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MOTION IN A PLANE

1 Displacement in terms of Position Vector

Let a body be displaced from

$A(x_1, y_1, z_1)$ to $B(x_2, y_2, z_2)$

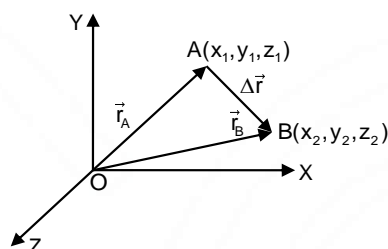
then its displacement is given by vector \overrightarrow{AB} .

$$\vec{r}_B = x_2\hat{i} + y_2\hat{j} + z_2\hat{k} \text{ (Position vector at B)}$$

and $\vec{r}_A = x_1\hat{i} + y_1\hat{j} + z_1\hat{k}$ (Position vector at A)

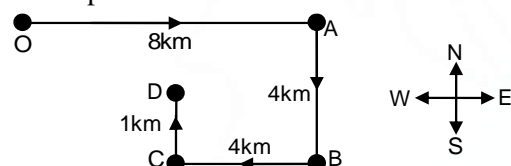
$$\Delta\vec{r} = \vec{r}_B - \vec{r}_A$$

$$\Delta\vec{r} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} + (z_2 - z_1)\hat{k}$$



Example 1:

A car moves from O to D along the path OABCD as shown in the figure. What is the distance travelled and net displacement of the car.



Solution:

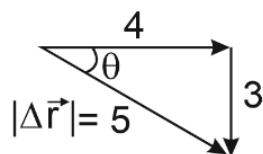
$$\text{Distance} = |\overrightarrow{OA}| + |\overrightarrow{AB}| + |\overrightarrow{BC}| + |\overrightarrow{CD}|$$

$$= 8 + 4 + 4 + 1 = 17 \text{ km}$$

$$\Delta\vec{r} = \text{Displacement} = \overrightarrow{OA} + \overrightarrow{AB} + \overrightarrow{BC} + \overrightarrow{CD}$$

$$= 8\hat{i} + (-4\hat{j}) + (-4\hat{i}) + \hat{j} = 4\hat{i} - 3\hat{j}$$

$$|\Delta\vec{r}| = |\text{displacement}| = \sqrt{(4)^2 + (3)^2} = 5$$



$$|\Delta\vec{r}| = 5$$

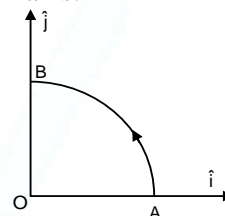
$$\tan \theta = \frac{3}{4}$$

$$\theta = 37^\circ$$

So, Displacement = 5 km, 37° S of E

Example 2:

A particle goes along a quadrant from A to B of a circle radius 10 m as shown in the figure. Find the magnitude of displacement and distance along path AB, and angle which the displacement vector \overrightarrow{AB} makes with the x-axis.



Solution:

$$\text{Displacement} = \overrightarrow{AB} = \overrightarrow{OB} - \overrightarrow{OA} = 10\hat{j} - 10\hat{i}$$

$$|\overrightarrow{AB}| = \sqrt{10^2 + 10^2} = 10\sqrt{2} \text{ m}$$

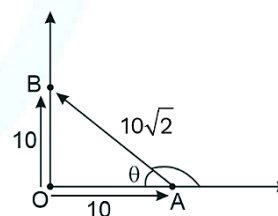
$$\text{From } \triangle OBA \quad \tan \theta = \frac{OB}{OA} = \frac{10}{10} = 1$$

$$\Rightarrow \theta = 45^\circ$$

Angle between displacement vector \overrightarrow{AB} and x-axis = $180^\circ - 45^\circ = 135^\circ$

$$\text{Distance} = \frac{1}{4} (\text{circumference})$$

$$= \frac{1}{4} (2\pi R) \text{ m} = (5\pi) \text{ m}$$



Example 3:

A body initially having position vector $\vec{r}_A = 2\hat{i} + \hat{j} + 4\hat{k}$ moves to $\vec{r}_B = 6\hat{i} + 9\hat{j} - 2\hat{k}$, then find the change in position vector of the body.

Solution:

We know that displacement of an object is change in its position vector

$$\text{Thus } \Delta\vec{r} = \vec{r}_B - \vec{r}_A$$

$$= (6\hat{i} + 9\hat{j} - 2\hat{k}) - (2\hat{i} + \hat{j} + 4\hat{k}) = 4\hat{i} + 8\hat{j} - 6\hat{k}$$

Example 4:

On an open ground a motorist follows a track that turns to his left by an angle of 60° after every 500 m. Starting from a given turn, specify the displacement of the motorist at the third, sixth and eighth turn. Compare the magnitude of displacement with the total path length covered by the motorist in each case.



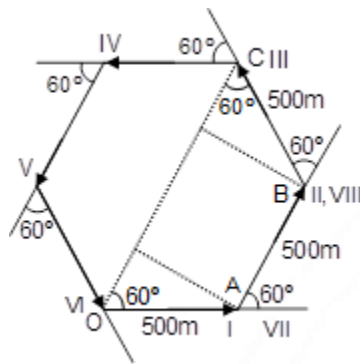
Solution:

At 3rd turn

$$\begin{aligned}\text{Displacement} &= \vec{OA} + \vec{AB} + \vec{BC} = \vec{OC} \\ &= 500 \cos 60^\circ + 500 + 500 \cos 60^\circ \\ &= 1000 \text{ m from O to C}\end{aligned}$$

$$\text{Distance} = 500 + 500 + 500 = 1500 \text{ m}$$

$$\therefore \frac{\text{Displacement}}{\text{Distance}} = \frac{1000}{1500} = \frac{2}{3}$$



At 6th turn

\therefore initial and final positions are same so

displacement = 0 and

$$\text{distance} = 500 \times 6 = 3000 \text{ m}$$

$$\therefore \frac{\text{Displacement}}{\text{Distance}} = \frac{0}{3000} = 0$$

At VIII turn

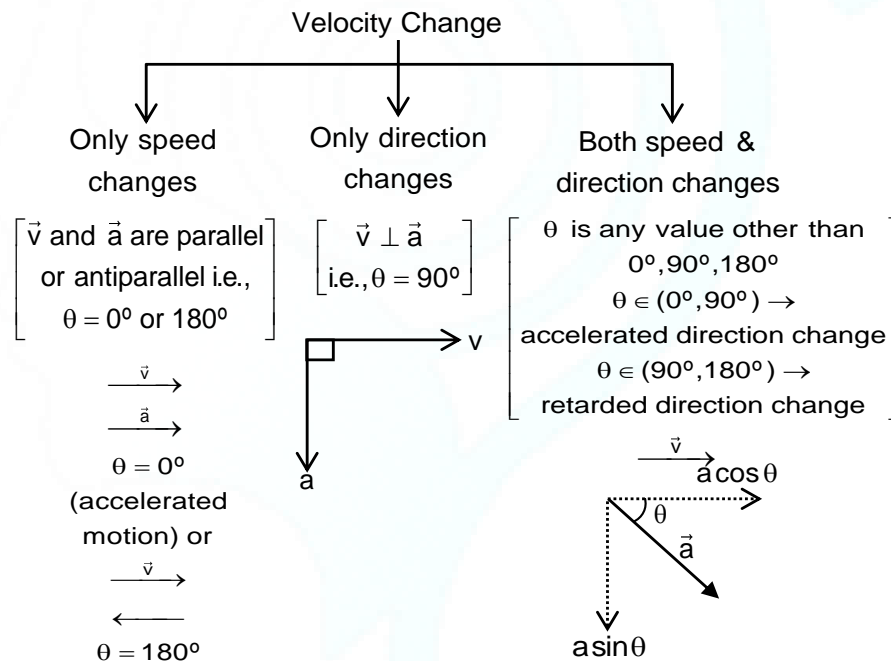
Displacement = length of OB = $2 \times 500 \times \cos$

$$\left(\frac{60^\circ}{2}\right) = 1000 \times \cos 30^\circ = 1000 \times \frac{\sqrt{3}}{2} = 500\sqrt{3} \text{ m}$$

$$\text{Distance} = 500 \times 8 = 4000 \text{ m}$$

$$\therefore \frac{\text{Displacement}}{\text{Distance}} = \frac{500\sqrt{3}}{4000} = \frac{\sqrt{3}}{8}$$

2. Velocity Change



Example 5:

A body is moving with velocity $2\hat{i} + 3t^2\hat{j}$, find its average acceleration after 2 seconds.

Solution:

As $\langle \vec{a} \rangle$ (average acceleration)

$$= \frac{\Delta \vec{v} (\text{Change in velocity})}{\Delta t (\text{Total time taken})}$$

$$\vec{v}_{\text{initial}} = 2\hat{i} + 0\hat{j}, \vec{v}_{\text{final}} = 2\hat{i} + 12\hat{j}$$

$$\text{therefore, } \Delta \vec{v} = \vec{v}_{\text{final}} - \vec{v}_{\text{initial}} = 0\hat{i} + 12\hat{j}$$

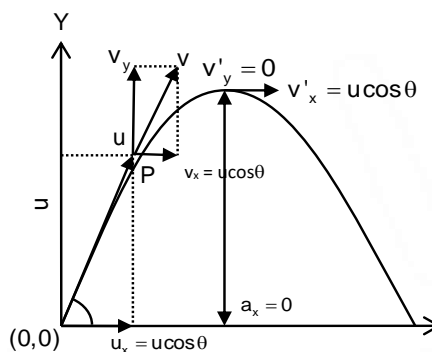
$$\Rightarrow \langle \vec{a} \rangle = 0\hat{i} + 6\hat{j}$$

3. Projectile Motion

When a body is projected such that velocity of projection is not parallel to the force (θ other than 0° and 180°), then it moves along a curved path. This motion is called two dimensional motion. If



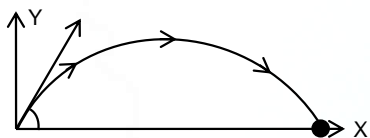
force on the body is constant then curved path of the body is parabolic. This motion is studied under projectile motion.



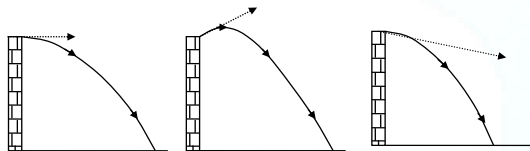
- It is an example of motion with constant (or uniform) acceleration. Thus equations of motion can be used to analyse projectile motion.
- A particle thrown in the space which moves under the effect of gravity only is called a "projectile".
- If a particle possesses a uniform acceleration in a direction different to its initial velocity, the resultant path will be parabolic. Path of projectile projected at an angle θ from the ground is as shown.

Types of Projectile

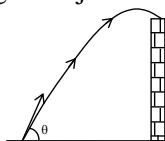
- Ground to Ground or Level to level Projectile



- Height to Ground Projectile



- Ground to Height Projectile



4. Ground to Ground Projection

Projectile motion can be considered as two mutually perpendicular motions, which are independent of each other i.e. Projectile motion = Horizontal motion + Vertical motion

4.1 Horizontal Motion

Initial velocity in horizontal direction

$$= u_x = u \cos \theta$$

Acceleration along horizontal direction

$$= a_x = 0 \text{ (Neglect air resistance)}$$

Therefore, horizontal velocity remains unchanged.

- At any instant horizontal velocity $u_x = u \cos \theta$
- At time t , x coordinate or displacement along x -direction is $x = u_x t \Rightarrow x = (u \cos \theta) t$

4.2 Vertical Motion

It is motion under the effect of gravity

Assuming vertically upward direction to be the positive direction of y -axis.

Initial velocity in vertical direction $= u_y = u \sin \theta$

Acceleration along vertical direction $= a_y = -g$

- At time t , vertical speed $v_y = u_y - gt = u \sin \theta - gt$
- In time t , displacement in vertical direction or "height" of the particle above the ground

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

4.3 Net motion

Net initial velocity $= \vec{u} = u_x \hat{i} + u_y \hat{j}$

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

Direction of u can be explained in terms of angle θ it makes with the ground

Net acceleration $\vec{a} = a_x \hat{i} + a_y \hat{j} = -g \hat{j}$ (direction of g is downwards)

4.4 Coordinates of particle at time t

Let (x, y) are coordinates of particle at general time t , then

$$x = u_x t \text{ and } y = u_y t - \frac{1}{2} gt^2$$

$$\text{Net displacement in time } t = \sqrt{x^2 + y^2}$$

4.5 Velocity of particle at time t

$$\vec{v} = v_x \hat{i} + v_y \hat{j} = u_x \hat{i} + (u_y - gt) \hat{j}$$

$$= u \cos \theta \hat{i} + (u \sin \theta - gt) \hat{j}$$

$$\text{magnitude of velocity } |\vec{v}| = \sqrt{v_x^2 + v_y^2}$$



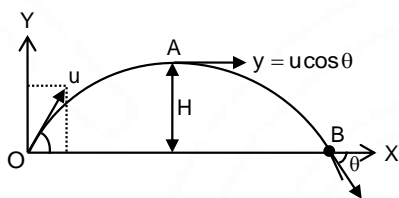
If angle made by velocity with the horizontal direction is α , then

$$\tan \alpha = \frac{v_y}{v_x} = \frac{u_y - gt}{u_x}$$

$$\Rightarrow \tan \alpha = \frac{u \sin \theta - gt}{u \cos \theta} = \tan \theta - \frac{gt}{u \cos \theta}$$

4.6 Change in velocity and momentum of projectile

When particle returns to ground again at B point, its y coordinate is zero and the magnitude of its velocity is u at angle θ with ground.



Initial velocity $\vec{u}_i = u \cos \theta \hat{i} + u \sin \theta \hat{j}$

Final velocity $\vec{u}_f = u \cos \theta \hat{i} - u \sin \theta \hat{j}$

Total change in velocity $|\Delta \vec{v}| = 2u \sin \theta$

Total change in momentum

$$|\Delta \vec{p}| = m |\Delta \vec{v}| = 2mu \sin \theta$$

- change in speed = 0

4.7 Time of flight (T)

At time T particle will be at ground again, i.e. displacement along Y-axis becomes zero.

$$\therefore y = u_y t - \frac{1}{2}gt^2 \quad \therefore 0 = u_y T - \frac{1}{2}gT^2$$

$$\text{or } T = \frac{2u_y}{g} = \frac{2u \sin \theta}{g}$$

Time of ascent = Time of descent

$$= \frac{T}{2} = \frac{u_y}{g} = \frac{u \sin \theta}{g}$$

at time $\frac{T}{2}$ particle attains maximum height of its trajectory.

4.8 Maximum height (H)

At maximum height, vertical component of velocity becomes zero. At this instant y coordinate is maximum

$$\therefore v_y^2 = u_y^2 - 2gy \quad \therefore 0 = u_y^2 - 2gH_{\max}$$

$$H_{\max} = \frac{u_y^2}{2g} = \frac{u^2 \sin^2 \theta}{2g}$$

4.9 Horizontal range (R) of the projectile

It is the displacement of particle along X-direction during its complete flight.

$$\therefore x = u_x t \quad \therefore R = u_x T = u_x \frac{2u_y}{g}$$

$$R = \frac{2u_x u_y}{g} = \frac{2(u \cos \theta)(u \sin \theta)}{g} = \frac{u^2 \sin 2\theta}{g}$$

4.10 Maximum horizontal range (R_{\max})

If value of θ is increased from $\theta = 0^\circ$ to 90° , then range increases from $\theta = 0^\circ$ to 45° but it decreases beyond 45° . Thus range is maximum at $\theta = 45^\circ$

For maximum range, $\theta = 45^\circ$ and

$$R_{\max} = \frac{u^2 \sin 2(45^\circ)}{g} = \frac{u^2 \sin 90^\circ}{g} \Rightarrow R_{\max} = \frac{u^2}{g}$$

4.11 Equation of Trajectory

Along horizontal direction

$$x = u_x t \quad \text{or} \quad x = (u \cos \theta) t$$

Along vertical direction

$$y = u_y t - \frac{1}{2}gt^2 \quad \text{or} \quad y = (u \sin \theta) t - \frac{1}{2}gt^2$$

On eliminating t from these two equations

$$y = (u \sin \theta) \left(\frac{x}{u \cos \theta} \right) - \frac{1}{2}g \left(\frac{x}{u \cos \theta} \right)^2$$

$$\Rightarrow y = x \tan \theta - \frac{1}{2}g \frac{x^2}{u^2 \cos^2 \theta}$$

This is an equation of a parabola so it can be stated that projectile follows a parabolic path.

$$\text{Again } y = x \tan \theta \left[1 - \frac{gx}{2u^2 \sin \theta \cos \theta} \right]$$

$$\Rightarrow y = x \tan \theta \left[1 - \frac{x}{R} \right]$$

4.12 Kinetic Energy of Projectile

$$\text{Kinetic energy} = \frac{1}{2} \times \text{Mass} \times (\text{Speed})^2$$

Let a body be projected with velocity u at an angle θ .

Thus initial kinetic energy of projectile,



$$K_0 = \frac{1}{2} mu^2$$

Since velocity of projectile at maximum height is $u \cos \theta$. So kinetic energy at maximum height

$$= \frac{1}{2} mu^2 \cos^2 \theta = K_0 \cos^2 \theta$$

which is the minimum kinetic energy during whole motion.

Key Points

- At maximum height, $v_y = 0$ and $v_x = u_x = u \cos \theta$ so at maximum height

$$v = \sqrt{v_x^2 + v_y^2} = u \cos \theta$$

- At maximum height angle between velocity and acceleration is 90° .

- Magnitude of velocity at height 'h'.**

Vertical component of velocity at height h

$$v_y^2 = u_y^2 - 2gh$$

$$v_y^2 = (u \sin \theta)^2 - 2gh$$

Horizontal component of velocity at height h

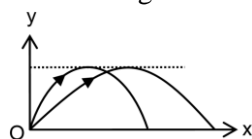
$$v_x = u \cos \theta$$

$$|\vec{v}| = \sqrt{v_x^2 + v_y^2} = \sqrt{u^2 \cos^2 \theta + (u^2 \sin^2 \theta - 2gh)}$$

$$\bullet \quad T = \frac{2u_y}{g}; \quad H = \frac{u_y^2}{2g}; \quad R = \frac{2u_x u_y}{g}$$

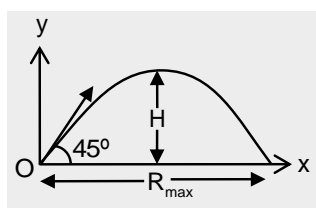
T and H depend only upon initial vertical speed u_y

- If two projectiles thrown in different directions, have equal times of flight then their initial vertical speeds are same so that their maximum height are also same.



If $H_A = H_B$ then $(u_y)_A = (u_y)_B$ and $T_A = T_B$

- For situation shown in figure for $\theta = 45^\circ$



$$\text{Here } R_{\max} = \frac{u^2}{g}$$

$$\text{and } H = \frac{u^2 \sin^2 45^\circ}{2g} = \frac{u^2}{4g}$$

$$\therefore R_{\max} = 4H = 4(\text{maximum height attained})$$

- When $R = H$

$$R = \frac{u^2 (2 \sin \theta \cos \theta)}{g} \text{ and } H = \frac{u^2 \sin^2 \theta}{2g}$$

$$\Rightarrow \frac{R}{H} = 4 \cot \theta = 1 \Rightarrow 4 \cot \theta = 1$$

$$\Rightarrow \tan \theta = 4 \Rightarrow \theta = \tan^{-1}(4)$$

Example 6:

A projectile is thrown with speed u making angle θ with horizontal at $t = 0$. It just crosses two points of equal height at time $t = 1$ s and $t = 3$ s respectively. Calculate the maximum height attained by it? ($g = 10 \text{ m/s}^2$)

Solution:

Displacement in y direction

$$y = u_y \times 1 - \frac{1}{2} g \times (1)^2 = u_y \times 3 - \frac{1}{2} g (3)^2$$

$$\Rightarrow u_y = 2g = 20 \text{ m/s}$$

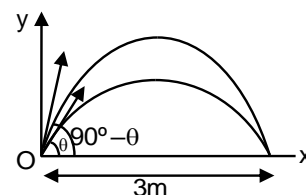
$$\text{Maximum height attained } h_{\max} = \frac{u_y^2}{2g} = 20 \text{ m.}$$

Example 7:

A stone is to be thrown so as to cover a horizontal distance of 3 m. If the velocity of the projectile is 7 m/s find:

- the angle at which it must be thrown
- the largest horizontal displacement that is possible with the projection speed of 7 m/s.

Solution:



$$(a) \text{ Range } R = \frac{u^2}{g} \sin 2\theta \Rightarrow \sin 2\theta = \frac{gR}{u^2}$$

$$= \frac{9.8 \times 3}{(7)^2} = 0.6 = \sin 37^\circ \Rightarrow 2\theta = 37^\circ \Rightarrow \theta = 18.5^\circ$$



angle of projection may also be $90^\circ - 18.5^\circ = 71.5^\circ$

- (b) For largest horizontal displacement $\theta = 45^\circ$ (maximum range)

$$R_{\max} = \frac{u^2}{g} = \frac{(7)^2}{9.8} = \frac{49}{98} \times 10 = 5\text{m}.$$

Example 8:

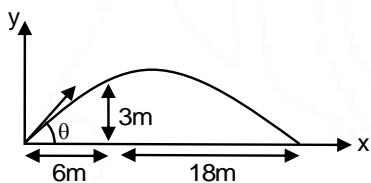
A ball is thrown from the ground to clear a wall 3 m high at a distance of 6 m and falls 18 m away from the wall. The angle of projection of ball is:-

- (A) $\tan^{-1}\left(\frac{3}{2}\right)$ (B) $\tan^{-1}\left(\frac{2}{3}\right)$
(C) $\tan^{-1}\left(\frac{1}{2}\right)$ (D) $\tan^{-1}\left(\frac{3}{4}\right)$

Ans. (B)

Solution:

From equation of trajectory, $y = x \tan\theta \left[1 - \frac{x}{R}\right]$



$$\Rightarrow 3 = 6 \tan\theta \left(1 - \frac{6}{24}\right) \Rightarrow \tan\theta = \frac{2}{3}$$

Example 9:

A particle is projected with initial velocity $\vec{u} = a\hat{i} + b\hat{j}$. Calculate range, maximum height and time of flight of particle.

Solution:

Initial horizontal velocity = $u_x = a$

Initial vertical velocity = $u_y = b$

$$\text{Then time of flight} = \frac{2u_y}{g} = \frac{2b}{g}$$

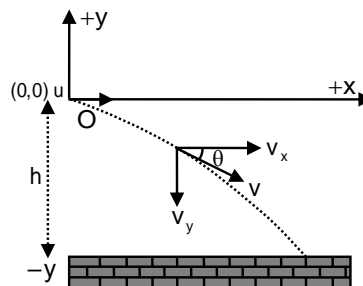
$$\text{Range of projectile} = \frac{2u_x u_y}{g} = \frac{2ab}{g}$$

$$\text{Maximum height of projectile} = \frac{u_y^2}{2g} = \frac{b^2}{2g}$$

FUNDAMENTAL UNLOCKED- (FU#1) :

- Q.1** A football player kicks a ball at an angle of 30° to the horizontal with an initial speed of 20 m/s. Calculate (a) the time at which the ball reaches the highest point (b) the maximum height reached (c) the horizontal range of the ball (d) the time for which the ball is in the air. ($g = 10 \text{ m/s}^2$)
- Q.2** A cricketer can throw a ball to a maximum horizontal distance of 100 m. How high above the ground can the cricketer throw the ball, with the same speed?
- Q.3** Two bodies are thrown with the same initial speed at angles α and $(90^\circ - \alpha)$ with the horizontal. What will be the ratio of (a) maximum height attained by them and (b) horizontal range ?
- Q.4** The range of a particle when launched at an angle of 15° with the horizontal is 1.5 km. What is the range of the projectile when launched at an angle 45° to the horizontal with the same speed.
- Q.5** A ball is thrown from the ground to clear a wall 5 m high at a distance of 10 m and falls 20 m away from the wall. The angle of projection of ball is:-
- Q.6** A particle is projected with the velocity $\vec{v} = 3\hat{i} + 4\hat{j}$ then calculate range, height and time of flight of particle.

5. Horizontal Projection from Height



Consider a projectile thrown from point O at some height h from the ground with a velocity u in horizontal direction.

Now we shall deal with the characteristics of projectile motion separately along horizontal and vertical directions i.e.



Horizontal direction :	Vertical direction :
(i) Initial velocity $u_x = u$	Initial velocity $u_y = 0$
(ii) Acceleration $a_x = 0$	Acceleration $a_y = -g$

5.1 Equation of the trajectory

The path traced by projectile is called its trajectory. After time t , $x = ut$ and $y = -\frac{1}{2}gt^2$.

$$\text{so } y = -\frac{1}{2}g\frac{x^2}{u^2} \quad \left(\because t = \frac{x}{u} \right)$$

This is equation of a parabola and because the coefficient of x^2 in the equation of parabola is negative the nature of parabola is concave downwards.

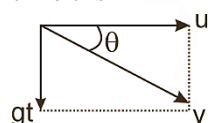
Above equation is called the equation of trajectory

5.2 Velocity at a general point P (x, y)

$$v = \sqrt{v_x^2 + v_y^2}$$

Horizontal velocity of the projectile after time t is $v_x = u$ (remains constant)

Velocity of projectile in vertical direction after time t is

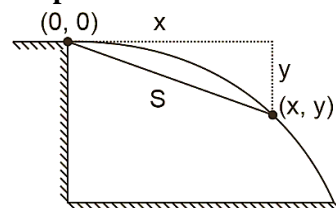


$$v_y = 0 - (g)t = -gt \text{ (downward)}$$

$$\therefore v = \sqrt{v_x^2 + g^2t^2}$$

$$\text{and } \tan\theta = \frac{v_y}{v_x} \text{ or } \tan\theta = \frac{gt}{u}$$

5.3 Displacement



The displacement of the particle is expressed by

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

$$\text{Where } |\vec{s}| = \sqrt{x^2 + y^2}$$

5.4 Time of flight

From equation of motion for vertical direction.

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

$$-h = -\frac{1}{2}gT^2$$

$$T = \sqrt{\frac{2h}{g}}$$

5.5 Velocity after falling a height h_1

Along vertical direction

$$v_y^2 = 0^2 + 2(-g)(-h) = 0^2 + 2gh$$

$$v_y = \sqrt{2gh}$$

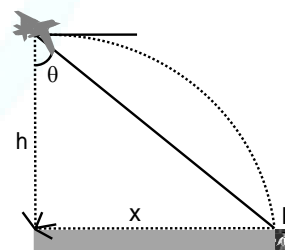
Along horizontal direction $v_x = u_x = u$

$$\text{So velocity, } v = \sqrt{v_x^2 + v_y^2} = \sqrt{u^2 + 2gh}$$

Example 10:

A relief airplane is flying at a constant height of 1960 m with 600 km/hr speed above the ground towards a point directly over a person struggling in flood water. At what angle of sight with the vertical should the pilot release a survival kit if it is to reach the person in water ? ($g = 9.8 \text{ m/s}^2$)

Solution:



$$\text{Plane is flying at a speed} = 600 \times \frac{5}{18} = \frac{500}{3} \text{ m/s}$$

horizontally (at a height 1960m)

time taken by the kit to reach the ground

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 1960}{9.8}} = 20 \text{ s}$$

in this time the kit will move horizontally by

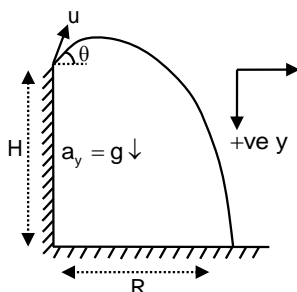
$$x = ut = \frac{500}{3} \times 20 = \frac{10,000}{3} \text{ m}$$

$$\text{So } \tan\theta = \frac{x}{h} = \frac{10,000}{3 \times 1960} = \frac{10}{5.88} = 1.7 = \sqrt{3}$$

$$\text{or } \theta = 60^\circ$$

6. Oblique Projection from a Certain Height

6.1 Projection from a Height at an Angle θ above horizontal



$$u_x = u \cos \theta \quad u_y = -u \sin \theta$$

$$x = (u \cos \theta) t \quad a_y = g$$

$$H = (-u \sin \theta) t + \frac{1}{2} g t^2$$

$$g t^2 - (2u \sin \theta) t - 2H = 0$$

After solving the above equation we get the value of T

Note : Here positive direction of y-axis is in downward direction.

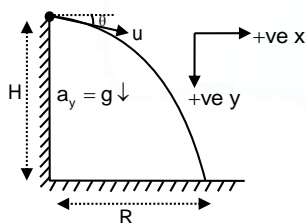
6.2 Velocity after falling height h

Along vertical direction; $v_y^2 = (-u \sin \theta)^2 + 2(h)(g)$

Along horizontal direction, $v_x = u_x = u \cos \theta$;

So, velocity, $v = \sqrt{v_x^2 + v_y^2} = \sqrt{u^2 + 2gh}$

6.3 Projection from a height at an angle θ below horizontal



$$u_x = u \cos \theta \quad u_y = u \sin \theta$$

$$x = (u \cos \theta) t \quad a_y = g$$

$$y = (u \sin \theta) t + \frac{1}{2} g t^2$$

$$g t^2 + (2u \sin \theta) t - 2H = 0$$

After solving the above equation we get the value of T.

Note: Here vertically downward direction has been assumed to be positive direction of y-axis.

6.4 Velocity after falling through a height 'h'

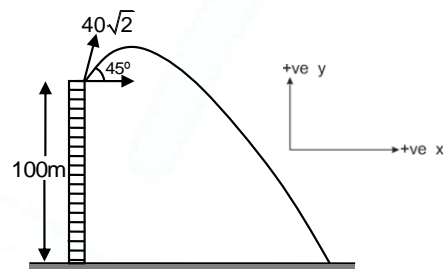
Along vertical direction, $v_y^2 = (u \sin \theta)^2 + 2gh$

Along horizontal direction, $v_x = u_x = u \cos \theta$;

So, velocity, $v = \sqrt{v_x^2 + v_y^2} = \sqrt{u^2 + 2gh}$

Example 11:

For the figure shown, find the:



- time of flight,
 - horizontal range,
 - maximum height attained from ground,
 - speed with which projectile hits the ground.
- ($g = 10 \text{ m/s}^2$)

Solution:

- By using $s = ut + \frac{1}{2} at^2$ in vertical direction

$$-100 = 40(T) + \frac{1}{2} (-10) T^2$$

$$\Rightarrow T^2 - 8T - 20 = 0$$

$$\Rightarrow T = 10 \text{ s}$$

- Horizontal range

$$R = u_x T = (40) (10) = 400 \text{ m}$$

- Maximum height = $100 + \frac{u_y^2}{2g} = 100 + \frac{(40)^2}{2(10)}$
 $= 180 \text{ m}$

- speed with which projectile hits the ground.

$$v = \sqrt{u^2 + 2gh} = \sqrt{(40\sqrt{2})^2 + 2(10)(100)}$$

$$= 20\sqrt{13} \text{ m/s}$$

FUNDAMENTAL UNLOCKED- (FU#2) :

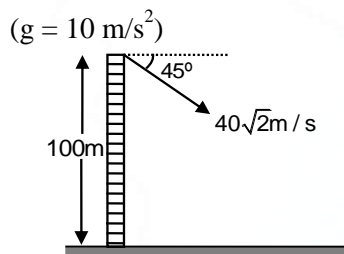
- Q.1** A projectile is fired horizontally with a velocity of 98 ms^{-1} from the top of a hill 490 m high. Find (i) the time taken to reach the ground (ii) the horizontal distance of the target from the hill and (iii) the angle at which the projectile hits the ground. ($g = 9.8 \text{ m/s}^2$).

Q.2 Two tall buildings face each other and are at a distance of 180 m from each other. with what velocity must a ball be thrown horizontally from a window 55 m above the ground in one building, so that it enters a window 10 m above the ground in the second building? ($g = 10 \text{ ms}^{-2}$)

Q.3 Two paper screens A and B are separated by a distance of 100 m. A bullet pierces A and then B. The hole in B is 10 cm below the hole in A. If the bullet is travelling horizontally at the time of hitting the screen A, calculate the velocity of the bullet. ($g = 9.8 \text{ ms}^{-2}$)

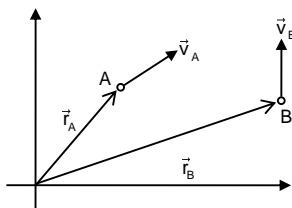
Q.4 A ball is thrown up from the top of a tower with an initial velocity of 10 m/s at an angle of 30° with the horizontal. It hits the ground at a distance of 17.3 m from the base of tower. Calculate the height of the tower. ($g = 10 \text{ m/s}^2$)

Q.5 For shown projection, find the:
(i) time of flight,
(ii) horizontal range,
(iii) speed just before striking the ground.



7. Relative Velocity in a Plane

For 2D motion



Relative velocity of B with respect to A can be calculated as

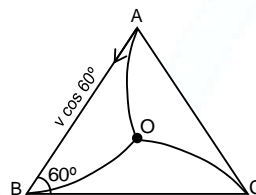
$$\vec{v}_{BA} = \vec{v}_B - \vec{v}_A$$

$$\Rightarrow |\vec{v}_{BA}| = \sqrt{v_B^2 + v_A^2 - 2v_B v_A \cos \theta}$$

Example 12:

Three boys A, B and C are situated at the vertices of an equilateral triangle of side d at $t = 0$. Each of the boys move with constant speed v . A always moves towards B, B towards C and C towards A. When and where will they meet each other.

Solution:



By symmetry they will meet at the centroid of the triangle. Approaching velocity of A and B towards each other is $v + v \cos 60^\circ$ and they cover distance d when they meet.

So that time taken, is given by

$$\therefore t = \frac{d}{v + v \cos 60^\circ} = \frac{d}{v + \frac{v}{2}} = \frac{2d}{3v}$$

7.1 The condition for collision of two particles

- Their combined relative displacement becomes zero.
- Their combined vertical velocities will be same: if they are projected from same level (incase of projectiles)
- Their combined motion can be converted into 1-D motion.

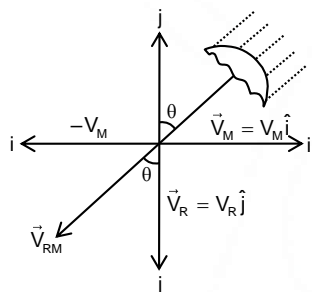
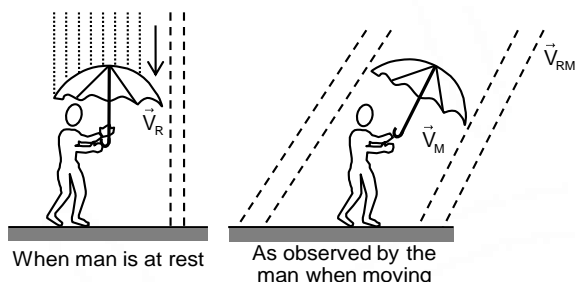
7.2 Relative path of a projectiles w.r.t. another projectile

Two projectiles are thrown from ground with different velocities at different angles. Since both projectiles have equal accelerations so their relative acceleration is zero. Thus path of one projectile w.r.t. other is a straight line and motion of one projectile w.r.t. other is uniform.

- If $u_1 \cos \theta_1 = u_2 \cos \theta_2$ then relative path is a vertical line.
- If $u_1 \sin \theta_1 = u_2 \sin \theta_2$ then relative path is a horizontal line.

8. Rain – Man Problem

- (i) If rain is falling vertically downward with a velocity \vec{v}_R , then its velocity is $\vec{v}_R = -v_R \hat{j}$ and an observer is moving horizontally with speed \vec{v}_M , then the velocity is $\vec{v}_M = v_M \hat{i}$ the velocity of rain relative to observer will be



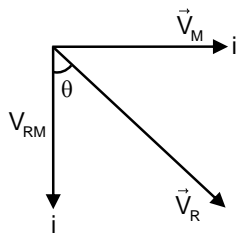
$$\vec{v}_{RM} = \vec{v}_R - \vec{v}_M \Rightarrow \vec{v}_{RM} = -v_R \hat{j} - v_M \hat{i}$$

The magnitude of velocity of rain with respect to man \vec{v}_{RM} is

$$v_{RM} = \sqrt{v_R^2 + v_M^2}$$

The direction of \vec{v}_{RM} is such that it makes an angle θ with the vertical direction given by $\theta = \tan^{-1}(v_M/v_R)$ as shown in figure.

- (ii) If rain is already falling at an angle θ with the vertical with a speed v_R , then $\vec{v}_R = v_R \sin \theta \hat{i} - v_R \cos \theta \hat{j}$ and an observer is moving horizontally with speed v_M , then $\vec{v}_M = v_M \hat{i}$. Here $\vec{v}_{RM} = \vec{v}_R - \vec{v}_M$
- $$\vec{v}_{RM} = (v_R \sin \theta - v_M) \hat{i} - v_R \cos \theta \hat{j}$$



for rain to appear falling vertically, the horizontal component of \vec{v}_{RM} should be zero, i.e.

$$v_R \sin \theta - v_M = 0 \Rightarrow \sin \theta = \frac{v_M}{v_R}$$

$$\text{and } |\vec{v}_{RM}| = v_R \cos \theta = v_R \sqrt{1 - \sin^2 \theta}$$

$$= v_R \sqrt{1 - \frac{v_M^2}{v_R^2}} \Rightarrow v_{RM} = \sqrt{v_R^2 - v_M^2}$$

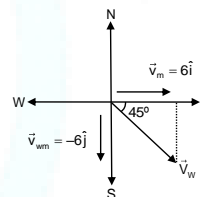
Example 13:

A person moves towards east with speed of 6m/s and finds the wind blowing towards south with a speed of 6m/s.

- (a) Find actual velocity of wind blow.
(b) If the person doubles his velocity then find the relative velocity of wind with respect to the man.

Solution:

(a) $\vec{v}_w = \vec{v}_{wm} + \vec{v}_m = -6\hat{j} + 6\hat{i} \Rightarrow \vec{v}_w = 6\hat{i} - 6\hat{j}$

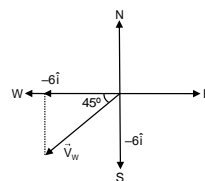


$|\vec{v}| = 6\sqrt{2}$ m/s and it is blowing along S-E

- (b) Person doubles its velocity then $\vec{v}_m = 12\hat{i}$ but actual wind velocity remains unchanged.

$$\vec{v}_{wm} = \vec{v}_w - \vec{v}_m = (6\hat{i} - 6\hat{j}) - 12\hat{i}$$

$$\Rightarrow \vec{v}_{wm} = -6\hat{i} - 6\hat{j}$$

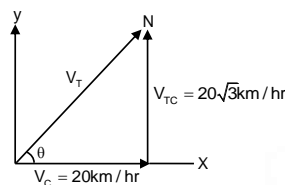


Now relative velocity of wind with respect to man is $6\sqrt{2}$ m/s along S-W.

Example 14:

A man is going eastwards in a car with a speed of 20 km/hr. A train appears to move towards north to him with a speed of $20\sqrt{3}$ km/hr. What is the actual velocity of the train ?

Solution:



$$\vec{v}_{TC} = \vec{v}_T - \vec{v}_C$$

$$\vec{v}_T = \vec{v}_{TC} + \vec{v}_C = 20\sqrt{3}\hat{j} + 20\hat{i}$$

$$|\vec{v}_T| = \sqrt{(20\sqrt{3})^2 + (20)^2} = \sqrt{1600} = 40 \text{ km/hr}$$

$$\tan \theta = \frac{20\sqrt{3}}{20} \Rightarrow \theta = 60^\circ$$

So direction of motion of train is 60° N of E

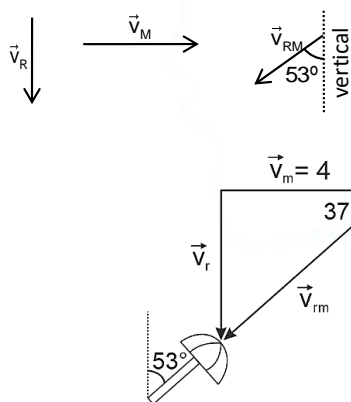
Example 15:

A man at rest observes the rain falling vertically. When he walks with a speed of 4 km/h, he has to hold his umbrella at an angle of 53° with the vertical. Find the velocity of rain.

Solution:

Assigning usual symbols \vec{v}_M , \vec{v}_R and $\vec{v}_{R/M}$ to velocity of man, velocity of rain and velocity of rain relative to man, we can express their relationship by the following equation

$$\vec{v}_{R/M} = \vec{v}_R - \vec{v}_M$$

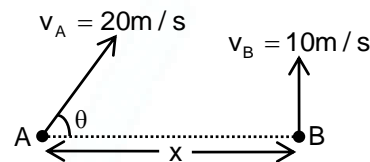


The above equation suggests that a still man observes velocity \vec{v}_R of rain, relative to the ground and while he is moving with velocity \vec{v}_M , he observes velocity of rain relative to himself $\vec{v}_{R/M}$. It is a common intuitive fact that umbrella must be held against $\vec{v}_{R/M}$ for optimum protection from rain. According to these facts, directions of the velocity vectors are shown in the adjoining figure.

Therefore $v_R = v_M \tan 37^\circ = 3 \text{ km/h}$

Example 16:

Two particles A and B are projected from the ground simultaneously in the directions shown in the figure with initial velocities $v_A = 20 \text{ m/s}$ and $v_B = 10 \text{ m/s}$ respectively. They collide after 0.5 s. Find out the angle θ and the distance x .



Solution:

Both particle will collide if they are at same height in same time.

$$y_A = y_B \Rightarrow (u_y)_A t - \frac{1}{2}gt^2 = (u_y)_B t - \frac{1}{2}gt^2$$

$$\Rightarrow (u_y)_A = (u_y)_B \Rightarrow (v_A \sin \theta) = v_B$$

$$\Rightarrow 20 \sin \theta = 10 \Rightarrow \sin \theta = \frac{1}{2} \Rightarrow \theta = 30^\circ$$

In 0.5 s horizontal distance covered by A is

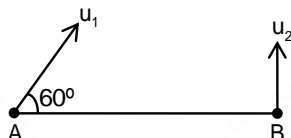
$$x = (u_x)_A t = (20 \cos 30^\circ) 0.5 = 10 \times \frac{\sqrt{3}}{2} = 5\sqrt{3} \text{ m}$$

FUNDAMENTAL UNLOCKED- (FU#3) :

- Q.1** A man 'A' moves along north with a speed 10 m/s and another man B moves 30° North of East with a speed of 10 m/s. Find the relative velocity of B w.r.t. A.
- Q.2** Rain is falling vertically with a speed of 30 ms^{-1} . A woman rides a bicycle with speed of 10 ms^{-1} in the north to south direction. What is the direction in which she should hold her umbrella ?
- Q.3** A man standing in the rain holds an umbrella at an angle of 30° with the vertical. He throws the umbrella and starts running with a speed of 10 km/hr. He find that the rain drops are hitting his head vertically. Find the velocity of rain with respect to the running man. Also calculate the actual speed of rain drops.
- Q.4** A man is running up hill with velocity $(2\hat{i} + 3\hat{j})$ m/s w.r.t. ground. He finds that the rain drops are falling vertically downwards with velocity

4 m/s. If he runs down hill with same speed, find the magnitude of velocity of rain as seen by the person.

- Q.5** A body is projected with velocity u_1 from point A as shown in figure. At the same time another body is projected vertically upwards with a velocity u_2 from point B. What should be value of $\frac{u_1}{u_2}$ for both bodies to collide.

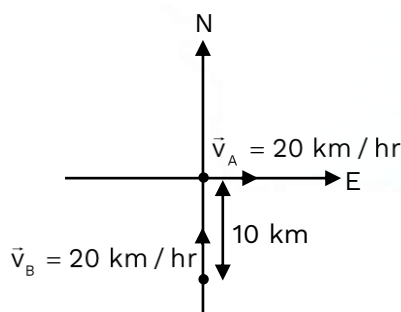


Example 17:

Two bodies A and B are 10 km apart such that B is to the south of A. A and B start moving with the same speed 20 km/hr eastward and northward respectively then find.

- relative velocity of A w.r.t. B.
- minimum separation attained during motion.
- time elapsed from starting, to attain minimum separation.

Solution:



- $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B = 20\hat{i} - 20\hat{j}$
 $\Rightarrow |\vec{v}_{AB}| = 20\sqrt{2} \text{ km/hr}$
- minimum distance
 $= \frac{v_2 \times d}{\sqrt{v_1^2 + v_2^2}} = \frac{20 \times 10}{20\sqrt{2}} = 5\sqrt{2} \text{ km}$
- time to attain minimum separation
 $= \frac{5\sqrt{2}}{20\sqrt{2}} = \frac{1}{4} \times 60 = 15 \text{ min}$

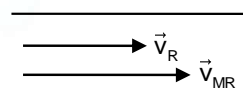
9. River-Boat or River swimmer Problem

A man can swim with velocity \vec{v}_{MR} , i.e. it is the velocity of man w.r.t. still water. If water is also flowing with the velocity \vec{v}_R then velocity of man relative to ground $\vec{v}_M = \vec{v}_R + \vec{v}_{MR}$

- If the swimming is in the direction of flow of water or along the downstream then

$$\vec{v}_M = \vec{v}_{MR} + \vec{v}_R$$

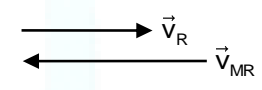
The magnitude of velocity of swimming man with respect to ground is $v_M = v_{MR} + v_R$



- If the swimming is in the direction opposite to the flow of water or along the upstream then

$$\vec{v}_M = \vec{v}_{MR} + \vec{v}_R$$

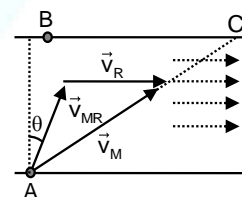
The magnitude of velocity of swimming man with respect to ground is $v_M = v_{MR} - v_R$



- If the man is crossing the river i.e. \vec{v}_{MR} and

\vec{v}_R are non colinear then use vector algebra.

$$\vec{v}_M = \vec{v}_{MR} + \vec{v}_R$$

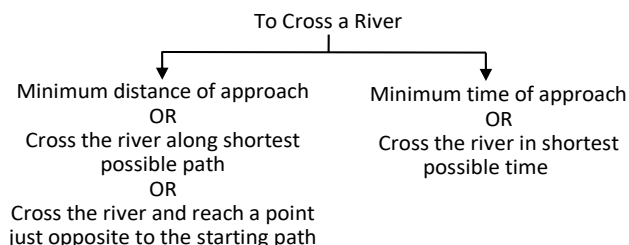


Velocity of swimming man with respect to ground along the river flow direction is

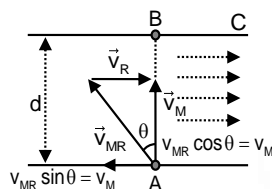
$$v_R + v_{MR} \sin \theta$$

Velocity of swimming man with respect to ground perpendicular to river flow direction is $v_{MR} \cos \theta$

9.1 Crossing The River



• For shortest path



If a man wants to cross the river such that his "displacement should be minimum", it means he intends to reach just opposite point across the river. He should start swimming at an angle θ with the perpendicular to the flow of river towards upstream.

Such that its resultant velocity

$$\vec{v}_M = \vec{v}_{MR} + \vec{v}_R$$

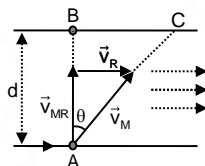
It is in the direction of displacement AB.

To reach at B $v_{MR} \sin \theta = v_R \Rightarrow \sin \theta = \frac{v_R}{v_{MR}}$

component of velocity of man along AB is $v_{MR} \cos \theta$ so time taken

$$t = \frac{d}{v_{MR} \cos \theta} = \frac{d}{\sqrt{v_{MR}^2 - v_R^2}}$$

• For minimum time



To cross the river in minimum time, the velocity along AB ($v_{MR} \cos \theta$) should be maximum.

It is possible if $\theta = 0$, i.e. swimming should start perpendicular to water current.

Due to effect of river velocity, man will reach at point C along resultant velocity, i.e. his displacement will not be minimum but time taken to cross the river will be minimum.

$$t_{\min} = \frac{d}{v_{MR}}$$

In time t_{\min} swimmer travels distance BC along the river with speed of river v_R .

distance travelled along river flow (drift of man) = $BC = t_{\min} v_R = \frac{d}{v_{MR}} v_R$

Example 18:

A boat moves along the flow of river between two fixed points A and B. It takes t_1 time when going downstream and takes t_2 time when going upstream between these two points. What time it will take in still water to cover the distance equal to AB.

Solution:

$$t_1 = \frac{AB}{v_{bR} + v_R}, \quad t_2 = \frac{AB}{v_{bR} - v_R}$$

$$\text{or } v_{bR} + v_R = \frac{AB}{t_1} \quad \text{and} \quad v_{bR} - v_R = \frac{AB}{t_2}$$

$$\Rightarrow 2v_{bR} = \frac{AB}{t_1} + \frac{AB}{t_2}$$

$$= AB \left(\frac{t_1 + t_2}{t_1 t_2} \right) \text{ or } \left(\frac{2t_1 t_2}{t_1 + t_2} \right) = \frac{AB}{v_{bR}} \text{ time taken by the}$$

boat to cover distance AB in still water.

Example 19:

A boat can be rowed at 5 m/s in still water. It is used to cross a 200 m wide river from south bank to the north bank. The river current has uniform velocity of 3 m/s due east.

- In which direction must it be steered to cross the river perpendicular to current ?
- How long will it take to cross the river in a direction perpendicular to the river flow ?
- In which direction must the boat be steered to cross the river in minimum time ? How far will it drift?

Solution:

- To cross the river perpendicular to current i.e. along shortest path

$$\sin \theta = \frac{v_R}{v_{bR}} = \frac{3}{5} \Rightarrow \theta = 37^\circ$$

- Time taken by boat,

$$t = \frac{d}{v_{bR} \cos \theta} = \frac{200}{5 \times \frac{4}{5}} = 50 \text{ s}$$

- To cross the river in minimum time, $\theta = 0^\circ$

$$\text{Therefore } t_{\min} = \frac{d}{v_{bR}} = \frac{200}{5} \text{ s} = 40 \text{ s}$$

$$\text{Drift} = v_R(t_{\min}) = 3(40)\text{m} = 120 \text{ m}$$



FUNDAMENTAL UNLOCKED- (FU#4) :

- Q.1** A man can swim at a speed 2 ms^{-1} in still water. He starts swimming in a river at angle 150° to the direction of water flow and reaches the directly opposite point on the opposite bank.
 (a) Find the speed of flowing water.
 (b) If width of river is 1 km then calculate the time taken to cross the river.
- Q.2** A river 2 km wide is flowing at the rate of 5 km/hr. A man can swim in still water with 10 km/hr. He wants to cross the river along the shortest path. Find –

- (a) The direction in which should the person should swim.
 (b) Time in which the boat crosses the river

- Q.3** A person climbs up on a moving escalator in 60 sec & comes down on the same escalator in 150 seconds. How much time he will be take to walk up on stalled escalator?

ANSWER KEY

FUNDAMENTAL UNLOCKED- (FU#1) :

1. (a) 1 sec (b) 5 m (c) $20\sqrt{3}\text{m}$ (d) 2 sec
 2. 50 m
 3. (a) $\tan^2 \alpha$ (b) 1: 1
 4. 3 km
 5. $\theta = 37^\circ$ 6. $\frac{12}{5} \text{ m}, \frac{4}{5} \text{ m}, \frac{4}{5} \text{ s}$

FUNDAMENTAL UNLOCKED- (FU#2) :

1. (i) 10 sec (ii) 980 m. (iii) $\theta = \pi/4$ rad or 45°
 2. $v = 60 \text{ m/sec}$ 3. $v = 700 \text{ m/sec}$
 4. $h = 10 \text{ m}$
 5. (i) $t = 2 \text{ sec} = \text{Time of flight}$ (ii) 80 m (iii) $|\vec{v}| = 20\sqrt{13} \text{ m/s}$

FUNDAMENTAL UNLOCKED- (FU#3) :

1. $5\sqrt{3}\hat{i} - 5\hat{j}$,
 2. $\alpha = \tan^{-1}\left(\frac{1}{3}\right) = 18.4^\circ$ towards south with respect to vertical 3. $10\sqrt{3} \text{ km/h}, 20 \text{ km/h}$
 4. $\sqrt{20} \text{ m/sec}$ 5. $\frac{2}{\sqrt{3}}$

FUNDAMENTAL UNLOCKED- (FU#4) :

1. (a) $v_R = \sqrt{3} \text{ m/s}$ (b) $t = 1000 \text{ sec}$
 2. (i) Angle made by velocity of man to the river flow = $\frac{2\pi}{3}$ rad or 120° (ii) crossing time $(t) = \frac{2}{5\sqrt{3}} \text{ hrs.}$
 3. $t = \frac{600}{7} \text{ seconds}$




EXERCISE - I
Projectile Motion

- The height y and the distance x along the horizontal plane of a projectile on a certain planet (with no surrounding atmosphere) are given by $y = (8t - 5t^2)$ meter and $x = 6t$ meter, where t is in second. The velocity with which the projectile is projected is:
 - 8 m/s
 - 6 m/s
 - 10 m/s
 - Not obtainable from the data
- Referring to question no. 1, the angle with the horizontal at which the projectile was projected is:
 - $\tan^{-1} (3/4)$
 - $\tan^{-1} (4/3)$
 - $\sin^{-1} (3/4)$
 - Not obtainable from the data
- Referring to question no. 1, the acceleration due to gravity is given by:
 - 10 m/s^2
 - 5 m/s^2
 - 20 m/s^2
 - 2.5 m/s^2
- When a body is thrown with a velocity u making an angle θ with the horizontal plane, the maximum distance covered by it in horizontal direction is:
 - $\frac{u^2 \sin \theta}{g}$
 - $\frac{u^2 \sin \theta}{2g}$
 - $\frac{u^2 \sin 2\theta}{g}$
 - $\frac{u^2 \cos 2\theta}{g}$
- If a projectile is fired at an angle θ with the vertical with velocity u , then maximum height attained is given by:–
 - $\frac{u^2 \cos \theta}{2g}$
 - $\frac{u^2 \sin^2 \theta}{2g}$
 - $\frac{u^2 \sin^2 \theta}{g}$
 - $\frac{u^2 \cos^2 \theta}{2g}$
- A ball is thrown at an angle θ with the horizontal and the range is maximum. The value of $\tan \theta$ is:
 - 1
 - $\sqrt{3}$
 - $\frac{1}{\sqrt{3}}$
 - 2
- A cricketer can throw a ball to a maximum horizontal distance of 100 m. The speed with which he throws the ball is (to the nearest integer):
 - 30 ms^{-1}
 - 42 ms^{-1}
 - 32 ms^{-1}
 - 35 ms^{-1}
- The horizontal range of a projectile is $4\sqrt{3}$ times its maximum height. Its angle of projectile will be:
 - 45°
 - 60°
 - 90°
 - 30°
- Two bodies are thrown up at angles of 45° and 60° respectively, with the horizontal. If both bodies attain same vertical height, then the ratio of velocities with which these are thrown is:
 - $\sqrt{\frac{2}{3}}$
 - $\frac{2}{\sqrt{3}}$
 - $\sqrt{\frac{3}{2}}$
 - $\frac{\sqrt{3}}{2}$
- A bullet is fired with a speed of 1000 m/sec in order to hit a target 100 m away. If $g = 10 \text{ m/s}^2$, the gun should be aimed:
 - Directly towards the target
 - 5 cm above the target
 - 10 cm above the target
 - 15 cm above the target
- The range of a projectile when fired at 75° with the horizontal is 0.5 km. What will be its range when fired at 45° with same speed:
 - 0.5 km.
 - 1.0 km.
 - 1.5 km.
 - 2.0 km.





12. The speed at the maximum height of a projectile is $\frac{\sqrt{3}}{2}$ times of its initial speed 'u' of projection. Its range on the horizontal plane:

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

13. If R is the maximum horizontal range of a particle, then the greatest height attained by it is:

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

14. A projectile is thrown into space so as to have the maximum possible horizontal range equal to 400 m. Taking the point of projection as the origin, the coordinates of the point where the velocity of the projectile is minimum are:

(1) (400, 100) (2) (200, 100)
(3) (400, 200) (4) (200, 200)

15. Two stones are projected with the same speed but making different angles with the horizontal. Their ranges are equal. If the angle of projection of one is $\frac{\pi}{3}$ and its maximum height is y_1 then the maximum height of the other will be:

(1) $3y_1$ (2) $2y_1$
(3) $\frac{y_1}{2}$ (4) $\frac{y_1}{3}$

16. An arrow is shot into the air. Its range is 200 metres and its time of flight is 5 s. Then the horizontal component of the velocity of arrow is:

(1) 25 m/s (2) 40 m/s
(3) 31.25 m/s (4) 12.5 m/s

Projectile from a Tower

17. An aeroplane moving horizontally with a speed of 180 km/hr. drops a food packet while flying at a height of 490 m. The horizontal range of the packet is ($g = 9.8 \text{ m/s}^2$):

(1) 180 m (2) 980 m
(3) 500 m (4) 670 m

18. A plane is flying horizontally at 98 ms^{-1} and releases an object which reaches the ground in 10 s. The angle made by it while hitting the ground is ($g = 9.8 \text{ m/s}^2$):

(1) 55° (2) 45°
(3) 60° (4) 75°

19. An aeroplane is moving with a velocity u. It drops a packet from a height h. The time t taken by the packet in reaching the ground will be:

(1) $\sqrt{\left(\frac{2g}{h}\right)}$ (2) $\sqrt{\left(\frac{2u}{h}\right)}$
(3) $\sqrt{\left(\frac{h}{2g}\right)}$ (4) $\sqrt{\left(\frac{2h}{g}\right)}$

20. An aeroplane is moving with horizontal velocity u at height h. The velocity of a packet dropped from it on the earth's surface will be (g is acceleration due to gravity)

(1) $\sqrt{u^2 + 2gh}$ (2) $\sqrt{2gh}$
(3) 2gh (4) $\sqrt{u^2 - 2gh}$

21. Particle is dropped from the height of 20 m on horizontal ground. There is wind blowing due to which horizontal acceleration of the particle becomes 6 ms^{-2} . Find the horizontal displacement of the particle till it reaches ground ($g = 10 \text{ m/s}^2$):

(1) 6m (2) 10 m
(3) 12m (4) 24 m




Equation of Trajectory

22. The equation of a projectile is $y = \sqrt{3}x - \frac{gx^2}{2}$ the angle of projection is:—
 (1) 30° (2) 60°
 (3) 45° (4) none
23. The equation of projectile is $y = 16x - \frac{x^2}{4}$ the horizontal range is:—
 (1) 16 m (2) 8 m
 (3) 64 m (4) 12.8 m

Relative Motion in Two Dimension

24. A bird is flying with a speed of 40 km/hr in the north direction. A train is moving with a speed of 40 km/hr in the west direction. A passenger sitting in the train will see the bird moving with velocity:—
 (1) 40 km/hr in NE direction
 (2) $40\sqrt{2}$ km/hr in NE direction
 (3) 40 km/hr in NW direction
 (4) $40\sqrt{2}$ km/hr in NW direction
25. A ship is travelling due east at 10 km/hr. A second ship heading 30° east of north is always due north from the first ship. The speed of the second ship in km/h is -
 (1) $20\sqrt{2}$ (2) $20\sqrt{3/2}$
 (3) 20 (4) 10
26. Two balls are thrown simultaneously, (A) vertically upwards with a speed of 20 m/s from the ground and (B) vertically downwards from a height of 40 m with the same speed and along the same line of motion. At which point the balls will collide:—
 (take $g = 10 \text{ m/sec}^2$)
 (1) 15 m above from the ground
 (2) 15 m below from the top of the tower
 (3) 20 m above from the ground
 (4) 20 m below from the top of the tower

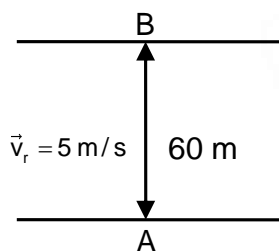
Relative Motion in River Flow

27. A river is flowing from east to west at a speed of 5 m/min. A man on south bank of river, capable of swimming 10 m/min in still water, wants to swim across the river in shortest distance; he should swim:—
 (1) 30° from perpendicular to the flow
 (2) 60° from perpendicular to the flow
 (3) 0° from perpendicular to the flow
 (4) none of the above
28. A boat is sailing at a velocity $(3\hat{i} + 4\hat{j})$ with respect to ground and water in river is flowing with a velocity $(-3\hat{i} - 4\hat{j})$. Relative velocity of the boat with respect to water is:
 (1) $8\hat{j}$ (2) $5\sqrt{2}$
 (3) $6\hat{i} + 8\hat{j}$ (4) $-6\hat{i} - 8\hat{j}$
29. A boat takes 2 hours to go 8 km and come back in still water lake. With water velocity of 4 km/hr, the time taken for going upstream of 8 km and coming back is:
 (1) 140 min (2) 150 min
 (3) 160 min (4) 170 min
30. A boat, which has a speed of 5 km/hr in still water, crosses a river of width 1 km along the shortest possible path in 15 minutes. The velocity of the river water in km/hr is:
 (1) 1 (2) 3
 (3) 4 (4) $\sqrt{41}$
31. A man wishes to swim across a river 0.5 km wide. If he can swim at the rate of 2 km/hr in still water and the river flows at the rate of 1 km/h. The angle (w.r.t. the flow of the river) along which he should swim so as to reach a point exactly opposite his starting point, should be:
 (1) 60° (2) 120°
 (3) 145° (4) 90°





32. A man is crossing a river flowing with velocity of 5 m/s. He reaches a point directly across at distance of 60 m in 5 s. His velocity in still water should be:



- (1) 12 m/s (2) 13 m/s
(3) 5 m/s (4) 0 m/s

33. A man is walking on a road with a velocity 3 km/hr. Suddenly rain starts falling. The velocity of rain is 10 km/hr in vertically downward direction. the relative velocity of the rain with respect to man is:

- (1) $\sqrt{13}$ km/hr (2) $\sqrt{7}$ km/hr
(3) $\sqrt{109}$ km/hr (4) 13 km/hr

34. It is raining vertically downwards with a velocity of 3 km/hr. A man walks in the rain with a velocity of 4 km/hr. The rain drops will fall on the man with a relative velocity of ;

- (1) 1 km/hr (2) 3 km/hr
(3) 4 km/hr (4) 5 km/hr




EXERCISE – II

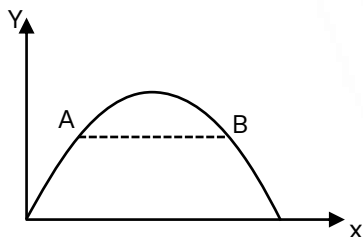
1. A boy is running on the plane road with velocity (v) with a long hollow tube in his hand. The water is falling vertically downwards with velocity (u). At what angle to the vertical, he must incline the tube so that the water drops enters in it without touching its side:-
 (1) $\tan^{-1}\left(\frac{v}{u}\right)$ (2) $\sin^{-1}\left(\frac{v}{u}\right)$
 (3) $\tan^{-1}\left(\frac{u}{v}\right)$ (4) $\cos^{-1}\left(\frac{v}{u}\right)$
2. For angles of projection of a projectile at angles $(45^\circ - \theta)$ and $(45^\circ + \theta)$, the horizontal ranges described by the projectile are in the ratio of:-
 (1) 1 : 1 (2) 2 : 3
 (3) 1 : 2 (4) 2 : 1
3. The speed of a projectile at its maximum height is half of its initial speed. The angle of projection is:-
 (1) 15° (2) 30°
 (3) 45° (4) 60°
4. A ball thrown upward at an angle of 30° to the horizontal lands on the top edge of a building 20 m away. The top edge is 5m above the throwing point. The ball was thrown with a speed of
 (1) 40 m/s (2) 10 m/s
 (3) 20 m/s (4) 30 m/s
5. A ball rolls from the top of a stair way with a horizontal velocity u . If the steps are h high and b wide, the ball will hit the edge of the n th step if
 (1) $n = 2hu/gb^2$ (2) $n = 2hu^2/gb^2$
 (3) $n = 2hu^2/gb$ (4) $n = hu^2/gb^2$
6. An aluminum ball X and an iron ball Y of the same volume are thrown horizontally with the same velocity from the top of a building. Neglecting air resistance, X reaches the ground
 (1) before Y and at the same distance from the building
 (2) at the same time as Y and at a near distance from the building
 (3) at the same time as Y and at a same distance from the building
 (4) at the same time as Y and at a farther distance from the building
7. The equation of projectile is $y = \sqrt{3}x - \frac{1}{2}gx^2$.
 The velocity of projection is
 (1) 1 m/s (2) 2 m/s
 (3) 3 m/s (4) 4 m/s
8. A particle moves along the positive branch of the curve $y = x^2/2$ with x governed by $x = t^2/2$ where x and y are measured in metre and t in second. At $t = 2$ s, the velocity of the particle is
 (1) $2\hat{i} - 4\hat{j}$ m/s (2) $2\hat{i} + 4\hat{j}$ m/s
 (3) $4\hat{i} + 2\hat{j}$ m/s (4) $4\hat{i} - 2\hat{j}$ m/s
9. Two particles are projected simultaneously in the same vertical plane from the same point, with different speeds u_1 and u_2 , making angles θ_1 and θ_2 respectively with the horizontal, such that $u_1 \cos\theta_1 = u_2 \cos\theta_2$. The path followed by one, as seen by the other (as long as both are in flight), is
 (1) a horizontal straight line
 (2) a vertical straight line
 (3) a parabola
 (4) a straight line making an angle $|\theta_1 - \theta_2|$ with the horizontal.





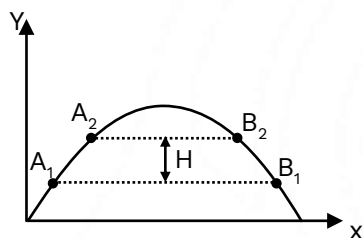
EXERCISE – III

1. A projectile is thrown from the origin such that it reaches the point A in time 2 sec. In the next 4 seconds, it reaches the point B. What is the maximum height attained by the projectile



- (1) 70 (2) 60
(3) 80 (4) none of these

2. As shown trajectory of projectile if time for $t_{A_1B_1} = 6$ sec and $t_{A_2B_2} = 2$ sec, then value of H?



- (1) 36 m
(2) 40 m
(3) 20 m
(4) 32 m

3. Displacement in x and y with t are given as $x = 5t$; $y = -t^2 + 5t$. What is the magnitude and direction of the velocity with which the body is projected?

- (1) 5 m/sec. At an angle 45° with the horizontal
(2) $5\sqrt{2}$ m/sec. At an angle 45° with the horizontal
(3) 5 m/sec. At an angle 30° with the horizontal
(4) $5\sqrt{2}$ m/sec. At an angle 30° with the horizontal

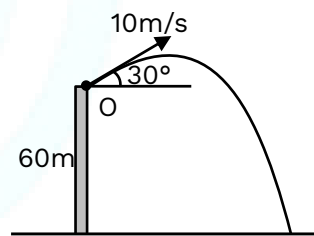
4. A particle is projected from ground with speed 80 m/s at an angle 30° with horizontal from ground. The magnitude of average velocity of particle in time interval $t = 2$ s to $t = 6$ s is [Take $g = 10 \text{ m/s}^2$]

- (1) $40\sqrt{2}$ m/s
(2) 40 m/s
(3) zero
(4) $40\sqrt{3}$ m/s

5. A ball is projected from ground at an angle 45° with horizontal from distance d_1 from the foot of a pole and just after touching the top of pole it falls on ground at distance d_2 from pole. Find the height of the pole

- (1) $2\sqrt{d_1d_2}$
(2) $\frac{d_1d_2}{d_1 + d_2}$
(3) $\frac{2d_1d_2}{d_1 + d_2}$
(4) $\frac{d_1 + d_2}{d_1 + d_2}$

6. A ball is projected from point O as shown in figure. It will strike the ground ($g = 10 \text{ m/s}^2$)



- (1) 4s
(2) 3s
(3) 2s
(4) 5s

Read the (7 to 11)

In the light of the above statements, choose the most appropriate answer from the options given below:

Assertion and **Reason** carefully and mark the correct options.

- (A) Both **Assertion** and **Reason** are true and **Reason** is the correct explanation of **Assertion**.
(B) Both **Assertion** and **Reason** are true but **Reason** is not correct explanation of **Assertion**.
(C) **Assertion** is true but **Reason** is false.
(D) **Assertion** and **Reason** are false





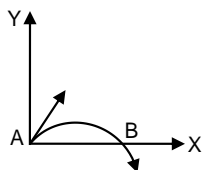
- | | |
|---|---|
| <p>7. Assertion: Total time of flight of a projectile remains unchanged if wind is blowing in horizontal direction.
Reason: Horizontal and vertical motion of a projectile are dependent on each other.
(1) A
(2) B
(3) C
(4) D</p> <p>8. Assertion: At an angle of projection of nearly 76°, the horizontal range and maximum height are equal.
Reason: $\tan\theta = 4H/R$
where H is maximum height, R is range and θ is angle of projection.
(1) A
(2) B
(3) C
(4) D</p> | <p>9. Assertion: At the highest point, velocity of projectile is zero.
Reason: At maximum height projectile comes to rest.
(1) A (2) B
(3) C (4) D</p> <p>10. Assertion: Horizontal range is same for angle of projection θ and $(90^\circ - \theta)$.
Reason: Horizontal range is independent upon the angle of projection.
(1) A (2) B
(3) C (4) D</p> <p>11. Assertion: Under constant force trajectory of a particle is always parabolic.
Reason: If angle between initial velocity and acceleration is zero then path is parabolic.
(1) A (2) B
(3) C (4) D</p> |
|---|---|





EXERCISE – IV (PREVIOUS YEAR QUESTIONS)

1. The velocity of a projectile at the initial point A is $(2\hat{i} + 3\hat{j})$ m/s. Its velocity (in m/s) at point B is: [AIPMT_2013]



- (1) $2\hat{i} + 3\hat{j}$ (2) $-2\hat{i} - 3\hat{j}$
 (3) $-2\hat{i} + 3\hat{j}$ (4) $2\hat{i} - 3\hat{j}$
2. A particle is moving such that its position coordinate (x, y) are
 (2m, 3m) at time t = 0
 (6m, 7m) at time t = 2 s and
 (13m, 14m) at time t = 5 s.
 Average velocity vector (\vec{v}) from t = 0 to t = 5s is: [AIPMT_2014]
- (1) $\frac{1}{5}(13\hat{i} + 14\hat{j})$ (2) $\frac{7}{3}(\hat{i} + \hat{j})$
 (3) $2(\hat{i} + \hat{j})$ (4) $\frac{11}{5}(\hat{i} + \hat{j})$
3. A projectile is fired from the surface of the earth with a velocity of 5 ms^{-1} and angle θ with the horizontal. Another projectile fired from another planet with a velocity of 3 ms^{-1} at the same angle follows a trajectory which is identical with the trajectory of the projectile fired from the earth. The value of the acceleration due to gravity on the planet is (in ms^{-2}) is: (given $g = 9.8 \text{ m/s}^2$) [AIPMT_2014]
- (1) 3.5 (2) 5.9
 (3) 16.3 (4) 110.8
4. A ship A is moving Westwards with a speed of 10 km h^{-1} and a ship B, 100 km South of A, is moving Northwards with a speed of 10 km h^{-1} . The time after which the distance between them becomes shortest, is: [AIPMT_2015]
- (1) 5 h (2) $5\sqrt{2} \text{ h}$
 (3) $10\sqrt{2} \text{ h}$ (4) 0 h

5. Two particles A and B, move with constant velocities \vec{v}_1 and \vec{v}_2 . At the initial moment their position vectors are \vec{r}_1 and \vec{r}_2 respectively. The condition for particle A and B for their collision is:

[REAIPTM_2015]

- (1) $\vec{r}_1 - \vec{r}_2 = \vec{v}_1 - \vec{v}_2$ (2) $\frac{\vec{r}_1 - \vec{r}_2}{|\vec{r}_1 - \vec{r}_2|} = \frac{\vec{v}_2 - \vec{v}_1}{|\vec{v}_2 - \vec{v}_1|}$
 (3) $\vec{r}_1 \cdot \vec{v}_1 = \vec{r}_2 \cdot \vec{v}_2$ (4) $\vec{r}_1 \times \vec{v}_1 = \vec{r}_2 \times \vec{v}_2$
6. The x and y coordinates of the particle at any time are $x = 5t - 2t^2$ and $y = 10t$ respectively, where x and y are in meters and t in seconds. The acceleration of the particle at t = 2s is:- [NEET_2017]
- (1) 5 m/s^2 (2) -4 m/s^2
 (3) -8 m/s^2 (4) 0
7. The speed of a swimmer in still water is 20 m/s. The speed of river water is 10 m/s and is flowing due east. If he is standing on the south bank and wishes to cross the river along the shortest path, the angle at which he should make his strokes w.r.t. north is given by: [NEET_2019]
- (1) 30° west (2) 0°
 (3) 60° west (4) 45° west
8. When an object is shot from the bottom of a long smooth inclined plane kept at an angle 60° with horizontal, it can travel a distance x_1 along the plane. But when the inclination is decreased to 30° and the same object the shot with the same velocity, it can travel x_2 distance. Then $x_1 : x_2$ will be [NEET_2019]
- (1) $1 : \sqrt{2}$ (2) $\sqrt{2} : 1$
 (3) $1 : \sqrt{3}$ (4) $1 : 2\sqrt{3}$
9. Two bullets are fired horizontally and simultaneously towards each other from roof tops of two buildings 100 m apart and of same height of 200 m with the same velocity of 25 m/s. When and where will the two bullets collide. ($g = 10 \text{ m/s}^2$) [NEET_2019(Odisha)]





- (1) after 2s at a height 180 m w.r.t. ground
- (2) after 2s at a height of 20 m w.r.t. ground
- (3) after 4s at a height of 120 m w.r.t. ground
- (4) they will not collide

10. A car starts from rest and accelerates at 5 m/s^2 . At $t = 4 \text{ s}$, a ball is dropped out of a window by a person sitting in the car. What is the velocity and acceleration of the ball at $t = 6 \text{ s}$? (Take $g = 10 \text{ m/s}^2$) [NEET_2021]

- (1) 20 m/s , 5 m/s^2
- (2) 20 m/s , 0
- (3) $20\sqrt{2} \text{ m/s}$, 0
- (4) $20\sqrt{2} \text{ m/s}$, 10 m/s^2

11. A ball is projected with a velocity, 10 ms^{-1} , at an angle of 60° with the vertical direction. Its speed at the highest point of its trajectory will be: [NEET_2022]

- (1) Zero
- (2) $5\sqrt{3} \text{ ms}^{-1}$
- (3) 5 ms^{-1}
- (4) 10 ms^{-1}

12. A horizontal bridge is built across a river. A student standing on the bridge throws a small ball vertically upwards with a velocity 4 ms^{-1} . The ball strikes the water surface after 4 s . The height of bridge above water surface is (Take $g = 10 \text{ ms}^{-2}$): [NEET_2023]

- (1) 56 m
- (2) 60 m
- (3) 64 m
- (4) 68 m

13. The position of a particle is given by

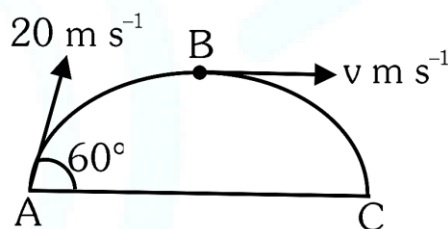
$$\vec{r}(t) = 4t\hat{i} + 2t^2\hat{j} + 5\hat{k}$$

where t is in seconds and r in metre. Find the magnitude and direction of velocity $v(t)$, at $t = 1 \text{ s}$, with respect to x -axis

[NEET_2023(Manipur)]

- (1) $4\sqrt{2} \text{ ms}^{-1}$, 45°
- (2) $4\sqrt{2} \text{ ms}^{-1}$, 60°
- (3) $3\sqrt{2} \text{ ms}^{-1}$, 30°
- (4) $3\sqrt{2} \text{ ms}^{-1}$, 45°

14. A ball is projected from point A with velocity 20 ms^{-1} at an angle 60° to the horizontal direction. At the highest point B of the path (as shown in figure), the velocity $v \text{ ms}^{-1}$ of the ball will be: [NEET_2023(Manipur)]



- (1) 20
- (2) $10\sqrt{3}$
- (3) Zero
- (4) 10





ANSWER KEY

EXERCISE – I

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	3	2	1	3	4	1	3	4	3	2	2	1	4	2	4
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	2	3	2	4	1	3	2	3	2	3	1	1	3	3	2
Que.	31	32	33	34											
Ans.	2	2	3	4											

EXERCISE – II

Que.	1	2	3	4	5	6	7	8	9
Ans.	1	1	4	3	2	3	2	2	2

EXERCISE – III

Que.	1	2	3	4	5	6	7	8	9	10	11
Ans.	3	2	2	4	2	4	3	1	4	3	4

EXERCISE – IV (PREVIOUS YEAR QUESTIONS)

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ans.	4	4	1	1	2	2	1	3	1	4	2	3	1	4

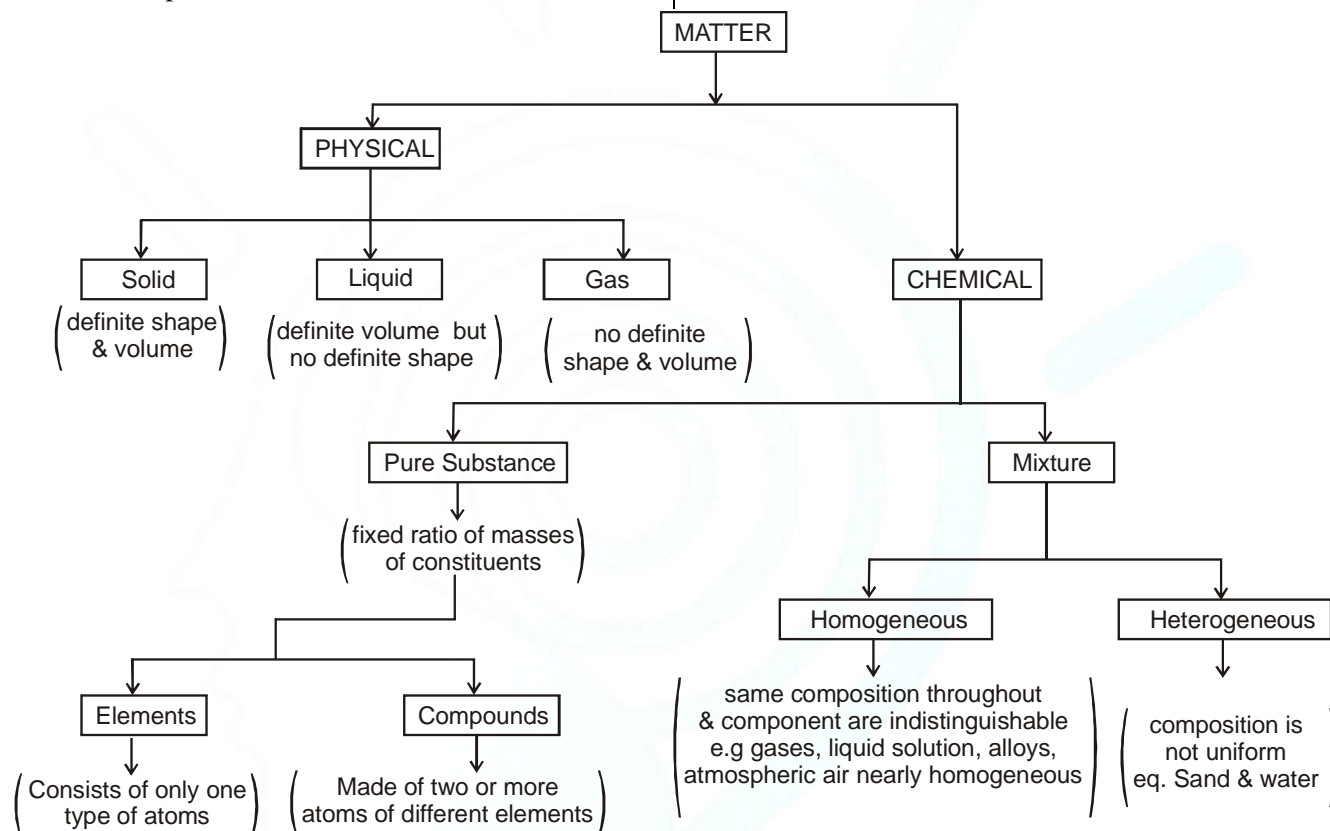


SOME BASIC CONCEPTS OF CHEMISTRY

Introduction

Chemistry deals with the composition, structure and properties of matter. These aspects can be best described and understood in terms of basic constituents of matter: **atoms** and **molecules**. That is why chemistry is called the science of atoms and molecules. Can we see, weight and perceive these entities? Is it possible to count the number of atoms

and molecules in a given mass of matter and have a quantitative relationship between the mass and number of these particles (atoms and molecules)? We will like to answer some of these questions in this Unit. We would further describe how physical properties of matter can be quantitatively described using numerical values with suitable units.



Classification of Universe

(A) Matter (B) Energy

(A) Matter: The thing which occupy space and having mass which can be felt by our five senses is called matter.

Matter is further classified into two categories:

- (I) Physical classification
- (II) Chemical classification

Physical Classification

It is based on physical state under ordinary conditions of temperature and pressure, so on the basis of two nature of forces matter can be classified into the following three ways :

(a) Solid (b) Liquid (c) Gas

(a) Solid: A substance is said to be solid if it possesses a definite volume and a definite shape.

Example: sugar, iron, gold, wood etc.

(b) Liquid: A substance is said to be liquid if it possesses a definite volume but not definite shape. They take up the shape of the vessel in which they are put.

Example: water, milk, oil, mercury, alcohol etc.

(c) Gas: A substance is said to be gas if it neither possesses a definite volume nor a definite shape. This is because they fill up the whole vessel in which they are put.

Example:

hydrogen(H_2), Oxygen(O_2), carbon dioxide(CO_2) etc.

**Chemical Classification:**

It may be classified into two types :

- (a) Pure Substance (b) Mixture

(a) Pure Substance: A material containing only one type of substance. Pure Substance can not be separated into simpler substance by physical method.

Example:

Element = Na, Mg, Ca etc.

Compound = HCl, H₂O, CO₂, HNO₃etc.

Pure substance is classified into two types :

- (a) Element (b) Compound

(i) Element: The pure substance containing only one kind of atoms.

It is classified into 3 types (depend on physical and chemical property)

(i) Metal → Zn, Cu, Hg, Ag, Sn, Pb etc.

(ii) Non-metal → N₂, O₂, Cl₂, Br₂, F₂, P₄, S₈ etc.

(iii) Metalloids → B, Si, As, Te etc.

(ii) Compound: It is defined as pure substance containing more than one kind of elements or atoms which are combined together in a fixed proportion by weight and which can be decomposed into simpler substance by the suitable chemical method. The properties of a compound are completely different from those of its constituent element.

Example:

HCl, H₂O, H₂SO₄, HClO₄, HNO₃ etc.

(b) Mixture: A material which contain more than one type of substances and which are mixed in any ratio by weight is called as mixture. The property of the mixture is the property of its components. The mixture can be separated by simple physical method.

Mixture is classified into two types :

(i) Homogeneous mixture: The mixture, in which all the components are present **uniformly** is called as homogeneous mixture. Components of mixture are present in single phase.

Example:

Water + Salt, Water + Sugar, Water + alcohol.

(ii) Heterogeneous mixture: The mixture, in which all the components are present **non-uniformly**

Example:

Water + Sand, Water + Oil, blood, petrol etc.

Mole Concept

In SI Units we represent mole by the symbol 'mol'. It is defined as follows:

(i) A mole is the amount of a substance that contains as many entities (atoms, molecules or other particles) as there are atoms in exactly 12g of the carbon - 12 isotope.

It may be emphasised that the mole of a substance always contains the same number of entities, no matter what the substance may be. In order to determine this number precisely, the mass of a carbon-12 atom was determined by a mass spectrometer and found to be equal to 1.992648×10^{-23} g. Knowing that 1 mole of carbon weighs 12g, the number of atoms in it is equal to:

$$\frac{12 \text{ g/mol C}^{12}}{1.992648 \times 10^{-23} \text{ g/C}^{12} \text{ atom}} = 6.0221367 \times 10^{23} \text{ atoms/mol}$$

(ii) In a simple way, we can say that mole has 6.0221367×10^{23} entities (atom, molecules or ions etc.) The number of entities in 1 mol is so important that it is given a separate name and symbol, known as '**Avogadro constant**' denoted by N_A .

Here entities may represent atoms, ions, molecules or other subatomic entities. Chemists count the number of atoms and molecules by weighing. In a reaction we require these particles (atoms, molecules and ions) in a definite ratio. We make use of this relationship between numbers and masses of the particles for determining the stoichiometry of reactions.

Formula to get moles are following :

$$(i) \quad \text{Number of moles}(n) = \frac{\text{Weight(g)}}{\text{molar mass}}$$

Where molar mass = gram atomic mass or gram molecular mass or gram ionic mass



$$(ii) \quad \boxed{\text{Number of moles}(n) = \frac{V_{(L)}}{22.4}} \quad (\text{Where } V$$

= Volume of gas in L at NTP or STP

$$(iii) \quad \boxed{\text{Number of moles}(n) = \frac{N}{N_A}}$$

(Where N = Number of particles)

$$\text{mole atoms} = \frac{\text{number of atoms}}{N_A} \quad \text{and mole}$$

$$\text{molecules} = \frac{\text{number of molecules}}{N_A}$$

Some Related Definitions

Atomic Mass (Relative Atomic Mass):

It is defined as the number which indicates how many times the mass of one atom of an element is heavier in comparison to $\frac{1}{12}$ th part of the mass of one atom of C-12.

Atomic mass unit (a.m.u.) : The quantity $\frac{1}{12}$ th mass

of an atom of C^{12} is known as atomic mass unit.

Since mass of 1 atom of C - 12 = 1.9924×10^{-23} g

$\therefore \frac{1}{12}$ part of the mass of 1 atom

$$= \frac{1.9924 \times 10^{-23} \text{ g}}{12} = 1.67 \times 10^{-24} \text{ g} = 1 \text{ a.m.u.}$$

$$= \frac{1}{6.023 \times 10^{23}}$$

It may be noted that the atomic masses as obtained above are the relative atomic masses and not the actual masses of the atoms. These masses on the atomic mass scale are expressed in terms of atomic mass units (abbreviated as amu). Today, 'amu' has been replaced by 'u' which is known as unified mass.

One atomic mass unit (amu) is equal to $\frac{1}{12}$ th of the

mass of an atom of carbon - 12 isotope.

Thus the atomic mass of hydrogen is 1.008 amu while that of oxygen is 15.9994 amu (or taken as 16 amu).

Gram Atomic Mass (or Mass of 1 Gram Atom) :

When numerical value of atomic mass of an element is expressed in grams then the value becomes gram atomic mass.

= mass of 1 **gram atom** = mass of 1 **mole atom**

gram atomic mass = mass of N_A atoms = mass of 6.023×10^{23} atoms.

Example.

gram atomic mass of oxygen = mass of 1 **g atom** of oxygen = mass of 1 **mol atom** of oxygen.

$$= \text{mass of } N_A \text{ atoms of oxygen.} = \left(\frac{16}{N_A} \text{ g} \right) \times N_A = 16 \text{ g}$$

Molecular Mass (Relative Molecular Mass)

The number which indicates how many times the mass of one molecule of a substance is heavier in

comparison to $\frac{1}{12}$ th part of the mass of an atom of C-12

Gram Molecular Mass (Mass of 1 Gram Molecule)

When numerical value of molecular mass of the substance is expressed in grams then the value becomes gram molecular mass.

gram molecular mass = mass of 1 **gram**

molecule = mass of 1 **mole molecule** = mass of N_A

molecules = mass of 6.023×10^{23} molecules

Example.

gram molecular mass of H_2SO_4 = mass of 1 **gram molecule** of H_2SO_4

= mass of 1 **mole molecule** of H_2SO_4

= mass of N_A molecules of H_2SO_4

$$= \left(\frac{98}{N_A} \text{ g} \right) \times N_A = 98 \text{ g}$$

Actual Mass

The mass of one atom or one molecule of substance expressed in gram is called as actual mass.

Example.

(i) Actual mass of O_2 = 32 amu = $32 \times 1.67 \times 10^{-24}$ g
→ Actual mass

(ii) Actual mass of H_2O = (2 + 16) amu = $18 \times 1.67 \times 10^{-24}$ g = 2.99×10^{-23} g

Atomicity

Total number of atoms in a **molecule** of elementary substance is called as atomicity.

**Example.4**

Molecule	Atomicity
H ₂	2
O ₂	2
O ₃	3
NH ₃	4

Example.

Calculate the number of molecules of sulphur dioxide in 0.064 g of the gas.

Solution.

Gram molecular weight of sulphur dioxide (SO₂) = 64gm

Given mass = 0.064 gm

Gram molecular weight of any gas contain avogadro number of molecules = 6.023×10^{23}

\therefore 0.064 g of sulphur dioxide contain molecules = 6.023×10^{20}

Example.

Which of the following contains the least number of molecules -

(1) 16g of CO₂ (2) 8g of O₂ (3) 4g of N₂ (4) 2g of H₂

Solution. (3)

(1) No. of moles of CO₂ = $\frac{\text{Weight}}{\text{Molecular weight}}$

$$= \frac{16}{44} = 0.36$$

(2) Number of moles of O₂ = $\frac{8}{32} = 0.25$

(3) Number of moles of N₂ = $\frac{4}{28} = 0.14$

(4) Number of moles of H₂ = $\frac{2}{2} = 1$

Example.

Atomic weight of helium is 4. Calculate the number of atoms in 1g of helium.

Solution.

4g of Helium contains 6.023×10^{23} atoms

1g of Helium contains $\frac{6.023 \times 10^{23}}{4} = 1.506 \times 10^{23}$

atoms

Example.

What is the mass of 1 molecule of CO

Solution.

Gram molecular weight of CO = 12 + 16 = 28g

6.023×10^{23} molecules of CO weighs 28gm

1 molecule of CO weighs = $\frac{28}{6.02 \times 10^{23}} = 4.65 \times 10^{-23}$ g

Example.

Calculate the volume at STP occupied by 240gm of SO₂.

Solution.

Molecular weight of SO₂ = 32 + 2 × 16 = 64

64 gm of SO₂ occupies 22.4 litre at STP

240 gm of SO₂ occupies = $\frac{22.4}{64} \times 240 = 84$ litre at STP

Example.

Calculate the number of atoms in each of the following -

(a) 52 mole of He (b) 52 amu (c) 52 g of He

Solution.

(a) 1mole of He contain 6.02×10^{23} atoms

\therefore 52 mole of He contain = $52 \times 6.02 \times 10^{23}$
= 31.3×10^{24} atoms

(b) Atomic weight of He = 4amu

\therefore 52 amu of He contain = $\frac{52}{4} = 13$ atoms of He

(c) Number of moles of He in 52g = $\frac{52}{4} = 13$ moles

\therefore no. of atoms in 52g of He i.e. 13 moles
= $13 \times 6.02 \times 10^{23}$ atoms
= 78.26×10^{23} atoms

Relation Between Molecular Weight and Vapour Density

Vapour density (V.D) : Vapour density of a gas is the ratio of densities of gas & hydrogen at the same temperature & pressure.

$$\text{Vapour Density (V.D.)} = \frac{\text{Density of gas}}{\text{Density of hydrogen}} = \frac{d_{\text{gas}}}{d_{\text{H}_2}} \left\{ d = \frac{m(\text{mass})(\text{g})}{V(\text{volume})(\text{mL})} \right\}$$





$$V.D. = \frac{(m_{\text{gas}}) \text{ for certain V litre volume}}{(m_{\text{H}_2}) \text{ for certain V litre volume}}$$

If N molecules are present in the given volume of a gas and hydrogen under similar condition of temperature and pressure.

$$V.D. = \frac{(m_{\text{gas}}) \text{ of N molecules}}{(m_{\text{H}_2}) \text{ of N molecules}}$$

$$= \frac{(m_{\text{gas}}) \text{ of 1 molecule}}{(m_{\text{H}_2}) \text{ of 1 molecule}}$$

$$= \frac{\text{Molecular mass of gas}}{2}$$

$$\therefore \boxed{\text{Molecular mass of gas}(M_w) = 2 \times V.D.}$$

Relation Between Molar Mass & Volume:

$$d_{\text{H}_2} = 0.000089 \frac{\text{g}}{\text{mL}} = \frac{m}{V} = \frac{m}{1000 \text{ mL}}$$

$$V = 1 \text{ litre} = 1000 \text{ mL}$$

$$\text{then } m_{\text{H}_2} = 0.089 \text{ g}$$

$$\text{At STP, } M_w = 2 \times V.D$$

=

$$2 \times \frac{d_{\text{gas}}}{d_{\text{H}_2}} = 2 \times \frac{(m_{\text{gas}}) \text{ for certain V litre volume}}{(m_{\text{H}_2}) \text{ for certain V litre volume}}$$

$$\text{or } M_w = 2 \times \frac{\text{mass of 1 litre gas}}{\text{mass of 1 litre H}_2}$$

$$\text{or } M_w = 2 \times \frac{\text{mass of 1 litre gas}}{0.089 \text{ g}}$$

$$M_w(\text{g}) = 22.4 \times \text{mass of 1 litre gas}$$

$$\boxed{M_w(\text{g}) = \text{Mass of 22.4 litre gas}}$$

$$\text{or } \boxed{M_w(\text{g}) = 22.4 \text{ litre (at STP)}}$$

Gram Molecular Volume (GMV)

At NTP, the volume of 1 mole of gaseous substance is 22.4 litre is called as gram molecular volume.

$$\text{At NTP, } d_{\text{H}_2} = 0.000089 \text{ g/mL} = \text{mass/volume} = \text{mass/1000 mL}$$

$$\text{If volume} = 1 \text{ litre} = 1000 \text{ mL then mass} = 0.089 \text{ g}$$

$$\therefore 0.089 \text{ g H}_2 \text{ occupies} = 1 \text{ litre at STP.}$$

$$\therefore 1 \text{ g H}_2 \text{ occupies} = \frac{1 \text{ litre}}{0.089} \text{ at STP.}$$

$$\therefore 2 \text{ g or 1 mol H}_2 \text{ occupies} = \frac{1 \text{ litre}}{0.089} \times 2 = 22.4 \text{ litre}$$

at STP

1 mole of any gaseous substance occupy 22.4 litre of volume at NTP or STP

$$\boxed{1 \text{ mol} = 22.4 \text{ litre (at STP)}}$$

Percentage Composition, Empirical Formula & Molecular Formula

Percentage Formula (% By Mass)

(In a molecule or compound) Mass % of an element

=

$$\frac{\text{Number of atom (Atomicity)} \times \text{atomic mass}}{\text{molecular mass}} \times 100$$

If number of atom = 1 : Molecular mass = **minimum molecular mass**

Empirical Formula

The empirical formula of a compound express the simplest whole number ratio of atoms of various elements present in 1 molecule of the compound.

Example.11	Molecular Formula			→
H ₂ O ₂	CH ₄	C ₂ H ₆	C ₂ H ₄ O ₂	
2 : 2	1 : 4	2 : 6	2 : 4 : 2	
1 : 1	1 : 4	1 : 3	1 : 2 : 1	
Empirical Formula	→	HO	CH ₄	



Molecular Formula

The molecular formula of a compound represents the **actual number** of atoms present in 1 molecule of the compound i.e. it shows the real formula of its 1 molecule.

Relationship between Empirical & Molecular Formula

$$\text{Molecular Formula} = n \times \text{Empirical Formula}$$

[Where n = natural no. (1, 2, 3,)]





$$\text{or } n = \frac{\text{Molecular Formula}}{\text{Empirical Formula}}$$

$$\text{or } n = \frac{\text{Molecular Formula mass}}{\text{Empirical Formula mass}}$$

Determination of Empirical Formula

Following steps are involved to determine the empirical formula of the compounds -

- (1) First of all find the % by weight of each element present in 1 molecule of the compound.
- (2) The % by weight of each element is divided by its atomic weight. It gives atomic ratio of elements present in the compounds.
- (3) Atomic ratio of each element is divided by the minimum value of atomic ratio as to get simplest ratio of atoms.
- (4) If the value of simplest atomic ratio is fractional then raise the value to the nearest whole number or Multiply with suitable coefficient to convert it into nearest whole number.
- (5) Write the Empirical formula as we get the simplest ratio of atoms.

Example.

Phosgene, a poisonous gas used during World war-I, contains 12.1% C, 16.2% O and 71.7% Cl by mass. What is the empirical formula of phosgene.

Solution.

Element	%	Mole ratio	Simplest mole ratio
C	12.1	$\frac{12.1}{12} = 1.01$	$\frac{1.01}{1.01} = 1$
O	16.2	$\frac{16.2}{16} = 1.01$	$\frac{1.01}{1.01} = 1$
Cl	71.7	$\frac{71.7}{35.5} = 2.02$	$\frac{2.02}{1.01} = 2$

Then empirical formula = COCl_2

Example.

5.325g sample of methyl benzoate, a compound used in the manufacture of perfumes is found to contain 3.758 g of carbon, 0.316g hydrogen and 1.251g of oxygen. What is empirical formulae, of compound. If mol. weight of methyl benzoate is 136.0, calculate its molecular formula.

Solution.

Element % Mole ratio Simplest whole ratio

$$\text{C} \quad \frac{3.758 \times 100}{5.325} = 70.57 \quad \frac{70.57}{12} = 5.88 \quad \frac{5.88}{1.47} = 4$$

$$\text{H} \quad \frac{0.316 \times 100}{5.325} = 5.93 \quad \frac{5.93}{1} = 5.93 \quad \frac{5.93}{1.47} = 4$$

$$\text{O} \quad \frac{1.251 \times 100}{5.325} = 23.50 \quad \frac{23.50}{16} = 1.47 \quad \frac{1.47}{1.47} = 1$$

Empirical = $\text{C}_4\text{H}_4\text{O}$

$$n = \frac{\text{Mol. wt}}{\text{Empirical formula wt.}} = \frac{136}{68} = 2$$

\Rightarrow Molecular formula = $\text{C}_8\text{H}_8\text{O}_2$

Chemical Equation

Representation of the chemical change in terms of symbol and formulae of the reactants & products is called a chemical equation.

Information conveyed by a chemical equation

- (1) Qualitatively, a chemical equation tells us the names of the various reactants
- (2) Quantitatively, it express
 - (a) The relative no. of molecules of reactants and products
 - (b) The relative no. of moles of reactant and products
 - (c) The relative masses of reactants and products
 - (d) The relative volumes of gaseous reactants and products

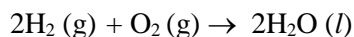
Limitations of chemical equations

- (1) The physical state of the reactants and products
- (2) The dilution of solution of reactants and products are in soluble state
- (3) The energy changes during chemical reaction
- (4) The conditions of P, T etc at which reaction occurs.
- (5) The rate of chemical reaction

Limiting Reagent

It may be defined as the reactant which is completely consumed during the reaction is called limiting reagent



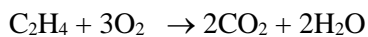
Example.


Reaction is started with one mole each of H_2 and O_2

Here H_2 is known as limiting reagent.

Examples Based on Chemical Reactions
Example.

Calculate the mass of oxygen required to burn 14g C_2H_4 completely-

Solution.


Mole ratio 1 3 2 2

$$\text{Moles of } \text{C}_2\text{H}_4 \text{ to be burnt} = \frac{14}{28} = \frac{1}{2} \text{ mole.}$$

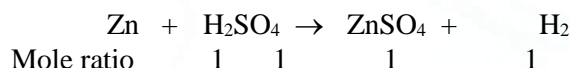
\therefore 1 mole C_2H_4 requires 3 mol O_2 for combustion

$$\therefore \frac{1}{2} \text{ mole } \text{C}_2\text{H}_4 \text{ requires } 3 \times \frac{1}{2} \text{ mole } \text{O}_2 = \frac{3}{2} \text{ mol}$$

$$\text{O}_2. \text{ \& Mass of } \text{O}_2 = \frac{3}{2} \times 32 = 48 \text{ gm}$$

Example.

Calculate the weight and volume of H_2 at STP that will be displaced by 1 gram of Zn when it is completely dissolved in dilute sulphuric acid.

Solution.


Mole ratio 1 1 1 1

\therefore 65.4 g of Zn displaces 2g of Hydrogen

$$\therefore 1.0 \text{ g of Zn displaces } \frac{2}{65.4} \times 1 = 0.0306 \text{ g of } \text{H}_2$$

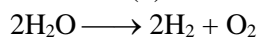
\therefore 65.4 g of Zn displaces 22.4 dm³ of H_2 at S.T.P.

$$\therefore 1.0 \text{ g of Zn displaces } \frac{22.4}{65.4} \times 1.0 = 0.3425 \text{ dm}^3$$

Example.

Find out the mass of O_2 obtained from 90 kg of water?

(1) 70 kg (2) 80 kg (3) 100 kg (4) 50 kg

Solution. (2)


2 mole H_2O forms 1 mole of O_2

$2 \times 18 \text{ g of } \text{H}_2\text{O}$ forms 32 g of O_2 from above reaction.

$$1 \text{ kg of } \text{H}_2\text{O} \text{ will form } \frac{32}{2 \times 18} \text{ kg of } \text{O}_2$$

$$\text{So, from } 90 \text{ kg of } \text{H}_2\text{O} = \frac{32 \times 90}{2 \times 18} \text{ kg of } \text{O}_2 = 80 \text{ kg of } \text{O}_2$$

Example.

Calculate the weight of Fe which will be converted into its oxide (Fe_3O_4) on action of 18g of steam?

(1) 21 gm (2) 42 gm (3) 63 gm (4) 84 gm

Solution. (2)

From the compound given the following can be deduced

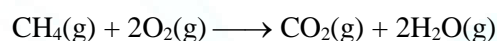
Molar ratio 3 mol Fe : 4 mol H_2O

Mass ratio $3 \times 56 \text{ g Fe} : 4 \times 18 \text{ g } \text{H}_2\text{O}$

$$\text{Using stoichiometry } m_{\text{Fe}} = \frac{3 \times 56 \times 18}{4 \times 18} = 42 \text{ gram}$$

Example.

Calculate the amount of water (g) liberated on burning of 16g of CH_4 .

Solution.


(i) 16 g of Methane is equal to one mole.

(ii) From above equation, a mol of $\text{CH}_4(\text{g})$ gives 2 mole of $\text{H}_2\text{O}(\text{g})$.

$$\text{So, mass of } \text{H}_2\text{O} = 2 \times 18 = 36\text{g}$$

Example.

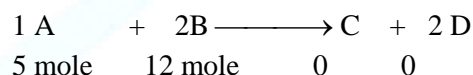
The number of litres of air required to burn 8 litres of C_2H_2 is approximately?

(1) 40 (2) 60 (3) 80 (4) 100

Solution.

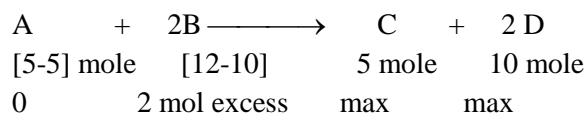
For a chemical reaction of the type given below:

Given mole at $t = 0$



5 mole 12 mole 0 0

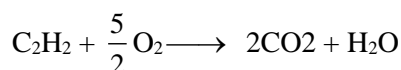
At the completion of reaction the following can be seen, when 12 moles of B reacts with 5 moles of A.



[5-5] mole [12-10] 5 mole 10 mole

0 2 mol excess max max

In this case, A gets consumed completely so it behaves as limiting reagent for the reaction



$$1 \text{ ml} : \frac{5}{2} \text{ ml}$$

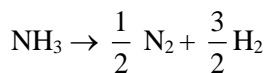
$$8 \text{ ml} : \frac{8 \times 5}{2} \text{ ml}$$

$$8 \text{ ml} : 20 \text{ ml of } \text{O}_2 \quad 20 \times 5 = V_{\text{air}}$$

$$V_{\text{air}} = 100 \text{ ml}$$

**Example.**

When 170 g NH_3 ($M = 17$) decomposes how many grams of N_2 & H_2 is produced.

Sol.

$$\frac{\text{moles of NH}_3}{1} = \frac{\text{moles of N}_2}{1/2} = \frac{\text{moles of H}_2}{3/2}$$

$$\text{So moles of N}_2 = \frac{1}{2} \times \frac{170}{17} = 5.$$

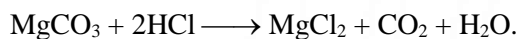
$$\text{So wt. of N}_2 = 5 \times 28 = 140 \text{ g.}$$

$$\text{Similarly moles of H}_2 = \frac{3}{2} \times \frac{170}{17} = 15.$$

$$\text{So wt. of H}_2 = 15 \times 2 = 30 \text{ g.}$$

Example.

4 mole of MgCO_3 is reacted with 6 moles of HCl solution. Find the volume of CO_2 gas produced at STP, the reaction is

**Sol.**

Here HCl is limiting reagent. So moles of CO_2 formed = 3.

$$\text{So vol. at STP} = 3 \times 22.4 = 67.2 \text{ lit.}$$

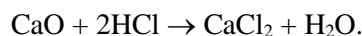
Percentage Yield

- The amount of product formed by a chemical reaction is less than the amount predicted by theoretical calculations.
- The ratio of the amount of product formed to the amount predicted when multiplied by 100 gives the percentage yield

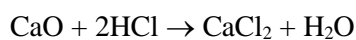
$$\text{Percentage Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100$$

Example.

Calculate the percentage yield for the reaction,



When 1.85 gm CaCl_2 is formed by reaction of 1.12 gm of CaO with excess of HCl .

Solution.

56 gm CaO will produce 111 gm CaCl_2

$$1.12 \text{ gram of CaO will produce} \rightarrow \frac{111}{56} \times 1.12 = 2.22 \text{ gm}$$

Thus Theoretical yield = 2.22 gm

$$\text{Actual yield} = 1.85 \text{ gm}$$

$$\% \text{ yield} = \frac{1.85}{2.22} \times 100 = 83.33\%$$

Percentage Purity

Percentage purity

=

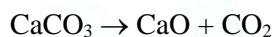
$$\left[\frac{\text{Amount of reactant calculated from the chemical equation}}{\text{Actual amount of reactant taken}} \right] \times 100$$

Example.

Find the quantity of (CaO) in kg which is produced when 200 kg of lime stone (90% pure CaCO_3) is heated ?

Solution.

$$\text{Mass of pure CaCO}_3 = \frac{200 \times 90}{100} = 180 \text{ kg}$$



$$100 \text{ kg} \quad 56 \text{ kg}$$

$$180 \times$$

$$\frac{100}{180} = \frac{56}{x} \Rightarrow x = 100.8 \text{ kg}$$

Laws of Chemical Combination**(a) Law of Mass Conservation (Law of Indestructibility of Matter)**

“It was given by **Lavoisier** and tested by **Landolt**”

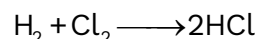
According to this law, the mass can neither be created nor be destroyed in a balanced chemical reaction or physical reaction. But one form is changed into another form is called as law of mass conservation.

If the reactant is completely converted in products, then the sum of the mass of reactants is equal to the sum of the mass of products.

$$\boxed{\text{Total mass of reactants} = \text{Total mass of products}}$$

If reactants are not completely consumed then the relationship will be :

$$\boxed{\begin{aligned} \text{Total mass of reactants} \\ = \text{Total mass of products} + \text{Mass of unreacted reactants} \end{aligned}}$$



Example. Mass in (g)

2	71	2(1+35.5)
↓		↓
2+71=73g		73g

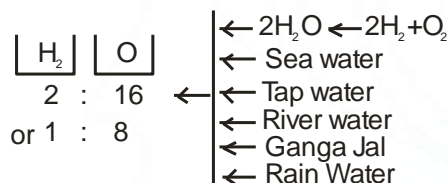
(b) Law of Definite Proportion / Law of Constant Composition

“It was given by **Proust**.”

According to this law, a compound can be obtained from different sources. But the ratio of each component (by weight) remain same. i.e. it does not depend on the method of its preparation or the source from which it has been obtained.

For example :- molecule of ammonia always has the formula NH_3 . That is one molecule of ammonia always contains, one atom of nitrogen and three atoms of hydrogen or 17.0g of NH_3 always contains 14.0 g of nitrogen and 3 g of hydrogen.

Example. Water can be obtained from different sources but the ratio of weight of H and O remains same.



(c) Law of Multiple Proportion

“It was given by **John Dalton**”

According to law of Multiple proportion if two elements combine to form more than one compound than the different mass of one element which combine with a fixed mass of other element bear a simple ratio to one another.

The following examples illustrate this law.

(i) **Nitrogen and oxygen combine to form five oxides, which are:** Nitrous oxide (N_2O), nitric oxide (NO), nitrogen trioxide (N_2O_3), nitrogen tetraoxide (N_2O_4) and nitrogen pentoxide (N_2O_5).

Weights of oxygen which combine with the fixed weight of nitrogen in these oxides are calculated as under:

Oxide Ratio of weights of nitrogen and oxygen in each compound

N_2O	28 : 16	NO	14 : 16	N_2O_3	28 : 48
N_2O_4	28 : 64	N_2O_5	28 : 80		

Number of parts by weight of oxygen which combine with 14 parts by weight of nitrogen from the above are 8, 16, 24, 32 and 40 respectively. Their ratio is 1 : 2 : 3 : 4 : 5, which is a simple ratio. Hence, the law is illustrated.

(ii) Sulphur combines with oxygen to form two oxides SO_2 and SO_3 the weights of oxygen which combine with a fixed weight of sulphur, i.e. 32 parts by weight of sulphur in two oxides are in the ratio of 32 : 48 or 2 : 3 which is a simple ratio. Hence the law of multiple proportions is illustrated.

(d) Law of Gaseous Volume

“It was given by **Gay Lussac**”

According to this law, in the gaseous reaction, the reactants are always combined in a simple ratio by volume and form products, which is **simple ratio by volume** at same temperature and pressure.

Example.

One volume of hydrogen combines with one volume of chlorine to produce 2 volumes of hydrogen chloride.

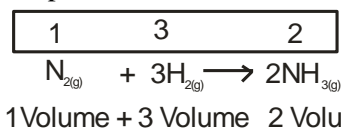
Simple ratio = 1 : 1 : 2.



Example.

One volume of nitrogen combines with 3 volumes of hydrogen to form 2 volumes of ammonia.

Simple ratio = 1 : 3 : 2



Special Note: This law is used only for gaseous reaction. It relates volume to mole or molecules. But not relate with mass.

**Concentration Terms****Molarity (M)**

- (i) Molarity is defined as the number of moles of the solute per liter of solution. Molarity expressed in mol/liter or mol/dm³.
- (ii) Mathematically,

$$M = \frac{\text{No. of moles of solute}(n)}{\text{Vol. of solution in litres}}$$

$$= \frac{\text{wt. of solute(gm)}}{\text{gm mol. wt. of solute}} \times \frac{1000}{\text{vol. of solution(ml)}}$$

Molality (m)

- (i) Molality is defined as the no. of moles of the solute per 1000 g of the solvent.
- (ii) Unit of molarity is mol/kg.
- (iii) Mathematically, molality can be calculated by the following formulae,

$$m = \frac{\text{Number of moles of solute}}{\text{weight of solvent in kg}}$$

$$= \frac{\text{Number of moles of solute}}{\text{weight of solvent in gm}} \times 1000$$

$$m = \frac{\text{wt. of solute}}{\text{mol. wt. of solute}} \times \frac{1000}{\text{Weight of solvent in gm}}$$

In terms of percentage

- (i) Weight by weight percentage (% w/W)
- $$= \frac{\text{Wt. of solute(g)}}{\text{Wt. of solution(g)}} \times 100$$
- e.g. 10% Na₂CO₃ solution w/W means 10g of Na₂CO₃ is dissolved in 100 g of the solution.
- (ii) Weight by volume percent (% w/V)
- $$= \frac{\text{Wt. of solute(g)}}{\text{Volume of solution(cm}^3\text{)}} \times 100$$
- e.g., 10% Na₂CO₃ (w/V) means 10 g Na₂CO₃ is dissolve in 100 cm³ of solution.
- (iii) Volume by volume percent (% v/V)
- $$= \frac{\text{Volume of solute(cm}^3\text{)}}{\text{Volume of solution(cm}^3\text{)}} \times 100$$
- e.g., 10 cm³ of ethanol dissolved in 100 cm³ of solution means 10% ethanol (v/V)

Parts per million (ppm) and parts per billion (ppb)

$$\text{ppm} = \frac{\text{Mass of solute}}{\text{Total mass of solution}} \times 10^6$$

$$\text{ppb} = \frac{\text{Mass of solute}}{\text{Total mass of solution}} \times 10^9$$

Mole fraction (x)

- (i) It is defined as ratio of number of moles of a component to total moles of all components (solvent and solute) present in solution.
- (ii) It is denoted by the letter X.

Number of moles of component A is given by, n_A

$$= \frac{W_A}{M_A}$$

Number of moles of component B is given by, n_B

$$= \frac{W_B}{M_B}$$

Total number of moles of A and B = n_A + n_B

$$\text{Moles fraction of A, } X_A = \frac{n_A}{n_A + n_B}$$

$$\text{Moles fraction of B, } X_B = \frac{n_B}{n_A + n_B}$$

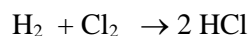
In a solution for all component the sum of mole fractions is always unity.

$$X_A + X_B = \frac{n_A}{n_A + n_B} + \frac{n_B}{n_A + n_B} = 1$$

SOLVED EXAMPLE**Example.**

8 litre of H₂ and 6 litre of Cl₂ are allowed to react to maximum possible extent. Find out the final volume of reaction mixture. Suppose P and T remains constant throughout the course of reaction -

- (1) 7 litre (2) 14 litre
(3) 2 litre (4) None of these.

Solution. (2)

Volume before reaction 8 lit 6 lit 0

Volume after reaction 2 0 12

∴ Volume after reaction

= Volume of H₂ left + Volume of HCl formed

= 2 + 12 = 14 lit

Example.



Calculate the mass in gm of 2g atom of Mg-

- (1) 12 gm (2) 24 gm
(3) 6 gm (4) None of these.

Solution. (4)

\therefore 1 gm atom of Mg has mass = 24 gm

\therefore 2 gm atom of Mg has mass
= $24 \times 2 = 48$ gm.

Example.

In 5 g atom of Ag (At. wt. of Ag = 108), calculate the weight of one atom of Ag -

- (1) 17.93×10^{-23} gm (2) 16.93×10^{-23} gm
(3) 17.93×10^{23} gm (4) 36×10^{-23} gm

Solution. (1)

\therefore N_A atoms of Ag weigh 108 gm

$$\therefore 1 \text{ atom of Ag weigh} = \frac{108}{N_A}$$

$$= \frac{108}{6.023 \times 10^{23}} = 17.93 \times 10^{-23} \text{ gm.}$$

Example.

In 5g atom of Ag (at. wt. = 108), calculate the no. of atoms of Ag -

- (1) 1 N_A (2) 3 N_A (3) 5 N_A (4) 7 N_A

Solution. (3)

\therefore 1 gm atom of Ag has atoms = N_A

\therefore 5 gm atom of Ag has atoms = 5 N_A

Example.

Calculate the mass in gm of 2 N_A molecules of CO_2 -

- (1) 22 gm (2) 44 gm
(3) 88 gm (4) None of these.

Solution. (3)

\therefore N_A molecules of CO_2 has molecular mass
= 44.

\therefore 2 N_A molecules of CO_2 has molecular mass
= $44 \times 2 = 88$ gm.

Example.

How many carbon atoms are present in 0.35 mol of $\text{C}_6\text{H}_{12}\text{O}_6$ -

- (1) 6.023×10^{23} carbon atoms

(2) 1.26×10^{23} carbon atoms

(3) 1.26×10^{24} carbon atoms

(4) 6.023×10^{24} carbon atoms

Solution. (3)

\therefore 1 mol of $\text{C}_6\text{H}_{12}\text{O}_6$ has = 6 N_A atoms of C

\therefore 0.35 mol of $\text{C}_6\text{H}_{12}\text{O}_6$ has

= $6 \times 0.35 N_A$ atoms of C

= 2.1 N_A atoms

= $2.1 \times 6.023 \times 10^{23} = 1.26 \times 10^{24}$ carbon atoms

Example.

How many molecules are in 5.23 gm of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) -

(1) 1.65×10^{22} (2) 1.75×10^{22}

(3) 1.75×10^{21} (4) None of these

Solution. (2)

\therefore 180 gm glucose has = N_A molecules

$$\therefore 5.23 \text{ gm glucose has} = \frac{5.23 \times 6.023 \times 10^{23}}{180}$$

= 1.75×10^{22} molecules

Example.

What is the weight of 3.01×10^{23} molecules of ammonia -

(1) 17 gm (2) 8.5 gm

(3) 34 gm (4) None of these

Solution. (2)

\therefore 6.023×10^{23} molecules of NH_3 has weight = 17 gm

\therefore 3.01×10^{23} molecules of NH_3 has weight

$$= \frac{17 \times 3.01 \times 10^{23}}{6.023 \times 10^{23}} = 8.50 \text{ gm}$$

Example.

At NTP, density of any gas has 0.00445 g/mL.

Calculate the vapour density and molecular weight of the gas (density of $\text{H}_2 = 0.000089$ g/mL).

(1) 10, 70 (2) 20, 40 (3) 50, 100 (4) 30, 80

Solution. (3)

$$\text{V.D.} = \frac{\text{Density of gas}}{\text{Density of } \text{H}_2} = \frac{0.004450}{0.000089} = 50$$

Molecular weight = $2 \times \text{V.D.} = 2 \times 50 = 100$

Example.





How many molecules are present in one mL of water vapours at STP -

- (1) 1.69×10^{19} (2) 2.69×10^{-19}
 (3) 1.69×10^{-19} (4) 2.69×10^{19}

Solution. (4)

\therefore 22.4 litre water vapour at STP has $= 6.023 \times 10^{23}$ molecules

\therefore 1×10^{-3} litre water vapours at STP has

$$\frac{6.023 \times 10^{23}}{22.4} \times 10^{-3} = 2.69 \times 10^{19}$$

Example.

An atom of an element weighs 6.644×10^{-23} g. Calculate g atoms of element in 40 kg-

- (1) 10 gm atom (2) 100 gm atom
 (3) 1000 gm atom (4) 10^4 gm atom

Solution. (3)

\therefore weight of 1 atom of element $= 6.644 \times 10^{-23}$ gm

\therefore weight of ' N_A ' atoms of element
 $= 6.644 \times 10^{-23} \times 6.023 \times 10^{23} = 40$ gm

\therefore 40 gm of element has 1 gm atom.

\therefore 40×10^3 gm of element has $\frac{40 \times 10^3}{40} = 10^3$ gm atom.

Example.

Calculate the number of Cl^- and Ca^{+2} ions in 222 g anhydrous CaCl_2 -

- (1) $2 N_A$ ions of Ca^{+2} 4 N_A ions of Cl^-
 (2) 2 N_A ions of Cl^- & 4 N_A ions of Ca^{+2}
 (3) 1 N_A ions of Ca^{+2} & 1 N_A ions of Cl^-
 (4) None of these.

Solution. (1)

\therefore mol. wt. of $\text{CaCl}_2 = 111$ g

\therefore 111 g CaCl_2 has $= N_A$ ions of Ca^{+2}

\therefore 222g of CaCl_2 has $\frac{2N_A \times 222}{111}$

$= 2N_A$ ions of Ca^{+2}

Also \therefore 111 g CaCl_2 has $= 2 N_A$ ions of Cl^-

\therefore 222 g CaCl_2 has $= \frac{2N_A \times 222}{111}$ ions of Cl^-
 $= 4N_A$ ions of Cl^-

Example.

The density of O_2 at NTP is 1.429g / litre. Calculate the standard molar volume of gas-

- (1) 22.4 lit. (2) 11.2 lit (3) 33.6 lit (4) 5.6 lit.

Solution. (1)

\therefore 1.429 gm of O_2 gas occupies volume $= 1$ litre.

\therefore 32 gm of O_2 gas occupies $= \frac{32}{1.429}$
 $= 22.4$ litre/mol.

Example.

Which of the following will weigh maximum amount-

- (1) 40 g iron
 (2) 1.2 g atom of N
 (3) 1×10^{23} atoms of carbon
 (4) 1.12 litre of O_2 at STP

Solution. (1)

(1) Mass of iron $= 40$ g

(2) Mass of 1.2 g atom of N $= 14 \times 1.2 = 16.8$ gm

(3) Mass of 1×10^{23} atoms of C $= \frac{12 \times 1 \times 10^{23}}{6.023 \times 10^{23}}$
 $= 1.99$ gm.

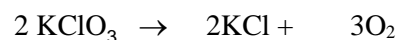
(4) Mass of 1.12 litre of O_2 at STP $= \frac{32 \times 1.2}{22.4}$
 $= 1.6$ g

Example.

How many moles of potassium chlorate to be heated to produce 11.2 litre oxygen -

- (1) $\frac{1}{2}$ mol (2) $\frac{1}{3}$ mol
 (3) $\frac{1}{4}$ mol (4) $\frac{2}{3}$ mol.

Solution. (2)



Mole for reaction 2 2 3

\therefore 3×22.4 litre O_2 is formed by 2 mol KClO_3

\therefore 11.2 litre O_2 is formed by $\frac{2 \times 11.2}{3 \times 22.4}$

$= \frac{1}{3}$ mol KClO_3

Example.



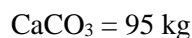


Calculate the weight of lime (CaO) obtained by heating 200 kg of 95% pure lime stone (CaCO_3).

- (1) 104.4 kg (2) 105.4 kg
(3) 212.8 kg (4) 106.4 kg

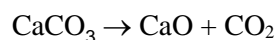
Solution. (4)

\therefore 100 kg impure sample has pure



\therefore 200 kg impure sample has pure CaCO_3

$$= \frac{95 \times 200}{100} = 190 \text{ kg.}$$



\therefore 100 kg CaCO_3 gives $\text{CaO} = 56 \text{ kg.}$

$$\therefore 190 \text{ kg } \text{CaCO}_3 \text{ gives } \text{CaO} = \frac{56 \times 190}{100} = 106.4 \text{ kg.}$$

Example.

Calculate how many methane molecules and how many hydrogen and carbon atoms are there in 25.0 g of methane ?

Solution.

$$\text{moles of } \text{CH}_4 = \frac{25}{16}$$

$$\therefore \text{No. of } \text{CH}_4 \text{ molecules} = \frac{25}{16} \times 6.02 \times 10^{23}$$

$$= 9.41 \times 10^{23}$$

\therefore 1 molecule of CH_4 contains one carbon atom and four hydrogen atom

$$\therefore \text{No. of C atom} = 9.41 \times 10^{23}$$

$$\therefore \text{No. of C atoms} = 4 \times 9.41 \times 10^{23} = 37.64 \times 10^{23}$$





EXERCISE - I

Problems Based on Mole

- Four one litre flasks are separately filled with the gases hydrogen, helium, oxygen and nitrogen at same room temp. and pressure. The ratio of total number of atoms of these gases present in the different flasks would be -
 (1) 1 : 1 : 1 : 1 (2) 1 : 2 : 2 : 3
 (3) 2 : 1 : 2 : 2 (4) 2 : 1 : 3 : 2
- Which of the following will contain same number of atoms as 2 g of He gas ?
 (1) 24g magnesium
 (2) 12g carbon
 (3) 8g oxygen gas
 (4) 16g oxygen atom
- Which of the following contains the least number of molecules?
 (1) 4.4 gm CO_2 (2) 3.4 gm NH_3
 (3) 1.6 gm CH_4 (4) 3.2 gm SO_2
- The number of molecule in 3.4 gms of NH_3 is -
 (1) 1.204×10^{23} (2) 3.01×10^{23}
 (3) 6.02×10^{23} (4) None of these
- 4.4 gm of an unknown gas occupies 2.24 litres of volume at NTP. The gas may be :-
 (1) N_2O (2) CO
 (3) CO_2 (4) 1 & 3 both
- Number of oxygen atoms in 8 gms of ozone is -
 (1) 6.02×10^{23} (2) $\frac{6.02 \times 10^{23}}{2}$
 (3) $\frac{6.02 \times 10^{23}}{3}$ (4) $\frac{6.02 \times 10^{23}}{6}$
- The actual weight of a molecule of water is -
 (1) 18 gm
 (2) 2.99×10^{-23} gm
 (3) both (1) & (2) are correct
 (4) None of these
- What is the mass of a molecule of CH_4 -
 (1) 16 g (2) 26.6×10^{22} g
 (3) 2.66×10^{-23} g (4) $16 N_A$ g
- Which of the following contains greatest number of oxygen atoms ?
 (1) 1 g of O
 (2) 1 g of O_2
 (3) 1 g of O_3
 (4) all have the same number of atoms
- The weight of one atom of Uranium is 238 amu. Its actual weight is gm.
 (1) 1.43×10^{26} (2) 3.94×10^{-22}
 (3) 6.99×10^{-23} (4) None of these
- Sum of number of protons, electrons and neutrons in 12gm of $^{12}_6\text{C}$ is :-
 (1) 1.8
 (2) 12.044×10^{23}
 (3) 1.084×10^{25}
 (4) 10.84×10^{23}
- 5 litre of gas at NTP weighs 6.25 gms. What is its gram molecular weight ?
 (1) 1.25 (2) 14 (3) 28 (4) 56
- 0.44 gms of a colourless oxide of nitrogen occupies 224 mL at STP. The compound is-
 (1) N_2O (2) NO
 (3) N_2O_4 (4) NO_2
- One litre of a certain gas weighs 1.16 gm at STP. The gas may possibly be -
 (1) C_2H_2 (2) CO
 (3) O_2 (4) NH_3
- Avogadro number is
 (1) Number of atoms in one gram of element
 (2) Number of millilitres which one mole of a gaseous substances occupies at NTP
 (3) Number of molecules present in one gram molecule of a substance
 (4) All of these
- Rearrange the following (I to IV) in the order of increasing masses and choose the correct answer from (1), (2), (3) and (4) (Atomic mass: N=14, O=16, Cu=63).
 I. 1 molecule of oxygen
 II. 1 atom of nitrogen
 III. 1×10^{-10} g molecular weight of oxygen



- IV. 1×10^{-10} g atomic weight of copper
 (1) II<I<III<IV (2) IV<III<II<I
 (3) II<III<I<IV (4) III<IV<I<II
17. How much coulomb charge is present on 1g ion of N^{3-} ?
 (1) 5.2×10^6 Coulomb
 (2) 2.894×10^5 Coulomb
 (3) 6.6×10^6 Coulomb
 (4) 8.2×10^6 Coulomb
18. The element whose an atom has mass of 10.86×10^{-26} kg is
 (1) Boron (At. wt. = 10.8u)
 (2) Calcium (At. wt. = 40u)
 (3) Silver (At. wt. = 108u)
 (4) Zinc (At. wt. = 65u)
19. Which of the following has least mass?
 (1) 2g atom of nitrogen
 (2) 3×10^{23} atoms of C
 (3) 1 mole of S
 (4) 7.0 g of Ag (At. wt. = 108u)
20. How many mole of helium gas occupy 22.4 L at 0°C at 1 atm. pressure?
 (1) 0.11 (2) 0.90
 (3) 1.0 (4) 1.11
21. Volume of a gas at NTP is 1.12×10^{-7} cc. Calculate the number of molecules in it
 (1) 3.01×10^{20} (2) 3.01×10^{12}
 (3) 3.01×10^{23} (4) 3.01×10^{24}
22. The volume occupied by 4.4 g of CO_2 at STP is
 (1) 22.4 L (2) 2.24 L
 (3) 0.224 L (4) 0.1 L
23. 19.7 kg of gold was recovered from a smuggler. How many atoms of gold were recovered (Au = 197)
 (1) 100 (2) 6.02×10^{23}
 (3) 6.02×10^{24} (4) 6.02×10^{25}
24. The number of molecules in 16 g of methane is
 (1) 3.0×10^{23} (2) 6.02×10^{23}
 (3) $\frac{16}{6.02} \times 10^{23}$ (4) $\frac{16}{3.0} \times 10^{23}$
25. How many atoms are present in one gram of hydrogen gas ?
 (1) 6.02×10^{23} (2) 3.01×10^{23}
 (3) 2.5×10^{23} (4) 1.5×10^{23}
26. The least number of molecules is in
 (1) 36g of water (2) 22g of CO_2
 (3) 64g of CH_3OH (4) 108g of N_2O_5
27. How many atoms are contained in one mole of sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$) ?
 (1) $45 \times 6.02 \times 10^{23}$ atoms/mole
 (2) $5 \times 6.62 \times 10^{23}$ atoms/mole
 (3) $5 \times 6.02 \times 10^{23}$ atoms/mole
 (4) None of these
28. The number of molecules of CO_2 present in 44g of CO_2 is
 (1) 6.0×10^{23} (2) 3×10^{23}
 (3) 12×10^{23} (4) 3×10^{10}
29. Vapour density of a gas is 22. What is its molecular mass?
 (1) 33 (2) 22 (3) 44 (4) 11
30. 5.6 lt. of oxygen at STP contains -
 (1) 6.02×10^{23} atoms
 (2) 3.01×10^{23} atoms
 (3) 1.505×10^{23} atoms
 (4) 0.7525×10^{23} atoms
31. The total number of gm-molecules of SO_2Cl_2 in 13.5g of SO_2Cl_2 is
 (1) 0.1 (2) 0.2 (3) 0.3 (4) 0.4
32. The number of atoms in 52 g of He is
 (1) 78.299×10^{24} atoms
 (2) 7.820×10^{-24} atoms
 (3) 7.829×10^{24} atoms
 (4) 78.234×10^{25} atoms

Problems Based on Percentage, Empirical Formula & Molecular Formula

33. A hydrocarbon contains 75% of carbon. Then its molecular formula is -
 (1) CH_4 (2) C_2H_4 (3) C_2H_6 (4) C_2H_2
34. An oxide of sulphur contains 50% of sulphur in it. Its empirical formula is -
 (1) SO_2 (2) SO_3 (3) SO (4) S_2O



35. A hydrocarbon contains 80% of carbon, then the hydrocarbon is -
 (1) CH₄ (2) C₂H₄
 (3) C₂H₆ (4) C₂H₂
36. Empirical formula of glucose is -
 (1) C₆H₁₂O₆ (2) C₃H₆O₃
 (3) C₂H₄O₂ (4) CH₂O
37. An oxide of metal M has 40% by mass of oxygen. Metal M has atomic mass of 24. The empirical formula of the oxide
 (1) M₂O (2) M₂O₃
 (3) MO (4) M₃O₄
38. The percentage of oxygen in NaOH is
 (1) 40 (2) 60 (3) 8 (4) 10
39. The percentage of nitrogen in urea (NH₂CONH₂) is about
 (1) 46 (2) 85 (3) 18 (4) 28
40. Insulin contains 3.4% sulphur. The minimum mol. wt. of insulin is -
 (1) 941.176 (2) 944
 (3) 945.27 (4) None
41. Caffeine has a molecular weight of 194. It contains 28.9% by mass of nitrogen. Number of atoms of nitrogen in one molecule of it -
 (1) 2 (2) 3 (3) 4 (4) 5
42. A giant molecule contains 0.25% of a metal whose atomic weight is 59. Its molecule contains one atom of that metal. Its minimum molecular weight is
 (1) 5900 (2) 23600
 (3) 11800 (4) $\frac{100 \times 59}{0.4}$
43. A compound of P and Q has equal mass of them. If their atomic weights are 40 and 60 respectively. Molecular formula of that compound :
 (1) P₂Q₂ (2) P₃Q₃ (3) P₂Q₃ (4) P₃Q₂
44. 2.2 g of a compound of phosphorous and sulphur has 1.24 g of 'P' in it. Its empirical formula is
 (1) P₂S₃ (2) P₃S₂ (3) P₃S₄ (4) P₄S₃
45. On analysis, a certain compound was found to contain iodine and oxygen in the ratio of 254:80. The formula of the compound is :
 (At. mass I = 127, O = 16)
 (1) IO (2) I₂O (3) I₅O₂ (4) I₂O₅
46. The number of atoms of Cr and O are 4.8×10^{10} and 9.6×10^{10} respectively. Its empirical formula is -
 (1) Cr₂O₃ (2) CrO₂ (3) Cr₂O₄ (4) CrO₅
47. An organic compound contains carbon, hydrogen and oxygen. Its elemental analysis gave C, 38.71% and H, 9.67%. The empirical formula of the compound would be :-
 (1) CHO (2) CH₄O (3) CH₃O (4) CH₂O
48. A compound with empirical formula CH₂O has a vapour density of 30. Its molecular formula is.
 (1) C₃H₆O₃ (2) C₂H₄O₂
 (3) C₂H₂O₂ (4) C₆H₁₂O₆
49. The empirical formula of a compound is CH₂O. Its molecular weight is 180. The molecular formula of the compound is.
 (1) C₂HO₄ (2) C₅H₁₀O₅
 (3) C₃H₆O₃ (4) C₆H₁₂O₆
50. A compound possesses 8% sulphur by mass. The least molecular mass
 (1) 200 (2) 400 (3) 155 (4) 355

Problems Based on Stoichiometry

51. 9 gms of Al will react, with
 $2\text{Al} + \frac{3}{2}\text{O}_2 \rightarrow \text{Al}_2\text{O}_3$
 (1) 6 gms O₂ (2) 8 gms O₂
 (3) 9 gms O₂ (4) 4 gms O₂
52. The equation :
 $2\text{Al}(\text{S}) + \frac{3}{2}\text{O}_2(\text{g}) \rightarrow \text{Al}_2\text{O}_3(\text{S})$ shows that:-
 (1) 2 mole of Al reacts with $\frac{3}{2}$ mole of O₂ to
 produce $\frac{7}{2}$ mole of Al₂O₃



- (2) 2gm of Al reacts with $\frac{3}{2}$ g of O_2 to produce one mole of Al_2O_3
- (3) 2 gm mole of Al reacts with $\frac{3}{2}$ litre of O_2 to produce 1 mole of Al_2O_3
- (4) 2 mole of Al reacts with $\frac{3}{2}$ mole of O_2 to produce 1 mole of Al_2O_3
- 53.** In a gaseous reaction of the type $aA + bB \longrightarrow cC + dD$, which statement is wrong ?
- a litre of A combines with b litre of B to give C and D
 - a mole of A combines with b moles of B to give C and D
 - a gm of A combines with b gm of B to give C and D
 - a molecules of A combines with b molecules of B to give C and D
- 54.** What quantity of limestone ($CaCO_3$) on heating will give 56kg of CaO ?
- 1000 kg
 - 10kg
 - 50 kg
 - 100 kg
- 55.** For the reaction $A + 2B \longrightarrow C$, 5 mole of A and 8 mole of B will produce
- 5 mole of C
 - 4 mole of C
 - 8 mole of C
 - 13 mole of C
- 56.** 2.76g of silver carbonate on being strongly heated yields a residue weighing (At. wt. Ag = 108u)
- $$Ag_2CO_3 \rightarrow 2Ag + CO_2 + \frac{1}{2} O_2$$
- 2.16g
 - 2.48g
 - 2.32g
 - 2.64g
- 57.** The volume of gas at NTP produced by 100g of CaC_2 with water is :-
- $$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$$
- 70L
 - 35L
 - 17.5L
 - 22.4L
- 58.** 10 mL of gaseous hydrocarbon on combustion give 40 mL of $CO_2(g)$ and 50 mL of H_2O (vap.). The hydrocarbon is –
- C_4H_5
 - C_8H_{10}
 - C_4H_8
 - C_4H_{10}
- 59.** 500 mL of a gaseous hydrocarbon when burnt in excess of O_2 gave 2.5 L of CO_2 and 3.0 L of water vapours under same conditions. Molecular formula of the hydrocarbon is –
- C_4H_8
 - C_8H_{10}
 - C_5H_{10}
 - C_5H_{12}
- 60.** How much oxygen is required for complete combustion of 560 g of ethene (C_2H_4)?
- 6.4 kg
 - 1.92 kg
 - 2.8 kg
 - 9.6 kg
- 61.** 0.5 mole of Mg combine with O_2 to form oxide MgO . The mass of O_2 that has combined is :
- 8g
 - 32g
 - 24g
 - 94g
- 62.** 4 gms of hydrogen are ignited with 4 gms of oxygen. The weight of water formed is
- 0.5 gm
 - 3.5 gm
 - 4.5 gm
 - 2.5 gm
- 63.** If 0.5 mol of $BaCl_2$ is mixed with 0.1 mole of Na_3PO_4 , the maximum number of mole of $Ba_3(PO_4)_2$ that can be formed is:-
- $$3BaCl_2 + 2Na_3PO_4 \rightarrow Ba_3(PO_4)_2 + 6NaCl$$
- 0.7
 - 0.05
 - 0.30
 - 0.10
- 64.** 12 lit. of H_2 and 11.2 lit. of Cl_2 are mixed and exploded. The composition by volume of mixture is–
- 24 lit. of HCl (g)
 - 0.8 lit. Cl_2 and 20.8 lit. HCl (g)
 - 0.8 lit. H_2 and 22.4 lit. HCl (g)
 - 22.4 lit. HCl (g)
- 65.** 0.5 mole of H_2SO_4 is mixed with 0.2 mole of $Ca(OH)_2$. The maximum number of moles of $CaSO_4$ formed is
- 0.2
 - 0.5
 - 0.4
 - 1.5
- 66.** The mass of carbon anode consumed (giving only carbondioxide) in the production of 270 Kg of aluminium metal from bauxite by the Hall process is :
- $$2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$$
- 180 Kg
 - 270 Kg
 - 240 Kg
 - 90 Kg
- 67.** What volume of oxygen gas (O_2) measured at $0^\circ C$ and 1 atm, is needed to burn completely 1L, of propane gas (C_3H_8) measured under the same conditions?
- 5 L
 - 10 L
 - 7 L
 - 6L



68. 10g of hydrogen and 64 g of oxygen were filled in a steel vessel and exploded. Amount of water produced in this reaction will be :
- (1) 1 mole (2) 2 mole
(3) 3 mole (4) 4 mole

Problems Based on Percentage Purity and Percentage Yield

69. How many grams of CaO will be produced on the decomposition of 40g of 20% pure CaCO_3
(1) 4.48g (2) 2.24g
(3) 1.12g (4) 0.6g
70. How many grams of 40% pure FeO can produce 5.6g Fe according to given equation (At. wt. of Fe = 56)
 $\text{FeO} + \text{CO} \rightarrow \text{Fe} + \text{CO}_2$
(1) 7.2g (2) 18g (3) 9g (4) 27g
71. 170g of sample of Al_2O_3 produce 18g Al. According to following equation
 $\text{Al}_2\text{O}_3 \rightarrow 2\text{Al} + \frac{3}{2} \text{O}_2$ Determine the percentage purity of Al_2O_3 in the original sample
(1) 2% (2) 10% (3) 30% (4) 20%
72. 40 g of a magnesium carbonate sample decomposes on heating to give carbon dioxide and 4g magnesium oxide what will be the percentage purity of magnesium carbonate in the sample
(1) 21% (2) 60% (3) 84% (4) 75%
73. How many moles of CaO will be produced on the decomposition of 10g of 90% pure CaCO_3
(1) 9 mol (2) 0.9 mol
(3) 0.09 mol (4) 0.1 mol
74. MgCO_3 is 10% pure. Volume of CO_2 collected at STP when 84g of MgCO_3 is decomposed
(1) 2.24 L (2) 22.4 L (3) 11.2 L (4) 1.12 L
75. Calculate the percentage yield for the reaction
 $\text{CaO} + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O}$
When 1.85g CaCl_2 is formed by reaction of 1.12g of CaO with excess of HCl
(1) 83.33% (2) 40%
(3) 60% (4) 66.66%

76. Calculate the percentage yield for the reaction
 $\text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2$
When 2g of MgO is produced by the decomposition of 21g MgCO_3
(1) 40% (2) 60% (3) 20% (4) 50%
77. If the reaction of 18g of $\text{C}_6\text{H}_{12}\text{O}_6$ reacts in excess of oxygen (O_2) and produces 5.4g of H_2O , what is the percentage yield.
 $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$
(1) 50% (2) 80% (3) 30% (4) 90%
78. When 61.25g of KClO_3 is heated, it decomposes to potassium chloride (KCl) and oxygen (O_2). What is the percent yield if 8g of oxygen (O_2) is produced.
 $2\text{KClO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2$
(1) 66.66% (2) 33.33%
(3) 50% (4) 25%

Problems Based on Laws of Chemical Combination

79. Which one of the following pairs of compounds illustrate the law of multiple proportions ?
(1) H_2O , Na_2O (2) MgO , Na_2O
(3) Na_2O , BaO (4) SnCl_2 , SnCl_4
80. In the reaction $\text{N}_2 + 3\text{H}_2 \longrightarrow 2\text{NH}_3$, ratio by volume of N_2 , H_2 and NH_3 is 1 : 3 : 2. This illustrates law of -
(1) Definite proportion
(2) Multiple proportion
(3) Reciprocal proportion
(4) Gaseous volumes
81. Different proportions of oxygen in the various oxides of nitrogen prove the law of-
(1) Equivalent proportion
(2) Multiple proportion
(3) Constant proportion
(4) Conservation of matter
82. A container of volume V, contains 0.28 gm of N_2 gas. If same volume of an unknown gas under similar condition of temperature and pressure weighs, 0.44 gm, the molecular mass of the gas is
(1) 22 (2) 44 (3) 66 (4) 88





83. Hydrogen combines with chlorine to form HCl. It also combines with sodium to form NaH. If sodium and chlorine also combine with each other, they will do so in the ratio of their masses as:-
 (1) 23 : 35.5 (2) 35.5 : 23
 (3) 1 : 1 (4) 23 : 1
84. Two flask A & B of equal capacity of volume contain NH_3 and SO_2 gas respectively under similar conditions which flask has more no. of moles –
 (1) A
 (2) B
 (3) Both have same moles
 (4) None
85. If law of conservation of mass was to hold true, then 20.8 gm. of BaCl_2 on reaction with 9.8 gm. of H_2SO_4 will produce 7.3 gm. of HCl and BaSO_4 equal to –
 (1) 11.65 gm. (2) 23.3 gm.
 (3) 25.5 gm. (4) 30.6 gm.
86. Carbon and oxygen combine to form two oxides, carbon monoxide and carbon dioxide in which the ratio of the weights of carbon and oxygen is respectively 12 : 16 and 12 : 32. These figures illustrate the
 (1) Law of multiple proportions
 (2) Law of reciprocal proportions
 (3) Law of conservation of mass
 (4) Law of constant proportions
87. After a chemical reaction, the total mass of reactants and products
 (1) is always increased
 (2) is always decreased
 (3) is not changed
 (4) is always less or more
88. A sample of pure carbon dioxide, irrespective of its source contains 27.27% carbon and 72.73% oxygen. The data support
 (1) Law of constant composition
 (2) Law of conservation of mass
 (3) Law of reciprocal proportions
 (4) Law of multiple proportions

Problems Based on Concentration Terms

89. What will be the molarity of a solution, which contains 5.85 g of NaCl(s) per 500 mL ?
 (1) 4 mol L^{-1} (2) 20 mol L^{-1}
 (3) 0.2 mol L^{-1} (4) 2 mol L^{-1}
90. If the concentration of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) in blood is 0.9 g L^{-1} , what will be the molarity of glucose in blood?
 (1) 5 M (2) 50 M
 (3) 0.005 M (4) 0.5 M
91. What will be the molality of the solution containing 18.25 g of HCl gas in 500 g of water?
 (1) 0.4 m (2) 0.2 m (3) 0.5 m (4) 1 m
92. One mole of any substance contains 6.022×10^{23} atoms/molecules. Number of molecules of H_2SO_4 present in 100 mL of 0.02M H_2SO_4 solution is_
 (1) 12.044×10^{20} molecules
 (2) 6.022×10^{23} molecules
 (3) 1×10^{23} molecules
 (4) 12.044×10^{23} molecules
93. What will be the molarity of a solution containing 5g of sodium hydroxide in 250 mL solution
 (1) 0.5 M (2) 1.0 M (3) 2.0 M (4) 0.1 M
94. A molal solution is one that contains one mole of a solute in
 (1) 1000 g of the solvent
 (2) One litre of the solvent
 (3) One litre of the solution
 (4) 22.4 litres of the solution
95. What will be the molality of a solution having 18g of glucose (mol. Wt. = 180) dissolved in 500g of water
 (1) 1 m (2) 0.5 m (3) 0.2 m (4) 2 m
96. How much mass of sodium acetate (CH_3COONa) is required to make 250 mL of 0.575 molar aqueous solution?
 (1) 11.79g (2) 15.38g
 (3) 10.81g (4) 25.35g





97. 4.28g of NaOH is dissolved in water and the solution is made to 250cc. what will be the molarity of the solution?
(1) 0.615 mol L^{-1} (2) 0.428 mol L^{-1}
(3) 0.99 mol L^{-1} (4) 0.301 mol L^{-1}
98. What will be the molarity of the solution in which 0.365g of HCl gas is dissolved in 100 mL of solution?
(1) 2 M (2) 0.2 M (3) 1 M (4) 0.1 M
99. What will be the molality of the solution made by dissolving 10g of NaOH in 100g of water?
(1) 2.5 m (2) 5 m
(3) 10 m (4) 1.25 m
100. The density of a solution prepared by dissolving 120g of urea (molar Mass = 60) in 1000g of water is 1.15 g/mL. The molarity of this solution is
(1) 0.50 M (2) 1.78 M
(3) 1.02 M (4) 2.05 M
101. Number of HCl molecules present in 10 ml of 0.1 M solution is :
(1) 6.022×10^{23} (2) 6.023×10^{22}
(3) 6.022×10^{21} (4) 6.022×10^{20}
102. An aqueous solution of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) is 10% w/v in strength. The volume in which 180g of glucose is dissolved will be
(1) 18 L (2) 9 L (3) 0.9 L (4) 1.8 L
103. 1000g aqueous solution of CaCO_3 contains 10g of CaCO_3 . Concentration of the solution is
(1) 10 ppm (2) 100 ppm
(3) 1000 ppm (4) 10000 ppm
104. The mole fraction of oxygen in a mixture of 7g of nitrogen and 8g of oxygen is :
(1) 8/15 (2) 0.5 (3) 0.25 (4) 1




EXERCISE – II

- Elements A and B form two compounds B_2A_3 and B_2A . 0.05 moles of B_2A_3 weight 9.0 gms and 0.10 mole of B_2A weight 10 gms atomic weight of A and B are-
 (1) 20 and 30 (2) 30 and 40
 (3) 40 and 30 (4) 30 and 20
- The empirical formula of an organic compound containing carbon and hydrogen is CH_2 . The mass of one litre of this organic gas is exactly equal to that of one litre of N_2 at same temperature and pressure. Therefore, the molecular formula of the organic gas is –
 (1) C_2H_4 (2) C_3H_6 (3) C_6H_{12} (4) C_4H_8
- When 100 g of ethylene polymerizes to polythylene according to equation $nCH_2 = CH_2 \rightarrow (-CH_2 - CH_2 -)_n$ The weight of polyethylene produced will be:-
 (1) $\frac{n}{2}$ gm (2) 100 gm
 (3) $\frac{100}{n}$ gm (4) 100ngm
- If 3.01×10^{20} molecules are removed from 98 mg of H_2SO_4 , then the number of moles of H_2SO_4 left are :-
 (1) 0.1×10^{-3} (2) 0.5×10^{-3}
 (3) 1.66×10^{-3} (4) 9.95×10^{-2}
- Number of neutrons present in 1.7 gms of ammonia is -
 (1) N_A (2) $N_A/10 \times 4$
 (3) $(N_A/10) \times 7$ (4) $N_A \times 10 \times 7$
- The number of atoms present in 0.5 g atom of nitrogen is same as the atoms in –
 (1) 12g of C (2) 32g of S
 (3) 8g of oxygen (4) 24g of Mg
- Which of the following has the highest mass ?
 (1) 1 g atom of C
 (2) $\frac{1}{2}$ mole of CH_4
 (3) 10 ml of water
 (4) 3.011×10^{23} atoms of oxygen
- Which of the following contains largest number of atoms ?
 (1) 4 gm of H_2 (2) 16 gm of O_2
 (3) 28 gm of N_2 (4) 18 gm of H_2O
- Vapour density of gas is 11.2 volume occupied by 2.4 gms of this at STP will be-
 (1) 11.2 L (2) 2.24 L
 (3) 22.4 L (4) 2.4 L
- If V ml of the vapours of substance at NTP weight W g. Then molecular wt. of substance is:-
 (1) $(W/V) \times 22400$ (2) $\frac{V}{W} \times 22.4$
 (3) $(W - V) \times 22400$ (4) $\frac{W \times 1}{V \times 22400}$
- The number of gram molecules of oxygen in 6.02×10^{24} CO molecules is –
 (1) 10 gm molecules
 (2) 5 gm molecules
 (3) 1 gm molecules
 (4) 0.5 gm molecules
- The number of moles of carbon dioxide which contain 8 gm of oxygen atom is –
 (1) 0.5 moles (2) 0.20 moles
 (3) 0.40 moles (4) 0.25 moles
- 22.4 litre of water vapour at NTP, When condensed to water occupies an approximate volume of -
 (1) 18 litre (2) 1 litre
 (3) 1 mL (4) 18 mL
- Given that one mole of N_2 at NTP occupies 22.4 litre the density of N_2 is -
 (1) 1.25 g/litre (2) 0.80 g/litre
 (3) 2.5 g/litre (4) 1.60 g/litre
- A person adds 1.71 gram of sugar ($C_{12}H_{22}O_{11}$) in order to sweeten his tea. The number of carbon atoms added are (mol. mass of sugar = 342)
 (1) 3.6×10^{22} (2) 7.2×10^{21}
 (3) 0.05 (4) 6.6×10^{22}
- Which of the following compounds has same empirical formula as that of glucose:-
 (1) CH_3CHO (2) CH_3COOH
 (3) CH_3OH (4) C_2H_6





17. If 8 mL of uncombined O_2 remain after exploding O_2 with 4 mL of hydrogen, the number of mL of O_2 originally were -
 (1) 12 (2) 2 (3) 10 (4) 4
18. If 1.6 gms of SO_2 , 1.5×10^{22} molecules of H_2S are mixed and allowed to remain in contact in a closed vessel until the reaction
 $2H_2S + SO_2 \longrightarrow 3S + 2H_2O$,
 proceeds to completion. Which of the following statement is true ?
 (1) Only 'S' and ' H_2O ' remain in the reaction vessel.
 (2) ' H_2S ' will remain in excess
 (3) ' SO_2 ' will remain in excess
 (4) None
19. The moles of O_2 required for reacting with 6.8g of ammonia
 ($\dots\dots NH_3 + \dots\dots O_2 \rightarrow \dots\dots NO + \dots\dots H_2O$) is
 (1) 5 (2) 2.5 (3) 1 (4) 0.5
20. How many moles of potassium chlorate ($KClO_3$) need to be heated to produce 11.2 litre oxygen at N.T.P.
 (1) $\frac{1}{2}$ mol (2) $\frac{1}{3}$ mol (3) $\frac{1}{4}$ mol (4) $\frac{2}{3}$ mol
21. If $1\frac{1}{2}$ moles of oxygen combine with Al to form Al_2O_3 , the weight of Al used in the reaction is (Al=27)
 (1) 27 g (2) 54 g (3) 40.5 g (4) 81 g
22. One litre of CO_2 is passed over red hot coke. The volume becomes 1.4 litre at same temperature and pressure. The composition of products is—
 (1) 0.6 litre CO
 (2) 0.8 litre CO_2
 (3) 0.6 litre CO_2 and 0.8 litre CO
 (4) None
23. Assuming that petrol is octane (C_8H_{18}) and has density 0.8 g/ml, 1.425 litre of petrol on complete combustion will consume.
 (1) 50 mole of O_2 (2) 100 mole of O_2
 (3) 125 mole of O_2 (4) 200 mole of O_2
24. The number of litres of air required to burn 8 litres of C_2H_2 is approximately—
 (1) 40 (2) 60 (3) 80 (4) 100
25. A sample of calcium carbonate ($CaCO_3$) has the following percentage composition: Ca = 40%; C = 12%; O = 48%
 If the law of constant proportions is true, then the weight of calcium in 4 g of a sample of calcium carbonate obtained from another source will be
 (1) 0.016 g (2) 0.16 g
 (3) 1.6 g (4) 16 g
26. The number of gram atoms of oxygen present in 0.3 gram mole of
 $(COOH)_2 \cdot 2H_2O$ is
 (1) 0.6 (2) 1.8 (3) 1.2 (4) 3.6
27. 100 mL of PH_3 on decomposition produced phosphorus and hydrogen. The change in volume is
 $PH_3(g) \rightarrow P(s) + \frac{3}{2} H_2(g)$
 (1) 50 mL increase
 (2) 500 mL decrease
 (3) 900 mL decrease
 (4) Nil.
28. The number of molecules in 8.96 L of a gas at $0^\circ C$ and 1 atmospheric pressure is approximately
 (1) 6.02×10^{23} (2) 12.04×10^{23}
 (3) 18.06×10^{23} (4) 24.08×10^{22}
29. The molecular weight of a gas is 45. Its density (g/L) at STP is
 (1) 22.4 (2) 11.2 (3) 5.7 (4) 2.0
30. The total number of protons in 10 g of calcium carbonate ($CaCO_3$) is
 ($N_A = 6.023 \times 10^{23}$)
 (1) 1.5057×10^{24} (2) 2.0478×10^{24}
 (3) 3.0115×10^{24} (4) 4.0956×10^{24}
31. Number of molecules in 100 ml of each of O_2 , NH_3 and CO_2 at STP are
 (1) In the order $CO_2 < O_2 < NH_3$
 (2) In the order $NH_3 < O_2 < CO_2$
 (3) The same
 (4) $NH_3 < CO_2 < O_2$
32. The number of water molecules in 1 litre of water is
 (1) 18 (2) 18×1000
 (3) N_A (4) $55.55 N_A$





- 33.** The number of electrons in a mole of hydrogen molecule is
 (1) 6.02×10^{23} (2) 12.046×10^{23}
 (3) 3.0115×10^{23} (4) Indefinite
- 34.** The numbers of moles of BaCO_3 which contain 1.5 moles of oxygen atoms is
 (1) 0.5 (2) 1
 (3) 3 (4) 6.02×10^{23}
- 35.** 2g of oxygen contains number of atoms equal to that in
 (1) 0.5g of hydrogen (2) 4g of sulphur
 (3) 7g of nitrogen (4) 2.3g of sodium
- 36.** The empirical formula of an acid is CH_2O_2 , the probable molecular formula of acid may be
 (1) CH_2O (2) CH_2O_2
 (3) $\text{C}_2\text{H}_4\text{O}_2$ (4) $\text{C}_3\text{H}_6\text{O}_6$
- 37.** What is the % H_2O of in $\text{Fe}(\text{CNS})_3 \cdot 3\text{H}_2\text{O}$ (At. wt. Fe = 56)
 (1) 45 (2) 30 (3) 19 (4) 25
- 38.** What weight of SO_2 can be made by burning sulphur in 5.0 moles of oxygen?
 (1) 640 grams (2) 160 grams
 (3) 80 grams (4) 320 grams
- 39.** Volume occupied by one molecule of water (density = 1 g cm^{-3}) is :-
 (1) $3.0 \times 10^{-23} \text{ cm}^3$ (2) $5.5 \times 10^{-23} \text{ cm}^3$
 (3) $9.0 \times 10^{-23} \text{ cm}^3$ (4) $6.023 \times 10^{-23} \text{ cm}^3$
- 40.** How many moles of lead (II) chloride (PbCl_2) will be formed from a reaction between 6.5 g of PbO and 3.2 g of HCl ? (Atomic wt. of Pb = 207)
 (1) 0.011 (2) 0.029
 (3) 0.044 (4) 0.333
- 41.** If a compound, on analysis was found to contain C = 18.5 %, H = 1.55 %, Cl = 55.04 % and O = 24.81 %, then its empirical formula is.
 (1) $\text{C}_2\text{H}_2\text{OCl}$ (2) CH_2ClO
 (3) CHClO (4) ClCH_2O
- 42.** One gram mole of a gas at N.T.P. occupies 22.4 liters. This fact was derived from.
 (1) Law of gaseous volumes
 (2) Dalton's atomic theory
 (3) Avogadro's Law
 (4) Law of constant proportions
- 43.** Percentage of Se (at. mass = 78.4) in peroxidase anhydrase enzyme is 0.5% by weight, then minimum molecular mass of peroxidase anhydrase enzyme is.
 (1) 1.568×10^4 (2) 1.568×10^3
 (3) 15. 68 (4) 2.136×10^4
- 44.** The maximum number of molecules is present in
 (1) 5L of N_2 gas at STP
 (2) 0.5 g of H_2 gas
 (3) 10 g of O_2 gas
 (4) 15 L of H_2 gas at STP
- 45.** The number of molecule at NTP in 1 ml of an ideal gas will be
 (1) 6×10^{23}
 (2) 2.69×10^{19}
 (3) 2.69×10^{23}
 (4) None of these
- 46.** The law of multiple proportions is illustrated by the two compounds
 (1) Sodium chloride and sodium bromide
 (2) Ordinary water and heavy water
 (3) Caustic soda and caustic potash
 (4) Sulphur dioxide and sulphur trioxide
- 47.** A organic compound has found 71.7% chlorine, 4.04% Hydrogen and remaining carbon. If molecular weight compound is 99 then molecular formula will be
 (1) CHCl_3 (2) $\text{C}_2\text{H}_4\text{Cl}_2$
 (3) $\text{C}_2\text{H}_2\text{Cl}_2$ (4) CH_3Cl
- 48.** A and B are two identical vessels. A contains 15 gm ethane at 1 atm and 298 K. The vessel B contains 75 gm of a gas X_2 at same temperature and pressure. The vapour density of X_2 is –
 (1) 75 (2) 150 (3) 37.5 (4) 45





EXERCISE – III (PREVIOUS YEAR QUESTIONS)

- The number of atoms in 0.1 mol of a triatomic gas is ($N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$)
[AIPMT PRELIMS 2010]
(1) 6.026×10^{22} (2) 1.806×10^{23}
(3) 3.600×10^{23} (4) 1.800×10^{22}
- Which has the maximum number of molecules among the following? [AIPMT MAINS 2011]
(1) 44 g CO_2 (2) 48 g O_3
(3) 8 g H_2 (4) 64 g SO_2
- 1.0 g of magnesium is burnt with 0.56 g O_2 in a closed vessel. Which reactant is left in excess and how much? (Atomic weight Mg = 24, O = 16)
[AIPMT-2014]
(1) Mg, 0.16 g (2) O_2 , 0.16 g
(3) Mg, 0.44 g (4) O_2 , 0.28 g
- When 22.4 litres of $\text{H}_2(\text{g})$ is mixed with 11.2 litres of $\text{Cl}_2(\text{g})$, each at STP, the moles of $\text{HCl}(\text{g})$ formed is equal to [AIPMT-2014]
(1) 1 mol of $\text{HCl}(\text{g})$ (2) 2 mol of $\text{HCl}(\text{g})$
(3) 0.5 mol of $\text{HCl}(\text{g})$ (4) 1.5 mol of $\text{HCl}(\text{g})$
- Equal masses of H_2 , O_2 and methane have been taken in a container of volume V at temperature 27°C in identical conditions. The ratio of the volumes of gases $\text{H}_2 : \text{O}_2 : \text{methane}$ would be [AIPMT-2014]
(1) 8 : 16 : 1 (2) 16 : 8 : 1
(3) 16 : 1 : 2 (4) 8 : 1 : 2
- A mixture of gases contains H_2 and O_2 gases in the ratio of 1 : 4 (w/w). What is the molar ratio of the two gases in the mixture?
[AIPMT-2015]
(1) 16 : 1 (2) 2 : 1 (3) 1 : 4 (4) 4 : 1
- The number of water molecules is maximum in [AIPMT-2015]
(1) 1.8 gram of water
(2) 18 gram of water
(3) 18 moles of water
(4) 18 molecules of water
- If Avogadro number N_A , is changed from ($6.022 \times 10^{23} \text{ mol}^{-1}$ to $6.022 \times 10^{20} \text{ mol}^{-1}$), this would change [AIPMT-2015]
(1) the mass of one mole of carbon
(2) the ratio of chemical species to each other in a balanced equation
(3) the ratio of elements to each other in a compound
(4) the definition of mass in units of grams
- 20.0 g of a magnesium carbonate sample decomposes on heating to give carbon dioxide and 8.0g magnesium oxide. What will be the percentage purity of magnesium carbonate in the sample?
(At. Wt. : Mg = 24) [AIPMT-2015]
(1) 60 (2) 84 (3) 75 (4) 96
- Suppose the elements X and Y combine to form two compounds XY_2 and X_2Y_2 . When 0.1 mole of XY_2 weighs 10g and 0.05 mole of X_2Y_2 weighs 9gm, the atomic weights of X and Y are [AIPMT-2016]
(1) 20, 30 (2) 30, 20 (3) 40, 30 (4) 60, 40
- A mixture of 2.3 g formic acid and 4.5g oxalic acid is treated with conc. H_2SO_4 . The evolved gaseous mixture is passed through KOH pellets. Weight (in g) of the remaining product at STP will be : [NEET-2018]
$$\text{HCOOH} \xrightarrow{\text{Conc. H}_2\text{SO}_4} \text{CO}$$
$$\begin{array}{c} \text{COOH} \\ | \\ \text{COOH} \end{array} \xrightarrow{\text{Conc H}_2\text{SO}_4} \text{CO} + \text{CO}_2$$

(1) 2.8 (2) 3.0 (3) 1.4 (4) 4.4
- In which case is the number of molecules of water maximum? [NEET-2018]
(1) 0.00224 L of water vapours at 1 atm and 273 K
(2) 0.18 g of water
(3) 18 mL of water
(4) 10^{-3} mol of water
- The number of moles of hydrogen molecules required to produce 20 moles of ammonia through Haber's process is : [NEET-2019]
(1) 30 (2) 40 (3) 10 (4) 20
- Which one of the following has maximum number of atoms? [NEET-2020]
(1) 1 g of Ag(s) [Atomic mass of Ag = 108]
(2) 1 g of Mg(s) [Atomic mass of Mg = 24]
(3) 1 g of $\text{O}_2(\text{g})$ [Atomic mass of O = 16]
(4) 1 g of Li(s) [Atomic mass of Li = 7]





15. One mole of carbon atom weighs 12 g. the number of atoms in it is equal to, (Mass of carbon-12 is 1.9926×10^{-23} g) [NEET-2020]

(1) 1.2×10^{23} (2) 6.022×10^{22}
(3) 12×10^{22} (4) 6.022×10^{23}

16. An organic compound contains 78% (by wt.) carbon and remaining percentage of hydrogen. The right option for the empirical formula of this compound is [Atomic wt. of C is 12, H is 1]

[NEET-2021]

(1) CH (2) CH₂ (3) CH₃ (4) CH₄

17. What mass of 95% pure CaCO₃ will be required to neutralize 50 mL of 0.5 M HCl solution according to the following reaction ?



[Calculate upto second place of decimal point]

[NEET-2022]

(1) 1.25 g (2) 1.32 g (3) 3.65 (4) 9.50 g

ANSWER KEY

EXERCISE – I

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	3	3	4	1	4	2	2	3	4	2	3	3	1	1	3
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	1	2	4	2	3	2	2	4	2	1	2	1	1	3	2
Que.	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Ans.	1	3	1	1	3	4	3	1	1	1	3	2	4	4	4
Que.	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	2	3	2	4	2	2	4	3	4	2	1	2	4	4	2
Que.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Ans.	1	3	2	3	1	4	1	4	1	2	4	1	3	1	1
Que.	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Ans.	3	1	2	4	4	2	2	1	3	2	1	3	1	3	3
Que.	91	92	93	94	95	96	97	98	99	100	101	102	103	104	
Ans.	4	1	1	1	3	1	2	4	1	4	4	4	4	2	

EXERCISE – II

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	3	1	2	2	3	3	1	1	4	1	2	4	4	1	1
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	2	3	3	4	2	2	3	3	4	3	2	1	4	4	3
Que.	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Ans.	3	4	2	1	2	4	3	4	1	2	3	3	1	4	2
Que.	46	47	48												
Ans.	4	2	1												

EXERCISE – III

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	2	3	1	1	3	4	3	1	2	3	1	3	1	4	4
Que.	16	17													
Ans.	3	2													



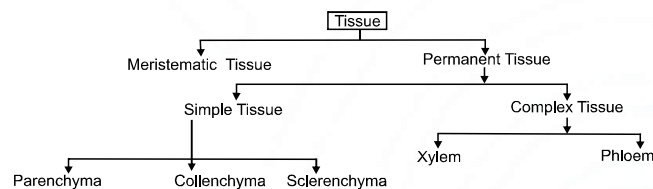
ANATOMY OF FLOWERING PLANTS

Plant Anatomy (Greek Word. Ana → As Under & Temnein → To Cut):

- It is the branch of Botany which deals with study of internal structures and organization of plants by the **Section Cutting** is called **Plant Anatomy**.
- N.Grew** is known as father of plant anatomy.
- Catherine Essau** → The anatomy of seed plant

Plant Tissues

- An organized group of cells which is having similar or dissimilar in shape, having a common origin and usually performing a common function is called **Tissue**.



Meristematic Tissues:

- Meristem (Meristos–Divided):** Growth in plants is largely restricted to specialised regions of active cell division called meristem.
- A meristem is a localized region in which actual cell division occurs.

Characteristics:

- It is an **Undifferentiated tissue or Dedifferentiated tissue**
- Cell cycle of meristem is in **Continuous** state of division. It means they have the capacity to divide. So meristematic tissue is composed of **immature cells**.
- Meristematic cells have only primary cell wall which is thin and flexible (elastic) and made up of cellulose. Secondary cell wall is absent.
- Cells of meristem are small and isodiametric.
- They have **Dense cytoplasm**.
- Normally vacuoles are absent in meristematic cells but if present then small.**
- They have **Prominent** and large nucleus.
- Meristematic cells are **Metabolically** highly active so lack of reserve food occur in these cells.

- Plastids** are **absent** in meristems. If they are present, then only in the **Proplastid stage** ER is poorly developed.
- They do not have **Intercellular** spaces. Cells are closely fitted (Packed) together. So it is a **Compact tissue**.

Classification of Meristematic Tissue

[A] Meristematic Tissue (Based on Origin and Development):

On the basis of origin and development meristems can be divided into following three types:

(i) Promeristem/Embryonic

Meristem/Primordial Meristem:

- This meristem develops in beginning during embryonic stage.
- They divide and give rise to primary meristem.

(ii) Primary Meristem:

- Meristematic cell developed from promeristem are known as **Primary Meristem**.
- These cells are always in division phase and form primary permanent tissue.
- They are made up of undifferentiated cell.
- They are present at shoot and root apices, at the apex of leaves and in intercalary parts.

e.g. **Apical meristem, Intercalary meristem, Intrafascicular cambium.**

(iii) Secondary Meristem:

- These are the meristems developed from primary permanent tissues. They are not present in the embryonic stage of the plant. These are present in mature region of root and stem of many plants particularly those that produce woody axis.
- Some of the cells of primary permanent tissues become meristematic and constitute secondary meristem.
- They are made up of dedifferentiated cell.
- By the activity of secondary meristems, **Secondary growth** takes place.



e.g. **Cork cambium, Interfascicular cambium & Root cambium.**

Note: Formation of meristem from any permanent tissue is called **Dedifferentiation**.

or

Formation of undifferentiated tissue from differentiated tissues is called **Dedifferentiation**.

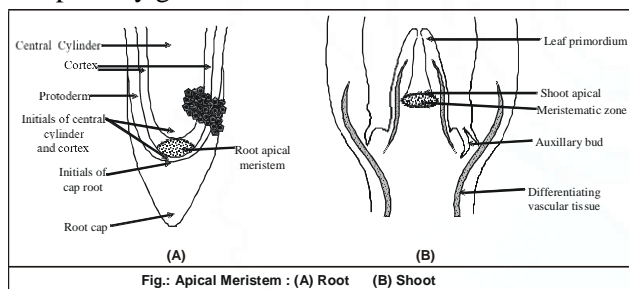
Promeristem → Primary Meristem → Permanent Tissue
→ Secondary Meristem → Secondary Permanent Tissue

[B] Meristematic Tissues Based on Location (Position) In Plant Body:

On the basis of position, meristematic tissues are divided into three types:

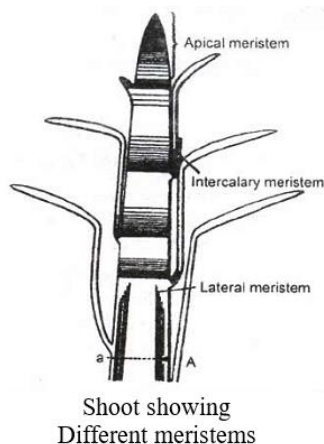
(i) Apical Meristem:

- The meristems which occur at the tips of roots and shoots and produce primary tissues are called apical meristems. They are responsible for increase in the length of plant organs. Example: **Root apex, Shoot apex.** They are responsible for primary growth.



- During formation of leaves and elongation of stem, some cells left behind, they form auxillary bud and from new branches or flowers.

(ii) Intercalary Meristem:



- The meristem which occurs between mature tissues.
- This is the separated region of apical meristem.
- By the activity of this meristem length of the plant organs increases.
- They are present in some plants stem.
- They are responsible for regeneration of parts removed by grazing herbivores in grasses.
- They are short lived and convert into permanent tissue.

Both apical meristem & intercalary meristems are primary meristem because they appear early in the life of a plant and contribute to the formation of primary plant body.

(iii) Lateral Meristem:

- Lateral meristem occurs in **Lateral side** of plant organs or parallel to the **Longitudinal axis** of plant organs. They are cylindrical meristem.
- Activity of lateral meristem increases the **Girth of plant organ**, so it is **Responsible for Secondary Growth and Produce Secondary Tissue**.
- Lateral meristems are both primary and secondary in origin (**Mostly Secondary in Origin**). There are two examples of **Primary Lateral Meristem**.
 - Marginal Meristem:** It occurs at the margin of leaf. Its activity increases the **width** of leaf.
 - Intra Fascicular Cambium or Fascicular Cambium:** This cambium occurs inside the vascular bundle of the stem.

Except Intra Fascicular Cambium all Cambium are Secondary in Origin.

- During the formation of primary plant body different region of apical meristem produce dermal tissue, ground tissue and vascular tissue.



FUNDAMENTAL UNLOCKED- (FU#1) :

1. A tissue is:
 - (1) Group of cells
 - (2) Common in origin
 - (3) Usually performing a common function
 - (4) All of these
2. Which meristem occurs at the tips of roots and shoots ?
 - (1) Apical meristem
 - (2) Intercalary meristem
 - (3) Secondary meristem
 - (4) Both (1) and (2)
3. The axillary buds are present in:
 - (1) Axil of leaf base (2) Axil of leaves
 - (3) Axil of stem (4) Axil of roots
4. Apical meristem and Intercalary meristem are:
 - (1) Secondary meristems
 - (2) Primary meristems
 - (3) Lateral meristem
 - (4) Both (1) & (2)
5. Axillary bud develops from:
 - (1) Root apical meristem
 - (2) Shoot apical meristem
 - (3) Primary meristem
 - (4) Secondary meristem
6. Root apical meristem occur the tip of:
 - (1) Radicle (2) Endosperm
 - (3) Plumule (4) Epicotyl
7. Which of following is **not** an example of secondary meristem?
 - (1) Interfascicular cambium
 - (2) Cork cambium
 - (3) Vascular cambium
 - (4) Intrafascicular cambium
8. Intercalary meristem is occurs between:
 - (1) Tip of stem (2) Immatured tissues
 - (3) Matured tissues (4) Both (2) & (3)
9. How many of the following are example of secondary meristem?
Cork cambium, Intercalary meristem, Apical Meristem, Intrafascicular cambium, Interfascicular cambium
 - (1) 5 (2) 4 (3) 2 (4) 3

10. The newly formed cells become structurally and functionally specialised and lose the ability to divide such cells are termed?
 - (1) Mature cells
 - (2) Immature cells
 - (3) Meristematic cells
 - (4) Undifferentiated cells
11. The axillary buds are capable of forming?
 - (1) Branch and flower (2) Buds and fruit
 - (3) Root and flower (4) Stem and branch

Permanent Tissues

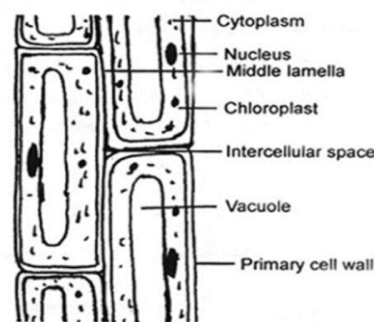
- Following division of cells in meristem the newly formed cells become structurally and functionally specialized and lose the division ability and they form permanent tissue. They are formed by division and differentiation of meristematic tissues.
- Their cells may be **living** or **dead**.

(A) Simple Tissues:

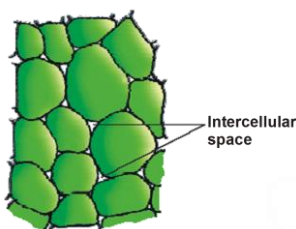
- These tissues are **made up of similar type of cells** that perform a common function and have common origin. Simple tissues are of three types:
 - (I) Parenchyma (II) Collenchyma
 - (III) Sclerenchyma

(I) Parenchyma: It is very **primitive** type of tissue. It is first evolved tissue. Remaining all different type of tissues are derived from this tissue. So it is also called as **fundamental tissue**.

- It is a **universal tissue** and a major component of internal plant organs.
- Parenchyma name coined by **Grew**.

Characteristic Features:


L.S. of Parenchyma



1. It is a living tissue.
2. Tissue first to be differentiated from meristem is parenchyma.
3. All the cells of parenchyma are thin walled. Cell wall is made up of pectocellulose. (**Mainly cellulose**). So parenchyma is a soft tissue.
4. Each cell containing large central vacuole.
5. Inter cellular spaces are present between cells of this tissue, it is a loose tissue. In origin intercellular space are schizogenous.
6. Body of Bryophyte is mainly composed of parenchyma.
7. Flesh of a fruit is mainly composed of parenchyma.
8. The cells are **isodiametric**. The cells of parenchyma are spherical, oval or polygonal in shape.

Modification of Parenchyma:

- (a) **Prosenchyma:** The cells of this parenchyma are long with pointed ends. This parenchyma forms the **Pericycle of roots**.
- (b) **Aerenchyma:** This parenchyma is made up of **rounded** cells. These cells surround the large **air chambers**. It is found in cortex region. It provides **buoyancy** to **hydrophyte** plants.
- (c) **Stellate Parenchyma:** The cells of this tissue are stellate and branched.
 - It is found in the leaf bases of **banana** and **canna**.
- (d) **Chlorenchyma:** Type of parenchyma in which abundant quantity of chloroplasts are found. Two types of chlorenchyma are present in dorsiventral leaves:
 - (i) **Palisade Tissues:** Inter cellular spaces are absent. Their cells are tightly fitted together. They are present towards adaxial/ventral/upper side of leaf. Numbers of chloroplasts are more in palisade tissue as compare to spongy tissue. So upper surface of a leaf appears more green as compared to lower surface.

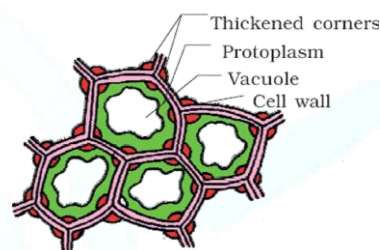
- (ii) **Spongy Tissues:** Large intercellular spaces are present. So they facilitate transpiration and gaseous exchange. They are present towards abaxial/dorsal/lower side of leaf.
- (e) **Idioblast:** In this type of parenchyma non-living ergastic substances like tannins, oils, crystals etc. are present.

Functions of Parenchyma:

The main function of this tissue is **storage of food, photosynthesis and secretion**.

(II) Collenchyma:

Main Characteristics:



Collenchyma

- Collenchyma is a **Living Mechanical Tissue**.
- It is made up of **elongated (Oval, Spherical or Polygonal** shape in section) cells.
- **Localized** deposition of pectocellulose (Mainly **Pectin**) & hemi cellulose is the characteristics feature of collenchyma.
- Vacuolated cytoplasm is found in the cells of collenchyma. Intercellular spaces are not present. These cell assimilate food when they contain chloroplast.

Occurance:

- It is found in the stems of **Herbaceous Dicotyledons**.
- Collenchyma is absent in woody plant parts, root and monocotyledons.
- Collenchyma forms the **Hypodermis** of **Dicotyledon** stems. It is found either as a homogenous layer or in patches.
- Collenchyma is absent in plants after the secondary growth because plant becomes woody.
- **Lamina Margins** of leaves also bear collenchyma. This protects the cracking of lamina margin due to the action of wind.
- They are present in leaf petiole.



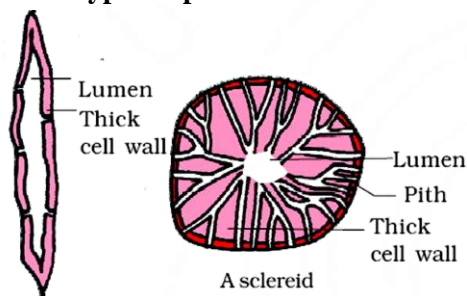
Functions:

- **Mechanical** as well as **Physiological**.
- They provide mechanical support to growing parts of plant such as young stem and petiole of leaf.
- Due to the presence of chloroplast, it is also participates in the process of **photosynthesis**.

(III) Sclerenchyma:

Main Features:

- Sclerenchyma is the **main mechanical tissue**.
- These cells are long, narrow, thick walled and dead.
- Cell wall is **thick** and **lignified** and have **different types of pit**.



Sclerenchyma

Function: It provide mechanical support/mechanical strength to plants.

Type of Sclerenchyma:

- On the basis of variation in form, structure, origin and development, sclerenchyma cells are of **two types**.

(1) Sclereids

(2) Sclerenchymatous fibres

- (1) **Sclereids:** These cells are small, extremely thick walled and their ends are not pointed. Sclereids are isodiametric or **irregular** in shape. Sclereids cells have **more pits** and **lumen** is almost **very narrow**.

(2) Sclerenchymatous Fibres:

- These cells are fibrous. They are longest cells in plant body. Their both ends are pointed (tapering). Due to thick wall, lumen is reduced. Fibers are generally occurring in groups.
- Their cell wall contains simple and bordered pits.

(B) Complex Permanent Tissues:

- The complex tissues are made up of more than one type of cells and these work as a unit. Complex tissue are heterogenous.
- Complex tissues are of two types:
(a) Xylem (b) Phloem.
- During vascularisation in plants differentiation of procambium followed by the formation of primary phloem and primary xylem simultaneously.
- Complex tissues are absent in gametophytes.

(a) Xylem [Name given by – Nageli Greek – Xyles – Wood]:

- The function of xylem is to conduct water and mineral salts upwards from the root to stem and leaves and to give mechanical strength to the plant body.
- For conduction of water, death of protoplasm is must. Dead tissues are more develop in water scares condition.
- On the basis of **origin**, xylem is divided into primary xylem and secondary xylem.

1. Primary xylem originates from procambium.

On the basis of development primary xylem divided into two parts.

(a) Protoxylem (b) Metaxylem

- Cells of protoxylem are small as compare to metaxylem. Metaxylem is more mature than protoxylem.

Important Points

Types of Primary Xylem:

It is of three types:

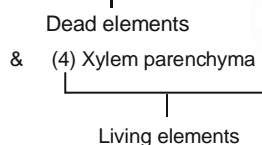
- Endarch:** In this type of development, the protoxylem formed near the central axis and metaxylem is formed away from the centre.
e.g.: stem of Angiosperm and Gymnosperm.
- Exarch:** Protoxylem is formed away from the centre near the pericycle and metaxylem is formed toward the centre. e.g. Roots.
- Mesarch:** Elements of metaxylem is formed from both side of the elements of protoxylem. In this type of development protoxylem is surrounded by metaxylem. e.g. Fern rhizome.



2. Secondary Xylem Originates from Vascular Cambium:

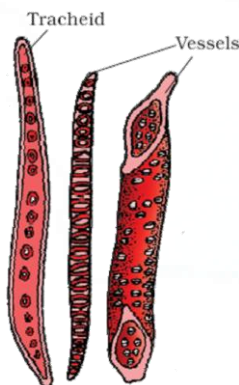
- The elements of xylem are:

(1) Tracheids, (2) Vessels or tracheae, (3) Xylem fibres



(1) Tracheids:

- Tracheids** are primitive **conducting elements** of xylem. They are present in all tracheophytes.
- They are elongated or tube like cell with thick and lignified wall and tapering end. **Tracheids** having a **narrow lumen**.
- Tracheids join together from **their ends** to form a **long row**. These rows extending from the root to leaves via stem.
- A **transverse septum** lies between each two tracheids. It bears **pits**.
- Water moves from one tracheid to another tracheids through pits.
- Due to presence of transverse septum lumen is discontinuous in tracheids.



Components of Xylem

- Tracheids are **dead** and **lignified** cells. The deposition of lignin on cell wall is responsible to form different type of thickenings.

Note:

- Usually bordered pits are present at end wall of tracheids.
- The maximum bordered pits are found in the tracheids of Gymnosperm plants.
- Maximum deposition of lignin is found in pitted type of thickening.

(2) Vessels:

- It is advance water conducting element of xylem.
- It is a long cylindrical tube like structure made up of many cell called vessel members each with lignified walls and large central cavity.
- The **lumen of vessels** is **wider** than tracheids and end wall is perforated **Transverse septum** is absent between two vessel elements, if present then **porous**. Thus vessels are more capable for conduction of water than tracheids. Due to presence of perforated end, vessels work as a pipe line during conduction of water.
- Vessels contain usually simple pits at their lateral wall.

Important Points

- Vessels are only found in xylem of angiosperm but exceptionally it is also present in some Gymnosperms like Ephedra, Gnetum and Welwitschia.
- Vessels are absent in some Angiospermic plants such as *Dracaena*, *Yucca*, *Dazinaria*, *Drimys*. There are some angiosperms families in which vesselless angiosperms are include. eg.: Winteraceae, Tetracentronaceae and Trochodendronaceae.

(3) Xylem Fibres:

- Xylem fibres **provides strength** to the tracheids and vessels, mainly these fibres provide strength to the vessels.
- They have highly thickened walls and obliterated central lumen.
- They are present **more abundantly** in **secondary xylem**.

(4) Xylem Parenchyma:

- It's cell wall is made up of cellulose. It store starch, fats and tannin etc.
- The **radial conduction of water** is the function of xylem parenchyma. (It conducts water to peripheral part of plant organs).
- Their wall possesses pits.

(b) Phloem:

- The main function of the phloem is to conduct food materials, usually from the leaf to other plant parts (eg., storage organ and growing regions.)



- On the basis of origin, phloem is classified into two categories primary and secondary phloem.
- Primary phloem originates from procambium and secondary phloem originates from vascular cambium.
- On the basis of development primary phloem categorised into protophloem and metaphloem.
- The protophloem has narrow sieve tubes whereas metaphloem has bigger sieve tubes.
- Phloem remains active for less duration as compared to xylem.
- Phloem consist of **4 types** of cells.

1. Sieve cell / Sieve tube

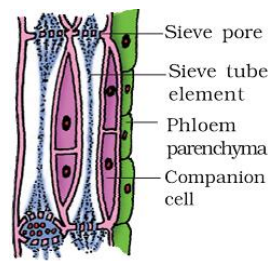


In Gymnosperms
and pteridophytes



In Angiosperms

- Sieve cell/sieve tube element are living and **thin walled**.
- Mature sieve tube elements are **enucleated** living cells.
- Central vacuole** is present in each sieve cells/sieve tube element.
- In Angiosperm plants** sieve tube elements are arranged with their ends and form **sieve tube**.
- Sieve plate (oblique transverse perforated septa) is present between the two sieve tube elements. Materials are transported through these pores.
- Callose** deposited on the radius of pores during **dropping season** (autumn) of leaves, to form a thick layer. This is called **Callose pad**.
- Sieve plate is protected by callose pad. It is also prevented from **bacterial infection** and drought.
- Callose dissolves during spring season by callase enzyme. Callose is a β -1-3 glucan.
- In Gymnosperms and pteridophytes sieve cells are arranged irregularly. Sieve cell have sieve plates on their lateral walls. Thus conduction of food takes place in zig-zag manner.
- In Angiosperms food conduction is erect and efficient.



Component of phloem

2. Companion Cell:

- The companion cells are specialized parenchymatous cell which are closely associated with sieve tube element. The sieve tube element and companion cells are connected by pits field present between their common longitudinal walls.
- Sieve tube element and companion cell originates together. Both of them originates from **a single mother cell**. So called as **sister cells**.
- Companion cells are only found in Angiosperms. Exception: Austrobaileya
- Special type of cells attached with the sieve cells in gymnosperm and pteridophytes in place of companion cells. These cells are called as **albuminous cells/strassburger cell**. It is analogous to companion cell.
- Function of companion cell.**
- Companion cell maintain pressure gradient in sieve tube.
- Functions of sieve tube are regulated by companion cell.
- Companion cell also involved in phloem loading.

3. Phloem Fibres:

- Fibres which are present in **phloem** are called **bast fibres**. These fibres are generally not found in **primary phloem**.
- These fibres provide mechanical support to the **conducting elements** (sieve cells and sieve tube.)
- Some of the phloem fiber are commercially important fiber e.g. Jute, Flax, Hemp.

4. Phloem Parenchyma:

- It is also known as **bast parenchyma**. It is made up of elongated tapering cylindrical cells which have dense cytoplasm and nucleus and connected through Plasmodesmata.



- It's cells are living and thin walled. It store various **material**. eg., Resin, Latex, Mucilage etc.
- The main function of phloem parenchyma is **conduction of food in radial direction** and **storage of food**.

Note: Phloem parenchyma is absent in the stems of **monocotyledon** plants and in primary phloem of dicot plant.

FUNDAMENTAL UNLOCKED- (FU#2) :

- In dicotyledonous stem, hypodermis is made up of:
 - (1) Parenchyma
 - (2) Collenchyma
 - (3) Sclerenchyma
 - (4) All of these
- Select the **correct** function of given simple tissues:
 - (1) Collenchyma – Photosynthesis, storage, secretion
 - (2) Sclerenchyma – Consist of large narrow cells without lignified cell
 - (3) Parenchyma – Petiole of leaf, young stem and growing part of the plant to provide mechanical support
 - (4) Complex tissues – Differentiated tissues, vascular tissues
- Sclerenchyma are commonly found in:
 - (1) Walls of nuts
 - (2) Pulp of fruits like Sapota
 - (3) Seed coat of legume
 - (4) All of these
- Sclereids are:
 - (1) Highly thickened dead cells
 - (2) Very narrow lumen
 - (3) Highly thin walled dead cells
 - (4) Both (1) and (2)
- Cell wall of xylem parenchyma is made up of:
 - (1) Hemicellulose
 - (2) Pectin
 - (3) Lignin
 - (4) Cellulose
- Select the **incorrect** option w.r.t complex tissue:
 - (1) The sieve tube elements and companion cells are connected by pit fields
 - (2) Xylem parenchyma cells are living and thin walled
 - (3) Endarch primary xylem is present in roots
 - (4) The companion cells are specialised parenchymatous
- Sclerenchyma fibres are:
 - (1) Elongated
 - (2) Thick walled
 - (3) Pointed cells usually occurring in groups
 - (4) All of these
- Which simple tissue provide mechanical support to the young stem?
 - (1) Parenchyma
 - (2) Sclerenchyma
 - (3) Collenchyma
 - (4) Chlorenchyma
- Collenchyma consists of cells which are much thickened at the corners due to deposition of:
 - (1) Pectin, lignin and hemicellulose
 - (2) Cellulose, lignin and pectin
 - (3) Pectin, cellulose and cutin
 - (4) Cellulose, hemicellulose and pectin
- Which one is elongated unbranched and have pointed needle like apices, found in flax:
 - (1) Sclereids
 - (2) Phloem fibres
 - (3) Xylem fibres
 - (4) Companion cells
- Primary xylem are:
 - (1) Protoxylem
 - (2) Metaxylem
 - (3) Protophloem
 - (4) Both (1) & (2)
- Gymnosperm lacks:
 - (1) Companion cells
 - (2) Sieve tube
 - (3) Vessels
 - (4) All of these

Tissue System

- In higher plants several tissues work together in form of a unit to perform a particular function. These tissues have the same origin. Such tissues form a system which is called **tissue system**. On the basis of **their structure and location** tissue categorized by **Sachs** into three different system.



- 1. Epidermal Tissue System:** The epidermal tissue system forms the outermost covering of the plant body. This system includes **epidermis** and its related structures. eg., **Root hairs, trichomes, stomata and bulliform cells** etc. It is developed from **protoderm**.

Epidermis:

- It is the outermost protective covering of primary plant body.
- The epidermis (Greek, Epi = upon ; Derma = skin) of most of plant organs is uniseriate, i.e. Composed of single layer of epidermal cells but in some cases it may be multilayered e.g., *Ficus*, *Nerium*.
- Epidermis is made up of parenchyma.
- Each cell has a large central vacuole & peripheral thin cytoplasm.
- The outside of the epidermis is often covered with waxy thick layer cuticle.

- Cuticle is absent in roots.
- Chloroplast is not present in epidermal cells.

Stomata:

- Stomata are minute apertures in the epidermis.
- Each aperture is bounded by two **kidney/ bean shaped cells**, called as **guard cells**.
- Dumbell shaped guard cell are present in grasses.
- Guard cell contains chloroplasts. Inner wall of guard cell is thickened and outer wall are thin.
- There are different numbers of cells of variable size in the epidermis around the guard cells.

These are called as **subsidiary cells**.

Stomatal apparatus = Guard cell + Stomatal pore + Subsidiary cell

- Stomata are absent in roots, underground parts and submerged hydrophytes.
- Stomata regulate the process of **transpiration** and **gaseous exchange**.

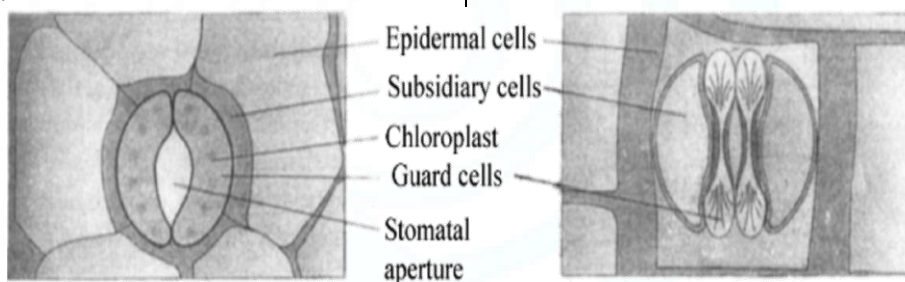


Fig.: Diagrammatic representation:
(a) Stomata with bean-shaped guard cells.
(b) Stomata with dumb-bell shaped guard cell.

Trichomes:

- On the stem the epidermal hairs are called **trichome**. These Trichome are usually **multicellular**. They may be **branched** or **unbranched** and **soft** and **stiff**. They may even be **secretory**.

Function of Trichomes:

- The trichomes help in **protection, dispersal of seeds and fruits and preventing water loss** due to transpiration.

Root Hairs:

- The root hairs are unicellular elongation of the epidermal cells. The thin wall is made up of cellulose and pectic materials. Root hairs are **endogenous** in origin.

Function Root Hairs:

- Root hairs play an important role in **anchoring the plant body** in the soil besides **absorbing water and mineral solution** from it.

Ground Tissue System:

- It is the largest tissue system. All the tissues except **epidermis and vascular bundle** form the **ground tissue system**.
- It includes **hypodermis, general cortex, endodermis, pericycle pith and medullary rays** (pith rays).
- It is also called as **fundamental tissue system**.
- In leaves ground tissue consist of chloroplast containing mesophyll.



It is also called the **fundamental tissue system**. This tissue system constitutes the main bulk of the body of plants. The tissues that do not come under the epidermal tissue system and vascular tissue system constitute the fundamental or ground tissue system. Various simple tissues like parenchyma, collenchyma and sclerenchyma are present in it.

The ground tissue system is clearly differentiated into various zones. In the transverse section of all dicot stems, monocot roots and dicot roots; the ground tissue exhibits clear zonation into an **outer cortex** and **central pith**. In between cortex and pith various other tissues are present which will be discussed later in anatomy of stems and roots. Such differentiation is not present in the monocot stems. In the leaves of monocot and dicot plants, ground tissue is called **mesophyll** and is not distinguished into cortex and pith. **Zonation in Ground Tissue System:** in dicot stems and all roots of angiosperms, following zonation is usually seen from outer to inner side in a transverse and longitudinal view.

(a) **Cortex:** It lies below the epidermis. It may be few to many layered in thickness. It is further differentiated into three sub-zones, i.e., hypodermis, general cortex and endodermis.

(i) **Hypodermis:** This is the outermost portion of cortex in stems of flowering plants.

Hypodermis is **absent** in **roots**. It may be single to multilayered. The dicotyledonous stems have collenchymatous hypodermis, i.e., made up of **collenchymatous** cells and the monocotyledonous stems have sclerenchymatous hypodermis, i.e., made up of **sclerenchymatous** cells. Hypodermis is **protective** in function. Its cells may have chloroplasts in them and thus, may perform **photosynthesis also**.

(ii) **General Cortex:** Next to hypodermis in stems and to epidermis in roots, lies the general cortex. It is few to many layered in thickness. It is **parenchymatous** in both stems and roots.

The cells are thin-walled and may or may not have the intercellular spaces between them.

The cells of cortex of young stems and leaves possess chloroplasts and perform photosynthesis. General cortex provides the **mechanical support**, performs **photosynthesis** in leaves and young stems and also **stores** the food material.

(iii) **Endodermis:** The innermost layer of cortex is called endodermis. All the tissues on the inner side of the endodermis constitute the **stele** which comprises pericycle, vascular bundles and pith. Hence, endodermis is the border between the general cortex and the stele.

(a) Endodermis is a **single layer** of compactly arranged cells. The cells constituting this layer are elongated with their long axis parallel to the longitudinal axis of plants.

(b) In transverse section (T.S.), the cells of endodermis appear **barrel-shaped** (drum or large cylinder shaped) or oval shaped.

(c) The cells constituting endodermis are **living** and may contain starch grains. This is the reason that endodermis is also called the **starch sheath**.

Casparian Strips: Endodermis is characterised by the presence of a special 'thickened' band in their wall called casparian strip. This thickening was first observed by **Caspary**, hence the name. This thickening appears on the **radial** as well as on the **tangential** walls of endodermal cells. This band-like structure is generally formed by the deposition of a water-impermeable waxy material **suberin**. Hence, walls of endodermal cells are suberized. Due to presence of casparian strips, the endodermis is impermeous to water.

A distinct endodermis is a constant feature of roots of all plants but in stems it is not very distinct.

(b) **Pericycle:** It is the outermost portion of stele. It is a cylinder of **thin-walled parenchymatous** or sometimes **thick-walled sclerenchymatous** tissue. It may be single-layered to multilayered. The cells may be thin-walled to thick-walled. Pericycle may be present in the form of patches also. Pericycle is **not present in monocotyledonous stems**.

Functions:

(i) Thick-walled pericycle gives **mechanical support** to the plants.

(ii) When composed of parenchymatous cells, it may act as **storage organ** of food materials.

(iii) In dicot roots, the pericycle becomes **meristematic** and forms a part of the cambial ring. This cambial ring gives rise to the secondary tissues.

(iv) Pericycle gives rise to the **lateral roots**.



(c) **Pith:** It is also called **medulla**. It occupies the central part in dicot stems, dicot roots and monocot roots. In monocot stems, pith cannot be distinguished as vascular bundles are present through out the stem. Pith is generally composed of large **parenchymatous** cells with intercellular spaces present between them. Sometimes sclerenchymatous cells are also present in pith. e.g., Compositae.

Pith Rays or Medullary Rays: These are the extensions of pith. In most dicotyledons, the peripheral layers of pith extend between the vascular bundles and are in contact with the pericycle. These extensions appear like rays and thus, they are called the pith rays. The pith rays are also called the medullary rays.

Ground Tissue in Leaves:

The ground tissue is not differentiated into cortex and pith in the leaves. Ground tissue consists of thin-walled chloroplast containing cells and is called **mesophyll**.

Vascular Tissue System:

This tissue system originates from **pro-cambium**.

- Xylem and phloem are collectively termed as **Vascular bundles** or **Vascular tissues system**.

Type of Vascular Bundles

On the basis of arrangement of different parts, vascular bundles are divided into three categories.

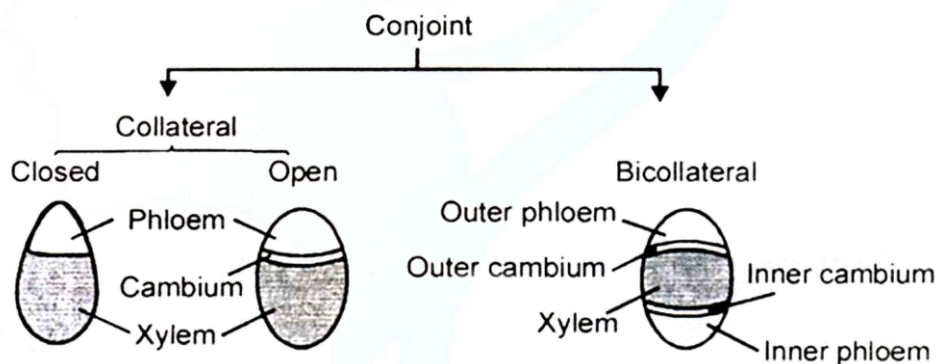
I. Radial Vascular Bundles:

- When the xylem and phloem are present separately on different radii in alternate manner. Such vascular bundles are called **radial vascular bundle**.
- The order of development of xylem in these vascular bundles is **centripetal**. Thus, these vascular bundles are called exarch. Example: Roots of plants.

II. Conjoint Vascular Bundles:

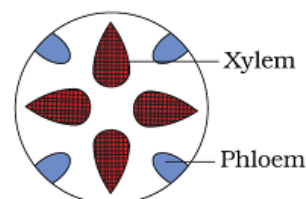
- In this type of vascular bundle xylem and phloem are present on the same radius. These are of two types

(1) **Conjoint Collateral:** In this type of vascular bundle xylem and phloem are present on the same radius and phloem present only towards the periphery. These are two types:



- (i) **Open:** If the cambium is present between the xylem and phloem, It is known as **open** vascular bundle. **Open vascular bundle** is found in stem of **dicotyledons** and **gymnosperm**.
- (ii) **Close:** When cambium is absent between the xylem and phloem, in conjoint vascular bundle, it is called as **closed vascular bundle**. Closed vascular bundles are found in **monocotyledons** stem. leaves of dicot and monocot.

- In this type of vascular bundle, order of development of xylem is **centrifugal**. So **endarch** condition is found in xylem.



Radial vascular Bundle



(2) **Conjoint Bicollateral and Open Vascular Bundle:** There are two patches of phloem, one on each side of xylem, are found. Such types of vascular bundles are known as conjoint, bicollateral and open vascular bundle. These vascular bundles are always open.

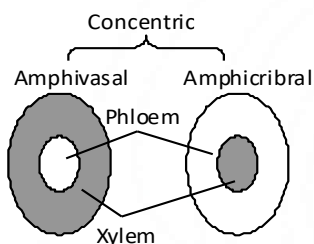
- Order of development of xylem is centrifugal so endarch condition is found.

e.g. **Stem of family Cucurbitaceae, Apocynaceae and Solanaceae.**

III. Concentric Vascular Bundles:

- In this type of vascular bundle either **xylem surrounds the phloem or phloem surrounds the xylem**. Concentric vascular bundles are **always closed**. They are of two types:

(a) Amphicribal or Hadrocentric:



- In this type of vascular bundle xylem is completely surrounded by phloem. Such type of vascular bundle is termed as **amphicribal**.
- The order development of xylem is centripetal and centrifugal so mesarch condition is found.
- Such types of vascular bundles are found **ferns rhizomes**.

(b) Amphivasal or Leptocentric:

- In this type of vascular bundle phloem is completely surrounded by xylem. eg., Stem of *Dracaena*, *Yucca* etc.
- The order of development of xylem in these vascular Bundles is Endarch.

FUNDAMENTAL UNLOCKED- (FU#3) :

- Which type of arrangement of vascular bundles occur in the stem of dicots ?
 - Conjoint close
 - Conjoint open
 - Radial open
 - Concentric

- In *Sorghum* stem, vascular bundles are:
 - Radial and closed
 - Scattered and open
 - Open and in a ring
 - Scattered and closed
- Trichomes and root hairs are respectively:-
 - Usually multicellular and unicellular
 - Unicellular and usually multicellular
 - Multicellular and multicellular
 - Usually unicellular and multicellular
- In grasses, shape of guard cells in stomata is:-
 - Bean shaped
 - Dumb-bell shaped
 - Oval shaped
 - Spindle shaped
- Which type of vascular bundle is common in leaves and stems:-

(1) Concentric	(2) Radial
(3) Conjoint	(4) All of these
- The size of the vascular bundles are dependent on the size of the:-

(1) Veinlets	(2) Vessels
(3) Veins	(4) Stomata
- Vascular bundle in dicot roots are:-
 - Open, conjoint and exarch
 - Closed, concentric and endarch
 - Radial and exarch
 - Closed conjoint and endarch
- Vascular bundles and epidermis are not part of:
 - Stelar tissue system
 - Epidermal tissue system
 - Ground tissue system
 - All of these
- Cuticle is absent in:

(1) Stem	(2) Roots
(3) Leaf	(4) Both (1) & (3)

Internal Structure of Stems, Roots And Leaves

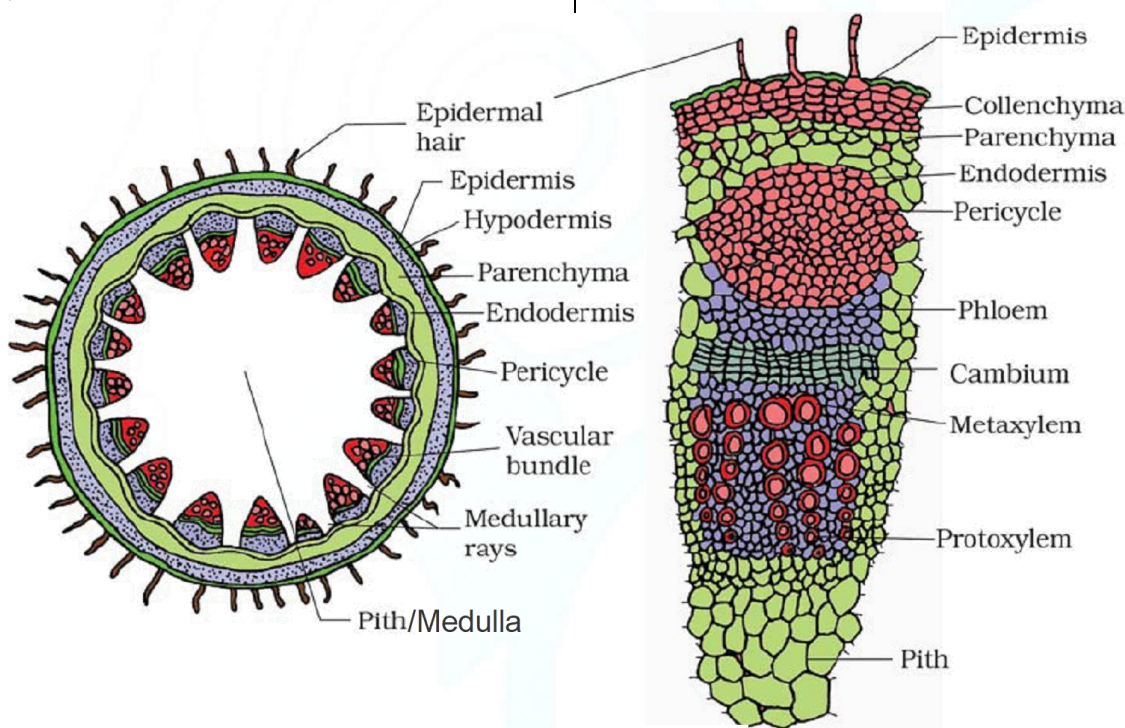
Internal Structure of Dicot Stem

Internal structure of a typical dicot stem show following features:



- 1. Epidermis:** Epidermis is the **outermost layer of the stem**. It is **single layered**. **Multicellular hair (trichomes) and stomata are found on epidermis**. Outer side of epidermis, a layer is present which is made up of cutin is called **cuticle**.
 - Epidermis plays a significant role in protection.
 - Cuticle and trichome reduce transpiration loss of water.
 - 2. Cortex:** In dicotyledon stem cortex divided into three parts:
 - (a) Hypodermis
 - (b) General cortex
 - (c) Endodermis
- (a) Hypodermis:** It is present just below the epidermis. It provides mechanical support to young stem. It is found as a homogenous layer or in patches. It is made up of collenchyma. Its few layers provide mechanical strength to the young stem.

- (b) General Cortex:** This part is composed of rounded thin walled **parenchyma**. **Storage of food** is the main function of the cortex. Resin canal/mucilage canal are present in it. These are **schizogenous** in origin. Conspicuous intercellular space are present in cortical cell.
- (c) Endodermis:** Inner most layer of cortex. It is single celled thick layer. The cells of **endodermis are barrel shaped**. These cells accumulate **starch** in stem of dicot. Thus, it is known as **“starch sheath”**.
- 3. Pericycle:** Pericycle is present on the inner side of the endodermis and above the phloem in the form of semi lunar patches of sclerenchyma.



T.S. of Dicotyledon Stem

- 4. Vascular Bundle:** Large number of vascular bundles (**wedge shaped**) are arranged in a ring. Each vascular bundle is **conjoint, collateral** and **open**. Each vascular bundle is made of phloem, Intra fascicular cambium and xylem.
- 5. Pith:** This is well developed region, spreading from ring of vascular bundle to the centre. The cells of this region mainly made up of **parenchyma**.

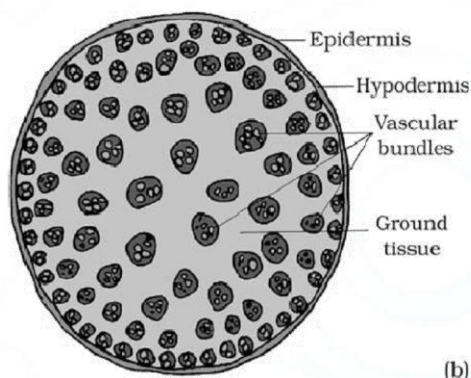
Function of Pith – Storage of water and food.

Note: The part of pith which is radially arranged between the vascular bundles, called **pith rays** or **medullary rays**. The main function of **pith rays** is **radial conduction** of food and water.

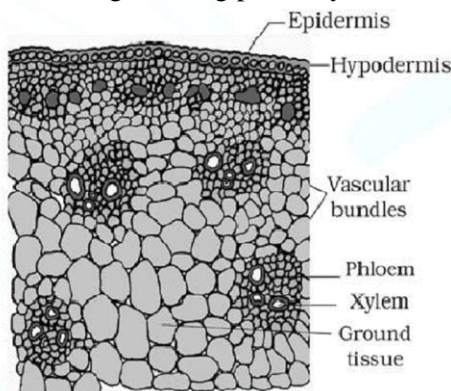


Internal Structure of Monocotyledon Stem

- 1. Epidermis:** Epidermis is the outer most single celled thick layer. It is covered with thick cuticle. Multicellular hair are absent and stomata are also less. It is made up of parenchyma.
- 2. Hypodermis:** Hypodermis of monocotyledon is made up of **sclerenchyma**. It is 2-3 layered. It provides **mechanical** support to plant.
- 3. Ground Tissue:** The entire mass of parenchyma cells next to hypodermis and extending to the centre is called ground tissue. There is **no differentiation** of ground tissue in monocotyledon stem.



(b)



T.S. of Monocotyledon Stem

- (b) **Phloem:** It consists of sieve tube elements and companion cells. **Phloem parenchyma** is absent.

Internal Structure of Typical Dicotyledon Root

Internal structure of a typical dicotyledon root shows following features: -

- 1. Epidermis:** It is **uniseriate** outermost layer. It comprises tubular living components. **Cuticle and stomata are absent. Unicellular root hairs** are formed due to elongation of some cells of epidermis. It is made up of parenchyma.
- 2. Cortex:** It is made up of parenchymatous cells with intercellular space.

Note: The cells of outer part of cortex are suberized in old root. It is called **exodermis**.

Exodermis found in some dicotyledon roots and most of the monocotyledon roots.

- 3. Endodermis:** Inner most layer of cortex is known as endodermis. **Casparian strips** are present on **radial and tangential wall of endodermis**. These strips are made up of **suberin**.
 - The cells of endodermis which are situated in front of protoxylem cells lack of casparian strips. These are called **passage cells**. The number of **passage cells** is equivalent to the **protoxylem cells** and number of rows of root hair equivalent to protoxylem cells.
 - Passage cells provide path to absorbed water from cortex to pericycle.

Note:

- (1) Root hairs are linearly arranged on root apex.
- (2) Casparian bands and passage cells are well developed in monocot root.
- (3) Endodermis acts as a **water tight jacket** and prevents radial conduction of water.



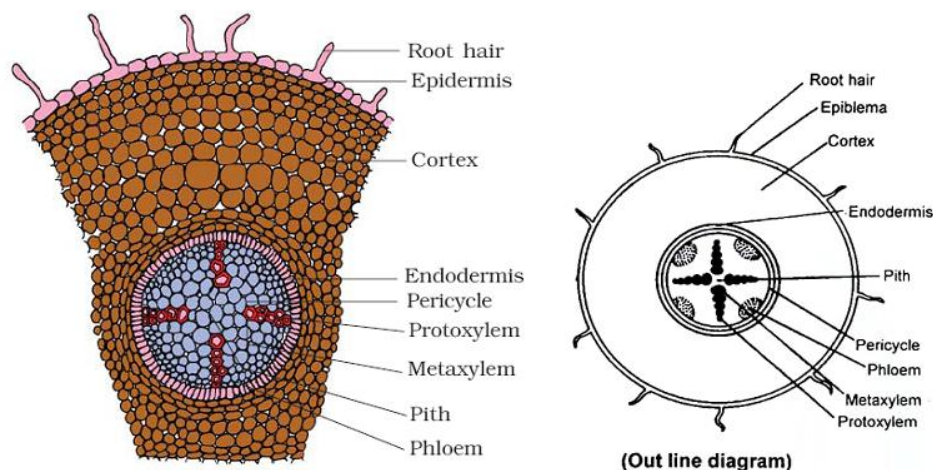


Fig.: T.S. of Typical Dicotyledon Root

4. **Pericycle:** It is few thick layered. It is composed of **prosenchyma**. (Elongated Parenchyma)
 - **Lateral** roots are originated from the part of **pericycle** which is lying opposite to protoxylem. Thus lateral root are **endogenous** in origin.
 - Some part of vascular cambium in root is originated from pericycle.
5. **Vascular Bundles:** Vascular bundles are **radial** and **exarch**. Xylem and phloems are separate and equal in number. The numbers of xylem bundles are usually two to four (**diarch** to **tetrarch upto hexarch**).
 - Parenchyma which is found between xylem and phloem, called **Conjunctive tissue**.

- Vascular cambium is developed from it.

6. **Pith:** In dicot root pith is **small or inconspicuous**. **Internal Structure of Monocotyledon-Root**

- The internal structure of a typical monocotyledon root is similar to dicotyledon root.

But

- (1) Number of xylem bundles are **more than six** (Polyarch) in monocotyledon root Exception: Onion
- (2) Pith is **well developed** in monocotyledon root
- (3) Only lateral roots are originated from pericycle.

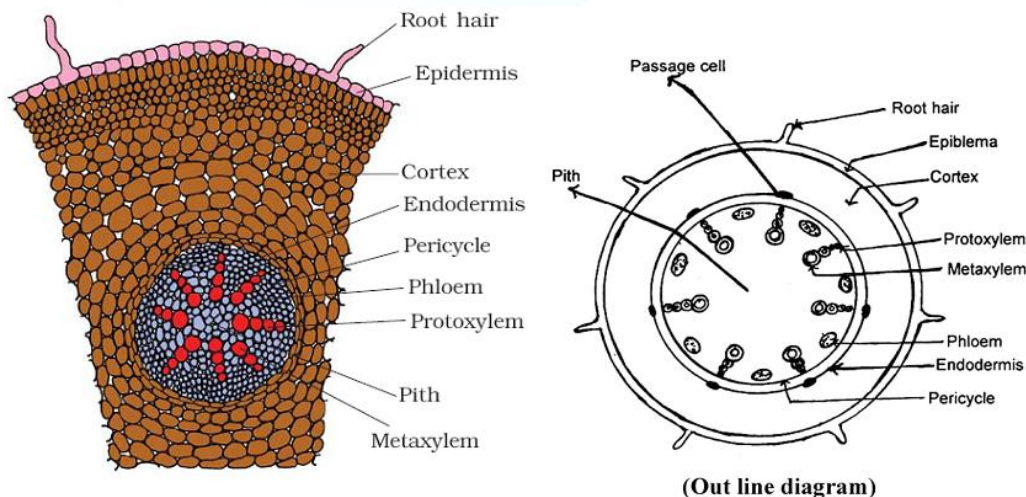


Fig.: T.S. of Monocotyledon Root



Internal Structure of Leaf:

Generally leaves divided into two categories—Dorsiventral leaves and isobilateral leaves. The differences in between them as follows:

Dorsiventral or Bi-Facial

1. Present at right angle to stem
2. Upper surface of leaf receive more sun light as compared to lower surface, so there are difference between internal structure of upper and lower surface of leaf.

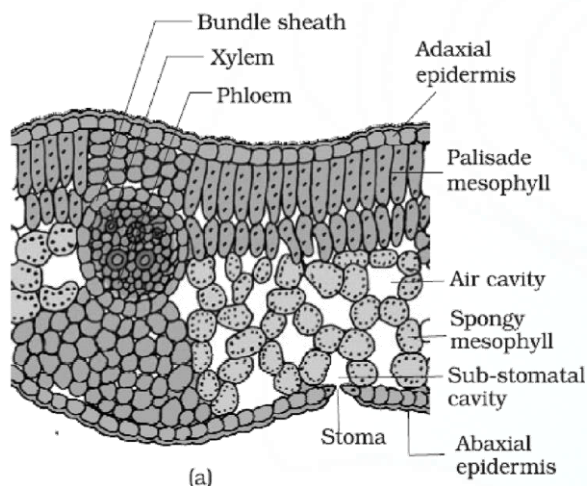
Examples: Dicots

Iso-Bilateral or Equifacial

1. Arranged parallel to stem.
2. Both surface of leaf receive equal amount of sun light so there are no difference between internal structure of upper & lower surfaces.

Example: - Monocots

Internal Structure of Dorsiventral Leaves:



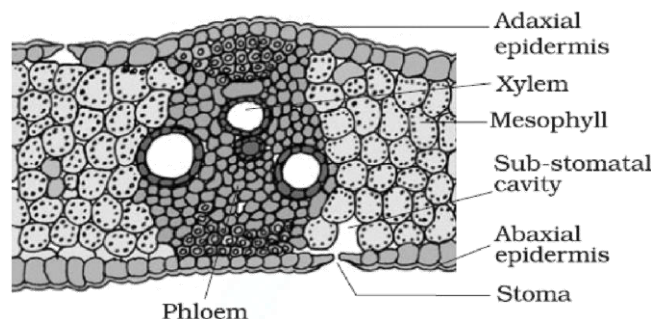
(a) T.S. of Dicot leaf

- Cuticle is present on both surfaces but **cuticle of upper surface is thicker**.
- Dorsiventral leaves are mostly **hypostomatic** i.e. stomata present on lower surface.

Note: In **amphistomatic** dorsiventral leaves stomata are more on lower surface.

- Mesophyll of these leaves is divided into two regions – **Palisade tissue** and **spongy tissue**.
- **Palisade tissue** is found towards **upper surface**. These cells have more **chloroplasts**. **Spongy tissues** is found towards **lower surface** and have **large intercellular space**.

Internal Structure of Isobilateral Leaves:



T.S. of Monocot

- The thickness of cuticle on the both surface is equal.
- Distribution of stomata on both surface's are **equal**.

Note: Isobilateral leaves are **Amphistomatic** i.e. stomata present on both sides.

- **Mesophyll of Isobilateral Leaves is not Differentiated** into palisade and spongy tissues. It is completely made up of **spongy tissues**. **Palisade tissues are absent**.
- **Bulliform Cells:** Large cells are found in the epidermis of psammophytic (desert) grasses which are filled by liquid or empty (mostly) and colourless are called **bulliform cells** or motor cells. When the bulliform cells in the leaves have absorb water and become turgid the leaf surface is exposed. When they are flaccid due to water stress they make the leaf curl and minimize water loss.

Vascular Bundles of Leaves :

- Similar types of vascular bundles are found in both dorsiventral and isobilateral leaves. Vascular bundles of leaves are **conjoint**, **collateral** and **closed**.
- **Protoxylem** is situated towards the **adaxial surface** and **protophloem** lies below xylem in the vascular bundle.
- The **sizes of the vascular bundle** are **dependant on the size of vein**. The veins vary in thickness in the reticulate venation. Thus **different size vascular bundles** are present in **dicot** while in parallel venation **similar size vascular bundle** are present.



- Vascular bundles are surrounded by a **bundle sheath**. Bundle sheath is **chlorenchymatous** in C-4 plants.
- Epidermis of **Nerium** (both upper & lower) and **Ficus** (only upper epidermis) becomes **multilayered**. This is an adaptation to reduce transpiration.

FUNDAMENTAL UNLOCKED- (FU#4) :

- Endodermis cells are:
 - Barrel-shaped
 - Bean shaped
 - Wedge shaped
 - Dumb-bell shaped
- The endodermal cells have a deposition of water impermeable, waxy material, it is:
 - Pectin
 - Lignin
 - Cellulose
 - Suberin
- The parenchymatous cells which lie between the xylem and phloem are called:
 - Simple tissue
 - Conjunctive tissue
 - vascular tissue
 - Complex tissue
- Epiblema is the outer most layer of:
 - Flower
 - Leaf
 - Stem
 - Root
- In grasses certain adaxial epidermal cells along the veins modify themselves into large, empty colourless cells are:
 - Bulliform cell
 - Cork cells
 - Subsidiary cells
 - Guard cells
- The 'ring' arrangement of vascular bundle is characteristic feature of:-
 - Monocot stem
 - Dicot stem
 - Dicot root
 - Monocot root
- Polyarch xylem bundles are present in:-
 - Monocot stem
 - Dicot stem
 - Dicot root
 - Monocot root
- Pericycle, vascular bundles and pith constitute:-
 - Stele
 - Endodermis
 - Periderm
 - Conjunctive tissue
- Parenchymatous cells are usually present in:-
 - Medullary rays
 - Cortex and pith
 - Pericycle
 - All of these
- Which one is the inner most layer of cortex is called ?
 - Epidermis
 - Pericycle
 - Endodermis
 - Hypodermis
- Root hair is out growth of:-
 - Epiblema
 - Hypodermis
 - Cortex
 - Endodermis
- In which type of vascular bundles the xylem and phloem are jointly situated along the same radius ?
 - Radial
 - Conjoint
 - Concentric
 - Both (1) and (3)
- Statement-1:** In dicot stems, the cells of the endodermis are rich in starch grains and the layer is also referred to as the starch sheath.

Statement 2: In between the vascular bundles of dicot stems, there are a few layers of radially placed sclerenchymatous cells

 - Statement (1) correct and statement (2) incorrect
 - Statement (1) incorrect and statement (2) correct
 - Both statements are correct
 - Both statements are incorrect

Secondary Growth

- By the activity of lateral meristems, increase in the **circumference/girth** of the plant organs due to the formation of **secondary tissues** in **stelar & extra stelar regions** called **secondary growth**.
- Normally secondary growth takes place in **roots and stem** of **dicotyledons & Gymnosperms**.
- Due to lack of cambium in monocotyledons, secondary growth is absent. But exceptionally secondary growth takes place in some monocotyledons. Such as- **Palm, Yucca, Dracaena, Smilax, Agave, Coconut** etc.
- Pteridophytes and monocots have only primary structure but gymnosperm and dicots soon start undergoing secondary growth.



Secondary Growth In Dicot Stem:

[A] Secondary growth in stelar region or secondary growth in vascular region

Secondary growth in stelar region begins earlier than the extra stelar region.

I. Formation of ring of vascular cambium: A cambium which is present inside the vascular bundle is called **intrafascicular cambium**. This is a type of **primary meristem**.

- First of all, cells of medullary rays become meristematic to form **interfascicular cambium** which is **secondary lateral meristem**.
- **Intrafascicular and interfascicular cambium** are collectively known as **vascular cambium**. Vascular cambium is formed in the form of a complete ring which is made up of single layer of cells.
- In dicot stem some part of **vascular cambium** is **primary** and some part is **secondary**.
- Two types of cells are found in the ring of this vascular cambium.
 - (i) Fusiform initials
 - (ii) Ray initials.
- Fusiform initials are long with **pointed ends**, while ray initials are **spherical** (oval).
- **Amount of fusiform initials** is more in **vascular cambium**.

II. Activity of Vascular Cambium:

(a) Activity of Fusiform Initials:

- Continuous **periclinal** divisions or **tangential** division takes place in fusiform initials.
- Due to this type of activity few cells are formed towards the periphery and these cells differentiate into secondary phloem or bast and some of the cells are formed towards the central axis and these cells are differentiated into secondary xylem or wood.

- Vascular cambium is more active towards inner side so, more secondary xylem is formed as compared to secondary phloem and form a compact mass.
- By the pressure of newly formed secondary xylem, primary phloem and initially formed secondary phloem is pushed towards the outside and get crushed.
- The primary xylem however remain less or more intact in or around centre.
- In old tree the greater part of secondary xylem is dark brown due to accumulation of organic compound like tannins, resins, oil, gums, aromatic substances and essential oil.
- All these waste materials are filled in the **lumen** (cavity) of **tracheids** and **vessels of secondary xylem**. It is called **Heart wood or Duramen**. The peripheral or outer wood which looks light in colour is known as **Sap wood or Alburnum**. As a result of growth of secondary xylem, the **diameter of heart wood increases**.

Duramen (Heart wood)

- (i) Duramen wood dark in colour.
- (ii) This wood does not conduct water.
- (iii) In this wood, tyloses are present.
- (iv) It gives the mechanical support to the plant.
- (v) It is present in the central part of the tree stem

Alburnum (Sap wood)

- (i) Alburnum wood light in colour.
- (ii) Alburnum wood conduct the entire water.
- (iii) In this wood, tyloses are not present.
- (iv) It does not gives mechanical support.
- (v) It is found in outer part of stem.



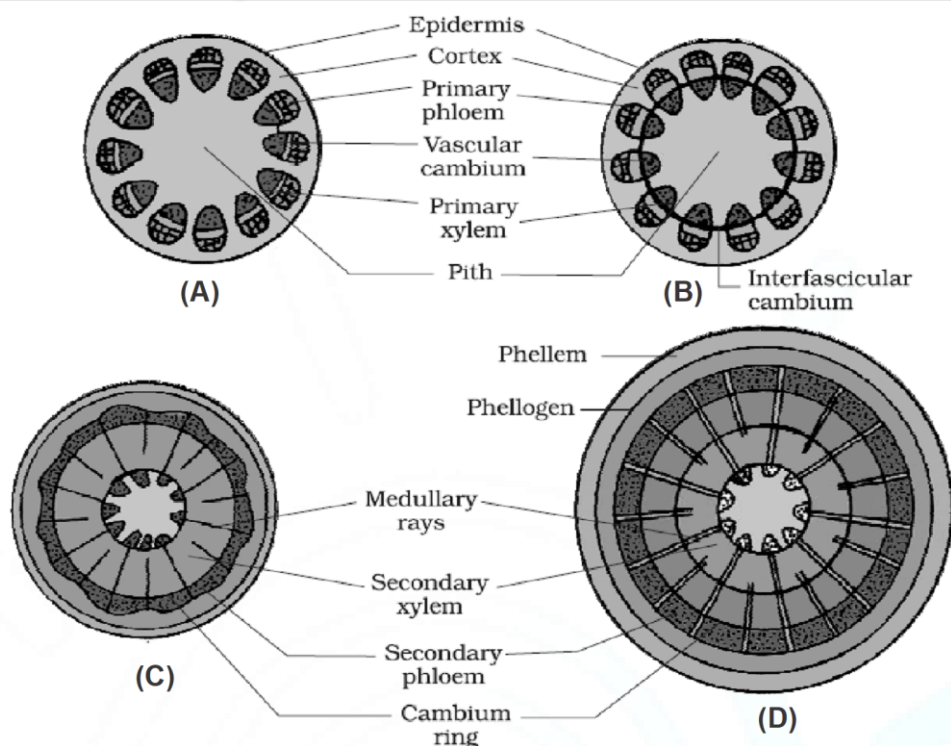
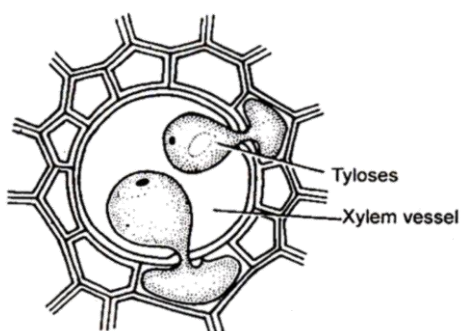


Fig.: Representation of Secondary growth in a dicot stem (diagrammatic)–Stages in transverse views

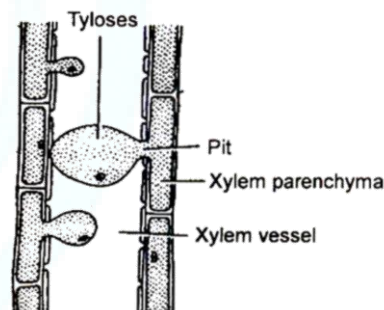
Physiologically Active wood is Sapwood. The main function of sap wood is water conduction. Heart wood provides maximum mechanical strength to stem.

Note: Conduction of water is not carried out by heart wood because:

1. Cavities of tracheids and vessels are progressively filled by waste materials.
2. The bladder like ingrowth of parenchyma cells, which enter the lumen of vessels (mainly) & tracheids through the pits in their wall. Such bladders like ingrowth are called as **tyloses**. Tyloses blocks the **conduction** of water.



T.S. of Sec. xylem vessels showing



L.S. of Sec. xylem vessels showing tyloses

Note: In gymnosperms **tylosoids** are formed in place of tyloses.

Special Points

- If the heart wood is destroyed in any stem, then there will be no effect on plants (any vital function is not effected), but if the sap wood is destroyed, then the plant will die because conduction of water will be blocked.
- Study of wood is known as **Xylotomy**.
- If a wood is exposed freely in air then **decomposition** of **sap wood** takes place **rapidly**.
- Position of youngest layer of secondary phloem is just outside the vascular cambium.



- Position of oldest layer of secondary phloem is just inside the primary phloem.
- Position of youngest layer of secondary xylem is just inside the vascular cambium.
- Position of oldest layer of secondary xylem is just outside the primary xylem.
- If xylem is blocked then shoot will die first.
- Heart wood is hard and highly durable due to accumulation of substances.

Activity of Ray initial: They conduct **water** and **food** in **radial direction**. Order of development of vascular rays is both centripetal and centrifugal manner. They pass through secondary xylem to secondary phloem in radial manner.

III. Formation of Annual Rings (Spring wood and Autumn wood):

Annual rings are formed due to unequal activity of vascular cambium.

- The activity of cambium does not remain same, it is **changeable** through out whole year. Activity of vascular cambium is affected by physiological and environmental factors.
- In **winter** or **autumn** season the activity of the cambium is less and forms fewer xylary elements. Cells formed during this period, are small, thick walled darker with higher, density and have narrow lumens. This is called **autumn wood** or **late wood**.
- At some places, the cambium forms a narrow band of parenchyma which passes through the secondary xylem and the secondary phloem.
- The vascular cambium is highly active in **spring** or **summer** season and produce a large number of xylary element and cells of secondary xylem are larger, thin walled lighter in colour with a lower density and have wider lumen. This wood is known as **spring wood** or **early wood**.

Spring wood

- Spring wood are generally light brown in colour.
- In plant, its quantity is more.
- Its vessel are broad and with large cavity.
- It is made up in favourable conditions.
- It is produce from more activity of cambium.
- In wood, the fibre are less present.

Autumn wood

- Autumn wood are dark brown in colour.
- In plant, its quantity is less.
- Its vessels are small and with narrow cavity.
- It is made up in unfavourable conditions.
- It is produce from less activity of cambium.
- In wood, the fibre are more present.

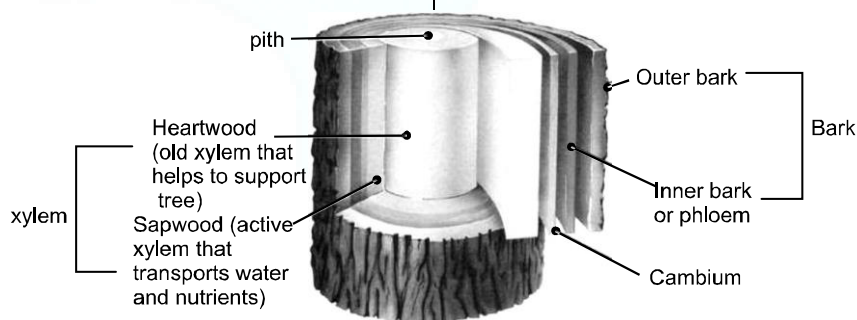
- The **autumn** and spring wood are formed in the form of rings. The ring of any type of wood is called **growth ring**. Thus **two growth** rings are formed in one year and they collectively constitute annual ring.
- Concentric alternate rings of autumn wood & spring wood is known as annual ring.
- The numbers of annual rings, formed in a tree give the idea of the age of the tree. The study of determination of age of the plant by this technique is called **Dendrochronology**.
- The annual rings are counted from the base of the stem because basal part has maximum annular rings and upper part has less. Therefore counting from the basal region can give the correct idea.
- The width of annual ring is less in unfavorable conditions and more in favorable conditions. Thus the annual rings are also indicative of environment period, the tree has encountered previously.
- More **distinct** annual rings are formed in that region where climatic variations are sharp.
- More distinct annual rings are formed in **temperate** plants.
- Distinct annual rings are not formed in tropical plants.
- Distinct annual rings are not formed in India except **Himalayan** regions.
- Least distinct annual rings are formed in **seashore** regions because the climate remains same through out the year.
- More clear annual rings are formed in **deciduous** plants as compared to **evergreen** plants. (In temperate region)
- In deserts annual rings are less distinct.



[B] Secondary Growth in Extra Stelar Region (Cork Cambium):

- Extra stelar secondary growth occurs after few years of stelar secondary growth because due to stelar secondary growth girth of system stem and the cortical and epidermal layer broken and head to be replaced by new protective covering.
- Secondary growth takes place in extra stelar region due to the activity of cork cambium. Cork cambium is also known as **Phellogen or Extrastelar cambium**.
- Cork cambium arises from the hypodermis** or from the **outer layer of cortex** because they become meristematic.
- Cork cambium forms some cells towards the outside (epidermis) and some cells towards the inside (cortex). Those cells formed towards **outside**, their middle lamella is **suberized**. Due to this, these cells become dead. These cells are known as **Cork or Phellem**. Those cells formed towards the inside, are differentiated into parenchyma and may contain chloroplasts. These are called **secondary cortex or Phelloderm**.

Phellem (cork) + Phellogen (cork cambium) + Phelloderm (secondary cortex) = Periderm



Function:

- The main function of lenticels is exchange of gases between plant and atmosphere.
- Transpiration also takes place through the lenticles, is known as **Lenticular transpiration**.

- Cork is formed in more quantity and secondary cortex is in less quantity because activity of cork cambium is more towards outside. The maximum activity of cork cambium is in **winter** (Autumn) season.
- Due to the activity of the cork cambium pressure build up on the remaining layers peripheral to phellogen and these layers die & sloughed off

Bark

- All the tissues situated out side the vascular cambium is called **Bark**. According to modern view bark includes both living and dead tissues. **Bark** has two parts. Outer layer of bark is called **Rhytidome** and inner layer of bark is **secondary phloem**.
- Bark that is formed early in the season is called early or soft Bark. Towards the end of season late or hard bark is formed.
- If complete bark of tree is removed then plant becomes dead due to excessive water loss.
- If bark is removed in the form of ring at the base of main stem then root will die first due to lack of food.

Lenticels:

At certain region the phellogen cuts off closely arranged parenchymatous cell on the outer side of the cork cell instead of cork cell (complementary cell). These cell rupture and form lens shaped opening which is known as Lenticels.

- Adventitious roots on cutting originate from the living cells of lenticels in vegetative reproduction.

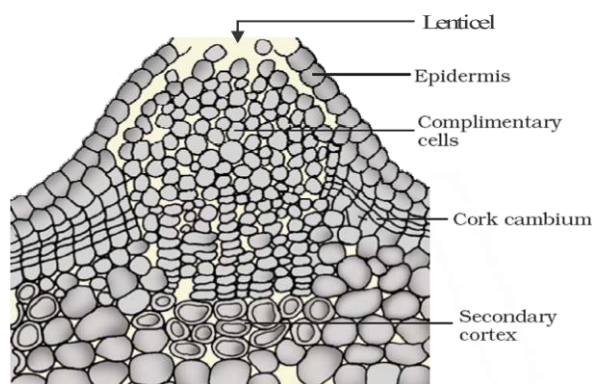


Fig. Showing

Secondary Growth in Dicot Root:

- First of all, conjunctive tissue becomes meristematic during the secondary growth in a dicotyledon root and form separate **curved strips** of vascular cambium below phloem bundles. Then after, the cells of pericycle lying opposite to protoxylem also become meristematic to form additional strips of cambium. In this way a complete ring of vascular cambium is formed.
- The portion of vascular cambium formed by pericycle is less. The main portion of vascular cambium is formed by conjunctive tissue. Vascular cambiums in roots are secondary in origin.
- The activity of vascular cambium of root is the same as the activity of vascular cambium of stem. Secondary xylem is formed towards the inner side and secondary phloem is formed towards the outer side by vascular cambium. The portion of vascular cambium which is formed by pericycle is responsible for the formation of **pith rays**. These are made up of parenchyma. These pith rays are known as **primary medullary rays** (Multiseriate). A few medullary or pith rays are also formed from remaining vascular cambium. These are called **secondary medullary rays** (uniseriate). Thus two types of medullary rays are found in the secondary structure of roots.

Note: The presence of two types of medullary rays is basic characteristic feature of roots. Only secondary medullary rays are found in stem after the secondary growth. Both of them conduct **water** and **food** in **radial direction**.

- Cork cambium is developed from the **pericycle** in roots. Cork is formed towards the outside and secondary cortex is formed towards the inner side by the cork cambium. Lenticles are also found in roots but less in number as compared to stem. Cortex completely degenerate in roots after the secondary growth of one or two years. This falls down due to the pressure of cork, whereas in stem, it degenerates after the long duration.

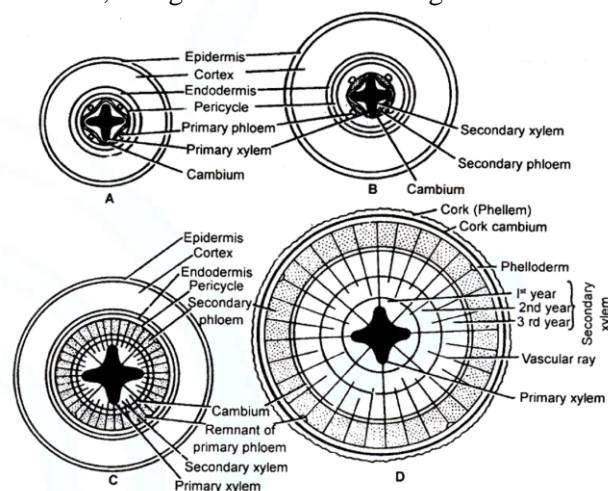


Fig.: (A–D) Different Stages in Secondary Growth of Dicot Root

- Secondary growth is essential in roots to provide strength to the growing aerial parts of the plants and fulfill the requirement of water and minerals.
- Annual rings are not formed in roots because these are not effected by the changes of environment.
- In roots, all cambia are secondary in origin.

Types of Wood:

- Classification based on vessels:**

On the basis of presence or absence of vessels, wood is **classified in two categories** –

- Non-Porous Wood:** Vessels are absent in such type of wood.

Example: Gymnosperm

- Porous Wood:** Vessels are present in such type of wood. On the basis of **arrangement** of **vessels** porous wood is divided into two groups.

- Ring Porous Wood:** Vessels are arranged in the form of a ring. Such wood conducts water more efficiently. Example: *Dalbergia*



II. Diffused Porous Wood: Vessels are irregularly arranged in wood.

Example: *Azadirachta* (Neem).

Non-porous wood is also called as homoxylous wood and porous wood is also called as heteroxylous wood.

Differences:

Porous wood (Hard wood)

- (i) This wood is found in angiosperms
- (ii) Vessels are present.
- (iii) This wood is hard.
- (iv) Xylem fibres are present.
- (v) Vessels are more in porous wood.
- (vi) It is also called heteroxylous wood

Non-porous wood (Soft wood)

- (i) It is found in Gymnosperms.
- (ii) Vessels do not present.
- (iii) It is soft.
- (iv) Xylem fibres are rarely present.
- (v) Xylem tracheids are dense.
- (vi) It is called homoxylous wood.

FUNDAMENTAL UNLOCKED- (FU#5) :

1. Choose the **incorrect** pair:
 - (1) Early wood - large number of xylary elements
 - (2) Late wood - have narrow vessels
 - (3) Spring wood - cambium is less active
 - (4) Autumn wood - fewer xylary elements
2. The activity of cambium is under the control of many
 - (1) Physiological factors
 - (2) Environmental factors
 - (3) Both (1) and (2)
 - (4) None of the above
4. Secondary growth does not occur in:
 - (1) Monocotyledons (2) Dicotyledons
 - (3) Gymnosperm (4) All of these
6. In dicot root the vascular cambium is:-
 - (1) Secondary as well as primary in origin
 - (2) Completely primary in origin
 - (3) Completely secondary in origin
 - (4) Not found

8. The heart wood does not conduct:-
 - (1) Water (2) Resins
 - (3) Food (4) All of these

9. Match column- I and column- II :

Column - I		Column - II	
(a)	Cork cambium	(i)	Phellogen
(b)	Secondary cortex	(ii)	Phellem
(c)	Cork	(iii)	Phelloderm

- (1) a - (i), b - (iii), c - (ii)
 - (2) a - (ii), b - (iii), c - (i)
 - (3) a - (iii), b - (i), c - (ii)
 - (4) a - (i), b - (ii), c - (iii)
10. Phellogen, phellem and phelloderm are collectively known as:
 - (1) Periblem (2) Pleurome
 - (3) Periderm (4) Pericycle
11. Bark is:
 - (1) non-technical term (2) technical term
 - (3) Exterior term (4) Interior term
12. Lenticels:
 - (1) Exchange of gases
 - (2) Occur in most woody trees
 - (3) Most common in monocots
 - (4) Both (1) and (2)
13. Bark is the nontechnical term which refers to:
 - (1) All tissue exterior to the cork cambium
 - (2) All tissue interior to the vascular cambium
 - (3) A few tissue exterior to the vascular cambium
 - (4) All tissue exterior to the vascular cambium
14. The cells of secondary cortex are:
 - (1) Sclerenchymatous
 - (2) Collenchymatous
 - (3) Parenchymatous
 - (4) All of these
15. Initiation of lateral roots and vascular cambium during secondary growth occurs through?
 - (1) Endodermis
 - (2) Conjunctive tissue
 - (3) Cortex
 - (4) Pericycle

**Do You Know?**

- Cricket bat → from *Salix* (Willow)
- Hockey → from *Morus* (Mulberry)
- Billiards's ball → *Phytelophus* (Ivory Palm)
- Violin → *Picea* (Spruce)
- Hardest wood → *Hardwickia binata*
- Heaviest wood → *Guaiacum officinale*
- Lightest wood → *Ochroma pyramidale* or *Ochroma lagopus*
- Heaviest wood of India → *Acacia sundra*
- Most durable soft wood → *Cedrus deodar*

ANSWER KEY**FUNDAMENTAL UNLOCKED- (FU#1) :**

Que.	1	2	3	4	5	6	7	8	9	10	11
Ans.	4	1	2	2	2	1	4	3	3	1	1

FUNDAMENTAL UNLOCKED- (FU#2) :

Que.	1	2	3	4	5	6	7	8	9	10	11	12
Ans.	2	4	4	4	4	3	4	3	4	2	4	4

FUNDAMENTAL UNLOCKED- (FU#3) :

Que.	1	2	3	4	5	6	7	8	9
Ans.	2	4	1	2	3	3	3	3	2

FUNDAMENTAL UNLOCKED- (FU#4) :

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13
Ans.	1	4	2	4	1	2	4	1	4	3	1	2	1

FUNDAMENTAL UNLOCKED- (FU#5) :

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	3	3	1	3	1	1	3	1	1	3	3	4	4	3	4




EXERCISE - I

1. A tissue is a group of cells which are:
 - (1) Similar in origin, but dissimilar in form and function
 - (2) Dissimilar in origin, form and function
 - (3) Dissimilar in origin, but similar in form and function
 - (4) Similar in origin, form and function
2. A meristem may be defined as the group of cells which:
 - (1) Add to the bulk of the Plants
 - (2) Conserve food
 - (3) Divide continuously to give rise to new cells
 - (4) Elongate and add to the group of cells
3. A 100 years old tree which shows well marked annual rings in its trunk will show:
 - (1) The same number of rings from base to its trunk
 - (2) More than 100 rings at base and about 20 rings at top
 - (3) Only about a hundred rings at base and a uniformly decreasing number of rings towards top
 - (4) None of the above
4. Maximum growth in root occurs:
 - (1) At its tip
 - (2) Towards light
 - (3) Behind the apex
 - (4) Towards apex
5. Which of the following is a well differentiated plant tissue?
 - (1) Apical meristem
 - (2) Cambium
 - (3) Parenchyma
 - (4) All of the above
6. Which of the following is a primary meristem?
 - (1) Intra fascicular cambium
 - (2) Cork cambium
 - (3) Vascular cambium in roots
 - (4) None of the above
7. The secondary meristem originates from:
 - (1) Promeristem
 - (2) Primary meristem
 - (3) Permanent tissue
 - (4) Secretory tissue
8. Which of the following is secondary meristem?
 - (1) Protoderm
 - (2) Procambium
 - (3) Cork cambium
 - (4) All of the above
9. The tissue not having specifically thickened walls are:
 - (1) Parenchyma
 - (2) Collenchyma
 - (3) Fibres
 - (4) Sclereids
10. Which of the following tissues form the main bulk of storage organ?
 - (1) Parenchyma
 - (2) Collenchyma
 - (3) Sclerenchyma
 - (4) Aerenchyma
11. Flesh of a fruit is mostly made up of:
 - (1) Parenchyma
 - (2) Collenchyma
 - (3) Sclereids
 - (4) Meristem
12. A simple mechanical tissue devoid of lignin is:
 - (1) Parenchyma
 - (2) Collenchyma
 - (3) Sclerenchyma
 - (4) Chlorenchyma
13. Collenchyma differs from sclerenchyma in:
 - (1) Retaining protoplasm at maturity
 - (2) Having thick walls
 - (3) Having a wide lumen
 - (4) Being meristematic
14. Shoot-apex protected by:
 - (1) Root cap
 - (2) Shoot cap
 - (3) Calyptra
 - (4) Primordial leaves
15. Which of the following tissue provide tensile strength against bending & swaying?
 - (1) Parenchyma
 - (2) Collenchyma
 - (2) Sclerenchyma
 - (4) Sclereids





- 16.** Sclerenchymatous cells in their cell walls have large percentage of:
 (1) Cellulose (2) Pectin
 (3) Lignin (4) Silica
- 17.** Fibre (longest plant cell), belongs to which tissue:
 (1) Parenchyma
 (2) Collenchyma
 (3) Sclerenchyma
 (4) Aerenchyma
- 18.** All the xylem elements, when mature are dead except:
 (1) Tracheids
 (2) Vessels
 (3) Xylem parenchyma
 (4) Xylem fibre
- 19.** Which of the following plant cells are without vacuoles and without nuclei ?
 (1) Cambium cells
 (2) Xylem vessels
 (3) Root hairs
 (4) Companion cells
- 20.** Vessels differ from tracheids:
 (1) In being living
 (2) In being derived from a single cell
 (3) In having vertical row of cells with cross walls dissolved
 (4) Because they conduct water
- 21.** Phloem of angiosperm is different from that of pteridophytes and gymnosperm in:
 (1) The absence of enzymes
 (2) Presence of endocytosis
 (3) Presence of companion cells
 (4) None of these
- 22.** Cell which is functionally related to sieve tube:
 (1) Phloem fiber
 (2) Phloem parenchyma
 (3) Companion cell
 (4) Collenchyma
- 23.** Mature sieve tube differs from vessels:
 (1) Absence of functional nuclei
 (2) Absence of lignified wall
 (3) Almost Dead
 (4) Absence in cytoplasm
- 24.** Vessels in xylem and companion cell in phloem is characteristic feature of:
 (1) Gymnosperm (2) Pteridophyta
 (3) Angiosperm (4) Bryophyta
- 25.** Phloem parenchyma is absent in:
 (1) Dicot stem (2) Dicot leaf
 (3) Monocot stem (4) Dicot root
- 26.** Thickening in collenchyma occurs due to deposition of:
 (1) Cellulose (2) Pectin
 (3) Lignin (4) Suberin
- 27.** Complex tissue are not present in:
 (1) Some Bryophyta
 (2) Pteridophyta
 (3) All gametophyte
 (4) All spermatophyta
- 28.** Main function of tracheids in plants are:
 (1) Sap conduction
 (2) Only mineral transportation
 (3) Loss of excess water in night
 (4) Translocation of organic solute
- 29.** Presence of vessels in plant is:
 (1) A primitive character
 (2) A progressive character
 (3) A vestigial character
 (4) None of the above
- 30.** Sieve tube elements are ideal component for nutrients translocation because :
 (1) End wall is not present
 (2) Bordered pits are present
 (3) Narrow lumen rich in cytoplasm
 (4) Broad lumen with small quantity of peripheral cytoplasm
- 31.** When xylem and phloem are on same radius, the vascular bundles are said to be?
 (1) Radial (2) Conjoint
 (3) Concentric (4) Exarch





- 32.** When a meristematic tissue “Cambium” is present inside a vascular bundle, the bundle is said to be?
 (1) Conjoint (2) Open
 (3) Closed (4) Collateral
- 33.** A vascular bundle in which phloem is on both the sides of the xylem and separated from it by strips of cambium is said to be:
 (1) Collateral open
 (2) Bicollateral open
 (3) Concentric
 (4) Bicollateral closed
- 34.** A concentric Amphivasal vascular bundle is that in which:
 (1) Centrally located xylem is surrounded by phloem
 (2) Centrally located phloem is surrounded by xylem
 (3) Phloem is flanked by xylem on interior sides only
 (4) Xylem is flanked by phloem on exterior sides only
- 35.** The basic difference between stem and root is that stem is:
 (1) Endarch (2) Exarch
 (3) Mesarch (4) Polyarch
- 36.** Bulliform cells are:
 (1) Water filled, colourless and highly vacuolated epidermal cell
 (2) Prokaryotic cell
 (3) Eukaryotic cell
 (4) Ball like parenchymatous cells
- 37.** Collenchymatous hypodermis is characteristic feature in:
 (1) Dicot stem
 (2) Monocot stem
 (3) Monocot as well as dicot stem
 (4) Hydrophytes
- 38.** In general, the cells of cortex lack:
 (1) Chlorophyll (2) Nucleus
 (3) Reserve food (4) Nucleous
- 39.** In roots, the pericycle give rise to:
 (1) Lateral roots and Cork cambium
 (2) Cortex and pith
 (3) Xylem and Phloem
 (4) Epidermis and vascular bundles
- 40.** The character of monocot is:
 (1) Reticulate venation
 (2) Annular rings
 (3) Seed with two masses of stored food
 (4) Conducting strands scattered in ground tissue
- 41.** T.S. of a material exhibits conjoint collateral endarch and closed bundles scattered in a ground tissue what should be the material:
 (1) Monocot root (2) Dicot root
 (3) Monocot stem (4) Dicot stem
- 42.** Cortex and pith are not distinguished in:
 (1) Monocot stem (2) Monocot root
 (3) Dicot stem (4) Dicot root
- 43.** What is the characteristics of a vascular bundle of monocot stem?
 (1) Open and surrounded by a sclerenchymatous bundle sheath
 (2) Closed and not surrounded by bundle sheath
 (3) Closed and surrounded by bundle sheath
 (4) Open and not surrounded by a bundle sheath
- 44.** In dicot root:
 (1) Vascular bundles are scattered with cambium
 (2) Vascular bundles are open and arranged in a ring
 (3) Xylem and phloem are radial
 (4) Xylem is always endarch
- 45.** The dicot root is identify by the presence of:
 (1) Exarch xylem
 (2) 2-6 radial vascular bundles
 (3) > 6 radial vascular bundles
 (4) Absence of pith and endodermis





- 46.** Position of protoxylem & protophloem in leaf respectively:
 (1) Abaxial & Adaxial
 (2) Adaxial & Abaxial
 (3) Both Adaxial
 (4) Both abaxial
- 47.** The function of hypodermis is:
 (1) Protection (2) Hardness
 (3) Support (4) Storage
- 48.** In leaves, the vascular bundles are:
 (1) Bicollateral & open
 (2) Collateral & open
 (3) Collateral & closed
 (4) Radial & exarch
- 49.** The hypodermis present in maize stem is:
 (1) Parenchymatous
 (2) Collenchymatous
 (3) Sclerenchymatous
 (4) Meristematic
- 50.** Passage cells are more distinct in endodermis of:
 (1) Dicot stem (2) Monocot stem
 (3) Dicot root (4) Monocot Roots
- 51.** Sugar transport elements of gymnosperms & pteridophytes are:
 (1) Sieve cells
 (2) Sieve elements
 (3) Sieve tubes
 (4) Sieve tube elements
- 52.** When protoxylem faces pericycle, it is called?
 (1) Endarch (2) Mesarch
 (3) Exarch (4) Polyarch
- 53.** Fatty substance found in epidermal cell walls is:
 (1) Cutin (2) Suberin
 (3) Wax (4) Both 2 & 3
- 54.** Stomata in true hydrophyte are present on:
 (1) Upper epidermis
 (2) Lower epidermis
 (3) Not on any surface
 (4) Both surface
- 55.** Layer of cell which is present in between endodermis and vascular tissue:
 (1) Cortex (2) Pith
 (3) Pericycle (4) Exodermis
- 56.** Leaves of some grasses shows rolling and unrolling. It occurs due to:
 (1) Parellel venetion
 (2) Isobilateral nature
 (3) Thin wall
 (4) Bulliform cell
- 57.** Which will decay faster if exposed freely to the air?
 (1) Heart wood
 (2) Sap wood
 (3) Wood with lots of fibres
 (4) Soft wood
- 58.** Periderm is formed from:
 (1) Vascular cambium
 (2) Phellogen
 (3) Fascicular cambium
 (4) Interfascicular cambium
- 59.** Compact wood with little parenchyma is termed:
 (1) Heart wood (2) Hard wood
 (3) Pycnoxylic wood (4) Manoxylic wood
- 60.** Dendrochronology is the study of:
 (1) Height of a tree
 (2) Diameter of a tree
 (3) Age of a tree with the help of annual rings
 (4) Counting of the number of branches
- 61.** A timber merchant told his customer that log of wood which he was purchasing comes from a 20 years old tree, he told so by inspecting the:
 (1) Diameter of log
 (2) Thickness of the heart wood
 (3) Number of cork layers
 (4) Growth rings
- 62.** Annual rings are well demarcated in trees growing in:
 (1) Simla (2) Bombay
 (3) Chennai (4) Udaipur



- 63.** The trees growing in deserts will:
 (1) Show alternate rings of xylem and sclerenchyma
 (2) Show distinct annual rings
 (3) Not show distinct annual rings
 (4) Have only conjunctive tissue and phloem formed by the activity of cambium
- 64.** In trees, the growth rings represent:
 (1) Primary xylem
 (2) Secondary xylem
 (3) Secondary phloem
 (4) Cambium
- 65.** Annual rings and growth rings are formed due to the fluctuations in the activity of:
 (1) Xylem (2) Phloem
 (3) Xylem and phloem (4) Cambium
- 66.** Growth rings are formed due to the activity of:
 (1) Intrastelar cambium
 (2) Intercalary cambium
 (3) Extrastelar cambium
 (4) Primary cambium
- 67.** In summer seasons the vascular cambium:
 (1) Dies
 (2) Becomes more active
 (3) Becomes less active
 (4) Becomes inactive
- 68.** When a tree grows older which of the following increases rapidly?
 (1) Heart wood (2) Sap wood
 (3) Pith (4) Cortex
- 69.** Sap wood differ from heart wood in being:
 (1) Darker and non conducting
 (2) Softer and non conducting
 (3) Lighter and conducting
 (4) Harder, darker and less conducting
- 70.** Sap wood is:
 (1) Inner part of secondary phloem
 (2) Outer part of secondary phloem
 (3) Both of these
 (4) None of these
- 71.** In older, woody tissue, the gaseous exchange takes place through:
 (1) Lenticel (2) Hydathode
 (3) Stomata (4) Aerenchyma
- 72.** Lenticels do not occur on:
 (1) Stem (2) Root
 (3) Leaf (4) Fruit
- 73.** Lenticels and its complementary cells are developed through the activity of:
 (1) Phellogen
 (2) Stellar cambium
 (3) Dermatogen
 (4) Intercalary meristem
- 74.** External Protective tissues are:
 (1) Cortex and epidermis
 (2) Cork and pericycle
 (3) Cortex and pericycle
 (4) Cork and epidermis
- 75.** Which of the tissue is present in periderm?
 (1) Xylem (2) Bast
 (3) Phellem (4) Duramen
- 76.** Spring wood (early wood) differs with autumn wood (late wood) in:
 (1) Size of vessels and tracheids
 (2) Thickness of cell wall
 (3) Amount of wood
 (4) All the above
- 77.** Most conspicuous annual rings form in:
 (1) Temperate evergreen plants
 (2) Tropical deciduous
 (3) Temperate deciduous plants
 (4) Tropical evergreen
- 78.** Which of the following provide maximum mechanical strength to a tree trunk?
 (1) Heart wood (2) Sap wood
 (3) Cork (4) Late wood
- 79.** Youngest layer of secondary xylem is located:
 (1) In centre of stem
 (2) Just outside pith
 (3) Just outside vascular cambium
 (4) Just inside vascular cambium



- 80.** Extra stellar secondary growth occurs due to the activity of:
 (1) Intrafascicular cambium
 (2) Inter fascicular cambium
 (3) Vascular cambium
 (4) Cork cambium
- 81.** Bottle cork is obtained from:
 (1) *Betula vulgaris* (2) *Eucalyptus*
 (3) *Calotropis procera* (4) *Quercus suber*
- 82.** Normal secondary growth takes place in:
 (1) Dicots & Monocots
 (2) Gymnosperms & Monocots
 (3) Dicots & Gymnosperms
 (4) Only in dicots
- 83.** In dicot root which tissue becomes dead due to activity of phellogen:
 (1) All tissue outside cortex
 (2) Tissue outside hypodermis
 (3) Tissue outside endodermis
 (4) Tissue outside pericycle
- 84.** In dicot root, vascular cambium originates from:
 (1) Conjunctive tissue (2) Pith rays
 (3) Pericycle (4) 1 & 3 both
- 85.** Formation of which tissue is example of dedifferentiation:
 (1) Inter fascicular cambium
 (2) Apical meristem
 (3) Intra fascicular cambium
 (4) Inter calary meristem
- 86.** What happens to primary phloem in stem after secondary growth?
 (1) Compresses outside and degenerates
 (2) Compresses inside and degenerates
 (3) Becomes part of secondary phloem
 (4) Modifies in sclerenchyma
- 87.** Which tissue remains more active during autumn?
 (1) Vascular cambium (2) Cork cambium
 (3) Parenchyma (4) Sclerenchyma
- 88.** Water conduction in stem of tree takes place by:
 (1) Duramen (2) Sapwood
 (3) Primary xylem (4) All the above
- 89.** Annual ring involves:
 (1) Early wood & Late wood
 (2) Heart wood
 (3) Sapwood
 (4) None of these
- 90.** Bark includes all the tissues:
 (1) Lying outside the vascular cambium
 (2) Formed by vascular cambium
 (3) Formed by phellogen
 (4) Phellem & phelloderm
- 91.** Cork cambium is:
 (1) Always primary meristem
 (2) Always secondary meristem
 (3) May be secondary or primary meristem
 (4) Partly primary & Partly secondary meristem
- 92.** Normally in dicot stems, phellogen develops from:
 (1) Hypodermis
 (2) Phellem
 (3) Endodermal cells
 (4) Epidermal & pericycle cells
- 93.** Physiologically functional part of wood is:
 (1) Heart wood only
 (2) Sap wood only
 (3) Only primary wood
 (4) Both heart wood & sap wood
- 94.** Suberin is chiefly deposited in the cells of:
 (1) Sclerenchyma
 (2) Collenchyma
 (3) Cork
 (4) Phelloderm
- 95.** Secondary growth in the cortical region of a dicot stem is due to the activity of:
 (1) Cambium (2) Phellogen
 (3) Phellem (4) Phelloderm



- | | |
|--|---|
| <p>96. Secondary growth in dicots and gymnosperms occurs by:</p> <ol style="list-style-type: none"> (1) Formation of vascular rays (2) Thickening of tracheary elements (3) Formation of meristematic cells in vascular region (4) Development of meristematic cells in vascular & cortical regions <p>97. Lenticels are:</p> <ol style="list-style-type: none"> (1) Scars on old stem (2) Special stomata (3) Aerating pores in bark (4) Special stomata on hydrophytic plants <p>98. The balloon like outgrowths of parenchyma in the lumen of a vessel are known as:</p> <ol style="list-style-type: none"> (1) Histogen (2) Tyloses (3) Phellogen (4) Tunica <p>99. Gymnosperm wood is non porous because it :</p> <ol style="list-style-type: none"> (1) Lacks vessels (2) Contains tracheae (3) Has abundant fibres (4) Contains no fibres <p>100. The wood of commerce is:</p> <ol style="list-style-type: none"> (1) Alburnum (2) Duramen (3) Spring wood (4) Autumn wood <p>101. Intrafascicular cambium is situated:</p> <ol style="list-style-type: none"> (1) In between the vascular bundles (2) In between Xylem and Phloem of the vascular bundles (3) Outside the vascular bundles (4) In pith | <p>102. Which of the following facts about monocots is incorrect?</p> <ol style="list-style-type: none"> (1) Vascular bundles in stem are surrounded by sclerenchymatous bundle sheath and have water cavity in the xylem (2) Both upper and lower epidermis in leaves have motor cells that assist in leaf curling during dessication (3) Roots have larger pith as compared to dicot root. (4) Leaves are amphistomatic <p>103. Stomata are absent in the epidermis of:</p> <ol style="list-style-type: none"> (1) Leaf (2) Stem (3) Branch (4) Root <p>104. Which of the statement is correct?</p> <ol style="list-style-type: none"> (1) Organic food movement up by phloem (2) Organic food movement up and down by phloem (3) Organic food movement up and down by xylem (4) All of these <p>105. Which of the following statements is not incorrect about xylem?</p> <ol style="list-style-type: none"> (1) Vessels are found in all tracheophytes (2) Monocots don't lack xylem parenchyma (3) Tracheids are multicellular in origin (4) These are invariably found in gametophytes of all phanerogames. |
|--|---|



EXERCISE – II (ANALYTICAL QUESTIONS)

1. Meristem is characterized by:
 - (1) Isodiametric cells with cellulosic thin wall
 - (2) Absence of intercellular space and vacuole
 - (3) Absence of reserve food material and plastids
 - (4) All of these
2. Collenchyma is a type of mechanical tissue but it is not as efficient as sclerenchyma. However, it has certain advantages like:
 - (1) It offers no resistance to the growing organs
 - (2) It has no cellulose in the cell wall
 - (3) It is flexible
 - (4) It has the power of growth, it offers no resistance to the growing organs and is not flexible
3. Isodiametric sclereids, found in hard endocarp of coconut and fleshy portion of some fruits are:
 - (1) Brachysclereids (2) Asterosclereids
 - (3) Osteosclereids (4) Trichosclereids
4. Main water conducting element of xylem in homoxylous plants is:
 - (1) Tracheary element
 - (2) Vessel
 - (3) Tracheid
 - (4) Xylem parenchyma
5. In trees, the death of protoplasm is essential for a vital function such as:
 - (1) Food transport
 - (2) Water transport
 - (3) Both (1) & (2)
 - (4) Stomatal movements
6. Find set cells connected by pit fields between their common longitudinal walls:
 - (1) Companion cell and phloem fibres
 - (2) Companion cell and sieve tube
 - (3) Sieve cell and albuminous cell
 - (4) Sieve tube and phloem fibre
7. In old sieve tubes at the end of growing season, which of the following gets deposited over sieve plate to regulate sugar transport:
 - (1) P-protein (2) Callose
 - (3) Lignin (4) Suberin
8. Parenchymatous structure with intercellular spaces is:
 - (1) Epidermis (2) Endodermis
 - (3) Cortex (4) Pericycle
9. Select **incorrect** features w.r.t. trichomes in shoot system :
 - (1) Usually unicellular
 - (2) Branched or unbranched
 - (3) May be secretory
 - (4) Soft or stiff
10. Pericycle of the roots is never sclerenchymatous because it:
 - (1) Does not act as a mechanical tissue in root
 - (2) Is the place of origin of root branches
 - (3) Gives rise to root hairs
 - (4) Gives rise to root hairs (when the root is young), and to root branches (at maturity)
11. Tissue commonly known as passport point or biological check post is characterised by:
 - (1) Bulliform cells and raphides
 - (2) Cystolith and motor cells
 - (3) Casparian bands and passage cells
 - (4) Passage cells and fats
12. Seat of origin of lateral root and formation of cork cambium are features related to:
 - (1) Endodermis (2) Pericycle
 - (3) Hypodermis (4) Pith rays
13. Centripetal and centrifugal xylem are the important features of:
 - (1) Root and stem respectively
 - (2) Exarch and endarch respectively
 - (3) Endarch and exarch respectively
 - (4) Both (1) and (2)



14. Members of Winteraceae, Tetracentraceae and trochodendraceae:
- (1) Do not have tracheids
 - (2) Do not have albuminous cells
 - (3) Do not have vessels
 - (4) More than one option is correct
15. Which of the following vascular bundles are always open?
- (1) Radial
 - (2) Collateral
 - (3) Bicollateral
 - (4) Concentric
16. The vascular bundles in the stems of most of dicots are conjoint, collateral and open. In each of these bundles:
- (1) Xylem and phloem are on the same radius with phloem towards the pith and xylem towards the pericycle without a strip of cambium between them
 - (2) Xylem and phloem are on the same radius with xylem situated towards the pith and phloem situated towards the pericycle and a strip of cambium separates the two
 - (3) Xylem completely surrounds the phloem on all sides but the two are separated by the cambium
 - (4) Phloem completely surrounds the xylem and a strip of cambium separates the two
17. Which is **not** true for monocot stem?
- (1) Sclerenchymatous hypodermis
 - (2) Presence of water canals in pith
 - (3) Conjoint, collateral closed vascular bundles
 - (4) Presence of bundle sheath
18. Vascular bundles are conjoint, collateral, endarch and lack cambium between xylem and phloem in all, but not in:
- (1) Maize
 - (2) Barley
 - (3) Wheat
 - (4) Sunflower
19. Select a set having **correct** match:
- | Dicot stem | Monocot stem |
|---------------------------------|---|
| (1) Sclerenchymatous hypodermis | Collenchymatous hypodermis |
| (2) Parenchymatous pericycle | Sclerenchymatous pericycle |
| (3) Epidermis with trichomes | Water containing cavities in vascular bundles |
| (4) Oval bundles | Wedge shaped bundles |
20. Monocot stem differs from dicot stem in having:
- (1) Endarch xylem element
 - (2) Collateral vascular bundles
 - (3) Well developed pith
 - (4) Polymorphic vascular bundles
21. Vascular cambium is a meristematic layer that cuts off:
- (1) Primary xylem and primary phloem
 - (2) Xylem vessels and xylem tracheids
 - (3) Primary xylem and secondary xylem
 - (4) Secondary xylem, secondary phloem and medullary rays
22. Derivatives of the secondary meristem in the steler region are:
- (1) Phellem and phelloderm
 - (2) Alburnum and primary phloem
 - (3) Duramen and alburnum
 - (4) Primary xylem and secondary phloem
23. What is the position of oldest secondary phloem?
- (1) Just outside the pericycle
 - (2) Just outside the vascular cambium
 - (3) Just below the pericycle
 - (4) Below the vascular cambium
- 24.
- A. Heart wood is durable, dark and central in position.
 - B. Tyloses are balloon like structures of xylem parenchyma in vessel lumen.
 - C. Late wood is formed during spring season.



- (1) All are correct
(2) Only A is correct
(3) Only B is incorrect
(4) Only C is incorrect
25. Seasonal activity of vascular cambium is influenced by many factors, except:
(1) Geographical location of plant
(2) Relative humidity and temperature
(3) Photoperiod and water supply
(4) Leaf orientation
26. When secondary growth is initiated in dicot stem, what will happen first ?
(1) The cells of cambium divide periclinally to form xylem mother cells
(2) Interfascicular cambium join with intrafascicular cambium
(3) Parenchymatous cells present between vascular bundles become meristematic
(4) Pith get obliterated
27. All given tissues are formed as a result of redifferentiation process, **except**:
(1) Phellem
(2) Phelloderm
(3) Secondary xylem
(4) Interfascicular cambium
28. Vascular cambium of dicot root is purely secondary in origin and arise from:
(1) Cells of conjunctive parenchyma just below phloem
(2) Cells of pericycle just outside protoxylem
(3) Cells of parenchyma between xylem and phloem
(4) More than one option is correct
29. Select **wrong** statement regarding secondary phloem:
(1) Arise due to activity of procambium
(2) Occurs during secondary growth
(3) No distinction between protophloem and metaphloem
(4) Secondary permanent tissue
30. Vascular bundles in dicot leaves are:
(1) Conjoint, collateral, open
(2) Conjoint, collateral, closed
(3) Conjoint, bicollateral, open
(4) Conjoint, bicollateral, closed
31. Lenticles are formed due to rupture in epidermis because of pressure exerted by:
(1) Epithem cells
(2) Tyloses
(3) Complementary cells
(4) Phellem



EXERCISE – III (PREVIOUS YEAR QUESTIONS)

[AIPMT – 2006]

1. A common structural feature of vessel elements and sieve tube elements is:
- (1) Presence of p-protein
 - (2) Eucleate condition
 - (3) Thick secondary walls
 - (4) Pores on lateral walls

[AIPMT – 2007]

2. For a critical study of secondary growth in plants, which one of the following pairs is suitable?
- (1) Wheat and maiden hair fern
 - (2) Sugarcane and sunflower
 - (3) Teak and pine
 - (4) Deodar and fern
3. Passage cells are thin-walled cells found in:
- (1) Central region of style through which the pollen tube grows towards the ovary.
 - (2) Endodermis of roots facilitating rapid transport of water from cortex to pericycle
 - (3) Phloem elements that serve as entry points for substances for transport to other plant parts
 - (4) Testa of seeds to enable emergence of growing embryonic axis during seed germination.

[AIPMT – 2008]

4. Vascular tissues in flowering plants develop from:
- (1) Plerome
 - (2) Periblem
 - (3) Dermatogen
 - (4) Phellogen
5. The length of different internodes in a culm of sugarcane is variable because of:
- (1) Position of axillary buds
 - (2) Size of leaf lamina at the node below each internode
 - (3) Intercalary meristem
 - (4) Shoot apical meristem

[AIPMT – 2009]

6. The annular and spirally thickened conducting elements generally develop in the protoxylem when the root or stem is:
- (1) Differentiating
 - (2) Maturing
 - (3) Elongating
 - (4) Widening

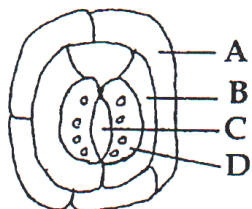
7. In barley stem vascular bundles are:
- (1) Closed and radial
 - (2) Open and scattered
 - (3) Closed and scattered
 - (4) Open and in a ring
8. Palisade parenchyma is *absent* in leaves of:
- (1) Gram
 - (2) Sorghum
 - (3) Mustard
 - (4) Soybean
9. Reduction in vascular tissue, mechanical tissue and cuticle is characteristic of:
- (1) Hydrophytes
 - (2) Xerophytes
 - (3) Mesophytes
 - (4) Epiphytes
10. Anatomically fairly old dicotyledonous root is distinguished from the dicotyledonous stem by:
- (1) Position of protoxylem
 - (2) Absence of secondary xylem
 - (3) Absence of secondary phloem
 - (4) Presence of cortex

[AIPMT – 2010]

11. Which one of the following is *not* a lateral meristem ?
- (1) Intercalary meristem
 - (2) Intrafascicular cambium
 - (3) Interfascicular cambium
 - (4) Phellogen
12. The chief water conducting elements of xylem in gymnosperms are:
- (1) Tracheids
 - (2) Vessels
 - (3) Fibres
 - (4) Transfusion tissue
13. Heartwood differs from sapwood in:
- (1) Being susceptible to pests and pathogens
 - (2) Presence of rays and fibres
 - (3) Absence of vessels and parenchyma
 - (4) Having dead and non-conducting elements
14. Transport of food material in higher plants takes place through:
- (1) Transfusion tissue
 - (2) Tracheids
 - (3) Sieve elements
 - (4) Companion cells
15. Kranz anatomy is one of the characteristics of the leaves of:
- (1) Wheat
 - (2) Sugarcane
 - (3) Mustard
 - (4) Potato



16. Given below is the diagram of a stomatal apparatus. In which of the following all the four parts labelled as A, B, C and D are correctly identified?



- (1) A-Guard cell B-Stomatal aperture
C-Subsidiary cell D-Epidermal cell
(2) A-Epidermal cell B-Guard cell
C-Stomatal aperture D-Subsidiary cell
(3) A-Epidermal cell B-Subsidiary cell
C-Stomatal aperture D-Guard cell
(4) A-Subsidiary cell B-Epidermal cell
C-Guard cell D-Stomatal aperture

[AIPMT – (PRE.) 2011]

17. Ground tissue includes:
(1) All tissues external to endodermis
(2) All tissues except epidermis and vascular bundles
(3) Epidermis and cortex
(4) All tissues internal to endodermis
18. The cork cambium, cork and secondary cortex are collectively called:
(1) Phelloderm
(2) Phellogen
(3) Periderm
(4) Phellem
19. In land plants, the guard cells differ from other epidermal cells in having:
(1) Cytoskeleton
(2) Mitochondria
(3) Endoplasmic reticulum
(4) Chloroplasts

[AIPMT (Mains) – 2011]

20. Function of companion cells is:
(1) Loading of sucrose into sieve elements.
(2) Providing energy to sieve elements for active transport.
(3) Providing water to phloem
(4) Loading of sucrose into sieve elements by passive transport.

21. Some vascular bundles are described as open because these:
(1) Are not surrounded by pericycle
(2) Are surrounded by pericycle but no endodermis
(3) Are capable of producing secondary xylem and phloem.
(4) Possess conjunctive tissue between xylem and phloem.

[AIPMT (Pre.) – 2012]

22. Gymnosperms are also called soft wood spermatophytes because they lack:
(1) Thick-walled tracheids
(2) Xylem fibres
(3) Cambium
(4) Phloem fibres

[AIPMT (Mains) – 2012]

23. Water containing cavities in vascular bundles are found in:
(1) *Cycas* (2) *Pinus*
(3) Sunflower (4) Maize
24. Closed vascular bundles lack:
(1) Cambium
(2) Pith
(3) Ground tissue
(4) Conjunctive tissues
25. Companion cells are closely associated with:
(1) Trichomes (2) Guard cells
(3) Sieve elements (4) Vessel elements

26. The common bottle cork is a product of:
(1) Xylem
(2) Vascular Cambium
(3) Dermatogen
(4) Phellogen

[(NEET – UG) – 2013]

27. Age of a tree can estimated by:
(1) Diameter of its heartwood
(2) Its height and girth
(3) Biomass
(4) Number of annual rings
28. Interfascicular cambium develops from the cells of:
(1) Pericycle
(2) Medullary rays
(3) Xylem parenchyma
(4) Endodermis



29. Lenticels are involved in:

- (1) Photosynthesis
- (2) Transpiration
- (3) Gaseous exchange
- (4) Food transport

[AIIMS – 2013]

30. Which statements is true?

- (1) Spring wood is darker in colour with higher density
- (2) Autumn wood is lighter in colour with higher density
- (3) Autumn wood is darker in colour with lower density
- (4) Spring wood is lighter in colour with lower density

[AIPMT – 2014]

31. You are given a fairly old piece of dicot stem and a dicot root. Which of the following anatomical structures will you use to distinguish between the two?

- (1) Secondary xylem
- (2) Secondary phloem
- (3) Protoxylem
- (4) Cortical cells

32. Tracheids differ from other tracheary elements in:

- (1) Having casparian strips
- (2) Being imperforate
- (3) Lacking nucleus
- (4) Being lignified

[AIPMT – 2015]

33. A major characteristic of the monocot root is the presence of:

- (1) Scattered vascular bundles
- (2) Vasculature without cambium
- (3) Cambium sandwiched between phloem and xylem along the radius
- (4) Open vascular bundles

34. In a girdled plant:

- (1) The root dies first
- (2) The shoot nor shoot will die
- (3) Neither root nor shoot will die
- (4) The shoot dies first

35. Vascular bundles in monocotyledonas are considered closed because:

- (1) Cambium is absent
- (2) There are no vessels with perforations
- (3) Xylem is surrounded all around by phloem
- (4) A bundle sheath surrounds each bundle

[(Re-AIPMT) – 2015]

36. Read the different components from (a) to (d) in the list given below and tell the correct order of the components with reference to their arrangement from outer side to inner side in a woody dicot stem:

- (a) Secondary cortex (b) Wood
- (c) Secondary phloem (d) Phellem

The **correct** order is:

- (1) (d), (c), (a), (b) (2) (c), (d), (b), (a)
- (3) (a), (b), (d), (c) (4) (d), (a), (c), (b)

[(NEET-I) – 2016]

37. Specialized epidermal cells surrounding the guard cells are called:

- (1) Complementary cells
- (2) Subsidiary cells
- (3) Bulliform cells
- (4) Lenticels

[(NEET-II) – 2016]

38. Cortex is the region found between:

- (1) Pericycle and endodermis
- (2) Endodermis and pith
- (3) Endodermis and vascular bundle
- (4) Epidermis and stele

39. The balloon-shaped structures called tyloses:

- (1) Characterize the sapwood.
- (2) Are extensions of xylem parenchyma cells into vessels.
- (3) Are linked to the ascent of sap through xylem vessels
- (4) Originate in the lumen of vessels.

[NEET – 2017]

40. Identify the wrong statement in context of heartwood:

- (1) Organic compound are deposited in it
- (2) It is highly durable
- (3) It conducts water and minerals efficiently
- (4) It comprises dead elements with highly lignified walls

41. Which of the following is made up of dead cells?

- (1) Xylem parenchyma (2) Collenchyma
- (3) Phellem (4) Phloem

42. The vascular cambium normally gives rise to:

- (1) Phelloderm (2) Primary phloem
- (3) Secondary xylem (4) Periderm

**[NEET – 2018]**

43. Secondary xylem and phloem in dicot stem are produced by:
(1) Apical meristems (2) Vascular cambium
(3) Phellogen (4) Axillary meristems
44. Casparian strips occur in:
(1) Epidermis (2) Pericycle
(3) Cortex (4) Endodermis

[NEET – 2019]

45. Phloem in gymnosperms lacks:
(1) Companion cells only
(2) Both sieve tubes and companion cells
(3) Albuminous cells and sieve cells
(4) Sieve tubes only
46. Grass leaves curl inwards during very dry weather. Select the most appropriate reason from the following:
(1) Shrinkage of air spaces in spongy mesophyll
(2) Tyloses in vessels
(3) Closure of stomata
(4) Flaccidity of bulliform cells
47. Xylem translocates:
(1) Water only
(2) Water and mineral salts only
(3) Water, mineral salts and some organic nitrogen only
(4) Water, mineral salts, some organic nitrogen and hormones
48. Which of the statements given below is not true about formation of annual rings in trees?
(1) Annual ring is a combination of spring wood and autumn wood produced in a year.
(2) Differential activity of cambium causes light and dark bands of tissue – early and late wood respectively
(3) Activity of cambium depends upon variation in climate.
(4) Annual rings are not prominent in trees of temperate region.

[NEET 2019 (ODISHA)]

49. In the dicot root the vascular cambium originates from:-
(1) Tissue located below the phloem bundles and a portion of pericycle tissue above protoxylem.
(2) Cortical region.
(3) Parenchyma between endodermis and pericycle.
(4) Intrafascicular and interfascicular tissue in a ring.

50. Regeneration of damaged growing grass following grazing is largely due to:-
(1) Lateral meristem
(2) Apical meristem
(3) Intercalary meristem
(4) Secondary meristem

[NEET 2020]

51. The transverse section of a plant shows following anatomical features:
(a) Large number of scattered vascular bundles surrounded by bundle sheath.
(b) Large conspicuous parenchymatous ground tissue.
(c) Vascular bundles conjoint and closed.
(d) Phloem parenchyma absent.
Identify the category of plant and its part:-
(1) Dicotyledonous root
(2) Monocotyledonous stem
(3) Monocotyledonous root
(4) Dicotyledonous stem
52. Identify the incorrect statement.
(1) Due to deposition of tannins, resins, oils etc., heart wood is dark in colour
(2) Heart wood does not conduct water but gives mechanical support
(3) Sapwood is involved in conduction of water and minerals from root to leaf
(4) Sapwood is the innermost secondary xylem and is lighter in colour

[NEET 2020 (Covid-19)]

53. Large, empty colourless cells of the adaxial epidermis along the veins of grass leaves are
(1) Lenticels
(2) Guard cells
(3) Bundle sheath cells
(4) Bulliform cells
54. Which of the following statements about cork cambium is incorrect?
(1) It forms secondary cortex on its outside
(2) It forms a part of periderm
(3) It is responsible for the formation of lenticels
(4) It is a couple of layers thick





[NEET – 2021]

55. Match List-I with List-II. List -I

List-I		List-II	
(a)	Cells with active cell division capacity	(i)	Vascular tissues
(b)	Tissue having all cells simillae	(ii)	Meristematic tissue
(c)	Tissue having different types of cells	(iii)	Sclereids
(d)	Dead cells with highly thickened walls and narrow lumen	(iv)	Simple tissue

Select the correct answer from the options given below.

- (a) (b) (c) (d)
 (1) (ii) (iv) (i) (iii)
 (2) (iv) (iii) (ii) (i)
 (3) (i) (ii) (iii) (iv)
 (4) (iii) (ii) (iv) (i)

56. Match List-I with List-II.

List-I		List-II	
(a)	Lenticels	(i)	Phellogen
(b)	Cork cambium	(ii)	Suberin deposition
(c)	Secondary cortex	(iii)	Exchange of gases
(d)	Cork	(iv)	Phelloderm

Choose the **correct** answer from the options given below.

- (a) (b) (c) (d)
 (1) (iv) (i) (iii) (ii)
 (2) (iii) (i) (iv) (ii)
 (3) (ii) (iii) (iv) (i)
 (4) (iv) (ii) (i) (iii)

57. Select the correct pair.

(1)	Large colourless empty cells in the epidermis of grass leaves	–	Subsidiary cells
(2)	In dicot leaves, vascular bundles are surrounded by large thick-walled cells	–	Conjunctive tissue
(3)	Cells of medullary rays that form part of cambial ring	–	Interfascicular cambium
(4)	Loose parenchyma cells rupturing the epidermis and forming a lens-shaped opening in bark	–	Spongy parenchyma

[NEET – 2022]

58. In old trees the greater part of secondary xylem is dark brown and resistant to insect attack due to:

- (a) secretion of secondary metabolites and their deposition in the lumen of vessels.
 (b) decomposition of organic compounds like tannins and resins in the central layers of stem.
 (c) deposition of suberin and aromatic substances in the outer layer of stem.
 (d) deposition of tannin, gum, resin and aromatic substances in the peripheral layers of stem.
 (e) Presence of parenchyma cells, functionally active xylem elements and essential oils.

Choose the correct answer from the options given below:

- (1) (a) and (b) Only (2) (c) and (d) Only
 (3) (d) and (e) Only (4) (b) and (d) Only

59. The flower are Zygomorphic in:

- (a) Mustard
 (b) Gulmohar
 (c) Cassia
 (d) Datura
 (e) Chilly

Choose the **correct answer** from the options given below:

- (1) (a), (b), (c) Only
 (2) (b), (c) Only
 (3) (d), (e) Only
 (4) (c), (d), (e) Only





ANSWER KEY

EXERCISE – I

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	4	3	3	3	3	1	3	3	1	1	1	2	1	4	2
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	3	3	3	2	3	3	3	2	3	3	2	3	1	2	4
Que.	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Ans.	2	2	2	2	1	1	1	1	1	4	3	1	3	3	2
Que.	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	2	3	3	3	4	1	3	1	3	3	4	2	2	3	3
Que.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Ans.	4	1	3	2	4	1	3	1	3	4	1	3	1	4	3
Que.	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Ans.	4	3	1	4	4	4	3	1	4	1	1	3	2	1	1
Que.	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
Ans.	2	1	2	3	2	4	3	2	1	2	2	2	4	2	2

EXERCISE – II (ANALYTICAL QUESTIONS)

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	4	3	1	3	2	2	2	3	1	2	3	2	4	4	3
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	2	2	4	3	4	4	3	3	4	4	3	4	4	1	2
Que.	31														
Ans.	3														

EXERCISE – III (PREVIOUS YEAR QUESTIONS)

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	2	3	2	1	3	2	3	2	1	1	1	1	4	3	2
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	3	2	3	4	1	3	2	4	1	3	4	4	2	3	4
Que.	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Ans.	3	2	2	1	1	4	2	4	2	3	3	3	2	4	2
Que.	46	47	48	49	50	51	52	53	54	55	56	57	58	59	
Ans.	4	4	4	1	3	2	4	4	1	1	2	3	1	2	

