Motion in a Plane

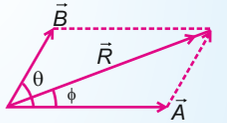
Chapter 4

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.

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

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

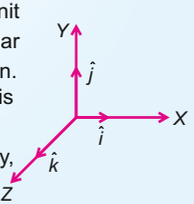


- **Subtraction of vector:** It can be defined as addition of a vector and negative of other vector.

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

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

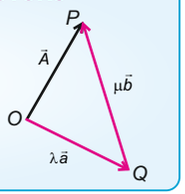
Unit Vectors: It is a vector of unit magnitude and points in a particular direction. It has no unit and dimension. Unit vectors along the *x*, *y* and *z* axis of a rectangular coordinate system represented by $\hat{i}, \hat{j}$ and $\hat{k}$ respectively, called basic unit vectors.



2 RESOLUTION OF VECTORS

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

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



3 RECTANGULAR COMPONENTS

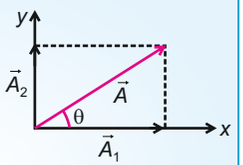
- $\vec{A} = \vec{A}_1 + \vec{A}_2$

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

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

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

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

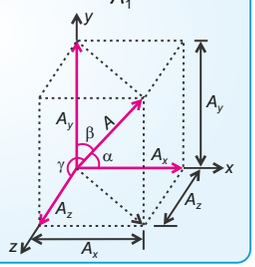


- Resolution in three rectangular components

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

$$A_z = A\cos\gamma$$

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



4 MOTION IN A PLANE

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

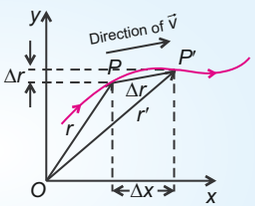
$$\vec{r}' = x'\hat{i} + y'\hat{j}$$

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

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

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

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



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

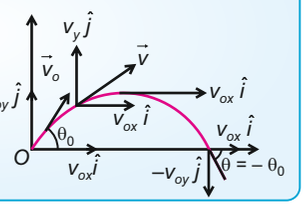
7 PROJECTILE MOTION

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

This is equation of parabola.

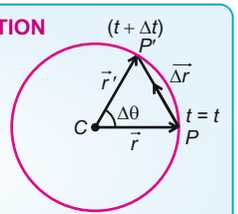
- Time of flight $T_f = \frac{2v_o\sin\theta_0}{g}$
- Maximum height $h_m = \frac{(v_o\sin\theta_0)^2}{2g}$
- Horizontal range $R = \frac{v_o^2\sin 2\theta_0}{g}$

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



8 UNIFORM CIRCULAR MOTION

In uniform circular motion particle moves with constant speed.



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

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

Sharpen Your Understanding

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

NCERT Based MCQs

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 $\left(3\hat{i}+4\hat{j}\right)$ m/s and particle *B* is moving with velocity $\left(-3\hat{i}-4\hat{j}\right)$ 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 $\left(3\hat{i}+4\hat{j}\right)$ in the direction of $\left(\hat{i}-\hat{j}\right)$ 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 $\left(6\hat{i}+4\hat{j}\right)$ 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

$$\Sigma\vec{F} = 0 \Rightarrow \Sigma\vec{F}_x = 0, \Sigma\vec{F}_y = 0 \text{ and } \Sigma\vec{F}_z = 0$$

Conservation of Liner Momentum

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

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

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

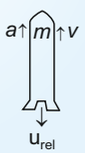
- Recoiling of Gun
- Rowing of boat
- When a man jumps from a boat, the boat moves backward
- It is difficult to walk on sand or ice.

Rocket Propulsion

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

Thrust

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



4 NON-INTERTIAL FRAME OF REFERENCE

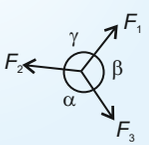
Pseudo Force $\vec{F}_{pseudo} = -M\vec{a}_{frame}$

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

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.

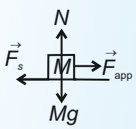
Friction

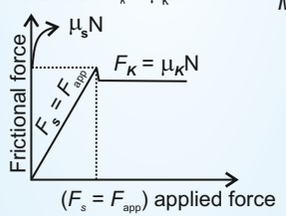
It is the resistance offered to the relative motion between two bodies in contact

- 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: $\theta = \tan^{-1}(\mu_s)$
- 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

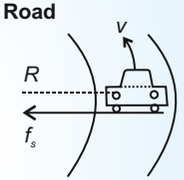
- $a = a_c = \frac{v^2}{R} = R\omega^2$
- $a = a_c = v.\omega$

Non-uniform circular motion

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

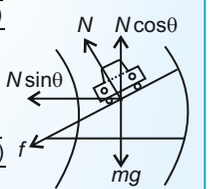
Motion of car on level Road

- $v_{max} = \sqrt{\mu_s Rg}$
- $\mu_{min} = \frac{v^2}{Rg}$
- $R_{min} = \frac{v^2}{\mu g}$



Motion of car on Banked Road

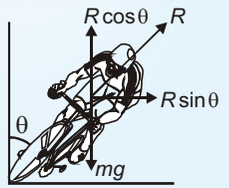
- $v_{max} = \sqrt{\frac{Rg(\mu_s + \tan\theta)}{(1 - \mu_s\tan\theta)}}$
- $v_{optimum} = \sqrt{Rg\tan\theta}$
- $v_{min} = \sqrt{\frac{Rg(\tan\theta - \mu_s)}{(1 + \mu_s\tan\theta)}}$



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

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]

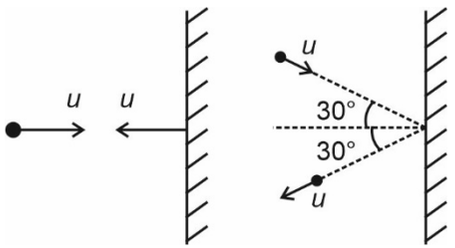
   (1) (a) only

   (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]



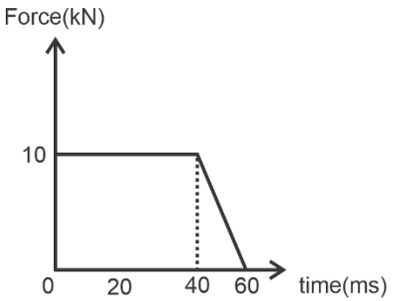
   (1) $\frac{2}{\sqrt{3}}$

   (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) 0º to each other

   (2) 90º to each other

   (3) 45º 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

NCERT Based MCQs

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]

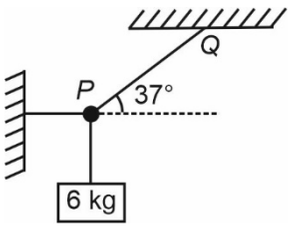
(1) 0.4

(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

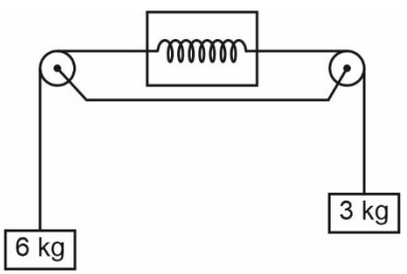
(2) 150 N

(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]



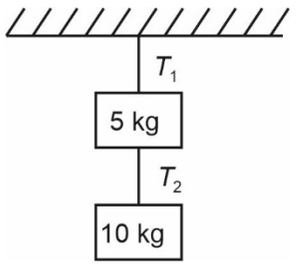
(1) 10 N

(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]

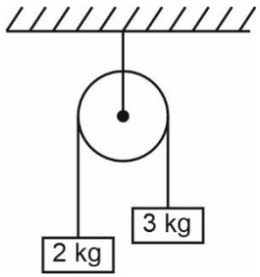
(1) $\sqrt{\frac{gR(\mu+\tan\theta)}{(1-\mu\tan\theta)}}$

(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]

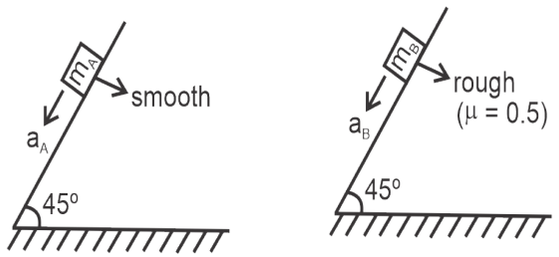
(1) Will be at rest

(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]

❑ ❑ ❑

Electrostatic Potential and Capacitance

Chapter 2

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.

$$U = \int_{\infty}^{r} \vec{F}_{ext} \cdot \vec{dr} \quad = -\int_{\infty}^{r} \vec{F}_{E} \cdot \vec{dr}$$

2 POTENTIAL ENERGY OF A SYSTEM OF CHARGES

- For assembly of two charges

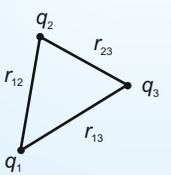
q_1 ——— q_2 for q_1 and q_2 at separation r

(r)

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$ (Depends on charge nature)

- For assembly of three charges

$$U = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right)$$



3 ELECTRIC POTENTIAL

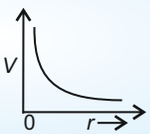
Work done by an external force in bringing a unit positive charge from infinity to that point without acceleration is equal to electrostatic potential at that point.

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

$$V = V_1 + V_2 + V_3 + \ldots\ldots = \frac{1}{4\pi\varepsilon_0}\sum\frac{q_i}{r_i}$$

6 POTENTIAL DUE TO AN ELECTRIC DIPOLE

- $V = \frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$

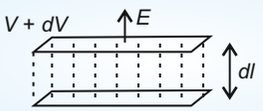
(r >> dipole length at general point)

- 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

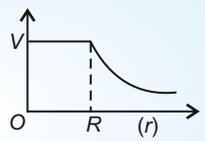
7 RELATION BETWEEN FIELD AND POTENTIAL



$E = -dV/dl$

8 POTENTIAL DUE TO UNIFORMLY CHARGED SPHERICAL CONDUCTING SHELL

- $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$ $(r \geq R)$



q is charge on shell and R is its radius.

- Potential is constant inside shell and is equal to potential at surface.

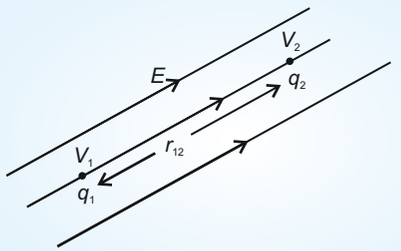
$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$$

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 :

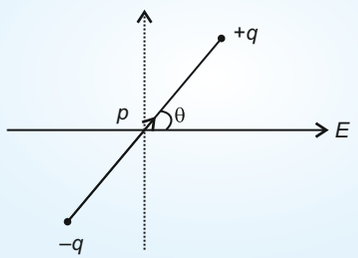
10 POTENTIAL ENERGY IN EXTERNAL FIELD



$$U = q_1V_1 + q_2V_2 + \frac{q_1q_2}{4\pi\varepsilon_0 r_{12}}$$

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.

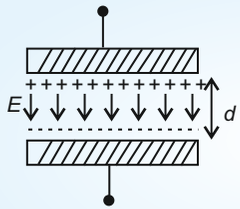
15 CAPACITANCE OF CAPACITORS

$$C = \frac{Q}{V}$$

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

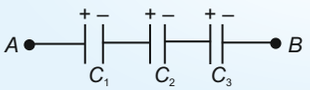
17 COMBINATION OF CAPACITORS

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

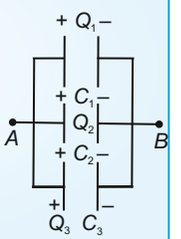
Same potential difference is applied across each capacitor.

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]

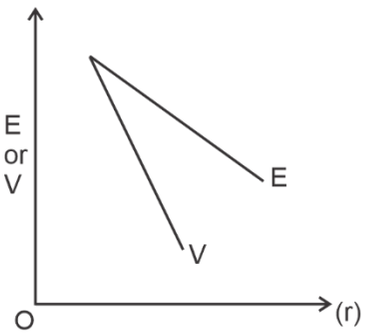
(1) 1.2 kV (2) 2.3 kV

(3) 3.7 kV (4) 2.7 kV

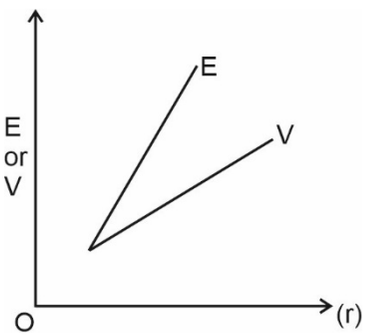
2. The comparative graph of potential and electric field due to a point charge at a distance r from it is best shown by graph.

[NCERT Pg. 55]

(1)



(2)



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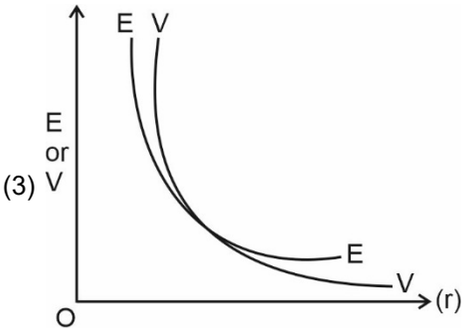

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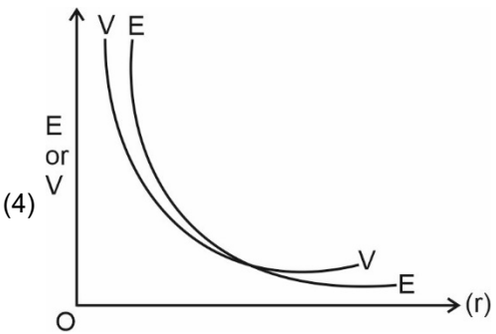


3. A point charge Q = 4 × 10^{-7} C is placed at a point in free space. How much work is required to bring a charge 2 nC from infinity to a point 9 cm from charge Q?

[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]

NCERT Based MCQs

(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 $\theta = 60^\circ$ 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

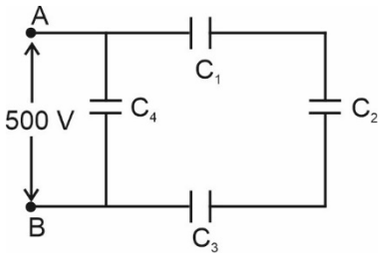
(3) 3×10^6 V (4) 1.5×10^4 V

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}

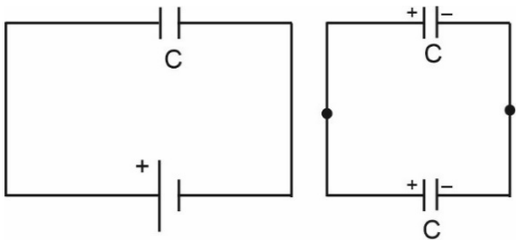
(2) 8.85×10^{-6} Jm^{-3}

(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]

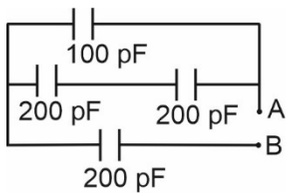
(1) Electric field due to charged plates induces a net dipole moment in the dielectric (insulating material)
(2) Net potential difference between the plates is reduced
(3) Capacitance C decreases from initial value C_0 to (C_0 / K)
(4) Both (1) and (2) are correct

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]

❑ ❑ ❑

Ray Optics and Optical Instruments

9 Chapter

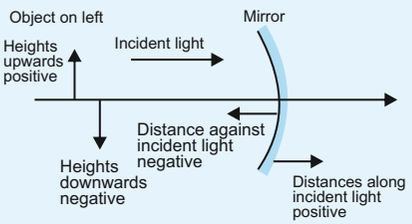
1 REFLECTION OF LIGHT

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.

$$f = \frac{R}{2}$$

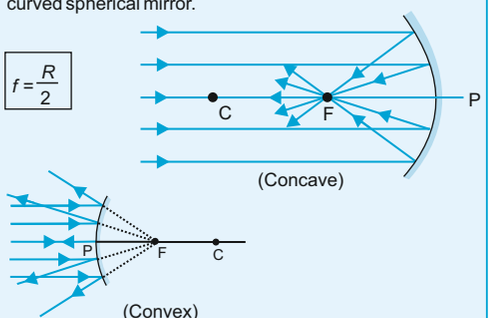
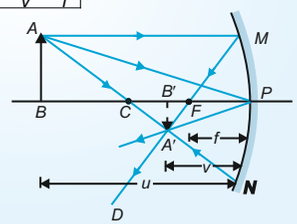


Image Formation by Spherical Mirrors

- 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

$$m = -\frac{v}{u} = \frac{f}{f-u} = \frac{f-v}{f}$$



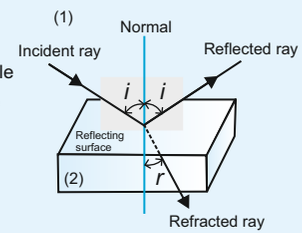
2 REFRACTION OF LIGHT

- 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.

$$\boxed{\frac{\sin i}{\sin r} = n_{21}}$$

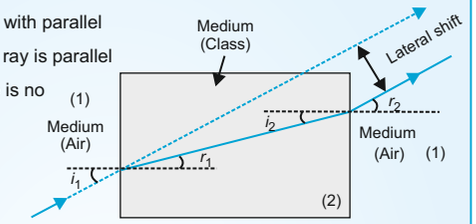


n_{21} is refractive index of second medium with respect to first.

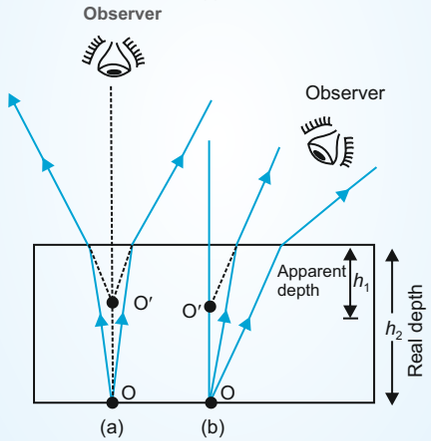
- Optical denser medium has high refractive index. Mass density of optical denser medium may be less than mass density of rarer medium.
- Elementary results from laws of refraction are

(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.

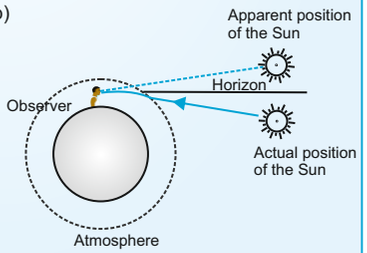


(3) Bottom of tank filled with water appears to be raised.



$$\text{Apparent depth} = \frac{\text{Real depth}}{n_{21}}$$

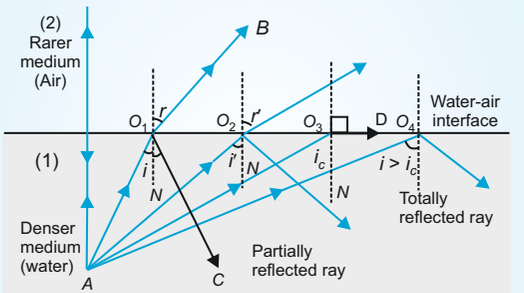
(4) Sun is visible a little before the actual sunrise and until a little after the sunset, this time difference is about 2 minute, the sun appears oval shaped.



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.

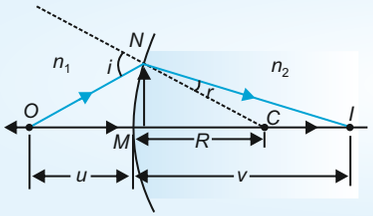


- Higher is value of refractive index, smaller will be critical angle.

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).

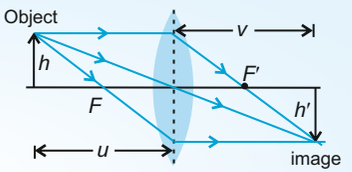
5 REFRACTION BY LENSES

- 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

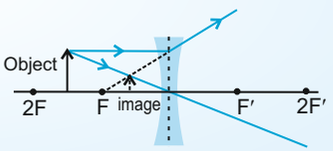
$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$m = \frac{\text{Size of image}}{\text{Size of object}} = \frac{h'}{h} = \frac{v}{u} = \frac{f}{f+u} = \frac{f-v}{f}$

- Formula is valid for convex and concave lenses and magnification produced by lens (for paraxial approximation)



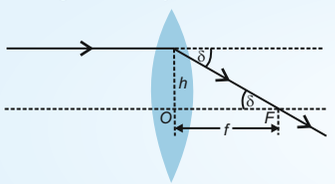
(a)



(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

$P = P_1 + P_2 + P_3 + ...$

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + ...$

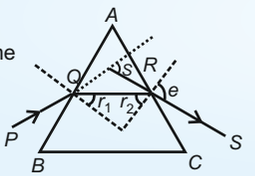
- Net power is individual power's algebraic sum. Some terms may be positive (convex) and some terms may be negative (concave) on right hand side.
- This combination helps to get diverging or converging lens combination of desired magnification.

8 REFRACTION THROUGH A PRISM

- For any triangular prism angle between incidence ray and emergent ray is called angle of deviation

$\delta = i + e - A$

- δ remains same if i and e are interchanged.

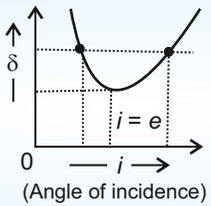


When $\delta = D_m$

$i = e$, $D_m = 2i - A$

$r = r_1 = r_2$ or $r_1 = A/2$

The refracted ray inside prism becomes parallel to its base.



- Refractive index of prism is calcutated by formula.

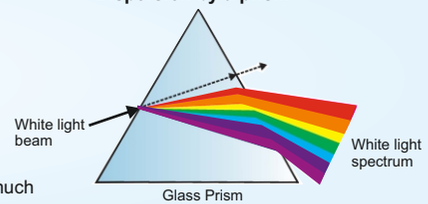
$$n_{21} = \frac{n_2}{n_1} = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin(A/2)}$$

- For small angle thin prism

$D_m = (n_{21} - 1)A$

- It implies thin prism don't deviate light much

Dispersion by a prism

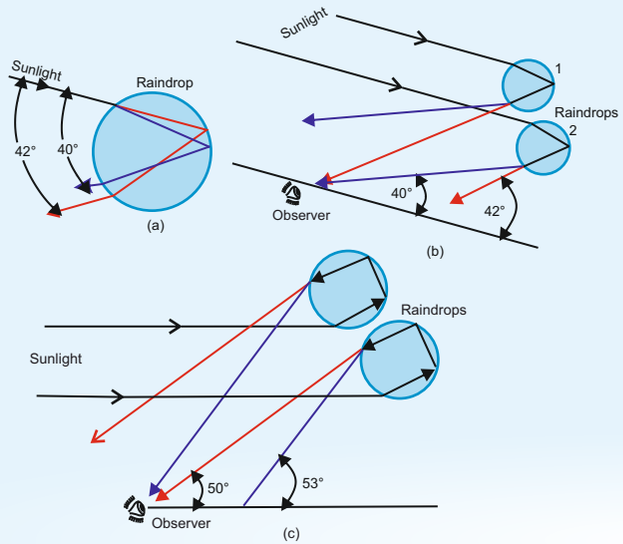


9 NATURAL PHENOMENA DUE TO SUNLIGHT

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

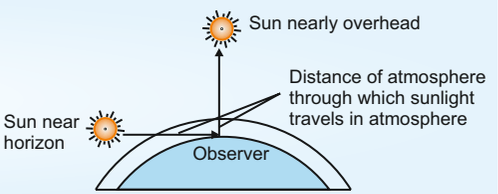
- It is used to provide angular magnification for distant objects
- Final image at infinity

$$m = \frac{f_o}{f_e} \text{ and } L = f_o + f_e$$

- 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

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

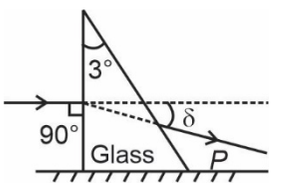
7. A screen is placed at a distance of 40 cm away from an illuminated object. A converging lens is placed between the source and screen and it is attempted to form the image of the source on the screen. If no lens position could be found, the focal length of the lens [NCERT Pg. 347]
   (1) Should be greater than 10 cm
   (2) May be 6 cm
   (3) May be infinity
   (4) Must be less than 10 cm

NCERT Based MCQs

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

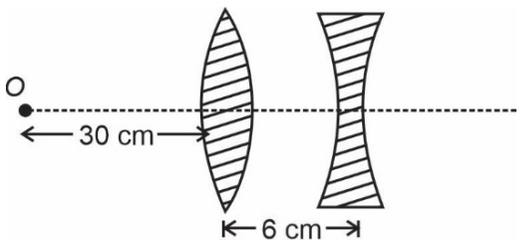
(3) 11 (4) 16

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

(1) True [NCERT Pg. 327]

(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

(1) True [NCERT Pg. 329]

(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

(1) True [NCERT Pg. 331]

(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

(1) True [NCERT Pg. 333]

(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

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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]