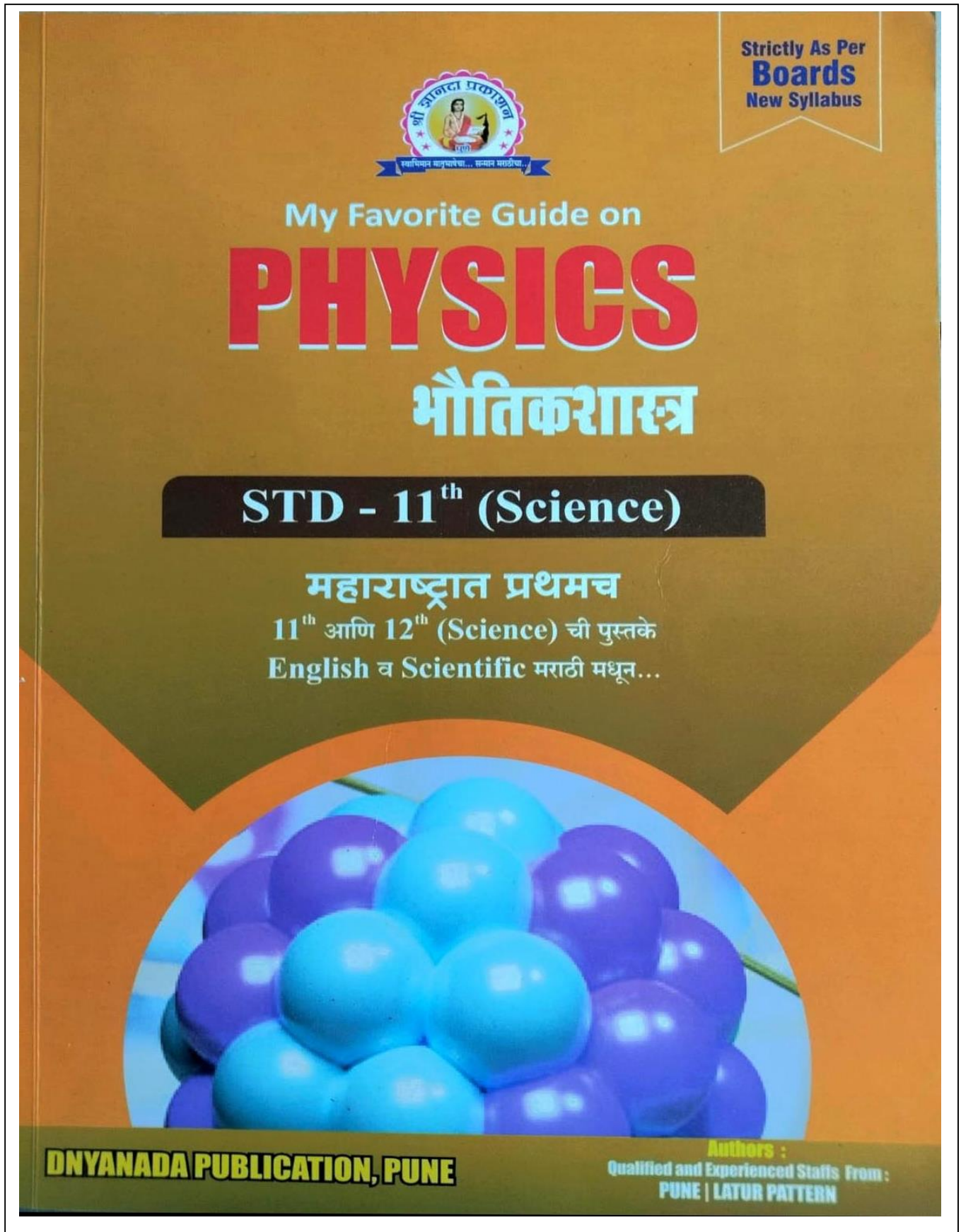




TOPIC - 01

UNITS AND MEASUREMENT

1.1. Introduction

Physics is the branch of science which deals with the study of nature and natural phenomena.

It is a quantitative science where various physical quantities are measured.

A quantity which can be measured and with the help of which, various physical happenings can be explained and expressed in the form of laws, is called a physical quantity.

Example: length, mass time force etc.

Q.1 What is the measurement?

Ans: Measurement: *A measurement is a comparison with internationally accepted standard measuring unit.*

1.2 System of Units

Q.2 Define a system of units? Explain different types of systems of units.

Ans: System of units: *"The whole set of units i.e. all the basics and derived units taken together forms a system of units."*

Systems of units are classified mainly into four types:

i) C.G.S. system:

This system is based on three fundamental units **Centimeter-Gram-Second**.

e.g. Unit of mass is 'gram'

Unit of length is 'centimeter'

Unit of time is 'second'

ii) M.K.S. system:

This system is based on three fundamental units **Meter-Kilogram-Second**. This system also called as **(SI) system International** and this is used all over world.

e.g. Unit of mass is 'kilogram'

Unit of length is 'meter'

Unit of time is 'second'

Unit of velocity is 'meter/second'

iii) F.P.S. system:

This system is based on three fundamental units **foot-pound-second**. In this system, length, mass and time are measured in foot, pound and second respectively. This is British system.

iv) S.I. system:

It stands for Standard International system. This system has replaced all other systems mentioned above. It has been internationally accepted and is being used all over world.

Q.3 List of conventions followed while using SI units.

Ans: Following conventions should be followed while writing S.I. units of physical quantities.

i) Unit of every physical quantity should be represented by its symbol

ii) Full name of a unit always starts with smaller letter even if it is named after a person, e.g. 1 newton, 1 joule etc. But symbol for unit named after a person should be in capital letter, e.g. N after scientist Newton, J after scientist Joule, etc.

iii) Symbols for units do not take plural form.

iv) Symbols for units do not contain any full stops at the end of recommended letter.

v) The units of physical quantities in numerator and denominator should be written as one ratio. For example the SI unit of acceleration is m/s^2 or m s^{-2} but not m/s/s .

vi) Use of combination of units and symbols for units is avoided when physical quantity is expressed by combination of two. For example. The unit J/kg K is correct while joule/kg K is not correct.

vii) A prefix symbol is used before the symbol of the unit.

1) Prefix symbol and symbol of unit constitute a new symbol for the unit which can be raised to a positive or negative power of 10.

For example,

$1 \text{ ms} = 1 \text{ millisecond} = 10^{-3} \text{ s}$

$1 \mu\text{s} = 1 \text{ microsecond} = 10^{-6} \text{ s}$

$1 \text{ ns} = 1 \text{ nanosecond} = 10^{-9} \text{ s}$

2) Use of double prefixes is avoided when single prefix is available

$10^{-6} \text{ s} = 1 \mu\text{s}$ and not 1 mms

$10^{-9} \text{ s} = 1 \text{ ns}$ and not 1 m μs

viii) Space or hyphen must be introduced while indicating multiplication of two units e.g. m/s should be written as m s^{-1} or m-s^{-1}

1.3 Measurement of Length

Q.4 Define a metre.

Ans: Metre: The metre is the length of the path travelled by light in vacuum during a time interval of $1/299,792,458$ of a second.

Q.5 What is parallax?

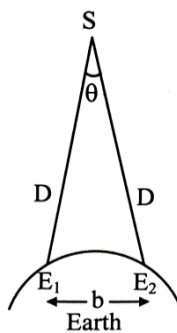
Ans: Parallax: Parallax is defined as the apparent change in position of an object due to a change in position of an observer.

When a pencil is held in front of our eyes and we look at it once with our left eye closed and then with our right eye closed, pencil appears to move against the background. This effect is called parallax effect.

Q.6 Explain the method of determine the distance of a planet from the Earth.

Ans: Method of determine the distance of a planet from the earth:

- Parallax method is used to determine distance of different planets from the Earth.
 - To measure the distance 'D' of a far distant planet S, select two different observations (E_1 and E_2).
 - The planet should be visible from E_1 and E_2 observatories simultaneously i.e. at the same time.
 - E_1 and E_2 are separated by distance 'b' as shown in figure.
- $\therefore E_1 E_2 = b$



- The angle between the two directions along which the planet is viewed, can be measured. It is parallax angle, which in this case is

$$\angle E_1 S E_2 = \theta$$

- The planet is far away from the (Earth) observers, hence

$$b \ll D$$

$$\therefore \frac{b}{D} \ll 1 \text{ and } \theta \text{ is also very small.}$$

Hence, $E_1 E_2$ can be considered as arc of length b of circle with S as centre and D as radius.

$$\therefore E_1 S = E_2 S = D$$

$$\therefore \theta = \frac{b}{D} \quad \text{----- } (\theta \text{ is taken in radian})$$

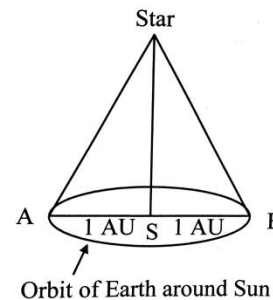
$$\therefore D = \frac{b}{\theta}$$

Thus, the distance 'D' of a far away planet 'S' can be determined using the parallax method.

Q.7 Explain how parallax method is used to measure distance of star from Earth.

Ans: Parallax method to measure distance of star from earth:

- The parallax measured from two farthest distance points on Earth for stars will be too small and hence cannot be measured.
- Instead, parallax between two farthest points (i.e., 2 AU apart) along the orbit of Earth around the Sun (s) is measured.



Q.8 Explain how size of a planet or star is measured.

Ans: Measurement of size of a planet or star:

- To determine the diameter (d) of planet or star, two diametrically opposite points of the planet are viewed from the same observatory.
 - If d is diameter of planet or star, angle subtended by it at any single point on the Earth is called angular diameter of planet.
 - Let angle α be angle between these two directions.
 - If distance between the Earth and planet or star (D) is known, $\alpha = \frac{d}{D}$
 - This relation gives, $d = \alpha D$
- Thus, diameter (d) of planet or star can be determined.

1.4 Measurement of Mass

Q.9 Explain the method to measure mass.

Ans: Method of measurement of mass:

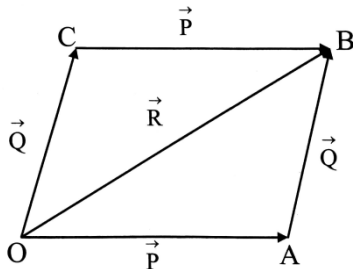
- Mass, until recently, was measured with a standard mass of the international prototype of the kilogram (a

Q.9 Prove that: Vector addition is commutative.**Ans: Commutative property of vector addition:**

According to commutative property, for two vectors $\vec{P}$ and $\vec{Q}$, $\vec{P} + \vec{Q} = \vec{Q} + \vec{P}$

Proof:

Let two vectors $\vec{P}$ and $\vec{Q}$ be represented in magnitude and direction by two sides $\vec{OA}$ and $\vec{OB}$ respectively.



Complete a parallelogram OACB such that $\vec{OA} = \vec{CB} = \vec{P}$ and $\vec{OB} = \vec{AC} = \vec{Q}$ then join OB.

In $\triangle OAB$, $\vec{OA} + \vec{AB} = \vec{OB}$
(By triangle law of vector addition)

$$\therefore \vec{P} + \vec{Q} = \vec{R} \quad \text{---- (1)}$$

In $\triangle OCB$, $\vec{OC} + \vec{CB} = \vec{OB}$
(By triangle law of vector addition)

$$\vec{Q} + \vec{P} = \vec{R} \quad \text{---- (2)}$$

From equation (1) and (2),

$$\vec{P} + \vec{Q} = \vec{Q} + \vec{P}$$

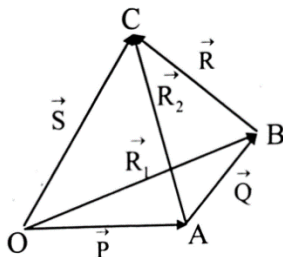
Hence, addition of two vectors obeys commutative law.

Q.10 Prove that: Vector addition is associative.**Ans: Associative property of vector addition:**

According to associative property,

For three vectors $\vec{P}$, $\vec{Q}$ and $\vec{R}$,

$$(\vec{P} + \vec{Q}) + \vec{R} = \vec{P} + (\vec{Q} + \vec{R})$$

**Proof:**

Let $\vec{OA} = \vec{P}$, $\vec{AB} = \vec{Q}$, $\vec{BC} = \vec{R}$

Join OB and AC

In $\triangle OAB$,

$\vec{OA} + \vec{AB} = \vec{OB}$ (From triangle law of vector addition)

$$\therefore \vec{P} + \vec{Q} = \vec{R}_1 \quad \text{---- (1)}$$

In $\triangle OBC$,

$\vec{OB} + \vec{BC} = \vec{OC}$ (From triangle law of vector addition)

$$\therefore \vec{R}_1 + \vec{R} = \vec{S}$$

From equation (1)

$$(\vec{P} + \vec{Q}) + \vec{R} = \vec{S} \quad \text{---- (2)}$$

In $\triangle ABC$,

$\vec{AB} + \vec{BC} = \vec{AC}$

$$\therefore \vec{Q} + \vec{R} = \vec{R}_2 \quad \text{---- (3)}$$

In $\triangle OAC$,

$\vec{OA} + \vec{AC} = \vec{OC}$

$$\therefore \vec{P} + \vec{R}_2 = \vec{S}$$

From equation (3)

$$\vec{P} + (\vec{Q} + \vec{R}) = \vec{S} \quad \text{----- (4)}$$

On comparing equation (2) and (4), we get,

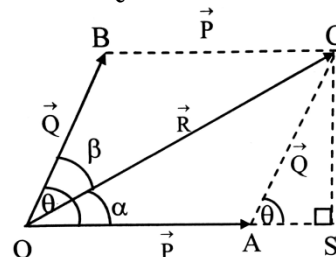
$$(\vec{P} + \vec{Q}) + \vec{R} = \vec{P} + (\vec{Q} + \vec{R})$$

Hence, associative law proved.

Q.11 State and prove parallelogram law of vector addition and determine magnitude and direction of resultant vector.**Ans: Parallelogram law of vector addition:**

If two vectors of same type starting from the same point (tails at the same point), are represented in magnitude and direction by the two adjacent sides of a parallelogram then, their resultant vector is given in magnitude and direction, by the diagonal of the parallelogram starting from the same point.

Proof: i) Consider two vectors $\vec{P}$ and $\vec{Q}$ of the same type, with their tails at the point 'O' and ' θ ' is the angle between $\vec{P}$ and $\vec{Q}$ as shown in the figure below.



Scientific मराठी स्पष्टीकरण:

Introduction (प्रस्तावना):

आपल्या दैनंदिन जीवनामध्ये measurements (मोजमापाला) अत्यंत महत्त्व आहे, मोजमापाविषयी आपले व्यवहारच पूर्ण होऊ शकत नाहीत. Physics (भौतिकशास्त्र) ही विज्ञानाची एक प्रमुख branch (शाखा) असून, त्यामध्ये खूप गोष्टींचा अत्यंत शास्त्रीय पद्धतीने अभ्यास केला जातो, त्यासाठी मोजमाप गरजेचे आहे.

Physics हे परिणात्मक विज्ञान असल्याने पावलोपावली Physical quantity (भौतिक राशी) चे अचूक मापन करणे जरूरीचे असते, बऱ्याच वेळा प्रयोगाद्वारे मिळालेल्या व सिध्दांताद्वारे अपेक्षित असलेल्या मापनाच्या मुल्यातील तफावतीमुळे नवीन सिध्दांत व सूत्रे विकास पावतात.

Introduction: Physics ही Science ची अशी branch आहे कि, ज्यामध्ये या सृष्टीतील सर्व materials चे अचूक व तंतोतंत description (वर्णन) केले जाते.

भौतिकशास्त्रामध्ये निसर्गात घडणाऱ्या निरनिराळ्या गोष्टींचा अभ्यास केला जातो.

उदा: आकाशाचा रंग निळाच का असतो? Rainbow (इंद्रधनुष्य) का दिसते? जहाज जड असून सुद्धा पाण्यावर का तरंगते? या प्रश्नांची उत्तरे Physics मध्ये मिळतात.

Physical quantity (भौतिक राशी) मोजमाप करण्यायोग्य राशींना भौतिक राशी असे म्हणतात. वरील प्रश्नामध्ये दिलेल्या सुत्रानुसार Physical quantity शोधता येतात. उदा: वस्तुमान, लांबी, वेळ इ.

Need of measurements (मापनपद्धतीची गरज):

i) भौतिक शास्त्रामध्ये कोणत्याही Phenomenon (घटनेचा) अभ्यास करून मापन करण्यासाठी शास्त्रज्ञ वेगवेगळे experiments (प्रयोग) करतात.

ii) या experiment मध्ये mass, length, time व volume यासारख्या Physical quantities चे मोजमाप करावे लागते.

iii) या प्रयोगाद्वारे मिळालेल्या observations (निरीक्षणावरून) नवीन सिध्दांत व सूत्रे निर्माण होतात.

iv) Experimental verification साठी वेगवेगळ्या theories (सिध्दांत) मांडले जातात.

v) कोणत्याही Physical quantity च्या accurate measurements साठी appropriate (नेमक्या) instruments (उपकरणांची) गरज असते

Unit of physical quantity (भौतिक राशीचे एकक) कोणत्याही Physical quantity (भौतिक राशीच्या) मापनासाठी एक reference standard (संदर्भमानकाची) आवश्यकता असते. त्याला Unit असे म्हणतात.

Characteristics of good units (एका चांगल्या एककाचे गुणधर्म):

i) Unit हे सहजरीत्या मिळणारे असावे.

ii) Unit हे वेळ व स्थान यानुसार Invariable (न बदलणारे) असावे.

iii) Unit हे Reproducible (पुनरुत्पादीय) असावे, त्याचे duplication करता येणारे नसावे.

iv) Unit हे universally (वैश्विकरीत्या) सर्वांनी स्वीकारलेले असावे.

v) Unit हे मोजलेल्या, Physical quantity ला सुसंगत असावे.

vi) Unit हे सहजपणे त्याच्या वेगवेगळ्या forms मध्ये मांडता येणारे असावे.

System of units (एकक पद्धती): Basic units/ fundamental (मुलभूत एकके) व Derived (व्युत्पन्न एकके) यांच्या whole set (एकत्रित गटाला) system of units असे म्हणतात.

System of units चे प्रामुख्याने चार प्रकारात वर्गीकरण करतात.

i) CGS System (Centimeter-Gram-Second) (सेंटीमीटर-ग्रॅम-सेकंद): यामध्ये Length (लांबी) साठी सेंटीमीटर, mass (वस्तुमान) साठी ग्रॅम व second (वेळ) साठी सेकंद वापरतात.

ii) MKS System (Meter-Kilogram-Second) (मीटर-किलोग्रॅम-सेकंद): यामध्ये Length (लांबी) साठी मीटर, mass (वस्तुमान) साठी किलोग्रॅम व second (वेळ), साठी सेकंद वापरतात तसेच velocity साठी मीटर/ सेकंद वापरतात.

iii) FPS System (Foot- Pound-Second) (फुट-पाउंड-सेकंद): यामध्ये length (लांबी) साठी फुट, mass (वस्तुमान) साठी पाउंड व second (वेळ) साठी सेकंद वापरतात.

iv) SI System: या System ला system of International units असे म्हणतात. सध्या वरील सर्व Systems च्या ऐवजी SI System ही सर्वत्र वापरली जाते. या System ला International (आंतरराष्ट्रीय) मान्यता असून ति संपूर्ण जगामध्ये वापरली जाते.

SI System of units :

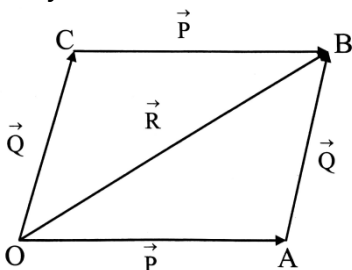
i) एकक पद्धतीमधील Different systems मुळे जगातील वेगवेगळ्या भागांमध्ये शास्त्रीय माहितीच्या देवाण-घेवाण मध्ये खूप अडचणी येत होत्या.

ii) या गैरसोयीमुळे संपूर्ण जगामध्ये एकचा Common system of units विकसित होणे गरजेचे होते.

iii) October १९६० मध्ये पॅरीस येथे International General Conference of weights and measures (वजने व मापे यांच्या आंतरराष्ट्रीय सर्वसाधारण परिषदेमध्ये) Systems Internationale d units अशा नावाची सामाईक एकक पद्धती अवलंबण्यात आली.

iv) SI system मध्ये प्रामुख्याने सात Fundamental units (मुलभूत एकके), दोन Supplementary (संपूरक एकके) व अनेक derived units (व्युत्पन्न एकके) यांचा समावेश करण्यात आला.

v) सध्याच्या काळामध्ये SI system ने इतर सर्व एकक पद्धतीची जागा घेतली असून, या system द्वारे जगातील वेगवेगळ्या भागातील

Q.9 Prove that: Vector addition is commutative.**Ans: Commutative property of vector addition:**According to commutative property, for two vectors $\vec{P}$ and $\vec{Q}$, $\vec{P} + \vec{Q} = \vec{Q} + \vec{P}$ **Proof:**Let two vectors $\vec{P}$ and $\vec{Q}$ be represented in magnitude and direction by two sides $\vec{OA}$ and $\vec{OB}$ respectively.Complete a parallelogram OACB such that $\vec{OA} = \vec{CB} = \vec{P}$ and $\vec{OB} = \vec{AC} = \vec{Q}$ then join OB.In $\triangle OAB$, $\vec{OA} + \vec{AB} = \vec{OB}$

(By triangle law of vector addition)

$$\therefore \vec{P} + \vec{Q} = \vec{R} \quad \text{---- (1)}$$

In $\triangle OCB$, $\vec{OC} + \vec{CB} = \vec{OB}$

(By triangle law of vector addition)

$$\vec{Q} + \vec{P} = \vec{R} \quad \text{---- (2)}$$

From equation (1) and (2),

$$\vec{P} + \vec{Q} = \vec{Q} + \vec{P}$$

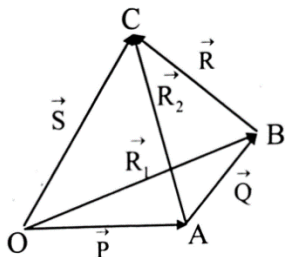
Hence, addition of two vectors obeys commutative law.

Q.10 Prove that: Vector addition is associative.**Ans: Associative property of vector addition:**

According to associative property,

For three vectors $\vec{P}$, $\vec{Q}$ and $\vec{R}$,

$$(\vec{P} + \vec{Q}) + \vec{R} = \vec{P} + (\vec{Q} + \vec{R})$$

**Proof:**Let $\vec{OA} = \vec{P}$, $\vec{AB} = \vec{Q}$, $\vec{BC} = \vec{R}$

Join OB and AC

In $\triangle OAB$, $\vec{OA} + \vec{AB} = \vec{OB}$ (From triangle law of vector addition)

$$\therefore \vec{P} + \vec{Q} = \vec{R}_1 \quad \text{---- (1)}$$

In $\triangle OBC$, $\vec{OB} + \vec{BC} = \vec{OC}$ (From triangle law of vector addition)

$$\therefore \vec{R}_1 + \vec{R} = \vec{S}$$

From equation (1)

$$(\vec{P} + \vec{Q}) + \vec{R} = \vec{S} \quad \text{---- (2)}$$

In $\triangle ABC$, $\vec{AB} + \vec{BC} = \vec{AC}$

$$\therefore \vec{Q} + \vec{R} = \vec{R}_2 \quad \text{---- (3)}$$

In $\triangle OAC$, $\vec{OA} + \vec{AC} = \vec{OC}$

$$\therefore \vec{P} + \vec{R}_2 = \vec{S}$$

From equation (3)

$$\vec{P} + (\vec{Q} + \vec{R}) = \vec{S} \quad \text{----- (4)}$$

On comparing equation (2) and (4), we get,

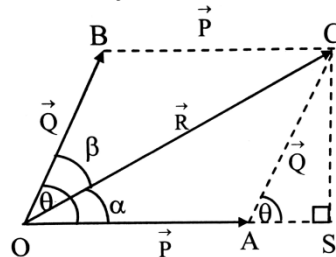
$$(\vec{P} + \vec{Q}) + \vec{R} = \vec{P} + (\vec{Q} + \vec{R})$$

Hence, associative law proved.

Q.11 State and prove parallelogram law of vector addition and determine magnitude and direction of resultant vector.**Ans: Parallelogram law of vector addition:**

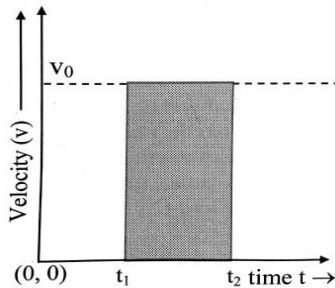
If two vectors of same type starting from the same point (tails at the same point), are represented in magnitude and direction by the two adjacent sides of a parallelogram then, their resultant vector is given in magnitude and direction, by the diagonal of the parallelogram starting from the same point.

Proof: i) Consider two vectors $\vec{P}$ and $\vec{Q}$ of the same type, with their tails at the point 'O' and ' θ ' is the angle between $\vec{P}$ and $\vec{Q}$ as shown in the figure below.

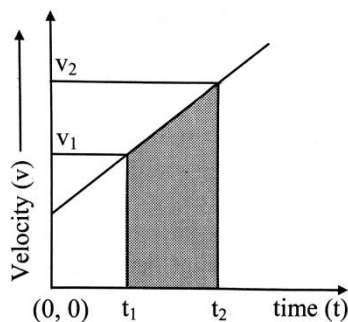


Q.14 Explain the velocity-time graphs of an object moving with zero acceleration.**Ans: Object is moving with zero acceleration:**

- i) As the acceleration is zero, the graph will be a straight line parallel to time axis.
- ii) Velocity of the particle is constant as the acceleration is zero.
- iii) Magnitude of displacement of object from t_1 to $t_2 = v_0 \times (t_2 - t_1) =$ shaded area under velocity-time graph.

**Q.15 Explain the velocity-time graph of an object moving with constant positive acceleration.****Ans: Object is moving with constant positive acceleration:**

- i) The velocity-time graph is linear.
- ii) Velocity increases with increase in time, as acceleration is positive (along the direction of velocity).
- iii) The area under the velocity-time graph between two instants of time t_1 and t_2 gives the displacement of the object during that time interval.
- iv) Slope of the graph is $\frac{\Delta v}{\Delta t} =$ positive acceleration.

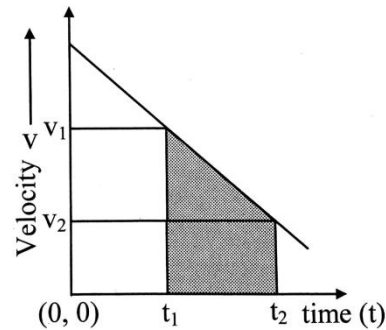
**Q.16 Explain the velocity-time graph of an object moving with constant negative acceleration.****Ans: Object is moving with constant negative acceleration:**

- i) The velocity-time graph is linear.

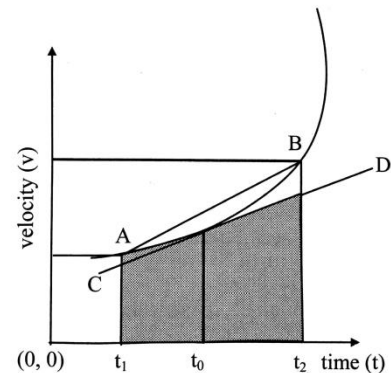
ii) Velocity decreases with increase in time, as acceleration is negative (opposite to the direction of velocities).

iii) The area under the velocity-time graph between two instants of time t_1 and t_2 gives the displacement of the object during that time interval.

iv) Slope of the graph is $\frac{\Delta v}{\Delta t} =$ negative acceleration.

**Q.17 Explain the velocity-time graph of an object moving with non-uniform acceleration.****Ans: Object is moving with non-uniform acceleration:**

- i) Velocity-time graph is non-linear.
 - ii) The area under the velocity-time graph between two instants of time t_1 and t_2 gives the displacement of the object during that time interval.
- area under the velocity-time curve =
- $$\text{Area} = \int_{t_1}^{t_2} v \, dt = \int_{t_1}^{t_2} \frac{dx}{dt} \, dt = \int_{t_1}^{t_2} dx = x(t_2) - x(t_1)$$
- = displacement of the object from t_1 to t_2 .



iii) हा force, electromagnetic force (विद्युत चुंबकीय बल) व strong nuclear force (प्रबळ अणुकेंद्रीय बलापेक्षा) खुपच weaker (निर्बल) असतात.

iv) या forces, ची range (कार्यक्षेत्र) खुपच कमी अंतरांपर्यंतचे असते. nucleus च्या size मध्ये 10^{-14} m पर्यंत ही forces, effective (प्रबळ) असतात.

i) Conservative force (अक्षय बल/संरक्षी बल)-एखाद्या वस्तुने त्याच्या closed path (बंद मार्गामध्ये) फिरत असताना केलेले work done (कार्य) हे जर zero असेल, तर त्या force ला conservative force असे म्हणतात.

उदा- gravitational force (गुरुत्वाकर्षणीय बल)

ii) Non-conservative force (असंरक्षी बल): एखाद्या वस्तुने त्याच्या closed path मध्ये फिरत असताना केलेले work done (कार्य) हे जर non-zero असेल, तर त्या force ला non-conservative force असे म्हणतात.

उदा. Frictional force (घर्षणीय बल)

Work energy (कार्य शक्तीचा सिद्धांत/तत्व)- एखाद्या force (बलामुळे) एखाद्या पदार्थाचे displacement (विस्थापन) झाले तर त्या force ने केलेले workdone (कार्य) हे त्या पदार्थाच्या kinetic energy (गतिज उर्जेच्या) बदलाएवढे असते. म्हणजेच (ज्यावेळी एखाद्या force कडून work done होते, तेव्हा त्या पदार्थाची kinetic energy वाढते, याउलट जर opposite दिशेने force लावल्यास kinetic energy कमी होते व kinetic energy मधील loss हा opposite force ने केलेल्या work done इतकी असते, अशाप्रकारे झालेले work व kinetic energy ही समकक्ष असतात).

प्रश्नामध्ये m वस्तुमान असलेल्या पदार्थाची initial velocity (सुरुवातीची गती) u व final velocity (अखेरची गती) v आहे, त्यावर लावलेल्या force F असून त्या पदार्थाने t या वेळेत आक्रमिलेले displacement s आहे, या सर्व notations वरून work done चे derivation प्रश्नामध्ये व्यवस्थित दिले आहे, त्याचा study करून सर्व लक्षात ठेवा.

Law of conservation of momentum (संवेगाच्या अक्षय्यतेचा नियम): जेव्हा colliding bodies / interacting bodies (एकमेकांवर धडकणा-या वस्तू) वरचा resultant external force (एकत्रीत / परिणामी बाह्य बल) हा zero असेल, तर त्यांच्यातील एकूण linear momentum साठवून ठेवले जाते किंवा त्यांचे संरक्षण होते.

प्रश्नामध्ये collision (संघात / धडक / टक्कर) होण्यापुर्वी, collision होताना व collision झाल्यानंतर सर्व equations दिली आहेत, त्याचा व्यवस्थित अभ्यास करा. शेवटी मिळालेला formula/result योग्य आहे का ते पहा. म्हणजेच collision पुर्वीचा संवेग व collision

नंतरचा संवेग समान असतो, यालाच अक्षय्यतेचा नियम असे म्हणतात.

Elastic collision (प्रत्यास्थ संघात)- ज्या collision मध्ये एकूण linear momentum (एकरेषिय संवेग) व kinetic energy (गतिज उर्जा) ही सतत साठवून ठेवली जाते, त्याला elastic collision (प्रत्यास्थ संघात/धडक) असे म्हणतात.

Elastic collision मध्ये दोन महत्वाच्या conditions आहेत.

i) Total linear momentum before collision (आघातापुर्वीचा एकूण संवेग) हा आघातानंतरच्या एकूण संवेगाएवढा असतो.

ii) Total kinetic energy before collision (आघातापुर्वीची गतिज उर्जा) ही आघातानंतरच्या गतिज उर्जे एवढी असते.

स्पष्टिकरण- यामध्ये m_1 व m_2 एवढे वस्तुमान असलेल्या दोन bodies चे collision figure मध्ये दाखवले आहे. u_1 व u_2 या collision पुर्वीच्या velocities व v_1 व v_2 ह्या collision झाल्यानंतरच्या velocities आहेत. यानंतरचे momentum before collision व after collision याची equations प्रश्नामध्ये व्यवस्थित दिली आहेत, त्याचा व्यवस्थित study करा.

Inelastic collision (अप्रत्यस्थ संघात): एखाद्या पदार्थाच्या/वस्तुच्या collision (आघात/टक्कर) मध्ये linear momentum (संवेग) conserved (अक्षय्यता/साठवणुक) होत असेल, मात्र kinetic energy (गतिज उर्जा) conserve होत नसेल, तर त्या collision ला Inelastic collision असे म्हणतात. यामध्ये दोन महत्वाच्या conditions आहेत.

i) Collision पुर्वीचे total momentum (एकूण संवेग) हा collision नंतरच्या total momentum इतका असतो .

ii) Collision पुर्वीची kinetic energy ही collision नंतरच्या kinetic energy एवढी नसते.

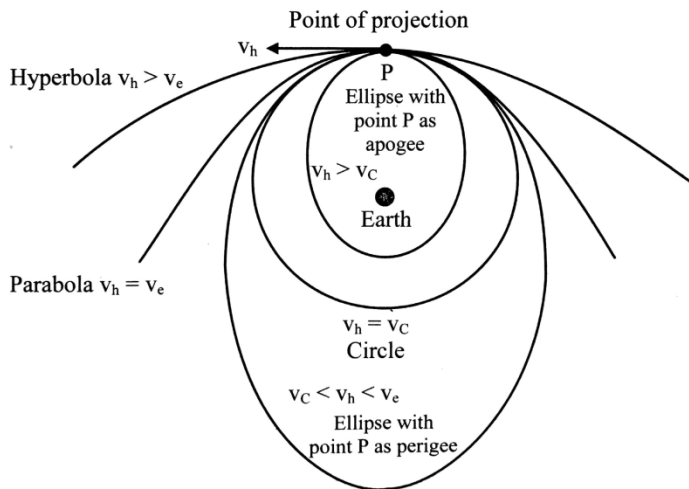
वरिल प्रश्नामध्ये inelastic collision वरिल सर्व equations व formula दिली आहेत, त्याचा व्यवस्थित अवलोकन करा.

Perfectly inelastic collision- ज्या collision मध्ये collision झाल्यावर दोन्ही bodies एकमेकांना चिकटतात किंवा एक होतात, व common (एकसमान) velocity ने पुढे जातात किंवा त्यांची गती थांबते, या collision ला perfectly inelastic collision असे म्हणतात.

उदा: meteorite (उल्काचे) पृथ्वीवर पडणे, त्या तेथेच पडून राहतात, lump of mud (चिखलाचा गोळा) भिंतीवर जोराने आपटल्यास तो भिंतीला चिकटून राहतो, कारण त्याच्या kinetic energy चा त्या टिकाणी पुर्ण नाश होतो.

Q.42 Draw a well labelled diagram to show different trajectories depending upon the tangential projection speed.

Ans:



Q.43 Why an astronaut in an orbiting satellite have a feeling of weightlessness?

Ans: i) For an astronaut in a satellite, the net force towards the centre of the Earth will always be, $F = mg - N$.

where, N is the normal reaction.

ii) In the case of a revolving satellite, the satellite is performing a circular motion. The acceleration for this motion is centripetal, which is provided by the gravitational acceleration g at the location of the satellite.

iii) In this case, the downward acceleration, $a_d = g$, or the satellite (along with the astronaut) is in the state of free fall.

iv) Thus, the net force acting on astronaut will be, $F = mg - ma_d = 0$ i.e., the apparent weight will be zero, giving the feeling of total weightlessness

Q.44 Define time period of a satellite.

Obtain an expression for the period of a satellite in a circular orbit round the Earth. Show that the square of the period of revolution of a satellite is directly proportional to the cube of the orbital radius.

Ans: Time period of satellite: *The time taken by a satellite to complete one revolution around the earth is called its time period.*

Expression for time period:

i) Consider, m = mass of satellite, h = altitude of satellite.

Thus, $r = R + h$ = radius of orbit of the satellite.

ii) In one revolution, distance traced by satellite is equal to circumference of its circular orbit.

iii) If T is the period of satellite, then

$$\text{Critical speed} = \frac{\text{Circumference of the orbit}}{\text{Time period}}$$

$$\therefore v_c = \frac{2\pi r}{T} \quad \dots\dots (1)$$

$$\text{But, } v_c = \sqrt{\frac{GM}{r}} \quad \dots\dots (2)$$

Substituting equation (2) in (1),

$$\sqrt{\frac{GM}{r}} = \frac{2\pi r}{T} \quad \dots\dots (3)$$

Squaring both sides of equation (3),

$$\frac{GM}{r} = \frac{4\pi^2 r^2}{T^2}$$

$$\therefore T^2 = \frac{4\pi^2 r^3}{GM} \quad \dots\dots (4)$$

Since π^2 , G and M are constant,

$$\therefore T^2 \propto r^3$$

Hence, square of the period of revolution of a satellite is directly proportional to the cube of the radius of its orbit.

Taking square roots on both the sides of equation (4) we get,

$$T = 2\pi \sqrt{\frac{r^3}{GM}}$$

$$\therefore T = 2\pi \sqrt{\frac{(R+h)^3}{GM}}$$

This is the required expression for period of satellite orbiting around the Earth in circular path.

Q.24 Define compressibility. State its unit and dimensions.

Ans: Compressibility: The reciprocal of bulk modulus of elasticity is called compressibility of the material.

$$\text{Compressibility} = \frac{1}{\text{Bulk modulus}}$$

i) Compressibility is the fractional decrease in volume, $(-dV/V)$ per unit increase in pressure.

$$\text{Compressibility} = \frac{-dV}{VdP}$$

ii) **Unit:** m^2/N or Pa^{-1} in SI system.

iii) **Dimensions:** $[L^1 M^{-1} T^2]$

Q.25 What is modulus of rigidity? Derive an expression for it.

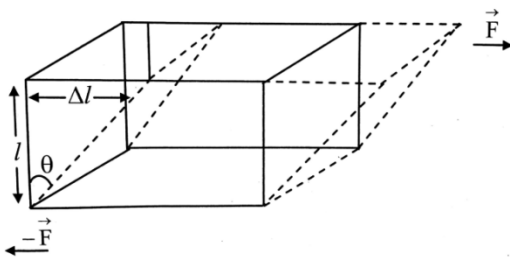
Ans: Modulus of rigidity: It is defined as the ratio of shear stress to shear strain within elastic limit. It is denoted by (η) .

Unit: N/m^2 or Pa in SI system.

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

Expression for modulus of rigidity:

Consider a solid cube as shown in the figure.



Let, F = Tangential force

A = Cross sectional area

Δl = Relative displaced length

l = Original length

θ = Shear strain

The forces applied on the block is subjected to a shear stress,

$$\text{Shearing stress} = F/A$$

The corner angle which changes by a small amount θ (expressed in radian) is given by,

$$\text{Shearing strain} = \frac{\Delta l}{l} \approx \theta$$

From definition,

$$\therefore \text{Modulus of rigidity} = \frac{\text{Shearing stress}}{\text{Shearing strain}}$$

$$= \frac{F/A}{\theta} = \frac{F}{A\theta}$$

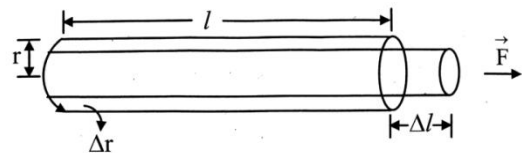
Q.26 Distinguish between Young's modulus, bulk modulus and modulus of rigidity.

Ans: Young's modulus, bulk modulus and modulus of rigidity:

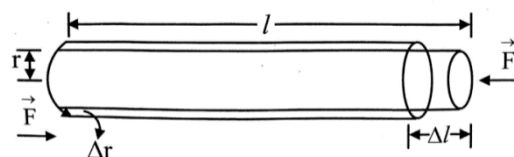
No	Young's modulus	Bulk modulus	Modulus of rigidity
i	It is ratio of longitudinal stress to longitudinal strain.	It is ratio of volume stress to volume strain.	It is the ratio of shearing stress to shearing strain.
ii	It is given by, $Y = \frac{MgL}{\pi r^2 l}$	It is given by, $K = \frac{Vdp}{dV}$	It is given by, $\eta = \frac{F}{A\theta}$
iii	It exists in solids.	It exists in solid, liquid and gases.	It exists in solids.
iv	It relates to change in length of a body.	It relates to change in volume of a body.	It relates to change in shape of a body.

Q.27 Explain the change of diameter of a wire when it is stretched and compressed.

Ans: i) When a wire is fixed at one end and a force is applied at its free end so that the wire gets stretched, length of the wire increases and at the same time, its diameter decreases, i.e., the wire becomes longer and thinner as shown in figure.



ii) If equal and opposite forces are applied to an object along its length inwards, the object gets compressed. There is a decrease in dimensions along its length and at the same time there is an increase in its dimensions perpendicular to its length. When length of the wire decreases, its diameter increases.



Thermometer चे प्रामुख्याने तीन प्रकार पडतात,

i) **Liquid-in-glass thermometer**- हा thermometer, glass मधील liquid चे volume (आकारमानाच्या) बदलानुसार कार्य करतो.

ii) **Constant volume of gas thermometer**: हा thermometer, volume स्थिर असताना pressure मधील बदलानुसार temperature चे variation देतो.

iii) **Resistance thermometer**- हा thermometer, electric resistance (विद्युत रोध) च्या बदलावरून temperature मधील variation दर्शवितो.

Triple point of water (पाण्याचा त्रिक बिंदु)-ज्या unique (अनन्य) temperature व pressure मध्ये Water हे solid, liquid व gases या तिन्ही अवस्थांत, एकाच वेळी equilibrium (संतुलितपणे) राहू शकते, तो बिंदु म्हणजेच triple point of water होय.

Physical significance (भौतिक महत्व)-

i) पाण्याच्या triple point (त्रिक बिंदुवर) त्याचा pressure ४.५८ mm of Hg व त्याचे Temperature हे २७३.१६ K म्हणजेच ०.०१ °C एवढे असते.

ii) Triple point चे महत्व म्हणजेच या point वर एक unique (अनन्य/अद्वितीय) अवस्था दिसून येते, यावरून आपल्याला absolute temperature (निरपेक्ष तापमान) ठरविता येते.

iii) त्यामुळे Kelvin Scale (केल्विन श्रेणी) किंवा absolute scale (निरपेक्ष श्रेणी) यावरून पाण्याचा triple point हा upper fixed point म्हणून व absolute zero हा lower fixed point म्हणून मानले जातात.

Charles law (चार्ल्सचा नियम): Constant pressure (दाब स्थिर) असताना, दिलेल्या वस्तुमानाच्या gas चे volume (आकारमान) हे त्याच्या absolute temperature (निरपेक्ष तापमानाच्या) समप्रमाणात असते.

म्हणजेच $V \propto T$, $v = K.T$ यामध्ये K हा constant (स्थिरांक) असतो. यानंतर gas ची वेगवेगळी volume व त्यांचे समप्रमाणातील temperature वरून तयार झालेल्या formula (सुत्र), प्रश्नामध्ये दिले आहे. ते लक्षात ठेवा.

Boyles law (बॉईलसचा नियम)-Temperature (तापमान) स्थिर असताना दिलेल्या वस्तुमानाच्या वायुचे volume (आकारमान) हे pressure (दाबाच्या) व्यस्त प्रमाणात असतो. म्हणजेच $V \propto \frac{1}{P}$ यानंतरचे सर्व simplification प्रश्नामध्ये दिले आहे.

Boyles law हा दुस-या प्रकारे असा मांडता येतो कि, दिलेल्या वस्तुमानाच्या gas चा pressure (P) व त्याचे volume (V) यांचा गुणाकार हा constant temperature (स्थिर तापमानाला) constant (स्थिर) असतो.

म्हणजेच, $PV = k = \text{constant}$

Ideal gas equation (आदर्श वायुचा नियम)- ज्या expression (समिकरणावरून) pressure (दाब), volume (आकारमान) व temperature (तापमान) यांचे एकत्रित relation दिले जाते, त्या equation ला Ideal gas equation म्हणतात.

Ideal gas equation हे Boyles law, Charles law व ह्या दोन laws नुसार एकत्रित equation प्रश्नामध्ये दिले आहे तसेच त्याचे simplification व्यवस्थित दिले आहे, त्याचे अवलोकन करा.

Thermal expansion (औष्णिक प्रसरण): कोणत्याही matter (वस्तुची) अशी tendency (प्रवृत्ती) कि, त्यामध्ये त्या matter च्या temperature बरोबर volume (आकारमान) वाढते.

उदा. Solid पदार्थ गरम केल्यानंतर expand (प्रसरण) पावतात व cooling केल्यावर contract (आकुंचन) पावतात.

ii) **Linear expansion of solids (स्थायु / घनाचे रेखीय प्रसरण)**: घन पदार्थ heat (गरम) केल्यानंतर त्याच्या length (लांबी मध्ये) वाढ होते, त्याला linear expansion of solids असे म्हणतात.

Coefficient of linear expansion (रेखीय प्रसरणाचा गुणांक):

घन पदार्थाचा coefficient of linear expansion of solids म्हणजेच ०°C तापमानाला असणा-या original length (मुळ एकक लांबीमध्ये) per degree rise in temperature (प्रति अंश तापमानाच्या) वाढीमुळे होणारी increase in length (लांबीमध्ये) झालेली वाढ होय. हा गुणांक (α) या अक्षराने दाखवितात, याचे unit °C⁻¹ किंवा K⁻¹ (प्रति अंश सें. किंवा प्रति अंश केल्विन) आहे. त्याच्या dimensions प्रश्नामध्ये दिले आहे.

Areal / Superficial expression (क्षेत्रीय प्रसरण): जेव्हा एखादी metal plate (धातूची तबकडी) heat (गरम) केल्यानंतर, त्याचा surface area (क्षेत्रफळ) वाढते याला areal expansion (क्षेत्रीय प्रसरण) असे म्हणतात.

जर A_0 = Metal plate चे सुरुवातीचे area (क्षेत्रफळ)

A_1 = Metal plate चे शेवटचे (गरम केल्यानंतरचे) क्षेत्रफळ

∴ क्षेत्रफळामध्ये झालेली वाढ = $A_1 - A_0$

Coefficient of superficial (areal) expansion of solid (घन पदार्थाच्या क्षेत्रीय प्रसरणाचा गुणांक)- घन पदार्थाचा coefficient of areal expansion (क्षेत्रीय प्रसरणाचा गुणांक) म्हणजे ०°C तापमानाला असणा-या original surface area (मुळ एकक क्षेत्रफळात), per degree rise in temperature (प्रति अंश

Solved and Unsolved Examples:

Ex.01) A bar magnet of magnetic moment 5.0Am^2 has the poles 20cm apart. Calculate the pole strength.

Solution: Given: $m = 5.0\text{ Am}^2$, $2l = 20\text{ cm} = 0.20\text{ m}$

Pole strength (q_m) = ?

We have, Formula: $q_m = \frac{m}{2l}$

$$q_m = \frac{5.0}{0.20} = 25\text{ Am}$$

Ans: The pole strength of the bar magnet is **25 Am**.

Ex.02) A bar magnet of magnetic moment 3.6 Am^2 and pole strength 10.8 Am . Determine its magnetic length and geometric length.

Solution: $m = 3.6\text{ Am}^2$, $q_m = 10.8\text{ Am}$

i) Magnetic length = ?

ii) Geometric length = ?

We have, Formula: i) Magnetic length = $\frac{m}{q_m}$

ii) Geometric length = $\frac{6}{5} \times$ magnetic length

$$\text{Magnetic length} = \frac{3.6}{10.8} = 0.33\text{ m}$$

From formula,

$$\text{Geometric length} = \frac{6}{5} \times 0.33$$

$$= 0.36\text{m} \approx 0.4\text{ m}$$

Ans: i) The magnetic length of the bar magnet is **0.33 m**

ii) The geometric length of the bar magnet is **0.4 m**.

Ex.03) A short magnetic dipole has magnetic moment 0.5 A m^2 . Calculate its magnetic field at a distance of 20 cm from the centre of magnetic dipole on

i) The axis

ii) The equatorial line

(Given $\mu_0 = 4\pi \times 10^{-7}\text{ SI units}$)

Solution: Given: $m = 0.5\text{Am}^2$, $r = 20\text{ cm} = 20 \times 10^{-2}\text{ m}$

i) Magnetic field on the axial point (B_a) = ?

ii) Magnetic field on the equatorial point (B_{eq}) = ?

We have, Formula: $B_a = \frac{\mu_0}{4\pi} \frac{2m}{r^3}$

$$B_a = 10^{-7} \times \frac{2 \times 0.5}{(0.2)^3}$$

$$= \frac{10^{-7}}{8 \times 10^{-3}}$$

$$= 1.25 \times 10^{-4}$$

$$\therefore B_a = 1.25 \times 10^{-5}\text{ Wb/m}^2$$

Again, we have, $B_a = 2B_{eq}$

$$\therefore B_{eq} = \frac{B_a}{2}$$

$$= \frac{1.25 \times 10^{-5}}{2}$$

$$= 0.625 \times 10^{-5}\text{ Wb/m}^2$$

Ex.04) A magnetic pole of bar magnet with pole strength of 100 A m is 20 cm away from the centre of a bar magnet. Bar magnet has pole strength of 200 A m and has a length 5 cm . If the magnetic pole is on the axis of the bar magnet, find the force on the magnetic pole.

Solution: Given that $(q_m)_1 = 200\text{ Am}$ and $(2l) = 5\text{cm} = 5 \times 10^{-2}\text{m}$

$$\therefore m = 200 \times 5 \times 10^{-2} = 10\text{ Am}^2$$

For a bar magnet, magnetic dipole moment is, $m = q_m(2l)$

For a point on the axis of a bar magnet at distance, $r = 20\text{cm}$

$$= 0.2\text{m},$$

$$B_a = \frac{\mu_0}{4\pi} \times \frac{2m}{r^3}$$

$$= 10^{-7} \times \frac{2 \times 10}{(0.2)^3}$$

$$= 0.25 \times 10^{-3}$$

$$= 2.5 \times 10^{-4}\text{Wb/m}^2$$

The force acting on the pole will be given by, $F = q_mB_a$

$$= 100 \times 2.5 \times 10^{-4} = 2.5 \times 10^{-2}\text{N}$$

Ex.05) Earth's magnetic field at the equator is approximately $4 \times 10^{-5}\text{T}$. Calculate Earth's dipole moment. (Radius of Earth = $6.4 \times 10^6\text{m}$, $\mu_0 = 4\pi \times 10^{-7}\text{ SI}$)

Solution: Consider earth's magnetic field as due to a bar magnet at the centre of earth, held along the polar axis of earth.

$$\therefore B_{eq} = \frac{\mu_0}{4\pi} \frac{2m}{R^3} \quad \dots\dots\dots (\text{where, } R = \text{radius of earth})$$

$$\therefore m = \frac{B_{eq} \times R^3}{\mu_0/4\pi}$$

We have,

$$B_{eq} = 4 \times 10^{-5}\text{T}$$

$$r = 6.4 \times 10^6\text{m}$$

Earth's dipole can be written as

$$= \frac{4 \times 10^{-5} \times (6.4 \times 10^6)^3}{10^{-7}}$$

$$= 4 \times (6.4)^3 \times 10^{20}$$

$$= 1048 \times 10^{20}$$

$$\therefore M = 1.048 \times 10^{23} \text{ Am}^2$$

Ans: Earth's dipole moment at equator is $1.048 \times 10^{23} \text{ Am}^2$.

Ex.06) A magnet makes an angle of 45° with the horizontal in a plane making an angle of 30° with the magnetic meridian. Find the true value of the dip angle at the place.

Solution: Let true value of dip ϕ . When the magnet is kept 45° aligned with declination 30° , the horizontal component of Earth's magnetic field.

$B'_H = B_H \cos 30^\circ$ Whereas, vertical component remains unchanged.

$\therefore$ For apparent dip of 45° ,

$$\tan 45^\circ = \frac{B'_V}{B'_H} = \frac{B_V}{B_H \cos 30^\circ} = \frac{B_V}{B_H} \times \frac{1}{\cos 30^\circ}$$

But, real value of dip is,

$$\tan \phi = \frac{B_V}{B_H}$$

$$\tan 45^\circ = \frac{\tan \phi}{\cos 30^\circ}$$

$$\tan \phi = \tan 45^\circ \times \cos 30^\circ$$

$$= 1 \times \frac{\sqrt{3}}{2}$$

$$\therefore \phi = \tan^{-1}(0.866)$$

Ans: The true value of angle of dip is $\tan^{-1}(0.866)$.

Multiple Choice Questions

1) Let r be the distance of a point on the axis of a bar magnet from its center. The magnetic field at r is always proportional to

- a) $1/r^2$ b) $1/r^3$
c) $1/r$ d) not necessarily $1/r^3$ at all points

2) Magnetic meridian is the plane

- a) perpendicular to the magnetic axis of Earth
b) perpendicular to geographic axis of Earth
c) passing through the magnetic axis of Earth
d) passing through the geographic axis

3) The horizontal and vertical component of magnetic field of Earth are same at some place on the surface of Earth. The magnetic dip angle at this place will be

- a) 30° b) 45° c) 0° d) 90°

4) Inside a bar magnet, the magnetic field lines

- a) are not present
b) are parallel to the cross sectional area of the magnet
c) are in the direction from N pole to S pole
d) are in the direction from S pole to N pole

5) A place where the vertical components of Earth's magnetic field is zero has the angle of dip equal to

- a) 0° b) 45° c) 60° d) 90°

6) A place where the horizontal component of Earth's magnetic field is zero lies at

- a) geographic equator
b) geomagnetic equator
c) one of the geographic poles
d) one of the geomagnetic poles

7) A magnetic needle kept nonparallel to the magnetic field in a nonuniform magnetic field experiences

- a) a force but not a torque
b) a torque but not a force
c) both a force and a torque
d) neither force nor a torque

8) Magnetic field lines

- a) do not intersect each other.
b) intersect each other at 45° .
c) intersect each other at 90° .
d) intersect each other at 60° .

9) The points A and B are situated perpendicular to the axis of 2 cm long bar magnet at large distances x

Friction (घर्षण): जेव्हा दोन bodies (वस्तु) एकमेकांच्या contact मध्ये असतात, म्हणजेच त्यांचे surface (पृष्ठभाग) एकमेकांवर घासत असतील, तर त्यांच्या एकमेकांवर घासण्याने त्यांच्यामधील relative motion ला एक प्रकारचा विरोध निर्माण होतो, असा oppose (विरोध) करण्याच्या property (गुणधर्माला) Friction (घर्षण) असे म्हणतात.

Force of Friction (घर्षणबल): एकमेकांच्या सानिध्यात असलेल्या contacting surfaces मध्ये एकमेकांच्या relative motion (गतिता) विरोध करणारा tangential force (स्पर्श रेणीय बलाला) Force Of friction असे म्हणतात.

Causes (घर्षण बल निर्माण होण्याची कारणे):

- दोन surfaces च्या मध्ये contact point (स्पर्श बिंदू) च्या ठिकाणी, त्या surfaces मधील atomic or molecular of force attraction (अणु-रेणू मधील) आकर्षण बलामुळे घर्षण होते.
- Contacting surface च्या पृष्ठभागावरील irregularities (खडबडीतपणा/अनियमितता किंवा उंचसखलपणा) यामुळे त्यांच्यामध्ये interlocking (अंतःपाश्चित) होते व त्यामुळे घर्षण होते.

Origin of friction (घर्षणाचा उगम / घर्षणजन्य बलाचे मुळ व त्याचे स्वरूप):

- Moving body (हलणा-या वस्तुचा) पृष्ठभाग आपल्याला डोळ्यांनी पाहिले, तर Smooth (गुळगुळीत) भासतो, परंतु त्या Surface वर असंख्य hills व dales (टेकड्या व खडे) असतात, हे आपल्याला microscopes (सुक्ष्मदर्शकाखाली) व्यवस्थित निदर्शनात येते.
- अशा प्रकारचे दोन surfaces (पृष्ठभाग), एकमेकांच्या contact मध्ये आले, तर एका surface चे elevations (चढ) हा दुस-या surface च्या depressions मध्ये interlock (अंतः पाश्चित) होतात.
- जेव्हा या दोन surfaces ची एकमेकांवर relative motion होते, त्यावेळी या surfaces चे एकमेकांमध्ये झालेले interlocking त्या motion ला oppose (विरोध) करते, या opposition ला force of friction (घर्षणजन्यबल) म्हणतात.
- Modern theory नुसार Point of contact (स्पर्श बिंदुचे) molecules (रेणू) एकमेकांवर force of attraction (आकर्षण बल) कार्यप्रवणित करतात.
- यामुळे contacting surface मध्ये त्यांच्यातील relative motion ला opposition होते, यातुनच friction (घर्षण/ घर्षण बल) याचा उगम होतो.

Friction घडण्याची मुख्य दोन कारणे पुढीलप्रमाणे आहेत.

- Contact surface च्या पृष्ठभागावरील irregularities (उंचसखलपणा) मधील interlocking.
- दोन surface मधील Intermolecular forces of attraction (आंतर-रेणू आकर्षण बले)

Static friction (स्थितीक घर्षण): दोन bodies च्या contact मध्ये असलेले असे friction कि, ज्या मध्ये एक body, दुस-या body च्या surface वर move होण्याचा कल करित असेल, तर त्या friction ला static friction असे म्हणतात.

First Law of Static Function (स्थितीक घर्षणाचा पहिला नियम):

दोन Surfaces एकमेकांच्या Contact मध्ये असतील तर Limiting Force of Static Friction (स्थितीक घर्षणाचे सिमाकारी बल) (F_s) हे वस्तूमधील, Normal Reaction (N) (लंब प्रतिक्रिया) यांच्याशी समप्रमाणात असते.

$$\text{म्हणजेच } F_s \propto N = F_s = \mu_s N$$

या ठिकाणी μ_s = coefficient of static friction (स्थितीक घर्षणाचा गुणांक) आहे.

Second Law of Static Friction (स्थितीक घर्षणाचा दुसरा नियम):

Limiting Force of Static Friction हे दोन पृष्ठभागांमधील परस्पराना स्पर्श होणा-या area (क्षेत्रावर) अवलंबून नसते.

Third Law of Friction (घर्षणाचा तिसरा नियम):

Limiting Force of Static Friction (स्थितीक घर्षणाचे सीमाकारी बल) हे परस्पराना स्पर्श होणा-या Nature (पृष्ठभागांच्या नैसर्गिक स्वरूपावर) व materials (पृष्ठभागांच्या पदार्थावर) अवलंबून असते.

Limiting Force Of Static Friction (स्थितीक घर्षणाचे

सीमाकारीबल): जेव्हा एखादी Body दुस-या Body च्या Surface वरती just begins to slide (घसरण्यास नुकतीच सुरुवात करतात) त्यावेळी त्या Sliding ला (सुरुवातीच्या Sliding ला) oppose करणारा Frictional Force हा Maximum असतो, त्याच Frictional Force ला Limiting Force Of Static Friction असे म्हणतात.

Kinetic friction (गतिज घर्षण): दोन bodies मधील असे friction कि, ज्यामध्ये एक body, दुस-या body वर slide (घासत) असेल, तर त्या Friction ला kinetic Friction असे म्हणतात.

Law Of Kinetic Friction (गतिज घर्षणाचे नियम):

i) First Law (पहिला नियम): Force Of Kinetic Friction (गतिज घर्षणाचे बल) हे Surface in Contact (परस्पराना स्पर्श करणा-या) पृष्ठभागांमधील Normal Reaction (लंब प्रतिक्रियेशी) समानुपाती असते.

$$\text{म्हणजेच, } F_k \propto N = F_k = \mu_k N$$

याठिकाणी

F_k = Kinetic Force Of Friction (गतिज घर्षणाचे बल)

N = Normal Reaction (लंब प्रतिक्रिया)

11.1 Introduction

The valence electrons become de-localized when large number of atoms come together in a metal. These electrons become conduction electrons or free electrons constituting an electric current when a potential difference is applied across the conductor.

11.2 Electric current

Q.1 Define current. State its formula and SI unit.

Ans: Current: Current is defined as the rate of flow of electric charge.

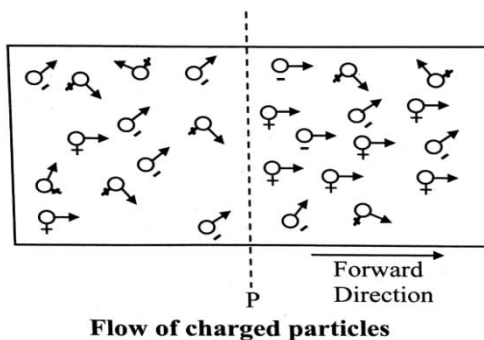
$$\text{Formula: } I = \frac{q}{t}$$

SI unit: ampere (A)

Q.2 Derive an expression for a current generated due to flow of charged particles across a plane.

Ans: Expression for a current generated due to flow of charged particles across a plane:

i) Consider an imaginary gas of both negatively and positively charged particles moving randomly in various directions across a plane P.



ii) In a time interval t , let the amount of positive charge flowing in the forward direction be q^+ and the amount of negative charge flowing in the forward direction be q^- . Thus, the net charge flowing in the forward direction is $q = q^+ - q^-$

iii) Let I be the current varying with time. Let Δq be the amount of net charge flowing across the plane P from time t to $(t + \Delta t)$, i.e. during the time interval Δt .

iv) Then the current is given by

$$I(t) = \lim_{\Delta t \rightarrow 0} \frac{\Delta q}{\Delta t}$$

Here, the current is expressed as the limit of the ratio $(\Delta q / \Delta t)$ as Δt tends to zero.

11.3 Flow of current through a conductor

Q.3 Explain flow of current in different conductor.

Ans: Flow of current in different conductor:

- A current can be generated by positively or negatively charged particles.
- In an electrolyte, both positively and negatively charged particles take part in the conduction.
- In a metal, the free electrons are responsible for conduction. These electrons flow and generate a net current under the action of an applied electric field.
- As long as a steady field exists, the electrons continue to flow in the form of a steady current.
- Such steady electric fields are generated by cells and batteries.

Q.4 State the sign convention used to show the flow of electric current in a circuit.

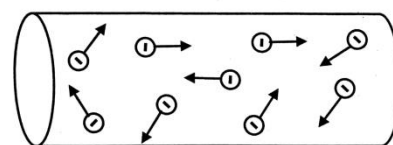
Ans: The direction of the current in a circuit is drawn in the direction in which positively charged particles would move, even if the current is constituted by the negatively charged particles, (electrons), which move in the direction opposite to that the electric field.

11.4 Drift speed

Q.5 Explain the concept of drift velocity with neat sketch.

Ans: Drift velocity:

i) When no current flows through a copper rod, the free electrons move in random motion. Therefore, there is no net motion of these electrons in any direction.

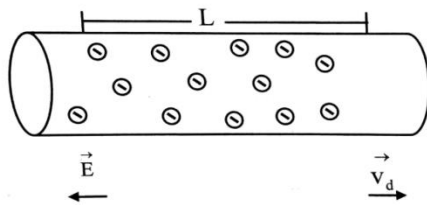


Free electrons in random motion inside the conductor.

ii) If an electric field is applied along the length of the copper rod, a current is set up in the rod. The electrons inside rod still move randomly, but tend to 'drift' in a particular direction.

iii) Their direction is opposite to that of the applied electric field.

iv) The electrons under the action of the applied electric field drift with a drift speed v_d .



Conducting wire with the applied electric field

Q.6 What is current density? State its SI unit.

Ans: Current density: Current density at a point in a conductor is the amount of current flowing per unit area of the conductor.

$$\text{Current density, } J = \frac{I}{A}$$

Where, I = Current

A = Area of cross-section

SI unit: A/m².

Q.7 Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons.

Ans: i) Consider a part of conducting wire with its free electrons having the drift speed v_d in the direction opposite to the electric field $\vec{E}$.

ii) All the electrons move with the same drift speed v_d and the current I is the same throughout the cross section (A) of the wire.

iii) Let L be the length of the wire and n be the number of free electrons per unit volume of the wire. Then the total number of free electrons in the length L of the conducting wire is nAL .

iv) The total charge in the length L is, $q = nALe$ (1)

Where, e is the charge of electron.

v) Equation (1) is total charge that moves through any cross section of the wire in a certain time interval t .

$$\therefore t = \frac{L}{v_d} \quad \text{..... (2)}$$

vi) Current is given by,

$$I = \frac{q}{t} = \frac{nALe}{L/v_d} \quad \text{..... [From equations (1) and (2)]}$$

$$= n A v_d e$$

Hence,

$$v_d = \frac{I}{n A e}$$

$$= \frac{J}{ne} \quad \text{..... } (\because J = \frac{I}{A})$$

Hence for constant 'ne', current density of a metallic conductor is directly proportional to the drift speed of electrons, $J \propto v_d$.

Q.8 DC current flows in a metal piece of non-uniform cross-section. Which of these quantities remains constant along the conductor: current, current density or drift speed?

Ans: Drift velocity and current density will change as it depends upon area of cross-section whereas current will remain constant.

11.5 Ohm's Law**Q.9 State and explain ohm's law.**

Ans: Statement: The current I through a conductor is directly proportional to the potential difference V applied across its two ends provided the physical state of the conductor is unchanged.

Explanation:

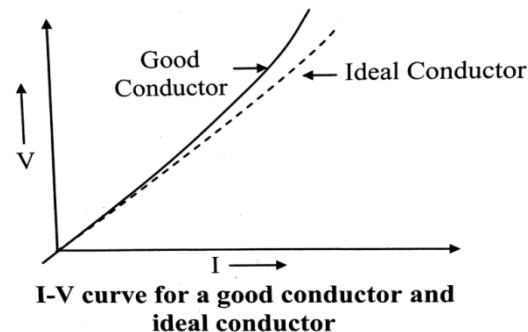
According to ohm's law, $I \propto V$

$$\therefore V = IR \quad \text{or} \quad R = \frac{V}{I}$$

Where, R is proportionality constant and is called the resistance of the conductor.

Q.10 Draw a graph showing the I-V curve for a good conductor and ideal conductor.

Ans:

**Q.11 Define one ohm.**

Ans: One ohm: If potential difference of 1 volt across a conductor produces a current of 1 ampere through it, then the resistance of the conductor is one ohm.

n-type semiconductor (n-ऋण प्रकारचा अर्धवाहक)-

- i) Germanium (Ge) हा semiconductor लक्षात घ्या. त्यामध्ये चार valence electrons असतात.
- ii) Antimony (sb) किंवा Arsenic (As) ह्या ५ व्या group मधील electron चा काही भाग हा impurity म्हणून Germanium crystal मध्ये टाकला जातो. ज्या process मध्ये semiconductor मध्ये impurity add केली जाते, त्या process ला doping म्हणतात.
- iii) Sb किंवा As च्या atom मध्ये पाच valence electrons असतात. Impurity atom मधील पाच पैकी चार electrons हे शेजारच्या Ge, सारख्या atoms मधील electrons बरोबर covalent bond (सहसंयुज बंध) निर्माण करतात.
- iv) Dopant atom चा ५ वा (जादा असलेला) electron हा covalent bond चा भाग नसतो, त्यामुळे तो स्वतंत्ररित्या core बरोबर bound होतो, त्याला मुक्त करण्यासाठी अगदी कमी प्रमाणात energy लागते.
- v) n-type semiconductor सुद्धा यातील bonds thermally (औष्णिकदृष्ट्या / उष्णतेने) तुटल्यामुळे electrons आणि holes निर्माण करतात, त्यामध्ये electron हे majority carriers असतात आणि holes हे minority carriers असतात.
- vi) जेव्हा doping झालेल्या Ge crystal च्या across potential difference apply केल्यावर free electrons हे positive potential end कडे move होतात, त्यामुळे त्यातून electric current वाहू लागतो. हा current, हा negatively charged electrons मुळे वाहत असल्याने त्या semiconductor ला n-type semiconductor असे म्हणतात.
- vii) जर n-type semiconductor मध्ये electrons ची संख्या खूप असेल, तर त्यांचा net charge zero असतो.
- viii) ह्या case मध्ये impurity atom कडून Ge crystal ला free electron दिले जातात, त्यामुळे त्या impurity ला donor impurity असे म्हणतात.
- ix) अशा प्रकारे n-type semiconductor हा pentavalently, doped germanium असतो.

p-Type semiconductor- (धन प्रकारचा अर्धवाहक)-

- i) Germanium किंवा silicon हा semiconductor लक्षात घ्या. त्यामध्ये चार valence electrons असतात.
- ii) समजा, तिसऱ्या group मधील element Indium (In) किंवा Aluminum (Al) यांचा काही भाग impurity म्हणून Germanium crystal मध्ये add केला. Impurity add करण्याच्या process ला doping असे म्हणतात.
- iii) In किंवा Al ह्या elements च्या atom मध्ये तीन valence electrons असतात, impurity atom मधील तीन valence electrons हे शेजारच्या Ge atoms मधील valence electrons बरोबर covalent bonds निर्माण करतात.
- iv) In atom च्या सभोवताली electrons चा absence असतो,

त्यालाच hole म्हणतात, हे holes, positive charge च्या समतोल असतात.

v) अशा प्रकारच्या doping झालेल्या Ge crystal ला potential difference, apply केला तर शेजारच्या covalent bond मधील electron हा hole मध्ये उडी मारतो, त्यामुळे त्या band मध्ये bond निर्माण होतो, हि प्रक्रिया अशीच चालू राहते आणि hole हे field च्या direction मध्ये move होत असलेले भासते, हे electrons च्या jumping मुळे भासते.

vi) जर p-type semiconductor ला किंवा p-type semiconductor मध्ये मोठ्या प्रमाणात holes असतील, तर त्यावरील net charge zero भासतो.

vii) अशा प्रकारे p-type semiconductor ला thermally (उष्णतेने) तुटलेल्या bonds निर्माण झालेल्या electron hole pairs आणि trivalent dopant मुळे निर्माण झालेली holes ची संख्या जास्त असते, त्यामुळे p-type semiconductor ला holes हे majority carriers आणि electrons हे minority carriers असतात.

viii) ह्या case मध्ये impurity atom हे Ge atom कडून electron accept करतात, त्यामुळे ह्या impurity ला acceptor impurity म्हणतात.

ix) त्यामुळे p-type semiconductor हा trivalently doped germanium असतो.

p-n junction (धन ऋण जोड झडप)- जेव्हा p-type semiconductor हा n-type semiconductor बरोबर जोडला जातो, त्या दोन्ही semiconductor च्या मधील common (समान) contacting region ला p-n junction म्हणतात.

Barrier potential (विभव रोधिका)- Junction च्या region मध्ये काही कालांतराने potential difference मुळे electrons आणि holes चे पुढील diffusion रोखले जाते, त्या potential ला Barrier potential असे म्हणतात. Electrons आणि holes च्या diffusion मुळे junction च्या जवळ, ions चा एक layer (पट्टा) निर्माण होतो, ह्या ions च्या layer मुळेच junction च्या across potential difference निर्माण होतो. प्रश्नातील diagram पहा.

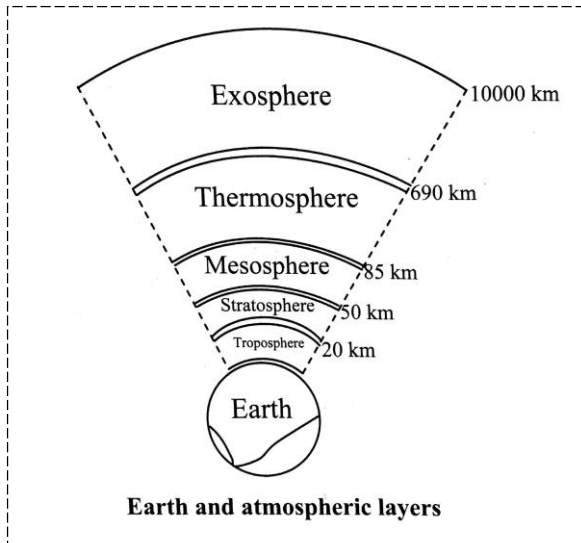
Depletion layer (नष्ट होणारा / कमी होणारा स्तर)- Junction च्या जवळचा भागामध्ये free charges म्हणजेच electrons आणि holes हे disappear (अदृश्य) होतात / नष्ट होतात, म्हणजेच junction जवळचा region हा free charge मुळे deplete होतो, त्यामुळे त्याला depletion layer असे म्हणतात.

Depletion layer ची width हि ०.५ μm ते १ μm इतकी असते. Electrons आणि holes हे junction ओलांडताना ions ची एक wall निर्माण करतात, त्यामुळे junction च्या भोवती potential difference निर्माण होते.

13.4 Propagation of EM Waves

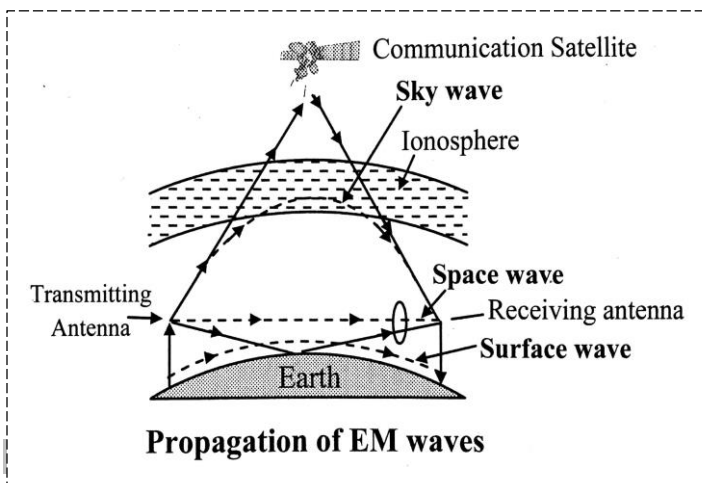
Q.21 Draw a schematic structure of earth's atmosphere describing different atmospheric layers.

Ans: Structure of earth's atmosphere:



Q.22 Draw a diagram showing different types of EM waves.

Ans: Different types of EM waves:



Ans: Ground wave propagation:

- When a radio wave from a transmitting antenna propagates near surface of the Earth so as to reach the receiving antenna, the wave propagation is called ground wave or surface wave propagation.
- In this mode, radio waves travel close to the surface of the Earth and move along its curved surface from transmitter to receiver.

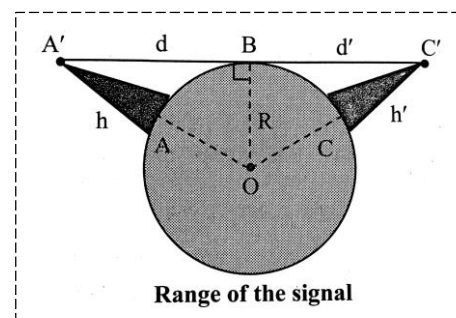
iii) The radio waves induce currents in the ground and lose their energy by absorption. Therefore, the signal cannot be transmitted over large distances.

iv) Radio waves having frequency less than 2 MHz (in the medium frequency band) are transmitted by ground wave propagation.

v) This is suitable for local broadcasting only. For TV or FM signals (very high frequency), ground wave propagation cannot be used.

Q.25 Explain the concept of range of the signal.

Ans: Range of signal: The maximum distance over which a signal can reach is called its range.



i) For large TV coverage, the height of the transmitting antenna should be as large as possible. This is the reason why the transmitting and receiving antennas are mounted on top of high rise buildings.

ii) Range is the straight line distance from the point of transmission (the top of the antenna) to the point on Earth where the wave will hit while travelling along a straight line.

iii) Let the height of the transmitting antenna (AA') situated at A be h. B represents the point on the surface of the Earth at which the space wave hits the Earth.

iv) The triangle OA'B is a right angled triangle.

From $\triangle OA'B$,

$$(OA')^2 = A'B^2 + OB^2$$

$$(R + h)^2 = d^2 + R^2 \quad \text{or}$$

$$R^2 + h^2 + 2Rh = d^2 + R^2$$

$$\text{As } h \ll R, \text{ neglecting } h^2$$

$$d \approx \sqrt{2Rh}$$

v) The range can be increased by mounting the receiver at a height h' say at a point C on the surface of the Earth. The range increases to $d + d'$ where $d' = \sqrt{2Rh'}$. Thus,

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