentum Conservation Law**

$\vec{\tau} = \frac{d\vec{L}}{dt}$ (time rate of change of angular momentum of a system of particles is equal to torque acting on it.)

- If total external torque on a system of particles is zero, total angular momentum remains constant for the system.

$\vec{\tau} = 0 \rightarrow \boxed{\frac{d\vec{L}}{dt} = 0}$

$\vec{L}$ = constant

8 EQUILIBRIUM OF RIGID BODY

A rigid body is said to be in mechanical equilibrium if both its linear momentum and angular momentum are not changing with time or equivalently, the body has neither linear acceleration nor angular acceleration.

- Vector sum of forces on rigid body is zero $\sum \vec{F}_i = 0$
- Vector sum of torques on rigid body is zero. $\sum \vec{\tau}_i = 0$
- Rotational equilibrium condition is independent of location of origin about which torques are taken.
- A body may be in partial equilibrium i.e. rotational equilibrium but not transnational.

9 MOMENT OF INERTIA : MOI

- Analogue of mass, in rotational motion is rotational inertia also called moment of inertia.
- This is a characteristics of rigid body and the axis about which it rotates. It depends on distribution of mass and position of axis of rotation.
- This parameter is independent of magnitude of angular velocity of body. For a system of particles moment of inertia is given by $I = \sum_{i=1}^{n} m_i r_i^2$

MOMENT OF INERTIA OF DIFFERENT RIGID BODIES

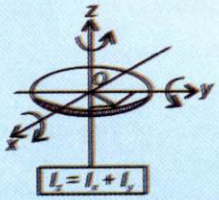
(Regular Shaped)

Body	Axis	I
Thin circular ring, radius R	Perpendicular to plane, at centre	MR^2
Thin circular ring, radius R	Diameter	$MR^2/2$
Thin rod, length L	Perpendicular to rod, at mid point	$ML^2/12$
Circular disc, radius R	Perpendicular to disc at centre	$MR^2/2$
Circular disc, radius R	Diameter	$MR^2/4$
Hollow cylinder, radius R	Axis of cylinder	MR^2
Solid cylinder, radius R	Axis of cylinder	$MR^2/2$
Solid sphere, radius R	Diameter	$2MR^2/5$
Hollow sphere, radius R	Diameter	$2MR^2/3$

THEOREMS OF MOI

Theorem of perpendicular axes

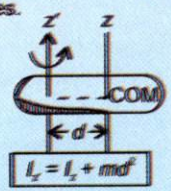
- Theorem is applicable to bodies whose thickness is small compared to other dimensions. (Planar body)
- MOI of a planar body about an axis perpendicular to its plane is equal to the sum of its MOI about two perpendicular axes concurrent with perpendicular axis and lying in plane of body.



$I_z = I_x + I_y$

Theorem of parallel axes

- The theorem is applicable to body irrespective of any shape.
- MOI of a body about any axis is equal to the sum of MOI of the body about a parallel axis passing through its COM and the product of its mass and the square of distance between the two parallel axes.



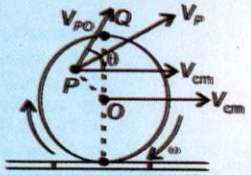
$I_z = I_z + md^2$

10 TRANSNATIONAL AND ROTATIONAL MOTION ANALOGY

Linear motion	Rotation about a fixed Axis
Displacement x	Angular displacement θ
Velocity $v = \frac{dx}{dt}$	Angular velocity $\omega = \frac{d\theta}{dt}$
Mass m	Moment of inertia I
Force $F = ma$	Torque $\tau = I\alpha$
Work $dW = Fds$	Work $= dW = \tau d\theta$
Kinetic energy $k = \frac{mv^2}{2}$	Kinetic energy $k = \frac{I\omega^2}{2}$
Power $P = \vec{F}.\vec{V}$	Power $P = \vec{\tau}.\vec{\omega}$
Linear momentum $P = mV$	Angular momentum $L = I\omega$
$\vec{F} = \frac{d\vec{p}}{dt}$	$\vec{\tau} = \frac{d\vec{L}}{dt}$

11 ROLLING MOTION

- All wheels used in transportation have rolling motion.
- It is combination of rotation and translation with axis moving.
- When disc rolls without slipping, At any instant of time bottom of disc which is in contact with surface is at rest with respect to surface.



$\vec{V}_P = \vec{V}_{PO} + \vec{V}_{cm}$

$|V_P| = [(V_{PO})^2 + V_{cm}^2 + 2V_{PO}V_{cm}\cos\theta]^{1/2}$

- In pure rolling with out slipping $\Rightarrow v = R\omega$
- Top of a rolling body has magnitude of velocity

$V_Q = V_{cm} + \omega_{cm}R = V_{cm} + V_{cm} = 2V_{cm}$, Bottom is at rest w.r.t. surface

12 KINETIC ENERGY OF TRANSLATING AND ROTATING BODIES:

- K.E of translation + K.E of rotational motion

$$KE = \frac{1}{2}MV_{cm}^2 + \frac{1}{2}I\omega^2$$

where $I = MK^2$, K is corresponding radius of gyration

Radius of Gyration : Distance from axis of rotation of a point mass whose mass is equal to mass of whole body and whose moment of inertia is equal to moment of inertia of body about the axis.

- **Kinetic Energy In Case Of Pure Rolling Motion**

$V_{cm} = R\omega_{cm}$

$$KE = \frac{1}{2}MV_{cm}^2 + \frac{1}{2}MK^2\left(\frac{V_{cm}^2}{R^2}\right)$$

$$KE = \frac{1}{2}MV_{cm}^2\left[1 + \frac{K^2}{R^2}\right]$$

This formula can be used to all rolling bodies like ring, disc, cylinder sphere.

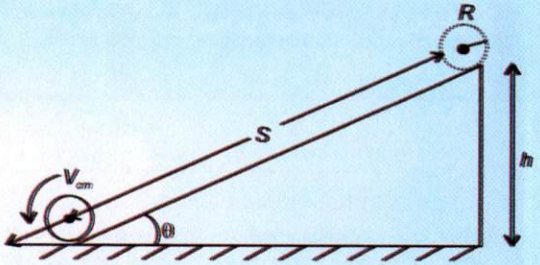
13 KINEMATICS OF ROLLING BODIES DOWN ROUGH INCLINE PLANE

We apply conservation of mechanical energy to rolling bodies as Rolling friction performs no work.

$\Delta P.E. = \Delta K.E.$

$$mgh = \frac{1}{2}mV_{cm}^2\left[1 + \frac{K^2}{R^2}\right]$$

Velocity at bottom $V_{cm} = \sqrt{\frac{2gh}{1 + \frac{K^2}{R^2}}}$



Acceleration of COM ; $a = \frac{g\sin\theta}{1 + (K/R)^2}$

Minimum coefficient of friction required for pure rolling $\mu = \left(\frac{K^2}{R^2 + K^2}\right)\tan\theta$

Time to reach the bottom $= \frac{1}{\sin\theta} \times \sqrt{\frac{2h}{g} \times \left(\frac{K^2}{R^2} + 1\right)}$

Sharpen Your Understanding

NCERT Based MCQs

1. Three particles of equal masses are placed at co-ordinates (1, 1), (2, 2) and (4, 4) respectively. The position co-ordinate of COM of system of three particles is [NCERT Pg. 146]

(1) (0, 0) (2) $\left(\frac{2}{7},\frac{7}{2}\right)$

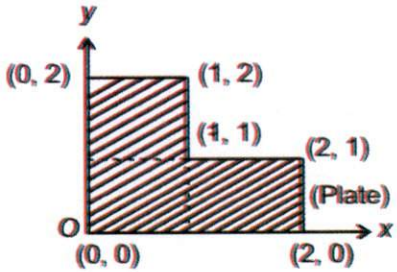
(3) $\left(\frac{7}{3},\frac{7}{3}\right)$ (4) (2, 2)

2. Consider a system of two identical particles. One of the particles is at rest and the other has an acceleration a. The centre of mass has an acceleration [NCERT Pg. 146]

(1) Zero (2) $\frac{1}{2}a$

(3) a (4) 2 a

3. A thin uniform flat plate is in shape of *L* as shown. The mass of lamina is 6 kg. The position of centre of mass from point *O* [NCERT Pg. 147]



(1) $\left(\frac{5}{3}m,\frac{5}{3}m\right)$ (2) $\left(\frac{2}{3}m,\frac{5}{3}m\right)$

(3) $\left(\frac{1}{6}m,\frac{2}{6}m\right)$ (4) $\left(\frac{5}{6}m,\frac{5}{6}m\right)$

4. Which relation regarding product of two vectors is incorrect? [NCERT Pg. 151]

(1) $\vec{a}\times\vec{a}=0$

(2) $a.(\vec{b}+\vec{c})=(\vec{a}.\vec{b})+(\vec{a}.\vec{c})$

(3) $\vec{a}\times\vec{b}=(-\vec{a})\times(-\vec{b})$

(4) $\vec{a}\times\vec{b}=\vec{b}\times\vec{a}$

5. The vector product of given two vectors $\vec{A}=3\hat{i}-4\hat{j}+5\hat{k}$ and $\vec{B}=2\hat{i}+\hat{j}+\hat{k}$ is [NCERT Pg. 152]

(1) $-9\hat{i}+13\hat{j}+11\hat{k}$ (2) $-9\hat{i}-13\hat{j}+11\hat{k}$

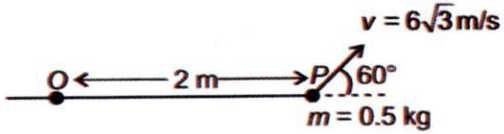
(3) $-9\hat{i}+7\hat{j}+11\hat{k}$ (4) $-9\hat{i}+7\hat{j}-11\hat{k}$

6. The force acting on a particle is $(\hat{i}+2\hat{j}+3\hat{k})$ N. Find the torque of this force about origin if position vector of force is $(7\hat{i}+3\hat{j}+5\hat{k})$ m. [NCERT Pg. 157]

(1) $\hat{i}+16\hat{j}-11\hat{k}$ (2) $-\hat{i}-16\hat{j}+11\hat{k}$

(3) $\hat{i}+16\hat{j}+11\hat{k}$ (4) $-\hat{i}+9\hat{j}+11\hat{k}$

7. The angular momentum of a particle of mass 0.5 kg about point *O* at the instant as shown in the figure, is [NCERT Pg. 158]



(1) 6 kgm^2s^{-1}

(2) 9 kgm^2s^{-1}

(3) 18 kgm^2s^{-1}

(4) $9\sqrt{3}$ kg m^2s^{-1}

8. Which of the following statement is incorrect? [NCERT Pg. 158]

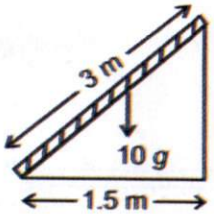
(1) Moment of couple is independent of point about which moment is taken.

(2) For translational equilibrium of a body vector sum of all the forces on it must be zero

(3) A body may be in translational equilibrium but may not be in rotational equilibrium simultaneously

(4) Rotational equilibrium depends on location of origin about which torques are taken

9. A 3 m long ladder weighing 10 kg leans on a frictionless wall. Its feet rest on floor 1.5 m from wall as shown. What is reaction force of the wall? [NCERT Pg. 162]



(1) $\frac{50}{\sqrt{3}}$N (2) $50\sqrt{3}$N

(3) $100\sqrt{3}$N (4) 120 N

10. Which of the following statement is incorrect? [NCERT Pg. 163]

(1) Moment of inertia depends on distribution of mass about rotational axis

(2) Moment of inertia depends on orientation and position of axis of rotation

(3) Moment of inertia changes when angular velocity of body changes

(4) Flywheel resists sudden increase or decrease of speed of vehicle

11. A ring has mass of 6 kg and radius of 2 m. What is moment of inertia of this ring about a tangent to the circle of ring in its plane? [NCERT Pg. 166]

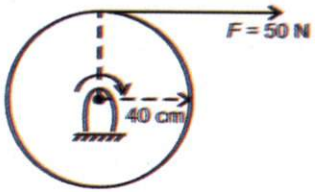
(1) 24 kg m^2

(2) 12 kg m^2

(3) 30 kg m^2

(4) 36 kg m^2

12. A cord of negligible mass is wound round the rim of flywheel disc with mass of 15 kg and radius of 40 cm. A steady pull of 50 N is applied to cord as shown. The wheel is mounted on horizontal axis. What is angular acceleration of wheel? [NCERT Pg. 171]



(1) 10.33 rad s^{-2} (2) 16.66 rad s^{-2}

(3) 20.66 rad s^{-2} (4) 4.99 rad s^{-2}

13. A cord of negligible mass is wrapped around a solid cylinder of a mass 20 kg and radius 20 cm. A steady pull of 25 N is applied on cord tangentially. The cylinder is mounted on horizontal axis with frictionless bearings. What is kinetic energy of wheel when 2 m cord is unwound? [NCERT Pg. 171]

(1) 50 J

(2) 100 J

(3) 150 J

(4) 90 J

14. Four bodies; a ring, a solid cylinder, a hollow sphere and a solid sphere of same mass are allowed to roll down a rough inclined plane without slipping from same level. The body with greatest rotational kinetic energy at bottom is [NCERT Pg. 178]

(1) Ring

(2) Solid cylinder

(3) Hollow sphere

(4) Solid sphere

15. A car weighs 1800 kg. The distance between its front axle and back axle is 1.8 m. Its centre of gravity is 1.05 m behind front axle. The force exerted by level ground on front wheels is (g = 10 ms^{-2}) [NCERT Pg. 178]

(1) 7500 N (2) 6500 N

(3) 9500 N (4) 1800 N

16. A ring (circular) of radius 2 m has mass of 100 kg. It rolls purely along horizontal floor so that its COM has speed 20 cm s^{-1}. The work required to stop it is [NCERT Pg. 179]

(1) 2 J

(2) 3 J

(3) 4 J

(4) 8 J

17. To maintain a rotor at a uniform angular speed of 200 rad s^{-1} an engine needs to transmit a torque of 125 Nm. What is power required by the engine? [NCERT Pg. 179]

(1) 15 kW (2) 20 kW

(3) 25 kW (4) 50 kW

18. A bullet of mass 10 gram is fixed with speed of 500 m s^{-1} into a door and gets embedded exactly at centre of door. The door is 1 m wide and weighs 12 kg. Door is hinged along one side and rotates about vertical axis without friction. The angular speed of door just after bullet embeds into it is [NCERT Pg. 180]

(1) 0.35 rad s^{-1}
(2) 0.625 rad s^{-1}
(3) 0.255 rad s^{-1}
(4) 0.935 rad s^{-1}

19. A solid disc of radius 10 cm are placed on a horizontal table (rough) with initial angular speed equal to 10 π rad s^{-1}. If coefficient of kinetic friction between disc and table is 0.2 then time taken by the disc to start pure rolling will be [NCERT Pg. 181]

(1) $\frac{\pi}{2}$ s
(2) $\frac{\pi}{3}$ s
(3) $\frac{\pi}{6}$ s
(4) $\frac{\pi}{4}$ s

20. A child stands at centre of turntable with his two arms outstretched. The turntable is set rotating with angular speed of 40 rad s^{-1}. What will be angular speed of child if he folds his hands back reducing moment of inertia to $\frac{2}{5}$ times the initial value (ignore friction?) [NCERT Pg. 180]

(1) 50 rad s^{-1}
(2) 75 rad s^{-1}
(3) 100 rad s^{-1}
(4) 150 rad s^{-1}

Thinking in Context

1. For three particles of equal masses placed at corners of an equilateral triangle, the centre of mass coincides with_____ of the triangle. [NCERT Pg. 145]
2. Centre of mass of homogeneous bodies of regular shapes, from symmetric consideration, lie at _____. [NCERT Pg. 146]
3. When total external force on the system is zero, the velocity of its centre of mass _____. [NCERT Pg. 148]
4. For rotation about a fixed axis, angular velocity vector lies along _____. [NCERT Pg. 153]
5. The rotational analogue of force in linear motion is _____. It is also called _____. [NCERT Pg. 154]
6. If total _____ on a system of particles is zero, then total angular momentum of the system is conserved. [NCERT Pg. 157]
7. A pair of forces of equal magnitudes but acting in opposite directions with different lines of action is known as _____ . [NCERT Pg. 159]
8. The centre of gravity (CG) of a body is that point where total gravitation _____ on the body is zero. [NCERT Pg. 161]
9. The centre of gravity of a body coincides with centre of mass in _____ [NCERT Pg. 162]
10. The distance from axis of a mass point whose mass is equal to mass of whole body and whose moment of inertia is equal to moment of inertia of body about the axis is called _____. [NCERT Pg. 164]
11. The work done by external torques is not dissipated then it goes on to increase _____ energy of the body. [NCERT Pg. 171]
12. For bodies which are not symmetric about the axis of rotation, the direction of angular momentum may not coincide with direction of _____. [NCERT Pg. 172]
13. A circus acrobat and a diver uses the advantage of principle of _____. [NCERT Pg. 172]
14. All wheels used in transportation have _____ motion. [NCERT Pg. 173]
15. Kinetic energy of a rolling body can be separated into kinetic energy of translation and kinetic energy of rotation. The fraction of rotational kinetic energy depends on _____. [NCERT Pg. 174]

16. Three bodies, a ring, a solid cylinder and solid sphere roll down the same incline without slipping. The least velocity of centre of mass at the bottom of incline plane is for_____. [NCERT Pg. 175]

17. A rigid body is in mechanical equilibrium then [NCERT Pg. 158]

(1) In translational equilibrium _____.

(2) In rotational equilibrium_____.

18. For rolling motion without slipping V_{cm} = _____where V_{cm} is velocity of translation of centre of mass. [NCERT Pg. 174]

19. The cross product of two vectors $\vec{A}$ and $\vec{B}$ is a vector written as $\vec{A} \times \vec{B}$. The magnitude of this vector is $AB\sin\theta$ and its direction is given by_____. [NCERT Pg. 151]

20. For pure rolling motion, work done against friction is_____ [NCERT Pg. 175]

❑ ❑ ❑

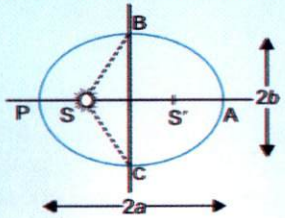
Gravitation

8 Chapter

1 KEPLER'S LAWS OF PLANETARY MOTION

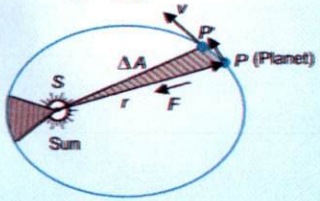
Law of Orbits

Every planet revolves around the sun in an elliptical orbit and the sun in situated at one of its foci.



Law of Areas

The areal velocity of the planet around the sun is constant i.e. $\frac{dA}{dt} = \frac{L}{2m}$ = constant



Law of Periods

The square of the time period of revolution of a planet is directly proportional to the cube of semi major axis length of the elliptical orbit *i.e.* $T^2 \propto a^3$

2 NEWTON'S LAW OF GRAVITATION

- The Gravitational force (F) between two bodies is directly proportional to product of masses and inversely proportional to square of distance between them.

$$\vec{F} = \frac{-Gm_1m_2}{r^2}\hat{r}$$

Characteristics of Gravitational Force

- It is alway attractive
- It is independent of the medium
- It is a conservative and central force
- It has infinite range

Superposition Principle

The Gravitational force on a point mass m_1 is the vector sum of the gravitational forces exerted by m_2, m_3 .....

i.e. $\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + ...$

3 ACCELERATION DUE TO GRAVITY

- For a body falling freely under gravity, the acceleration of body is called acceleration due to gravity
- $g = \frac{GM_e}{R_e^2} = \frac{4}{3}\pi G\rho R_e$

Where G = Gravitational constant

$\rho \rightarrow$ Average density of earth

$M_e \rightarrow$ Mass of earth

$R_e \rightarrow$ Radius of earth

4 VARIATION OF ACCELERATION DUE TO GRAVITY (g)

Due to Altitude (h)

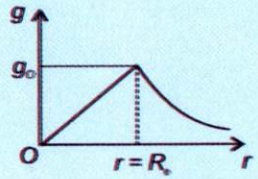
The value of g goes on decreasing with height (h)

$$g_h = \frac{GM_e}{(R_e + h)^2}$$

Due to Depth (d)

The value of g decreases with depth

$$g_d = g\left(1 - \frac{d}{R_e}\right)$$



5 GRAVITATIONAL POTENTIAL ENERGY

- The work done in bringing a body from infinity to a point in the gravitational field is gravitational potential energy

For two point mass system

$$U = -\frac{Gm_1m_2}{r}$$

Gravitational Potential due to a point mass

It is the work done in bringing a unit mass from infinity to a point in the gravitational field. $V = -\frac{Gm}{r}$

6 ESCAPE SPEED

- The minium speed of projection of a body from surface of earth so that it just crosses the gravitational field of earth

$$v_e = \sqrt{\frac{2GM_e}{R_e}} = \sqrt{2gR_e} = \left(\sqrt{\frac{8\pi G\rho}{3}}\right)R_e$$

It is independent of angle of projection.

- Escape velocity from moon is about 5 times smaller than earth.

7 EARTH'S SATELLITE

Orbital Speed of Satellite

- The speed required to put satellite into a given circular orbit

$$v_0 = \sqrt{\frac{GM_e}{R_e + h}} = R_e\sqrt{\frac{g}{R_e + h}}$$

- For satellite very close to earth orbital speed

$$v_0 = \sqrt{\frac{GM_e}{R_e}} = \sqrt{gR_e} = \frac{v_e}{\sqrt{2}}$$

Time Period of Satellite

- $T = \frac{2\pi}{\sqrt{GM_e}}(R_e + h)^{3/2} = \frac{2\pi}{R_e}\sqrt{\frac{(R_e + h)^3}{g}}$
- For satellite very close to earth's surface

$$T = 2\pi\sqrt{\frac{R_e}{g}} = 84.6 \text{ min}$$

Energy of Satellite

- Kinetic energy $K = \frac{GM_em}{2(R_e + h)}$
- Potential energy $U = -\frac{GM_em}{(R_e + h)}$
- Total energy (E) = $K + U$

$$= -\frac{GM_em}{2(R_e + h)}$$

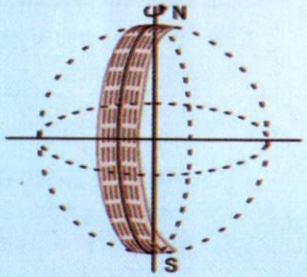
- Binding energy (BE) = $-E$

$$= +\frac{GM_em}{2(R_e + h)}$$

8 TYPES OF SATELLITES

Polar Satellite

- Revolves in polar orbit around the earth
- Height is approximately 500 to 800 km
- Time period is nearly 100 min
- Used in military spying, weather forecasting, meteorology etc.



Geostationary Satellite

- Time period is 24 h.
- Height is approximately 35800 km.
- Have same angular speed and sense of rotation as of earth
- Used for satellite communication, GPS
- INSAT is group of Geostationary satellites sent up by India.

9 WEIGHTLESSNESS

An Astronaut experiences weight- lessness in a space satellite. This is not because the gravitational force is small at that location in space. It is because both the astronaut and every part of satellite has an acceleration towards the center of the earth which is exactly the value of earth's acceleration due to gravity at that position.

Sharpen Your Understanding

NCERT Based MCQs

1. The escape speed of a body from the earth depends on [NCERT Pg. 201]

(1) Mass of the body

(2) The direction of projection

(3) The height of location from where the body is launched

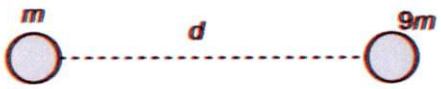
(4) All of these

2. A planet of mass m revolved around the sun of mass M in an elliptical orbit. The maximum and minimum distance of the planet form the sun are r and $3r$ respectively. The time period of the planet is proportional to [NCERT Pg. 184]

(1) r^3 (2) $(2r)^{\frac{3}{2}}$

(3) $4r$ (4) $(4r)^{\frac{2}{3}}$

3. Two point masses m and $9m$ are separated by a distance d on a line. A third point mass of 1 kg is to be placed at a point on the line such that the net gravitational force on it is zero.



The distance of 1 kg mass from mass m is [NCERT Pg. 187]

(1) $\frac{d}{4}$ (2) $\frac{d}{2}$

(3) $\frac{d}{3}$ (4) $\frac{d}{6}$

4. The force of gravitation between two masses is 10 mN in vacuum. If both the masses are placed in a liquid at the same distance, then new force of gravitation will be [NCERT Pg. 187]

(1) 10 mN (2) $\frac{40}{3}$ mN

(3) $\frac{30}{4}$ mN (4) Can't say

5. Three equal masses of 3 kg each are fixed at the vertices of an equilateral triangle ABC. The gravitational force acting on mass 2 kg placed at the centroid of triangle is [NCERT Pg. 187]

(1) Zero

(2) 6.67×10^{-3} N

(3) 9×10^{-9} N

(4) Data is insufficient

6. An object is projected from earth's surface, with speed half of the escape speed of earth, then maximum height attained by it is [NCERT Pg. 192]

(1) $\frac{R_E}{2}$ (2) $\frac{R_E}{3}$

(3) R_E (4) $2R_E$

7. The change in gravitational potential energy when a body of mass m is raised to height $4R_E$ from the earth surface is (R_E is radius of earth) [NCERT Pg. 192]

(1) $\frac{4}{3}mgR_E$ (2) mgR_E

(3) $\frac{mgR_E}{5}$ (4) $\frac{4}{5}mgR_E$

8. The potential energy of a system of four particles each of mass m, placed at vertices of a square of side a is [NCERT Pg. 192]

(1) $-(4+\sqrt{2})\frac{Gm^2}{a}$ (2) $-4\frac{Gm^2}{a}$

(3) $-4\sqrt{2}\frac{Gm^2}{a}$ (4) $-\frac{4Gm}{a}$

9. A satellite of mass m is in a circular orbit of radius $2R_E$ around the earth. The energy required to transfer it to a circular orbit of radius $4R_E$ is [NCERT Pg.196]

(1) $\frac{mgR_E}{2}$ (2) $\frac{7}{8}mgR_E$

(3) $\frac{mgR_E}{8}$ (4) $\frac{mgR_E}{4}$

10. If the gravitational potential at the surface of earth is V_0, then potential at a point at height equal to radius of earth is [NCERT Pg. 192]

(1) V_0 (2) $\frac{V_0}{2}$

(3) $\frac{V_0}{3}$ (4) $\frac{V_0}{4}$

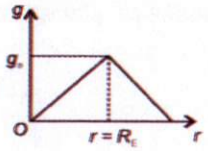
11. A satellite revolving around earth has potential energy – 2 MJ, then the binding energy of the satellite is [NCERT Pg.196]

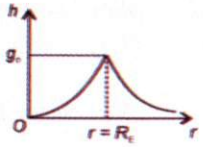
(1) 1 MJ (2) 2 MJ

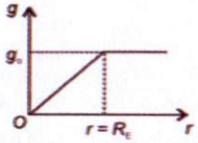
(3) – 1 MJ (4) 8 MJ

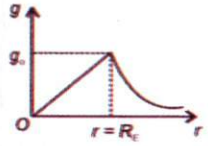
12. Starting from the centre of earth having radius R_E, the variation is acceleration due to gravity is best represented by the curve

[NCERT Pg. 191]

(1) 

(2) 

(3) 

(4) 

13. A body weighs 90 N on the surface of earth. The gravitational force on it due to earth at a height equal to half the radius of earth is [NCERT Pg. 190]

(1) 81 N (2) 40 N

(3) 45 N (4) 30 N

14. The escape speed of a projectile on the earth surface is 11.2 km/s. A body is projected out with three times of escape speed. The speed of body far away from the earth is (Ignore the presence of sun and other planets)

[NCERT Pg. 202]

(1) 31.7 km/s

(2) 24 km/s

(3) 22.4 km/s

(4) Zero

15. The density of a newly invented planet is twice that of earth. The acceleration due to gravity at the surface of the planet is double that at the surface of earth. If radius of earth is R_E, then the radius of the planet would be [NCERT Pg. 190]

(1) R_E (2) $\frac{R_E}{2}$

(3) $2R_E$ (4) $4R_E$

16. For a satellite moving in a circular orbit around the earth, the ratio of kinetic energy to the magnitude of potential energy is

[NCERT Pg. 196]

(1) 1 (2) $\frac{1}{2}$

(3) 2 (4) $\frac{1}{4}$

17. A point mass m is placed inside a spherical shell of mass M and radius R. The gravitational force experienced by the point mass is [NCERT Pg. 189]

(1) $\frac{GMm}{R^2}$ (2) $\frac{GMm}{2R^2}$

(3) $\frac{2GMm}{R^2}$ (4) Zero

18. A Geostationary satellite is orbiting at a height of $6R_E$ above the surface of earth. The time period of another satellite at a height $2.5R_E$ above the surface of earth is (R_E is radius of earth) [NCERT Pg. 196]

(1) 6 hours

(2) $6\sqrt{2}$ hours

(3) $\frac{6}{\sqrt{2}}$ hours

(4) 12 hours

19. A particle is projected vertically up with velocity $v = \sqrt{\frac{5}{4}gR_E}$ from earth surface. The velocity of particle at height equal to the maximum height reached by it is

[NCERT Pg.196]

(1) $\sqrt{\frac{gR_E}{4}}$ (2) $\sqrt{\frac{gR_E}{3}}$

(3) $\sqrt{\frac{gR_E}{5}}$ (4) Zero

20. When energy of a satellite-Earth system is non-zero positive, then satellite will

[NCERT Pg.196]

(1) Move around the earth in circular orbit

(2) Just escape out

(3) Move around the earth in elliptical orbit

(4) Escape out with speed some interstellar speed

Thinking in Context

1. All planets move in _____ orbits with the Sun situated at one of the foci. [NCERT Pg. 184]
2. Law of area is the consequence of conservation of _____ [NCERT Pg. 185]
3. The force on a point mass (m_1) due to another point mass (m_2) separated by distance d is $|\vec{F}|=$ _____. [NCERT Pg. 187]
4. Gravitational force is _____ in nature. [NCERT Pg. 188]
5. The force of attraction due to a hollow spherical shell of uniform density, on a point mass situated _____ is zero [NCERT Pg. 189]
6. The value of G is _____. [NCERT Pg. 189]
7. If earth is assumed to be of uniform mass density ρ, then gravitational acceleration g is given as _____. [NCERT Pg. 190]
8. The value of acceleration due to gravity at a height $h(h<<R_e)$ above the surface of earth is _____. [NCERT Pg. 191]
9. If we go down a distance d, below the earth's surface, the acceleration due to gravity becomes _____ of g at the surface. [NCERT Pg. 191]
10. The acceleration due to gravity at the centre of earth is _____. [NCERT Pg. 191]
11. The gravitational potential energy associated with two particles of masses m_1 and m_2 separated by a distance r is _____. [NCERT Pg. 192]
12. For a circular orbit near the earth's surface, the relation between escape velocity v_e and orbital velocity v_0 will be _____. NCERT Pg. 194]
13. For a satellite near the earth's surface, time period of satellite is $T_0 = 2\pi\sqrt{\frac{R_e}{g}}$, which is nearly equal to _____. [NCERT Pg. 194]
14. From Kepler's third law, for earth satellite $T^2 = K(R_e + h)^3$. Here K is given as _____. [NCERT Pg. 194]
15. When orbit of a satellite is elliptical, both KE and PE vary from point to point but total energy remains _____ and negative as in the circular orbit case. [NCERT Pg. 196]
16. Polar satellite are low altitude satellites having $h \approx$ _____. [NCERT Pg. 197]
17. The satellite in a circular orbits around the earth in the equatorial plane with T = 24 hours in same sense of rotation as of earth is called _____ satellite. [NCERT Pg. 196]
18. Inside an orbiting satellite, everything is in state of _____. [NCERT Pg. 198]
19. The INSAT group of satellite sent up by India are one of the group of Geostationary satellites widely used for _____ in India. [NCERT Pg. 197]
20. Time period of geostationary satellite is 24 h, while that of polar satellite is about _____. [NCERT Pg. 197]

❑ ❑ ❑

Mechanical Properties of Solids

9 Chapter

1 ELASTICITY AND PLASTICITY

- **Elasticity :** Property of a body to regain its original shape and size, on removing the deforming force
- **Plasticity:** The inability of a body to regain its original size and shape on the removal of the deforming forces

2 STRESS AND STRAIN

- Stress $= \frac{\text{Restoring force}}{\text{Area}} = \frac{F}{A}$ unit : $N\,m^{-2}$

(a) **Longitudinal stress :**

Tensile stress : When a cylinder is stretched by two equal forces normal to its cross-sectional area the restoring force per unit area is called Tensile stress.

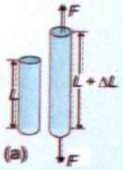
Compressive stress : If the cylinder is compressed under the action of applied forces, the restoring force per unit area is called compressive stress.

(b) **Tagential stress (or shear stress) :** The restoring force per unit area developed due to applied tangential force is called tangential or shearing stress.

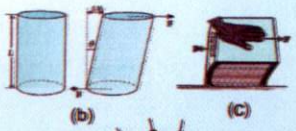
(c) **Hydraulic stress :** It is the restoring force per unit area. When a body under high pressure is compressed uniformly on all sides, the magnitude is equal to hydraulic pressure.

- Strain $= \frac{\text{Change in dimension}}{\text{Original dimension}}$ (No unit)

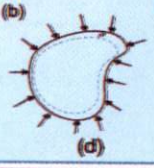
(a) Longitudinal strain $= \frac{\Delta L}{L}$



(b) Shear strain $= \frac{\Delta x}{L} = \tan\theta$



(c) Volume strain $= \frac{\Delta V}{V}$



3 HOOKE'S LAW

Stress $\propto$ strain

Stress = k strain

k = modulus of elasticity

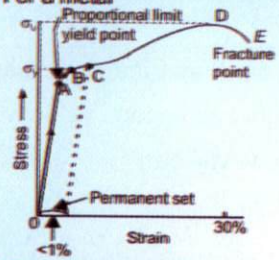
6 POISSON'S RATIO

$$\sigma = \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \frac{(\Delta d/d)}{(\Delta L/L)}$$

Δd : Contraction in diameter of stretched wire.

4 STRESS - STRAIN CURVE

- For a metal



O to A : linear curve(Hooke's Law)

A : Proportional limit

B : Yield point(elastic limit) → Corresponding stress is yield strength(σ_y)

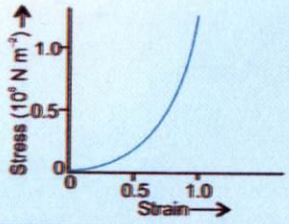
D : Ultimate tensile strength (σ_u)

E : Fracture point

- Material is brittle if D and E are close and ductile if D and E are far apart

- For an elastomer

Very large elastic region, even if material does not obey Hooke's law and there is no well defined plastic region.



5 VARIOUS OF MODULUS OF ELASTICITY

(a) Young's Modulus

$$Y = \frac{\text{longitudinal stress}}{\text{longitudinal strain}} = \frac{FL}{A\Delta L}$$

(b) Bulk Modulus

$$B = \frac{\text{hydraulic stress}}{\text{volume strain}}$$

$$= -\frac{p}{(\Delta v/v)}$$

Compressibility $k = \frac{1}{B}$

(c) Shear modulus or modulus of rigidity

$$G = \frac{\text{shearing stress}}{\text{shearing strain}} = \frac{FL}{A\Delta x}$$

For most materials, $G = \frac{Y}{3}$

7 ELASTIC POTENTIAL ENERGY (IN A STRETCHED WIRE)

$$U = \frac{1}{2}\ YA \times \frac{\Delta L^2}{L} = \frac{1}{2} F\Delta L$$

$$= \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume}$$

Elastic potential energy per unit volume

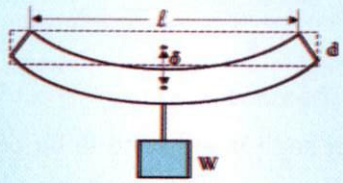
$$u = \frac{1}{2}\ \text{stress} \times \text{strain} = \frac{1}{2}\sigma\varepsilon$$

8 APPLICATIONS OF ELASTIC BEHAVIOUR OF MATERIALS

- Minimum area of cross - section of wire of crane

$$A = \frac{Mg}{\sigma_y}$$

- Designing beams for bridges



$$\delta = \frac{Wl^3}{(4bd^3Y)}$$

$\delta \propto d^{-3}$

So I shaped beam is preferred

- Maximum height of a mountain

$h = \frac{E}{\rho g}$, E is elastic limit

Sharpen Your Understanding

NCERT Based MCQs

1. Which of the following materials is/are close to ideal plastics? [NCERT, XI Pg. 235]
   (1) Putty (2) Mud
   (3) Steel (4) Both (1) & (2)

2. The restoring mechanism in solids can be visualized by taking a model of [NCERT, XI Pg. 236]
   (1) Spring-ball system (2) Atwood machine
   (3) Plum - Pudding (4) Liquid - Drop

3. Bulk modulus is relevant for [NCERT, XI Pg. 246]
   (1) Solids only (2) Solid
   (3) Fluids (4) Both (2) & (3)

4. The strain produced by a hydraulic pressure is called [NCERT, XI Pg. 238]
   (1) Longitudinal strain
   (2) Shearing strain
   (3) Volume strain
   (4) Both (1) & (2)

5. The ratio of stress and strain, within proportional limit is called [NCERT, XI Pg. 239]
   (1) Modulus of elasticity
   (2) Compressibility
   (3) Poisson's ratio
   (4) Both (2) & (3)

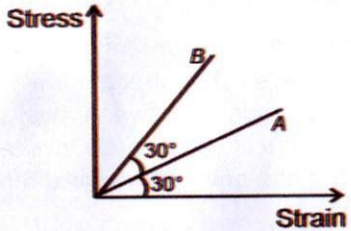
6. For most materials [NCERT, XI Pg. 242]
   (1) $G \approx \frac{Y}{3}$ (2) $G \approx \frac{Y}{2}$
   (3) $G \approx 3Y$ (4) $G \approx 2Y$

7. The strain perpendicular to the applied force is called [NCERT, XI Pg. 244]
   (1) Longitudinal strain (2) Volume strain
   (3) Lateral strain (4) Shear strain

8. For aluminium alloys Poisson's ratio is about [NCERT, XI Pg. 244]
   (1) 0.20 (2) 0.16
   (3) 0.33 (4) 0.40

9. The average depth of Indian ocean is about 3000 m. The fractional compression, $\frac{\Delta V}{V}$, of water at the bottom of the ocean is ($B = 2 \times 10^9$ N m^{-2}, $g = 10$ m s^{-2}) [NCERT, XI Pg. 243]
   (1) 1.5% (2) 2.5%
   (3) 4% (4) 3%

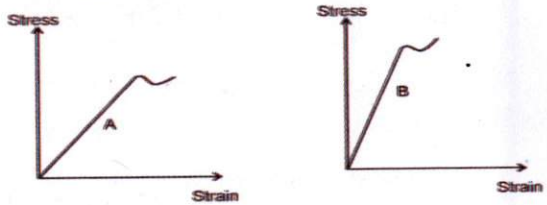
10. In the graph shown, if the Young's Modulus of material *A* is *Y*, then the Young's Modulus for material *B* is [NCERT, XI Pg. 238]



   (1) $\sqrt{3}Y$
   (2) $Y/3$
   (3) $3Y$
   (4) $2Y$

11. The volume contraction of a solid copper cube, 10 cm on an edge, when subjected to a hydraulic pressure of 10^7 Pa is ($B = 140 \times 10^9$ N m^{-2}) [NCERT, XI Pg. 248]
   (1) 0.07 cm^3
   (2) 0.03 cm^3
   (3) 0.02 cm^3
   (4) 0.01 cm^3

12. The stress-strain graphs for materials A and B are as shown in figure



   The correct statement is [NCERT, XI Pg. 247]
   (1) A is having greater Young's modulus and B is stronger
   (2) B is having greater Young's modulus and A is stronger
   (3) B is having greater Young's modulus and it is stronger as well
   (4) A is having greater Young's modulus and it is stronger as well

13. The edge of an aluminum cube is 10 cm. One face of the cube is firmly fixed to a vertical wall. A mass of 100 kg is attached to the opposite face of the cube. The vertical deflection of this face is ($G = 25 \times 10^9$ Pa)

[NCERT, XI Pg. 248]

(1) 4×10^{-7} m (2) 3×10^{-6} m

(3) 2×10^{-6} m (4) 1×10^{-6} m

14. A rigid bar of mass 15 kg is supported symmetrically by three wires each 2.0 m long. Those at each end are of copper and the middle one is of iron. If tension in each rod is same, the ratio of diameters is nearly

[NCERT, XI Pg. 248]

(1) 6 (2) 0.8

(3) 4.2 (4) 2.0

15. The density of water at a depth where pressure is 80.0 atm (Given density at the surface is 1.03×10^3 kg m^{-3}, $B = 2.2 \times 10^9$ N m^{-2}) [NCERT, XI Pg. 248]

(1) 1.034×10^3 kg m^{-3}

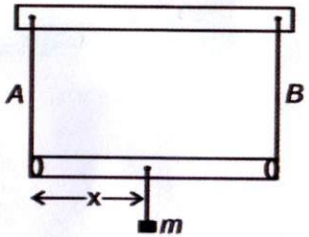
(2) 1.34×10^3 kg m^{-3}

(3) 1.64×10^3 kg m^{-3}

(4) 2.084×10^3 kg m^{-3}

16. A rod of length 1.05 m having negligible mass is supported at its ends by two wires of steel (wire A) and aluminum (wire B) of equal lengths as shown in figure. The cross-sectional areas of wire *A* and *B* are 2.0 mm^2 and 4.0 mm^2, respectively. The distance *x* from left end, where *a* mass *m* is suspended in order to produce equal stresses, is

($Y_{steel} = 2\times10^{11}$ N m^{-2}, $Y_{Al} = 7\times10^{10}$ N m^{-2})



[NCERT, XI Pg. 249]

(1) 70 cm (2) 35 cm

(3) 65 cm (4) 40 cm

17. In Q16, the distance *x* from left end to produce equal strains is

[NCERT, XI Pg. 249]

(1) 70 cm (2) 43.2 cm

(3) 65 cm (4) 35 cm

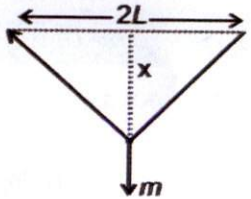
18. A 15 kg mass, fastened to the end of a steel wire of unstretched length 1.0 m, is whirled in a vertical circle with an angular velocity of 4π radian/s at the bottom of the circle. The cross-sectional area of the wire is 0.065 cm^2. The elongation of the wire when the mass is at the lowest point is ($g = 10$ m/s^2)

[NCERT, XI Pg. 248]

(1) 1.93 mm (2) 2.05 mm

(3) 1.65 mm (4) 3.05 mm

19. A mild steel wire of length 2*L* and cross-sectional area *A* is stretched, within elastic limit, horizontally between two pillars as shown in the figure. A mass *m* is suspended from the mid-point of the wire. Strain in the wire is

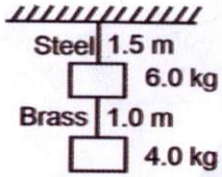


[NCERT, XI Pg. 249]

(1) $\frac{x^2}{L^2}$ (2) $\frac{x^2}{2L^2}$

(3) $\frac{x}{L}$ (4) $\frac{2x^2}{L^2}$

20. Two wires of diameter 0.25 cm, one made of steel and the other made of brass are loaded as shown in the figure. The unloaded length of steel wire is 1.5 m and that of brass wire is 1.0 m. The ratio of tensile stress in steel to brass wire is ($g = 10$ m/s^2)



[NCERT, XI Pg. 248]

(1) $\frac{5}{9}$

(2) $\frac{5}{2}$

(3) $\frac{3}{2}$

(4) $\frac{4}{3}$

Thinking in Context

1. Stress is defined as _____ per unit area [NCERT, XI Pg. 236]
2. A class of solids called _____ does not obey Hooke's Law. [NCERT, XI Pg. 239]
3. Our feeling that a material which stretches more is more _____ is a misnomer. [NCERT, XI Pg. 247]
4. _____ modulus is relevant for solid, liquid and gases. [NCERT, XI Pg. 242]
5. The elastic potential energy per unit volume is equals to $\frac{1}{2}$ × stress × _____. [NCERT, XI Pg. 238]
6. If ultimate tensile strength and fracture point are close, the material is called _____. [NCERT, XI Pg. 238]
7. On stress-strain curve, yield point is also called _____ limit [NCERT, XI Pg. 238]
8. For steel, the value of Poisson's ratio is in between _____ and _____. [NCERT, XI Pg. 244]
9. Compressibility K and Bulk modulus B are related as K = _____ [NCERT, XI Pg. 242]
10. The elastic potential energy per unit volume in terms of longitudinal strain σ and Young's modulus Y is _____. [NCERT, XI Pg. 244]
11. Rubber is _____ elastic than steel. [NCERT, XI Pg. 239]
12. _____ are most compressible. [NCERT Pg. 243]
13. A pillar with rounded ends supports _____ load than that with distributed shape at the ends. [NCERT Pg. 245]
14. A bar of length l, breadth b, and depth d, when loaded at the centre by a load W sags by an amount δ. This δ is proportional to d^n. The value of n is _____. [NCERT Pg. 245]
15. Metals have _____ values of Young's modulus than elastomers. [NCERT Pg. 247]
16. When a massless wire is suspended from ceiling and stretched under the action of a weight F suspended from its other end, tension at any cross-section is _____. [NCERT Pg. 246]
17. Stress is vector quantity. (True/False) [NCERT Pg. 247]
18. The Young's modulus and shear modulus are relevant only for _____. [NCERT Pg. 246]
19. A force F is required to break a wire of length l and radius r. The force required to break a wire of same material and same length, having twice the radius is _____. [NCERT Pg. 238]
20. If ultimate tensile strength and fracture point are far apart, then material is said to be _____. [NCERT Pg. 238]

❑ ❑ ❑

Mechanical Properties of Fluids

10
Chapter

1 PRESSURE

- Average pressure is defined as the normal force acting per unit area

$$P_{av} = \frac{F}{A}$$

$$P = \lim_{\Delta A \to 0}\left(\frac{\Delta F}{\Delta A}\right)$$, It is a scalar quantity.

2 VARIATION OF PRESSURE WITH DEPTH

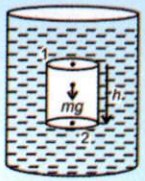
Pressure difference

$P_2 - P_1 = \rho g h$

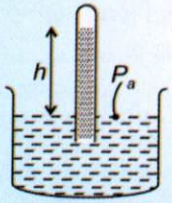
If point 1 is at free surface of liquid

then $P_2 = P_a + \rho g h$

$P - P_a = \rho g h$ (called gauge pressure)

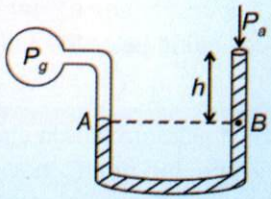


- **Instruments used to measure pressure**



Mercury barometer used to measure atmospheric pressure

$P_a = \rho g h$



The open tube manometer, used to measure pressure of gas

$P_g = P_a + \rho g h$

3 PASCAL'S LAW

- When ever an external pressure is applied on any part of a fluid contained in a vessel, it is transmitted undiminished and equally in all directions.

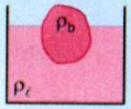
Devices based on Pascal's law

(i) Hydraulic lift (ii) Hydraulic brakes

4 ARCHIMEDES PRINCIPLE

- Loss of weight of a body submerged (partially or completely) in a fluid is equal to the weight of the fluid displaced.

Weight of fluid displaced $= \rho_\ell V_s g = F_B$



If $\rho_b < \rho_\ell$; then body will float

If $\rho_b = \rho_\ell$; body will just float with fully submerged

If $\rho_b > \rho_\ell$; then body will sink

- **Law of Floatation**

For Floating object $\frac{V_s}{V_b} = \frac{\rho_b}{\rho_\ell}$

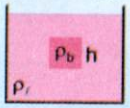
Fraction of vol. submerged = ratio of density of body and fluid

- **Buoyant Force**

Buoyant force is equal to weight of the fluid displaced.

Buoyant force depends on g_{eff}

Buoyant force acts opposite to g_{eff}



5 STREAMLINE FLOW

- The flow is said to be steady if at any given point, the velocity of each passing fluid particle remains constant in time. The path taken by fluid particle under steady flow called streamline.
- **Equation of continuity:** In stream line flow, mass of liquid coming out equals to the mass of liquid flowing in

$A_1 v_1 = A_2 v_2$

It is based on conservation of mass.

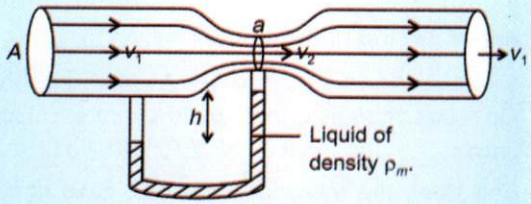
6 BERNOULLI'S EQUATION

- It states that for a steady flow of an ideal fluid, the sum of pressure energy per unit volume (P), kinetic energy per unit volume and potential energy per unit volume remains constant.

$P + 1/2\,\rho v^2 + \rho g h = \text{constant}$

- Phenomenons associated: Heart attack, magnus effect and aerofoil (lift of aircraft)
- **Venturi-meter:** It is a device used to measure the flow speed of incompressible fluid.

$$v_1 = \sqrt{\frac{2\,\rho_m\, g h}{\rho}}\left[\left(\frac{A}{a}\right)^2 - 1\right]^{-1/2}$$

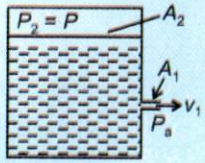


- **Speed of efflux: Torricelli's Law**

$A_1 v_1 = A_2 v_2$, if $v_2 << v_1$

$$v_1 = \sqrt{2gh + \frac{2(P - P_a)}{\rho}}$$

- When $P >> P_a$ and $2gh$ may be ignored.
- On the other hand tank is open to atmosphere, then $P = P_a$



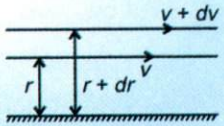
$v_1 = \sqrt{2gh}$

7 VISCOSITY

- The property of fluid due to which it opposes relative motion between its different layers in steady flow called viscosity.
- Tangential force between the layer

$F = -\eta A \frac{dv}{dr}$

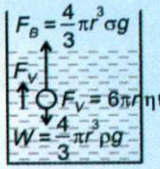
η = coefficient of viscosity



- $\eta = \frac{\text{Shearing stress}}{\text{Shear strain rate}}$
- SI unit is poiseiulle (ρ_l).

8 STOKE'S LAW

- The viscous force acting on a spherical body of radius a. $F = -6\pi\eta av$



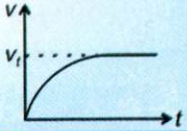
- **Terminal velocity:**

$v_t = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{\eta}$

ρ = density of sphere material

σ = density of fluid

- **Variation of Velocity with Time**



9 REYNOLDS NUMBER (R_e):

$R_e = \frac{\text{Inertial force}}{\text{Viscous force}}$ (dimensionless)

$R_e = \frac{\rho v d}{\eta}$

Where v = velocity of liquid

ρ = density of liquid

- The flow is turbulent for $R_e > 2000$.
- Flow is unsteady for R_e between 1000 and 2000.
- Flow is streamline for R_e less than 1000.
- Critical Reynold number is one at which turbulence sets.
- Reynold number helps study nature of fluid flow.
- Turbulence dissipates kinetic energy in the form of heat.

10 SURFACE TENSION

- **Surface:** It is the thickness of few molecular size.
- **Surface Tension:** The property of liquid by which the free surface of liquid at rest tends to have minimum surface area called surface tension.

  Surface tension can be defined as the force per unit length on imaginary line drawn at the surface of liquid

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

- Surface tension of a liquid falls with temperature.
- **Surface energy:** Molecules on the surface of liquid have some extra potential energy in comparison to molecules in the interior. A liquid thus tends to have minimum surface area.

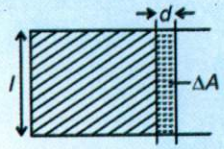
11 SURFACE ENERGY AND SURFACE TENSION

- Work done in increasing surface area.

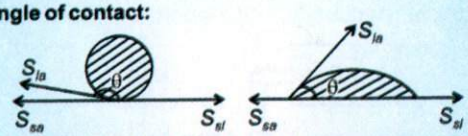
  $W = S(\Delta A_{eff})$

  - Thin film, liquid bubble have two surfaces so,

  $\Delta A_{eff} = 2\Delta A_{Geo}$.



- **Angle of contact:**

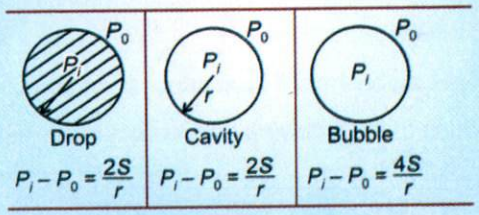


- At the point of contact, the angle between tangent planes drawn at the surface of liquid and at surface of solid inside liquid called angle of contact.
  - If $\theta < 90° \rightarrow$ Surface will be concave, liquid stick to solid and rise in capillary.
  - If $\theta > 90° \rightarrow$ Surface will be convex, liquid does not stick to solid and fall in capillary.
  - If $\theta = 90° \rightarrow$ Surface will be plane, liquid does not stick to solid neither rise nor fall in capillary.
  - Water forms droplets over a lotus leaf while spreads over a clean plastic plate.

12 DROPS AND BUBBLES

- $P_{inside} > P_{outside}$ (For liquid-gas interface, the convex side has lower pressure than on concave side.)
  - Liquid drop, air bubble in water have one surfaces so,

  $\Delta A_{eff} = \Delta A_{Geo}$

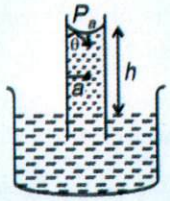


13 CAPILLARITY

- When a capillary tube is dipped in any liquid then liquid either rise or fall inside the capillary tube.
- Height of liquid column rise or fall inside a capillary tube is

$h = \frac{2S\cos\theta}{a\rho g}$

$h \propto \frac{1}{a}$



- In a tube of insufficient length, liquid will rise to the top of capillary, increase radius of curvature and stay there. Never comes out in the form of fountain.
- This is consequence of pressure difference across a curved liquid air interface a well known effect that water rises up in narrow tube inspite of gravity.

Sharpen Your Understanding

NCERT Based MCQs

1. The energy required for having a molecule at the surface of liquid is [NCERT Pg. 261]
   (1) Heat of evaporation
   (2) Roughly half the heat of evaporation
   (3) Heat capacity
   (4) Roughly half of heat capacity of liquid

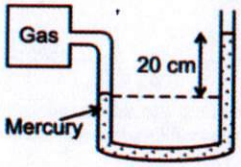
2. Which of the following conversion is correct? [NCERT Pg. 250]
   (1) 1 atm = 1.01×10^4 Pa
   (2) 1 mm of Hg = 133 Pa
   (3) 1 bar = 10^7 Pa
   (4) 1 torr = 10^2 Pa

3. Pressure is equal to [NCERT Pg. 247]
   (1) It is product of force and area and both force and area are vectors
   (2) It is the ratio of force which is a vector and parallel to area
   (3) It is ratio of the component of force normal to area
   (4) It depends on size of area chosen

4. Along a streamline in flow [NCERT Pg. 253]
   (1) The velocity of a fluid particle remains constant
   (2) The velocity of all fluid particles crossing a given position is constant
   (3) The velocity of all fluid particles at a given instant is constant
   (4) The speed of all fluid particle at any instant must be constant

5. Which of the following statements is incorrect? [NCERT Pg. 257]
   (1) Blood is more viscous than water
   (2) The blood pressure in humans is greater at the feet than at the brain
   (3) The angle of contact of mercury with glass is obtuse while that of water with glass is acute
   (4) A spinning cricket ball in air follows a parabolic trajectory

6. A manometer reads the pressure of a gas in an enclosure as shown in figure. The absolute and gauge pressure of the gas (in cm of mercury) in the enclosure is



(Take atmospheric pressure = 76 cm of Hg) [NCERT Pg. 250]
   (1) 76, 20
   (2) 20, 76
   (3) 96, 20
   (4) 20, 96

7. Streamline flow is more likely for liquids with [NCERT Pg. 260]
   (1) High density and high viscosity
   (2) Low density and low viscosity
   (3) High density and low viscosity
   (4) Low density and high viscosity

8. The ratio of inertial force to the viscous force represents [NCERT Pg. 260]
   (1) Magnus effect
   (2) Reynold's number
   (3) Relative density
   (4) Torricelli's law

9. The onset of turbulence in a liquid is determined by [NCERT Pg. 260]
   (1) Pascal's law
   (2) Avogadro number
   (3) Stoke's law
   (4) Reynold's number

10. A plane is in level flight and each of its wings has an area 20 m^2. If the speed of air on upper and lower surfaces are 80 m/s and 70 m/s respectively, then the mass of plane is (density of air = 1 kg/m^3) [NCERT Pg. 271]
   (1) 1500 kg (2) 1700 kg
   (3) 1650 kg (4) 1750 kg

11. Which of the following instrument is used to measure blood pressure in humans? [NCERT Pg. 273]

(1) Sphygmomanometer

(2) Cardioverter defibrillator

(3) Barometer

(4) Syphnometer

12. When temperature increases, the viscosity of [NCERT Pg. 259]

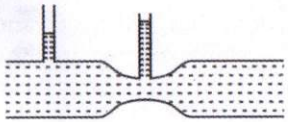
(1) Gases decreases and liquids increases

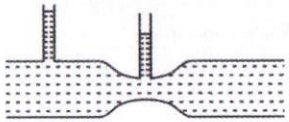
(2) Gases increases and liquid decreases

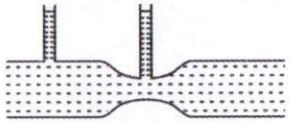
(3) Both gases and liquids increases

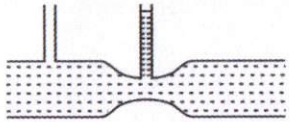
(4) Both gases and liquids decreases

13. Which of the following figure shown below is correct regarding the steady flow of an ideal liquid? [NCERT Pg. 269]

(1) 

(2) 

(3) 

(4) 

14. When a drop of water splits up into number of droplets [NCERT Pg. 264]

(1) Surface area will increase

(2) Volume decreases

(3) Energy is absorbed

(4) Both (1) and (3)

15. Which of the following statement is not true about angle of contact? [NCERT Pg. 263]

(1) The angle of contact for pure water and glass is nearly zero

(2) Angle of contact may increase with increase in temperature

(3) If the angle of contact of a liquid and a solid surface is less than 90°, then liquid spread on surface of solid

(4) Angle of contact depends upon the inclination of the solid surface to the liquid surface

16. A soap bubble is having internal and external radii as R and $2R$ respectively. If surface tension of soap solution is T, then excess pressure inside bubble will be [NCERT Pg. 264]

(1) $\frac{4T}{R}$

(2) $\frac{3T}{R}$

(3) $\frac{2T}{R}$

(4) $\frac{4T}{3R}$

17. When a capillary tube is dipped in a liquid, the liquid rises to a height h in the tube. The free liquid surface in the tube is hemispherical in shape. The tube is now pushed down so the height of the tube outside the liquid is less than h. Then the [NCERT Pg. 265]

(1) Liquid will come out of the tube in the form of small fountain

(2) Liquid will ooze out of the tube slowly

(3) Free liquid surface inside the tube remain hemispherical

(4) Liquid will rise to the top of capillary tube increase the radius of curved surface and stay there

18. Dynamic lift due to spinning of a ball is [NCERT Pg. 257]

(1) Magnus effect (2) Doppler's effect

(3) Pascal effect (4) Torricelli effect

19. A solid sphere falls with a terminal velocity v in air. If it is allowed to fall in vacuum, then [NCERT Pg. 260]

(1) Terminal velocity of sphere is equal to v

(2) Terminal velocity of sphere is greater than v

(3) Terminal velocity of sphere is less than v

(4) Sphere will never attain terminal velocity

20. The sap in tree rises in a system of capillaries of radius 2.5×10^{-5} m. The surface tension of sap is 7.28×10^{-2} N/m and the angle of contact is 0°. The maximum height to which sap can rise in a tree through capillary action is (density of sap is = 1×10^3 kg/m^3) [NCERT Pg. 265]

(1) 0.21 m (2) 0.59 m

(3) 0.87 m (4) 0.91 m

Thinking in Context

1. Shearing stress of fluids is about _____ times smaller than that of solids. [NCERT Pg. 246]
2. Force due to pressure on a surface is _____ to the surface. [NCERT Pg. 247]
3. The excess pressure ($P - P_a$) at depth h in liquid is called _____ at that point. [NCERT Pg. 248]
4. In manometer for measuring small pressure differences we use _____ density liquids. [NCERT Pg. 250]
5. Whenever external pressure is applied on any part of a fluid contained in a vessel it is transmitted _____ and _____ in all directions. [NCERT Pg. 251]
6. In steady flow at any given point, the velocity of each passing fluid particle _____ in time. [NCERT Pg. 253]
7. Equation of continuity is a statement of _____ in flow of incompressible fluids. [NCERT Pg. 253]
8. Steady flow is achieved at _____ flow speeds. [NCERT Pg. 253]
9. In laminar flow velocities at different points in the fluid may have _____ but their directions are _____. [NCERT Pg. 254]
10. Bernoulli's equation is a general expression that relates the pressure difference between two points in a pipe to both _____ and _____. [NCERT Pg. 254]
11. A fluid flowing out of a small hole in a vessel results in a _____ on the vessel. [NCERT Pg. 268]
12. The venturimeter is a device to measure the _____ of incompressible fluid. [NCERT Pg. 256]
13. The speed of flow of the blood in an artery in a region of constriction is raised which lowers the _____ inside the artery and it may collapse due to _____. [NCERT Pg. 257]
14. The dynamic lift due to spinning is called _____. [NCERT Pg. 257]
15. In fluids, the stress is found experimentally to depends on _____. [NCERT Pg. 258]
16. Relative viscosity (η/η_{water}) of blood remains constant between temperature _____. [NCERT Pg. 259]
17. In a turbulent flow, the velocity of the fluids at any point in space varies _____ and _____ with time. [NCERT Pg. 260]
18. Turbulence promotes mixing and increase the rates of transfer of _____, momentum and _____. [NCERT Pg. 261]
19. The pressure at the concave surface of liquid is _____ than, that at the convex surface. [NCERT Pg. 266]
20. The coefficient of viscosity for a fluid is defined as the ratio of _____. [NCERT Pg. 267]

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Thermal Properties of Matter

11
Chapter

1 TEMPERATURE

- Temperature is a relative measure of hotness or coldness.
- Heat transfer takes place between system and surrounding medium until they are at same temperature.
- Measure of temperature is obtained using a thermometer.
- Some properties of material change with temperature to be used as basis of constructing thermometer.
- For standard scale a fixed reference point is taken.
- A relationship for conversion between Fahrenheit and Celsius temperature scale is

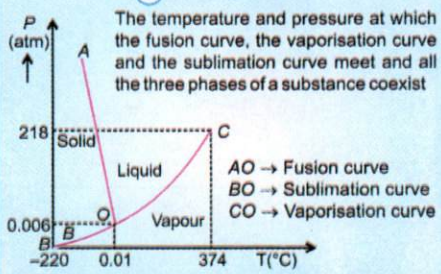
$$\frac{t_F - 32}{180} = \frac{t_C}{100}$$

- A temperature –273.15°C is designated as absolute zero. This is foundation of Kelvin temperature scale.
- Size of unit of Kelvin and Celsius temperature scales is the same. Relation between scales is

$$T_K = t_C + 273.15$$

6 TRIPLE POINT

The temperature and pressure at which the fusion curve, the vaporisation curve and the sublimation curve meet and all the three phases of a substance coexist



Pressure-temperature phase diagrams for water

2 HEAT

A form of energy transferred between two or more systems by virtue of temperature difference.

Thermal Expansion

- A change in temperature of a body causes change in its dimensions.

Three types of expansion

1. Linear Expansion

$$\alpha_l = \frac{\Delta l}{l} \times \frac{1}{\Delta T}$$

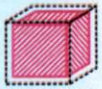
2. Area Expansion

$$\alpha_a = \frac{\Delta A}{A} \times \frac{1}{\Delta T}$$

$\alpha_a = 2\alpha_l$

For anisotropic solid $\alpha_a = \alpha_{l_1} + \alpha_{l_2}$

3. Volume Expansion



$$\alpha_V = \frac{\Delta V}{V} \times \frac{1}{\Delta T}$$

- α_V is constant only at high temperature
- Pyrex glass and invar has low α_V.
- Alcohol has high volume expansion coefficient than mercury.
- $\alpha_V = \frac{1}{T}$ for ideal gases

  $(\alpha_V)_{gases} > (\alpha_V)_{liquid} > (\alpha_V)_{solids}$
- When a solid rod has its ends rigidly fixed, it results in thermal stress in material which is proportional to temperature change.

$$\text{Thermal Stress} = Y \cdot \alpha_l \cdot \Delta T$$

3 CALORIMETRY

- Heat lost by a part at higher temperature is equal to heat gained by the part at lower temperature.
- Calorimetry means measurement of heat.
- A device in which heat measurement can be done is called a calorimeter.

4 HEAT CAPACITY

The change in temperature of a substance, when a given quantity of heat is absorbed or rejected is characterised by a quantity called heat capacity.

$$S = \frac{\Delta Q}{\Delta T}$$

Specific heat capacity

This is unique value of heat absorbed or given off, to change unit mass of it by one unit temperature change.

$$s = \frac{S}{m} = \frac{1}{m}\frac{\Delta Q}{\Delta T}$$

Molar specific heat

If the amount of substance is specified in terms of moles
we define heat capacity per mole

$$C = \frac{S}{\mu} = \frac{1}{\mu}\left(\frac{\Delta Q}{\Delta T}\right) \quad \text{J mol}^{-1}\text{ K}^{-1}$$

For gases two molar specific heat capacities

- Molar specific heat capacity at constant pressure C_P
- Molar specific heat capacity at constant volume C_V

$C_P - C_V = R$ (for ideal gases)

5 CHANGE OF STATE

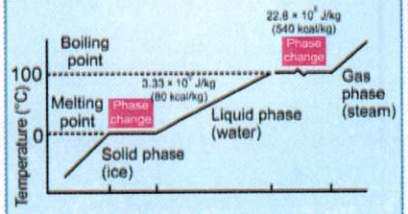
- Change of state from solid to liquid is called melting or fusion.
- Change of state from liquid to vapour is called vaporisation
- The temperature at which the liquid and vapour states of substance coexist is called its Boiling point.
- Boiling point increases with increase in pressure and vice versa.
- The change from solid state to vapour state without passing through the liquid state is called sublimation and substance is said to sublime.

Latent heat

- Amount of heat transferred during change of state of substance is called its latent heat.

$$L = \frac{\Delta Q}{M} \quad \text{J kg}^{-1}$$

- L depends on pressure.
- Solid-liquid state change → Latent heat of fusion (L_f)
- Liquid-gas state change → Latent heat of vaporisation (L_v)

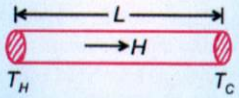


HEAT TRANSFER MODES

7 CONDUCTION

- It is a mechanism of heat transfer between adjacent parts of a body due to temperature difference.
- At steady state, the temperature of bar, through which heat is flowing, decreases with distance, and heat starts flowing at a constant rate.
- The rate of flow of heat

$$H = KA\left(\frac{T_H - T_C}{L}\right)$$



T_H = Hot end Temperature

T_C = Cold end Temperature

L = Length of rod

A = Cross -section of rod

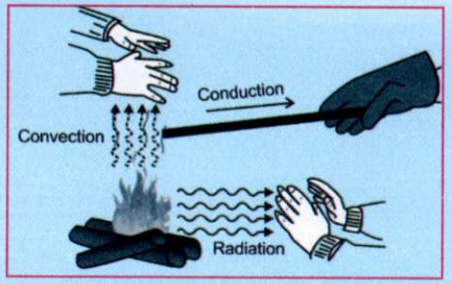
K is called thermal conductivity of material.

- Greater value of K for a material, more rapidly will it conduct heat. Its SI units are $Wm^{-1}K^{-1}$

8 CONVECTION

In convection mode heat transfer by actual motion of matter occurs.

- Convection occurs in fluids only.
- Two types of convections are
  1. Natural convection
  2. Forced convection
- Trade winds is example of natural convection in which gravity plays an important role.
- In forced convection material is forced to move by a pump. Human circulatory system, cooling system of automobile engine are forced convection method.



9 RADIATION

- This heat transfer mechanism needs no medium.
- Energy transferred by waves is called radiant energy.
- Heat transferred from sun to earth is by radiation.
- Radiations emitted by hot bodies are called thermal radiations.

LAWS OF RADIATIONS

10 Wien's Displacement Law

Wavelength for which radiation energy is maximum decreases with increasing temperature.

$$\lambda_m T = \text{constant}$$

Value of constant (Wien's constant) is 2.9×10^{-3} m K.

- This law is used to measure surface temperature of celestial bodies like stars, moon and sun.

11 Stefan-Boltzmann's Law

For a black body which is perfect radiator energy emitted per unit time is given as

$$H = A\sigma T^4$$

A is area, T is absolute temperature of body, σ is called Stefan Boltzmann's constant

$\sigma = 5.67 \times 10^{-8} Wm^{-2}K^{-4}$

- But if a body is surrounded by surroundings at temperature T_s.

For perfect radiator net rate of heat radiated

$$H = \sigma A(T^4 - T_s^4)$$

- For body with emissivity e modified relation is

$$H = e\sigma A(T^4 - T_s^4) \quad 0 < e \le 1$$

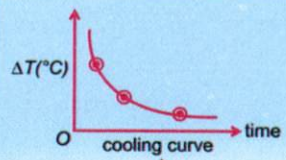
12 Newton's law of cooling

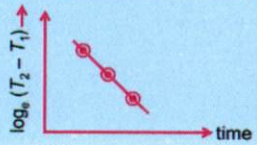
Rate of heat loss of a body is directly proportional to difference of temperature of body and surroundings.

- This law holds for small temperature difference only.

$$-\frac{dQ}{dt} = k(T_B - T_S)$$

$$\log_e(T_2 - T_1) = -kt + C$$





Average method

$$\frac{\text{Change in temperature}}{\text{time}} = k\Delta T$$

$$\Delta T = (T_{av} - T_s)$$

13 Greenhouse effect:

The absorption of infrared waves by greenhouse gases such as CO_2, methane (CH_4) nitrous dude (N_2O) chlorofluorocarbon (CF_xCl_x) and ozone (O_3). Heating of atmosphere → More energy to earth → Warmer surface. Without Greenhouse effect temperature of earth would have been –18°C

Sharpen Your Understanding

NCERT Based MCQs

1. A rod of length 5 m is prevented from thermal expansion by fixing its ends rigidly. Its cross-sectional area is 40 cm^2. Calculate thermal stress developed on a temperature rise of 20°C, if $Y = 2 \times 10^{11}$ Nm^{-2} and $\alpha = 1.2 \times 10^{-5} K^{-1}$.

[NCERT Pg. 283]

(1) 2.4×10^3 N m^{-2}

(2) 2.4×10^7 N m^{-2}

(3) 4.8×10^7 N m^{-2}

(4) 5.6×10^7 N m^{-2}

2. A blacksmith fixes iron ring on rim of woods wheel of a cart. The diameter of rim and iron ring are 3.243 m and 3.231 m respectively at 27°C. To what temperature should ring be heated to fit on rim? ($\alpha = 1.2 \times 10^{-5}$ K^{-1})

[NCERT Pg. 283]

(1) 309.5°C

(2) 336.5°C

(3) 412°C

(4) 232.6°C

3. A temperature of 60°C in Fahrenheit scale is equal to [NCERT Pg. 279]

(1) 104°F

(2) 140°F

(3) 119°F

(4) 100°F

4. The property of water that has important environmental effect on marine life is

[NCERT Pg. 282]

(1) Low viscosity

(2) Low thermal conductivity

(3) High heat capacity

(4) Maximum density at 4°C

5. Coefficient of volume expansion of ideal gases at constant pressure and at temperature T K is equal to

[NCERT Pg. 282]

(1) $\frac{1}{T}$

(2) T

(3) $\frac{1}{T^2}$

(4) $\sqrt{T}$

6. Assertion: When hot water is poured in a beaker of thick glass, the beaker cracks.

Reason: The beaker experiences unequal expansion. [NCERT Pg. 280]

(1) If both assertion and reason are true and reason is true explanation of assertion

(2) If both assertion and reason are true but reason is not correct explanation of assertion

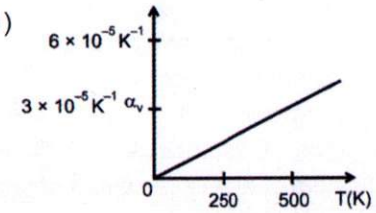
(3) Assertion is true but reason is false

(4) Both assertion and reason are false

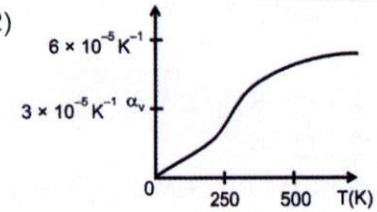
7. Which of the following graph gives the correct dependency of coefficient of volume expansion of copper with temperature?

[NCERT Pg. 281]

(1)



(2)



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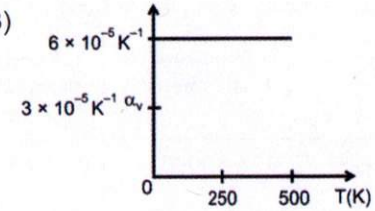
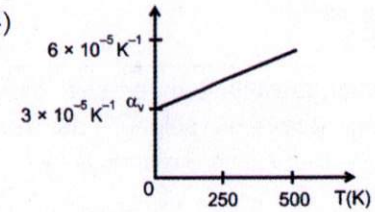


(4)



8. The specific heat of a substance depends on [NCERT Pg. 284]
(1) Nature of substance
(2) Temperature of the substance
(3) Mass of the substance
(4) Both (1) and (2)

9. An aluminium sphere of mass 47 gm is at 100°C. It is then transferred to 140 gm copper calorimeter containing 250 gm of water at 20°C. In steady state the temperature of water rises by 3°C. What is specific heat of aluminium if that of copper is 386 J kg^{-1} K^{-1}? [NCERT Pg. 286]
(1) 911 J kg^{-1} K^{-1}
(2) 516 J kg^{-1} K^{-1}
(3) 312 J kg^{-1} K^{-1}
(4) 612 J kg^{-1} K^{-1}

10. Two ideal gas thermometers A and B use oxygen and hydrogen gas respectively. Following observation were made

Temperature	Pressure thermometer *A*	Pressure thermometer *B*
Triple point of water	1.25×10^5 Pa	2×10^4 Pa
Normal melting point of sulphur	1.797×10^5 Pa	2.87×10^4 Pa

What is absolute temperature of normal melting point of sulphur as read by thermometer *A* and *B* respectively? [NCERT Pg. 300]
(1) 392.69 K, 391.98 K
(2) 362.3 K, 378.6 K
(3) 378.4 K, 375.4 K
(4) 387.5 K, 386.3 K

11. Boiling water is converting into steam at atmospheric pressure. The heat supplied is now being utilised to change water from liquid state to vapour state. Under this condition, specific heat of water is [NCERT Pg. 287]
(1) Less than zero
(2) Zero
(3) Slightly greater than zero
(4) Infinite

12. Certain amount of heat is given to 200 gm of copper to increase its temperature by 20°C. If same amount of heat is given to 60 gm of water, then rise in its temperature is (Specific heat of copper = 385 J kg^{-1} K^{-1} and water = 4200 J kg^{-1} K^{-1}) [NCERT Pg. 289]
(1) 4°C (2) 5°C
(3) 6°C (4) 9°C

13. When 150 gm of ice at 0°C is mixed with 300 gm of water at 50°C in a container, the resulting temperature is
($L_f = 3.34 \times 10^5$ J kg^{-1}, $S_w = 4186$ J kg^{-1} K^{-1}) [NCERT Pg. 289]
(1) 2.7°C (2) 3.7°C
(3) 5.7°C (4) 6.7°C

14. Steam at 100°C causes more burns than boiling water at 100°C because [NCERT Pg. 289]
(1) Low specific heat of steam
(2) Steam is in gaseous phase
(3) Steam at 100°C carries more heat than water at 100°C
(4) Steam has low viscosity

15. The incorrect statement among the following is [NCERT Pg. 293]
(1) Cooking pots have copper coating on bottom to promote distribution of heat quickly
(2) Plastic foams are insulators because they contain pockets of air
(3) Convection can be forced or natural but is possible only in fluids
(4) Trade winds is an example of forced convection

16. An iron bar of conductivity K_1 = 79 W m^{-1} K^{-1} and an identical brass bar of conductivity K_2 = 109 W m^{-1} K^{-1} are soldered end to end. The free end of iron and brass bars are maintained at 400 K and 300 K respectively. What is temperature of junction of two bars? [NCERT Pg. 292]
(1) 350 K
(2) 342 K
(3) 333 K
(4) 305 K

17. When a piece of iron is heated in a hot flame, it first becomes dull red, then reddish yellow and finally white hot. This phenomenon can be explained by [NCERT Pg. 294]

(1) Stefan- Boltzmann's law

(2) Greenhouse effect

(3) Wien's displacement law

(4) Newton's law of cooling

18. A tungsten lamp at a temperature of 3000 K has surface area of 0.3 cm^2. If the lamp has emissivity of 0.4, the rate of heat radiated is [NCERT Pg. 295]

(1) 40 W (2) 50 W

(3) 90 W (4) 55 W

19. The amount of radiations emitted by a perfectly black body is proportional to [NCERT Pg. 295]

(1) Temperature on ideal gas scale

(2) Fourth power of temperature on ideal gas scale

(3) Square of area of the black body

(4) Square of temperature on Celsius scale.

20. A box filled with hot tea cools from 94°C to 86°C in 4 minute, when room temperature is 40°C. How long will it take to cool from 71°C to 69°C? [NCERT Pg. 297]

(1) 10 minute

(2) 3 minute

(3) 100 second

(4) 50 second

Thinking in Context

1. Heat transfer takes place between system and surrounding medium, until the body and surrounding medium are at same _____. [NCERT Pg. 278]

2. Heat is a form of energy transferred between two systems or a system and surroundings by virtue of _____. [NCERT Pg. 279]

3. On the Fahrenheit scale, there are _____ equal intervals between two reference points and on the Celsius scale, there are _____. [NCERT Pg. 279]

4. If Fahrenheit is plotted along *y*-axis and Celsius temperature on *x*-axis, the shape of graph obtained is a _____. [NCERT Pg. 279]

5. With a constant volume gas thermometer, temperature is read in terms of _____. [NCERT Pg. 280]

6. Coefficient of volume expansion of a substance depends in general on temperature, it becomes constant only at _____ temperature [NCERT Pg. 281]

7. Value of α_v for alcohol (ethanol) is _____ than mercury. [NCERT Pg. 282]

8. The volume of a given amount of water _____ as it is cooled from room temperature until its temperature reaches 4°C. Below 4°C, the density _____. [NCERT Pg. 282]

9. Consider a steel rail of length 5 m and area of cross-section 40 cm^2 that is prevented from expansion. Its temperature rises by 10°C and coefficient of linear expansion is $1.2 \times 10^{-5}\ K^{-1}$. The thermal strain produced is _____ [NCERT Pg. 283]

10. Coefficient of area expansion is _____ times its linear expansivity in solids. [NCERT Pg. 283]

11. If equal amount of heat is added to equal masses of different substances, the resulting temperature change will be different. [NCERT Pg. 284]

(1) True (2) False

12. Specific heat capacity of a substance depends on nature of substance and its mass. [NCERT Pg. 284]

(1) True (2) False

13. Water is used as a coolant in automobile radiators as well as a heater in hot water bags due to its _____ specific heat capacity. [NCERT Pg. 285]

14. The temperature at which the liquid and the vapour states of the substance co-exist is called its _____. [NCERT Pg. 287]

15. The temperature and pressure at which the fusion curve, the vaporisation curve and sublimation curve meet and all three phases coexist is called _____. [NCERT Pg. 287]

16. Boiling point of water inside the cooker is _____ by increasing the pressure. [NCERT Pg. 288]

17. The heat required during a change of state of substance depends upon the heat of transformation and mass of substance undergoing the change. [NCERT Pg. 289]

(1) True (2) False

18. Cooling system of an automobile engine, human circulatory system, heating system in homes are examples of _____. [NCERT Pg. 293]

19. The amount of heat that a body can absorb by radiation depends on the colour of the body. This statement is [NCERT Pg. 294]

(1) True

(2) False

20. The wavelength (λ_m) for which energy radiated by a hot body is maximum decreases with increasing temperature. This statement is related with _____ law. [NCERT Pg. 295]

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Thermodynamics

12
Chapter

1 THERMODYNAMIC EQUILIBRIUM

- Temperature of a body is related to its average internal energy, not to kinetic energy of motion of centre of mass.
- Equilibrium in thermodynamics refer to situation when macroscopic variables defining thermodynamic state of system don't depend on time.

2 ZEROTH LAW OF THERMODYNAMICS

- Two systems in thermal equilibrium with third system separately are in thermal equilibrium with each other.
- If $T_A = T_C$ and $T_B = T_C$, then $T_A = T_B$
- Thermodynamic variable whose value is equal for two systems in thermal equilibrium is called temperature.

3 HEAT, INTERNAL ENERGY AND WORK

- Heat is energy transfer arising due to temperature difference between system and surroundings.
- Internal energy is simply the sum of kinetic energies and potential energies of the molecules in the frame of reference to which centre of mass of system is at rest.
- Internal energy depends on state of the system, not how the state was achieved.
- There are two ways to change internal energy of a thermodynamic system
  (1) To do work on system
  (2) Supply heat to system
  So heat and work are two modes of altering the state of a thermodynamic system and changing internal energy.
- Heat and work in Thermodynamics are not state variables.
- U is a state variable. ΔU depends only on initial and final states and not on path taken by gas to go from one to another.
- ΔQ and ΔW will depend on path taken to go from initial to final state.
- Work done during thermodynamic process
  $\Delta W = \int_{V_1}^{V_2} PdV$
- Area under the $P-V$ diagram with the volume axis gives the work done in thermodynamic process.

4 SPECIFIC HEAT CAPACITY

- Molar specific heat at constant volume.
  $C_V = \left(\frac{\Delta Q}{\Delta T}\right)_V = \left(\frac{\Delta U}{\Delta T}\right)$
- Molar specific heat at constant pressure
  $C_P = \left(\frac{\Delta Q}{\Delta T}\right)_P = \left(\frac{\Delta U}{\Delta T}\right)_P + P\left(\frac{\Delta V}{\Delta T}\right)_P$
  $PV = RT \therefore P\left(\frac{\Delta V}{\Delta T}\right)_P = R$
- $\boxed{C_P = C_V + R}$ (MAYER'S Equation)
- $\gamma = \frac{C_P}{C_V} = \frac{C_V + R}{C_V} = 1 + \frac{R}{C_V}$
  $\boxed{C_P = \gamma \times C_V}$

5 FIRST LAW OF THERMODYNAMICS

- $\Delta Q = \Delta U + \Delta W$ (Energy conservation law)
  ΔQ = heat supplied to system by the surrounding
  ΔW = work done by the system on the surrounding
  ΔU = Change in internal energy of a the system
- Heat supplied to system goes in partly to increase internal energy and rest in work on environment.
- This is simply the general law of conservation of energy applied to any system in which energy transfer is taken into account.
- $\Delta W = P\Delta V$
  $\therefore \Delta Q = \Delta U + P\Delta V$

8 THERMODYNAMIC PROCESSES

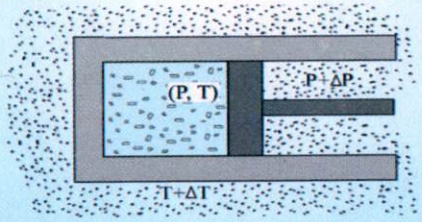
- A thermodynamic process is an activity where a thermodynamic system is taken from one equilibrium state to another.
- Reversible process
- Irreversible process
- Cyclic process

6 THERMODYNAMIC STATE VARIABLES

- Thermodynamic state variables describe equilibrium state of system. These state variables are not necessarily independent.
- The connection among state variables is called equation of state.
- Equilibrium state of thermodynamic system is described by state variables. The value of state variable depends on particular state not by the path used to arrive that state. Pressure, volume, temperature and mass are state variable. Heat and work are not state variables.
- For an ideal gas, equation of state is $\boxed{PV = \mu RT}$
- Thermodynamic state variables are of two types
  (1) Extensive
  (2) Intensive
- Extensive variables indicates size of system.
- Internal energy, volume and mass are extensive variables. But pressure, temperature and density are intensive variables.

7 REVERSIBLE AND IRREVERSIBLE PROCESS

- Spontaneous processes in nature are irreversible.
- A process is reversible if the process can be turned back such that both the system and surrounding return to their original states with no any other change anywhere else in universe.
- A quasi-static isothermal expansion of an ideal gas in a cylinder fitted with a frictionless movable piston is a reversible process.
- A quasi-static process is an infinitely slow process such that system remains in thermal and mechanical equilibrium with surroundings throughout. In this process pressure and temperature of the environment can differ from those of system only infinitesimally.



No accelerated motion of Piston

9 ISOTHERMAL PROCESS

- For isothermal process Temperature during the process should be constant

  $PV = \text{constant}$
- So pressure of given mass of a gas varies inversely as its volume.
- **Work done in isothermal process.**

  If a system of ideal gas at temperature T goes from (P_1, V_1) to (P_2, V_2) equilibrium state, then work done

  $$W = \mu RT \ln\left(\frac{V_2}{V_1}\right) = \mu RT \ln\left(\frac{P_1}{P_2}\right)$$
- Here $\Delta T = 0$ $\quad \therefore \Delta U = 0$

  $$\Delta Q = \Delta W = \mu RT \ln\left(\frac{V_2}{V_1}\right)$$

10 ADIABATIC PROCESS

- In adiabatic process heat interaction between system and surrounding is zero. *i.e.* $\Delta Q = 0$
- $PV^{\gamma} = \text{constant}$

  Where γ = ratio of molar specific heats at constant pressure and at constant volume.
- System is insulated from surroundings and heat absorbed or released is zero.
- Work done by gas results in decrease in its internal energy.
- If system change from (P_1, V_1, T_1) to (P_2, V_2, T_2)

  $$\Delta W = \frac{\mu R(T_1 - T_2)}{\gamma - 1} = \frac{(P_1V_1 - P_2V_2)}{(\gamma - 1)} \text{ where } \gamma = C_p/C_v$$
- If work done by gas ($W > 0$), then, $T_2 < T_1$

11 ISOBARIC PROCESS

- For isobaric process pressure during the process should be constant

  $$\frac{V}{T} = \text{constant}$$
- Work done in isobaric process

  $W = P(V_2 - V_1) = \mu R(T_2 - T_1)$
- Heat partly to do absorbed goes partly to increase internal energy and mechanical work.

  $\Delta Q = \Delta U + \Delta W$

  $\Delta U = \mu C_v \Delta T$, $\Delta Q = \mu C_p \Delta T$ and $\Delta W = \mu R \Delta T$

  $$\frac{\Delta W}{\Delta Q} = \frac{R}{C_p} = \frac{\gamma - 1}{\gamma} \text{ and } \frac{\Delta U}{\Delta Q} = \frac{C_v}{C_p} = \frac{1}{\gamma}$$

12 ISOCHORIC PROCESS

- For isochoric process volume during the process should be constant

  $$\frac{P}{T} = \text{constant}$$
- Work done in isochoric process, $\Delta W = P\Delta V = 0$
- $\Delta Q = \Delta U + \Delta W$

  $\Delta Q = \Delta U$
- Heat absorbed by gas goes entirely to change its internal energy and its temperature.
- Change in internal energy is determined by specific heat at constant volume and temperature change.

13 CYCLIC PROCESS

- In any cyclic process system returns to initial state, $\Delta U = 0$
- Hence total heat absorbed equals the work done by the system, $\Delta Q = \Delta W$

15 REFRIGERATOR

- A refrigerator is the reverse of a heat engine. Working substance extracts heat from cold reservoir, some external work is done on system and heat is released to reservoir at high temperature.
- Coefficient of performance of refrigerator $= \dfrac{\text{heat extracted}}{\text{work input}}$

  $$\beta = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{(T_1 - T_2)} = \frac{1 - \eta}{\eta}$$
- Coefficient of performance for heat pump is

  $$\beta = \frac{Q_1}{W} = \frac{T_1}{T_1 - T_2} = \frac{1}{\eta}$$

16 SECOND LAW OF THERMODYNAMICS

- **Kelvin-Planck statement :** No process is possible whose sole result is absorption of heat from a reservoir and complete conversion of heat into work.
- **Clausius statement :** No process is possible whose sole result is transfer of heat from cold reservoir to hotter object.
- Two statements are completely equivalent.
- It shows that efficiency of a heat engine can never be unity so heat released to cold reservoir can never be made zero.
- Kelvin Planck and Clausius deny the perfect heat engine and refrigerator.

14 HEAT ENGINE

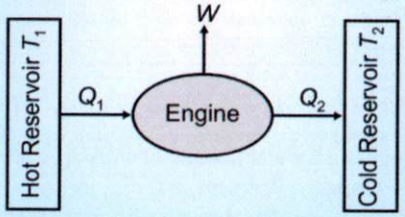
- Heat engine is a device in which a system undergoes a cyclic process resulting in conversion of heat in to the sink.
- Efficiency of the engine is

  $$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

  Q_1 = heat absorbed from source

  Q_2 = heat released to sink

  η = efficiency of heat engine

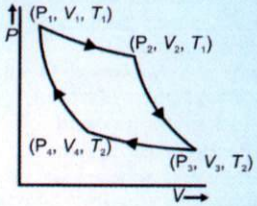


- Heat engine based on idealised reversible processes achieve the highest possible efficiency.

17 CARNOT ENGINE

- Carnot engine is a reversible engine operating between two temperatures T_1 and T_2. Carnot cycle consists of two isothermal and two adiabatic processes. Its efficiency is

  $$\eta = 1 - \frac{T_2}{T_1}$$



- Engine efficiency of Carnot engine does not depend on nature of working substance.

  Carnot Theorem: Any other engine working between temperature T_1 and T_2 can not have efficiency more than that of Carnot engine. The Carnot engine's efficiency is independent of nature of working substance.

  In Carnot cycle

  $\dfrac{Q_1}{Q_2} = \dfrac{T_1}{T_2}$ is universal relation and this relation can be used to design universal thermodynamic scale.

Sharpen Your Understanding

NCERT Based MCQs

1. 1 gm of water is changed from its liquid to vapour phase. The measured latent heat of water is 2256 J/g. What is the amount of change in internal energy?[NCERT Pg. 308]
(1) 169.2 J (2) 3068.2 J
(3) 2086.8 J (4) 2548.3 J

2. A monoatomic ideal gas undergoes an adiabatic process from temperature 300 K to 600 K. The gas has 2 moles, calculate work done by this ideal gas. [NCERT Pg. 312]
(1) 600 R (J) (2) –200 R (J)
(3) –450 R (J) (4) –900 R (J)

3. A reversible cyclic heat engine absorbs 900 joule of heat from source. If 400 J of heat is released to the sink, what is the efficiency of the engine? [NCERT Pg. 314]
(1) $\frac{2}{9}$ (2) $\frac{3}{7}$
(3) $\frac{5}{9}$ (4) $\frac{4}{9}$

4. In an isothermal process, two moles of an ideal gas expands from volume 2 m^3 to 8 m^3 at temperature of 227°C. Heat absorbed by the gas during process is nearly [NCERT Pg. 311]
(1) 2752 cal (2) 3250 cal
(3) 1945 cal (4) 1875 cal

5. In a refrigerator, the system extracts heat of 600 J from a cold reservoir and released 900 J of heat to hot reservoir. The coefficient of performance of a refrigerator is given by [NCERT Pg. 314]
(1) 2 (2) 3
(3) 6 (4) 9

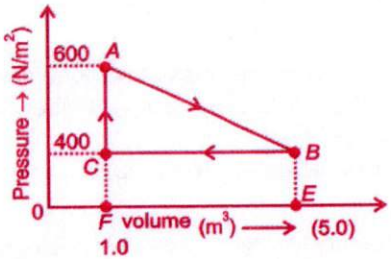
6. What amount of heat must be supplied to 2×10^{-2} kg of nitrogen at room temperature to raise its temperature, by 25°C at constant pressure? (Molecular wt. of N_2 = 28) [NCERT Pg. 321]
(1) 270.5 J (2) 519.6 J
(3) 370.4 J (4) 148.3 J

7. In changing the state of a gas adiabatically from an equilibrium state *A* to another equilibrium state *B*, an amount of work equal to 104.6 J is done on the system. If this gas is taken from state *A* to *B* via a process in which the net heat absorbed by the system is 35 cal, how much is net work done by the system in later case? (1 cal = 4.19 J) [NCERT Pg. 321]
(1) 192.7 J (2) 89.6 J
(3) 42.05 J (4) 142.5 J

8. A cylinder with movable piston contains 2 moles of hydrogen at standard temperature and pressure. The cylinder walls of the cylinder are made of heat insulator. By what factor does the pressure of a gas increase when gas is suddenly compressed to half of its original volume? [NCERT Pg. 321]
(1) 1.5 (2) 3.82
(3) 2.64 (4) 6.23

9. Two cylinders *A* and *B* of equal capacity are connected to each other via a stopcock. *A* contains a gas at standard temperature and pressure. *B* is completely evacuated. The entire system is thermally insulated. The stopcock is suddenly opened. What is effect on internal energy of gas? [NCERT Pg. 321]
(1) Increases
(2) Decreases
(3) No change
(4) May decrease or no change

10. A thermodynamic system is taken from original state to another intermediate state by linear process shown in diagram. Its volume is then reduced to original volume from *B* to *C* by an isobaric process. What is total work done by gas from *A* to *B* to *C*? [NCERT Pg. 322]



(1) 500 J (2) 400 J
(3) 1200 J (4) 2000 J

11. A steam engine working like an ideal heat engine delivered 5.4×10^8 J of work per minute and takes 3.6×10^9 J of heat per minute from its boiler at 127°C. What is sink temperature? [NCERT Pg. 322]
(1) 37°C
(2) 47°C
(3) 57°C
(4) 67°C

12. A diatomic gas with three moles are in a container at 400 K. Under isobaric process, its temperature is changed to 900 K. How much heat is absorbed by the gas during this process? [NCERT Pg. 312]

(1) 6.4 kcal
(2) 9.4 kcal
(3) 10.4 kcal
(4) 12.4 kcal

13. Which of the following is incorrect statement? [NCERT Pg.315]

(1) Free expansion of a gas is irreversible process
(2) A thermodynamic process is reversible if process can be turned back so that both system and surrounding return to their original states
(3) No process is possible whose sole result is transfer of heat from a colder object to hotter object
(4) The efficiency of an ideal heat engine is unity.

14. In thermodynamic processes, correct match of column-I with column-II is [NCERT Pg.306]

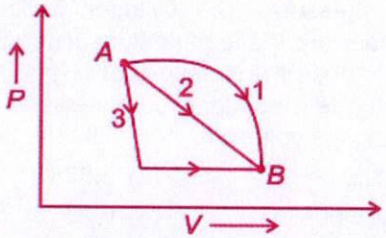
Column-I Type of process	Column-II Feature
a. Isothermal	(i) Volume constant
b. Isobaric	(ii) Pressure constant
c. Isochoric	(iii) No heat flow between system and surroundings
d. Adiabatic	(iv) Temperature constant

(1) a(i), b(ii), c(iii), d(iv)
(2) a(iv), b(i), c(iii), d(ii)
(3) a(iv), b(ii), c(iii), d(i)
(4) a(iv), b(ii), c(i), d(iii)

15. Molar specific heat of an ideal gas at constant volume is 21 joule/mol K and molar specific heat at constant pressure is about 35 joule/mol K. The ideal gas is [NCERT Pg. 314]

(1) Monoatomic
(2) Diatomic
(3) Triatomic
(4) Polyatomic

16. An ideal gas goes from state A to state B via three different processes as indicated in $P - V$ diagram. If Q_1, Q_2 and Q_3 indicate the heat absorbed by gas along the three processes and ΔU_1, ΔU_2 and ΔU_3 indicate the change in internal energy along three processes, then [NCERT Pg. 306]



(1) $Q_1 > Q_2 > Q_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$
(2) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$
(3) $Q_1 = Q_2 = Q_3$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$
(4) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$

17. If Q, E and W denote respectively the heat added, change in internal energy and work done in a closed cyclic process, then [NCERT Pg. 312]

(1) $Q = 0$
(2) $Q = W = 0$
(3) $W = 0$
(4) $E = 0$

18. Thermodynamic state variables may be [NCERT Pg. 310]

(1) Extensive only
(2) Intensive only
(3) Both (1) and (2)
(4) Neither (1) nor (2)

19. An ideal gas is compressed to half of its initial volume by means of different thermodynamic processes. Which of the process result in the maximum work done on the gas? [NCERT Pg. 312]

(1) Isothermal
(2) Adiabatic
(3) Isobaric
(4) Isochoric

20. Refrigerator is to maintain eatables kept inside at 7°C. If the room temperature is 43°C, coefficient of performance of refrigerator must be [NCERT Pg. 322]

(1) 7.78
(2) 13.7
(3) 9.72
(4) 0.75

Thinking in Context

1. Thermodynamics is a _____ science. It deals with bulk systems and does not go into molecular constitution of matter.
[NCERT Pg. 304]

2. Two systems in thermal equilibrium with a third system separately are in thermal equilibrium with each other. This forms the basis of _____ law of thermodynamics.
[NCERT Pg. 305]

3. The thermodynamic variable whose value is equal in two systems in thermal equilibrium is called _____. [NCERT Pg. 305]

4. Internal energy depends only on the state of system, not how the state was achieved. This is an example of thermodynamic _____.
[NCERT Pg. 306]

5. Internal energy of a system can change through two modes of energy transfer. These are _____ and _____
[NCERT Pg. 307]

6. First law of thermodynamics is the general law of _____, applied to any system in which energy transfer from or to system is taken into account. [NCERT Pg. 307]

7. _____ and _____ will in general depend on the path taken to go from one state to another state. [NCERT Pg. 307]

8. The connection between state variables in thermodynamics is called _____.
[NCERT Pg. 310]

9. Thermodynamic state variables are of two type _____ and _____. _____ variables indicate size of the system. The variables that remain unchanged for each part are _____. [NCERT Pg. 310]

10. A process in which temperature of the thermodynamic system is kept fixed throughout is called an _____ process.
[NCERT Pg. 312]

11. There is no change in internal energy of a gas in an isothermal process. In isothermal compression work is done _____ gas and heat energy is _____ [NCERT Pg. 312]

12. Heat absorbed by the gas goes entirely to change its internal energy and temperature, the process is _____ [NCERT Pg. 312]

13. Heat engine is a device by which a system is made to undergo a cyclic process that results in conversion of _____ to _____.
[NCERT Pg. 313]

14. A refrigerator cannot work without some external work done on the system. So coefficient of performance cannot be _____.
[NCERT Pg. 314]

15. According to _____ statement no process is possible whose sole result is the absorption of heat from a reservoir and complete conversion of heat into work.
NCERT Pg. 315]

16. The dissipative effects are present everywhere and cannot be eliminated but can only be minimized so most processes that we deal with are _____ in nature.
[NCERT Pg. 315]

17. Heat capacity in general, depends on _____ of the system goes through when heat is supplied. [NCERT Pg. 306]

18. When work is done by a gas in thermodynamic adiabatic process then final temperature of gas is _____ than its initial temperature. [NCERT Pg. 312]

19. Carnot engine is a reversible engine operating between two temperatures T_1(source) and T_2(sink). The efficiency of Carnot engine is given by $\eta = 1 - (—)$
[NCERT Pg. 317]

20. The second law of thermodynamics gives a fundamental limitation to the _____ of a heat engine. [NCERT Pg. 315]

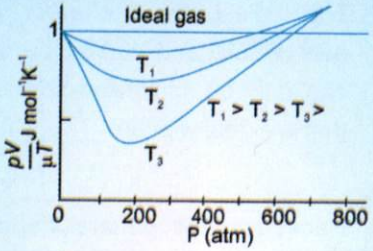
❑ ❑ ❑

Kinetic Theory

13
Chapter

1 LAWS ASSOCIATED WITH KTG

- An ideal gas is only theoretical model of a gas. No real gas is truly ideal. Without interactions gas behaves like an ideal gas. At low pressure or high temperature, molecules are far apart and molecular interaction is negligible.



- **Boyle's Law :** Pressure of a given ideal gas is inversely proportional to its volume if temperature is kept constant.
- **Charle's Law :** Volume of given ideal gas is directly proportional to its temperature in kelvin if pressure is kept constant.
- **Gay Lussac's Law :** Pressure of an ideal gas is directly proportional to its absolute temperature if volume is kept constant.
- **Avogadro's Law :** Equal volume of all the gases under similar conditions of temperature and pressure contain equal number of molecules.

$$\frac{P_1V_1}{N_1T_1} = \frac{P_2V_2}{N_2T_2} = K_B$$

Ideal gas equation connecting the variables is

$$PV = \mu RT = K_B NT \qquad P = \frac{\rho RT}{M_0}$$

- **Dalton's Law of Partial Pressure :** Total pressure of a mixture of non-reactive gases is the sum of their partial pressures.

2 AVERAGE PRESSURE OF GAS

$$P = \frac{1}{3} n m\bar{v}^2 \text{ and } PV = \frac{1}{3} nV m\bar{v}^2$$

$n \rightarrow$ Number density $\qquad m \rightarrow$ Mass of molecule

$\bar{v}^2 \rightarrow$ Mean of squared speed

3 KINETIC INTERPRETATION OF TEMPERATURE

- **Average kinetic energy of molecule**

$$= \frac{1}{2} m\bar{v}^2 = \frac{3}{2} K_B T$$

$$\bar{V}_{RMS} = (\bar{V}^2)^{\frac{1}{2}} = \sqrt{\frac{3K_BT}{m}}$$

- In a mixture of gases at a given temperature, heavier molecule has lower average speed.
- Translational kinetic energy of gas

$$E = \frac{3}{2} K_B NT \text{ and } PV = \frac{2}{3} E, \frac{E}{N} = \frac{1}{2} m\bar{v}^2 = \frac{3}{2} K_B T$$

- Average KE is proportional to temperature.
- R.M.S. speed of gas molecule,

$$V_{RMS} = \sqrt{\frac{3RT}{M}}$$

- Most probable speed of molecule

$$= \sqrt{\frac{2RT}{M}}$$

- Average speed of gas molecule

$$= \sqrt{\frac{8RT}{\pi M}}$$

- This concept of maxwell energy distribution predict specific heat of gases theoretically.

LAW OF EQUIPARTITION OF ENERGY

- KTG is consistent with ideal gas equation.
- For a system in equilibrium at absolute temperature T, total energy is distributed equally in different modes of absorptions. Energy of each mode is equal to $1/2\, K_BT$.
- Each translational and rotational degree of freedom corresponds to one energy mode of absorption.

4 SPECIFIC HEAT CAPACITIES

- Specific heat capacity for solids = $3R$
- Specific heat capacity of water = $9R$
- C_v(monoatomic gas) = $\frac{3}{2}R$ ○ $\gamma = 1 + \frac{2}{f}$
- $\gamma = \frac{5}{3}$ (monoatomic) ○ $\gamma = \frac{7}{5}$ (rigid diatomic)
- Polyatomic gases in general a polyatomic molecules has 3 translational, 3 rotational degree of freedom and a certain number (f) of vibrational modes. Then for one mole of gas

$$U = \left[\frac{3}{2} K_BT + \frac{3}{2} K_BT + fK_BT\right] N_A$$

$$C_V = (3 + f)R \qquad C_P = (4 + f)R \qquad \gamma = \frac{(4+f)}{(3+f)}$$

- Each vibrational frequency has two modes of energy with corresponding energy equal to K_BT.
- Molecules of a monatomic gas have only translational degree of freedom.
- Molecules like CO even at moderate temperature has mode of vibration.
- Diatomic molecule, like a dumbell, has five degree of freedom.
- Polyatomic molecule has 3 transitional, 3 rotational and a degree of a certain number of vibrational modes.

5 MEAN FREE PATH

- Molecules of gas have rather large speeds of the order of speed of sound.
- Molecules of gas undergo collisions and their paths keep getting deflected.
- Average distance a molecule can travel without collision is called mean free path.
- Mean free path of gas molecule is related to number of molecules per unit volume and size of gas molecule.

$$\lambda = \frac{1}{\sqrt{2}\pi n d^2} \equiv \lambda = \frac{K_BT}{\sqrt{2}\pi P d^2}$$

n : number density; d : diameter of molecules

- Mean free path in gases is of order of thousands of angstrom.

P : Pressure of gas; T : Absolute temperature

K_B : Boltzmann's Constant

Sharpen Your Understanding

1. A vessel contains two non-reactive gases; monoatomic neon and diatomic oxygen. The ratio of their partial pressure is 5 : 3. Estimate the ratio of number of moles of neon and oxygen in a vessel. (Molar mass oxygen O_2 = 32.0 u and atomic mass of neon = 20.2 u) [NCERT Pg. 322]
   (1) 5 : 3
   (2) 3 : 5
   (3) 4 : 3
   (4) 2 : 5

2. In case of two ideal gases under ideal conditions of same temperature, pressure and volume, the ratio of mean free paths of molecules having molecular diameter 1Å and 2Å is [NCERT Pg. 337]
   (1) 2 : 1
   (2) 4 : 1
   (3) 1 : 4
   (4) 8 : 1

3. An inflated rubber balloon contains one mole of an ideal gas has a pressure *P*, volume *V* and temperature *T*. If temperature rises to 1.1 T and volume increases to 1.05 V, final pressure will be [NCERT Pg. 322]
   (1) 1.1 P
   (2) P
   (3) Less than P
   (4) Between P and 1.1 P

NCERT Based MCQs

4. Which of the following statement is incorrect? [NCERT Pg. 327]
   (1) In case of collision of gas molecules in a given amount of gas in container, total kinetic energy is conserved
   (2) All collisions of gas molecules is elastic in nature
   (3) Average kinetic energy per degree of freedom depends on temperature only and is independent of nature of gas
   (4) By law of equipartition of energy, the energy for each degree of freedom in thermal equilibrium is K_BT

5. Which of the following is not an assumption of kinetic theory of gases? [NCERT Pg. 327]
   (1) The volume occupied by molecule of gas is negligible
   (2) The force of attraction between molecules is negligible
   (3) All molecules have same speed at a temperature
   (4) The collisions of molecules among themselves are elastic

6. The temperature of the gas is increased from 120 K to 480 K. If at 120 K, the rms speed of gas molecules is V_{RMS} then at 480 K, it becomes [NCERT Pg. 325]
   (1) 4 V_{RMS}
   (2) 2 V_{RMS}
   (3) V_{RMS}
   (4) $\frac{V_{RMS}}{2}$

7. Three moles of oxygen are mixed with two moles of helium, what will be approx. ratio of specific heat at constant pressure and constant volume for the mixture? [NCERT Pg. 329]
   (1) 1.2
   (2) 1.4
   (3) 1.5
   (4) 1.67

8. The kinetic theory of gases gives the formula $P = \frac{1}{3}\frac{Nm}{V}(\bar{v}^2)$ for the pressure *P* exerted by a gas enclosed in a vessel of volume *V*, the term *Nm* represents [NCERT Pg. 324]
   (1) Mass of one mole of the gas
   (2) Mass of gas present in volume *V*
   (3) Total number of molecules present in volume *V*
   (4) Average mass of one molecule of the gas

9. A balloon contains 1500 m^3 of helium at 300 K and 4 atmospheric pressure. The volume of helium at 270 K and 2 atmospheric pressure will be
   [Assuming no leakage of gas] [NCERT Pg. 321]
   (1) 1500 m^3
   (2) 1900 m^3
   (3) 1700 m^3
   (4) 2700 m^3

10. A vessel contains 6 g of oxygen at pressure P and temperature 400 K. A small hole is made in it so that oxygen leaks out. How much oxygen leaks out if final pressure is $\frac{P}{2}$ and temperature is 300 K? [NCERT Pg. 339]

(1) 5 g (2) 3 g
(3) 2 g (4) 4 g

11. If the pressure and volume of a certain quantity of an ideal gas is halved, then its temperature becomes [NCERT Pg. 325]

(1) Doubled (2) One fourth
(3) Four times (4) Remains same

12. Pressure of a gas at constant volume is proportional to [NCERT Pg. 325]

(1) Total internal energy of gas
(2) Square of average kinetic energy of gas molecule
(3) Average potential energy of molecules
(4) Speed of the gas molecule

13. If three molecules have speeds of 2000 ms^{-1}, 1000 ms^{-1} and 500 ms^{-1}, the ratio of rms speed to average speed is [NCERT Pg. 325]

(1) 1.14
(2) 0.92
(3) 1.78
(4) 1.71

14. A real gas behaves like an ideal gas if its [NCERT Pg. 321]

(1) Both pressure and temperature are high
(2) Both pressure and temperature are low
(3) Pressure is high and temperature is low
(4) Pressure is low and temperature is high

15. What will be mean free path of a nitrogen molecule in a container at 2 atmospheric pressure and at 17°C, radius of nitrogen molecule is about 1Å? [NCERT Pg. 337]

(Molar mass of nitrogen = 28.0 u)

(1) 1.11×10^{-7} m
(2) 2.3×10^{-6} m
(3) 2.4×10^{-7} m
(4) 1.8×10^{-9} m

16. Air has density of 1.3 kg m^{-3} and temperature of air is 37°C. If molar mass of air is 28.8, what will be air pressure? [NCERT Pg. 326]

(1) 1.16×10^5 N m^{-2}
(2) 2.1×10^4 N m^{-2}
(3) 1.92×10^5 N m^{-2}
(4) 0.92×10^5 N m^{-2}

17. The ratio of degrees of freedom of a monoatomic gas to diatomic gas is [NCERT Pg. 327]

(1) 3:5 (2) 3:1
(3) 4:5 (4) 1:1

18. A flask contains argon and chlorine in the ratio of 2 : 1 by mass. The mixture temperature is 300 K. What is ratio of root mean square speed of molecules of two gases? [NCERT Pg. 330]

[Atomic mass of argon = 39.9 u and molecular mass of chlorine = 70.9 u]

(1) 1.33
(2) 1. 55
(3) 1.77
(4) 1.66

19. A polyatomic gas has 3 translational, 3 rotational degrees of freedom and 2 vibrational modes. What is molar specific heat ratio for the gas? [NCERT Pg. 334]

(1) 1.50
(2) 1.30
(3) 1.40
(4) 1.20

20. A cylinder of capacity 44.8 litres contains helium gas at standard temperature and pressure. What amount of heat is needed to raise the temperature of gas in cylinder by 10°C? [NCERT Pg. 335]

(1) 173.5 J
(2) 249.3 J
(3) 205.2 J
(4) 374.2 J

Thinking in Context

1. In a closed vessel if pressure is increased by adding some gas, the mean free path of a molecule of gas _____. [NCERT Pg. 332]
2. When an ideal gas undergoes an isothermal expansion, the pressure of the gas in enclosure _____. [NCERT Pg. 321]
3. If a gas container in motion is suddenly stopped, the temperature of the gas may _____. [NCERT Pg. 325]
4. The absolute temperature of a gas is increased three times; the root mean square speed of gas molecule will increase _____. [NCERT Pg. 325]
5. If the pressure of a closed vessel is reduced by drawing out some gas with help of a pump, the mean free path of molecules of the gas is _____. [NCERT Pg. 331]
6. Equal volume of all gases under similar conditions of temperature and pressure contains equal number of molecules. This statement was given by _____. [NCERT Pg. 320]
7. At low pressure or high temperature, the gas molecules are far apart and molecular interaction is minimum. Without interactions the gas behaves like _____. [NCERT Pg. 321]
8. Total pressure of a mixture of ideal gases is the sum of partial pressures. This is called _____ law of partial pressure. [NCERT Pg. 321]
9. Average kinetic energy of a gas molecule is proportional to _____ of the gas. [NCERT Pg. 325]
10. Internal energy of an ideal gas depends only on parameter _____ not on _____ and _____. [NCERT Pg. 325]
11. When gases diffuse, their rate of diffusion is inversely proportional to _____. [NCERT Pg. 327]
12. Molecules of monoatomic gas like argon have only _____ degrees of freedom. [NCERT Pg. 328]
13. In equilibrium, in a gas total energy is equally distributed in all possible energy modes, with each mode having an average energy equal to _____. This is known as the law _____. [NCERT Pg. 328]
14. For one mole of solid, total energy at absolute temperature T is equal to _____. [NCERT Pg. 330]
15. Mean free path depends inversely on _____ and inversely as square of _____ the gas molecules. [NCERT Pg. 331]
16. The ratio of specific heat of a gas at constant pressure and specific heat at constant volume for a diatomic gas is _____ than that of a monatomic gas. [NCERT Pg. 329]
17. Heat capacity of a system, in general depends on _____ it goes through when heat is supplied. [NCERT Pg. 329]
18. Number of molecules per unit volume is the same for all gases at fixed _____ and _____. [NCERT Pg. 320]
19. All collisions between molecules among themselves or between molecules and wall of container are _____. This is in accordance with kinetic theory of an ideal gas. [NCERT Pg. 320]
20. In equilibrium, total energy is equally distributed in all possible energy modes, with each mode has an average energy equal to $\frac{1}{2}K_BT$. But each vibrational mode has energy contribution of _____. [NCERT Pg. 333]

❑ ❑ ❑

Oscillations

14
Chapter

1 SPECIAL TYPES OF MOTIONS

Periodic Motion

A motion which repeats itself after regular intervals of time, (T) is periodic. Examples:

- Motion a particle in circle with constant speed
- Skipping
- Spring block system
- Simple pendulum
- Motion of Earth around sun
- Motion of needle of sewing machine
- A boat tossing up and down in a lake
- Piston of engine going back and forth can be periodic

Oscillatory Motion

Special type of periodic motion in which a particle moves to and fro about a fixed point. The force acting on the particle in a direction directed towards equilibrium position is called **restoring force**.

- Every oscillatory motion is periodic but every periodic motion may not be oscillatory.
- Back and Forth motion can be oscillatory or vibratory. When oscillations frequency is small we call it oscillatory, at high frequency we call it vibratory.

Oscillations can be

A. **Free oscillations**

- When a system oscillates with its natural frequency the oscillations are called free oscillations.

B. **Damped oscillations**

- If some external resisting force appears opposing restoring force, oscillatory amplitude starts decreasing with time.

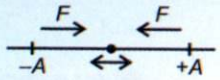
C. **Forced oscillations**

- Forced oscillations are those in which damping is not allowed by applying an external time varying force, which compensates the effect of damping force acting on it.

2 SIMPLE HARMONIC MOTION

- Simple harmonic motion is an example of periodic oscillatory motion.
- Special type of oscillatory motion which satisfies following conditions.
  A. Oscillatory amplitude of particle is small.
  B. During oscillation, acceleration towards mean position, due to net restoring force, is directly proportion to displacement from mean position.
- Force displacement relation in S.H.M.
  $F = -ky$, where K is force constant (Force law in S.H.M.), y is displacement from mean position.
- Acceleration of particle

$$a = \frac{F}{m} = -\left(\frac{K}{m}\right)y = -\omega^2 y$$



∴ Acceleration and displacement are antiparallel

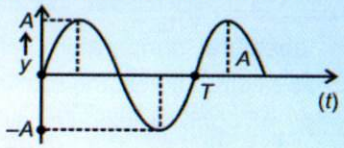
$$\frac{d^2y}{dt^2} + \omega^2 y = 0, \text{ here } \omega = \sqrt{\frac{K}{m}} \text{ (Angular frequency)}$$

m is mass oscillating, K is force constant.

- **General equation for displacement in S.H.M.**
  $y = A\sin(\omega t + \phi)$ or $y = A\cos(\omega t \pm \phi)$
  $\omega = \frac{2\pi}{T} = 2\pi n$ is angular frequency and $(\omega t + \phi)$ is called phase, a time varying quantity.
  Here ϕ is called **epoch** or initial phase.
  A. If particle at $t = 0$ is at equilibrium position. $(y = 0)$
  $y = A\sin\omega t$
  B. If particle at $t = 0$ is at extreme right position $(y = A)$
  $y = A\cos\omega t$
- **Velocity of particle in SHM.**
  $v_P = \frac{dy}{dt} = \omega A\cos(\omega t \pm \phi)$
  If at $t = 0$ particle is at origin.
  $v_P = \omega A\cos\omega t = \omega\sqrt{A^2 - y^2}$
- **Acceleration of particle in SHM**
  $a_P = -\omega^2 A\sin\omega t$, at $t = 0$ particle is at mean position.
- Velocity displacement graph will be an ellipse $(\omega \neq 1)$ or a circle $(\omega = 1 \text{ rad s}^{-1})$.
- The maximum velocity of particle executing SHM will be at mean position and at extremes speed becomes minimum (zero).
- Different graphs for a particle executing SHM

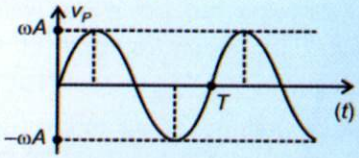
(A) **Displacement - time graph**

If at $t = 0$ particle is at mean position



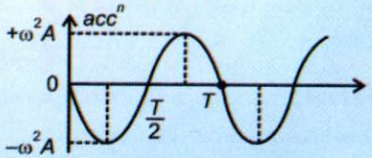
$y = A\sin(\omega t)$

(B) **Velocity - time graph**



$v = A\omega\cos(\omega t)$

(C) **Acceleration time graph**

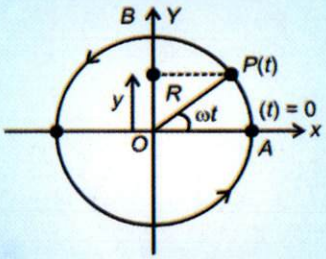


$a = -\omega^2 A\sin(\omega t)$

- Velocity leads displacement by a phase of $(\pi/2)$ rad.
- Acceleration leads velocity a phase of $\pi/2$ rad.

3 SIMPLE HARMONIC MOTION AND UNIFORM CIRCULAR MOTION

- Projection of uniform circular motion on a diameter of the circle follows simple harmonic motion.



Particle position
$y = R \sin \omega t$ is SHM.

This is an equation of S.H.M. for particle displacement at any time.

4 SPECIAL PARAMETERS IN SHM

- Since particles speed is not constant ; from mean position to half of amplitude it takes half of time than to move from half of amplitude to extreme position.
- Minimum velocity in S.H.M. is $v_{min} = 0$ at extremes and maximum velocity at equilibrium position. $v_{max} = \omega A$
- Maximum acceleration of particle is at extreme positions $a_{max} = \omega^2 A$ and minimum (zero) is at equilibrium.
- Maximum force on particle is at extreme positions and zero at mean, in between it varies linearly always directed towards equilibrium.

$F_{max} = m\omega^2 A$ and F_{min} = zero

5 MECHANICAL ENERGY IN SIMPLE HARMONIC OSCILLATOR

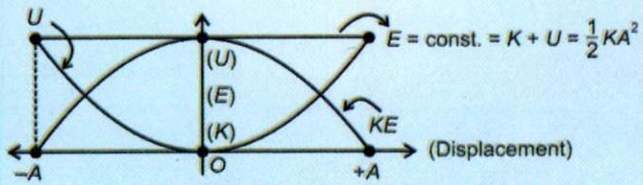
- Potential energy in SHM $U = \frac{1}{2}ky^2 + U_0$

  U_0 is generally taken zero at equilibrium.

  $F_{int} = -\frac{dU}{dy}$; instantaneous force on particle.
- Maximum potential energy occurs at extreme positions and minimum at mean position.
- Graph of potential energy versus displacement of particle will be parabolic, symmetric about y-axis.
- Kinetic energy of particle in S.H.M. varies directly as square of its velocity at any location.

  $KE = \frac{1}{2}(m\omega^2)(A^2 - y^2) = \frac{1}{2}m\omega^2 A^2 \cos^2(\omega t + \phi)$
- Kinetic energy can not be negative. Potential energy increases at expense of KE and vice versa.
- Kinetic energy will be maximum at mean position and zero at extreme position.
- Total mechanical energy is independent of time.
- Potential energy and kinetic energy peaks twice during every period. Element of springiness stores potential energy and element of inertia stores its kinetic energy.
- Graph of kinetic energy versus position of particle will be an inverted parabola.
- In absence of damping ; total mechanical energy of harmonic oscillator will remain constant.

  $E = k_{max} = U_{max} = \frac{1}{2}m\omega^2 A^2$
- Potential energy and kinetic energy is periodic with period $\frac{T}{2}$.
- The graphs for energy versus position are



6 OSCILLATIONS DUE TO A SPRING

(1) **Oscillations of a spring block system**

(Linear S.H.M.)

Force law, $F = -kx$

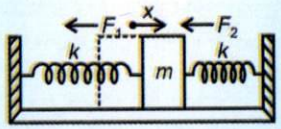
$F = -ma = -m\omega^2 x$

$\therefore \quad k = m\omega^2$ or $\omega = \sqrt{\frac{k}{m}}$

Where k spring constant of spring and m is mass of block executing SHM.

(2) **For two Identical Springs**

This is also linear harmonic oscillator



When displaced right, restoring forces towards left

$F_1 = -kx, F_2 = -kx, F = F_1 + F_2$

$F = -2kx$

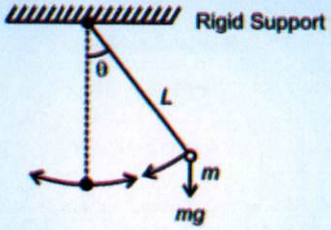
Since force acting on mass is proportional to displacement and directed towards mean position. It is SHM. The period of oscillation is

$T = 2\pi\sqrt{\frac{m}{2k}}$

7 SIMPLE PENDULUM

Simple Pendulum

- By attaching a small mass to an inextensible string, a simple pendulum can be made.
- The mass executes SHM for small displacements only.



$T = 2\pi\sqrt{\frac{I}{mgL}}$ Also here $I = mL^2$, about rigid support point.

$T = 2\pi\sqrt{\frac{L}{g}}$

- The time period of a simple pendulum depends on its length and acceleration due to gravity but is independent of its mass and amplitude.
- Time period of a clock pendulum which ticks every second is 2s and its length is approximately 1 metre.

9 FORCED OSCILLATIONS AND RESONANCE

- An external agency can maintain motion by resisting damping forces. These are called driven or forced oscillations. An external force which is periodic is applied to damped oscillator. Equation of oscillations of mass is $\frac{md^2y}{dt^2} + b\frac{dy}{dt} + ky = F_0 \cos\omega_d t$, and after natural oscillation, die out eqn. is

  $y = A\cos(\omega_d t + \phi)$ and A depends on ω_d and ω.
- If ω_d is close to ω then $A = \frac{F_0}{\omega_d b}$
- The phenomenon of increase of amplitude when driving frequency is close to natural frequency of the oscillators is called resonance.

8 DAMPED SIMPLE HARMONIC MOTION

- A viscous surroundings will apply force on simple pendulum or a spring pendulum and system will ultimately come to rest.
- The damping force depends on nature of surrounding medium. When damping is high, energy is quickly dissipated. This force is generally proportion to velocity of oscillator.

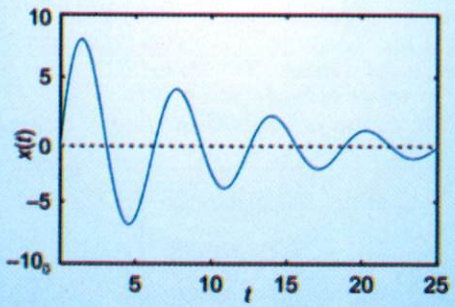
  $\vec{F}_d \propto \vec{v} \Rightarrow \vec{F} = -b\vec{v}$
- Net force $F = -ky - bv$ ($b \rightarrow$ damping factor)

  $ma = -ky - bv$

$\frac{md^2y}{dt^2} + b\frac{dy}{dt} + ky = 0$ is damped equation, whose solution is given by

$y = Ae^{-\frac{bt}{2m}}\cos(\omega' t + \phi)$ for displacement of oscillator.

Where $\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$



- Small damping means $\frac{b}{\sqrt{km}} << 1$
- $\left[E = \frac{1}{2}kA^2e^{-bt/m}\right]$ energy eqn.

Sharpen Your Understanding

1. The equation of motion is represented by $y = \sin \omega t + \cos \omega t$. The time period of periodic motion is [NCERT Pg. 339]

(1) $\frac{\pi}{\omega}$ (2) $\frac{2\pi}{\omega}$

(3) $\frac{2\pi}{\omega}$ (4) $\frac{4\pi}{\omega}$

2. The equation of motion of particle executing SHM is given as $y = \sin^2 \omega t$. The position of equilibrium is [NCERT Pg. 341]

(1) $y = 0$ (2) $y = 1$

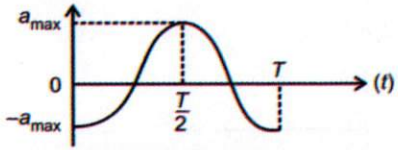
(3) $y = \frac{1}{2}$ (4) $y = -1$

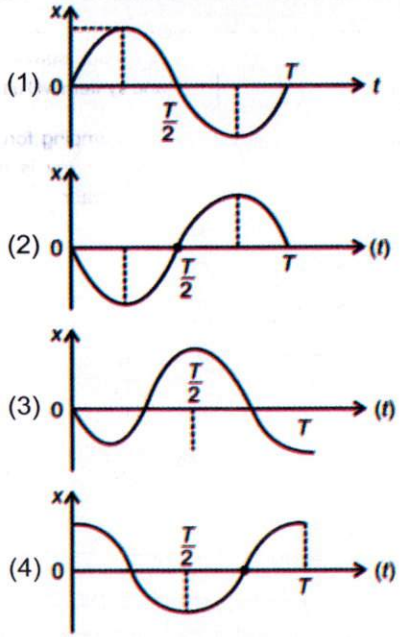
3. A body execute SHM according to equation $x = 10 \cos(2\pi t + \pi/4)$. At $t = 3/2$ s, what is speed of the particle? [NCERT Pg. 339]

(1) 10 ms^{-1} (2) 20 ms^{-1}

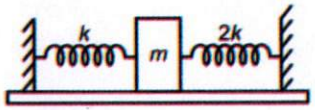
(3) 22 ms^{-1} (4) 44 ms^{-1}

4. Acceleration versus time graph for a particle executing SHM is shown in figure below. Corresponding position time graph will be [NCERT Pg. 344]





5. Two springs with spring constants K and 2K are attached to a block of mass m and with fixed supports as shown. When mass is displaced from equilibrium position on either side, it executes SHM. The frequency of oscillation is [NCERT Pg. 345]



(1) $\frac{1}{2\pi}\sqrt{\frac{3m}{K}}$ (2) $\frac{1}{2\pi}\sqrt{\frac{m}{2K}}$

(3) $\frac{1}{2\pi}\sqrt{\frac{3m}{2K}}$ (4) $\frac{1}{2\pi}\sqrt{\frac{3K}{m}}$

NCERT Based MCQs

6. A particle executes SHM. Its time period is T. The kinetic energy of the particle is also periodic with time period of [NCERT Pg. 346]

(1) T

(2) $2T$

(3) $\frac{T}{2}$

(4) Infinity

7. A block whose mass is 500 g is fastened to a spring. The spring has spring constant of 100 N/m. The block is pulled to a distance of x = 10 cm from its equilibrium position state of x = 0 from rest at t = 0. What is kinetic energy of block at x = 5 cm? [NCERT Pg. 347]

(1) 0.375 J (2) 0.19 J

(3) 0.56 J (4) 0.76 J

8. A block of mass 2 kg is attached to a spring of spring constant 200 Nm^{-1} oscillates without friction over a smooth horizontal surface. The block is displaced by 10 cm from equilibrium position and released. What is maximum acceleration of block? [NCERT Pg. 348]

(1) 1 ms^{-2} (2) 2 ms^{-2}

(3) 0.5 ms^{-2} (4) 1.5 ms^{-2}

9. Length of a simple pendulum whose time period is 2 second on earth surface will be nearly [NCERT Pg. 351]

(1) 0.5 m

(2) 1 m

(3) 1.5 m

(4) 2 m

10. A block of mass 500 g and attached to one end of a spring of spring constant K = 450 Nm^{-1}. The friction is also present which dissipate energy and damping constant of system is 25 g/s. What is time taken for its amplitude of oscillation to drop to half of its initial value. [NCERT Pg. 352]

(1) 18.73 s

(2) 27.72 s

(3) 32.2 s

(4) 6.52 s

11. Which of the following example does not represents SHM? [NCERT Pg. 358]

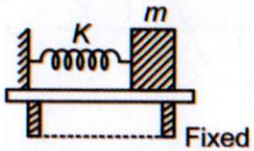
(1) Oscillations of a spring block system

(2) Motion of ball bearing inside smooth curved bowl, when released slightly away from equilibrium

(3) Motion of oscillating mercury column in vertical U-tube

(4) Rotation of earth about its axis

12. A spring having spring constant of 800 Nm^{-1} is mounted on a horizontal table as shown. A mass of 2 kg is attached to free end of the spring. The mass is pulled sideways to distance of 2.5 cm and released. How much time the mass takes from one extreme to other [NCERT Pg. 359]



(1) 0.157 s (2) 0.2 s

(3) 0.314 s (4) 0.782 s

13. The acceleration due to gravity on the surface of moon is 1.7 ms^{-2}. What will be period of oscillation of a simple pendulum on the surface of moon if its time period on the surface of earth is 2s? [NCERT Pg. 361]

(1) 4.8 s (2) 2.8 s

(3) 1.8 s (4) 3.5 s

14. A particle executes SHM has maximum speed of 20 cm s^{-1} and maximum acceleration of 40 cm s^{-2}. The period of oscillation is [NCERT Pg. 361]

(1) π s (2) $\frac{\pi}{2}$s

(3) $\frac{\pi}{3}$s (4) 2π s

15. A spring balance has a scale that reads from 0 to 100 kg. The length of scale is 25 cm. A block suspended from this balance when displaced and released oscillates with time period of 0.2 s. What is mass of block approximately? [NCERT Pg. 359]

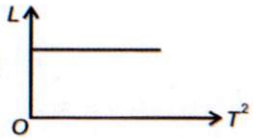
(1) 2 kg

(2) 4 kg

(3) 5 kg

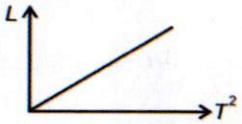
(4) 6 kg

16. The graph between length of pendulum and square of its time period is shown below. The best graph is [NCERT Pg. 351]

(1)


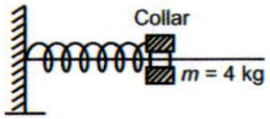
(2)

(3)

(4)


17. A collar of mass 4 kg is attached to a spring of spring constant 500 Nm^{-1}. If collar is displaced from equilibrium position by a distance of 2 cm and released, what is frequency of oscillation?

[NCERT Pg. 348]



(1) 5.4 Hz

(2) 1.78 Hz

(3) 9.36 Hz

(4) 3.26 Hz

18. Two identical springs of spring constant K each are attached to block of mass m and fixed supports as shown in figure (a). The period of oscillation was observed to be T. If one more identical spring is attached as shown in figure (b) then new period will be

[NCERT Pg. 345]

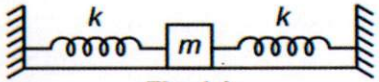


Fig. (a)

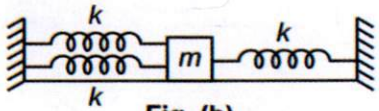


Fig. (b)

(1) $\sqrt{\frac{2}{3}}\,T$

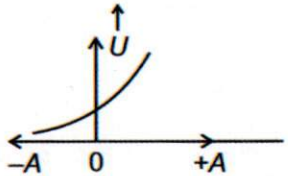
(2) $\sqrt{\frac{3}{2}}\,T$

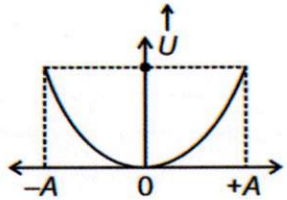
(3) $2T$

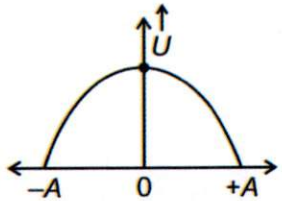
(4) $\sqrt{\frac{1}{3}} \times T$

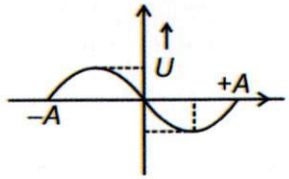
19. A particle executes SHM, has potential energy which changes with position. If potential energy at equilibrium position is assumed to be zero, then potential energy versus position graph is best represented by

[NCERT Pg. 347]

(1) 

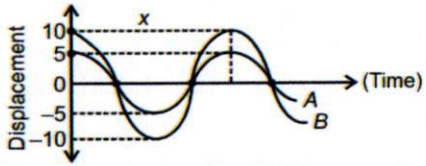
(2) 

(3) 

(4) 

20. The graph of a particle executing SHM is shown for two particles A and B. The ratio of maximum accelerations of A to B is

[NCERT Pg. 341]



(1) 1 : 1

(2) 1 : 2

(3) 2 : 1

(4) 1 : 4

Thinking in Context

1. The direction of acceleration in case of SHM is always towards mean position and is _____ to displacement. [NCERT Pg. 344]
2. The ratio of distance travelled by an oscillator to its amplitude in one time period is _____. [NCERT Pg. 344]
3. In case of a particle executing SHM, phase difference between velocity and acceleration is _____. [NCERT Pg. 343]
4. The length of second's pendulum on surface of Earth is 1 m. The length of second's pendulum on surface of moon will be _____. [NCERT Pg. 351]
5. The displacement of the particle executing SHM where PE and KE are equal is _____ times amplitude of motion. [NCERT Pg. 346]
6. A spring pendulum and simple pendulum have equal time period on earth surface. On the surface of moon simple pendulum has time period _____ than spring pendulum. [NCERT Pg. 348]
7. A body is performing SHM, then its average velocity over a complete cycle is _____. [NCERT Pg. 343]
8. Motion of a ball bearing inside a smooth hemispherical bowl, when released from a point slightly above equilibrium point is _____. [NCERT Pg. 358]
9. The phenomenon of increase in amplitude when driving force is closed to natural frequency of the oscillation is called _____. [NCERT Pg. 354]
10. The mechanical energy in a real oscillating system decreases during oscillations. The real oscillator and its motion are then said to be _____. [NCERT Pg. 351]
11. Every periodic motion is not simple harmonic motion, only that periodic motion governed by the force law in which force is linear proportion to _____ is simple harmonic motion. [NCERT Pg. 345]
12. The kinetic energy of a particle executing simple harmonic motion is maximum at _____. [NCERT Pg. 346]
13. The graph between acceleration and displacement of a particle executing S.H.M. is _____. [NCERT Pg. 344]
14. When amplitude of a particle executing S.H.M. increases its time period _____. [NCERT Pg. 348]
15. The motion of a sewing needle when handle rotated at constant speed is _____. [NCERT Pg. 337]
16. Maximum possible time period of a simple pendulum on the surface of earth will be _____. [NCERT Pg. 344]
17. The projection of uniform circular motion on a diameter of circle follows _____. [NCERT Pg. 342]
18. A particle executing SHM of amplitude 10 cm. At extreme position the force acting is 6 N. At a point midway between mean and extreme position the force is _____. [NCERT Pg. 345]
19. A particle executes SHM with amplitude A and period T. The time taken by the particle from extreme position to half of amplitude is _____. [NCERT Pg. 344]
20. In simple harmonic motion at mean position _____ energy is minimum and _____ energy is maximum. [NCERT Pg. 346]

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Waves

15 Chapter

WAVE

It is a disturbance produced, which transfer energy and momentum without transfer of matter.

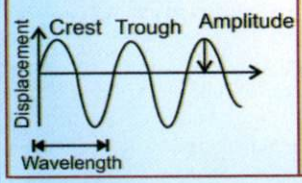
1 TYPES OF WAVES

- **Electromagnetic Wave** – wave propagates in the form of time varying electric and magnetic fields. It require no medium.
- **Matter waves** – wave associated with the particles having momentum.
- **Mechanical waves** – The waves which require a material medium for their propagation.

MECHANICAL WAVES

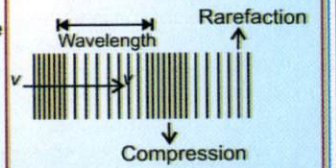
Transverse waves

The individual particle of medium vibrate perpendicular to direction of propagation.



Longitudinal waves

The individual particle of medium vibrate parallel to direction of propagation



- Trasverse waves are possible in solids like strings (under tension), due to shear modulus.
- Longitudinal waves, involve compressive stress, i.e. (Bulk modulus), so is possible in both solids and fluids
- Waves on the surface of water are of two kinds capillary waves and gravity waves

2 DISPLACEMENT RELATION IN A PROGRESSIVE WAVES

- $y(x, t) = a\sin(kx - \omega t + \phi)$

  a = amplitude of wave

  is linear combination of sine and cosine function

  $y(x, t) = A\sin(kx - \omega t) + B\cos(kx - \omega t)$

  Amplitude of resultant wave, $a = \sqrt{A^2 + B^2}$

  $\phi = \tan^{-1}\left(\frac{B}{A}\right)$

  Speed of wave $v = \frac{\omega}{k} = v\lambda$

  $k = \frac{2\pi}{\lambda}$ called angular wave number)

  $(kx - \omega t + \phi)$ = Phase of wave

- **Speed of a Transverse Wave on a Stretched String**

  $v = \sqrt{\frac{T}{\mu}}$

  Here

  T = tension in string (in newton)

  $\mu = \frac{m}{l}$ (mass per unit length of string)

Speed of a Longitudinal wave

- Speed of longitudinal wave in a solid bar $v = \sqrt{\frac{Y}{\rho}}$

  where Y = Young's modulus of material of bar

  ρ = Density of material of bar

- Speed of longitudinal wave in gases

  According to Newton, $v = \sqrt{\frac{P}{\rho}}$ (Isothermal)

  According to Laplace, $v = \sqrt{\frac{\gamma P}{\rho}}$ (Adiabatic)

3 PRINCIPLE OF SUPERPOSITION OF WAVES

- If $y_1(x, t)$ and $y_2(x, t)$ be the displacement due to two wave disturbances in the medium and the waves arrive in a region simultaneously and overlap, the net displacement $y(x, t)$ is given by

  $y(x, t) = y_1(x, t) + y_2(x, t)$

  Similarly, resultant waveform

  $$y = \sum_{i=1}^{n} f_i(x - vt)$$

  In the phenomenon of **interference** of two waves

  $y_1(x, t) = a\sin(kx - \omega t)$

  and $y_2(x, t) = a\sin(kx - \omega t - \phi)$

  The net displacement

  $$y(x, t) = 2a\cos\frac{\phi}{2}\ \sin\left(kx - \omega t + \frac{\phi}{2}\right)$$

  So, amplitude is a function of phase difference

  $$A(\phi) = 2a\cos\left(\frac{\phi}{2}\right)$$

  For $\phi, = 0, A = 2a$ (Constructive interference)

  For constructive interference, path difference between two waves, $\Delta x = 0, \lambda, 2\lambda, \ldots n\lambda$

  For $\phi = \pi, A = 0$ (Destructive interference)

  For destructive interference, path difference between two waves,

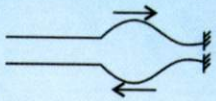
  $$\Delta x = \frac{\lambda}{2}\ \frac{3\lambda}{2}, \ldots (2n-1)\frac{\lambda}{2}$$

4 REFLECTION OF WAVES

- Rigid Boundary – At rigid boundary wave suffer a phase change of π.

$y_i = a\sin(\omega t - kx)$

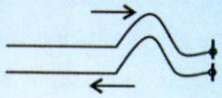
$y_r = -a\sin(\omega t + kx)$



- Open Boundary or Free boundary : At open boundary phase change is 0.

$y_i = a\sin(\omega t - kx)$

$y_r = a\sin(\omega t + kx)$



Standing Waves and Normal Modes

When two waves of same amplitude and of same frequency travel in opposite direction then resultant wave pattern from their superposition is called standing waves.

From open boundary.

$y_i(x, t) = a\sin(\omega t - kx)$,

$y_r(x, t) = a\sin(\omega t + kx)$

$y = y_i + y_r$

$y(x, t) = 2a\sin\omega t\cos kx$

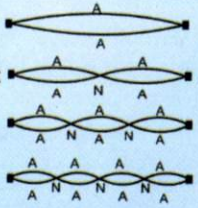
- The amplitude varies from point to point, but each element of string oscillate with same angular frequency (ω)
- **Nodes** – The point at which amplitude is zero or there is no motion called nodes. Distance between two consecutive nodes is $\lambda/2$.
- **Antinodes** – The points at which amplitude is maximum called antinodes. Distance between two consecutive antinodes is $\lambda/2$

Normal modes of stretched string Fixed At Both Ends

$L = \frac{n\lambda}{2}$, $n = 1, 2\ 3$

Frequencies of different modes

$\nu = \frac{nv}{2L}$, $n = 1, 2\ 3$--



(a) fundamental or first harmonic

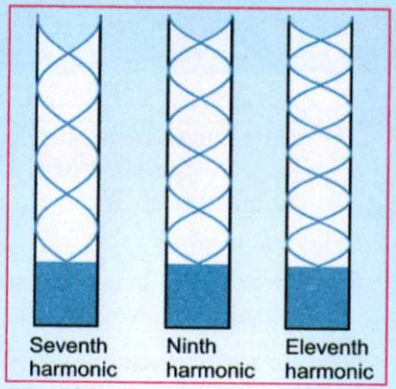
(b) second harmonic

(c) third harmonic

(d) fourth harmonic

5 NORMAL MODES OF ORGAN PIPES

Closed organ pipe



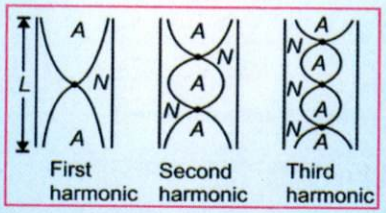
$L = \left(n + \frac{1}{2}\right)\frac{\lambda}{2}$: for $n = 0, 1, 2, 3,.....$

Possible wavelengths $\lambda = \frac{2L}{\left(n + \frac{1}{2}\right)}$

for $n = 0, 1, 2, 3$

Natural frequencies $\nu = \left(n + \frac{1}{2}\right)\frac{v}{2L}$, for n or $= 0, 1, 2, 3$

Open Organ Pipe



$L = n\frac{\lambda}{2}$, for $n = 1, 2, 3...$

Wavelength of stationary wave, $\lambda = \frac{2L}{n}$, for $n = 1, 2, 3...$

Frequencies of different modes, $\nu = \frac{nv}{2L}$, for $n = 1, 2, 3...$

- A compression is reflected as compression from the closed end of the organ pipe and as rarefaction from the open end.
- A rarefaction is reflected as rarefaction from the closed end of the organ pipe and as compression from the open end.

6 BEATS

- When two harmonic sound waves of nearly same frequencies travel in the same direction then the intensity of resultant wave produced from their superposition increase and decrease continuously at same point with time. It is called beat formation.
- Two waves of angular frequencies ω_1 and ω_2 superimpose at, $x = 0$ at time t

$s_1 = a_1\cos\omega_1 t$, $s_2 = a_2\cos\omega_2 t$

from superposition, $s = s_1 + s_2$

$$s = 2a\cos\left(\frac{\omega_1 - \omega_2}{2}\right)t.\cos\left(\frac{\omega_1 + \omega_2}{2}\right)t$$

$$\omega_b = \frac{(\omega_1 - \omega_2)}{2} \text{ and } \omega_a = \frac{(\omega_1 + \omega_2)}{2}$$

Beat frequency, $\nu_{beat} = |\nu_1 - \nu_2|$

- We hear a waxing and warning of sound with frequency equal to difference between the frequencies of superposing waves.

7 DOPPLER EFFECT

Generally, if there is relative motion between a source(s) and observer then observed frequency will be other than real frequency. This apparent change in frequency is called Doppler effect.

- Both source and observer moving

$$\nu = \nu_0\left(\frac{v + v_0}{v + v_s}\right)$$

here v is the speed of sound through the medium, v_0 is the velocity of observer relative to the medium, and v_s is the source velocity relative to the medium. In using this formula, velocities in the direction O to S should be treated as positive and those opposite to it should be taken to be negative.

- When source and observer stationary and wind is blowing towards stationary observer with speed v_w, apparent wavelength

$$\lambda_a = \frac{(v_0 - v_w)}{\nu}$$

- When source is moving towards the stationary observer with medium at rest, apparent wavelength

$$\lambda_a = \frac{(v - v_s)}{\nu}$$

Sharpen Your Understanding

NCERT Based MCQs

1. Some examples of wave motion are given in the following options. In which case wave motion is a combination of both transverse and longitudinal waves?

[NCERT XI Pg. 370]

(1) Motion of a kink in a longitudinal spring produced by displacing one end of the spring side ways

(2) Waves produced in a cylinder containing a liquid by moving its piston back and forth

(3) Waves produced by a motorboat sailing in water

(4) Both (1) and (3)

2. Longitudinal waves in a medium propagate due to [NCERT XI Pg. 390]

(1) Shear modulus

(2) Bulk modulus

(3) Both Shear and Bulk modulus

(4) Young's modulus

3. Modification in Newton's formula for speed of sound in air was made by

[NCERT XI Pg. 376]

(1) Stefan

(2) Boltzman

(3) Laplace

(4) Edison

4. At what temperature will the speed of sound in air becomes 3 times of its value at 0°C?

[NCERT XI Pg. 391]

(1) 1184°C (2) 1148°C

(3) 2184°C (4) 2148°C

5. A bat emits ultrasonic sound of frequency 1000 kHz in air. If the sound meets a water surface, the wavelength of the reflected and transmitted sound are (speed of sound in air = 340 m/s and in water 1500 m/s)

[NCERT XI Pg. 391]

(1) 3.4 mm, 30 mm (2) 6.8 mm, 15 mm

(3) 0.34 mm, 1.5 mm (4) 6.8 mm, 30 mm

6. A pipe 30 cm long, is open at both the ends. Which harmonic mode of the pipe resonates with 1.1 kHz source?

(v = 330 m s^{-1}) [NCERT XI Pg. 382]

(1) First

(2) Second

(3) Third

(4) Forth

7. A progressive wave is represented by $y = 2\sin(100\pi t - 2\pi x)$, where x and y are in cm and t is in second. The maximum particle velocity and wave velocity respectively are

[NCERT XI Pg. 373]

(1) 628 cm/s, 628 cm/s

(2) 50 cm/s, 50 cm/s

(3) 628 cm/s, 50 cm/s

(4) 50 cm/s, 628 cm/s

8. Equation of a plane progressive wave is given by $y = 0.6\sin 2\pi\left(t - \frac{x}{2}\right)$. On reflection from a denser medium its amplitude becomes $\left(\frac{2}{3}\right)^{rd}$ of the amplitude of incident wave. The equation of reflected wave is

[NCERT XI Pg. 379]

(1) $y = 0.6\sin 2\pi\left(t + \frac{x}{2}\right)$

(2) $y = 0.4\sin 2\pi\left(t + \frac{x}{2}\right)$

(3) $y = -0.4\sin 2\pi\left(t - \frac{x}{2}\right)$

(4) $y = -0.4\sin 2\pi\left(t + \frac{x}{2}\right)$

9. A sound is produced by plucking a string in a musical instrument, then

[NCERT XI Pg. 381]

(1) The velocity of wave in string is equal to the sound velocity in string

(2) The frequency of wave in string is equal to the frequency of sound produced

(3) The wave in string is progressive

(4) The frequency of the wave in string is double the frequency of sound

10. A glass tube of 100 cm length is filled with water. The water can be drained out slowly at the bottom of the tube. If a vibrating tuning fork of frequency 500 Hz is brought at the upper end of the tube and the velocity of sound in air is 330 m/s, then the total number of resonances obtained will be [NCERT XI Pg. 382]

(1) 4

(2) 3

(3) 2

(4) 1

11. A tuning fork A of frequency 512 Hz produces 5 beats per second when sounded with another tuning fork B of unknown frequency. If B is loaded with wax the number of beats is again 5 per second. The frequency of fork B before it was loaded is [NCERT XI Pg. 384]

(1) 507 Hz (2) 502 Hz

(3) 517 Hz (4) 522 Hz

12. The equation of a stationary wave along a stretched string is given by $y = 5\sin\frac{2\pi x}{3}\cos 40\,\pi t$ in, where x and y are cm and t is in second. The separation between two adjacent nodes is [NCERT XI Pg. 379]

(1) 1.5 cm (2) 3 cm

(3) 6 cm (4) 4 cm

13. A second harmonic has to be generated in a string of length L stretched between two rigid support. The point where the string has to be plucked and touched are [NCERT XI Pg. 381]

(1) Plucked at $\frac{L}{4}$ and touch at $\frac{L}{2}$

(2) Plucked at $\frac{L}{4}$ and touch at $\frac{3L}{8}$

(3) Plucked at $\frac{L}{2}$ and touch at $\frac{L}{4}$

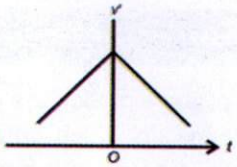
(4) Plucked at $\frac{L}{2}$ and touch at $\frac{3L}{4}$

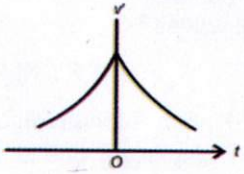
14. An observer moves towards a stationary source of sound with a velocity one fifth of the velocity of sound. The percentage change in apparent frequency is [NCERT XI Pg. 386]

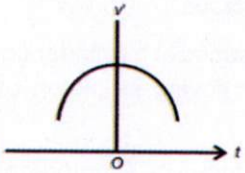
(1) 0% (2) 5%

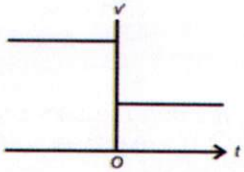
(3) 10% (4) 20%

15. A railway engine whistling at a constant frequency moves with a constant speed.It goes past a stationary observer standing beside the railway track. The frequency (ν') of the sound heard by observer is plotted against time (t). Which of the following graph best represent the variation in apparent frequency with time? [NCERT XI Pg. 385]

(1) 

(2) 

(3) 

(4) 

16. If a wave is incident on a surface and a part of the incident wave is reflected back and a part is transmitted into the second medium, then [NCERT XI Pg. 378]

(1) Incident and refracted waves obey Snell's law of refraction

(2) Incident and refracted waves doesn't obey laws of refraction

(3) Incident and reflected waves obey the usual laws of reflection

(4) Both (1) and (3)

17. Two sitar strings *A* and *B* playing a note are slightly out of tune and produce beats of frequency 5 Hz. When the tension in the string *B* is slightly increased, the beat frequency is found to reduce to 3 Hz. If the frequency of string *A* is 427 Hz. The original frequency of string *B* is [NCERT XI Pg. 392]

(1) 422 Hz

(2) 424 Hz

(3) 430 Hz

(4) 432 Hz

18. The transverse displacement of a string clamped at its both ends is given by $y = 0.06\sin\left(\frac{2\pi x}{3}\right)\cos(120\pi t)$, where *x* and *y* are in metre and *t* is in second. The length of the string is 1.5 m and its mass is 3×10^{-2} kg. The tension in string is [NCERT XI Pg. 392]

(1) 324 N

(2) 648 N

(3) 832 N

(4) 972 N

19. In longitudinal stationary waves, displacement nodes are the points where there is [NCERT XI Pg. 379]

(1) Maximum displacement and maximum pressure

(2) Minimum displacement and minimum pressure change

(3) Minimum displacement and maximum pressure change

(4) Maximum displacement and maximum pressure change

20. Newton assumed that sound propagation in a gas takes under [NCERT XI Pg. 376]

(1) Isothermal condition

(2) Adiabatic condition

(3) Isotropic condition

(4) Isochoric condition

Thinking in Context

1. In any mechanical wave, _____ and not _____ is transferred from one point to the other. [NCERT XI Pg. 367]

2. Transverse wave can propagate only in a medium which can sustain _____ stress. [NCERT XI Pg. 370]

3. The lowest possible natural frequency of a system is called its _____ mode. [NCERT XI Pg. 380]

4. Relative to an observer at rest in a medium the speed of a mechanical wave in that medium depends only on _____ and Inertial properties of medium. [NCERT XI Pg. 374]

5. At rigid boundary there is a phase difference of _____ between incident and reflected wave. [NCERT XI Pg. 379]

6. When two or more waves traverse in opposite direction in the same medium, the net displacement of any element of the medium is the _____ of displacement due to each wave. [NCERT XI Pg. 377]

7. In stationary waves, wavelength is equal to _____ the distance between two consecutive nodes or antinodes. [NCERT XI Pg. 379]

8. The speed of sound in air at constant temperature is independent of _____. [NCERT XI Pg. 391]

9. The propagation constant represents 2π times the _____ that can be accommodated per unit length. [NCERT XI Pg. 372]

10. For a travelling wave, minimum distance between two point having the _____ is called the wavelength of wave.
[NCERT XI Pg. 367]

11. The argument of trigonometric function representing a travelling wave is called the _____ of the wave.
[NCERT XI Pg. 370]

12. The phase determine the _____ of the wave at any position and at any instant.
[NCERT XI Pg. 371]

13. Beats arise when two waves having _____ frequencies and comparable amplitudes are superposed.
[NCERT XI Pg. 389]

14. The waves in an ocean are the combination of both _____ and _____ waves.
[NCERT XI Pg. 370]

15. In a harmonic progressive wave of a given frequency, all the particles have the same amplitude but different _____ at a given instant of time. [NCERT XI Pg. 371]

16. In a stationary wave, all particles between two nodes have the same _____ at a given instant but have different _____.
[NCERT XI Pg. 379]

17. In a stationary wave, all the particles on the two sides of a node oscillates in _____ phase. [NCERT XI Pg. 379]

18. If a wave is incident obliquely on the boundary between two different media, the transmitted wave is called the _____ wave [NCERT XI Pg. 378]

19. If there is no medium present Doppler shifts are _____ irrespective of whether the source moves or the observer moves.
[NCERT XI Pg. 385]

20. In stationary waves, the points at which the amplitude is largest are called _____.
[NCERT XI Pg. 379]

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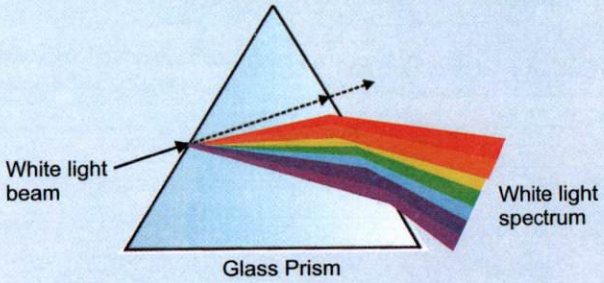
NCERT Maps

PHYSICS

Class XII



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Electric Charges and Fields

1 Chapter

1 ELECTRIC CHARGE

Positive and negative charges were named by Benjamin Franklin.

Charging can be done by

1. Friction 2. Induction 3. Conduction

Charging by friction

When glass rod is rubbed with silk, the rod acquires one type of charge and silk acquires other type of charge.

2 PROPERTIES OF CHARGES

- Two types of charges exist.
- Like charges repel unlike attract.
- A body is charged by loss or gain of electrons.
- In an isolated systems, total charge remains conserved.
- Charge exists in discrete nature. $q = \pm n \times e$
- Moving charge has magnetic effects along with electric effects.
- Accelerating charges emit radiations.
- Gold leaf electroscope detects charge on a body.
- Charge is scalar and additive in nature.

3 CONDUCTORS AND INSULATORS

- Some substances which readily allow passage of electricity through them are called conductors
- Metals, human body and earth are conductors.
- Materials which opposes flow of charge through them are insulators.
- Glass, porcelain, plastic, nylon, wood etc are insulators.

Earthing

A process of sharing charges with earth is called grounding or earthing

4 CHARGES INTERACTION

Coulomb's law is quantitative statement about force between two point charges.

- Force varies inversely as square of distance between the charges and directly proportional to product of magnitude to two charges and acts along the line joining two charges
- Two charges q_1 and q_2 separated by distance r in vacuum, the magnitude of force (F) between them

$$F = K\frac{|q_1 q_2|}{r^2}$$

K depends on system of units and medium. In SI unit in vacuum $K = 9 \times 10^9$. Unit of charge is coulomb(C)

$$F = \frac{1}{4\pi\varepsilon_0}\frac{(q_1 q_2)}{r^2}, \ \varepsilon_0 = 8.854 \times 10^{-12}\ C^2N^{-1}m^{-2}$$

5 FORCE BETWEEN MULTIPLE CHARGES

Force on any charge due to number of other charges is the vector sum of all the forces on that charge due to the other charges, taken one at a time, the individual forces are unaffected by presence of other charges. This is termed as superposition principle of electrostatics. Vector sum of forces is obtained by parallelogram law of addition of vectors. Force on first charge due to other is given as $\vec{F}_1 = \frac{q_1}{4\pi\varepsilon_0}\sum_{i=2}^{n}\frac{q_i}{r_{1i}^2}\hat{r}_{1i}$

6 ELECTRIC FIELD OF GHARGES

- A charge placed at a point produces an electric field everywhere in the surrounding. When another charge is brought in field, field there acts on it and produces a force. Faraday introduced field concept.
- Electric field intensity produced by a charge Q at a point distance r is given by

$$E(r) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{r}$$

- SI unit of electric field is N/C. Field intensity at a point due to charge Q in space is defined as the force that a unit positive charge would experience if placed at that point.

$$\vec{E} = \lim_{q \to 0}\left(\frac{\vec{F}}{q}\right)$$

- Field vary from point to point and is a vector quantity. Field can transport energy.

Field Due to System of Charges

Electric field at a point P in space due to system of charges is defined as force experienced by a unit test charge placed at that point

$$\vec{E}(r) = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_{ip}^2}\hat{r}_{ip}$$

7 ELECTRIC DIPOLE

- An electric dipole is an arrangement of pair of equal and opposite point charges separated by a distance.
- Direction from $-q$ to $+q$ is direction of dipole moment.

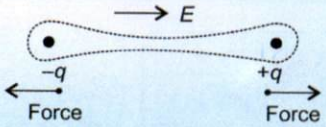
Electric fields due to dipole

On Axis of Dipole	On Equatorial Plane
$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}r}{(r^3 - a^2)^2} \approx \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$ (if $r >> a$)	$\vec{E} = \frac{-1}{4\pi\varepsilon_0}\frac{\vec{p}}{(r^2 + a^2)^{3/2}} \approx \frac{-1}{4\pi\varepsilon_0}\frac{\vec{p}}{(r^3)}$ (if $r >> a$)

- Polar molecule : H_2O have permanent electric dipole moment even in absence of electric field.
- Non polar molecule : CH_4, CO_2. The Dipole moment is zero.
- A dipole in external uniform electric field experience torque but no net force.

$\vec{\tau} = \vec{p} \times \vec{E}$

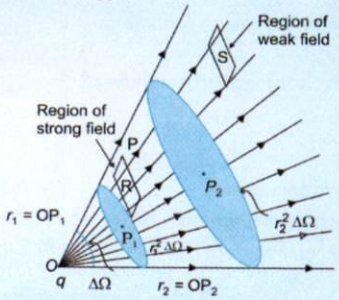
$|\tau| = PE \sin\theta$



8 ELECTRIC FIELD LINES

(Lines of force by Faraday)

Field lines carry information about direction of electric field at different points in space. Relative density of field lines at different points indicates relative strength of electric fields at these points. Faraday introduced non mathematical way of visualizing electric field around charge configuration.



9 ELECTRIC FIELD LINES PROPERTIES

- It is a way of pictorially mapping the electric field around a configuration of charges.
- A line is a curve drawn in such a way that tangent to it at each point is in the direction of net field at that point.
- A field line is a space curve (A curve in three dimension)
- Field lines of a single positive charge are radially outward.
- Field lines start from positive charges and end at negative charges.
- From a single charge, line can start from or end at infinity.
- In a charge free region, electric field lines can be taken to be continuous curves without any breaks.
- Two field lines can never cross each other.
- Electrostatic field lines don't form any closed loop. This follows from their conservative nature.

10 ELECTRIC FLUX

- Similar to fluid flow an analogous quantity exists in electrostatic called electric flux. There is no flow of observable quantity.
- The number of (field) lines crossing a unit area placed normal to field at a point is measure of strength of electric field at that point.
- Number of field lines crossing ΔS area is proportional to $E\Delta S\cos\theta$. This is called electric flux through area element ΔS.

  $\Delta\phi = \vec{E}\cdot\Delta\vec{S} = E\Delta S\cos\theta$

  θ = angle between $\vec{E}$ and outward drawn normal to area element $\Delta\vec{S}$.
- Units : $NC^{-1}m^2$
- Total flux $\phi \approx \Sigma\vec{E}\cdot\Delta\vec{S}$

  Approximate sign is because electric field is taken uniform over area element.

  If $\Delta S \to 0$ then, $\phi = \int \vec{E}\cdot d\vec{s}$

11 GAUSS'S LAW

- Total electric flux through closed surface $s = \frac{q}{\varepsilon_0}$, where q = Total charge enclosed by s
- Total flux is zero if closed surface encloses no charge.
- Gauss law is true for any surface, no matter what its shape or size is.
- q is total charge enclosed by surface, located anywhere inside.
- Gaussian surface should not pass through discrete charges.
- Any violation of Gauss's law will indicate departure of inverse square law.

Application of Gauss's law

- Electric field due to infinitely long wire

  $E = \frac{\lambda}{2\pi\varepsilon_0 r}$, at distance r from linearly charged rod.
- Field of Uniformly Charged Shell

  $E = \frac{q}{4\pi\varepsilon_0 r^2}$ $(r \geq R)$

  Directed out for $q > 0$, directed inwards for $q < 0$

  $E = 0$ $(r < R)$ field is zero inside shell.
- Electric field due to infinite plane sheet

  $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$ is independent of distance from sheet.

Sharpen Your Understanding

NCERT Based MCQs

1. The electrostatic force between two small charged spheres having charges of 2×10^{-6} C and 3×10^{-6} C placed 30 cm apart in air is [NCERT Pg. 46]

(1) 0.9 N (2) 0.6 N

(3) 1.2 N (4) 1.8 N

2. Four point charges $q_A = -2\ \mu C$, $q_B = -5\ \mu C$, $q_C = -2\ \mu C$ and $q_D = -5\ \mu C$ are located at the corners of a square of side 20 cm (In cyclic order). What is electric force on a charge of 1 μC placed at the centre of square? [NCERT Pg. 46]

(1) 0.9 N (2) Zero

(3) 0.6 N (4) 2.4 N

3. A system of two charges $q_A = 2.5 \times 10^{-7}$ C and $q_B = -2.5 \times 10^{-7}$ C are located at points A: (0, 0, – 15 cm) and B: (0, 0, 15 cm) respectively. The electric dipole moment of system is [NCERT Pg. 46]

(1) 2.5×10^{-7} C m (2) 5×10^{-7} C m

(3) 7.5×10^{-8} C m (4) Zero

4. A polythene piece rubbed with wool is found to have negative charge of 3.2×10^{-6} C. The number of excess electrons on polythene is NCERT Pg. 46]

(1) 2×10^{13} (2) 4×10^{12}

(3) 5.5×10^{9} (4) 6×10^{20}

5. An electron falls through distance of 2×10^{-2} m in uniform electric field from state of rest. The time of fall if $E = 6 \times 10^{4}$ NC^{-1} is [NCERT Pg. 21]

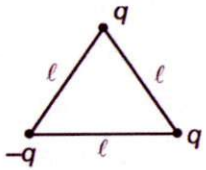
(1) 1.5×10^{-6} s

(2) 1.94×10^{-9} s

(3) 3.3×10^{-5} s

(4) 2.3×10^{-6} s

6. Consider charges q, $-q$ and q placed at vertices of an equilateral triangle as shown in figure. Calculate force on $-q$ charge due to other. [NCERT Pg. 17]



(1) $\frac{q^2}{2\pi\varepsilon_0\ell^2}$ (2) $\frac{q^2}{4\pi\varepsilon_0\ell^2}$

(3) $\frac{\sqrt{2}q^2}{\pi\varepsilon_0\ell^2}$ (4) $\frac{\sqrt{3}q^2}{4\pi\varepsilon_0\ell^2}$

7. Which among the given statements is incorrect statement? [NCERT Pg. 19]

(1) For every positive point charge, electric field lines will be directed radially outwards from charge.

(2) Magnitude of electric field E will depend on distance form point charge

(3) The electric field due to a point charge has spherical symmetry

(4) A test charge q experiences electric force $\vec{F}$ at a point then electric field intensity is defined as $\vec{E} = \frac{\vec{F}}{q^2}$

8. A proton and an electron are released form rest in uniform electric field then the correct statement among the following is [NCERT Pg. 46]

(1) Time required to fall through certain distance is more for an electron

(2) The force experiences by proton will be more

(3) Magnitude of acceleration experienced by proton is more

(4) KE gained by both charges in moving through same distance are equal

9. Regarding electric lines of force, the correct statement is/are [NCERT Pg.24]

(1) Field lines carry information about direction of electric field

(2) Relative density of field lines at different points indicates relative strength of electric field at these points

(3) The field lines crowd where field is weak and spaced apart where field in strong

(4) Both (1) and (2) are correct

10. The incorrect statement among the following statements is [NCERT Pg. 25]

(1) Electric field lines can never cross each other

(2) Electrostatic field lines do not form any closed loop

(3) In charge free region, electric field lines can be taken to be continuous curve

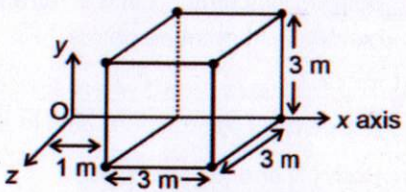
(4) Field lines around a system of two positive charges is straight and parallel lines pictorially

11. A dipole consist of two charges q and $-q$ separated by a distance $2a$. The electric field of this dipole at distance r from centre of dipole at a point A on axis is [NCERT Pg.28]

(1) $\frac{2p}{4\pi\varepsilon_0 r^2}$ (2) $\frac{2p}{4\pi\varepsilon_0 (r^2+a^2)^{\frac{3}{2}}}$

(3) $\frac{p}{4\pi\varepsilon_0 r^3}$ (4) $\frac{2pr}{4\pi\varepsilon_0 (r^2-a^2)^2}$

12. Electric field components are $E_x = 100x^{\frac{1}{2}}, E_y = E_z = 0$. Calculate net electric flux though the cube placed in electric field at shown position. [NCERT Pg. 35]



(1) 900 $Nm^2 C^{-1}$ (2) 1800 $Nm^2 C^{-1}$

(3) 600 $Nm^2 C^{-1}$ (4) 3600 $Nm^2 C^{-1}$

13. An infinite long straight wire has linear charge density $\lambda = 4 \times 10^5$ C m^{-1}. The electric force experienced by a proton at perpendicular distance of 10 mm from axis of wire is [NCERT Pg. 37]

(1) 1.25×10^{-4} N (2) 1.68×10^{-3} N

(3) 2.8×10^{-6} N (4) 1.15×10^{-1} N

14. Coulomb's law of electrostatic for the force between two point charges most closely resembles [NCERT Pg. 12]

(1) Law of conservation of charges

(2) Law of conservation of energy

(3) Newton's second law of motion

(4) Newton's law of gravitation

15. A point charge q of mass m is placed in front of a uniformly charged infinite sheet and released. The surface charge density of sheet is σ C m^{-2}. The kinetic energy of charge after t second is [NCERT Pg. 39]

(1) $\frac{q^2\sigma^2t^2}{4\varepsilon_0^2 m}$ (2) $\frac{q^2\sigma^2t^2}{\varepsilon_0^2 m}$

(3) $\frac{q^2\sigma^2t^2}{8\varepsilon_0^2 m}$ (4) $\frac{q^2\sigma^2t^2}{4\varepsilon_0^2 m^2}$

16. An electric dipole consists of two equal and opposite charges 0.02 μC separated by 2 mm. The dipole is placed is uniform electric field of 10^7 N C^{-1}. Maximum torque exerted by field on dipole is [NCERT Pg. 31]

(1) 2×10^{-4} Nm (2) 4×10^{-4} Nm

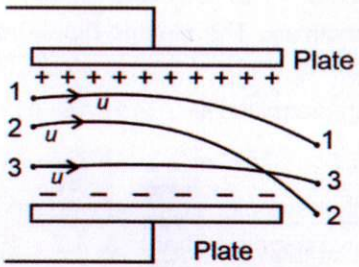
(3) 8×10^{-4} Nm (4) 2×10^{-6} Nm

17. A thin spherical shell is given a charge $q = 4$ μC, uniformly distributed over its surface. Consider a point P outside the shell at distance of 2 m from surface. If the radius of shell is 1 m, what is electric field at point P? [NCERT Pg. 39]

(1) 4 kN C^{-1} (2) 2 kN C^{-1}

(3) 9 kN C^{-1} (4) 36 kN C^{-1}

18. Figure shows track of three positive charged particles through uniform electric field E. All charges are equal in value. Which charge particle has more initial kinetic energy on entering horizontally between the plate? [NCERT Pg. 47]



(1) Particle 1

(2) Particle 2

(3) Particle 3

(4) Both 1 and 2 have equal initial KE

19. A uniformly charged conducting sphere of 3 m diameter has a surface charge density of 90 $\mu C/m^2$. What is total electric flux leaving the surface of sphere?

[NCERT Pg.48]

(1) 1.76×10^8 N m^2 C^{-1}
(2) 2.87×10^8 N m^2 C^{-1}
(3) 5.2×10^8 N m^2 C^{-1}
(4) 4.52×10^6 N m^2 C^{-1}

20. Incorrect statement among the following is

[NCERT Pg.48]

(1) Gauss's law is useful in calculating electric field when system has some symmetry
(2) Gaussian surface can pass through a continuous charge distribution
(3) Gauss's law is based on inverse square dependence of electric field on distance
(4) In situation when surface is so chosen that some charges are outside and some inside, electric field (whose flux appears on left side of Gauss's equation) is only due to the charges inside the closed surface

Thinking in Context

1. When a charge is put on an insulator, it stays at same place, when some charge is transferred to conductor it gets distributed over _____ surface of conductor.

[NCERT Pg. 5]

2. A body is positively charged by ____ electrons and negatively charged by ____ electrons. [NCERT Pg. 4]

3. A simple apparatus to detect charge on a body is ____. [NCERT Pg. 3]

4. When electrified rods are brought near light objects. The rod induces opposite charges on near surface of the objects and similar type of charges move to farther side of objects, this method is called _____.

[NCERT Pg. 6]

5. Experimentally, it is established that all free charges are integral multiple of basic unit of charge. This discrete nature of charge is called _____ of change. [NCERT Pg. 08]

6. SI units of absolute permittivity of free space is _____. [NCERT Pg. 11]

7. Coulomb's law of electrostatic agrees with the Newton's _____ law. [NCERT Pg. 12]

8. The ratio of electrostatic force between two protons to gravitational force at same separation in vacuum is ____.

[NCERT Pg. 13]

9. Experimentally it is verified that force on any charge due to number of other charges is the vector sum of all the forces on that charge due to other charges. This is termed as _____. [NCERT Pg. 15]

10. Away from a point charge, the field gets weaker and density of field lines is less, resulting in well separated field line away from charge. This statement is

[NCERT Pg. 23]

(1) True (2) False

11. Electrostatic field lines do not form any closed loops. This follows from the conservative nature of electric field. The statement is [NCERT Pg. 25]

(1) True (2) False

12. Total charge of electric dipole is _____. The electric field at distance much larger than dipole length of a dipole, on a plane perpendicular to dipole axis varies as ____.

NCERT Pg. 27]

13. Total electric flux through a closed surface is equal to $\frac{q}{\varepsilon_0}$, here q is _____.

[NCERT Pg. 34]

14. In a situation when surface is so chosen that there are some charges inside and some outside. The electric field whose flux appears on left side of Gauss's equation is due to all charges ____ the surface. [NCERT Pg. 34]

15. The shape of graph between electric field intensity and distance from axis of uniformly charged wire is _____. [NCERT Pg. 38]

16. Electric field due to uniformly charged large planar sheet from the surface of planar sheet is _____ distance from sheet. [NCERT Pg. 39]

17. Electric field inside uniformly charged thin spherical shell is ___and for points outside the shell, entire charge of the shell is assumed to be concentrated at ____. [NCERT Pg. 39]

18. **Statement A:** Coulomb's force and gravitational force follow the same inverse law.

Statement B: Gravitation force has one sign (Only attractive) and Coulomb force can give both signs (attractive and repulsive). Both statements are [NCERT Pg. 45]

(1) True

(2) False

19. The electric field due to a discrete charge configuration is not defined at the location of the discrete charges. The statement is [NCERT Pg. 45]

(1) True (2) False

20. The electric field due to charge configuration with total charge zero is not zero, but for distance large compared to the configuration, its field falls of faster than $\frac{1}{r^2}$, typical of field due to single charge. This statement is [NCERT Pg. 46]

(1) True (2) False

❑ ❑ ❑

Electrostatic Potential and Capacitance

2
Chapter

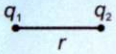
1 ELECTROSTATIC POTENTIAL ENERGY

- Work done by external force in moving a charge against electrostatic repulsive force gets stored in it as potential energy.
- Electric potential energy difference between two points is work required to be done by an external force in slowly moving charge from one point to another against electric field of any charge configuration.
- Potential energy of a charge at a point in electric field due to any charge configuration, is the work done by external force in slowly bringing the charge from infinity to that point.

$$U = \int_{\infty}^{r} \vec{F}_{ext} \cdot \vec{dr} = -\int_{\infty}^{r} \vec{F}_{E} \cdot \vec{dr}$$

2 POTENTIAL ENERGY OF A SYSTEM OF CHARGES

- For assembly of two charges

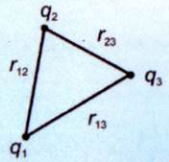


for q_1 and q_2 at separation r

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} \quad \text{(Depends on charge nature)}$$

- For assembly of three charges

$$U = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_2}{r_{12}} + \frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}}\right)$$



3 ELECTRIC POTENTIAL

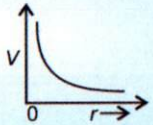
Work done by an external force in bringing a unit positive charge from infinity to that point without acceleration is equal to electrostatic potential at that point.

Its SI unit is volt.

4 ELECTROSTATIC POTENTIAL DUE TO A POINT CHARGE

$$V(r) = \frac{Q}{4\pi\varepsilon_0 r}$$

For $Q > 0, V > 0$
For $Q < 0, V < 0$



5 POTENTIAL DUE TO A SYSTEM OF CHARGES (SUPERPOSITION LAW)

- Potential at a point due to total charge configuration is the algebraic sum of the potentials due to individual charges

$$V = V_1 + V_2 + V_3 + \ldots\ldots = \frac{1}{4\pi\varepsilon_0}\Sigma\frac{q_i}{r_i}$$

6 POTENTIAL DUE TO AN ELECTRIC DIPOLE

- $V = \dfrac{p\cos\theta}{4\pi\varepsilon_0 r^2}$

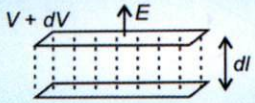
  ($r >>$ dipole length at general point)

- Potential on axis of dipole

$$V = \pm\frac{1}{4\pi\varepsilon_0}\frac{p}{r^2} \qquad \begin{bmatrix} + \text{For } \theta = 0 \\ - \text{For } \theta = \pi \end{bmatrix}$$

- Potential in the equatorial plane of dipole is zero

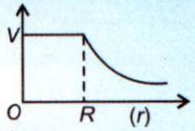
7 RELATION BETWEEN FIELD AND POTENTIAL



$E = -dV/dl$

8 POTENTIAL DUE TO UNIFORMLY CHARGED SPHERICAL CONDUCTING SHELL

- $V = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r} \quad (r \geq R)$



q is charge on shell and R is its radius.

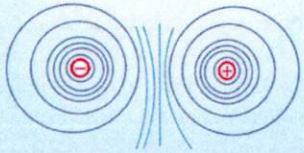
- Potential is constant inside shell and is equal to potential at surface.

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$$

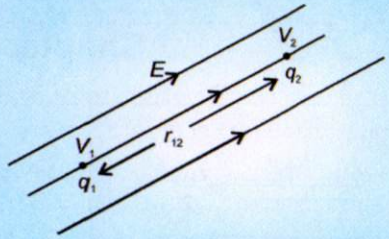
9 EQUIPOTENTIAL SURFACES

- It is a surface with a constant value of potential at all points on its surface.
- Equipotential surfaces of a single point charge are concentric spherical shells centered at the charge.
- For any charge configuration, an equipotential surface is normal to electric field at that point
- No two equipotential surfaces cut each other.

For dipole : Equipotential surfaces :



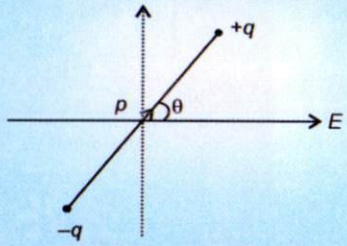
10 POTENTIAL ENERGY IN EXTERNAL FIELD



$$U = q_1V_1 + q_2V_2 + \frac{q_1q_2}{4\pi\varepsilon_0 r_{12}}$$

11 POTENTIAL ENERGY OF A DIPOLE

$$U(\theta) = -pE\cos\theta = -\vec{p}.\vec{E}$$



12 ELECTROSTATICS OF A CONDUCTOR

- Inside conductor, electrostatic field is zero, either is neutral or charged.
- Electrostatic potential is constant throughout volume of the conductor & same value as on surface.
- If a cavity is created inside conductor and a charge is kept outside cavity. Any electric field outside conductor does not enter into the cavity. So cavity of conductor remains shielded.
- No work done is done in moving a charge on a conducting surface.
- When a conductor placed in external electric field, field lines are always normal to conducting surface.

13 DIELECTRICS

- Dielectrics are non conducting substances having no charge carriers.
- Polar dielectric : Polar dielectric has permanent dipole moment. Ex. HCl, H_2O.
- Non polar dielectric : Non polar dielectric has no dipole moment. Ex. O_2, H_2.
- A dielectric with polar/non polar molecules develops a net dipole moment in an external electric field. The dielectric is polarized. Dipole moment developed per unit volume called polarization P.

  $P = \varepsilon_0\chi_e E$, χ_e = electric susceptibility of dielectric medium.

  $\chi_e = (K-1)$

14 DIELECTRIC STRENGTH

- Maximum value of electric field that a dielectric medium can withstand without breakdown (of its insulating property) is called its dielectric strength.
- For air dielectric strength is $E = 3 \times 10^6$ V/m
- For any capacitor, the electric field do not exceed the break down limits. There is limit to charge amount that can be stored on a given capacitor without significance leakage.

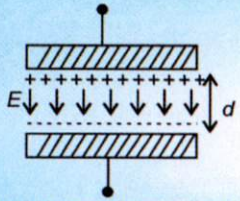
15 CAPACITANCE OF CAPACITORS

$$C = \frac{Q}{V}$$

C is independent of Q and V but depends on shape, size and separation of system of two conductors & also on dielectric, separating two conductors. Every capacitor has limited electric capacity.

SI unit : F (farad)

16 PARALLEL PLATE CAPACITOR



$$C = \frac{\varepsilon_0 A}{d}$$

Plate area : A (For each)

Plate separation : d

Dielectric inserted occupying full intervened region

$$C = \frac{K\varepsilon_0 A}{d}$$

K = dielectric constant of the substance

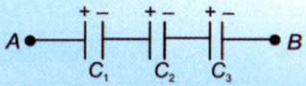
17 COMBINATION OF CAPACITORS

Series Combination of Capacitors

Charges on plates ± Q are same on each capacitor.

$$V = V_1 + V_2 + V_3$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$



- Equivalent capacity decreases.

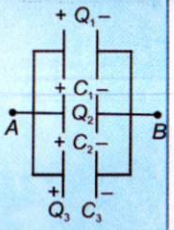
Parallel Combination of Capacitors

Same potential difference is applied across each capacitor.

Plate charges not necessarily same.

Equivalent capacity $C = C_1 + C_2 + C_3$

$$Q = Q_1 + Q_2 + Q_3$$



- Equivalent capacity increases in parallel

18 ENERGY STORED IN A CAPACITOR

- $U = \frac{QV}{2} = \frac{1}{2}CV^2 = \frac{Q^2}{2C}$
- $U/V = u = \frac{1}{2}\varepsilon_0 E^2$ (Enegry density)

19 CHARGE SHARING IN CAPACITORS

- When two capacitors of different potential are joined with positive plates together and negative together, common potential is

$$V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$

- Final energy is less than initial and is lost as heat and electromagnetic radiation

$$\Delta U = \frac{1}{2}\frac{C_1C_2}{C_1 + C_2}(V_1 - V_2)^2$$

Sharpen Your Understanding

1. An electric point charge q = 6μC is placed at origin of x – y Co-ordinate axis. Calculate electric potential due to the charge at point P(12m, 16m) in free space.

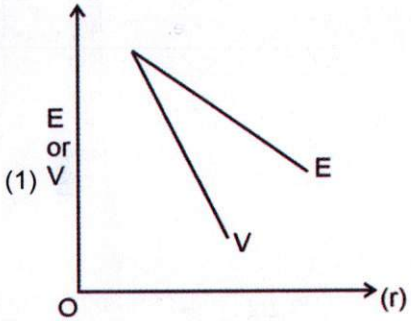
[NCERT Pg. 54]

(1) 1.2 kV (2) 2.3 kV

(3) 3.7 kV (4) 2.7 kV

2. The comparative graph of potential and electric field due to a point charge at a distance r from it is best shown by graph.

[NCERT Pg. 55]

(1)


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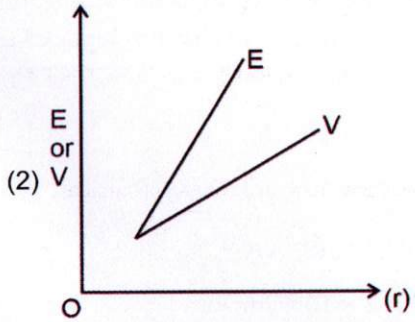

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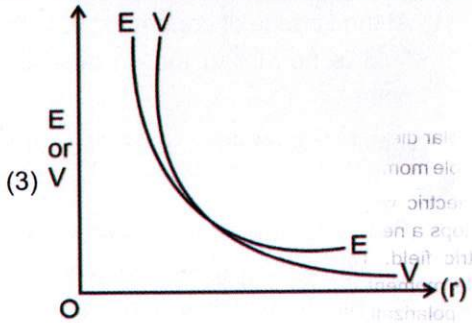

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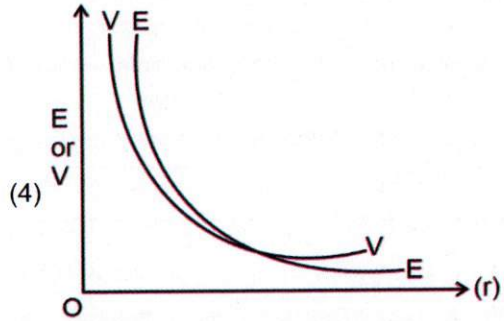


3. A point charge Q = 4 × 10^{-7} C is placed at a point in free space. How much work is required to bring a charge 2 nC from infinity to a point 9 cm from charge Q?

[NCERT Pg. 55]

(1) 3 × 10^{-4} J

(2) 8 × 10^{-5} J

(3) 2 × 10^{-5} J

(4) 5 × 10^{-5} J

4. Which among the following statements is an incorrect statement? [NCERT Pg. 57]

(1) The electric dipole potential falls off, at large distance, as $1/r^2$

(2) The electric potential due to dipole in the equatorial position is zero

(3) The electric potential due to dipole has axial symmetry about dipole moment vector $\vec{P}$

(4) Electric potential on dipole axis is maximum.

5. Two charges 6 nC and –4 nC are located 15 cm apart. At what point on line joining two charges is electric potential zero?

[NCERT Pg. 58]

(1) 6 cm from 6 nC charge

(2) 45 cm from 6 nC charge

(3) 38 cm from 6 nC charge

(4) 9 cm from –4 nC charge

6. The incorrect statement regarding equipotential surface is [NCERT Pg. 60]

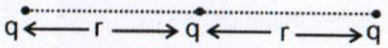
(1) Equipotential surface through a point is normal to electric field at that point

(2) An equipotential surface is a surface with a constant value of potential at all points on the surface

(3) Equipotential surfaces of a single point charge are concentric spherical surfaces centred at the charge

(4) For uniform electric field along x-axis, equipotential surfaces are planes parallel x – y plane

7. Work done by external agent in assembling three identical charges from infinity to given locations is



[NCERT Pg. 62]

(1) $\frac{5}{8\varepsilon_0}\frac{q^2}{r}$ (2) $\left(\frac{5}{8\pi\varepsilon_0}\frac{q^2}{r}\right)$

(3) $\frac{5}{2\pi\varepsilon_0}\frac{q^2}{r}$ (4) $\frac{3q^2}{8\pi\varepsilon_0 r}$

8. Two point charges 7 μC and –2 μC are placed at position (–9 cm, 0) and (9 cm, 0) respectively. How much work is required to separate two charges infinitely away from each other? [NCERT Pg. 66]

(1) 0.2 J (2) 0.5 J

(3) 0.6 J (4) 0.7 J

9. A dipole with dipole moment 3×10^{-9} C m is placed in external uniform field of $E = 4 \times 10^5$ N C^{-1}. Calculate amount of work done by field in rotating the dipole from $\theta = 60°$ to 0°. (θ is angle between electric field E and dipole moment vector) [NCERT Pg. 66]

(1) 200 μJ

(2) 600 μJ

(3) 300 μJ

(4) 90 μJ

10. When a conductor is placed inside uniform electric field. Then [NCERT Pg. 68]

(1) At the surface of conductor, electrostatic field is normal to the surface at every point.

(2) Inside the conductor, electrostatic field is zero.

(3) The electrostatic potential is constant throughout the volume of conductor and has the same value on its surface

(4) All of above are correct

11. Two conductors are separated by distance of 1 cm in air. The dielectric strength of air is about 3×10^6 Vm^{-1}. What maximum safe potential difference can be applied across conductors? [NCERT Pg. 78]

(1) 3×10^4 V (2) 6×10^4 V

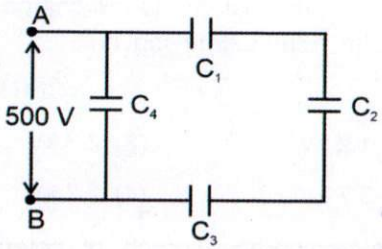
(3) 3×10^6 V (4) 1.5×10^4 V

12. A slab of material having dielectric constant K = 1.5 has the same area as of a plates of parallel plate capacitor but has thickness $\frac{3}{4}$ of plate separation is introduced between the plates of the capacitor having capacitance C. On introducing slab, capacity becomes factor of [NCERT Pg. 78]

(1) $\frac{12}{7}$ C (2) $\frac{5}{7}$ C

(3) $\frac{6}{7}$ C (4) $\frac{4}{3}$ C

13. A network of four capacitors each 10 μF are connected as shown with 500V supply. Calculate the ratio of charges stored on C_4 and C_2



[NCERT Pg. 80]

(1) 1

(2) $\frac{1}{2}$

(3) $\frac{1}{3}$

(4) 3

14. A 900 pF parallel plate capacitor is charged by 100 V ideal battery. The space between the plates is 1cm. How much electrostatic energy is stored per unit volume of empty space of capacitor? NCERT Pg. 82]

(1) 4.42×10^{-4} Jm^{-3}

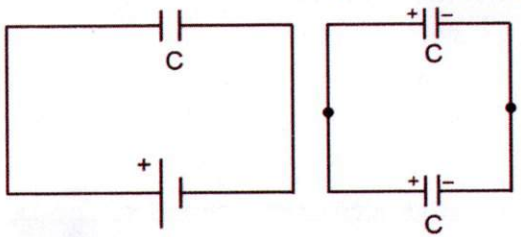
(2) 8.85×10^{-6} Jm^{-3}

(3) 2.21×10^{-7} Jm^{-3}

(4) 6.2×10^{-6} Jm^{-3}

15. A 90 pF capacitor is charged by a 10 V battery. The capacitor is then disconnected from battery and connected to another charged 90 pF capacitor. Final electrostatic energy stored by the system is

[NCERT Pg. 82]



(1) 225 pJ (2) 2.25 nJ
(3) 4.5 pJ (4) 4.5 nJ

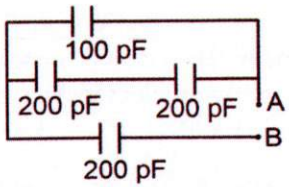
16. A parallel plate capacitor is charged by a battery. Now battery is removed and medium between the plates of the capacitor is filled with an insulating material of dielectric constant K, then [NCERT Pg. 85]

(1) Electric field due to charged plates induces a net dipole moment in the dielectric (insulating material)
(2) Net potential difference between the plates is reduced
(3) Capacitance C decreases from initial value C_0 to (C_0 / K)
(4) Both (1) and (2) are correct

17. A parallel plate capacitor with each plate of area 6×10^{-3} m^2 has plate separation of 3 mm. A 3 mm thick mica sheet of dielectric constant K = 6 was inserted between the plates. If this capacitor is connected to 100 volt supply, what is charge on positive plate of capacitor? [NCERT Pg. 87]

(1) 1.92×10^{-9} C (2) 1.06×10^{-8} C
(3) 4.2×10^{-8} C (4) 4.36×10^{-7} C

18. Equivalent capacitance of the network across points A and B is



[NCERT Pg. 90]

(1) 200 pF (2) 150 pF
(3) 100 pF (4) 700 pF

19. A spherical capacitor consists of two concentric spherical conductors held in position by filling insulating material of dielectric constant 6. The inner sphere has radius of 10 cm and outer has 40 cm. The capacitance of spherical capacitor is

[NCERT Pg. 91]

(1) 100 pF (2) 108 pF
(3) 88.8 pF (4) 73.3 pF

20. A parallel plate capacitor is to be designed with a voltage rating of 2 kV, using a material of dielectric constant 3 and dielectric strength about 12×10^6 Vm^{-1}, for safety we should like the field never exceed 20% of dielectric strength. What minimum area of plate is required to have capacitance of 60 pF?

[NCERT Pg. 91]

(1) 1.2×10^{-6} m^2
(2) 4.75×10^{-4} m^2
(3) 1.88×10^{-3} m^2
(4) 5.65×10^{-3} m^2

Thinking in Context

1. The electric field is discontinuous across the surface of a charged conductor, but electric potential is continuous over the surface. The statement is _____ (True/False)

[NCERT Pg. 91]

2. Two large conducting spheres carrying charges Q_1 and Q_2 are brought close to each other. The electrostatic potential energy of the configuration_____.

[NCERT Pg. 91]

3. Constant uniform electric field is along Y axis, then equipotential surfaces corresponding to field is in____ plane.

[NCERT- Pg. 91]

4. A large number of 1 μF capacitors are available which can withstand a potential difference of 250 V. A technician requires a capacitance of 1 μF in a circuit across 1000 V, the minimum number of capacitors required will be_____. [NCERT Pg. 89]

5. Any cavity in a conductor remains shielded from outside electric influence. This is known as _____. [NCERT Pg. 87]

6. Equivalent capacitance when capacitors are arranged in series is _____ than when same capacitors are arranged in parallel. [NCERT Pg. 86]

7. The electrostatic force is conservative in nature, so work done on charging a capacitor gets stored as potential energy of system. This statement is ____ (True/False) [NCERT Pg. 81]

8. A parallel plate air capacitor of capacity 1F cannot be kept in a room. This statement is _____. (True/False) [NCERT Pg. 75]

9. Electric field between plates of parallel capacitor is uniform. But this is not true near the outer boundaries of the plates. The field lines bend outward at the edge, this effect is called_____. [NCERT Pg. 75]

10. The maximum electric field that a dielectric medium can withstand without breakdown of its insulating property is called its_____. [NCERT Pg. 74]

11. The capacity of any capacitor is independent of Q or V but capacity depends only on_____. [NCERT Pg. 74]

12. When a polar or non polar dielectric develops a net dipole moment in the presence of external field, the dipole moment per unit volume is called _____. [NCERT Pg. 72]

13. No work is done in moving a charge (test) within the conductor and on its surface. Thus there is no potential difference between any two points inside or on the surface of the conductor. This statement is _____ (True/False) [NCERT Pg. 68]

14. Electric field is in the direction in which electric potential _____. The magnitude of electric field is given by change in magnitude of potential _____ normal to an equipotential surface at the point. [NCERT Pg. 61]

15. An equipotential surface through a point is _____ electric field at that point. [NCERT Pg. 60]

16. Electric field inside uniformly charged conducting shell is _____ and electric potential inside shell is_____. [NCERT Pg. 58]

17. The electric potential due to dipole depends not just on distance from dipole but also on angle between position vector and dipole moment vector. This statement is _____ (True/False) [NCERT Pg. 57]

18. Work done by an external force in bringing a unit positive charge from infinity to that point is equal to _____ at that point [NCERT Pg. 53]

19. Actual value of potential energy is not physically significant, it is only the difference of potential energy that is significant. So there is always a freedom in choosing a point where potential energy is zero. The statement is _____ (True/False) [NCERT Pg. 53]

20. 64 identical mercury droplets equally charged are combined to form a big drop. The capacity of big drop compared to one droplet increases by a factor of_____. [NCERT Pg. 90]

❑ ❑ ❑

Current Electricity

3
Chapter

1 ELECTRIC CURRENT

Current through a given area is net charge passing per unit time through the area.

- Current may not always be steady. We define current in general

$$I = \lim_{\Delta t \to 0}\left(\frac{\Delta Q}{\Delta T}\right)$$

- Its SI unit is ampere (A)
- A cell can maintain a steady current

2 DRIFT VELOCITY

The charge carriers like electrons move with an average velocity which is independent of time, this is phenomenon of drift, and is called drift velocity.

$$\vec{v}_d = \frac{-e\vec{E}}{m}\tau$$

τ = relaxation time.

Although collision of electrons don't occur at regular intervals but average time between successive collision is taken as relaxation time.

4 OHM's LAW

The current flowing through a conductor is proportional to potential difference across it, provided temperature is constant.

$$V \propto I \text{ or } V = RI$$

R is the resistance of substance. SI unit of is ohm ($1\,\Omega = 1\,VA^{-1}$)

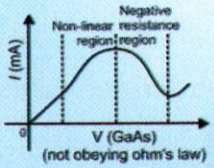
Equivalent form: $\vec{J} = \sigma\vec{E}$ ($\vec{J}$: Current density vector)

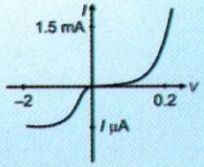
Factors affecting R: $R = \frac{\rho l}{A}$

1. Material of conductor
2. Area of cross-section of conductor
3. Length of conductor,

Limitation of ohm's law

- The relation of V and I is not unique in GaAs.
- V ceases to be proportional to I. Material becomes non-ohmic material.
- For a diode, relation of V and I depends on sign of V. This material is used in electronic devices.





5 RESISTIVITY AND ITS TEMPERATURE DEPENDENCE

- Materials are classified as conductors, semiconductors and insulators according to their resistivity value.
- Metals have resistivity range $10^{-8}\,\Omega$ m to $10^{-6}\,\Omega$ m.
- Insulators have resistivity range from 10^{5} to $10^{18}\,\Omega$ m.
- For metallic conductor over a limited range, resistivity is approximately given by

$\rho_T = \rho_0[1 + \alpha(T - T_0)]$

ρ_T = resistivity at temp. T

ρ_0 = resistivity at temp. T_0

α = temperature coefficient of resistivity

6 TYPES AND COLOUR CODING OF RESISTORS

(a) Wire Bound Resistors

- Made of materials which are relatively insensitive to temperature.
- Winding of wires are of alloys viz., manganin, constantan, nichrome etc.
- Range : fraction of an ohm to few hundred ohms.

(b) Carbon Resistors

- Compact, inexpensive and have higher range.
- Colour coding of carbon resistors

Colour	Number	Multiplier	Tolerance (%)
Black	0	1	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
No colour			20

3 CURRENT DENSITY AND MOBILITY

Current through unit cross-sectional area is called current density.

- It is denoted by J and is a vector.
- SI unit is $A\,m^{-2}$
- $\vec{J} = \sigma\vec{E} = \left(\frac{ne^2}{m}\tau\right)\vec{E}$

σ = conductivity

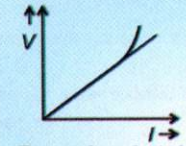
E = electric field inside conductor

The relation is Ohm's law in microscopic form.

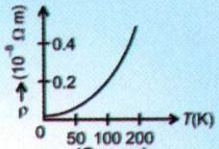
- Conductivity is due to mobile carriers.
- In metals, charge carriers are electrons.
- In ionised gas, they are electrons and positive charged ions.
- In electrolytes they are positive and negative ions.
- Mobility is magnitude of drift velocity per unit electric field.

$$m = \frac{|v_d|}{E} = \frac{e\tau}{m}$$

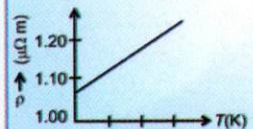
- SI units are $m^2V^{-1}s^{-1}$



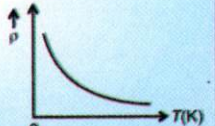
(For good conductor)



(Copper)



(Nichrome)



Semi-conductors

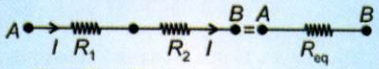
7 CELL AND ITS EMF

- It is a simple device which can maintain a steady current in electric circuit.
- EMF of cell is potential difference between positive and negative electrode when no current is flowing through the cell.
- $V = \varepsilon - ir$ (discharging)
  $V = \varepsilon + ir$ (charging)
- r is called internal resistance. The actual value of r vary from cell to cell.
- Internal resistance of dry cell is higher than electrolytic cell.

8 COMBINATION OF RESISTORS

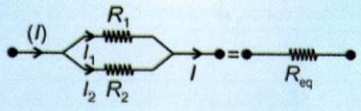
The resistors are sometimes joined together and there are simple rules for calculation of equivalent resistance of such combination.

1. **Series combination:** If only one of their end point is joined.



$R_{eq} = R_1 + R_2$

2. **Parallel combination:** If one end of all the resistors are joined together and similarly other ends joined together. (The potential drop across resistors is same).



$I = I_1 + I_2$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

9 Electrical Energy and Power

Under a potential difference in a conductor charges are moving. These charges suffer collisions with ions and atoms during transit. Energy shared by ions and atoms heats up the conductor. Amount of energy dissipated as heat per unit time is called power loss.

$$P = I^2R = V^2/R = IV$$

R is resistance when current I is flowing through it.

This energy is supplied by source in circuit.

- For long distance transmission, power loss is minimised by transmitting it at high voltage.

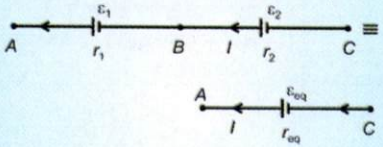
10 KIRCHHOFF'S RULES

- For complicated electric circuits to determine all the currents and potential differences, Kirchhoff formulated two laws:
  - **Junction rule:** At any junction, sum of currents entering the junction is equal to sum of currents leaving the junction.
  - **Mesh or loop rule:** The algebraic sum of changes in potential around any closed loop involving resistors and cells in the loop is equal to zero.

Note: Binding or reorientation of wire does not change the validity of junction law.

11 COMBINATION OF CELLS

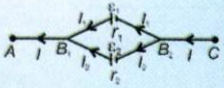
- Cell can be grouped in series or parallel depending upon current requirements.
- In series: Two cells of emf ε_1 and ε_2 with internal resistances r_1 and r_2 the combination can be considered as one cell of emf ε_{eq} and internal resistance r_{eq}



$(\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2)$ and $(r_{eq} = r_1 + r_2)$

- In parallel combination of two cells

$$\varepsilon_{eq} = \left(\frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}\right)$$



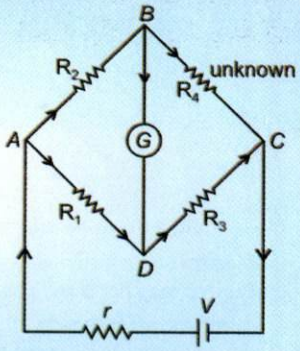
$$r_{eq} = \left(\frac{r_1 r_2}{r_1 + r_2}\right)$$

12 WHEATSTONE BRIDGE

- Wheatstone bridge in its balanced condition provide a practical method for determination of internal resistance.
- If R_1 and R_2 are two resistances in first and second arm and R_3 in third arm. R_3 is kept on changing till galvanometer shows no deflection. The bridge is then balanced and from balance condition R_4 is known.

$$R_4 = R_3 \times \frac{R_2}{R_1}$$

- The value of one resistance is determined knowing other three resistors.

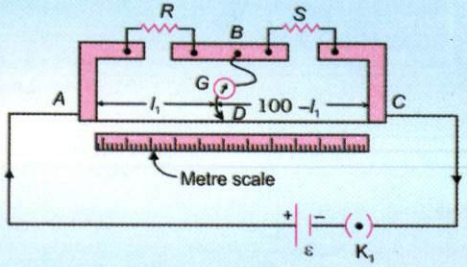


13 METER-BRIDGE

- It is based on wheatstone bridge.
- With same principle as of Wheatstone bridge it is used to calculate unknown resistance, R, under balance condition.

$$R = S \times \frac{l_1}{100 - l_1}$$

- Percentage error in R is minimised by adjusting balance point near the middle of bridge.



14 POTENTIOMETER

This is a versatile electric instrument used to compare emf(s) and to determine internal resistance of a cell.

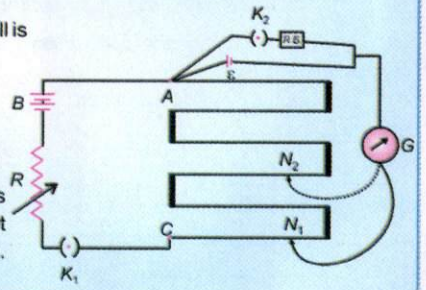
- The method involves condition of no current flow. In this way it can compare emfs of two cells.
- The potentiometer wire has uniform cross-section and homogeneous material so potential drop per unit length of potentiometer wire is constant.
- The formula for internal resistance calculation of cell is

$$r = R\left(\frac{l_1}{l_2} - 1\right)$$

l_1 = balancing length without shorting cell

l_2 = balancing length with cell by parallel resistance R

- The potentiometer has the advantage that it draws no current from voltage source being measured. It is not affected by internal resistance of the source. Thus it has high accuracy.



Sharpen Your Understanding

1. Estimate the average drift speed of conduction electrons in a conductor of cross-sectional area 10^{-7} m^2 carrying current of 1.5 A. The number density of conduction electrons is 8.5×10^{28} m^{-3}.

[NCERT Pg. 99]

(1) 2.2 mm s^{-1}

(2) 1.1 mm s^{-1}

(3) 3.3 mm s^{-1}

(4) 0.1 mm s^{-1}

2. Average collision time for electrons in a conductor under a certain potential difference is found to be 10^{-15} s. The mobility of electron in metal conductor is

[NCERT Pg. 101]

(1) 1.5×10^{-3} m^2/V s

(2) 2.2×10^{-3} m^2/V s

(3) 2.9×10^{-3} m^2/V s

(4) 1.75×10^{-4} m^2/V s

3. A charged particle is having drift velocity of 7.5×10^{-4} m s^{-1} in an electric field of 3×10^{-9} V m^{-1}. The electron mobility is

[NCERT Pg. 101]

(1) 2.5×10^4 m^2 V^{-1} s^{-1}

(2) 2.5×10^5 m^2 V^{-1} s^{-1}

(3) 2.25×10^{-13} m^2 V^{-1} s^{-1}

(4) 4.1×10^3 m^2 V^{-1} s^{-1}

NCERT Based MCQs

4. Arrange following materials in correct order of their conductivity. Nichrome, Copper, Germanium, Silver.

[NCERT Pg. 102]

(1) Silicon > Germanium > Nichrome > Copper

(2) Silver > Copper > Germanium > Nichrome

(3) Silver > Copper > Nichrome > Germanium

(4) Germanium > Nichrome > Copper > Silver

5. The resistivity of alloy manganin

[NCERT Pg. 102]

(1) Increases rapidly with increase of temperature

(2) Decreases linearly with increase in temperature

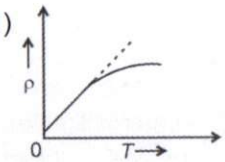
(3) Increases rapidly with decrease in temperature

(4) Is nearly independent of temperature

6. The graph of resistivity versus temperature for copper is best represented by graph shown below. The correct graph is

[NCERT Pg. 104]

(1)



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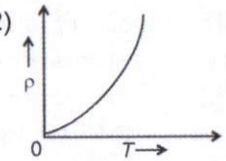

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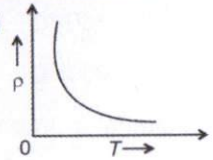

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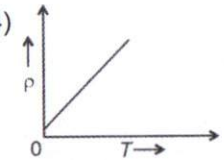


7. A resistor is marked with rings coloured as brown, black, green and gold. The resistance in ohm is [NCERT Pg. 103]

(1) $(3 \times 10^6 \pm 5\%)\ \Omega$

(2) $(1.10 \times 10^5 \pm 5\%)\ \Omega$

(3) $(10^6 \pm 5\%)\ \Omega$

(4) $(8.5 \times 10^6 \pm 5\%)\ \Omega$

8. Which among the following statements is correct? [NCERT Pg. 104]

(1) In a metal, number density is independent of temperature

(2) With increase in temperature, relaxation time in metal decreases

(3) For semiconductors and insulators number density increases with increase in temperature

(4) All the above

9. Nichrome has resistance of 75.3 Ω at 30°C. The resistance of nichrome becomes 85.8 Ω when current passes through it, if average temperature coefficient of resistance of

nichrome is 1.7×10^{-4} C^{-1}. The temperature of nichrome now is [NCERT Pg. 105]

(1) 700 °C (2) 750 °C

(3) 850 °C (4) 900 °C

10. The incorrect statement among the following statements is [NCERT Pg. 111]

(1) Emf of a cell is the potential difference between its positive and negative electrodes in an open circuit

(2) Internal resistance of dry cells is much higher than common electrolyte cells.

(3) The terminal potential difference of a cell can be zero

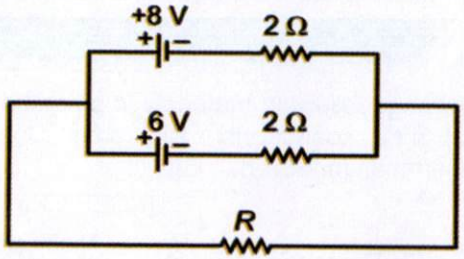
(4) When current passes from positive to negative terminal of a cell inside it, terminal potential difference is less than its emf.

11. When a current of 2 A flows in a battery from its negative to positive terminal, the potential difference across it is 12 V. If a current of 3 A is flowing in opposite direction it produces a potential difference of 15 V, the emf of the battery is [NCERT Pg. 111]

(1) 12.6 V (2) 13.5 V

(3) 14.0 V (4) 13.2 V

12. In the combination of two cells in parallel by joining positive terminals together and similarly two negative ones, the value of $\frac{E_{eq}}{r_{eq}}$ in circuit is [NCERT Pg. 115]



(1) 7 A (2) 10 A

(3) 2 A (4) 8 A

13. When a metal conductor connected to right gap of meter bridge is heated, the balancing point from left end [NCERT Pg. 120]

(1) Shifts towards left

(2) Shifts towards right

(3) Remains unchanged

(4) Shift to zero position

14. Resistance P, Q, S and R are arranged in clockwise cyclic order to form a balanced wheatstone bridge. The ratio of electric power consumed in the branches $(P + Q)$ and $(R + S)$ is [NCERT Pg. 109]

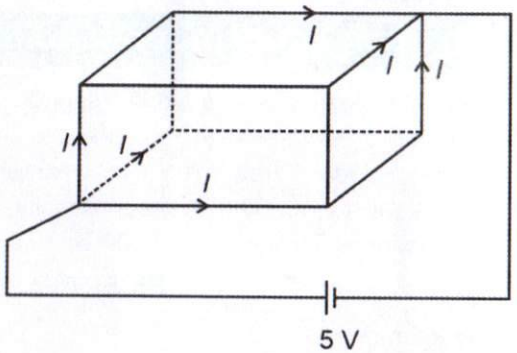
(1) 1 : 1

(2) $R : P$

(3) $R^2 : P^2$

(4) $Q : S$

15. A battery of e.m.f. 5 V and negligible internal resistance is connected across the diagonally opposite corners of a cubical network consisting of 12 resistors of network each of resistance 1 Ω. The current along one edge of the cube is [NCERT Pg. 116]



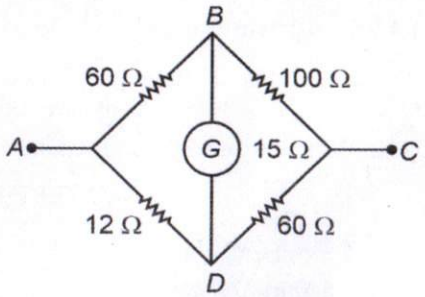
(1) 1 A

(2) 2 A

(3) 3 A

(4) 4 A

16. Four arms of wheat-stone bridge have the following resistances, AB = 60 Ω, BC = 100 Ω, CD = 60 Ω, DA= 12 Ω. A galvanometer of 15 Ω is connected across BD. Calculate the value of additional resistance connected across CD to balance the bridge. [NCERT Pg. 119]

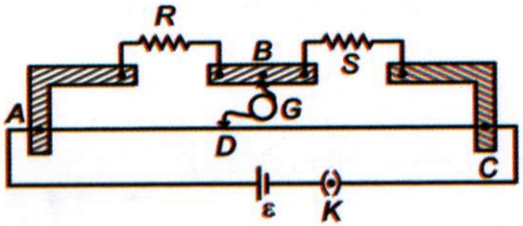


(1) 12 Ω (2) 15 Ω

(3) 18 Ω (4) 30 Ω

17. In a Meter Bridge null point is found to be at 30 cm from end *A*. If now a resistance of 10 Ω is connected in parallel with *S*, the null point occurs at 65 cm, value of *S* is nearly

[NCERT Pg. 121]



(1) 20 Ω

(2) 28 Ω

(3) 33 Ω

(4) 38 Ω

18. In a potentiometer of 8 wires, the balance point is obtained on fifth wire. To shift balance point to 6th wire, we should

[NCERT Pg. 122]

(1) Decrease resistance in main circuit

(2) Increase resistance in main driver circuit

(3) Decrease resistance in series with cell whose emf is to measure

(4) Taking driver battery with higher emf

19. A potentiometer with driver battery of emf 2 V is used for determination of internal resistance of 1.5 V cell. The balance point of the cell in open circuit is 225 cm. When a resistance of 7.0 Ω is used in external circuit across of the cell, the balance point shifts to 210 cm length of potentiometer wire. The internal resistance of the cell is

[NCERT Pg. 131]

(1) 1 Ω (2) 0.5 Ω

(3) 2 Ω (4) 5 Ω

20. Pick out wrong statement about the Kirchhoff's laws of electric circuit.

[NCERT Pg. 116]

(1) Outgoing currents adds up and are equal to incoming currents at a junction

(2) Electric potential in electric circuit is position dependent. Starting with any point if we come back to same point, total potential change must be zero

(3) Junction rule is based on conservation of energy law

(4) Bending or reorienting the wire does not change the validity of Kirchhoff's junction rule.

Thinking in Context

1. Resistance of a conductor depends on material of conductor and also on _____ of conductor. [NCERT Pg. 95]

2. Halving the area of cross-section of a conductor by dividing the conductor into two (by cutting it lengthwise); doubles its resistance. The statement is

[NCERT Pg. 96]

(1) True (2) False

3. Ohm's law is often stated in an equivalent form $\vec{J} = \sigma\vec{E}$ where $\vec{J}$ is current density and $\vec{E}$ the magnitudes of electric field. The statement is [NCERT Pg. 97]

(1) True (2) False

4. In a conductor, when no potential difference is applied, average velocity of all free electrons is _____. [NCERT Pg. 97]

5. In a conductor, collision of electrons don't occur at regular intervals but at random times. The average time between two successive collision is called _____.

[NCERT Pg. 98]

6. Conductivity of conductor has relation with number density of free electrons as $\sigma = \frac{me^2}{n}\tau$. This relation is [NCERT Pg. 99]

(1) True (2) False

7. The direction of drift velocity of conduction electrons is _____ to the electric field direction. [NCERT Pg. 99]

8. Thermal speed of a copper atom with mass 63.5 u at 300 K is about _____. [NCERT Pg. 99]

9. The ratio of drift speed of an electron to the magnitude of speed of electromagnetic wave along conductor is approximately _____. [NCERT Pg. 99]

10. When electrons drift in a metal from lower to higher potential, it means that all free electrons of metal are moving in same direction. This statement is [NCERT Pg. 100]

(1) True

(2) False

11. Between two successive collisions, path of electrons are straight line in the absence of electric field but in the presence of electric field, the paths are in general curved. This statement is [NCERT Pg. 100]

(1) True

(2) False

12. SI units of mobility is _____. [NCERT Pg. 100]

13. The relation between potential difference V applied and flowing current I in certain materials depends on sign of V, in other words, if I is current for certain V, then reversing the direction of V keeping its magnitude fixed does not produce current of same magnitude. One such material is _____. [NCERT Pg. 101]

14. The relation between potential difference 'V' applied and current (I) flowing through a conductor is not unique. There is more than one value of voltage V for same current. A material exhibiting such behaviour is _____. [NCERT Pg. 101]

15. Metals have low resistivities in the order of _____ Ω m to _____ Ω m and for semiconductors like graphite and silicon, its order is from _____ to _____ Ω m respectively. [NCERT Pg. 102]

16. Materials like Nichrome, manganin and constantan are widely used in wire bound standard resistors, since their resistance value would change very little with _____. [NCERT Pg. 104]

17. The emf of a cell is potential difference between the positive and negative electrode of a cell when _____. [NCERT Pg. 110]

18. The algebraic sum of changes in potential around any closed loop, involving resistors and cells in a loop, is zero. This rule is a statement of _____ rule. [NCERT Pg. 116]

19. The Wheatstone Bridge and its balance condition provide a practical method of determination of _____. [NCERT Pg. 119]

20. An error in measurement of resistance R, by meter bridge method can be reduced by adjusting balance point on wire near _____. [NCERT Pg. 121]

❑ ❑ ❑

Moving Charges and Magnetism

4 Chapter

1 MAGNETIC FIELD

- It is space around a current carrying conductor in which its magnetic effects can be felt.
- Oersted concluded that moving charges or currents produced a magnetic field in the surrounding space.

2 LORENTZ FORCE

Mechanical force experienced by a moving charge through electric and magnetic field

$F = q\left[\vec{E} + (\vec{v} \times \vec{B})\right] = \vec{F}_{electric} + \vec{F}_{magnetic}$

- Magnetic force depends on magnitude of charge, its nature and its velocity.
- When charge is at rest, it does not experience any magnetic force.
- When charge is moving parallel to magnetic field, it does not experience any mechanical force.

4 MOTION IN MAGNETIC FIELD

In uniform magnetic field charge particle can have three types of path.

1. Straight line: when $\vec{B} \parallel \vec{v}$
2. Circular path: $\vec{v} \perp \vec{B}$

   Perpendicular force acts as a centripetal force and produces a circular motion perpendicular to magnetic field.

   Radius of circle $r = \frac{mv}{qB}$ and $T = \frac{2\pi m}{qB}$
3. Helical path: velocity $\vec{v}$ and $\vec{B}$ are inclined at angle $\theta \neq 0,\ \theta \neq 90°,\ \theta \neq 180°$

   Velocity component along magnetic field remains unchanged, due to other component motion is circular. The combined path is helical motion.

   $r = \frac{mv_\perp}{qB}, \omega = \frac{qB}{m}, p = \frac{2\pi m v_\parallel}{qB}$

3 VELOCITY SELECTOR

When electric field and magnetic fields are crossed and velocity of particle is perpendicular to both fieldsthen particles with speed $v = \frac{E}{B}$ pass undeflected. This principle is employed in mass spectrometer.

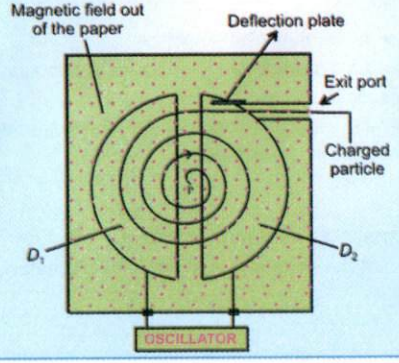
5 CYCLOTRON

A machine to accelerate charged particles or ions to high energies cyclotron; uses both electric and magnetic field in combination to increase kinetic energy of charge particles

- Frequency of revolution of charge particle is independent of its energy.
- $f = \frac{qB}{2\pi m}$. The frequency is called cyclotron frequency.

The frequency of electric field is in resonance with cyclotron frequency. Final KE of ion

$E_K = \frac{q^2B^2R^2}{2m}$, R = radius of Dee



6 BIOT-SAVART'S LAW

- According to this law, the magnetic field at a point due to a current element of length dl carrying current I at distance r from element is

$$|d\vec{B}| = \frac{\mu I dl \sin\theta}{4\pi r^2}$$

θ is angle between $\vec{dl}$ and $\vec{r}$

7 MAGNETIC FIELD ON AXIS OF CIRCULAR COIL

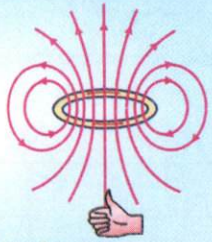
$B = \frac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}}$

where R = radius of coil

x = distance along axis from centre of coil plane

- At the centre of loop, $x = 0$

$B = \frac{\mu_0 I}{2R}$



Field lines form closed loop around circular wire

8 AMPERE'S CIRCUITAL LAW

Law states $\oint_c \vec{B} \cdot \vec{dl} = \mu_0 I$, where I refers to current passing the loop through open surface S. The sign of current is determined from right hand rule.

- If B is directed along tangent to amperian loop of perimeter L and field is constant in magnitude

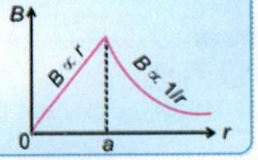
  $BL = \mu_0 I_e$

  I_e = net current enclosed by closed loop.

9 MAGNETIC FIELD DUE TO SOLID CONDUCTOR

A long straight wire with circular cross-section of radius a

- Magnetic field in region $r < a$, $B = \left(\frac{\mu_0 I}{2\pi a^2}\right) r$
- Magnetic field in region $(r \geq a)$, $B = \frac{\mu_0 I}{2\pi r}$



10 MAGNETIC FIELD DUE TO A LINE CURRENT

- Magnetic field at distance R from straight long infinite wire carrying a current I.

$B = \frac{\mu_0 I}{2\pi R}$, field lines are circles concentric with wire.

11 DIRECTION OF MAGNETIC FIELD

The rule is called right hand rule:

Grasp the wire in your right hand with your extended thumb pointing in the direction of the current, your fingers will curl around in the direction of magnetic field.

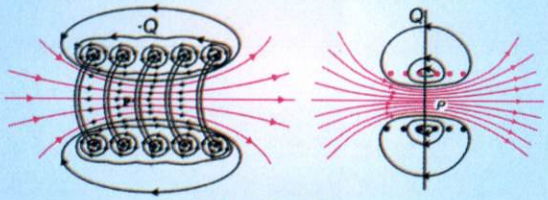
12 LONG SOLENOID

Magnetic field inside long solenoid (B)

When solenoid carries current I is

$B = \mu_0 nI$

n = number of turns per unit length



FOR A TOROID

$B = \frac{\mu_0 NI}{2\pi r}$

N = total number of turns and r = average radius

13 MECHANICAL FORCE ON A CURRENT CARRYING CONDUCTOR

A current carrying conductor of straight length L carrying current I experience force

$\vec{F} = I(\vec{l} \times \vec{B})$

But if wire is of arbitrary shape

$\vec{F} = \sum i(\vec{dl} \times B)$

Summation can be converted into integration in most cases

14 FORCE BETWEEN CURRENT CARRYING WIRES

- Two current carrying conductors placed near each other experience magnetic forces.

When conductors are parallel

$F = \frac{\mu_0 I_1 I_2}{2\pi d} L$

- Force on one conductor of length L due to current in other at separation d. Parallel currents attract and antiparallel currents repel. The results are in accordance with Newton's third law.

15 TORQUE ON CURRENT LOOPS

- Torque on magnetic dipole

$\tau = mB\sin\theta$

$\tau = NIA\sin\theta$

- Any planner current loop is equivalent to magnetic dipole of dipole moment

$m = IA$

16 MAGNETIC MOMENT OF REVOLVING CHARGED PARTICLES

- Magnetic moment associated with revolving electron with speed v in a radius of circle r is

$\mu = -\frac{evr}{2}$

and $\vec{\mu} = \frac{-e}{2m_e}\vec{J}$

Where $\vec{J}$ is angular momentum of the electron

- For electron, angular momentum is opposite in direction to magnetic moment.
- In general for any charge q angular momentum and magnetic moment are in same direction.

$\frac{\mu}{J} = \frac{e}{2m}$

This is called Gyromagnetic ratio and is constant.

Minimum value of magnetic moment is called Bohr magneton

$\mu_m = 9.27 \times 10^{-24}\ Am^2$

17 MOVING COIL GALVANOMETER

- Torque due to radial magnetic field on loop of area A with N number of turns carrying current I is

$\tau = NIAB$

- deflection on scale

$\phi = \left(\frac{NAB}{K}\right) I$

- Quantity in bracket is constant for galvanometer. This makes linear scale
- Current sensitivity of galvanometer

$S_i = \frac{\phi}{I} = \frac{NAB}{K}$

- Current sensitivity can be easily increased by changing N

18 GALVANOMETER CONVERSION AMMETER

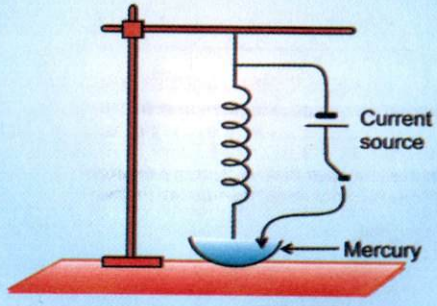
- Modification of galvanometer by connecting a low resistance in parallel.

VOLTMETER

- To measure voltage across any section of circuit. It is connected in parallel. When a large resistance is in series with galvanometer, it becomes a voltmeter.

19 ROGET'S SPIRAL

- When current passes through spring the effect is length of parallel current produces attraction, decreasing spring length, oscillations starts and continue with tick - tick - tick ...



Sharpen Your Understanding

NCERT Based MCQs

1. A current element $\Delta l = dx\hat{i}$ (where dx = 1 cm) is placed at the origin and carries a large current of 10 A. The magnetic field on y-axis at distance of 50 cm from it is [NCERT Pg. 148]

(1) 2×10^{-8} T
(2) 2×10^{-5} G
(3) 4×10^{-8} T
(4) 3×10^{-5} G

2. Consider a tightly wound 100 turn coil of radius 12 cm carrying current of 10 A. What is magnetic field at centre of this coil. [NCERT Pg. 146]

(1) 1.2×10^{-3} T
(2) 5.2×10^{-3} T
(3) 4.6×10^{-5} T
(4) 1.9×10^{-6} T

3. A straight wire carrying current of 15 A is bent into a semicircular arc of radius 2.5 cm. The magnetic field at the centre of semicircular arc is [NCERT Pg. 150]

(1) 1.88×10^{-4} T
(2) 2.6×10^{-4} T
(3) 3.77×10^{-4} T
(4) 5.2×10^{-4} T

4. Consider a tightly wound 200 turns coil of radius 10 cm carrying current of 10 A. The magnitude of magnetic field at the centre of the coil is [NCERT Pg. 151]

(1) $2\pi \times 10^{-4}$ T
(2) $4\pi \times 10^{-3}$ T
(3) $6\pi \times 10^{-4}$ T
(4) $3\pi \times 10^{-3}$ T

5. A long straight wire of circular cross-section of radius 5 cm is carrying a steady current of 20 A, uniformly distributed over its cross-section. The magnetic field induction at 2 cm from the axis of the wire is [NCERT Pg. 149]

(1) 1.6×10^{-4} T
(2) 2.8×10^{-2} T
(3) 3.3×10^{-6} T
(4) 3.2×10^{-5} T

6. A long straight cylindrical wire carries current I and current is uniformly distributed across cross-section of conductor. Figures below shows a plot of magnitude of magnetic field with distance from centre of the wire. The correct graph is [NCERT Pg. 150]

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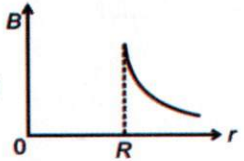

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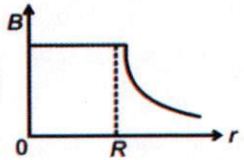

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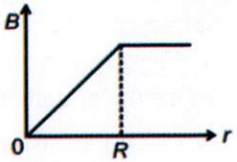

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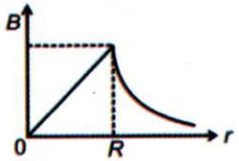


7. A closely wound solenoid 80 cm long has 5 layers of winding of 400 turns each. The diameter of solenoid is 1.8 cm. If it carries current of 8 A then magnitude of magnetic field intensity inside solenoid near its centre is [NCERT Pg. 173]

(1) 1.62×10^{-4} T
(2) 25.13×10^{-3} T
(3) 3.1×10^{-2} T
(4) 16.8×10^{-3} T

8. A circular coil of 30 turns and radius 8 cm carries a current of 6 A. It is suspended in a uniform horizontal magnetic field of 1.0 T. The field lines make an angle of 60° with the normal of the coil. The magnitude of counter torque that must be applied to prevent the coil from turning is [NCERT Pg. 169]

(1) 3.133 N m
(2) 0.236 N m
(3) 30.8 N m
(4) 35 N m

9. In a chamber, a uniform magnetic field of 1.2 T is maintained. An electron is shot into the field with a speed of 3.2×10^6 m s^{-1} normal to the field. The radius of circular orbit in which it starts circular path is

($m_e = 9.1 \times 10^{-31}$ kg) [NCERT Pg. 169]

(1) 15.16 μm

(2) 6.27 μm

(3) 12.42 μm

(4) 22.4 μm

10. Two moving coil galvanometers M_1 and M_2 have the following particulars. $N_1 = 30$, $B_1 = 0.25$ T, $A_1 = 7.2 \times 10^{-3}$ m^2, $G_1 = 10\Omega$ and $N_2 = 60$, $B_2 = 0.50$ T, $A_2 = 1.8 \times 10^{-3}$ m^2, $G_2 = 5\Omega$ respectively. The spring constants are identical to both galvanometers. The ratio of their current sensitivity is [NCERT Pg. 173]

(1) 1 : 1

(2) 2 : 1

(3) 4 : 1

(4) 1 : 4

11. A toroid ring has inner radius 21 cm and outer radius 23 cm in which 4400 turns of wire are wound. If the current in the wire is 10 A, then magnetic field inside the core of the toroid will be [NCERT Pg. 170]

(1) 4.4×10^{-4} T

(2) 4×10^{-2} T

(3) 6.6×10^{-4} T

(4) 12.6×10^{-3} T

12. Two concentric circular coils X and Y of radius 20 cm and 25 cm respectively lie in the same vertical plane. Coil X has 40 turns and coil Y has 100 turns. If coil X and Y carries currents of 18 A each but in opposite sense, the net magnetic field due to the coils at their centre is [NCERT Pg. 170]

(1) 3.12×10^{-4} T

(2) 1.2×10^{-5} T

(3) 7.2×10^{-4} T

(4) 2.26×10^{-3} T

13. A galvanometer has resistance of 60 Ω. It is converted in to an ammeter by connecting a shunt resistance of 1.2 Ω. Its range becomes [NCERT Pg. 172]

(1) 68

(2) 50

(3) 51

(4) 60

14. To convert a galvanometer into a voltmeter of large range, we connect a resistance with galvanometer. The resistance

[NCERT Pg. 165]

(1) Is connected in parallel and of higher value

(2) Is connected in series and of lower value

(3) Is connected in parallel and of lower value

(4) Is connected in series and of higher value

15. Magnetic moment associated with an electron moving at speed v in a circular orbit of radius r is (in magnitudes)

[NCERT Pg. 162]

(1) evr (2) $\frac{evr}{2}$

(3) $\frac{evr}{4}$ (4) $\frac{ev^2}{2r}$

16. The horizontal component of earth's magnetic field at a certain place is 3.2×10^{-5} T and field is directed from south to North. A long straight conductor is carrying a current of 3 A. What is force per unit length experienced by it when it is placed on horizontal table and current in wire is from west to east? [NCERT Pg. 156]

(1) 9.6×10^{-5} Nm^{-1}, upwards

(2) 9.6×10^{-5} Nm^{-1}, downwards

(3) 3.6×10^{-5} Nm^{-1}, upwards

(4) 9.6×10^{-5} Nm^{-1}, horizontal

17. Two long straight parallel wires A and B carrying current of 20 A and 10 A is same direction are separated by a distance of 5 cm. The force of 15 cm section of wire B is

[NCERT Pg. 173]

(1) 1.5×10^{-3} N, attractive

(2) 1.6×10^{-4} N, repulsive

(3) 1.2×10^{-3} N, attractive

(4) 1.2×10^{-4} N, attractive

18. A cyclotron's oscillatory frequency is 10 MHz. What should be the operating magnetic field for accelerating deuterons? [NCERT Pg. 146]

(1) 0.96 T (2) 1.52 T

(3) 0.46 T (4) 1.32 T

19. A charge $q = 1.6 \times 10^{-12}$ C moving with speed of v m s^{-1} crosses electric field $|\vec{E}| = 6 \times 10^4$ Vm^{-1} and magnetic field $|\vec{B}| = 1.2$ T. The electric field and magnetic fields are crossed and velocity v is also perpendicular to both. If the charge particle crosses both fields undeflected, the value of v is [NCERT Pg. 140]

(1) 7.2×10^5

(2) 7.2×10^4

(3) 5×10^5

(4) 5×10^4

20. A proton is moving with speed of 2×10^5 m s^{-1} enters a uniform magnetic field $B = 1.5$ T. At the entry velocity vector makes an angle of 30° to the direction of the magnetic field. The pitch of helical path it describes is nearly [NCERT Pg. 138]

(1) 6.25 mm

(2) 4.37 mm

(3) 7.25 mm

(4) 1.67 mm

Thinking in Context

1. Earth's natural magnetic field is about _____ tesla and that on the surface of a neutron star is about _____ tesla. [NCERT Pg. 135]

2. Magnetic field exerts a mechanical force on current carrying wire $\vec{F}$ = _____, where $\vec{l}$ is conductor length with a direction identical to current I. [NCERT Pg. 136]

3. The product of μ and ε has relation with speed v of electromagnetic wave in a medium and $\mu\varepsilon$ = _____. [NCERT Pg. 136]

4. If magnetic field is parallel to positive y axis and a positive charge particle is moving along positive x-axis, it will experience Lorentz force along _____. [NCERT Pg. 137]

5. In uniform magnetic $\vec{B}$, when a charge particle has motion directed perpendicular to field, particle will move on _____ and work done by magnetic force is _____. [NCERT Pg. 138]

6. When a charged particle enters perpendicular in a uniform magnetic field, magnitude of its angular velocity will be independent of the _____. [NCERT Pg. 138]

7. When electric field and magnetic field are perpendicular to each other and also perpendicular to velocity of a charged particle, then electric and magnetic force are in _____ directions. [NCERT Pg. 140]

8. Cyclotron uses the concept that frequency of revolution of the charged particle in magnetic field is independent of its _____. [NCERT Pg. 140]

9. In a cyclotron, under perpendicular magnetic field $\vec{B}$ (uniform) and radius of Dee R, maximum kinetic energy gained by an ion of charge q and mass m is _____. [NCERT Pg. 141]

10. The electrostatic field is produced by a scalar source, namely, electric charge. The magnetic field is produced by a vector source namely _____. [NCERT Pg. 143]

11. A current element is placed at origin along +x-axis. The observation point where magnetic field is desirable is along +y axis, then magnetic field is directed along _____ axis. [NCERT Pg. 144]

12. Magnetic field due to a long current carrying wire at finite distance is directly proportional to _____ and inversely proportional to _____. [NCERT Pg. 148]

13. There exists a simple rule to determine the direction of magnetic field due to a long wire. This rule is called _____.
[NCERT Pg. 149]

14. A long straight wire of circular cross-section is carrying steady current. The current is uniformly distributed over the cross-section of wire. The magnitude of magnetic field on the axis of wire is _____.
[NCERT Pg. 149-150]

15. A solenoid consists of a long wire wound in the form of helix where neighbouring turns are closely packed. The field outside the solenoid is _____ and field inside the solenoid is parallel to axis and _____.
[NCERT Pg. 151]

16. Toroid can act like magnetic container and are expected to play key role in _____, an equipment for plasma confinement in fusion power reactors.
[NCERT Pg. 153]

17. Two current carrying wires placed near each other can exert mechanical forces on each other. When two straight wires are held parallel it can be observed that parallel currents _____ and antiparallel currents _____ each other.
[NCERT Pg. 155]

18. One ampere is the value of that steady current which when maintained in each of two long, straight, parallel conductors of negligible cross-section, and placed one metre apart in vacuum, would produce on each of these conductors a force equal to _____ newton per metre of length.
[NCERT Pg. 155]

19. Dimensions of magnetic moment are _____ and its SI unit is _____.
[NCERT Pg. 158]

20. Voltage sensitivity is defined as the deflection per unit _____.
[NCERT Pg. 163]

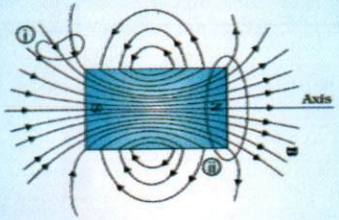
❑ ❑ ❑

Magnetism and Matter

5 Chapter

1 BAR MAGNET

- It is a magnet in form of a bar
- When freely suspended, it points in N - S direction
- Like poles repel each other, unlike poles attract each other
- Magnetic monopoles do not exist
- Magnetic field lines of magnet form continous closed loops
- The tangent at a given point represents the direction of net magnetic field $\vec{B}$ at that point
- Magnetic field lines do not intersect each other.



- When magnet cut transverse to length or along its length $M' = M/2$
- Bar magnet as an equivalent solenoid

$$B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$$

- Magnetic moment of solenoid

$m = nI\,(2l) \times (\pi a^2)$

- Bar magnetic in uniform magnetic field

$\vec{\tau} = \vec{m} \times \vec{B}$

$U_m = -\vec{m}\cdot\vec{B} = -mB\cos\theta$

- $\theta = 0°$ (Most unstable position)
- $\theta = 180°$ (Most unstable position)
- Time period of oscillation of a magnet when freely suspended

$$T = 2\pi\sqrt{\frac{I}{mB}} \text{ and } B = \frac{4\pi^2}{mT^2}$$

2 THE ELECTROSTATIC ANALOGUE

Magnetism	Electrostatics
$\vec{B}$	$\vec{E}$
$\vec{m}$	$\vec{P}$
μ_0	$\frac{1}{\varepsilon_0}$
$\vec{\tau} = \vec{m}\times\vec{B}$	$\vec{\tau} = \vec{P}\times\vec{E}$
$U = -\vec{m}\cdot\vec{B}$	$U = -\vec{P}\cdot\vec{E}$
$\vec{B}_{axial} = \frac{\mu_0}{4\pi}\frac{2\vec{m}}{r^3}$	$E_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{P}}{r^3}$
$\vec{B}_{eq} = \frac{-\mu_0}{4\pi}\frac{\vec{m}}{r^3}$	$\vec{E}_{eq} = \frac{-1}{4\pi\varepsilon_0}\frac{\vec{P}}{r^3}$

3 GAUSS'S LAW FOR MAGNETISM

- $\oint \vec{B}\cdot d\vec{A} = 0$
- Isolated magnetic poles do not exist.
- The net magnetic flux is zero for any closed surface.

5 MAGNETISM AND MAGNETIC INTENSITY

- $\vec{M} = \frac{\vec{m}_{net}}{V} = \frac{\text{Net magnetic moment}}{\text{Volume}}$
- Net field in the interior of a solenoid

$\vec{B} = \vec{B}_0 + \vec{B}_m$

$\vec{B}_0$: Field in free space

$\vec{B}_m$: Field contributed by material core

$\vec{B}_0 = \mu_0\vec{H}$ $\quad$ $\vec{B}_m = \mu_0\vec{M}$

$\vec{B} = \mu_0(\vec{H} + \vec{M})$ $\quad$ $\vec{M} = \chi\vec{H}$

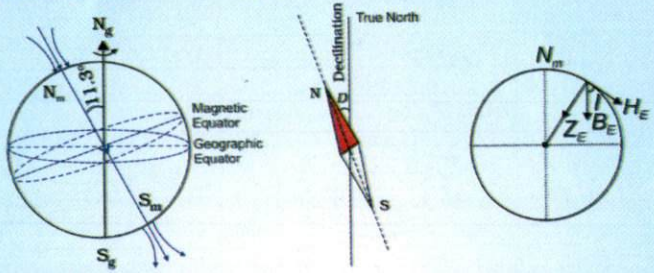
$\vec{B} = \mu_0(1+\chi)\vec{H}$ $\quad$ $\mu_r = 1+\chi$

$\vec{B} = \mu_0\mu_r\vec{H}$ $\quad$ $\mu = \mu_0\mu_r = \mu_0(1+\chi)$

$\vec{B} = \mu\vec{H}$

4 EARTH'S MAGNETISM

- Magnetic field of earth is now thought to arise due to electrical current produced by convective motion of metallic fluids in outer core of the earth. This is known as dynamo effect .
- Magnetic poles inside earth change position with times.



- Earth's magnetic field varies from point to point on earth surface, its value being of order of 10^{-5} T.
- Magnetic field lines of earth resemble that of a hypothetical magnetic dipole located at the centre of earth.
- The vertical plane which passes through the imaginary line joining the magnetic north and the south poles is called magnetic meridian.
- The vertical plane containing longitudinal circle and axis of rotation of earth is called geographic meridian.
- **Inclination or magnetic dip(I)**

  Angle made by the net magnetic field of earth with the horizontal

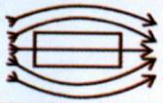
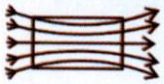
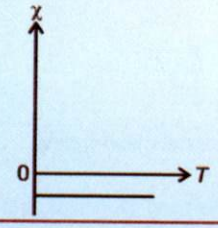
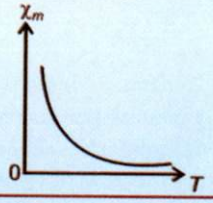
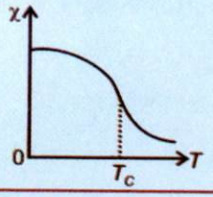
  $I_{equator} = 0$

  $I_{pole} = 90°$
- **Horizontal component (H_E)**

  Horizontal Component of net magnetic field of earth
- **Magnetic declination(D)**

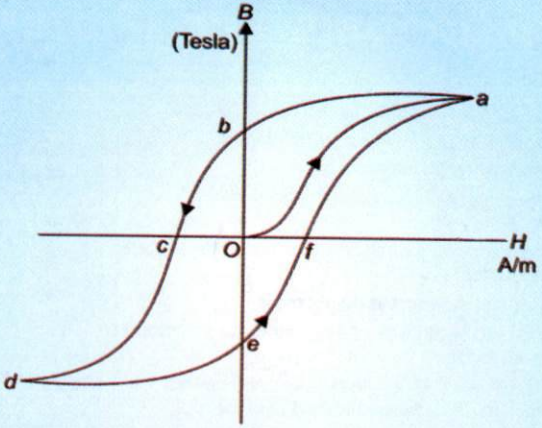
  Angle between magnetic meridian and geographic meridian
- Declination in India is small. It is 0°41' E at Delhi.
- Declination is greater at higher latitudes and smaller near equator.
- $B_E\sin I = Z_E$, $B_E\cos I = H_E$, $\tan I = Z_E/H_E$

6 MAGNETIC PROPERTIES OF MATERIALS

Properties	Diamagnetic	Paramagnetic	Ferromagnetic
χ	$-1 \le \chi \le 0$	$0 < \chi < k$ (k is a small positive number)	$\chi >> 1$
μ_r	$0 \le \mu_r < 1$	$1 < \mu_r < 1 + k$	$\mu_r >> 1$
μ	$\mu < \mu_0$	$\mu > \mu_0$	$\mu >> \mu_0$
Magnetisation	Weak magnetisation is opposite direction	Weak magnetisation in same direction	Strong magnetisation in same direction
Movement in non-uniform magnetic field	(Weak tendency) from strong to weak magnetic field	(Weak tendency) from weak to strong magnetic field	(Strong tendency) from weak to strong magnetic field
Magnet	Weak Repulsion	Weak Attraction	Strong Attraction
E.g.	Bi, Au, Pb, Si, H_2O, NaCl N_2 (STP), Ag, superconductor	Al, Na, O_2 (STP), Pt, W	Fe, Co, Ni, Fe_2O_3 and Gd
Mag. Field lines			
Susceptibility	Independent of temperature $\chi_m \propto T^0$ 	Inversely proportional to temperature $\chi_m = \frac{C\mu_0}{T}$ Where C is curie constant 	Curie temperature: The temperature at which ferromagnetic substance becomes paramagnetic Disappearance of magnetisation with temperature is gradual. Beyond curie temperature Susceptibility obeys Curie-Weiss law $\chi_m = \frac{C}{T - T_C} (T > T_C)$ T_C for iron is 1043 K T_C for nickel is 631 K 

- Domain formation is special characteristic of ferromagnetic material. Typical domain size is 1 mm and domain contains about 10^{11} atoms.

7 HYSTERESIS LOOP



- **Retentivity:** The value of B at $H = 0$
- **Coercivity:** The value of H for which net magnetic field becomes zero.
- Energy is lost in the form of heat during complete cycle of magnetisation and de-magnetisation.
- Hysteresis curve of soft iron is tall and narrow.
- Hysteresis curve of steel is broad

8 PERMANENT MAGNETS AND ELECTROMAGNETS

Permanent Magnets	Electromagnets
Material should have	Material should have
High Retentivity	Low Retentivity
High Coercivity	High permeability
High permeability	Low Coercivity
Material used for making these magnets are Alnico, Cobalt, Steel, Ticonal	Material used for making these magnets is soft Iron
These materials retain their ferromagnetic property for long period of time.	Electromagnets are used in electric bells, loud speakers and telephone diaphragms.

Sharpen Your Understanding

1. The net magnetic flux through any closed surface is [NCERT Pg. 182]
   (1) Always positive
   (2) Always negative
   (3) May be positive or negative
   (4) Always zero

2. The vertical plane which passes through the imaginary line joining the magnetic north & the south poles is known as [NCERT Pg. 186]
   (1) Geographical meridian
   (2) Magnetic meridian
   (3) Magnetic declination
   (4) Magnetic dip

3. Which of the following quantities include in the element of earth's magnetic field? [NCERT Pg. 187]
   (1) The declination
   (2) Angle of dip
   (3) Horizontal component of earths magnetic field
   (4) All of the above

4. The magnetic needle shown in the figure has magnetic moment 6.7×10^{-2} A m^2 and moment of inertia 7.5×10^{-6} kg m^2. It performs 10 complete oscillations in 6.70 s. The magnitude of magnetic field is

[NCERT Pg. 178]
   (1) 0.02 T (2) 0.01 T
   (3) 0.03 T (4) 0.05 T

5. A short bar magnet placed with its axis at 53° with an external field of 600 G experiences a torque of 0.024 N m. Magnetic moment of the magnet is [NCERT Pg. 179]
   (1) 0.4 A m^2 (2) 0.8 A m^2
   (3) 0.6 A m^2 (4) 0.5 A m^2

6. A magnetic needle is placed in an external magnetic field at an angle θ with the field. Needle is in most stable position if the value of θ is [NCERT Pg. 178]
   (1) 180° (2) 90°
   (3) 0° (4) 60°

7. In the magnetic meridian of a certain place, the horizontal component of earth's magnetic field is 0.48 G and the dip angle is 53°. Magnetic field of the earth at this location is [NCERT Pg. 188]
   (1) 0.3 G
   (2) 0.8 G
   (3) 0.64 G
   (4) 0.96 G

8. Which of the following is a correct relation? [NCERT Pg. 190]
   (1) $\mu_r = \chi\mu$
   (2) $\mu_r = 1 + \chi$
   (3) $\mu_r = 1 - \chi$
   (4) $\mu_r = \frac{1}{\chi}$

NCERT Based MCQs

9. A solenoid has a core of a magnetic material with relative permeability 500. Number of turns in the solenoid are 1000 per metre and carry a currents of 5 A. Magnetic intensity H will be. [NCERT Pg. 191]
   (1) 5×10^3 A/m
   (2) 2.5×10^6 A/m
   (3) 10^5 A/m
   (4) 250 A/m

10. Which of the following is not a diamagnetic material? [NCERT Pg. 192]
   (1) Bismuth (2) Copper
   (3) Nitrogen (STP) (4) Sodium

11. According to Curie's law for paramagnetic material [NCERT Pg. 193]
   (1) $\mu_0 = \frac{C\chi}{T}$ (2) $\chi = C\mu_0 T$
   (3) $\chi = \frac{C\mu_0}{T}$ (4) $\mu_0\chi = CT$

12. The temperature of transition from ferromagnetic to paramagnetic is called the [NCERT Pg. 194]
   (1) Transition temperature
   (2) Inversion temperature
   (3) Curie temperature
   (4) Neutral temperature

13. Suitable materials for permanent magnets, should have [NCERT Pg. 196]
(1) High retentivity and low coercivity
(2) Low retentivity and high coercivity
(3) High retentivity and high coercivity
(4) Low retentivity and low coercivity

14. Curie temperature for cobalt is [NCERT Pg. 194]
(1) 1394 °C (2) 1394 K
(3) 1043 °C (4) 1043 K

15. At a certain place a freely suspended magnetic needle makes 20 oscillations per minute. At another place where the magnetic field is 4 times, time period of same needle will be [NCERT Pg. 178]
(1) 10 s (2) 1 s
(3) 1.5 s (4) 3 s

16. Correct dimensional formula for the permeability of free space is [NCERT Pg. 198]
(1) $[MLT^{-2}A^{-2}]$ (2) $[ML^{-1}T^{-2}A^{3}]$
(3) $[M^{-1}L^{2}T^{-2}A]$ (4) $[ML^{3}T^{-3}A^{2}]$

17. Which of the following relation is correct? (symbols have their usual meaning) [NCERT Pg. 190]
(1) $B = \mu_0(1 + \chi)H$ (2) $B = \mu_0\mu_r H$
(3) $B = \mu_0 (H - M)$ (4) Both (1) and (2)

18. The phenomenon of perfect diamagnetism in superconductors is called [NCERT Pg. 192]
(1) Dynamo effect
(2) Meissner effect
(3) Stark effect
(4) Zeeman effect

19. A closely wound solenoid of 3000 turns and area of cross- section 1.6×10^{-4} m^2, carrying a current of 5.0 A, is suspended through its centre. Magnetic moment associated with the solenoid is [NCERT Pg. 201]
(1) 12.8 A m^2
(2) 5.6 A m^2
(3) 4.8 A m^2
(4) 2.4 A m^2

20. Electromagnets are used in [NCERT Pg. 196]
(1) Electric bells
(2) Cranes to lift machinery
(3) Loudspeaker
(4) All of the above

Thinking in Context

1. The word magnet is derived from the name of an island in Greece called _____. [NCERT Pg. 173]

2. A thin long piece of magnet, when suspended freely points in _____ direction. [NCERT Pg. 173]

3. The magnetic field lines of a magnet form _____ loops. [NCERT Pg. 175]

4. Magnetic _____ do not exist [NCERT Pg. 174 & 177]

5. When a magnetic needle is placed perpendicular to uniform external magnetic field, its potential energy is _____. [NCERT Pg. 178]

6. The electrostatic analog of μ_0 is _____. [NCERT Pg. 180]

7. The pole near the geographic north pole of the earth is called _____ magnetic pole. [NCERT Pg. 185]

8. The vertical plane containing the longitude circle and the axis of rotation of the earth is called _____. [NCERT Pg. 186]

9. The declination is greater at higher latitudes and smaller near the _____ [NCERT Pg. 186]

10. _____ is the angle that the total magnetic field of the earth makes with surface of the earth. [NCERT Pg. 187]

11. Magnetization of a sample is defined as the _____ per unit volume [NCERT Pg. 189]

12. Magnetic susceptibility of a material is small and positive. This material is _____. [NCERT Pg. 190]

13. Relative magnetic permeability of a substance is analog of _____ in electrostatics. [NCERT Pg. 190]

14. Diamagnetic substance has tendency to move from _____ to _____ part of the external non-uniform magnetic field. [NCERT Pg. 192]

15. In diamagnetic substances resultant magnetic moment in an atom is _____ [NCERT Pg. 192]

16. Paramagnetic substances have tendency to move from _____ to _____ part of the external magnetic field. [NCERT Pg. 192]

17. Aluminum, sodium, calcium and oxygen all are the examples of _____ substances. [NCERT Pg. 193]

18. Typical domain size in ferromagnetic material is _____ mm [NCERT Pg. 193]

19. Substances which at room temperature retain their ferromagnetic property for a long period of time are called _____ magnets [NCERT Pg. 195]

20. Gadolinium is an example of _____ material. [NCERT Pg. 194]

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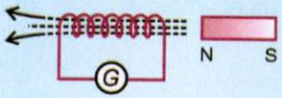
Electromagnetic Induction

6
Chapter

1 FARADAY'S EXPERIMENTS

(a) First experiment : Relative motion between a bar magnet and wire loop produces a small amount of current.



(b) Second experiment : If one coil is connected to a battery and another coil is moved towards or away from it, electric current is produced in neighbouring coil.

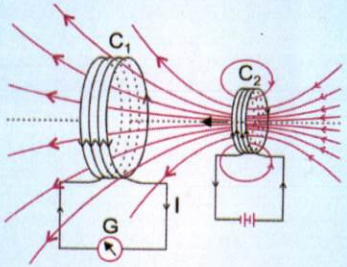
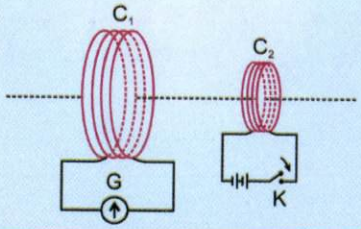


Fig. : Current is induced in coil C_1 due to motion of the current carrying coil C_2.

(c) Third experiment : Galvanometer shows a momentarily deflection when tapping key K is pressed



2 MAGNETIC FLUX

Magnetic flux through a surface of area $\vec{A}$ placed in uniform magnetic field $\vec{B}$ is written as $\phi_B = \vec{B}\cdot\vec{A} = BA\cos\theta$

For non-uniform magnetic field

$$\phi = \int \vec{B}\cdot d\vec{A}$$

3 FARADAY'S LAWS OF INDUCTION

Conclusion of experiments was formulation of laws:

(1) The magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit.

(2) Mathematically the emf induced is given by

$$\boxed{\varepsilon = -\frac{d\phi_B}{dt}}$$

- Negative sign indicates the direction of ε and hence the direction of current in the closed loop.
- If loop contains N turns, change of flux is associated with each turn.

$$\boxed{\varepsilon = -N\left(\frac{d\phi_B}{dt}\right)}$$

- The induced emf can be increased by increasing the number of turns of closed coil.

4 LENZ'S LAW

- **LENZ'S LAW:** This law gives the polarity of induced emf. The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.
- The law is in accordance with the law of conservation of energy.

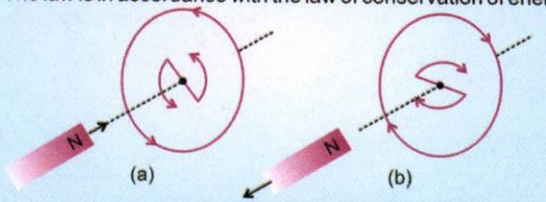
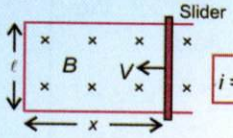


Fig. : Illustration of Lenz's law.

5 MOTIONAL EMF

(1) Straight conductor in motion: In uniform and time independent magnetic field.

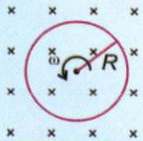


$\boxed{e = Blv}$ (emf across rod)

$\boxed{i = \frac{\varepsilon}{R} = \frac{Blv}{R}}$ $\boxed{\Delta Q = \frac{\Delta\phi_B}{R}}$ $\boxed{P = \frac{B^2l^2v^2}{R}}$

- Mechanical energy which is needed to move arm is converted into electric energy and then to thermal energy.

(2) Rod rotated about one end :



$$\boxed{\varepsilon = \frac{B\omega R^2}{2}}$$

Fleming's Right hand Rule : This gives the direction of induced emf or current in a conductor moving in a magnetic field. If we stretch forefinger, central finger and thumb of our right hand in mutually perpendicular directions such that forefinger along field, thumb along direction of motion of conductor then central finger will give the direction of induced current.

6 EDDY CURRENTS

Electric currents are induced in well defined path in a conductor like circular loops, when bulk piece of conductor is subjected to changing magnetic flux, induced currents are produced in them known as eddy currents.

The eddy currents are also called Foucault currents after its discovery.

- The changing magnetic flux induces current.
- These currents are used to advantage in many applications.
  - (1) Magnetic braking of trains
  - (2) Electromagnetic damping
  - (3) Induction furnace
- Eddy currents dissipate energy in the form of heat energy.
- Eddy currents are minimized using laminations of metal to make a metal core

7 INDUCTANCE

The current can be induced in a coil by the flux change produced by same coil OR another coil.

- In both cases, flux through a coil is proportional to current

$$\frac{d\phi_B}{dt} \propto \frac{dI}{dt}$$

- Constant of proportionality is called inductance.
- Inductance is the ratio of flux linkage and current.
- This inductance depends on geometry of the coil and intrinsic material properties.

SELF INDUCTANCE

Phenomenon of induced EMF in a single isolated coil due to changing flux through the coil by means of varying the current through same coil is self induction.

Total flux linkage = Li

L is called self inductance.

$$\varepsilon = -L\frac{di}{dt}$$

- Self induced emf always opposes any change of current in the coil.

Self inductance of a solenoid is $L = \mu_0 n^2 Al$

n is number of turns per meter of solenoid length.

When solenoid is filled with some material

$$L = \mu_0\mu_r n^2 Al$$

- Self inductance plays the role of inertia. It is electromagnetic analogue of mass in mechanics.
- Unit of self inductance is henry (H) in SI units.
- Self inductance of the coil depends on its geometry and on the permeability of the medium.

MUTUAL INDUCTANCE

- Varying current in one coil can induce emf in neighbouring coil.

$$\varepsilon_1 = M\frac{di_2}{dt}$$

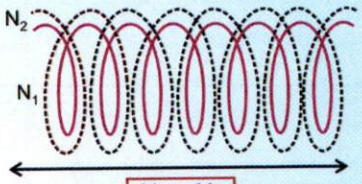
The magnitude of induced emf depends on rate of change of current and mutual inductance of two coils:

- SI unit of inductance is Henry and is denoted by H. Its dimensional formula is $ML^2T^{-2}A^{-2}$.

For two long co-axial solenoids each of length l

$$M_{12} = \mu_0 n_1 n_2 Al$$

M_{12} is coefficient of mutual induction



$$M_{12} = M_{21}$$

- Mutual inductance of a pair of coils, solenoids depends on their separation as well as their relative orientations.
- For two concentric circular coils with radius r and R ($R >> r$) coils are coplanar also.

$$M_{12} = M_{21} = \frac{\mu_0\pi(r)^2}{2R}$$

8 MAGNETIC POTENTIAL ENERGY

- Energy required to built any current I in a system of self inductance L

$$W = \frac{1}{2}\times L\times I^2$$

- This work done gets stored as magnetic potential energy.

$$U_B = \frac{1}{2}LI^2 = \frac{B^2 A\ell}{2\mu_0}$$

- Magnetic energy per unit volume.

$$u_B = \frac{B^2}{2\mu_0}$$ → Energy is proportional to square of field strength

9 AC GENERATOR

- This technology is based on electromagnetic induction phenomenon.
  - Modern A.C. generator has output capacity upto 100 MW.
  - This machine converts mechanical energy into electric energy.
  - The emf induced is sinusoidal.

$$\varepsilon = NBA\omega\sin\omega t$$

$NBA\omega$ is the maximum value of emf when $\sin\omega t = \pm 1$.

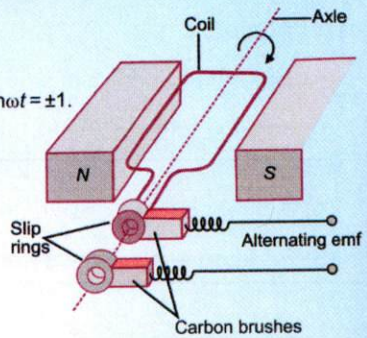
$$\varepsilon_0 = NBA\omega \qquad \varepsilon = \varepsilon_0\sin\omega t$$

ω is angular speed of rotor of ac generator.

The direction of current and emf changes periodic with time

$$\varepsilon = \varepsilon_0\sin(2\pi\nu t)$$

- ν in India is 50Hz
- ν in USA is 60Hz



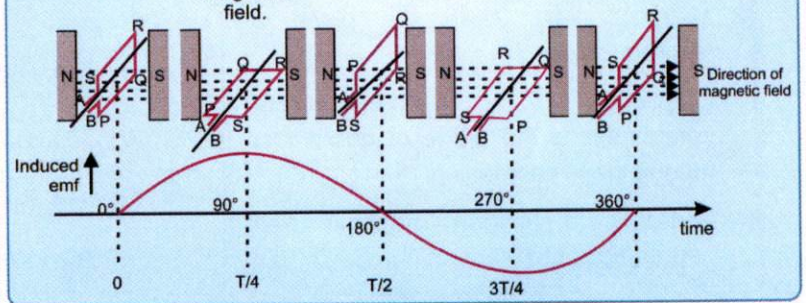
Stage-1 : The plane of the armature is perpendicular to the magnetic field.

Stage-2 When the armature rotates about through 90° the plane of the armature is parallel to magnetic field.

Stage-3 Armature after a rotation of 180°

Stage-4 Armature after a rotation of 270°

Stage-5 Armature after a rotation through 360°



Sharpen Your Understanding

NCERT Based MCQs

1. Direction of current induced in a wire by moving it in a uniform magnetic field is found using [NCERT Pg. 215]
   (1) Newton's laws
   (2) Lenz's law
   (3) Ampere's rule
   (4) Right hand grip rule

2. A metallic plate is getting heated. It cannot be due to [NCERT Pg. 218]
   (1) A direct current passing through plate
   (2) An alternating current passing through it
   (3) It is placed static in space varying magnetic field but does not vary with time
   (4) It is placed in time varying magnetic field

3. A rectangular coil expands on pulling from two diagonal edges in a region of magnetic field and no emf is induced in the coil. This can be because of [NCERT Pg. 230]
   (1) Magnetic field is constant
   (2) Magnetic field is in the plane of rectangular coil
   (3) Magnetic field has a perpendicular component to the plane of coil whose magnitude is decreasing
   (4) There is a uniform magnetic field perpendicular to plane of coil

4. The self-inductance L of a solenoid of length l and area of cross section A, with fixed number of turns per unit length increases as [NCERT Pg. 223]
   (1) l and A increases
   (2) l decreases and A increases
   (3) Both l and A decreases
   (4) l increases and A decreases

5. The mutual inductance of pair of co-axial neighbouring coils [NCERT Pg. 220]
   (1) Increases when they are brought nearer
   (2) Increases when one of them is rotated about an axis
   (3) Is independent of current passing through coils
   (4) Both (1) and (3) are correct

6. A square loop of side length L meter lies in x-y plane in a region, where the magnetic field is given by $\vec{B} = B_0(\hat{i} + 2\hat{j} + 3\hat{k})\ T$, B_0 is positive constant. The magnitude of magnetic flux passing through square is [NCERT Pg. 207]
   (1) $5\,B_0L^2$ Wb
   (2) $3\,B_0L^2$ Wb
   (3) $\sqrt{14}\,B_0L^2$ Wb
   (4) B_0L^2 Wb

7. A 20 cm long conductor carrying a current of 10 A is kept perpendicular to magnetic field of 0.6T. The mechanical power required to move conductor with a speed of 1 ms^{-1} is [NCERT Pg. 215]
   (1) 1.2 W (2) 1.5 W
   (3) 0.6 W (4) 0.4 W

8. A square loop of edge 20 cm and resistance of 1 Ω is placed vertically in horizontal plane. A uniform magnetic field of 0.5T is set up across the plane in the direction at 45° to the plane. The magnetic field is decreased to zero in 0.2 s, at a steady rate. Calculate magnitude of current induced in this time interval. [NCERT Pg. 208]
   (1) 20 mA (2) 50 mA
   (3) 60 mA (4) 70 mA

9. A circular loop with its plane parallel to plane of paper is entering into uniform magnetic field directed into the plane of paper perpendicularly. The loop is moved at constant speed V. Then [NCERT Pg. 212]
   (1) No. emf will be induced in the coil
   (2) Induced emf is constant in magnitude only
   (3) Induced emf is varying with time
   (4) Induced emf is constant in magnitude as well as in direction

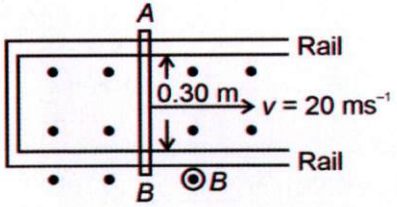
10. A metallic rod of length 20 cm is rotated with, frequency of 50 rev/s with one end pivoted at the centre and other end at circumference of circular metallic ring of radius 20 cm about an axis passing through centre and perpendicular to plane of the ring. A constant and uniform magnetic field 1.5 T parallel to axis is present everywhere. What is emf induced between centre and periphery of circular ring. [NCERT Pg. 214]

(1) 2.6 V (2) 9.4 V
(3) 4.7 V (4) 12.3 V

11. A cycle wheel with 20 metallic spokes each 1 m long is rotated with speed of 60 rad/s in a plane normal to horizontal component of earth's magnetic field B_H = 0.5 G at a place. The emf induced between axle and rim of wheel is [NCERT Pg. 215]

(1) 1.5 mV (2) 12.3 mV
(3) 3.0 mV (4) 0.75 mV

12. A conducting arm AB of length 30 cm moves on conducting rails held parallel. A uniform magnetic field B = 0.2 T exists perpendicular to planes of rails. Only the conducting arm has resistance of 0.5 Ω. The arm is pulled out with constant speed of 20 ms^{-1}, how much force is required parallel to rails to keep it moving at same speed. [NCERT Pg. 216]



(1) 0.14 N (2) 8 N
(3) 16 N (4) 0.25 N

13. Which statement regarding eddy currents among the following is incorrect? [NCERT Pg. 218]

(1) If rectangular slots are made in copper plate, the magnitude of eddy currents will decrease
(2) Dissipation of heat produced is proportional to strength of eddy currents
(3) Dead beat galvanometer has fixed core made of non-magnetic metallic material
(4) Magnetic brakes in train use the application of eddy current

14. Two circular coils one of small radius r and other of larger radius R ($r << R$) are placed co-axially with centres coinciding. The mutual inductance of the arrangement is [NCERT Pg. 221]

(1) $\frac{\mu_0 \pi R^2}{2r}$ (2) $\frac{\mu_0 \pi r^2}{2R}$
(3) $\frac{\mu_0 \pi r R}{(r+R)}$ (4) $\frac{2\mu_0 \pi r^2}{R}$

15. A long solenoid is of length 1.25 m and 600 turns per unit length. It is connected to a source which establishes a current of 2A in circuit. Magnetic energy stored in the solenoid coil with cross-sectional area 0.1 m^2 is [NCERT Pg. 224]

(1) 0.1 J (2) 0.4 J
(3) 0.6 J (4) 1.2 J

16. A rectangular coil of 100 turns with area 0.1 m^2 is rotated at 10 revolution per second and placed in a uniform magnetic field of 0.01 T perpendicular to axis of rotation of the coil. The maximum voltage generated in coil is [NCERT Pg. 226]

(1) 3.14 V (2) 6.28 V
(3) 9.42 V (4) 31.4 V

17. Two thin cylindrical pipes of equal internal diameters made of aluminum and plastic are taken. The pipes are kept vertical. A small cylindrical magnet without touching sides of wall of pipe is allowed to fall one by one. Then correct observations are [NCERT Pg. 219]

(1) Magnet takes longer time to cross aluminum pipe
(2) Magnet takes longer time to cross plastic pipe
(3) Eddy currents are generated in aluminum pipe but not in plastic
(4) Both (1) and (3) are correct

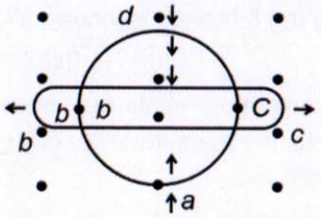
18. Which of the following statement is wrong? [NCERT Pg. 225]

(1) In ac generator when flux through coil is maximum, emf induced is minimum
(2) Maximum emf is induced when plane of coil is parallel to magnetic field
(3) The emf induced changes periodically with time if coil is rotated at uniform rate
(4) The frequency of rotation of armature coil is 60 Hz in India and 50 Hz in USA

19. A pair of adjacent coils has mutual inductance of 1.5 H. If the current in one coil changes from 0 to 10 A in 0.5 s, the rate of change of flux linkage with other coil is [NCERT Pg. 219]

(1) 20 V (2) 30 V
(3) 4 V (4) 5 V

20. A circular coil is being deformed into a narrow straight wire at regular stretch. Then [NCERT Pg. 230]



(1) The direction of induced current is clockwise
(2) The direction of induced current is anticlockwise
(3) Magnetic flux through coil increases
(4) The amount of charge flowing in coil depends on time

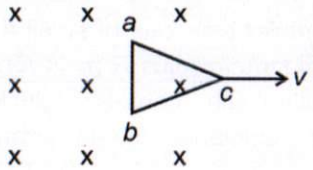
Thinking in Context

1. The relative motion between a magnet and a coil is responsible for generation of _____ in coil. [NCERT Pg. 205]

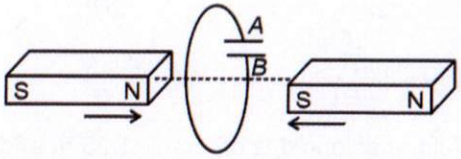
2. SI units of magnetic flux is _____. [NCERT Pg. 207]

3. The polarity of induced emf is such that it tends to produce a current which apposes the change in _____ that produced it. [NCERT Pg. 210]

4. A magnetic field is directed normal to plane of triangular loop away from reader. Due to outward motion, magnetic flux through loop decreases due to which induced current flows along path *cabc*. This statement is [NCERT Pg. 211]



(1) True (2) False

5. 

Due to motion of the magnets, the polarity of plate *A* of capacitor will be positive with respect to plate *B*. This statement is [NCERT Pg. 212]

(1) True (2) False

6. We are able to produce induced emf by moving a conductor instead of varying the magnetic field, that is, by changing magnetic flux enclosed by the circuit. This statement is [NCERT Pg. 213]

(1) True (2) False

7. A charge in motion can exert force on a stationary magnet. Conversely a bar magnet in motion can lead to a force on stationary charges. This statement is [NCERT Pg. 213]

(1) True (2) False

8. Lenz's law is consistent with the law of conservation of _____ [NCERT Pg. 215]

9. Relation between total charge flowing through closed circuit of resistance R and change in magnetic flux through it, is_____ [NCERT Pg. 216]

10. When bulk pieces of conductors are subjected to changing magnetic flux, induced currents are produced in them. These currents are called _____ [NCERT Pg. 218]

11. Eddy currents are minimized using laminations of metal. The laminations are separated by an insulating material like lacquer. This statement is [NCERT Pg. 218]

(1) True (2) False

12. Galvanometer has a fixed core made of _____ metallic material. When coil oscillates, the eddy currents generated in core oppose the motion and bring the coil to rest quickly. [NCERT Pg. 218]

13. Inductance is a scalar quantity. It has the dimensions of _____ [NCERT Pg. 220]

14. Mutual inductance of a pair of coils, solenoids depends on their separation as well as on their _____ [NCERT Pg. 221]

15. It is possible that emf is induced in a single isolated coil due to change of flux through coil by means of varying current through same coil. This phenomenon is called _____ [NCERT Pg. 222]

16. Self-inductance plays the role of inertia. It is electromagnetic analogue of _____ in mechanics. [NCERT Pg. 223]

17. The expression of magnetic energy stored in a solenoid in terms of magnetic field B length and area of solenoid is _____ [NCERT Pg. 224]

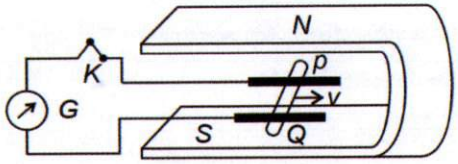
18. The basic principle behind ac generator machine is of changing magnetic flux by rotating coil in a magnetic field. An ac generator converts _____ energy into _____ energy [NCERT Pg. 225]

19. In an ac generator, the coil has N turns and A area rotated at f revolutions per second in a uniform magnetic field B, then peak value of motional emf is directly proportional to frequency and area. This statement is _____ [NCERT Pg. 228]

(1) True

(2) False

20. In the shown experiment excess positive charge is built at end P of the metal rod. This statement is



[NCERT Pg. 231]

(1) True (2) False

❑ ❑ ❑

Alternating Current

7 Chapter

1 ALTERNATING CURRENT

Current which changes continuously in magnitude and periodically in direction.

2 ROOT MEAN SQUARE VALUE

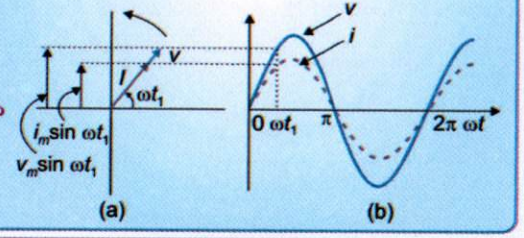
r.m.s. value of a function over a period T is given by $\sqrt{\dfrac{\int f(t)^2 dt}{\int dt}}$

- RMS current is equivalent to *dc* current that would produce same average power loss as alternating current.

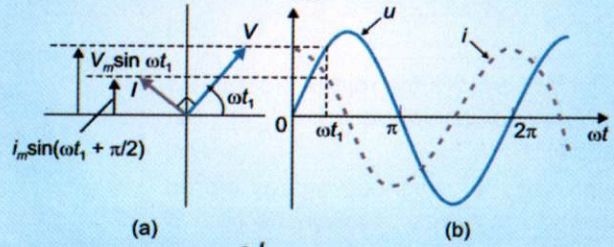
3 AVERAGE VALUE

Average value of a function over a period T is given by $< f(t) > = \dfrac{1}{T}\int_0^T f(t)dt$

4 PURELY RESISTIVE CIRCUIT

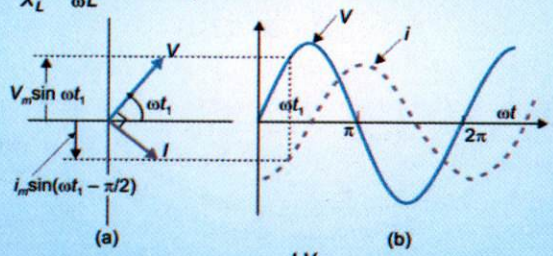
- Let applied voltage is $\varepsilon = \varepsilon_0 \sin \omega t$
- Alternating voltage is in phase with current
- $I = \dfrac{\varepsilon}{R} = I_0 \sin \omega t$
- $I_0 = \dfrac{\varepsilon_0}{R}$
- $P_{av} = \dfrac{1}{2} I_0^2 R$
- 

5 PURELY CAPACITIVE CIRCUIT

- Let applied voltage is $\varepsilon = \varepsilon_0 \sin \omega t$
- Current leads the voltage by a phase angle $\pi/2$
- $I = I_0 \sin\left(\omega t + \dfrac{\pi}{2}\right)$
- $I_0 = \dfrac{\varepsilon_0}{X_C} = \omega C \varepsilon_0$, where $X_C = \dfrac{1}{\omega C}$
- 

- Instantaneous power $= \dfrac{\varepsilon_0 I_0}{2} \sin[2\omega t]$
- Average power = 0

6 PURELY INDUCTIVE CIRCUIT

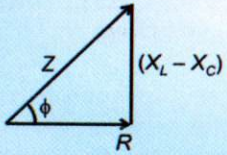
- Let applied voltage is $\varepsilon = \varepsilon_0 \sin \omega t$
- Current lags behind the voltage by a phase angle $\pi/2$
- $I = I_0 \sin(\omega t - \pi/2)$
- Current reaches maximum value later than voltage by one fourth of period.
- $I_0 = \dfrac{\varepsilon_0}{X_L} = \dfrac{\varepsilon_0}{\omega L}$, where $X_L = \omega L$
- 

- Instantaneous power supplied $= -\dfrac{I_0 V_m}{2} \sin 2\omega t$
- Average power supplied by an inductor over one complete cycle is zero.

7 SERIES LCR CIRCUIT

- $\varepsilon = \varepsilon_0 \sin \omega t$ and $I = I_0 \sin(\omega t - \phi)$
- $I_0 = \dfrac{\varepsilon_0}{z}$, where $z = \sqrt{R^2 + (X_L - X_C)^2}$, $\varepsilon_0^2 = (V_{Ro})^2 + (V_{Co} - V_{Lo})^2$
- Phase difference between current and voltage is ϕ, $\tan\phi = \dfrac{X_L - X_C}{R}$
- If $X_L > X_C \Rightarrow \phi$ is +ve (Inductive)
- If $X_L < X_C \Rightarrow \phi$ is –ve (Capacitive)
- If $X_L = X_C \Rightarrow \phi = 0$ (Resistive)

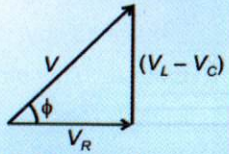
Impedance and Voltage Triangles



Impedance Triangle

$\tan\phi = \dfrac{V_{Lo} - C_{Co}}{V_{Ro}}$

$\tan\phi = \dfrac{X_L - X_C}{R}$



Voltage Triangle

8 POWER IN AC CIRCUITS

$$P_{avg} = \varepsilon_{rms} I_{rms} \cos\phi = \frac{\varepsilon_0 I_0}{2}\cos\phi = I_{RMS}^2 Z \cos\phi$$

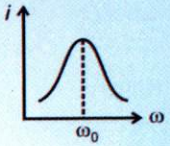
$$= I_{rms}^2 R = \left(\frac{\varepsilon_{rms}^2}{z^2}\right) R$$

9 POWER FACTOR

- Power factor: $\cos\phi = \dfrac{R}{Z}$
- In pure resistive circuit
  $\phi = 0° \Rightarrow \cos\phi = 1$
- In pure inductive circuit or pure capacitive circuit
  $\phi = \pm\dfrac{\pi}{2} \Rightarrow \cos\phi = 0$
- In series LCR circuit at resonance, $X_L = X_C$
  $\Rightarrow$ $Z = R$ and $\phi = 0°$
  $\Rightarrow$ $\cos\phi = 1$ (POWER FACTOR)

10 RESONANCE IN LCR SERIES CIRCUIT

- When $X_L = X_C \Rightarrow Z = R$
- Current become maximum
- $i_0 = \frac{V_0}{R}$
- $\omega_0 = \frac{1}{\sqrt{LC}}$
- $\Delta\omega = \frac{R}{2L}$



where $\omega_1 = \omega_0 + \Delta\omega$

$\omega_2 = \omega_0 - \Delta\omega$

- **Quality factor**

It is a measure of sharpness of resonance

$$Q = \frac{\omega_0}{2\Delta\omega} = \frac{\text{Resonance frequency}}{\text{Band width}}$$

$$= \frac{\omega_0 L}{R}$$

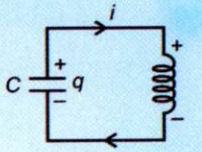
$$= \frac{1}{\omega_0 RC}$$

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

- Resonance circuits are used in tuning mechanism of radio or TV set.
- Resonance phenomenon is exhibited by a circuit having both L and C present in circuit.
- If resonance is not sharp, maximum current is less, the circuit is close to resonance for a larger range of $\Delta\omega$ of frequencies and tuning of circuit will not be good. For good quality L be large and R low.

11 LC OSCILLATIONS

- $\frac{d^2q}{dt^2} + \frac{1}{LC}(q) = 0$
- $q = q_0 \cos(\omega_0 t + \phi)$
- $\omega_0 = \frac{1}{\sqrt{LC}}$
- $U_{Total} = \frac{q_m^2}{2C} = \frac{1}{2}Li_m^2$



Analogies Between Mechanical and Electrical Quantites

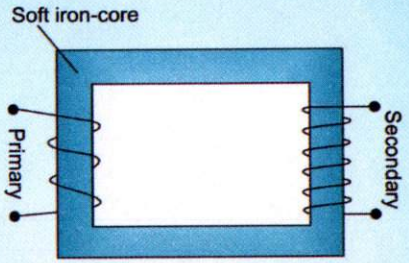
Mechanical system	Electrical (system)
Mass (m)	Inductance (L)
Force constant (K)	Reciprocal capacitance $\left(\frac{1}{C}\right)$
Displacement (x)	Charge (q)
Velocity $\left(v = \frac{dx}{dt}\right)$	Current $\left(i = \frac{dq}{dt}\right)$
Mechanical energy $E = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$	Electromagnetic energy $U = \frac{q^2}{2C} + \frac{1}{2}Li^2$

- Every inductor has resistance. This introduces damping effect on charge and current and oscillation finally die away.
- Total energy is radiated away from the system in the form of electromagnetic waves. The Radio and TV transmission depend on this radiation.

12 TRANSFORMER

- To change an alternating voltage from one to another of greater or smaller value, we use transformer.

A transformer consists of two sets of coils, insulated from each other. It works on mutual induction principle.



$$\frac{\varepsilon_P}{\varepsilon_S} = \frac{I_S}{I_P} = \frac{N_P}{N_S} = \frac{\phi_P}{\phi_S} = \text{constant}$$

- Efficiency of transformer

$$\eta = \frac{P_{out}}{P_{in}} = \frac{\varepsilon_S I_S}{\varepsilon_P I_P}$$

Step-up Transformer	Step-down Transformer
Number of turns in primary binding is lesser than in secondary binding	Number of turns in secondary binding is lesser than in primary binding
$N_S > N_P$	$N_S < N_P$
$E_S > E_P$	$E_S < E_P$
$I_S < I_P$	$I_S > I_P$

- Output voltage of transformer is out of phase with input.
- Energy losses in a transformer are due to
  - A. Flux Leakage
  - B. Resistance of winding
  - C. Eddy currents
  - D. Hysteresis

Sharpen Your Understanding

NCERT Based MCQs

1. A $\frac{10}{\pi}$ μF capacitor is connected to a 200 V, 50 Hz ac source. The capacitive reactance of the circuit is [NCERT Pg. 242]

(1) 1000 Ω

(2) 500 Ω

(3) 212 Ω

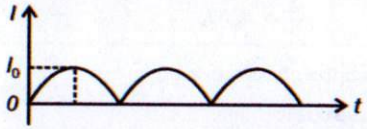
(4) 100 Ω

2. A light bulb is rated at 100 W for a 220 V, 50 Hz supply. The rms current through the bulb is [NCERT Pg. 236]

(1) $\frac{5}{110}$ A (2) $\frac{5}{11}$ A

(3) $\frac{3}{11}$ A (4) $\frac{4}{11}$ A

3. An ac signal (sinusoidal) output from a device is shown in the figure. The average value and rms value respectively in the given case are



[NCERT Pg. 235]

(1) $\frac{I_0}{\pi}, \frac{I_0}{\sqrt{2}}$ (2) $\frac{2I_0}{\pi}, \frac{I_0}{\sqrt{2}}$

(3) $\frac{2I_0}{\pi}, \frac{I_0}{2}$ (4) $\frac{I_0}{\pi}, \frac{I_0}{2}$

4. The instantaneous values of alternating current and voltage in an ac circuit are given as $i = \frac{1}{\sqrt{2}}\sin(100\pi t)$ A and $\varepsilon = \sqrt{2}\sin\left(100\pi t + \frac{\pi}{3}\right)$ V. The average power dissipated through the circuit is [NCERT Pg. 252]

(1) $\frac{\sqrt{3}}{2}$ W (2) $\frac{1}{4}$ W

(3) $\frac{1}{8}$ W (4) $\frac{\sqrt{3}}{4}$ W

5. For a series LCR circuit, the power dissipated at resonance is [NCERT Pg. 252]

(1) $\frac{v^2}{(X_L - X_C)}$ (2) $I^2\omega L$

(3) $I^2(X_L - X_C)$ (4) $I_{rms}^2 R$

6. The primary winding of a transformer has 200 turns whereas its secondary winding has 2000 turns. If the primary is connected to an ac source of 20 V and 60 Hz, then secondary will have output of [NCERT Pg. 261]

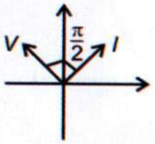
(1) 200 V and 6 Hz

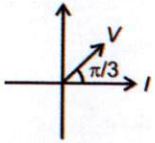
(2) 2 V and 60 Hz

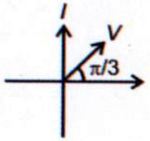
(3) 200 V and 60 Hz

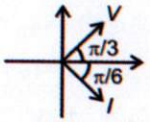
(4) 2 V and 6 Hz

7. An ac supply is connected across a series LCR circuit. If capacitor is removed then which of the following phasor diagram may be correct? [NCERT Pg. 245]

(1) 

(2) 

(3) 

(4) 

8. The analogue of displacement x in mechanical system (spring block) is P in electrical system (LC oscillation). Then P is [NCERT Pg. 257]

(1) Inductance (L) (2) Charge (q)

(3) Current (i) (4) Capacitance (C)

9. A capacitor (C), initially charged upto q_m is connected to an inductor (L). The differential equation of LC oscillator is [NCERT Pg. 255]

(1) $\frac{d^2q}{dt^2} + q = 0$ (2) $\frac{dq}{dt} + q = 0$

(3) $\frac{dq}{dt} + \frac{q}{LC} = 0$ (4) $\frac{d^2q}{dt^2} + \frac{q}{LC} = 0$

10. For pure resistive ac circuit the phase angle between voltage and current and power factor are respectively. [NCERT Pg. 252]

(1) 0°, 1 (2) 0°, 0

(3) 90°, 1 (4) 90°, 0

11. A resistor of 100 Ω is connected in series with series combination of inductor and capacitor. If X_L and X_C are the reactances of inductor and capacitor respectively, then reactance of circuit will be [NCERT Pg. 245]

(1) $|X_L + X_C|$ (2) $|X_L - X_C|$

(3) $\sqrt{X_L^2 + X_C^2}$ (4) $\sqrt{X_L X_C}$

12. The quantity which measures the sharpness of resonance is [NCERT Pg. 249

(1) Quality factor (2) Peak factor

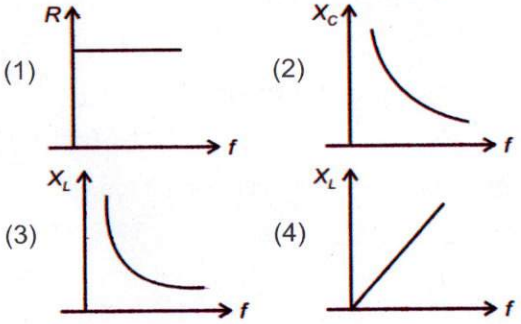
(3) Form factor (4) Ripple factor

13. A steady current of 2 A flowing through a resistor produces a heat of 100 W. To produce a heat of 400 W by supplying an ac current through the same circuit, the value of peak current will be [NCERT Pg. 235

(1) 4 A (2) 5.6 A

(3) 2.8 A (4) 8 A

14. The variation of impedance of an ac circuit (having one of the element) with frequency of source is given for different elements. Choose the incorrect plot. [NCERT Pg. 246]

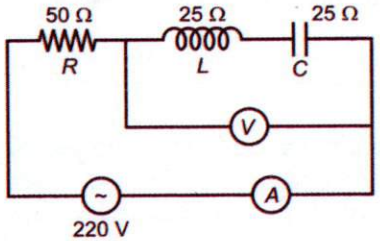


15. Consider a series *LCR* circuit in which reactance and resistance are 100 Ω each. When the circuit is connected to ac source 220 V, 50 Hz, then current drawn from the source is [NCERT Pg. 245]

(1) $2.2\sqrt{2}$ A (2) $1.1\sqrt{2}$ A

(3) $3.3\sqrt{2}$ A (4) 2.2 A

16. In the circuit shown in the figure. The voltmeter and ammeter reading will respectively be (source, voltmeter and ammeter are ideal) [NCERT Pg. 245]



(1) 0 V, $2\sqrt{2}$ A (2) 0 V, 4.4 A

(3) 110 V, $2\sqrt{2}$ A (4) 110 V, 3 A

17. In an oscillating *L-C* circuit, Q_m is the maximum charge on the capacitor. If at any time, the energy stored in capacitor and inductor are equal, then charge stored on the capacitor at that instant is [NCERT Pg. 256]

(1) $\frac{Q_m}{\sqrt{2}}$ (2) $\frac{Q_m}{2}$

(3) $\frac{Q_m}{3}$ (4) $\frac{Q_m}{\sqrt{3}}$

18. For an ideal transformer, which of the following option is correct?

(Symbols have their usual meaning)

[NCERT Pg. 261]

(1) $\frac{I_S}{I_P} = \frac{N_S}{N_P}$ (2) $\frac{I_S}{I_P} = \frac{V_S}{V_P}$

(3) $V_S I_S = V_P I_P$ (4) $\frac{V_S}{V_P} = \frac{N_P}{N_S}$

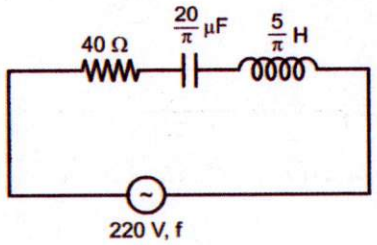
19. A radio can tune over the frequency range (800 - 1200) kHz. If *LC* circuit has an effective inductance of 200 μH. What should be the range of its variable capacitor? [NCERT Pg. 266]

(1) 100 pF – 280 pF (2) 88 pF – 198 pF

(3) 40 pF – 80 pF (4) 200 pF – 400 pF

20. The figure shows a series *LCR* circuit connected to a variable frequency and 220 V source. The source frequency which drives the circuit in resonance will be

[NCERT Pg. 248]



(1) 25 Hz (2) 100 Hz

(3) 50 Hz (4) 80 Hz

Thinking in Context

1. In pure resistive circuit, voltage and current are in _____ with each other. [NCERT Pg. 234]

2. An alternating voltage $v = v_0 \sin \omega t$ is applied across an ac circuit containing a resistor R only. The current through the circuit is given by _____. [NCERT Pg. 234]

3. If an alternating current is expressed as $i = i_0 \sin \omega t$, then its average value for half time period is _____. [NCERT Pg. 235]

4. Average value of a function $\langle \sin^2 \omega t \rangle$ over a complete cycle is _____. [NCERT Pg. 235]

5. The effective voltage of an ac supply is also called as _____ voltage. [NCERT Pg. 236]

6. A _____ is a vector that rotates about the origin with angular speed ω. [NCERT Pg. 237]

7. If an alternating voltage source having emf $\varepsilon = \varepsilon_0 \sin\left(\omega t + \frac{\pi}{6}\right)$ is applied across an ac circuit containing pure inductor L, then the expression of current through inductor is _____. [NCERT Pg. 238]

8. The average power supplied to an inductor over one complete cycle is _____. [NCERT Pg. 239]

9. The reactance of inductor is _____ proportional to signal frequency applied across inductor. [NCERT Pg. 238]

10. If an alternating voltage $\varepsilon = \varepsilon_0 \sin \omega t$ is applied across a pure capacitor of capacitance C, then amplitude of alternating current (i_0) is _____. [NCERT Pg. 241]

11. In pure capacitive ac circuit voltage _____ the current by phase angle _____. [NCERT Pg. 242]

12. In a series LCR circuit, the impedance of the circuit is $Z =$ _____. [NCERT Pg. 245]

13. An ac source given by $\varepsilon = \varepsilon_0 \sin \omega t$ is applied to a series LCR circuit, then current is given by $i = I_0 \sin (\omega t + \phi)$. Here ϕ is given by _____. [NCERT Pg. 246]

14. In an LCR series circuit, if X_L is the reactance of inductor and X_C is the reactance of capacitor then at resonance _____. [NCERT Pg. 248]

15. At resonance, the impedance of circuit is _____. [NCERT Pg. 248]

16. Quality factor of a series LCR circuit is given by _____. [NCERT Pg. 250]

17. Average power dissipated in series LCR circuit at resonance is _____. [NCERT Pg. 252]

18. The mechanical equivalent of inductance (L) in electrical system, is _____. [NCERT Pg. 257]

19. In step-up transformer I_S is _____ than I_P. [NCERT Pg. 261]

20. For pure inductive circuit power factor is _____. [NCERT Pg. 252]

❑ ❑ ❑

Electromagnetic Waves

8
Chapter

1 MAXWELL'S EQUATIONS

$\oint \vec{E}.d\vec{A} = \frac{q}{\varepsilon_0}$ (Gauss's Law of electrostatics)

$\oint \vec{B}.d\vec{A} = 0$ (Gauss's Law of magnetism)

$\oint \vec{E}.d\vec{l} = -\frac{d\phi_B}{dt}$ (Faraday's Law of EMI)

$\oint \vec{B}.d\vec{l} = \mu_0\left(i_c + \varepsilon_0\frac{d\phi_E}{dt}\right)$ Maxwell-Ampere's circuital theorem

- These equations express all basic laws of electromagnetism

2 DISPLACEMENT CURRENT

- Source of a magnetic field is not just the conduction electric current but also time varying rate of change of electric field.
- It arises whenever the electric flux is changing with time.

$i_d = \varepsilon_0\frac{d\phi_E}{dt}$

- Changing electric field must also produce a magnetic field.

3 ELECTROMAGNETIC WAVES

Sources of Waves

- Through accelerating charges
- Through oscillating electric dipoles
- By harmonically oscillating electric charges
- Oscillating fields of electromagnetic waves can accelerate charges and can produce oscillating currents
- Electromagnetic waves in interaction with matter interacts through its electric and magnetic field which set in oscillating charges present in all matter
- Mechanism of absorption and scattering depends on wavelength of electromagnetic wave, nature of atoms and molecules in medium

4 NATURE OF ELECTROMAGNETIC WAVES

- Waves are sinusoidal, having variation of electric and magnetic field at right angles to each other and perpendicular to direction of wave propogation.
- Frequency of electromagnetic wave equals the frequency of oscillating charge.
- Energy associated with propagating wave comes from energy of source, the accelerated charge.
- Produced and detected by Hertz in 1887 in laboratory. This verified a basic prediction of Maxwell's equation.
- No material medium is involved in vibration of electric and magnetic fields.
- E.M. wave carry energy and energy is shared equally by electric and magnetic fields.
- Electromagnetic wave other than light also have same velocity in vacuum.
- Wave transports momentum and exerts pressure

  $P = \frac{U}{c}$, (U = Energy transfer for complete absorption by surface)

- The magnitude of total momentum delivered.
- So wave can carry energy from one place to another.
- $E_x = E_0\sin(kz - \omega t)$ and $B_0 = E_0/c$

  $By = B_0 \sin(kz - \omega t)$ (wave equations)

- k = wave vector and speed of propagation is, $v = \frac{\omega}{k}$

  in medium, speed of wave, $v = \frac{1}{\sqrt{\mu\varepsilon}}$

  In vacuum, $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

- This is fundamental constant. These waves can be polarized.
- Energy density in E field, $u_E = \frac{1}{2}\varepsilon_0 E^2$
- Energy density in B field, $u_B = \frac{B^2}{2\mu_0}$
- $u_E = u_B$
- $I = \varepsilon_0 E_{rm}^2 c$

5 SPECTRUM OF ELECTRO-MAGNETIC WAVES AND PROPERTIES

A. RADIO WAVES

- Wavelength greatest
- Produced by vibrating electrons
- AM BAND : 530 kHz to 1710 kHz ,
- SHORT band: 3 MHz to 54 MHz
- FM band : 88 MHz to 108 MHz
- UHF band : CELULAR PHONE

B. MICRO WAVES

- Wavelength 0.1 m to 1 mm (Frequency GHz)
- Produced by special vacuum tubes (Klystrons, Magnetrons and Gunn diodes)
- Used in radar system
- Micro wave oven works with microwaves
- Used in speed guns

C. INFRARED WAVES

- Wavelength 1 mm to 700 nm
- Produced in vibration of atoms and molecules
- These are called heat waves
- Used in physical therapy
- Trapped by greenhouse gases
- Remote switches
- Infrared detector

D. VISIBLE RAYS

- Wave length 700 nm to 400 nm from electrons in atom by transitions from high to lower level
- Detected by human eye
- Different animals are sensitive to different ranges of wave length

E. UV RAYS

- Wavelength 400 nm to 1 nm
- Sun is import ant source
- Absorbed by glass used by welders
- Used in eye surgery (LASIK)
- UV lamps for water purefication

F. X-RAY

- Wavelength 10 nm to 10^{-4} nm
- Obtained from bombarding a metal target by high energy electron
- Used as diagnostic tools to treat cancer.
- Photographic films

G. γ-RAYS

- Wavelength 10^{-10} m to 10^{-14} m
- Produced in nuclear reaction
- Emitted by radioactive nuclei
- used in medicine to destory cancer cells

ORDER OF FREQUENCY

- Gamma rays > X rays > U.V > Visible > Infrared > microwaves > short radio waves > FM and TV > AM Radio > Long Radio waves

Sharpen Your Understanding

1. The correct order of arrangement of electromagnetic waves according to their frequency is [NCERT Pg. 283]
   (1) Radio waves > Microwaves > γ-rays > U.V. rays
   (2) Radio waves > U.V. rays > Microwaves > γ -rays
   (3) γ -rays > Microwaves > U.V. rays > Radio waves
   (4) γ -rays > U.V. rays > Microwaves > Radio waves

2. The electromagnetic radiations used in radar system is [NCERT Pg. 281]
   (1) Gamma rays (2) Radio waves
   (3) Infrared (4) Microwaves

3. Microwaves oven works on the principle of [NCERT Pg.281]
   (1) Giving rotational energy to water molecules
   (2) Giving vibrational energy to water molecules
   (3) Giving translational energy to water molecules
   (4) Both (1) and (2) are correct options

4. The RMS value of electric field of light coming from sun is 400 N C^{-1}. Total energy density of electromagnetic waves is [NCERT Pg. 279]
   (1) 1.42×10^{-6} J m^{-3} (2) 1.92×10^{-6} J m^{-3}
   (3) 2.6×10^{-5} J m^{-3} (4) 8.85×10^{-7} J m^{-3}

NCERT Based MCQs

5. Cellular phones use radio waves to transmit voice communication in [NCERT Pg. 281]
   (1) Frequency modulated radio bands
   (2) Ultra high frequency bands
   (3) Short wave bands
   (4) Amplitude modulated bands

6. Which of the following is not an electromagnetic wave? [NCERT Pg. 283]
   (1) Heat rays
   (2) *X*-rays
   (3) γ -rays
   (4) β-rays

7. Which among the following statement is incorrect? [NCERT Pg. 283]
   (1) Wavelength of X-rays can range from 10 nm to 10^{-4} nm.
   (2) X-rays are used in treatment of certain form of cancer
   (3) X-rays are produced by bombarding a metal target by high energy electrons
   (4) X-rays are used to observe growth of crops

8. Which among the following statement may be incorrect? [NCERT Pg. 282]
   (1) Infrared detectors are used in earth satellites
   (2) Electronic devices emit infrared radiations and are used in remote switches
   (3) U.V. lamps are used in physical therapy
   (4) Visible range of many insects extend well into ultraviolet waves

9. The instantaneous magnitudes of electric field E and magnetic field B vectors in electromagnetic wave propagating in vacuum are related as [NCERT Pg. 276]
   (1) $E = \frac{c}{B}$ (2) $E = cB$
   (3) $E = \frac{B}{c}$ (4) $EB = c^2$

10. A plane electromagnetic wave $E = 100 \sin(5 \times 10^8 t + 3x)$ V/m is propagating through a medium. The refractive index of the medium is [NCERT Pg.276]
    (1) 1.6 (2) 1.7
    (3) 1.8 (4) 1.9

11. Light with energy flux 1.2 W/m^2 falls on a non-reflecting surface at normal incidence. The pressure on the plate is [NCERT Pg.279]
    (1) 3×10^{-8} N m^{-2} (2) 2×10^{-8} N m^{-2}
    (3) 4×10^{-9} N m^{-2} (4) 2×10^{-9} N m^{-2}

12. What is peak electric field produced by the radiations coming from 100 W bulb at a distance 3 m. Assuming that bulb is point source with efficiency of 2.5%?

[NCERT Pg. 279]

(1) 2.9 V/m (2) 3.1 V/m

(3) 1.6 V/m (4) 4.07 V/m

13. In electromagnetic wave, if peak value of magnetic field is 1.4×10^{-8} T, then RMS value of electric field will be

[NCERT Pg. 280]

(1) 4.07 V/m (2) 2.9 V/m

(3) 6.2 V/m (4) 3.4 V/m

14. Light with an energy flux of 6 W/cm^2 falls on a non reflecting surface at normal incidence. If surface has an area of 50 cm^2. What is total momentum transferred in one minute to the surface (for complete absorption)?

[NCERT Pg. 279]

(1) 6×10^{-5} kg m s^{-1} (2) 3×10^{-5} kg m s^{-1}

(3) 2×10^{-5} kg m s^{-1} (4) 6.4 kg m s^{-1}

15. The electric field component propagating along x-axis is given as $E_y = 30 \sin (4.5 \times 10^2 x + 1.5 \times 10^{11} t)$ V/m. The frequency of propagating wave is [NCERT Pg. 278]

(1) 5 GHz

(2) 17.6 GHz

(3) 23.9 GHz

(4) 15.4 GHz

16. A capacitor is made of two circular plates each of radius 7 cm and separated by 2 cm. The capacitor is being charged by an external source. The charging current is constant and equal to 0.2 A. What is the rate of change of potential deference between the plates? [NCERT Pg.285]

(1) 1.62×10^{10} V/s

(2) 2.94×10^{10} V/s

(3) 3.54×10^{10} V/s

(4) 3.24×10^{10} V/s

17. A radio is tuned to station in the 30 MHz to 54 MHz. What is corresponding wavelength band? [NCERT Pg. 281]

(1) AM band

(2) FM band

(3) Short band

(4) UHF band

18. Which among the following statement is incorrect in electromagnetic spectrum?

[NCERT Pg. 282]

(1) Long distance radio broadcast use short waves

(2) X-rays astronomy is possible from satellite orbiting earth

(3) Microwaves range from 400 nm to 0.6 nm

(4) Snakes are sensitive to infrared waves

19. Correct match of column I with column II is

[NCERT Pg. 283]

	C-I (waves)		C-II (Production)
A.	Infra-red	P	Rapid vibration of electrons in aerials
B.	Radio	Q	Electrons in atoms emit light when they move from higher to lower energy level.
C.	Light	R	Klystron valve
D.	Microwave	S	Vibration of atoms and molecules

(1) A-P, B-R, C-S, D-Q

(2) A-S, B-P, C-Q, D-R

(3) A-Q, B-P, C-S, D-R

(4) A-S, B-R, C-P, D-Q

20. Find the incorrect statement among the following. [NCERT Pg. 285]

(1) Accelerated charge particles radiate electromagnetic waves

(2) Visible radiations emitted by atoms is much longer in wavelength than atomic size

(3) X-rays are emitted from heavy atoms

(4) Radio waves are produced by atomic nucleus

Thinking in Context

1. Maxwell's work, unified the domain of electricity. magnetism and_____. [NCERT Pg. 269]
2. The current carried by conductors due to flow of charges is called conduction current and current due to changing electric field is called_____. [NCERT Pg. 271]
3. The source of magnetic field is not just conduction electric current due to flowing charges but also time rate of change of electric field. This statement is
   (1) True (2) False
   [NCERT Pg. 272]
4. "Total current passing through any surface of which the closed loop is a perimeter" is sum of the conduction current and displacement current. So ampere Maxwell's law is $\oint \vec{B}.d\vec{l} = \mu_0 i_C + \mu_0(....)$
   [NCERT Pg. 272]
5. Electric field changing with time gives rise to a _____ and a consequence of displacement current being a source of a _____. [NCERT Pg. 273]
6. A charge oscillating with some frequency produces an oscillating electric field in space which produces a magnetic field which is also oscillating which in turn is a source of oscillating electric field. The statement is
   (1) True (2) False
   [NCERT Pg.274]
7. The frequency of the electromagnetic wave is equal to frequency of _____. The energy associated with the propagating wave comes at the expense of energy of the source i.e._____. [NCERT Pg. 274]
8. Maxwell's equations show that electric and magnetic fields in an electromagnetic wave are _____ to each other, and to the direction of propagation. [NCERT Pg. 275]
9. Magnitude of electric and magnetic fields in an electromagnetic waves are related as $B_0 = \ldots$ [NCERT Pg. 276]
10. In an AM radio, antenna is telescopic, it responds to electric part of the signal. When antenna is turned horizontal, the signal is greatly diminished. This is due to fact that electromagnetic waves are_____. [NCERT Pg. 277]
11. If total energy transferred by an electromagnetic wave in time t is U, magnitude of total momentum delivered to surface for complete absorption is p =_____. [NCERT Pg. 277]
12. If an electromagnetic wave propagates along x-axis and E is along y-axis, the B should be along _____ axis. [NCERT Pg. 278]
13. Radio waves are used in radio communication system. The frequency modulation (FM) radio wave extends from _____ Hz to _____ Hz. [NCERT Pg. 281]
14. Microwaves which are short wavelength radio waves with frequency in GHz are produced by_____. [NCERT Pg. 281]
15. The frequency of microwaves is selected to match the resonant frequency of water molecules so that energy from waves is transferred efficiently to kinetic energy of molecules. This concept is used for_____. [NCERT Pg. 281]
16. These radiations are trapped by green-house gases, These radiations are easily absorbed by water molecules and are used in light emitting diodes. These radiation are _____. [NCERT Pg. 282]
17. These radiations are absorbed by glass and are produced by special lamps. The radiations are_____. [NCERT Pg. 282]
18. In LASIK eye surgery, the radiations used are_____. [NCERT Pg. 282]
19. The radiations are used in treatment of certain forms of cancer and as a diagnostic tool in medicine, these radiations are_____. [NCERT Pg. 283]
20. High frequency radiations are produced in nuclear reactions and also emitted by radio-active nuclei. These are used to destroy cancer cells. The radiations are_____. [NCERT Pg. 283]

❑ ❑ ❑

Ray Optics and Optical Instruments

9 Chapter

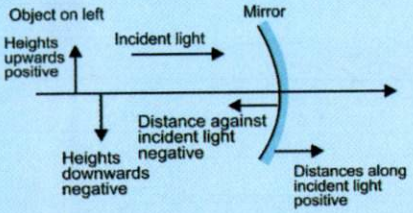
1 REFLECTION OF LIGHT

Law of Reflection

- Incident ray, reflected ray and normal to reflecting surface at the point of incidence lie in the same plane.
- Angle of incidence is equal to angle of reflection.

Sign-convention

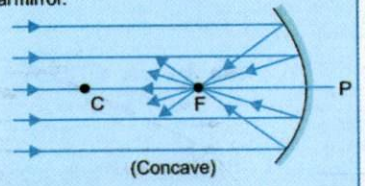
- In sign convention, all distances measured in the same direction as incidence ray are taken positive and those measured in the direction opposite of incident ray are taken negative.
- The heights taken above the principal axis are positive and below negative.



Focal Length of Spherical Mirrors

- The distance between focus and pole of a mirror is called focal length.
- Focal length is equal to half of radius of curvature of the curved spherical mirror.

$$f = \frac{R}{2}$$



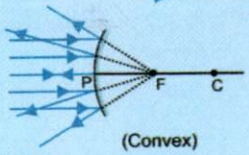
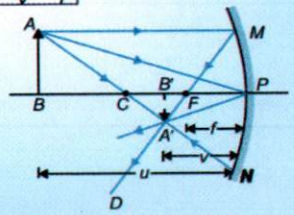


Image Formation by Spherical Mirrors

- The image by a mirror is real if rays after reflection actually meet and virtual if rays are not actually meeting but appear to diverge from a point.
- An incident ray passing through centre of curvature of mirror retraces its path.
- Mirror equation is $\boxed{\frac{1}{u} + \frac{1}{v} = \frac{1}{f}}$ and magnification formula

$$m = -\frac{v}{u} = \frac{f}{f-u} = \frac{f-v}{f}$$



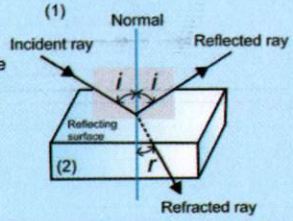
2 REFRACTION OF LIGHT

- When a beam of light encounters another transparent medium, part of light is reflected back. This called internal reflection. The rest of light enter other medium.
- When light is incident obliquely, its propagation direction changes in other medium, this phenomenon is called refraction.
- Red light travels faster than blue light in same medium.

Law of Refraction

- The incident ray, refracted ray and normal to interface at the point of incidence, all lie in same plane.
- The ratio of sine of angle of incidence to the sine of angle of refraction is constant.

$$\boxed{\frac{\sin i}{\sin r} = n_{21}}$$

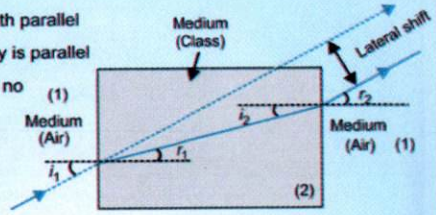


n_{21} is refractive index of second medium with respect to first.

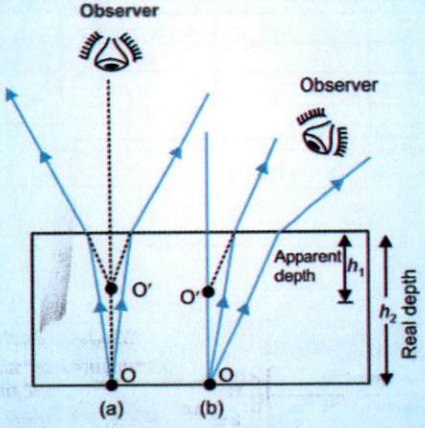
- Optical denser medium has high refractive index. Mass density of optical denser medium may be less than mass density of rarer medium.
- Elementary results from laws of refraction are

(1) $n_{32} = n_{31} \times n_{12}$

(2) For rectangular slab with parallel faces, the emergent ray is parallel to incident ray, there is no deviation but has lateral shift.

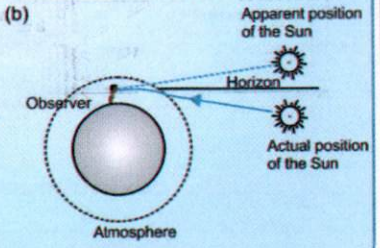


(3) Bottom of tank filled with water appears to be raised.



$$\text{Apparent depth} = \frac{\text{Real depth}}{n_{21}}$$

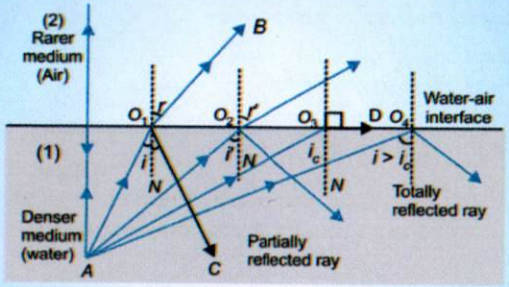
(4) Sun is visible a little before the actual sunrise and until a little after the sunset, this time difference is about 2 minute, the sun appears oval shaped.



3 TOTAL INTERNAL REFLECTION

- If angle of incidence, for light traveling from denser to rarer medium is greater than certain angle called critical angle for the media, no light is transmitted.

$\sin i_c = \frac{1}{n_{12}}$ n_{12}: refractive index of denser medium w.r.t rarer medium.

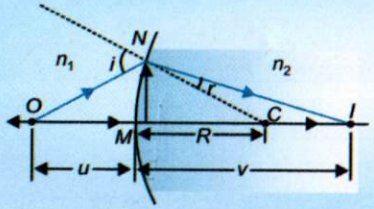


- Higher is value of refractive index, smaller will be critical angle.

Substance	Ref. index	Critical angle
Water	1.33	48.75°
Flint glass	1.62	37.31°
Diamond	2.42	24.41°

Phenomenon based on TIR are
- Mirage
- Sparkling of diamond
- Special prisms of flint glass to bend light by 90° and 180°
- Optical fibre for communication

4 REFRACTION AT SPHERICAL SURFACES



$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

R = radius of curvature of the curved spherical surface. It holds for any curved surface (for paraxial approximation).

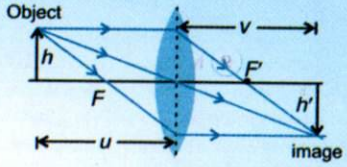
5 REFRACTION BY LENSES

- A lens is a transparent optical medium bounded by two surfaces.
  At least one surface should be spherical.
- After two refraction through a lens, image is formed.
  The thin lens formula becomes

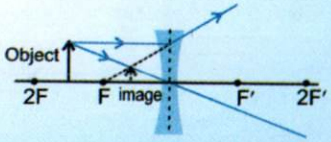
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$m = \frac{\text{Size of image}}{\text{Size of object}} = \frac{h'}{h} = \frac{v}{u} = \frac{f}{f+u} = \frac{f-v}{f}$$

- Formula is valid for convex and concave lenses and magnification produced by lens (for paraxial approximation)



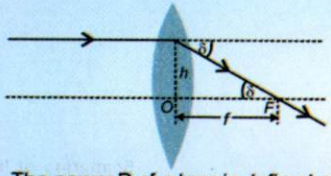
(a)



(b)

6 POWER OF THIN LENS

- It is measure of its convergence or divergence ability.



- The power P of a lens is defined as the tangent of the angle by which it converges or diverges a beam of light parallel to the principal axis falling at unit distance from the optical centre.
- A lens of shorter focal length bends incident ray more and has high power.

$$P = \frac{1}{f}$$

- Its SI unit is dioptre (D)

$1D = 1\ m^{-1}$

- It is positive for converging lens and negative for diverging lens.

Lens maker's formula

$$P = \frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

- n is relative refractive index of glass with respect to surrounding and R_1 and R_2 are radii of curvature of two surfaces.
- A converging lens in a transparent liquid of refractive index greater than lens glass behaves like a diverging lens and vice versa.

7 THIN LENSES IN CONTACT

- When thin lenses are kept in contact

$P = P_1 + P_2 + P_3 + ...$

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + ...$

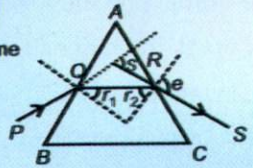
- Net power is individual power's algebraic sum. Some terms may be positive (convex) and some terms may be negative (concave) on right hand side.
- This combination helps to get diverging or converging lens combination of desired magnification.

8 REFRACTION THROUGH A PRISM

- For any triangular prism angle between incidence ray and emergent ray is called angle of deviation

$\boxed{\delta = i + e - A}$

- δ remains same if i and e are interchanged.

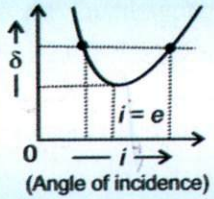


When $\delta = D_m$

$i = e$, $D_m = 2i - A$

$r = r_1 = r_2$ or $r_1 = A/2$

The refracted ray inside prism becomes parallel to its base.



- Refractive index of prism is calcutated by formula.

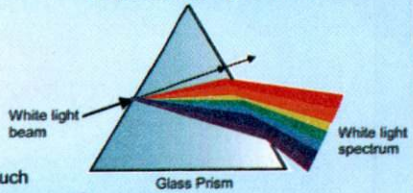
$$\boxed{n_{21} = \frac{n_2}{n_1} = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin(A/2)}}$$

- For small angle thin prism

$\boxed{D_m = (n_{21} - 1)A}$

- It implies thin prism don't deviate light much

Dispersion by a prism

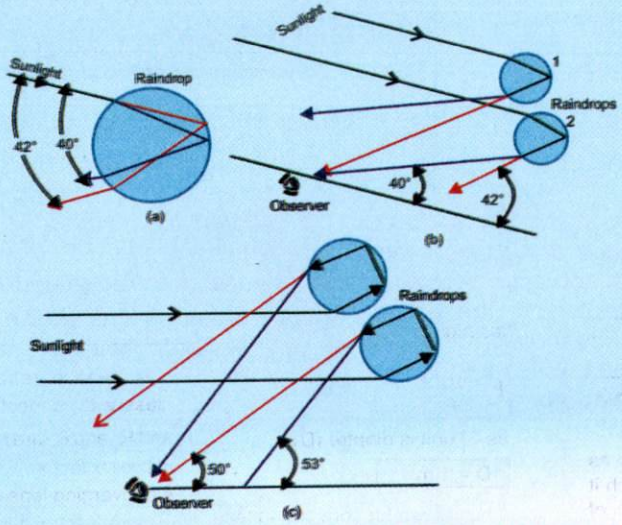


9 NATURAL PHENOMENA DUE TO SUNLIGHT

Dispersion of Light

- The phenomenon of splitting of light into constituent colours is known as dispersion.
- Dispersion takes place due to different refractive index of medium for different wavelengths.
- Chromatic aberration in thick lenses is due to dispersion.
- Rainbow is an example of dispersion of light (sun) by water drops
- In vacuum speed of light is independent of wavelength. So Vacuum is non dispersive medium.

Rainbow



Rainbow: (a) The sun rays incident on a water drop get refracted twice and reflected internally by a drop; (b) Enlarge view of internal reflection and refraction of a ray of light inside a drop form primary rainbow; and (c) Secondary rainbow is formed by rays undergoing internal reflection twice inside the drop.

10 OPTICAL INSTRUMENTS

Eye Defects Cure

- Myopia → Concave lens
- Hypermetropia → Convex lens
- Astigmatism → Cylindrical lens

Simple Microscope

- Microscope : A simple magnifier or microscope is a converging lens of high power.
- Angular magnification is equal to ratio of angular size of image to angular size of object
- Final image at near point

$$m = \left[1 + \frac{D}{f}\right]$$

- Final image at infinity

$$m = \frac{D}{f}$$

Compound Microscope

- For large magnification objective and eye piece should have low focal length
- Final image at near point

$$m = m_o \times m_e = \frac{v_o}{u_o}\left[1 + \frac{D}{f_e}\right]$$

- Final image at infinity

$$m = \frac{v_o}{u_o}\left(\frac{D}{f_e}\right)$$

Telescope

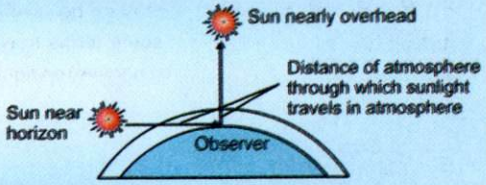
- It is used to provide angular magnification for distant objects
- Final image at infinity

$$m = \frac{f_o}{f_e} \text{ and } L = f_o + f_e$$

- Final image at near point

$$m = \frac{f_o}{f_e}\left[1 + \frac{f_e}{D}\right] \text{ and } L = f_o + \frac{Df_e}{D + f_e}$$

Scattering of light: Light of shorter wavelength is scattered much more than of longer wavelength. Amount of scattering is inversely proportional to fourth power of wavelength.



Sharpen Your Understanding

NCERT Based MCQs

1. Which of the following statements is wrong for an image formation of a real object? [NCERT Pg. 315]
   (1) The magnification produced by convex mirror is always less than one
   (2) A virtual, inverted, same size image can be obtained using plane mirror
   (3) A virtual, erect, magnified image can be formed using a concave mirror
   (4) A real, inverted, same sized image can be formed using a convex mirror

2. Advanced sunset and delayed sunset is due to [NCERT Pg. 318]
   (1) Atmospheric reflection
   (2) Atmospheric refraction
   (3) Atmospheric scattering
   (4) Atmospheric dispersion

3. If μ_a, μ_b and μ_c are refractive indices of media *A*, *B* and *C* respectively such that $\mu_a > \mu_b > \mu_c$, total internal reflection can take place when a ray of light travels from [NCERT Pg. 320]
   (1) *C* to *A* (2) *C* to *B*
   (3) *B* to *A* (4) *B* to *C*

4. Which of the following concept is used in optical fibre? [NCERT Pg. 322]
   (1) Refraction of light
   (2) Scattering of light
   (3) Dispersion of light
   (4) Total internal reflection

5. In the position of minimum deviation when a ray of yellow light passes through the prism, then its [NCERT Pg. 331]
   (1) Angle of incidence is less than angle of emergence
   (2) Angle of incidence is greater than emergent angle
   (3) Sum of angle of incidence and emergent angle is equal to 90°
   (4) Angle of incidence is equal to angle of emergence

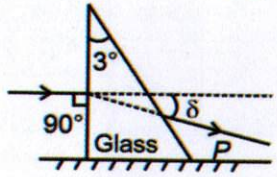
6. The focal length of a lens depends upon [NCERT Pg. 327]
   (1) Nature of material of lens
   (2) Colour of light
   (3) Medium in which lens is placed
   (4) All of these

7. A screen is placed at a distance of 40 cm away from an illuminated object. A converging lens is placed between the source and screen and it is attempted to form the image of the source on the screen. If no lens position could be found, the focal length of the lens [NCERT Pg. 347]
   (1) Should be greater than 10 cm
   (2) May be 6 cm
   (3) May be infinity
   (4) Must be less than 10 cm

8. In a compound microscope, the intermediate image is [NCERT Pg. 340]
   (1) Virtual, erect and magnified
   (2) Real, erect and magnified
   (3) Real, inverted and magnified
   (4) Virtual, erect and reduced

9. Mark the correct option among following statements. [NCERT Pg. 337]
   (1) If far point come closer to eye, the defect is farsightedness.
   (2) If near point goes ahead (away from eye), the defect is called myopia.
   (3) If defective far point is 1 m away from eye, divergent lens should be used
   (4) If near point is 1 m away from eye, divergent lens should be used

10. *P* is a small angled prism of angle 3° made from material of refractive index 1.2. A ray of light is incident on it as shown in figure. The angle of deviation for the rays refracted from prism is [NCERT Pg. 331]



   (1) 2° (2) 3°
   (3) 0.8° (4) 0.6°

11. When white light enters a prism, it gets split into its constituent colours. This is due to [NCERT Pg. 333]

(1) Scattering of light
(2) Dispersion of light
(3) Reflection of light
(4) Diffraction of light

12. A compound microscope consists of an objective lens of focal length 1 cm and an eye piece with focal length of 2.0 cm and tube has length 20 cm. What is its magnification? [NCERT Pg. 341]

(1) 100 (2) 200
(3) 220 (4) 250

13. With regards to a telescope, which statement is incorrect. [NCERT Pg. 340]

(1) Telescope is used to provide angular magnification of distant objects
(2) Telescope has objective lens of large power
(3) Final image of refracting telescope is inverted
(4) With larger diameter of objective fainter objects can be observed

14. Match the elements of List-I with List-II

	List-I		List-II
(A)	Simple microscope	(E)	Image magnified, inverted and virtual
(B)	Compound microscope	(F)	Image virtual, erect and high resolution
(C)	Astronomical telescope	(G)	Virtual, inverted and high resolution
(D)	Terrestrial telescope	(H)	Image virtual, erect and enlarged

[NCERT Pg. 339]

(1) A–H, B–F, C–E, D–G
(2) A–H, B–E, C–G, D–F
(3) A–H, B–E, C–F, D–G
(4) A–F, B–G, C–E, D–G

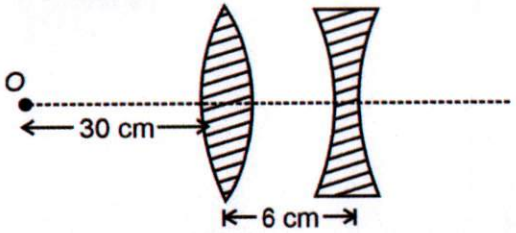
15. A simple magnifier has converging lens of focal length 2.5 cm. What is its linear magnification for the image formed at near point? [NCERT Pg. 341]

(1) 6 (2) 9
(3) 11 (4) 16

16. A prism has prism angle of 60° and its absolute refractive index is 1.76. The prism is dipped in a transparent liquid of refractive index x. If the angle of minimum deviation is found to 46° in liquid, what is x? [NCERT Pg. 331]

(1) 1.1 (2) 1.3
(3) 1.4 (4) 1.5

17. Find the position of the image formed by lens combination with convex lens of focal length 10 cm and concave lens of focal length 12 cm. The object is kept at 30 cm from the convex lens as shown [NCERT Pg. 330]



(1) 36 cm to right of convex lens
(2) 36 cm to right of concave lens
(3) 16 cm to left of concave lens
(4) 20 cm to right of convex lens

18. A small pin fixed on table top is viewed from above from a distance of 40 cm. By what distance would pin appear to be raised if viewed from the same point through a 12 cm thick glass slab held parallel to the table? Refractive index of glass is 1.5

[NCERT Pg. 345]

(1) 4 cm
(2) 5 cm
(3) 6 cm
(4) 8 cm

19. Biconvex lenses are to be manufactured from glass of refractive index 1.5 with both faces of same radii of curvature. The radius of curvature required if focal length is 15 cm will be [NCERT Pg. 344]

(1) 10 cm (2) 15 cm
(3) 20 cm (4) 25 cm

20. A light pipe is made of glass fibre of refractive index 1.57. The outer covering of the pipe is made of a material of refractive index 1.36. The range of angles of incident rays with the axis of the pipe for which total internal reflection inside the pipe take place is nearly [NCERT Pg. 345]

(1) $0° < i < 38°$ (2) $0° < i < 90°$
(3) $0° < i < 60°$ (4) $0° < i < 53°$

Thinking in Context

1. The direction of propagation of an obliquely incident ($0 < i < 90$) ray of light that enter the other medium, changes at the interface of two media, this phenomenon is called _____ of light. [NCERT Pg. 316]

2. In case of light, the ratio of velocity of light in vacuum to that in medium $\left(\frac{c}{v}\right)$, is called _____ of medium. [NCERT Pg. 319]

3. The refractive index of diamond is 2.42, then its critical angle is _____. [NCERT Pg. 320]

4. When layers of air close to ground having varying temperature, with hottest layer near ground, image of tree may create an illusion to an observer that the tree is near a pool of water. This is due to phenomenon of _____. [NCERT Pg. 321]

5. A ray of light passing through first principal focus of a convex lens emerges _____ after refraction. [NCERT Pg. 327]

6. A glass lens with refractive index 1.33 disappears in a trough of water with refractive index 1.33. The statement is [NCERT Pg. 327]

(1) True
(2) False

7. Power of a convex lens is always positive and that of concave lens is negative. The statement is [NCERT Pg. 328]

(1) True
(2) False

8. Power of lens combination is equal to algebraic sum of individual powers and magnification of combination is product of magnification of lenses. The statement is [NCERT Pg. 329]

(1) True
(2) False

9. In prism theory in general any given value of angle of deviation; except $i = e$; there corresponds to two values of $\angle i$ and $\angle e$ (*i.e.* deviation angle remains same if $\angle i$ and $\angle e$ are interchanged). This statement is [NCERT Pg. 331]

(1) True
(2) False

10. Thick lenses show chromatic aberration due to _____. [NCERT Pg. 333]

11. Vacuum is a non-dispersive medium in which all colours travel with same speed. But glass is a dispersive medium. The statement is [NCERT Pg. 333]

(1) True
(2) False

12. The rainbow is a phenomenon due to combined effect of dispersion, refraction and reflection of sunlight by spherical droplets of rain water. This statement is [NCERT Pg. 333]

(1) True
(2) False

13. When light rays undergoes two internal reflections inside a rain drop, a secondary rainbow is formed and order of colours is reversed to primary rainbow. The statement is [NCERT Pg. 334]
(1) True
(2) False

14. At the sunset or sunrise, the sun looks reddish. The reddish appearance of sun near horizon is due to _____.
[NCERT Pg. 335]

15. Angular magnification of a magnifier when the image formed at infinity compared to final image at near point is _____.
[NCERT Pg. 337]

16. The final image formed by a compound microscope is inverted and magnified. The statement is [NCERT Pg. 338]
(1) True
(2) False

17. A telescope has objective of larger focal length and large aperture, whereas eyepiece has small focal length and small aperture. The statement is
(1) True [NCERT Pg. 339]
(2) False

18. The virtual image produced by a convex mirror is generally diminished in size and located between the focus and pole.
(1) True
(2) False [NCERT Pg. 345]

19. An object placed between f and $2f$ of a concave mirror produces a real inverted image beyond $2f$.
(1) True
(2) False [NCERT Pg. 315]

20. If eye lens focusses the incoming light at a point behind the retina, a convergent lens is needed to compensate for the defect in vision. This defect is called _____
[NCERT Pg. 345]

❑ ❑ ❑

Wave Optics

10
Chapter

① HUYGEN'S PRINCIPLE

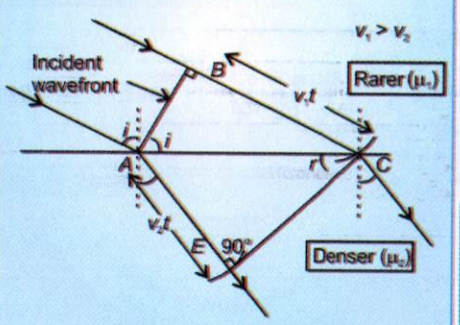
- Huygen gave a geometrical method for the propagation of wave in any medium.
- **Wavefront :** Surface of constant phase. The line drawn perpendicular to wavefront gives direction of propagation of wave and energy.
- Each point on primary wavefront behaves like a new wave source from which secondary waves emit in all directions.
- If we draw the envelope of these secondary wavelets then it will give the position of secondary wavefront.
- The shape of wavefront depends on shape of wave source.
- Point source - Spherical wave fronts
- Line source - Cylindrical wavefronts
  at a large distance from the source, a small portion of wavefront is planar.

② REFRACTION OF PLANE WAVEFRONT

From ΔABC, $\sin i = \frac{BC}{AC}$

From ΔAEC, $\sin r = \frac{AE}{AC}$

$$\frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1 t}{v_2 t} = \frac{v_1}{v_2} = \frac{\mu_2}{\mu_1}$$



③ REFLECTION OF A PLANE WAVEFRONT AT PLANE SURFACE

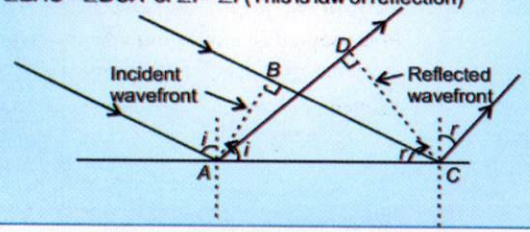
From ΔABC and ΔACD, $BC = AD = vt$

$\angle ABC = \angle ADC = 90°$

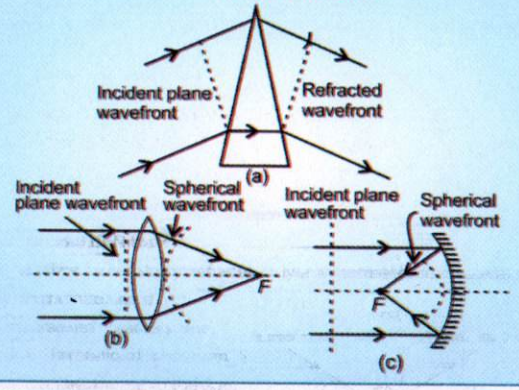
AC is common.

So ΔABC and ΔACD are congruent

$\therefore \angle BAC = \angle DCA$ or $\angle i = \angle r$ (This is law of reflection)



④ REFRACTION OF PLANE WAVE BY PRISM, LENS AND MIRROR



⑤ THE DOPPLER'S EFFECT

When the source moves away from observer the frequency as measured by source will be smaller and wavelength will be longer, this is called red shift. Towards the observer, there is an apparent decrease in wavelength, this is called red shift. $\frac{\Delta\nu}{\nu} = -\frac{v_{radial}}{C}$

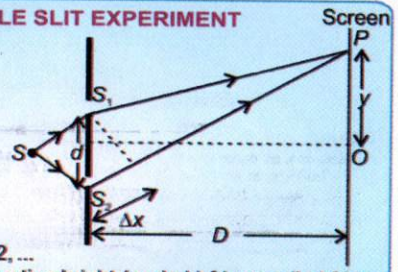
⑥ COHERENT SOURCE

- If the phase difference between two waves reaching at a point remains constants with time, then the sources are said to be coherent.
- When the phase difference between two waves change with time it is incoherent.

⑦ PRINCIPLE OF SUPERPOSITION

- If number of waves reach at a point, then the resultant displacement of point is the vector sum of displacement of individual waves at that point and at that time.
- Consider two waves reach at origin $y_1 = a_1\cos\omega t$, $y_2 = a_2\cos(\omega t + \phi)$
  From superposition law resultant amplitude is $A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}$
- **For A_{max} or constructive interference**
  Phase difference, $\phi = 0, 2\pi, 4\pi \ldots 2n\pi$
  Path difference, $\Delta x = \lambda, 2\lambda, \ldots n\lambda$ where $n = 0, 1, 2, 3 \ldots$
  $A_{max} = (a_1 + a_2)$, $I_{max} \propto (a_1 + a_2)^2$
  For A_{min} or destructive interference
  Phase difference, $\phi = \pi, 3\pi, 5\pi \ldots (2n+1)\pi$
  Path difference, $\Delta x = \lambda/2, 3\lambda/2 \ldots, (2n+1)\lambda/2$ where $n = 0, 1, 2, 3, \ldots$
  $A_{min} = (a_1 - a_2)$, $I_{min} \propto (a_1 - a_2)^2$
  - If $a_1 = a_2 = a$, $A = 2a\cos(\phi/2)$ and $I_1 = I_2 = I_0 \Rightarrow I = 4I_0\cos^2(\phi/2)$
  - When phase difference between two vibrating sources changes rapidly with time, two sources are incoherent and the intensities just add up. i.e. $I = I_1 + I_2$

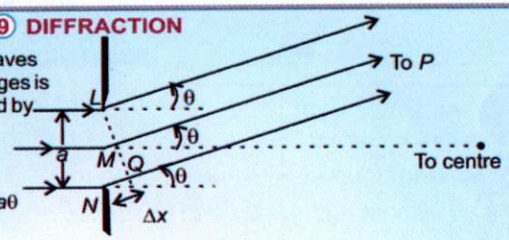
⑧ YOUNG'S DOUBLE SLIT EXPERIMENT



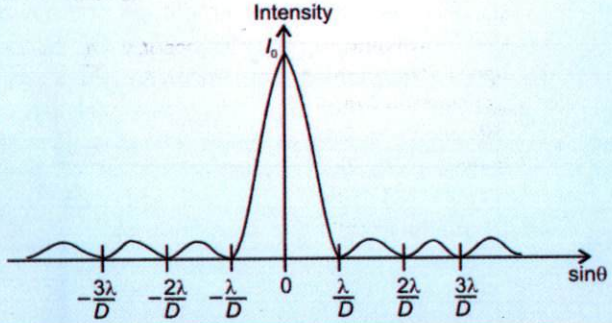
- Path difference,
  $\Delta x = S_2P - S_1P$, $\Delta x = yd/D$
- For constructive interference or bright fringes
  $yd/D = n\lambda$, $n = 0 \pm 1, \pm 2, \ldots$
- For destructive interference or Dark fringes
  $yd/D = (2n+1)\lambda/2$, $n = 0 \pm 1, \pm 2, \ldots$
- Distance between two consecutive bright (or dark) fringe called fringe width(β)
  $\beta = x_{n+1} - x_n = \lambda D/d$
- The fringe pattern is hyperbolic, for large distances the fringe will be nearly straight lines.

9 DIFFRACTION

- The phenomena of bending of waves at the narrow holes and sharp edges is called diffraction. This is exhibited by all types of waves.
- **Single slit diffraction**
  Path difference at point P
  $\Delta x = NP - LP = NQ$; $\Delta x = a\sin\theta \approx a\theta$

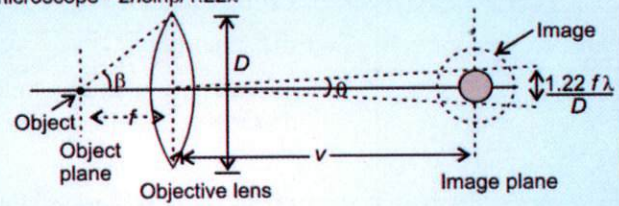


- **For central maxima** $\theta = 0$
- **For secondary maxima :** $\theta \approx (n + 1/2)\lambda/a$ where $n = \pm1, \pm2, \pm3, ...$
- **For minima :** $\theta \approx n\lambda/a$ where $n = \pm1, \pm2, \pm3, ...$
- Width of central fringe $W_c = 2\lambda D/a$
- Width of secondary fringe $W = \lambda D/a$

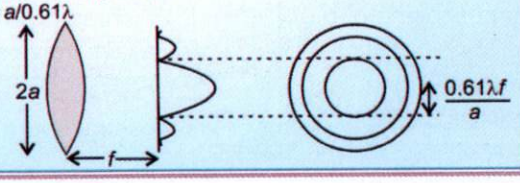


10 RESOLVING POWER OF OPTICAL INSTRUMENTS

- It is the ability to resolve the image of two nearby objects distinctly.
- Resolving power of microscope = $2n\sin\beta/1.22\lambda$



- The product $n\sin\beta$ is called the numerical aperture.
- Resolving power of telescope = $a/0.61\lambda$



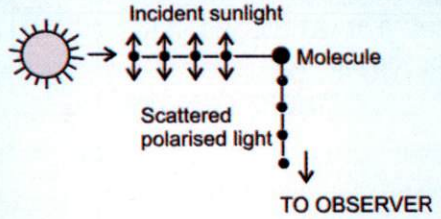
11 VALIDITY OF RAY OPTICS

Fresnel's Distance :

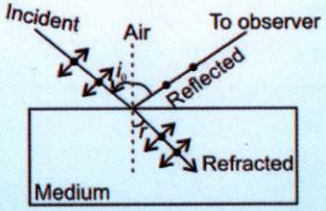
- Distance at which diffraction spread is equal to the size of aperture. $z_f \approx a^2/\lambda$
- This gives the distance beyond which divergence of beam of width a becomes significant.
- Ray optics is valid in the limit of wavelength tending to zero.

12 POLARISATION

- The phenomena of restricting the vibration of electric vector only in one direction perpendicular to the direction of propagation is called polarisation.
- **Malus' law :** The intensity of transmitted light passed through an analyser is $I = I_0\cos^2\theta$
  where, I_0 = Intensity of polarised light after passing through polariser.
  θ = Angle between axis of polariser and analyser
- **Polarisation by scattering :** An observer looking at 90° to the direction of sun. The radiations scattered by the molecules perpendicular to the incident unpolarised light (figure) is polarised.
- Scattering of light by molecules studied by C.V. Raman is called Raman effect.



- **Polarisation by Reflection :** When an unpolarised light is incident at Brewster's angle (i_B), then reflected light is polarised and refracted light is partially polarised. Brewster's angle depends on refractive index of two media,
  $\mu = \tan i_B$ and $i_B + r = 90°$



- Electric field vector perpendicular to plane of incidence is reflected.

Sharpen Your Understanding

NCERT Based MCQs

1. The phenomenon of diffraction takes place for [NCERT Pg. 367]
   (1) Sound waves only
   (2) Light waves only
   (3) Matter waves only
   (4) All type of waves

2. If Young's double slit experiment uses a monochromatic light, the shape of fringes formed on the screen is [NCERT Pg. 364]
   (1) Parabola (2) Straight line
   (3) Circle (4) Hyperbola

3. A diffraction pattern is obtained by using beam of red light. What will happen, if red light is replaced by the blue light? [NCERT Pg. 369]
   (1) Bands disappear
   (2) Bands become broader and farther apart
   (3) Diffraction bands becomes narrow and crowded
   (4) No change takes place

4. Which of the following is correct for light diverging from a point source? [NCERT Pg. 360]
   (1) The intensity changes in proportion to the distance squared
   (2) The wavefront is parabolic
   (3) The intensity changes inversely proportional to distance squared
   (4) The intensity changes inversely proportional to distance

5. In Young's double slit experiment, the slits are separated by 0.28 mm and the screen is placed 1.4 m away. The width of bright fringe is measured to be 1.2 cm. The wavelength of light used in the experiment is [NCERT Pg. 364]
   (1) 2.4×10^{-6} m (2) 3×10^{-7} m
   (3) 1.5×10^{-7} m (4) 5×10^{-7} m

6. The angle between the axis of two polaroids is 30°. The ratio of intensities of the emergent and unpolarised incident light will be [NCERT Pg. 378]
   (1) 1 : 4 (2) 1 : 3
   (3) 3 : 4 (4) 3 : 8

7. In Young's double slit experiment, the phase difference between two waves reaching at a point is $\pi/3$. The intensity of this point expressed as a fraction of maximum intensity I_0 is [NCERT Pg. 364]
   (1) $\frac{3}{2}I_0$ (2) $\frac{I_0}{2}$
   (3) $\frac{4}{3}I_0$ (4) $\frac{3}{4}I_0$

8. When a low flying aircraft passes overhead, we sometimes notice a slight shaking of the picture in our T.V. screen. This is because of _____ between the direct signal and reflected signal [NCERT Pg. 364]
   (1) Interference (2) Diffraction
   (3) Polarisation (4) Refraction

9. The idea of secondary wave wavelets for the propagation of the light wave was first given by [NCERT Pg. 354]
   (1) Fresnel
   (2) Newton
   (3) Maxwell
   (4) Huygen

10. The ratio of the amplitude of the two sources producing interference is 3 : 5, the ratio of intensities at maxima and minima is [NCERT Pg. 360]
    (1) 25 : 6 (2) 5 : 3
    (3) 16 : 1 (4) 25 : 9

11. Colours of the soap bubble is due to [NCERT Pg. 360]
    (1) Interference
    (2) Heat radiation
    (3) Polarisation
    (4) Absorption

12. Intensity of a bright fringe in a single slit diffraction pattern on a screen [NCERT Pg. 369]
    (1) Is same for all bright fringes
    (2) Increases and decreases alternatively as we move away from central fringe
    (3) Decreases as we move away from central bright fringe
    (4) Increases as we move away from central bright fringe

13. Wavefronts associated with point source of wave is [NCERT Pg. 353]
(1) Spherical (2) Planar
(3) Cylindrical (4) Ellipsoid

14. Light of wavelength 600 nm is incident on an aperture of size 2mm. The distance upto which light can travel such that its spread is less than the size of aperture is [NCERT Pg. 379]
(1) 12.13 m (2) 6.67 m
(3) 3.33 m (4) 2.19 m

15. The slits in Young's double slit experiment are illuminated by light of wavelength 6000 Å. If the path difference at the central bright fringe is zero, then the path difference at fourth bright fringe is [NCERT Pg. 364]
(1) 2.4×10^{-6} m
(2) 1.2×10^{-6} m
(3) 10^{-6} m
(4) 0.5×10^{-6} m

16. The refractive index of a medium is $\sqrt{3}$. If the unpolarised light is incident on it from air at the polarizing angle of the medium, the angle of refraction is [NCERT Pg. 379]
(1) 60°
(2) 45°
(3) 30°
(4) 0°

17. When interference of light waves takes place [NCERT Pg. 361]
(1) Energy is created in the region of maximum intensity
(2) Energy is destroyed in the region of minimum intensity
(3) Conservation of energy hold good and energy is redistributed
(4) Conservation of energy does not hold good

18. Two points separated by a distance of 0.1 mm can just be inspected in a microscope when light of wave length 6000 Å is used. If the light of wavelength of 8000 Å is used, then the limit of resolution will be [NCERT Pg. 373]
(1) 0.8 mm (2) 1.2 mm
(3) 0.1 mm (4) 0.13 mm

19. Transverse nature of light was confirmed by the phenomena of [NCERT Pg. 376]
(1) Reflection of light
(2) Diffraction of light
(3) Interference of light
(4) Polarisation of light

20. A light of wavelength 550 nm coming from a distant star. The limit of resolution of a telescope whose objective has a diameter of 2 m is [NCERT Pg. 373]
(1) 3.38×10^{-7} rad
(2) 3.35×10^{-5} rad
(3) 3.35×10^{-6} rad
(4) 2.15×10^{-7} rad

Thinking in Context

1. The branch of optics in which one completely neglects the finiteness of wavelength is called _____ optics. [NCERT Pg. 352]

2. Locus of points, which oscillate in _____ is called a wavefront. [NCERT Pg. 353]

3. If a plane wavefront is incident on a convex lens then the emerging wavefront will be _____ and converge to a _____ [NCERT Pg. 358]

4. When the source moves away from the observer, astronomers observes increase in _____ and it is called _____. [NCERT Pg. 358]

5. According to principle of superposition, the resultant displacement produced by a number of waves is the _____ of displacements produced by _____ of the waves. [NCERT Pg. 362]

6. When the phase difference between the displacements produced by each of the waves does not change with time then the sources are said to be _____.
[NCERT Pg. 352]

7. Locus of a point lying in a plane such that path difference of two waves reaching the point is constant, is a _____.
[NCERT Pg. 364]

8. If instead of in air, interference experiment is performed in water then the fringe width will _____ [NCERT Pg. 383]

9. A micrometer size obstacle will be able to stop a light ray from diffracting. (True/False)
[NCERT Pg. 353]

10. The interference pattern has a number of _____spaced bright and dark bands.
[NCERT Pg. 362]

11. For a single slit of width *a* and wavelength λ, the first null of the interference pattern occurs at an angle of _____.
[NCERT Pg. 371]

12. The limit of resolution of a microscope can be decreased by filling a liquid of _____ between _____ and _____
[NCERT Pg. 372]

13. Light waves are _____ in nature, i.e. the electric field associated with a propagating light wave is always at _____ to the direction of propagation of wave.
[NCERT Pg.377]

14. The intensity of light coming through a single polaroid is _____ of the incident intensity.
[NCERT Pg. 378]

15. Huygens argued that the amplitude of the secondary wavelets is _____ in the forward direction and zero in the backward direction. [NCERT Pg. 354]

16. The width of central maximum in single slit diffraction is distance between _____ on either side of _____. [NCERT Pg. 369]

17. In diffraction of a single slit of width *a*, using wavelength λ, condition for nth minima is _____ [NCERT Pg. 369]

18. Resolving power of an optical instrument is the ability of the instrument to _____ or _____ the image of two _____objects
[NCERT Pg. 372]

19. Angular width of central maxima in diffraction at a single slit is equal to _____.
[NCERT Pg. 369]

20. The condition of constructive interference of a point is that path difference between two waves reaching the point should be _____ or _____ of full wavelength
[NCERT Pg. 361]

❑ ❑ ❑

Dual Nature of Radiation and Matter

11
Chapter

1 ELECTRON EMISSION

Thermionic Emission

- The process of emission of electrons when a metal is heated is known as thermionic emission
- The emitted electrons are called thermions
- Emitted number of thermions depends on temperature of metal surface

Field Emission

- The process of emission of free electrons when a strong electric field ($\simeq 10^8$ V/m) is applied across the metal surface is called field emission or cold emission, as in spark plug.

Photoelectric Emission

- The process of emission of electrons when light of suitable frequency is incident on metal surface is called as photoelectric emission
- Emitted electrons are called photoelectrons
- Number of photoelectrons emitted depends on the intensity of incident light

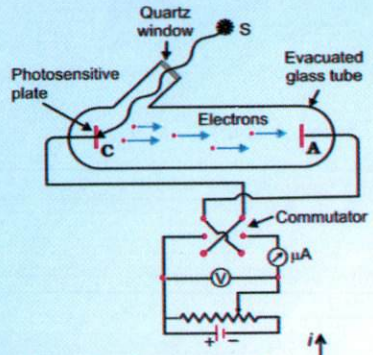
Secondary Emission

- The process of emission of free electrons when highly energetic electron beam is incident on a metal surface is called secondary emission.
- The emitted electron is called secondary electrons.

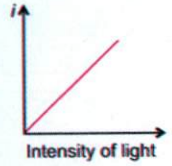
2 PHOTOELECTRIC EFFECT

- The phenomenon of photoelectric emission was discovered in 1887 by Heinrich Hertz
- Wilhelm Hallwachs and Philipp Lenard investigated the phenomenon of photoelectric emission in detail during 1886-1902.
- Certain metals like zinc, cadmium, magnesium etc responded only to ultraviolet light to cause electron emission. However, some alkali metals such as Lithium, Sodium, Potassium, Caesium and rubidium were sensitive to visible light.

3 EXPERIMENTAL STUDY OF PHOTOELECTRIC EFFECT

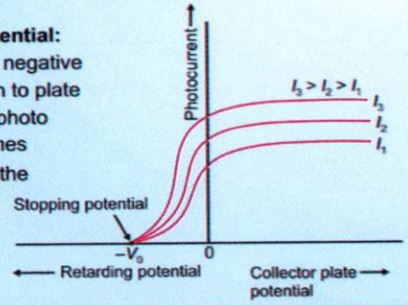


1. **Effect of Intensity:** The number of photoelectrons emitted per second or photoelectirc current is directly proportional to the intensity of radiation.

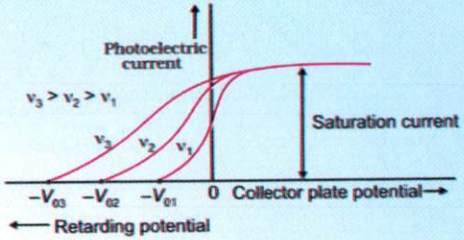


2. **Effect of potential on photoelectric current:**
   (i) For a given frequency of incident radiation, stopping potential is independent of intensity.
   (ii) Maximum kinetic energy
   $K_{max} = eV_0$

- **Stopping potential:** The minimum negative potential given to plate for which the photo current becomes zero is called the cut-off or stopping potential.



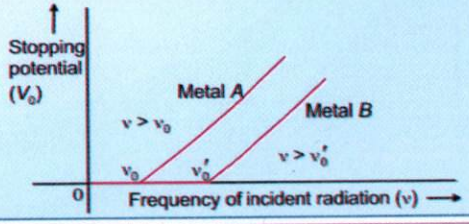
3. **Effect of frequency of incident radiation on stopping potential:**
   (i) Saturation current is independent of frequency
   (ii) Stopping potential depends on frequency of radiation.
   $(h\nu - h\nu_0 = eV_0)$



- The maximum kinetic energy of photoelectrons varies linearly with the frequency of incident radiation, but is independent of intensity.
- For a frequency less than threshold ($\nu < \nu_0$) no photoelectric emission is possible even if intensity is large.
- **Threshold frequency (ν_0):** The minimum frequency of incident radiation required to emit electrons called threshold frequency. It is different for different metals.
- **Work function (ϕ_0):** The minimum energy of incident radiation required to emit electrons from metal called work function

$$\phi_0 = h\nu_0$$

- Emission starts in a time of the order of 10^{-9} s or less.



4 EINSTEIN'S PHOTOELECTRIC EQUATION: ENERGY QUANTUM OF RADIATION

In 1905 Albert Einstein proposed that radiation energy is built up of discrete units-the so called quanta of energy radiation. Later it was called photon. Each photon has energy ($h\nu$). When energy of photon striking at surface is greater than work function (ϕ_0), electron is emitted

Maximum kinetic energy of electrons

$K_{max} = eV_0 = h\nu - \phi_0$ h = Planck's constant = 6.626×10^{-34} Js

$$V_0 = \left(\frac{h}{e}\right)\nu - \frac{\phi_0}{e}$$

This is equation of straight line with slope $\left(\frac{h}{e}\right)$

- $\left(\frac{h}{e}\right)$ is independent of nature of material
- All photons of frequency (ν), have the same energy ($h\nu$), momentum, $P = \left(\frac{h}{\lambda}\right)$
- Photons are electrically neutral
- Increase in intensity of a given frequency means increase in number of photons per second crossing a given area.

5 PHOTOCELL

- It is a device which converts light energy into electrical energy.
- The photocurrent produced is of order of microampere.
- In gas filled photocell, current is increased due to ionization of the gas.
- It is also called electronic eye
- It is used in operation of control system and in light measuring devices

6 WAVE NATURE OF MATTER

de-Broglie proposed that the wavelength λ associated with a particle of momentum P is

$$\lambda = \frac{h}{P} = \frac{h}{mv} = \frac{h}{\sqrt{2Km}}$$

- If a charged particle having charge q accelerate from rest through a potential V.

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

(i) For electron, $\lambda = \frac{1.227}{\sqrt{V}}$ nm.

(ii) For proton, $\lambda = \frac{0.0286}{\sqrt{V}}$ nm.

(iii) For α-particle, $\lambda = \frac{0.0101}{\sqrt{V}}$ nm.

- According to Heisenberg, it is not possible to measure both the position and momentum of a particle at the same time exactly.
- $\Delta x \Delta p \approx \frac{h}{2\pi}$

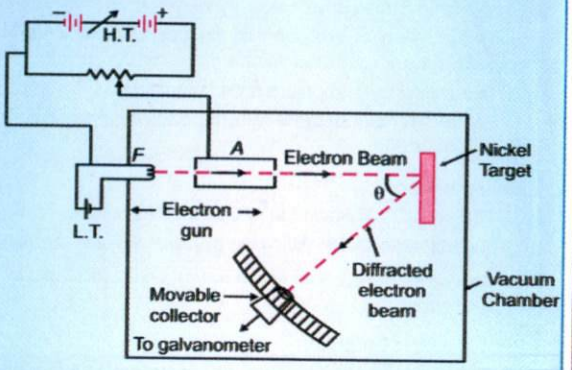
8 ELECTRON MICROSCOPE

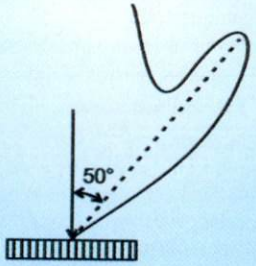
- It is a practical device that relies the wave characteristics of electron.
- Resolving power of electron microscope $\propto \frac{1}{\lambda}$

  $\propto \sqrt{V}$ (V is accelerating potential)
- Resolving power of electron microscope is approximately 10^5 times the resolving power of optical microscope.

7 DAVISSON AND GERMER EXPERIMENT

- The experimental set up used by Davisson and Germer is as shown in figure to verify wave nature of electrons
- The experiment was performed by varying the voltage from 44 V to 68 V. It was noticed that strong peak appeared in intensity (I) of scattered electron for voltage 54 V at scattering angle 50°





Sharpen Your Understanding

NCERT Based MCQs

1. Work function depends on [NCERT Pg. 387]
   (1) Metal only
   (2) Nature of surface only
   (3) Both metal and nature of surface
   (4) Threshold frequency

2. Saturation photoelectric current [NCERT Pg. 391]
   (1) Increase with increase in plate potential
   (2) Increase with decrease in plate in plate potential
   (3) Is independent of plate potential
   (4) Increase with increase in frequency

3. Monochromatic light of frequency 6×10^{14} Hz is produced by a laser. The power emitted is 2×10^{-3} W. The number of photons emitted per second by source is [NCERT Pg. 396]
   (1) 5.0×10^{15}
   (2) 5.0×10^{16}
   (3) 5.0×10^{17}
   (4) 5.0×10^{18}

4. A particle is moving three times as fast as an electron. The ratio of de-Broglie wavelength of particle to that of electron is 1.813×10^{-4}. The particle may be [NCERT Pg. 402]
   (1) Proton (2) Deutron
   (3) α-particle (4) Triton

5. An electron microscope uses electrons accelerated by a voltage of 50 kV, how does the resolving power of this electron microscope compare with that of an optical microscope which uses yellow light? [NCERT Pg. 411]
   (1) 10^4 times
   (2) 10^5 times
   (3) 10^6 times
   (4) 10^3 times

6. A particle is dropped from a height H. The de-Broglie wavelength of the particle as a function of height is proportional to [NCERT Pg. 400]
   (1) H
   (2) $H^{1/2}$
   (3) H^0
   (4) $H^{-1/2}$

7. A proton and an α-particle are accelerated through the same potential difference. The ratio of de-Broglie wavelength λ_p to that λ_α is [NCERT Pg. 400]
   (1) $\sqrt{2}:1$
   (2) $2:1$
   (3) $2\sqrt{2}:1$
   (4) $1:\sqrt{2}$

8. Which of the following statements is incorrect about the photons? [NCERT Pg. 396]
   (1) Momentum of photon is $\frac{h}{\lambda}$
   (2) Rest mass of photon is zero
   (3) Photons exert no pressure
   (4) Energy of photon is $h\nu$

9. The wavelength of matter wave is independent of [NCERT Pg. 398]
   (1) Mass
   (2) Velocity
   (3) Kinetic energy
   (4) Charge

10. Which experiment best support the theory that matter has wave nature? [NCERT Pg. 403]
    (1) Photoelectric effect
    (2) α-scattering experiment
    (3) Davisson and Germer experiement
    (4) Compton effect

11. Which among the following phenomenon shows particle nature of light? [NCERT Pg. 395]
    (1) Photoelectric effect
    (2) Interference
    (3) Polarization
    (4) Matter waves

12. Which of the following device is some times called electric eye? [NCERT Pg. 399]
(1) Light emitting diode
(2) Photocell
(3) Electric generator
(4) Integrated chip

13. For a certain metal, incident frequency ν is five times of threshold frequency ν_0 and maximum speed of coming out photoelectrons is 8×10^6 m/s. If $\nu = 2\nu_0$, the maximum speed of photoelectrons will be [NCERT Pg. 395]
(1) 4×10^6 m/s (2) 6×10^6 m/s
(3) 3×10^6 m/s (4) 1×10^6 m/s

14. An electron is moving with an initial velocity $\vec{v} = v_0\hat{i}$ enters in a uniform magnetic field $\vec{B} = B_0\hat{j}$. Then its de-Broglie wavelength [NCERT Pg. 400]
(1) Increase with time
(2) Decrease with time
(3) Remains constant
(4) Increases and decreases periodically

15. For a wavelength of 400 nm, kinetic energy of emitted photoelectron is twice that for a wavelength of 600 nm from a given metal. The work function of metal is [NCERT Pg. 395]
(1) 1.03 eV (2) 2.11 eV
(3) 4.14 eV (4) 2.43 eV

16. The linear momentum of a 3 MeV photon is [NCERT Pg. 398]
(1) 0.01 eV s m^{-1} (2) 0.02 eV s m^{-1}
(3) 0.03 eV s m^{-1} (4) 0.04 eV s m^{-1}

17. A particle of mass $4m$ at rest decays into two particles of mass m and $3m$. The ratio of de-Broglie wavelength of two particles will be [NCERT Pg. 400]
(1) $\frac{1}{2}$
(2) 4
(3) 2
(4) 1

18. In a photon particle collision (such as photon electron collision). Which of the following may not be conserved? [NCERT Pg. 396]
(1) Total energy
(2) Number of photons
(3) Total momentum
(4) None of above

19. If the momentum of an electron is changed by P, then the de-Broglie wavelength associated with it changes by 0.5%. The initial momentum of electron will be [NCERT Pg. 400]
(1) $200P$ (2) $400P$
(3) $\frac{P}{200}$ (4) $100P$

20. The phenomena of photoelectric effect was first explained by [NCERT Pg. 395]
(1) Albert Einstein
(2) Heinrich Hertz
(3) Wilhelm Hallwachs
(4) Philipp Lenard

Thinking in Context

1. The minimum energy required by an electron to just _____ from the metal surface is called _____. [NCERT Pg. 387]

2. The maximum kinetic energy of emitted photoelectrons depends on the _____ of incident radiation and _____ of cathode. [NCERT Pg. 390]

3. The maximum kinetic energy of emitted photoelectrons is independent of _____ of radiation. [NCERT Pg. 392]

4. The speed of photon in different media is _____. [NCERT Pg. 395]

5. Photon is not a material body, it is a _____. [NCERT Pg. 395]

6. The intensity of light depends upon the _____ present in light. [NCERT Pg. 391]

7. The maximum wavelength required to emit electrons from the surface of metal called _____. [NCERT Pg. 389]

8. The momentum of a photon of energy E is _____ and of wavelength λ is _____. [NCERT Pg. 398]

9. The de-Broglie wavelength of a photon of an electromagnetic radiation is _____ the wavelength of the radiation. [NCERT Pg. 398]

10. A photon and an electron have got same de-Broglie wavelength. Total energy of an electron is _____ than that of photon. [NCERT Pg. 400]

11. It is now known that photoelectric emission starts in a time of the order of _____. [NCERT Pg. 392]

12. 1 eV is equal to _____ J. [NCERT Pg. 387]

13. The de-Broglie wavelength λ of electron of kinetic energy E and mass m is _____. [NCERT Pg. 400]

14. The rest mass of a photon is _____. [NCERT Pg. 396]

15. The de-Broglie wavelength associated with a proton accelerated through a potential difference 100 V is _____. [NCERT Pg. 400]

16. The main aim of Davisson-Germer experiment is to verify wave nature of _____. [NCERT Pg. 403]

17. The minimum de-Broglie wavelength of emitted photoelectron _____ with the increase in intensity of radiation. [NCERT Pg. 398]

18. Slope of graph of variation of stopping potential with frequency of incident radiation, with frequency axis is _____. [NCERT Pg. 392]

19. The intensity of radiations depends on _____ striking per unit area per second. [NCERT Pg. 395]

20. In Davisson and Germer experiment, when beam of electrons accelerated through a potential of _____ was made to incident on a nickel crystal, the intensity of scattered beam was maximum at scattering angle _____. [NCERT Pg. 404]

❑ ❑ ❑

Atoms

12
Chapter

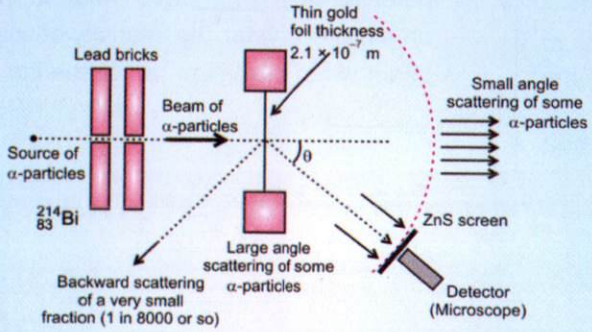
1 ATOMIC MODELS

Thomson's Model | Rutherford Model | Bohr's Model

Thomson's Model

Atom is a spherical cloud of positive charge with electrons embedded into it, like seeds in watermelon.

α-Particle Scattering Experiment and Rutherford nuclear model of atom



Conclusions

1. Only about 0.14% of incident α-particle scatter by more than 1°
2. About 1 in 8000 deflect by more than 90°
3. Size of nucleus to be about 10^{-15} m to 10^{-14} m
4. For large impact parameter the α-particle goes nearly undeviated.
5. In case of head on collision, the impact parameter is minimum and α-particle rebound back ($\theta \cong \pi$)

Rutherford's Model

According to Rutherford most of the mass of atom and all its positive charge are concentrated in a tiny space of the order of 10^{-14} m, called nucleus and electrons revolve around it. Centripetal force is obtained from electrostatic attraction between electron and nucleus.

Draw backs

(i) Stability of atom

(ii) Line spectrum of atoms

2 IMPACT PARAMETER

It is perpendicular distance of initial velocity vector of the α particle from the centre of nucleus.

$$b = \frac{Ze^2 \cot\left(\frac{\theta}{2}\right)}{4\pi\varepsilon_0 E}$$

Electron orbit

- radius $(r) = \dfrac{e^2}{4\pi\varepsilon_0 mv^2}$
- Kinetic energy $(K) = \dfrac{e^2}{8\pi\varepsilon_0 r}$
- Potential energy $(U) = -\dfrac{e^2}{4\pi\varepsilon_0 r}$
- Total energy $(E) = K + U = -\dfrac{e^2}{8\pi\varepsilon_0 r}$

Bohr's Model

Bohr combined classical and quantum concepts and gave the theory in terms of three postulates.

1. An electron can revolve in certain stable orbits without emission of radiant energy.
2. Electron can revolve only in those orbits in which angular momentum is integral multiple of $\left(\dfrac{h}{2\pi}\right)$

   $L = mv_n r_n = \dfrac{nh}{2\pi}$, $n = 1, 2, 3, \ldots$
3. When an electron makes a transition from one of the specified non radiatory orbit to another lower energy orbit then radiate energy equal to the difference of energy equal to final and initial state.

- Bohr's model is applicable for hydrogen and hydrogen like elements.

Limitations of Bohr's Model

- Bohr's model is applicable for single electron atom/ions.
- Bohr's model correctly predict the frequencies of the light emitted by hydrogenic (hydrogen like) atoms but unable to explain the relative intensities of light

3 DIFFERENT QUANTITIES FOR HYDROGEN LIKE ELEMENTS

- **Radius of the nth orbit:**

$$r_n = \left(\frac{\varepsilon_0 h^2}{\pi m e^2}\right)\frac{n^2}{Z} = 0.529\frac{n^2}{Z}\,\text{Å}$$

$$\Rightarrow r_n \propto \frac{n^2}{Z}$$

- **Speed of electron in n^{th} orbit:**

$$v_n = \frac{e^2}{2h\varepsilon_0}\frac{Z}{n} = \frac{C}{137}\frac{Z}{n}$$

$$\Rightarrow v_n \propto \frac{Z}{n}$$

- **Energy of electron in n^{th} orbit**

$$E_n = -\left(\frac{me^4}{8\varepsilon_0^2 h^2}\right)\frac{Z^2}{n^2}\,\text{J} = (2.18\times10^{-18})\frac{Z^2}{n^2}\,\text{J}$$

$$\text{or } E_n = -\frac{13.6Z^2}{n^2}\,\text{eV}$$

$$\Rightarrow E_n \propto \frac{Z^2}{n^2}$$

- **Time period of revolution of electron in n^{th} orbit.**

$$T = \left(\frac{4\varepsilon_0 h^3}{me^4}\right)\frac{n^3}{Z^2}$$

$$= \frac{n^3}{Z^2}(1.51\times10^{-16}\,\text{s})$$

$$\Rightarrow T \propto \frac{n^3}{Z^2}$$

4 HYDROGEN SPECTRUM

1. Lyman series

$$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{n^2}\right],\ n = 2, 3, 4 \ldots \infty$$

lies in U.V. region

2. Balmer series

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right],\ n = 3, 4, 5 \ldots \infty$$

Mostly lies in visible region

3. Paschen series

$$\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n^2}\right],\ n = 4, 5, 6 \ldots \infty$$

lies in near infra red region

4. Bracket series

$$\frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{n^2}\right],\ n = 5, 6, 7 \ldots \infty$$

lies in infra red region

5. Pfund series

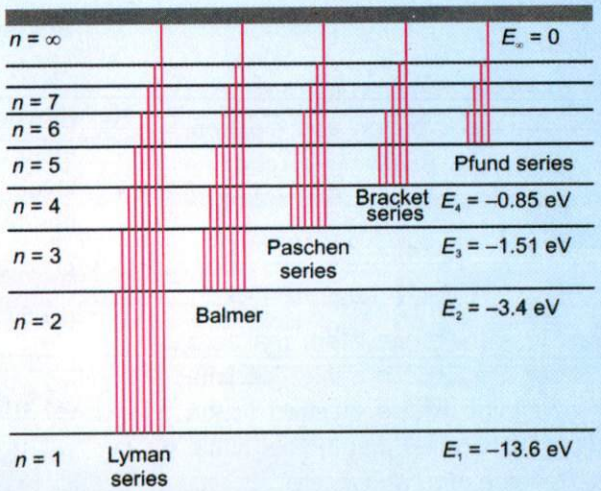
$$\frac{1}{\lambda} = R\left[\frac{1}{5^2} - \frac{1}{n^2}\right],\ n = 6, 7, 8 \ldots \infty$$

lies in far infra red region

Rydberg constant

$$R = \frac{me^4}{8\varepsilon_0 h^3 c} = 1.03 \times 10^7\ \text{m}^{-1}$$ (By Bohr-model)

$R = 1.097 \times 10^7\ \text{m}^{-1}$ (from Balmer empirical formula)



(Line spectra originate in Transition between energy levels)

5 DE BROGLIE'S EXPLANATION OF BOHR'S SECOND POSTULATE OF QUANTISATION

de-Broglie explained second postulate of Bohr's atomic model by assuming an electron has wave nature.

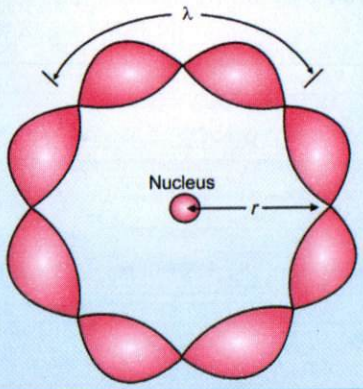
The circumference of orbit should be integer multiple of de-Broglie wavelength of electron in n^{th} orbit.

- $2\pi r_n = n\lambda,\ n = 1,2,3,\ldots$

  or

  $$mv_n r_n = \frac{nh}{2\pi}$$

- This is quantum condition proposed by Bohr for an angular momentum of an electron.



6 LASER

Acronym: light amplification by stimulated emission of radiation.

- It involves population inversion.
- It is highly coherent
- Laser light is highly monochromatic
- Divergence of laser beam is very less
- If there are N atoms, each emitting light with intensity I, then net intensity produced by ordinary source is proportional to NI whereas in laser source, it is proportional to N^2I
- There are low power lasers with a power of 0.5 mW, called pencil lasers which serve as pointers. There lasers are used for delicate surgery of eye or glands in stomach.
- Laser can cut and weld steel.

Sharpen Your Understanding

NCERT Based MCQs

1. The thickness of gold foil used in α-particle scattering experiment was [NCERT Pg. 416]

(1) 2.1×10^{-7} m (2) 2.1×10^{-3} m

(3) 3.1×10^{-10} m (4) 2.1×10^{-12} m

2. In α-particle scattering experiment number of α-particles scatter by more than 1° is about [NCERT Pg. 416]

(1) 0.3%

(2) 0.24%

(3) 0.20%

(4) 0.14%

3. In α-particle scattering experiment, number of α-particles deflected by more than 90° is [NCERT Pg. 416]

(1) 1 in 8000

(2) 1 in 2000

(3) 1 in 1000

(4) 1 in 10,0000

4. Rutherford's experiments suggested that the size of nucleus is about [NCERT Pg. 417]

(1) 10^{-14} m to 10^{-11} m

(2) 10^{-16} m to 10^{-13} m

(3) 10^{-15} m to 10^{-14} m

(4) 10^{-15} m to 10^{-10} m

5. In which of the following, will the radius of the first orbit (n = 1) be minimum? [NCERT Pg. 425]

(1) Doubly ionized lithium

(2) Singly ionized helium

(3) Deuterium atom

(4) Hydrogen atom

6. If 13.6 eV energy is required to separate a hydrogen atom into a proton and electron, then the velocity of revolving electron is [NCERT Pg. 425]

(1) 1.2×10^6 m/s (2) 2.2×10^6 m/s

(3) 3.2×10^6 m/s (4) 1.8×10^6 m/s

7. An electron in a hydrogen atom makes a transition from $n = n_1$ to $n = n_2$. The time period of revolution of the electron in the initial state is eight times that in final state. The possible value of n_1 and n_2 are [NCERT Pg. 429]

(1) $n_1 = 4, n_2 = 2$ (2) $n_1 = 8, n_2 = 2$

(3) $n_1 = 8, n_2 = 1$ (4) $n_1 = 6, n_2 = 2$

8. If muonic hydrogen atom is an atom in which a negatively charged muon (μ) of mass about $207m_e$ revolve around a proton, then first Bohr radius of this atom is (radius of electron orbit is 0.53 Å) [NCERT Pg. 437]

(1) 2.56×10^{-10} m (2) 2.56×10^{-11} m

(3) 2.56×10^{-12} m (4) 2.56×10^{-13} m

9. The minimum energy that must be given to a hydrogen atom in ground state so that it can emit an Hγ line in Balmer series. [NCERT Pg. 429]

(1) 12.4 eV

(2) 10.2 eV

(3) 13.06 eV

(4) 12.75 eV

10. A hydrogen atom initially in the ground state absorbs a photon and is excited to n = 4 level, then the wavelength of photon is nearly [NCERT Pg. 427]

(1) 790 Å

(2) 870 Å

(3) 970 Å

(4) 1070 Å

11. The wavelength of first line of Lyman series is 1215 Å, the wavelength of first line of Balmer series will be [NCERT Pg. 421]

(1) 4545 Å (2) 5295 Å

(3) 6563 Å (4) 6750 Å

12. The ratio of the speed of electron in the ground state of hydrogen atom to the speed of light in vacuum is [NCERT Pg. 425]

(1) $\frac{1}{2}$ (2) $\frac{2}{237}$

(3) $\frac{1}{137}$ (4) $\frac{1}{237}$

13. Ionization potential of hydrogen atom is 13.6 eV. Hydrogen atoms in the ground state are excited by monochromatic radiation of photon energy 12.1 eV. According to Bohr's theory, the spectral lines emitted by hydrogen will be [NCERT Pg. 429]
(1) One
(2) Two
(3) Three
(4) Five

14. Bohr's basic idea of discrete energy levels in atoms and process of emission of photons from the higher levels to the lower levels was experimentally confirmed by experiments performed by[NCERT Pg. 428]
(1) Michelson-Morley
(2) Millikan
(3) Joule
(4) Franck and Hertz

15. If E is the energy of nth orbit of hydrogen atom, the energy of nth orbit of He^+ ion will be [NCERT Pg. 425]
(1) E (2) $2E$
(3) $3E$ (4) $4E$

16. The shortest wavelength present in, the Paschen series of spectral lines is nearly [NCERT Pg. 429]
(1) 720 nm (2) 790 nm
(3) 800 nm (4) 820 nm

17. If there are N atoms in a source of Laser light and each atom is emitting light with intensity I, then the total intensity produced by it is [NCERT Pg. 432]
(1) NI (2) N^2I
(3) N^3I (4) N^4I

18. Which of the following statements is true for hydrogen atom? (n is principal quantum number of orbit) [NCERT Pg. 425]
(1) Angular momentum $\propto \frac{1}{n}$
(2) Radius of orbit $\propto \frac{1}{n}$
(3) Magnitude of linear momentum of electron in any orbit $\propto \frac{1}{n}$
(4) Energy of electron in any orbit $\propto \frac{1}{n^3}$

19. The first spectral series of hydrogen atom was discovered by [NCERT Pg. 421]
(1) Balmer (2) Lyman
(3) Paschen (4) Bohr

20. In a hydrogen atom, total energy of electron is [NCERT Pg. 420]
(1) $\frac{e^2}{4\pi\varepsilon_0 r}$ (2) $\frac{-e^2}{4\pi\varepsilon_0 r}$
(3) $\frac{-e^2}{8\pi\varepsilon_0 r}$ (4) $\frac{e^2}{8\pi\varepsilon_0 r}$

Thinking in Context

1. The source of α-particles in Rutherford experiment is _____. [NCERT Pg. 416]

2. Emission line spectrum consists of _____ lines on a _____ background. [NCERT Pg. 421]

3. _____ the impact parameter, α-particle goes nearly undeviated [NCERT Pg. 418]

4. At room temperature most of hydrogen atoms are in _____ state. [NCERT Pg. 427]

5. According to Thomson model, the entire mass and charge of an atom are _____ distributed throughout the volume of atom. [NCERT Pg. 414]

6. Total energy of electron in inner orbits is _____ than in outer orbits [NCERT Pg. 425]

7. Orbital velocity of electrons in inner orbits _____ as compared to outer orbits. [NCERT Pg. 425]

8. Total energy of electron in any orbit of atom is _____. This indicates that electron is bound to nucleus. [NCERT Pg. 425]

9. According to Bohr, _____ momentum of revolving electron in hydrogen atom is quantised. [NCERT Pg. 424]

10. Lyman series lies in _____ region of hydrogen spectrum. [NCERT Pg. 429]
11. In Bohr model, contrary to ordinary classical expectation, the frequency of revolution of an electron in its orbit is not connected to _____ of spectral lines. [NCERT Pg. 423]
12. According to classical electromagnetic theory _____ charge particles emits radiation in the form of electromagnetic wave. [NCERT Pg. 423]
13. According to Quantum theory when an electron makes a transition from one of the specified orbit to lower energy orbit a _____ is emitted having energy equal to the _____ of two levels. [NCERT Pg. 424]
14. Bohr model is valid for only _____atom/ions. [NCERT Pg. 426]
15. If there are N atoms in a source, each emitting light with intensity I, then the total intensity produced by an ordinary source is proportional to _____ where as in laser source it is proportional to _____ [NCERT Pg. 432]
16. An electron can have any total energy above $E = 0$ eV. In such situations the electron is _____. [NCERT Pg. 427]
17. In Balmer series, the line with _____ colour is called H_β line. [NCERT Pg. 421]
18. Thomson's model is unstable electrostatically, while Rutherford model is unstable _____. [NCERT Pg. 434]
19. With the increase in principal quantum number in the stationary states, the difference of energy from ground state _____. [NCERT Pg. 427]
20. According to _____ postulate of Bohr's, an electron in an atom could revolve in certain stable orbits without the emission of radiant energy. [NCERT Pg. 423]

❑ ❑ ❑

Nuclei

13 Chapter

1 ATOMIC MASSES AND COMPOSITION OF NUCLEUS

- Before discovery of neutron, nucleus was assumed to be made up of protons and electrons but later this was ruled out using argument of quantum theory.

2 DISCOVERY OF NEUTRON

- In 1932 James Chadwick observed emission of neutral radiation, when beryllium nuclei was bombarded with α-particle on the basis of energy and momentum conservation.

  Chadwick concluded that it was a new type of neutral particle called neutron.

  ${}^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$
- All nuclides with same atomic number but having different mass are called isotopes.
- All nuclides with same mass number are called isobars.
- Nuclides with same neutron but different atomic number are called isotones.
- $A = Z + N$

3 SIZE OF NUCLEUS

- The radius of nucleus with mass number 'A' is $R = R_0 A^{1/3}$ where, $R_0 = 1.2 \times 10^{-15}$ m.
- Density of nucleus is approximately 2.3×10^{17} kg/m^3 and is independent of mass number.

4 MASS ENERGY AND NUCLEAR BINDING ENERGY

- **Mass energy :** Einstein showed that mass is another form of energy and one can convert into other form. Einstein gave the famous mass energy equivalence relation $E = mC^2$.
- $1u = 931.5\ \text{MeV}/C^2$

5 NUCLEAR BINDING ENERGY

- The difference in mass of a nucleus (${}_{Z}X^{A}$) and its constituents, ΔM, is called the mass defect.

  $\Delta M = [Zm_p + (A - Z)m_n] - M$
- If one wants to break the nucleus into protons and neutrons. This extra energy $(\Delta M)c^2$, has to be supplied. This energy called binding energy.

  $E_b = \Delta Mc^2$
- Binding energy per nucleon is the measure of stability of nucleus.
- The binding energy per nucleon is practically constant for nuclei of middle mass number ($30 < A < 170$), with maximum of 8.75 MeV for $A = 56$ and has a value of 7.6 MeV for $A = 238$.
- Binding energy per nucleon is lower for both light nuclei ($A < 30$) and heavy nuclei ($A > 170$)

7 LAW OF RADIOACTIVE DECAY

- Rate of disintegration, $\frac{dN}{dt} = -\lambda N$
- $N = N_0 e^{-\lambda t}$
- Half life : $T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.6931}{\lambda}$
- λ = Decay constant.
- Mean life, $\tau = \frac{1}{\lambda} = 1.44 T_{1/2}$

  α-Decay : During α-decay, atomic number decreases by two and mass number by four.
- It is nuclei of helium

  ${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + Q$

  $Q = (m_x - m_y - m_{He})C^2$
- **β-Decay :**

  (i) β^- decay: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^- + \bar{\nu}$

  $$Q = \left[m\left({}_{Z}X^{A}\right) - m\left({}_{Z+1}Y^{A}\right)\right]C^2$$

  (ii) β^+ decay: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + e^+ + \nu$

  $$Q = \left[m\left({}_{Z}X^{A}\right) - m\left({}_{Z-1}Y^{A}\right) - 2m_e\right]C^2$$

  γ-Decay :
- Like an atom, a nucleus also has discrete energy levels, the ground state and excited states. When a nucleus in an excited state spontaneously decays to ground state (or to lower energy state), a photon is emitted. This is called γ-decay.
- The difference in nuclear energy levels is of the order of MeV.

6 NUCLEAR FORCE

- Inside the nucleus, a large attractive force is required to bind the nucleons against repulsion. The force is called nuclear force.
- It is strongest attractive force. $F_{P-P} = F_{n-n} = F_{P-n}$
- It is charge independent force i.e.
- It is short range force.
- It has property of saturation.
- For a distance ($r < 0.8$ fm) it is repulsive force.

8 NUCLEAR FISSION

- When a slow moving neutron strikes a heavy nucleus, which breaks into two intermediate mass nuclear fragments. This is called nuclear fission.

  ${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3{}^{1}_{0}n$
- The energy released (the Q-value) in the fission of single uranium is of the order of 200 MeV.
- Multiplication factor $(K) = \frac{\text{Rate of production of neutrons}}{\text{Rate of loss of neutrons}}$
- Uncontrolled chain reaction is the principle of atom bomb.
- Controlled chain reaction is the principle of nuclear reactors.

9 NUCLEAR REACTOR

- U^{235} or Pu^{239} is used as fuel in a nuclear reactor.
- D_2O, graphite and beryllium oxide are used as moderator to slow down the fast neutrons.
- Rate of reaction is controlled by control rods made of cadmium or boron
- Air, ice cold water, molten sodium or CO_2 are used as coolant.

10 NUCLEAR FUSION

It is the phenomenon in which two or more lighter nuclei combine to form a single middle weight nucleus.

Some examples of nuclear fusion.

${}^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{2}_{1}H + e^+ + \nu + 0.42\ \text{MeV}$

${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + n + 3.27\ \text{MeV}$

${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{1}H + {}^{1}_{1}H + 4.03\ \text{MeV}$

Sharpen Your Understanding

1. The atomic masses of various elements expressed in atomic mass unit (u) are close to being integral multiples of mass of [NCERT Pg. 439]
   (1) A hydrogen atom
   (2) A proton
   (3) A neutron
   (4) Both (2) and (3)

2. The density of nuclear matter [NCERT Pg. 441]
   (1) Increases with mass number
   (2) Decreases with mass number
   (3) Is independent of mass number
   (4) Increases up to mass number 56 then decreases

3. For thermonuclear fusion reaction, the estimated temperature of the system should be about [NCERT Pg. 456]
   (1) 3×10^3 K (2) 3×10^9 K
   (3) 1×10^5 K (4) 3×10^6 K

4. Nuclear force is [NCERT Pg. 445]
   (1) Attractive for distance, $r = 0.5$ fm
   (2) Repulsive for distance, $r < 0.8$ fm
   (3) Attractive for distance, $r < 0.8$ fm
   (4) Repulsive for distance, $r > 0.8$ fm

NCERT Based MCQs

5. The SI unit of activity is [NCERT Pg. 447]
   (1) Becquerel (2) Curie
   (3) Rutherford (4) Both (1) and (2)

6. The mass of iron nucleus is $55.85u$ and $A = 56$. The nuclear density of iron is [NCERT Pg. 441]
   (1) 2.5×10^{15} kg/m^3 (2) 2.3×10^{16} kg/m^3
   (3) 2.3×10^{17} kg/m^3 (4) 3.5×10^{16} kg/m^3

7. 1 curie is equal to [NCERT Pg. 448]
   (1) 3.7×10^7 Bq (2) 3.7×10^{10} Bq
   (3) 3.7×10^8 Bq (4) 3.7×10^6 Bq

8. The half life of $_{92}U^{238}$ undergoing α-decay is 4.5×10^9 years. The activity of 4 g sample of $_{92}U^{239}$ is [NCERT Pg. 448]
   (1) 1.23×10^4 Bq
   (2) 1.23×10^5 Bq
   (3) 4.9×10^4 Bq
   (4) 4.9×10^5 Bq

9. 1 mg radium has 2.68×10^{18} atoms. Its half life is 1620 years. How many radium atoms will disintegrate from 1 mg of pure radium in 3240 years. [NCERT Pg. 448]
   (1) 2.01×10^9 (2) 2.01×10^{18}
   (3) 0.67×10^{18} (4) 1.01×10^9

10. In a sample of radioactive material, what fraction of the initial number of active nuclei will remain undisintegrated after half of the half life of the sample? [NCERT Pg. 448]
    (1) $\frac{1}{4}$ (2) $\frac{1}{2\sqrt{2}}$
    (3) $\frac{1}{\sqrt{2}}$ (4) $\sqrt{2}-1$

11. The natural boron of atomic mass 10.81 u is found to have two isotopes ^{10}B and ^{11}B. The ratio of abundance of isotopes of natural boron should be nearly [NCERT Pg. 439]
    (1) 11 : 10 (2) 81 : 19
    (3) 10 : 11 (4) 19 : 81

12. The energy liberated in a single uranium fission is about [NCERT Pg. 457]
    (1) 200 MeV
    (2) 235 MeV
    (3) 20 MeV
    (4) 100 MeV

13. Pick out the incorrect statement from the following. [NCERT Pg. 450]
    (1) β^- emission from the nucleus is always accompanied with a neutrino
    (2) The energy of the α-particle emitted from a given nucleus is constant
    (3) γ-ray emission makes the nucleus more stable
    (4) Nuclear force is charge-independent

14. The radius of a spherical nucleus as measured by electron scattering is 3.6 fm. What is the mass number of the nucleus most likely to be? [NCERT Pg.441]

(1) 27 (2) 40

(3) 56 (4) 120

15. The number of β^--particles emitted by a radioactive substance is twice the number of α-particles emitted by it. The resulting daughter is an [NCERT Pg. 450]

(1) Isomer of parent (2) Isotone of parent

(3) Isobar of parent (4) Isotope of parent

16. In nuclear reactors, the controlling rods are made of [NCERT Pg. 454]

(1) Cadmium (2) Graphite

(3) Krypton (4) Plutonium

17. A nucleus with mass number 220 initially at rest emits an α-particle. If the Q-value of reaction is 5.5 MeV, the kinetic energy of α-particle is [NCERT Pg. 449]

(1) 4.4 MeV

(2) 5.4 MeV

(3) 5.0 MeV

(4) 4.8 MeV

18. Choose the incorrect nuclear fusion reactions among the following [NCERT Pg. 455]

(1) ${}^1_1H + {}^1_1H \rightarrow {}^2_1H + e^+ + \nu + 0.42$ MeV

(2) ${}^2_1H + {}^2_1H \rightarrow {}^3_2He + n + 3.27$ MeV

(3) ${}^2_1H + {}^2_1H \rightarrow {}^3_1H + {}^1_1H + 4.03$ MeV

(4) $e^+ + e^- \rightarrow \gamma$

19. Fission of nuclei is possible because the binding energy per nucleon in them [NCERT Pg. 444]

(1) Decreases with mass number at low mass numbers

(2) Increases with mass number at low mass numbers

(3) Increases with mass number and high mass numbers

(4) Decreases with mass number at high mass numbers

20. Consider α, β-particles and γ-rays. The increasing order of penetration power is [NCERT Pg. 451]

(1) α, β, γ (2) γ, β, α

(3) β, α, γ (4) β, γ, α

Thinking in Context

1. The radius of nucleus is smaller than the radius of atom by a factor of about _____ [NCERT Pg. 438]

2. Nucleus of an atom contains more than _____ of the mass of an atom [NCERT Pg. 438]

3. The fractional atomic masses of elements in atomic mass unit shows that most of elements have _____ [NCERT Pg. 439]

4. α-particles are the _____ of helium [NCERT Pg. 449]

5. A free neutron, unlike a free proton is _____ and has a mean life of about _____ [NCERT Pg. 440]

6. If a certain number of neutrons and protons are brought together to form a nucleus, then energy is _____ [NCERT Pg. 443]

7. The constancy of binding energy in the range $30 < A < 170$ is a consequence of the fact that nuclear force is _____ force [NCERT Pg. 444]

8. The property that a given nucleon influences only nucleons close to it, is also referred as _____ property of nuclear force. [NCERT Pg. 445]

9. Like an atom, nucleus has _____ energy levels [NCERT Pg. 451]

10. The difference in nuclear energy levels is of order of _____ [NCERT Pg. 451]

11. If nuclei with less total binding energy transform to nuclei with greater binding energy, there will be a net energy _____ [NCERT Pg. 451]

12. In nuclear fusion two lighter nuclei combine to form a comparatively _____ nucleus [NCERT Pg. 445]

13. Energy associated with nuclear processes is about a _____ times larger than in a chemical process. [NCERT Pg. 452]

14. The mass density of the nuclei is _____ of mass number [NCERT Pg. 441]

15. The energy equivalent to 1 amu is_____ [NCERT Pg. 443]

16. Isobars are atom of different elements which have same _____ number but different _____ number [NCERT Pg. 441]

❑ ❑ ❑

17. The Apsara reactor at Bhabha Atomic Research Centre, Mumbai uses _____ as moderator [NCERT Pg. 454]

18. Isotones are the nuclides which contains same number of _____ [NCERT Pg. 441]

19. Radioactivity is an indication of the _____ of nuclei. [NCERT Pg. 461]

20. The mass of the nucleus is ____ the sum of the masses of nucleons forming it [NCERT Pg. 443]

Semiconductor Electronics : Material, Devices and Simple Circuits

14
Chapter

1 SEMICONDUCTOR

- Its conductivity or resistivity lies between conductor and insulator
- Negative temperature coefficient of resistance
- Band gap is less than 3 eV

Intrinsic Semiconductor

- It is pure semiconductor
- Carriers are thermally generated
- At 0 K, behaves like insulator
- $n_e = n_h = n_i$

Extrinsic Semiconductor

- Conductivity is increased by doping.

p-type semiconductor

- Doped with trivalent atom
- Holes are majority carriers
- $n_h >> n_e$

n-type semiconductor

- Doped with pentavalent atom
- Electrons are majority carriers
- $n_e >> n_h$
- Law of mass action $n_e n_h = n_1^2$

2 p-n JUNCTION

- A p-type semiconductor is brought in contact with a *n*-type semiconductor
- A depletion layer is formed at junction.
- Thickness of depletion layer decreases with increase in doping and forward biasing

Biasing of p-n junction

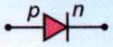
Forward biasing

- Width of depletion layer decreases
- Effective barrier potential decreases
- Low resistance at junction
- Current flown is of the order of mA

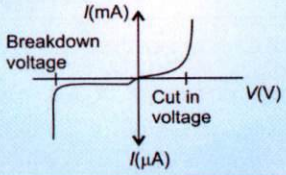
Reverse biasing

- Width of depletion layer increases
- Effective barrier potential increases
- High resistance at junction
- Current flown is of the order of μA
- Breakdown occurs at high reverse bias voltage

3 SEMICONDUCTOR DIODE

- It is a device having single p-n junction
- Symbol: Anode  Cathode

V-I characteristics

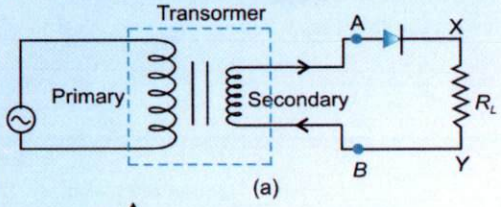


4 APPLICATION OF DIODE

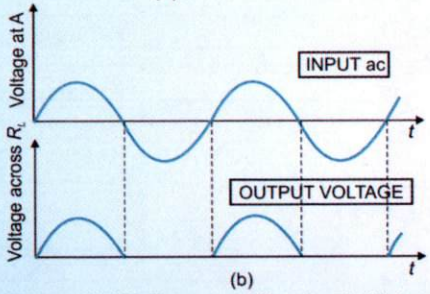
Diode as a Rectifier

Half wave-rectifier

- It rectifies either positive or negative cycle only, of input signal
- Frequency of output and input are same



(a)



(b)

Figure : (a) Half-wave rectifier circuit, (b) Input ac voltage and output voltage waveforms from the rectifier circuit.

Zener diode as a Voltage Regulator

- Zener diode is highly order reverse doped p-n junction diode
- It is operated as regulator when diode is in reversed bias
- The output voltage is fixed and is equal to Zener voltage

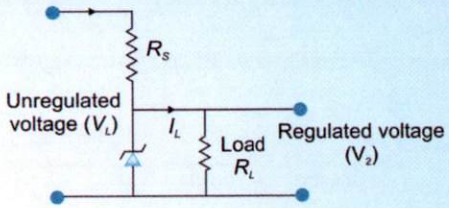
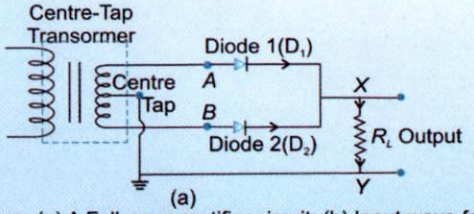


Figure: Zener diode as DC voltage regulator

Full wave rectifier

- It rectifies both the cycles of input
- Frequency of output is two times the frequency of input



(a)

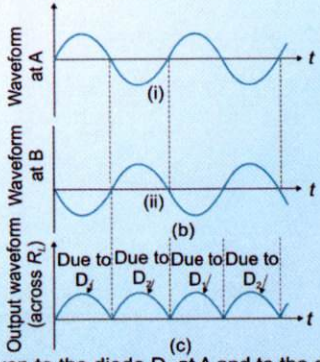


Figure: (a) A Full-wave rectifier circuit; (b) Input wave forms given to the diode D_1 at A and to the diode D_2 at B; (c) Output waveform across the load RL connected in the full-wave rectifier circuit.

5 OPTOELECTRONIC DEVICE

Light Emitting Diode

- It is generally operated in forward bias
- It is used to transmit optical signals
- V-I characteristics is same as of normal p-n junction diode
- E_g should be in range of energy of visible light
- Band width of emitted light is 100 Å to 500 Å

Photodiode

- It is generally operated in reverse bias
- It is used to detect the optical signal
- V-I characteristics lies in 3rd quadrant
- Reverse current increases with increase in intensity of incoming signal

Solar Cell

- It is used in unbiased condition
- It generates emf from solar radiations
- V-I characteristics lies in 4th quadrant
- Semiconductor with E_g closed to 1.5 eV are ideal material for solar cell.

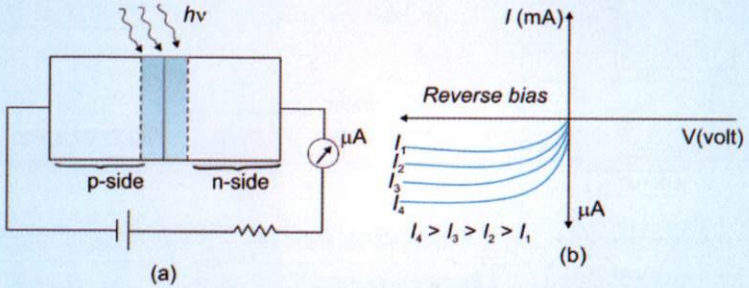


Fig. : (a) An illuminated photodiode under reverse bias, (b) I-V characteristics of a photodiode for different illumination intensity $I_4 > I_3 > I_2 > I_1$

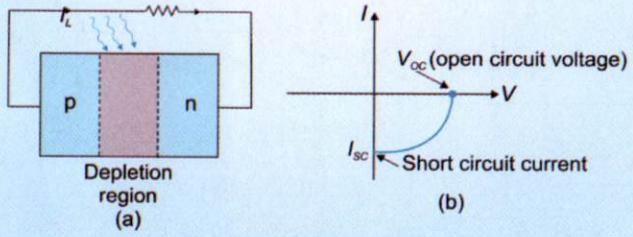


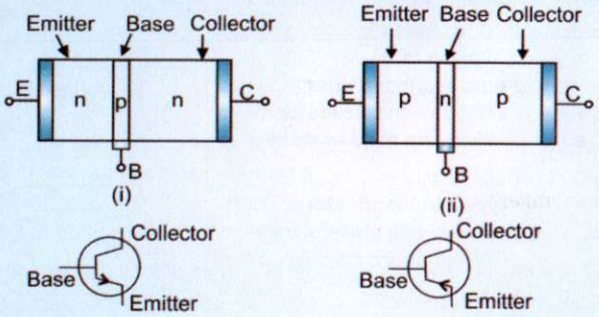
Figure : (a) A typical illuminated p-n junction solar cell; (b) I-V characteristics of a solar cell.

6 JUNCTION TRANSISTOR

- It is two junction and three terminal device
- Fundamental action of transistor is transfer resistor
- Length profile $L_C > L_E > L_B$
- Doping profile $E > C > B$

Types of transistor

- n-p-n transistor
- p-n-p transistor



Modes of Operation

E-B junction	B-C junction	Mode of operation	Application
Forward	Reverse	Active	Amplifier
Forward	Forward	Saturation	Switch (on)
Reverse	Reverse	Cut off	Switch (off)

Configuration of transistor (BJT)

- Common base configuration
- Common emitter configuration
- Common collector configuration

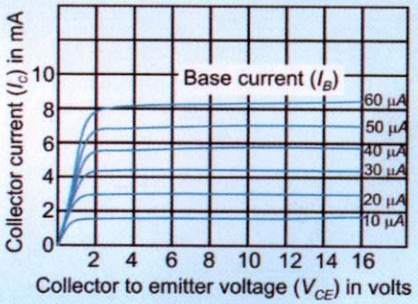
7 COMMON EMITTER (CE) CONFIGURATION

Transistor characteristics

- Input resistance $(r_i)_{CE} = \dfrac{\Delta V_{BE}}{\Delta I_B}$
- Output resistance $(r_o)_{CE} = \dfrac{\Delta V_{CE}}{\Delta I_C}$
- Transconductance $(g_m) = \left(\dfrac{\Delta I_C}{\Delta V_{BE}}\right)$
- Current gain of different configuration

$$\alpha_{ac} = \frac{\Delta I_C}{\Delta I_E},\ \beta_{ac} = \frac{\Delta I_C}{\Delta I_B},\ \gamma_{ac} = \frac{\Delta I_E}{\Delta I_B}$$

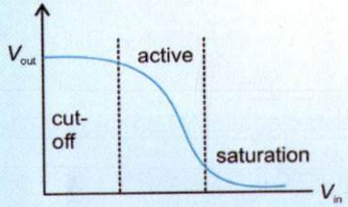
- Output characteristics of CE amplifier



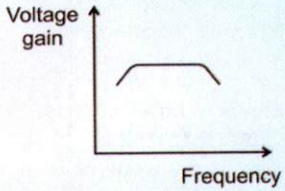
8 APPLICATION OF TRANSISTOR

- **Transistor as an amplifier**
  - Voltage gain $(A_v) = \frac{V_o}{V_i}$

    $= -\beta \frac{R_{out}}{R_{in}} = -g_m R_{out}$
  - Power gain $(A_P) = A_v \times \beta_{ac}$
- Transistor as a switch

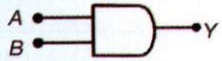
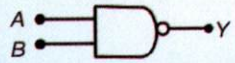


- Variation of voltage gain with frequency is given as



- Transistor as an oscillator
  - Barkhausen criteria for sustained oscillation is $A\beta = 1$

9 LOGIC GATES

Logic gate	Symbol	Characteristic equation	Truth table
NOT		$Y = \overline{A}$	A: 0, 1; Y: 1, 0
OR		$Y = A + B$	A: 0, 0, 1, 1; B: 0, 1, 0, 1; Y: 0, 1, 1, 1
AND		$Y = A \bullet B$	A: 0, 0, 1, 1; B: 0, 1, 0, 1; Y: 0, 0, 0, 1
NAND		$Y = \overline{A \bullet B}$	A: 0, 0, 1, 1; B: 0, 1, 0, 1; Y: 1, 1, 1, 0
NOR		$Y = \overline{A + B}$	A: 0, 0, 1, 1; B: 0, 1, 0, 1; Y: 1, 0, 0, 0

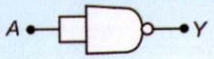
10 BOOLEAN LOGIC

- $A + A = A$
- $A \cdot A = A$
- $A + 1 = 1$
- $A \cdot 1 = A$
- $A + 0 = A$
- $A \cdot 0 = 0$
- $A \cdot \overline{A} = 0$
- $A + \overline{A} = 1$
- $\overline{A + B} = \overline{A} \cdot \overline{B}$
- $\overline{A \cdot B} = \overline{A} + \overline{B}$

11 REALISATION OF BASIC GATES USING NAND OR NOR GATES

Using NAND only

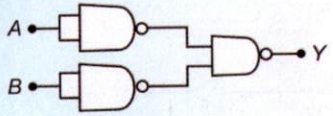
- **NOT**



$Y = \overline{A \cdot A}$

$= \overline{A}$

- **OR**

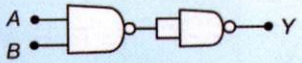


$Y = \overline{\overline{A} \cdot \overline{B}}$

$= \overline{\overline{A + B}}$

$= A + B$

- **AND**

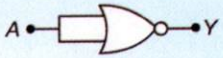


$Y = \overline{\overline{A \cdot B}}$

$= A \cdot B$

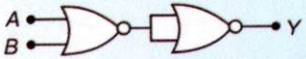
Using NOR only

- **NOT**



$Y = \overline{A \cdot A} = \overline{A}$

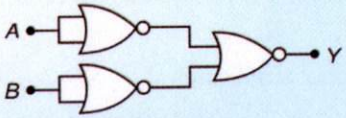
- **OR**



$Y = \overline{\overline{A + B}}$

$= A + B$

- **AND**



$Y = \overline{\overline{A} + \overline{B}}$

$= \overline{\overline{A \cdot B}}$

$= A \cdot B$

Sharpen Your Understanding

NCERT Based MCQs

1. Which of the following is correct range of resistivity for the semiconductor material? [NCERT Pg. 468]

(1) (10^{-2} to 10^{-8}) Ω m

(2) (10^{-5} to 10^{6}) Ω m

(3) (10^{11} to 10^{19}) Ω m

(4) (10^{5} to 10^{16}) Ω m

2. A material has band gap energy (E_g) greater than 2 eV. The material [NCERT Pg. 471]

(1) Must be conductor

(2) Must be semiconductor

(3) Must be insulator

(4) May be semiconductor

3. A sample of semiconductor material having hole as minority carrier is of [NCERT Pg. 476]

(1) p-type

(2) n-type

(3) Intrinsic

(4) Data is insufficient

4. An intrinsic semiconductor sample is doped with both pentavalent and trivalent dopants. If N_a is number of acceptor atoms per unit volume, N_d is number of donor atoms per unit volume and n and h are electron and hole concentrations, then [NCERT Pg. 510]

(1) $N_a + N_d = n + h$

(2) $N_a + n = N_d + h$

(3) $N_d + n = N_a + h$

(4) $N_a^2 + N_d^2 = n^2 + h^2$

5. A pure Si crystal has 5×10^{28} atoms/m^3. It is doped by 1 ppm concentration of As atom. The number of holes per unit volume is (consider $n_i = 1.5 \times 10^{16}$ m^{-3}) [NCERT Pg. 477]

(1) 4.5×10^{9} m^{-3}

(2) 4×10^{9} m^{-3}

(3) 2×10^{9} m^{-3}

(4) 2.25×10^{10} m^{-3}

6. Consider the following statements [NCERT Pg. 485]

(a) Zener diode is fabricated by lightly doped p-n junction

(b) After breakdown of Zener diode the current in the circuit is limited by external resistance

Choose the correct statement(s)

(1) (a) only

(2) (b) only

(3) Both (a) and (b)

(4) Neither (a) nor (b)

7. The semiconductor used for fabrication of visible LEDs must at least have a band gap [NCERT Pg. 488]

(1) 1.1 eV

(2) 1.21 eV

(3) 1.8 eV

(4) 2.4 eV

8. The *V-I* characteristics of photodiode lies in [NCERT Pg. 487]

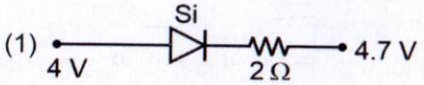
(1) I quadrant

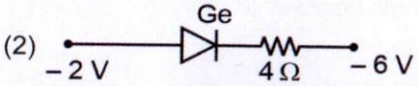
(2) II quadrant

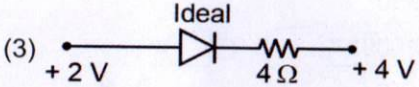
(3) III quadrant

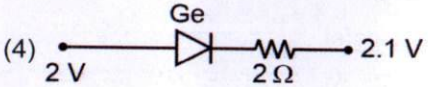
(4) IV quadrant

9. Which of the following diode is in forward bias condition? (When current is flowing) [NCERT Pg.480]

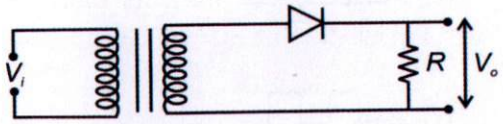
(1) 

(2) 

(3) 

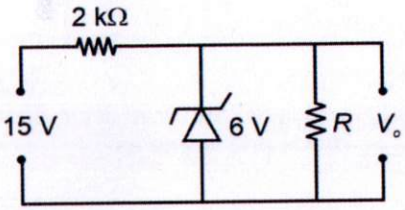
(4) 

10. The output across the load R is [NCERT Pg. 483]



(1) Half wave rectified
(2) Full wave (centre tap) rectified
(3) Quarter wave rectified
(4) AC

11. The value of output voltage V_0 in the circuit as shown in the figure is [NCERT Pg.486]

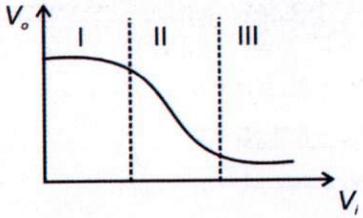


(1) 9 V (2) 4.5 V
(3) 12 V (4) 6 V

12. An n-p-n transistor is configured in *CE* configuration. The input resistance is 2 kΩ and load is 10 kΩ. If α = 0.99, then voltage gain will be [NCERT Pg. 497]

(1) 495
(2) 990
(3) 1000
(4) 500

13. The transfer characteristics of a CE amplifier is shown in the figure. The transistor works as an amplifier in region [NCERT Pg. 496]

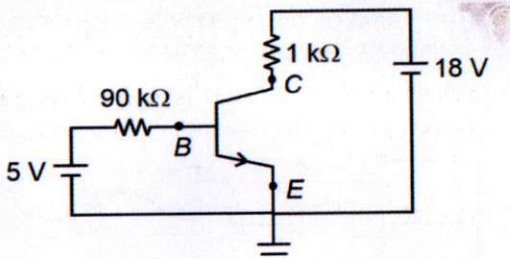


(1) I
(2) II
(3) III
(4) In both (I) and (III)

14. The input signal given to a CE amplifier having voltage gain 100 is $V_i = (20\text{ mV})\cos\left(10t + \frac{\pi}{6}\right)$. The corresponding output signal will be [NCERT Pg. 449]

(1) $(2\text{ V})\cos\left(10t + \frac{\pi}{6}\right)$
(2) $(2\text{ V})\cos\left(10t - \frac{\pi}{6}\right)$
(3) $(2\text{ V})\cos\left(10t + \frac{7\pi}{6}\right)$
(4) $(2000\text{ V})\cos\left(10t + \frac{2\pi}{3}\right)$

15. A common emitter amplifier is shown in the figure. If β = 200 and V_{BE} = 0.5 V, then value of I_C and V_{CE} respectively will be [NCERT Pg. 499]



(1) (10 mA, 10 V) (2) (10 mA, 8 V)
(3) (5 mA, 8 V) (4) (10 mA, 18 V)

16. Which of the following relations is/are correct? (Symbols have their usual meaning) [NCERT Pg. 499]

(1) $A_V = \beta \frac{R_{out}}{R_{in}}$ (2) $A_P = \beta^2 \frac{R_{out}}{R_{in}}$
(3) $\beta = \frac{\alpha}{1-\alpha}$ (4) All of these

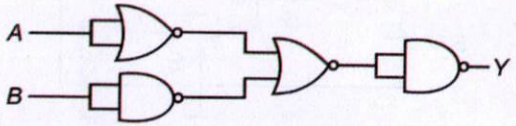
17. A transistor with CE configuration can be realized as [NCERT Pg. 502]

(1) NOT gate
(2) AND gate
(3) OR gate
(4) NOR gate

18. A p-n photodiode is fabricated from a semiconductor with band gap of 2.0 eV. The maximum wavelength of a incident radiation that can be detected is [NCERT Pg. 487]

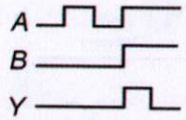
(1) 7200 Å
(2) 6200 Å
(3) 6200 nm
(4) 7200 nm

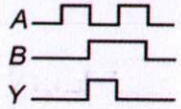
19. The name of logic gate represented by the following symbol is [NCERT Pg. 511]

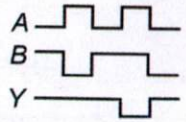


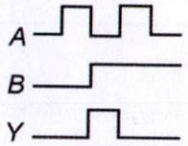
(1) NOR (2) OR
(3) AND (4) NAND

20. If A and B are inputs to a NAND gate and Y is output, then choose the correct option. [NCERT Pg. 504]

(1) 

(2) 

(3) 

(4) 

Thinking in Context

1. For semiconductor, band gap energy is _____ than 3 eV. [NCERT Pg. 471]
2. At 0 K, semiconductors behave like an _____. [NCERT Pg. 474]
3. Doped semiconductor (p-type or n-type) is electrically _____. [NCERT Pg. 476]
4. Electron and hole concentrations at thermal equilibrium are related as _____. [NCERT Pg. 477]
5. The movement of electrons or holes due to concentration gradient is known as _____. [NCERT Pg. 478]
6. For V-I characteristics of p-n junction dipole, forward current is measured in _____ and reverse current is measured in _____. [NCERT Pg. 481]
7. The dynamic resistance for p-n junction diode is defined as r_d = _____. [NCERT Pg. 482]
8. Zener diode is used as _____. [NCERT Pg. 486]
9. _____ are used to detect the optical signals. [NCERT Pg. 487]
10. LED converts the _____ energy into _____ energy. [NCERT Pg. 488]
11. The magnitude of photocurrent in photodiode, depends on the _____ of incident light. [NCERT Pg. 487]
12. I-V characteristics of solar cell lies in _____ quadrant of co-ordinate system. [NCERT Pg. 489]
13. Colour of LED light depends on the _____ of semiconductor material. [NCERT Pg. 488]
14. The colour of light emitted from diode made by the material $Ga\,As_{0.6}\,P_{0.4}$ is _____ [NCERT Pg. 488]
15. When both junctions of transistor are reverse biased then transistor operates in _____ mode and works as _____. [NCERT Pg. 510]
16. In a p-n junction Si diode, the diode current is expressed as _____. [NCERT Pg. 511]
17. The criteria for stable oscillations to be sustained as $A\beta = 1$, is called _____. [NCERT Pg. 509]
18. NAND or NOR gates are also called as _____ gates [NCERT Pg. 504]
19. In CE amplifier output voltage and input voltage are _____ phase. [NCERT Pg. 499]
20. Two amplifiers each having voltage gain 10 are connected in series (cascaded), then overall voltage gain of the amplifier is _____. [NCERT Pg. 510]

❑ ❑ ❑

ANSWERS

Class XI

Chapter-1 : Physical World

Sharpen Your Understanding

1. (4)
2. (3)
3. (1)
4. (2)
5. (4)
6. (1)
7. (3)
8. (4)
9. (2)
10. (3)

Thinking in Context

1. Terrestrial
2. Energy
3. Momentum
4. Electrons
5. Nuclear
6. Cyclotron
7. Angular momentum
8. Same
9. Four
10. Weak nuclear

Chapter-2 : Units and Measurements

Sharpen Your Understanding

1. (1)
2. (3)
3. (3)
4. (4)
5. (4)
6. (1)
7. (2)
8. (1)
9. (3)
10. (2)
11. (1)
12. (4)
13. (4)
14. (1)
15. (3)
16. (4)
17. (3)
18. (1)
19. (1)
20. (2)

Thinking in Context

1. 1.745×10^{-2}
2. 5.82×10^{-4}
3. Derived
4. [caesium – 133]
5. Parallax
6. Earth orbit, one arc second
7. 10^{-15}
8. $\pm 1 \times 10^{-13}$
9. Smallest
10. Absolute error
11. Relative errors
12. Precision
13. Number
14. Addition or subtraction
15. Powers or exponents
16. Significant
17. Multiplication or division
18. 3
19. 6.6×10^{-27}
20. 3.7×10^{-3}

Chapter-3 : Motion in a Straight Line

Sharpen Your Understanding

1. (2)
2. (3)
3. (4)
4. (4)
5. (3)
6. (2)
7. (1)
8. (4)
9. (2)
10. (4)
11. (2)
12. (3)
13. (2)
14. (3)
15. (1)
16. (1)
17. (2)
18. (4)
19. (1)
20. (4)

Thinking in Context

1. Straight line
2. Kinematics
3. Frame of reference
4. Magnitude, direction
5. May or may not be
6. Less
7. Average velocity, infinitesimally
8. Average velocity
9. Speed, Direction, Both
10. Displacement
11. Continuous
12. Uniform acceleration
13. Instantaneous
14. Slope of line
15. On
16. Constant
17. Parallel
18. Uniform acceleration
19. Increasing, Decreasing
20. Acceleration

Chapter-4 : Motion in a Plane

Sharpen Your Understanding

1. (3)
2. (2)
3. (1)
4. (3)
5. (3)
6. (1)
7. (2)
8. (2)
9. (4)
10. (1)
11. (2)
12. (2)
13. (3)
14. (4)
15. (2)
16. (3)
17. (1)
18. (4)
19. (3)
20. (2)

Thinking in Context

1. Magnitude
2. Same, Different
3. Free vectors
4. Opposite
5. Commutative, Associative
6. Zero vector or null vector
7. Unit, dimension and unit
8. One
9. Average acceleration
10. 0° and 180°
11. 0° or 180°
12. One dimensional
13. Vector
14. Vector difference
15. Constant
16. Remains constant, continuous change
17. Continuous change
18. Constant speed
19. Acceleration
20. Radius

Chapter-5 : Laws of Motion

Sharpen Your Understanding

1. (4)
2. (3)
3. (1)
4. (2)
5. (1)
6. (3)
7. (2)
8. (1)
9. (2)
10. (3)
11. (3)
12. (1)
13. (4)
14. (1)
15. (2)
16. (2)
17. (3)
18. (2)
19. (1)
20. (1)

Thinking in Context

1. Rest
2. Motion
3. Backward
4. Momentum
5. Change in momentum
6. Directly, Direction
7. Time, Impulse
8. Internal
9. mg
10. Different
11. Conserved
12. Zero
13. Impending
14. Independent
15. Component
16. Friction
17. Independent
18. $\sqrt{\frac{Rg(\mu_s + \tan\theta)}{(1-\mu_s \tan\theta)}}$
19. $[MLT^{-1}]$
20. Less

Chapter-6 : Work, Energy and Power

Sharpen Your Understanding

1. (2)
2. (2)
3. (3)
4. (1)
5. (1)
6. (3)
7. (4)
8. (2)
9. (3)
10. (1)
11. (2)
12. (3)
13. (2)
14. (1)
15. (1)
16. (3)
17. (3)
18. (1)
19. (2)
20. (3)

Thinking in Context

1. Component of force
2. 3.6×10^6
3. Kinetic
4. Work done
5. Second law
6. Position
7. Conservative
8. ML^2T^{-2}, joule (J)
9. Zero
10. Conservative
11. Gravity and tension in string
12. Positive
13. Kinetic, Potential
14. Friction
15. Heat
16. Linear momentum, Total kinetic energy
17. Completely inelastic
18. Inelastic
19. Maximum
20. Right angles

Chapter-7 : System of Particles and Rotational Motion

Sharpen Your Understanding

1. (3)
2. (2)
3. (4)
4. (4)
5. (3)
6. (2)
7. (2)
8. (4)
9. (1)
10. (3)
11. (4)
12. (2)
13. (1)
14. (1)
15. (1)
16. (3)
17. (3)
18. (2)
19. (3)
20. (3)

Thinking in Context

1. Centroid
2. Their geometric centre
3. Remains constant
4. Axis of rotation
5. Moment of force, torque
6. External torque
7. Couple
8. Torque
9. Uniform gravity
10. Radius of Gyration
11. Rotational kinetic
12. Angular velocity
13. Conservation of angular momentum
14. Rolling
15. Shape of body
16. Ring
17. (a) Total external force is zero $(\Sigma F_i = 0)$
    (b) Total external torque is zero $(\Sigma \tau_i = \Sigma \vec{r}_i \times \vec{F}_i = 0)$
18. $R\omega$
19. Right hand rule
20. Zero

Chapter-8 : Gravitation

Sharpen Your Understanding

1. (3)
2. (2)
3. (1)
4. (1)
5. (1)
6. (2)
7. (4)
8. (1)
9. (3)
10. (2)
11. (1)
12. (4)
13. (2)
14. (1)
15. (1)
16. (2)
17. (4)
18. (2)
19. (4)
20. (4)

Thinking in Context

1. Elliptical
2. Angular momentum
3. $\frac{Gm_1m_2}{d^2}$
4. Attractive
5. Inside it
6. 6.67×10^{-11} Nm²/kg²
7. $\frac{4}{3}\pi G\rho R_e$
8. $g\left(1-\frac{2h}{R_e}\right)$
9. $\left(1-\frac{d}{R_e}\right)$
10. Zero
11. $\frac{-Gm_1m_2}{r}$
12. $v_e = \sqrt{2}v_0$
13. 84.6 min
14. $\left[\frac{4\pi^2}{GM_e}\right]$
15. Constant
16. 500-800 km
17. Geostationary
18. Free fall
19. Telecommunication
20. 100 minutes

Chapter-9 : Mechanical Properties of Solids

Sharpen Your Understanding

1. (4)
2. (1)
3. (4)
4. (3)
5. (1)
6. (1)
7. (3)
8. (3)
9. (1)
10. (3)
11. (1)
12. (3)
13. (1)
14. (2)
15. (1)
16. (1)
17. (2)
18. (1)
19. (2)
20. (2)

Thinking in Context

1. Restoring force
2. Elastomers
3. Elastic
4. Bulk
5. Strain
6. Brittle
7. Elastic
8. 0.28 and 0.30
9. $\frac{1}{B}$
10. $\frac{Y\sigma^2}{2}$
11. Less
12. Gases
13. Less
14. –3
15. Larger
16. *F*
17. False
18. Solids
19. 4F
20. Ductile

Chapter-10 : Mechanical Properties of Fluids

Sharpen Your Understanding

1. (2)
2. (2)
3. (3)
4. (2)
5. (4)
6. (3)
7. (4)
8. (2)
9. (4)
10. (1)
11. (1)
12. (2)
13. (2)
14. (4)
15. (4)
16. (2)
17. (4)
18. (1)
19. (4)
20. (2)

Thinking in Context

1. Million
2. Normal
3. Gauge pressure
4. Low
5. Undiminished, equally
6. Remains constant
7. Conservation of mass
8. Low
9. Different magnitude, parallel
10. Kinetic energy change, potential energy change
11. Backward thrust
12. Flow speed
13. Pressure, external pressure
14. Magnus effect
15. Strain rate
16. 0°C and 37°C
17. Rapidly, Randomly
18. Mass, energy
19. More
20. Shearing stress, strain rate

Chapter-11 : Thermal Properties of Matter

Sharpen Your Understanding

1. (3)
2. (2)
3. (2)
4. (4)
5. (1)
6. (1)
7. (2)
8. (4)
9. (1)
10. (1)
11. (4)
12. (3)
13. (4)
14. (3)
15. (4)
16. (2)
17. (3)
18. (4)
19. (2)
20. (3)

Thinking in Context

1. Temperature
2. Temperature difference
3. 180, 100
4. Straight line
5. Pressure
6. High
7. More
8. Decreases, decreases
9. 1.2×10^{-4}
10. Two
11. True
12. False
13. High
14. Boiling point
15. Triple point
16. Increased
17. True
18. Forced convection
19. True
20. Wien's displacement

Chapter-12 : Thermodynamics

Sharpen Your Understanding

1. (3)
2. (4)
3. (3)
4. (1)
5. (1)
6. (2)
7. (3)
8. (3)
9. (3)
10. (2)
11. (4)
12. (3)
13. (4)
14. (4)
15. (1)
16. (1)
17. (4)
18. (3)
19. (2)
20. (1)

Thinking in Context

1. Macroscopic
2. Zeroth
3. Temperature
4. State variable
5. Heat and work
6. Conservation of energy
7. ΔQ and ΔW (Heat and work)
8. Equation of state
9. Extensive, Intensive, Extensive, Intensive
10. Isothermal
11. On the, released
12. Isochoric process
13. Heat, work
14. Infinite
15. Kelvin Planck
16. Irreversible
17. Process
18. Less
19. $\frac{T_2}{T_1}$
20. Efficiency

Chapter-13 : Kinetic Theory

Sharpen Your Understanding

1. (1) 2. (2)
3. (4) 4. (4)
5. (3) 6. (2)
7. (3) 8. (2)
9. (4) 10. (3)
11. (2) 12. (1)
13. (1) 14. (4)
15. (1) 16. (1)
17. (1) 18. (1)
19. (4) 20. (2)

Thinking in Context

1. Decreases
2. Falls
3. Increase
4. $\sqrt{3}$ times
5. Increases
6. Avogadro
7. Ideal gas
8. Dalton's law
9. Absolute temperature
10. Temperature, volume, pressure
11. Square root of their masses
12. Translational
13. $\frac{1}{2}K_BT$, of equipartition of energy
14. 3 RT
15. Number density, diameter
16. Less
17. Process
18. Temperature, pressure
19. Elastic
20. K_BT

Chapter-14 : Oscillations

Sharpen Your Understanding

1. (2) 2. (3)
3. (4) 4. (4)
5. (4) 6. (3)
7. (1) 8. (1)
9. (2) 10. (2)
11. (4) 12. (1)
13. (1) 14. (1)
15. (2) 16. (4)
17. (2) 18. (1)
19. (2) 20. (2)

Thinking in Context

1. Opposite
2. Four
3. $\pi/2$
4. $\frac{1}{6}$ m
5. $\frac{1}{\sqrt{2}}$
6. More
7. Zero
8. Periodic and simple harmonic
9. Resonance
10. Damped
11. Negative of displacement
12. Mean position
13. Straight line
14. Remains same
15. Periodic
16. 84.6 min = 1.4 hour
17. Simple Harmonic motion
18. 3 N
19. $\frac{T}{6}$
20. Potential, Kinetic

Chapter-15 : Waves

Sharpen Your Understanding

1. (4)
2. (2)
3. (3)
4. (3)
5. (3)
6. (2)
7. (3)
8. (4)
9. (2)
10. (2)
11. (3)
12. (1)
13. (1)
14. (4)
15. (4)
16. (4)
17. (1)
18. (2)
19. (3)
20. (1)

Thinking in Context

1. Energy, Matter
2. Shearing
3. Fundamental
4. Elastic properties
5. 180°
6. Algebraic sum
7. Twice
8. Pressure
9. Number of waves
10. Same phase
11. Phase
12. Displacement
13. Slightly different
14. Longitudinal, transverse
15. Phases
16. Phase, Amplitudes
17. Opposite
18. Refracted
19. Same
20. Antinodes

❑ ❑ ❑

ANSWERS

Class XII

Chapter-1 : Electric Charges and Fields

Sharpen Your Understanding

1. (2) 2. (2)
3. (3) 4. (1)
5. (2) 6. (4)
7. (4) 8. (4)
9. (4) 10. (4)
11. (4) 12. (1)
13. (4) 14. (4)
15. (3) 16. (2)
17. (3) 18. (3)
19. (2) 20. (4)

Thinking in Context

1. Outer
2. Losing, gaining
3. Gold-leaf electroscope
4. Charging by induction
5. Quantisation
6. $C^2 N^{-1} m^{-2}$
7. Third law
8. 1.3×10^{36}
9. Principle of superposition
10. True
11. True
12. Zero, $\frac{1}{r^3}$
13. Total charge enclosed by the surface.
14. Both inside and outside
15. Hyperbola
16. Independent of
17. Zero, Center
18. True
19. True
20. True

Chapter-2 : Electrostatic Potential and Capacitance

Sharpen Your Understanding

1. (4) 2. (4)
3. (2) 4. (4)
5. (2) 6. (4)
7. (2) 8. (4)
9. (2) 10. (4)
11. (1) 12. (4)
13. (4) 14. (1)
15. (2) 16. (4)
17. (2) 18. (3)
19. (3) 20. (3)

Thinking in Context

1. True
2. Increases
3. x – z plane
4. 16 Capacitors
5. Electrostatic shielding
6. Less
7. True
8. True
9. Fringing of the field
10. Dielectric strength
11. Geometrical configuration (shape, size, separation)
12. Polarization
13. True
14. Decreases steepest, per unit displacement
15. Normal to
16. Zero, Non zero
17. True
18. Electrostatic potential
19. True
20. 3

Chapter-3 : Current Electricity

Sharpen Your Understanding

1. (2)
2. (4)
3. (2)
4. (3)
5. (4)
6. (2)
7. (3)
8. (4)
9. (3)
10. (4)
11. (4)
12. (1)
13. (1)
14. (2)
15. (2)
16. (4)
17. (3)
18. (2)
19. (2)
20. (3)

Thinking in Context

1. Dimensions
2. True
3. True
4. Zero
5. Relaxation time
6. False
7. Opposite
8. 2×10^2 m s^{-1}
9. 10^{-11}
10. False (drift velocities are superposed over random velocities)
11. True
12. $\left(\frac{m^2}{V\,s}\right)$
13. *p-n* junction diode
14. Ga As
15. $10^{-8}\ \Omega$ m to $10^{-6}\ \Omega$ m; $10^{-5}\ \Omega$ m to $10^{3}\ \Omega$ m
16. Temperature
17. No current is flowing through cell *i.e.* cell in open circuit
18. Kirchhoff's loop
19. An unknown resistance
20. Mid-point

Chapter-4 : Moving Charges and Magnetism

Sharpen Your Understanding

1. (3)
2. (2)
3. (1)
4. (2)
5. (4)
6. (4)
7. (2)
8. (1)
9. (1)
10. (1)
11. (2)
12. (4)
13. (3)
14. (4)
15. (2)
16. (1)
17. (4)
18. (4)
19. (4)
20. (3)

Thinking in Context

1. 3.6×10^{-5} T, 10^8 T
2. $I(\vec{l} \times \vec{B})$
3. $\frac{1}{v^2}$
4. Positive z-axis
5. Circular path, Zero
6. Velocity or energy
7. Opposite
8. Kinetic energy
9. $\frac{q^2B^2R^2}{2m}$
10. $Id\vec{l}$ (current element)
11. (+z axis)
12. Current, distance from wire
13. Right hand rule
14. Zero
15. Zero; uniform
16. Tokamak
17. Attract, repel
18. 2×10^{-7}
19. $[A][L]^2$, Am^2
20. Voltage

Chapter-5 : Magnetism and Matter

Sharpen Your Understanding

1. (4) 2. (2)
3. (4) 4. (2)
5. (4) 6. (3)
7. (2) 8. (2)
9. (1) 10. (4)
11. (3) 12. (3)
13. (3) 14. (2)
15. (3) 16. (1)
17. (4) 18. (2)
19. (4) 20. (4)

Thinking in Context

1. Magnesia
2. North-South
3. Closed
4. Monopoles
5. Zero
6. $1/\varepsilon_0$
7. North
8. Geographic meridian
9. Equator
10. Angle of dip
11. Net magnetic moment
12. Paramagnetic
13. Dielectric constant
14. Stronger, weaker
15. Zero
16. Weaker, stronger
17. Paramagnetic
18. 1
19. Permanent
20. Ferromagnetic

Chapter-6 : Electromagnetic Induction

Sharpen Your Understanding

1. (2) 2. (3)
3. (2) 4. (1)
5. (4) 6. (2)
7. (1) 8. (4)
9. (3) 10. (2)
11. (1) 12. (1)
13. (2) 14. (2)
15. (1) 16. (2)
17. (4) 18. (4)
19. (2) 20. (2)

Thinking in Context

1. Electric current
2. Weber (Wb or T m^2)
3. Magnetic flux
4. False
5. True
6. True
7. True
8. Energy
9. $\Delta Q = \frac{\Delta\phi_B}{R}$
10. Eddy currents
11. True
12. Non-magnetic
13. $ML^2T^{-2}A^{-2}$
14. Relative Orientation
15. Self-induction
16. Mass
17. $U_B = \frac{B^2}{2\mu_0} A\ell$
18. Mechanical, electrical
19. True
20. True

Chapter-7 : Alternating Current

Sharpen Your Understanding

1. (1)
2. (2)
3. (2)
4. (2)
5. (4)
6. (3)
7. (2)
8. (2)
9. (4)
10. (1)
11. (2)
12. (1)
13. (2)
14. (3)
15. (2)
16. (2)
17. (1)
18. (3)
19. (2)
20. (3)

Thinking in Context

1. Same phase
2. $I = \frac{V_0}{R} \sin \omega t$
3. $\frac{2i_0}{\pi}$
4. $\frac{1}{2}$
5. r.m.s.
6. Phasor
7. $I = \frac{\varepsilon_0}{\omega L} \sin\left(\omega t - \frac{\pi}{3}\right)$
8. Zero
9. Directly
10. $\varepsilon_0 \omega C$
11. Lags, $\frac{\pi}{2}$
12. $\sqrt{R^2 + (X_L - X_C)^2}$
13. $\tan^{-1}\left(\frac{X_L - X_C}{R}\right)$
14. $X_L = X_C$
15. Minimum
16. $Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC} = \frac{\omega_0}{BW}$
17. $I_{rms}^2 R$
18. Mass (m)
19. Less
20. Zero

Chapter-8 : Electromagnetic Waves

Sharpen Your Understanding

1. (4)
2. (4)
3. (4)
4. (1)
5. (2)
6. (4)
7. (4)
8. (3)
9. (2)
10. (3)
11. (3)
12. (4)
13. (2)
14. (1)
15. (3)
16. (2)
17. (3)
18. (3)
19. (2)
20. (4)

Thinking in Context

1. Light.
2. Displacement current.
3. True
4. $\varepsilon_0 \left(\frac{d\phi_E}{dt}\right)$.
5. Magnetic field, magnetic field.
6. True
7. Oscillation of charge, the accelerated charge.
8. Perpendicular.
9. $\frac{E_0}{c}$
10. Polarised.
11. $\frac{U}{c}$
12. Z-(direction).
13. 88 MHz to 108 MHz.
14. Special vacuum tubes.
15. Microwave ovens.
16. Infrared waves.
17. U.V. radiations.
18. U.V. radiations.
19. X-rays.
20. Gamma rays.

Chapter-9 : Ray Optics and Optical Instruments

Sharpen Your Understanding

1. (4)
2. (2)
3. (4)
4. (4)
5. (4)
6. (4)
7. (1)
8. (3)
9. (3)
10. (4)
11. (2)
12. (4)
13. (2)
14. (2)
15. (3)
16. (1)
17. (2)
18. (1)
19. (2)
20. (1)

Thinking of Content

1. Refraction
2. Refractive index
3. 24.4°
4. Mirage (Total internal reflection)
5. Parallel to principal axis
6. True
7. False (depends on refractive index of glass and surrounding)
8. True
9. True
10. Dispersion of light
11. True
12. True
13. True
14. Scattering of sunlight
15. Less
16. True
17. True
18. True
19. True
20. Hypermetropia (farsightedness)

Chapter-10 : Wave Optics

Sharpen Your Understanding

1. (4)
2. (4)
3. (3)
4. (3)
5. (1)
6. (4)
7. (4)
8. (1)
9. (4)
10. (3)
11. (1)
12. (3)
13. (1)
14. (2)
15. (1)
16. (3)
17. (3)
18. (4)
19. (4)
20. (1)

Thinking in Context

1. Geometrical
2. Phase
3. Spherical, point
4. Wavelength, red shift
5. Vector sum, each
6. Coherent
7. Hyperbola
8. Decrease
9. False
10. Equally
11. $\frac{\lambda}{a}$
12. High refractive index, object, objective lens.
13. Transverse, at right angles
14. Half
15. Maximum
16. First minima, central maxima
17. $a\sin\theta = n\lambda$
18. Resolve, to separate, closely spaced
19. $\frac{2\lambda}{a}$
20. Zero, integral multiple

Chapter-11 : Dual Nature of Radiation and Matter

Sharpen Your Understanding

1. (3)
2. (3)
3. (1)
4. (1)
5. (2)
6. (4)
7. (3)
8. (3)
9. (4)
10. (3)
11. (1)
12. (2)
13. (1)
14. (3)
15. (1)
16. (1)
17. (4)
18. (2)
19. (1)
20. (1)

Thinking in Context

1. Escape, work function
2. Frequency, material
3. Intensity
4. Different
5. Packet of energy
6. Number of photons
7. Threshold wavelength
8. $\frac{E}{c}, \frac{h}{\lambda}$
9. Equal to
10. Greater
11. $\sim 10^{-9}$ s or less
12. 1.6×10^{-19}
13. $\frac{h}{\sqrt{2mE}}$
14. Zero
15. 0.0286 Å
16. Electrons
17. Remains unchanged
18. $\frac{h}{e}$
19. Number of photons
20. 54 V, 50°

Chapter-12 : Atoms

Sharpen Your Understanding

1. (1)
2. (4)
3. (1)
4. (3)
5. (1)
6. (2)
7. (1)
8. (4)
9. (3)
10. (3)
11. (3)
12. (3)
13. (3)
14. (4)
15. (4)
16. (4)
17. (2)
18. (3)
19. (1)
20. (3)

Thinking in Context

1. $^{214}_{83}Bi$
2. Bright, dark
3. Larger
4. Ground
5. Uniformly
6. Less
7. More
8. Negative
9. Angular
10. Ultraviolet
11. Frequency
12. Accelerating
13. Photon, Difference
14. Single electron
15. NI, N^2I
16. Free
17. Blue-green
18. Electrodynamically
19. Decreases
20. First

Chapter-13 : Nuclei

Sharpen Your Understanding

1. (1)
2. (3)
3. (2)
4. (2)
5. (1)
6. (3)
7. (2)
8. (3)
9. (3)
10. (3)
11. (4)
12. (1)
13. (1)
14. (1)
15. (4)
16. (1)
17. (2)
18. (4)
19. (4)
20. (1)

Thinking in Context

1. 10^4
2. 99.9%
3. Isotopes
4. Nuclei
5. Unstable, 1000 s
6. Released
7. Short range
8. Saturation
9. Discrete
10. MeV
11. Release
12. Heavy
13. Million
14. Independent
15. 931.5 MeV
16. Mass, atomic
17. Water
18. Neutrons
19. Instability
20. Less than

Chapter-14 : Semiconductor Electronics : Material, Devices and Simple Circuits

Sharpen Your Understanding

1. (2)
2. (4)
3. (2)
4. (2)
5. (1)
6. (2)
7. (3)
8. (3)
9. (2)
10. (1)
11. (4)
12. (1)
13. (2)
14. (3)
15. (2)
16. (4)
17. (1)
18. (2)
19. (4)
20. (3)

Thinking in Context

1. Less
2. Insulator
3. Neutral
4. $n_e n_h = n_i^2$
5. Diffusion
6. mA, μA
7. $\frac{\Delta V}{\Delta I}$
8. Voltage Regulator
9. Photodiodes
10. Electrical, optical

11. Intensity

12. IVth

13. Band gap energy

14. Red

15. Cut-off, switch (off)

16. $I = I_0\left(e^{\frac{eV}{2k_BT}} - 1\right)$

17. Barkhausen Criteria

18. Universal

19. Out of

20. 100

❑ ❑ ❑