

BRILLIANT PUBLIC SCHOOL, SITAMARHI

(Affiliated up to +2 level to C.B.S.E., New Delhi)



XI Physics Chapter Notes

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Class XI: Physics
Chapter 1: Unit of Measurement

Chapter Notes

Key Learnings:

1. In India National Physical Laboratory maintains the standards of measurements.
2. The system of units used around the world is International System of SI.
3. The units for the base quantities are called fundamental or base units. The units of all other physical quantities can be expressed as a combination of base units. Such units obtained are called derived units.
- 4.

Base quantity	Name	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	Mol
Luminous intensity	candela	cd

5. Other physical quantities, derived from the base quantities, can be expressed as a combination of the base units and are called derived units. A complete set of units, both fundamental and derived, is called a system of units.

6. In computing any physical quantity, the units from derived quantities involved in the relationship(s) are treated as though they were algebraic quantities till the desired units are obtained.

7. The apparent shift in the position of the object against the reference point in the background is called parallax.

8. Parallax is caused whenever there is change in the point of observation. The distance between the two points of observation is called the basis. Let the basis be b and angle subtended by this at some point is θ then and distance of the point $D = \frac{b}{\theta}$.

9. The size of the molecules of solution = volume of film / area of film

10. The unit used to measure the size of the nucleus of an atom is Fermi which is 10^{-15} m.

11. The unit used to measure the distance between the earth and the sun is the astronomical unit.

12. The smallest value measured by an instrument is called its least count. The least count of vernier calipers is 0.01 cm and that of screw gauge is 0.001 cm.

13. Different types of errors: absolute error, relative error and percentage error

14. True value is the mean of all the observed readings.

15. Absolute error is the magnitude of the difference between the individual measured value and the true value.

Absolute error: Measured value - True value.

16. The fractional error is the ratio of mean absolute error to the true value. It is also known as relative error.

$$\text{Relative error} = \frac{\text{Mean absolute error}}{\text{True value}}$$

17. Direct and indirect methods can be used for the measurement of physical quantities. In measured quantities, while expressing the result, the accuracy and precision of measuring instruments along with errors in measurements should be taken into account.

18. Significant Figures in a measured or observed value, is the number of reliable digits plus the first uncertain digit.

19. Rules to identify the significant figures

- i. All non zero digits are significant. Powers of ten are not counted in significant figures. For example 1.7×10^5 has 2 significant figures.
- ii. In a number with a decimal, Zeroes appearing to the left of a digit are not counted in significant figures. For example 0.002 has only one significant figure in it.
- iii. In a number with a decimal, the number of zeroes at the end is counted in significant figures. For example 1.700 has 4 significant figures.
- iv. Shifting the position of the decimal does not change the number of significant figures. For example 2.340 and 234.0 have 4 significant figures.

v. All the zeros between two non-zero digits are significant, no matter where the decimal place is, if at all. For example, 203.4 cm has 4 significant digits, 2.05 has 3 significant digits

vi. The terminal or trailing zeros in a number without a decimal point are not significant. Thus 125 m=12500cm=125000 mm has three significant figures.

20. Changing the units do not change the number of significant figures

21. Dimensions of a physical quantity are the powers (or exponents) to which the base quantities are raised to represent that quantity.

22. Dimensional formula: The expression which shows how and which of the base quantities represent the dimensions of a physical quantity.

23. Applications of dimensional analysis

i. Dimensional analysis can be used to derive a physical equation

ii. Dimensional analysis can be used to verify if the given equation is dimensionally correct.

iii. Dimensional analysis can be used to find the dimensions of unknown parameter in the equation.

Top Formulae

1. Mean value: $a_{\text{mean}} = (a_1 + a_2 + a_3 + \dots + a_n) / n$

or,

$$a_{\text{mean}} = \sum_{i=1}^n a_i / n$$

2. The errors in the individual measurement values from the true value (Absolute Error):

$$\Delta a_1 = a_1 - a_{\text{mean}}$$

$$\Delta a_2 = a_2 - a_{\text{mean}}$$

$$\dots = \dots$$

$$\dots = \dots$$

$$\Delta a_n = a_n - a_{\text{mean}}$$

3. Mean absolute errors:

$$\Delta a_{\text{mean}} = (|\Delta a_1| + |\Delta a_2| + |\Delta a_3| + \dots + |\Delta a_n|) / n$$

$$= \sum_{i=1}^n |a_i| / n$$

4. Relative error = $\Delta a_{\text{mean}} / a_{\text{mean}}$

5. Percentage error:

$$\delta a = (\Delta a_{\text{mean}} / a_{\text{mean}}) \times 100\%$$

6. Error of a sum or a difference:

$$\pm \Delta Z = \pm \Delta A \pm \Delta B$$

or,

The maximum value of the error ΔZ is $\Delta A + \Delta B$.

7. Error of a product or a quotient:

$$\Delta Z / Z = (\Delta A / A) + (\Delta B / B)$$

8. Error in case of a measured quantity raised to a power

$$\text{If } Z = A^p B^q / C^r$$

$$\Delta Z / Z = p (\Delta A / A) + q (\Delta B / B) + r (\Delta C / C)$$

Class XI: Physics
Chapter 2: Motion in a Straight Line
Chapter Notes

Key Learnings:

1. For motion in a straight line, position to the right of the origin is taken as positive and to the left as negative.
2. A body in straight line motion can have the line of path as vertical, horizontal or slanted.
3. Path length is defined as the total length of the path traversed by an object.
4. Distance: Total path length covered during a given time interval.
5. Displacement: Shortest straight line distance between the initial and final position.
6. Path length is greater or equal to the magnitude of the displacement between the same points.
7. An object is said to be in uniform motion in a straight line if its displacement is equal in equal intervals of time. Otherwise the motion is said to be non-uniform.
8. Average speed: Total distance traveled divided by the total time taken.
9. Average velocity: Total displacement divided by total time taken.
10. The average speed of an object is greater or equal to the magnitude of the average velocity over a given time interval.
11. Slope of the x - t graph gives the velocity at a given instant.

12. Position time graph of a body in non uniform motion is curved.
13. Velocity time graph of a body in non uniform accelerated motion is curved.
14. Slope of v-t graph gives the acceleration at that instant.
15. The area between the v-t graph and the time axis gives the displacement
16. The steepness of the slope of position vs. time graph tells us the magnitude of the velocity & its sign indicates the direction of the velocity.
17. If the tangent to the position vs. time curve slopes upward to the right on the graph, the velocity is positive.
18. If the tangent to the position time graph slopes downward to the right, the velocity is negative.
19. For one-dimensional motion, the slope of the velocity vs. time graph at a time gives the acceleration of the object at that time.

Top formulae

1. Displacement: $\Delta x = x_2 - x_1$

2. Average velocity: $\bar{v} = \frac{\text{Displacement}}{\text{time interval}} = \frac{\Delta x}{\Delta t}$

3. Instantaneous velocity: $v = \lim_{\Delta t \rightarrow 0} \bar{v} = \lim_{\Delta t \rightarrow 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$

4. Average acceleration: $\bar{a} = \frac{\Delta v}{\Delta t}$

5. Instantaneous acceleration: $a = \lim_{\Delta t \rightarrow 0} \bar{a} = \lim_{\Delta t \rightarrow 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$

6. Kinematics' equations of motion:

$$v = v_0 + at$$

$$x = v_0 t + \frac{1}{2} at^2$$

$$v^2 = v_0^2 + 2ax$$

Class XI: Physics
Chapter 3: Motion in Plane
Chapter Notes

Key Learnings

1. Scalar quantities are quantities with magnitudes only. Examples are distance, speed, mass and temperature.
2. Vector quantities are quantities with magnitude and direction both. Examples are displacement, velocity and acceleration. They obey special rules of vector algebra.
3. A vector A multiplied by a real number λ is also a vector, whose magnitude dependent upon whether λ is positive or negative.
4. Two vectors A and B may be added graphically using head – to – tail method or parallelogram method.

5. Vector addition is commutative:

$$A + B = B + A$$

It also obeys the associative law:

$$(A + B) + C = A + (B + C)$$

6. A null or zero vector is a vector with zero magnitude. Since the magnitude is zero, we don't have to specify its direction. It has the properties:

$$A + O = A$$

$$\lambda O = O$$

$$OA = O$$

7. The subtraction of vector B from A is defined as the sum of A and $-B$:

$$A - B = A + (-B)$$

8. A vector A can be resolved into component along two given vectors a and b lying in the same plane:

$$A = \lambda a + \mu b$$

Where λ and μ are real numbers.

9. A unit vector associated with a vector A has magnitude one and is along the vector A :

$$\hat{n} = \frac{A}{|A|}$$

The unit vectors $\hat{i}, \hat{j}, \hat{k}$ are vectors of unit magnitude and point in the direction of the x , y , and z – axes, respectively in a right – handed coordinate system.

11. Two vectors can be added geometrically by placing them head to tail. The vector connecting the tail of the first to the head of the second is the vector sum or resultant vector.

12. Vector R can be resolved into perpendicular components given as R_x and R_y along x and y axis respectively.

$$R_x = R \cos \theta \text{ and } R_y = R \sin \theta$$

An efficient method for adding vectors is using method of components.

13. Unit vectors i, j , and k have magnitudes of unity and are directed in the positive direction of the x, y and z axes.

14. The position vector of particle at that instant is a vector that goes from the origin of the coordinate system to that point P .

15. The displacement vector is equal to the final position vector minus the initial position vector.

16. Average velocity vector is equal to change in position vector divided by the corresponding time interval.

17. Instantaneous velocity or simply velocity of a particle is along the tangent to the particle's path at each instant

18. Average acceleration is a vector quantity in the same direction as the velocity vector.

19. Projectile is an object on which the only force acting is gravity.

20. The projectile motion can be thought of as two separate simultaneously occurring components of motion along the vertical and horizontal directions.

21. During a projectile's flight its horizontal acceleration is zero and vertical acceleration is -9.8m/s^2 ..

22. The trajectory of particle in projectile motion is parabolic.

23. When a body P moves relative to a body B and B moves relative to A, then velocity of P relative to A is velocity of P relative to B + velocity of P relative to A.

$$\vec{V}_{P/A} = \vec{V}_{P/B} + \vec{V}_{B/A}$$

24. $\vec{V}_{A/B} = -\vec{V}_{B/A}$

25. When an object follows a circular path at constant speed, the motion of the object is called uniform circular motion. The magnitude of its acceleration is $a_c = v^2 / R$. The direction of a_c is always towards the centre of the circle.

26. The angular speed w , is the rate of change of angular distance. It is related to velocity v by $v = wR$. The acceleration is $a_c = w^2 R$.

27. If T is the time period of revolution of the object in circular motion and v is the frequency, we have $w = 2\pi vR$, $a_c = 4\pi^2 v^2 R$

Top Formulae:**Projectile Motion**

Thrown at an angle with horizontal

$$(a) \quad y = x \tan \theta - \frac{1}{2} \cdot g \cdot \left[\frac{x}{u \cos \theta} \right]^2$$

$$\vec{U}_x = u \cos \theta \hat{i} \quad a_x = 0$$

$$\vec{U}_y = u \sin \theta \hat{j} \quad a_x = -g \hat{j}$$

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

$$(b) \quad \text{Time to reach max, height} \quad t = \frac{u \sin \theta}{g} = \frac{u_y}{a_y}$$

$$(c) \quad \text{Time of flight} \quad T = \frac{2u \sin \theta}{g} = \frac{2u_y}{a_y}$$

$$(d) \quad \text{Horizontal range} \quad R = \frac{u^2 \sin 2\theta}{g} = u_x \times T$$

$$(e) \quad \text{Max. height} \quad H_{\max} = \frac{u^2 \sin^2 \theta}{2g} = \frac{u_y^2}{2a_y}$$

$$(f) \quad \text{Horizontal velocity at any time} \\ v_x = u \cos \theta$$

$$(g) \quad \text{Vertical component of velocity at any time} \\ v_y = u \sin \theta - gt$$

$$(h) \quad \text{Resultant velocity} \quad \vec{v} = v_x \hat{i} + v_y \hat{j}$$

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

$$v = |\vec{v}| = \sqrt{u^2 + g^2 t^2} = 2ugt \sin \theta$$

$$\text{And} \quad \tan \alpha = \frac{v_y}{v_x}$$

General Result

For max. range $\theta = 45^\circ$

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

And $H_{\max} = \frac{R_{\max}}{4}$, at $\theta = 45^\circ$ and initial velocity u
 $= \frac{R_{\max}}{2}$; at $\theta = 90^\circ$ and initial velocity u

- (i) Change in momentum
- (ii) For complete motion $= -2 m u \sin \theta$
- (iii) at highest point $= -m u \sin \theta \hat{j}$

Projectile thrown parallel to the horizontal

(a) Equation $y = -\frac{1}{2} g \frac{x^2}{u^2}$

$$u_x = u \quad v_x = u$$

$$u_y = 0 \quad v_y = gt \text{ (down ward)} \\ = -gt \text{ (upward)}$$

- (b) velocity at any time

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

$$\tan \alpha = \frac{v_y}{v_x}$$

(c) Displacement $S = x \hat{i} + y \hat{j} = ut \hat{i} + \frac{1}{2}gt^2 \hat{j}$

(d) Time of Flight $T = \sqrt{\frac{2h}{g}}$

(e) Horizontal range $R = u \sqrt{\frac{2h}{g}}$

Projectile thrown from an inclined plane

$$\vec{a}_x = -g \sin \theta_0 \hat{i}$$

$$\vec{a}_y = -g \cos \theta_0 \hat{j}$$

$$\vec{u}_x = u \cos(\theta - \theta_0) \hat{i}$$

$$\vec{u}_y = u \sin(\theta - \theta_0) \hat{j}$$

(a) Time of flight $T = \frac{2u_y}{a_y} = \frac{2u \sin(\theta - \theta_0)}{g \cos \theta_0}$

$$R = u \cos(\theta - \theta_0) T - \frac{1}{2} g \sin \theta_0 T^2$$

$$R = \frac{2u^2 \sin(\theta - \theta_0) \cos \theta}{g \cos^2 \theta_0}$$

$$R = \frac{2u^2 \sin(\theta - \theta_0) \cos \theta}{g \cos^2 \theta_0}$$

Important for $R_{\max} = \theta = \frac{\pi}{4} + \frac{\theta_0}{2}$ and $R_{\max} = \frac{u^2}{g(1 + \sin \theta_0)}$

Circular Motion

(a) angle (in radius) = $\frac{ac}{\text{radius}}$

Or $\Delta\theta = \frac{\Delta S}{r}$ $\pi \text{ rad.} = 180^\circ$

(b) Angular velocity ($\vec{\omega}$)

1. Instantaneous $\omega = \frac{d\theta}{dt}$

2. Average $\vec{\omega}_{av} = \frac{\text{total angular displacement}}{\text{total time taken}} = \frac{\Delta\theta}{\Delta t}$

If $v \rightarrow$ linear velocity

$\alpha \rightarrow$ angular acceleration

$a \rightarrow$ linear acceleration

(c) $v = r \omega$ In vector form $\vec{v} = \vec{\omega} \times \vec{r}$

(d) $\alpha = \frac{d\vec{\omega}}{dt}$

(e) $a = \alpha r$ and $\vec{a} = \vec{\alpha} \times \vec{r}$

Newtons equation in circular motion

$$\omega = \omega_0 + \alpha t$$

$$\theta = \omega_0 t + \frac{1}{2} \alpha t^2$$

$$\omega^2 = \omega_0^2 + 2\alpha \theta$$

Centripetal Force

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

$$= m \omega v$$

$$a_c = \frac{v^2}{r} \text{ in vector } \vec{F}_c = m(\vec{v} \times \vec{\omega})$$

Total Acceleration

$$a_T = \sqrt{a_t^2 + a_c^2} \quad a_T \rightarrow \text{Tangential acceleration}$$

$$a_c \rightarrow \text{Centripetal acceleration}$$

Motion In Horizontal Circle

$$T \cos \theta = mg$$

$$T \sin \theta = mv^2 / r \quad \tan \theta = \frac{v^2}{rg}$$

$$T = mg \sqrt{1 + \frac{v^4}{r^2 g^2}}$$

The time period of revolution

$$T = 2\pi \sqrt{\frac{h}{g}} = 2\pi \sqrt{\frac{\ell \cos \theta}{g}}$$

Banking of Tracks

$$\tan \theta = \frac{v^2}{rg}, \text{ on frictionless road, banked by } \theta$$

Maximum speed for skidding, on circular un-banked road

$$v_{\max} = \sqrt{\mu rg}$$

Class XI: Physics
Chapter 4: Laws of Motion
Chapter Notes

Key Learning:

1. Galileo extrapolated simple observations on motion of bodies on inclined planes, and arrived at the law of inertia. Newton's first law of motion is the same law as the law of inertia. According to it an object acted upon by no net force, will remain at rest or continue to move with a constant velocity and zero acceleration.
2. The tendency of an object to remain at rest or continue to move at a constant velocity is called inertia.
3. The frame of reference in which Newton first law is valid is called inertial frame of reference.
4. The frame of reference in which Newton first law is not valid is known as Non inertial frame of reference. These are accelerating reference frames.
5. Momentum (p) of an object is a vector quantity and is defined as the product of its mass (m) and velocity (v), i.e., $p = mv$.
6. Newton second law: The rate of change of momentum of an object is equal to the net external force and takes place in the direction in which the net force acts.
7. The net external force on an object is equal to its mass times the acceleration, i.e., $F = ma$
8. Impulse is the product of average force and time and equals change in momentum.
9. Newton's third law of motion states whenever object1 exerts a force on object2, then object2 must exert a force on object1 which is equal in magnitude and opposite in direction or to every action force, there is always an equal and opposite reaction force
10. Action and reaction act on different bodies and so they cannot cancel each other.

11. Law of Conservation of Momentum: The total momentum of an isolated system of particles is conserved. The law follows from the second and third law of motion.

12. If an object is at equilibrium, net resultant force acting on it is zero.

13. Normal reaction is the contact force perpendicular to the surface in contact.

14. Tension force is the restoring force in the rigid inextensible string or rope when being pulled down.

15. Centripetal force is always directed along the radius towards the centre.

16. A free body diagram is a diagram showing the chosen body by itself, free of its surroundings.

17. Two points for which one should be careful about while drawing Free Body diagrams are:

- i. Include all the forces acting on the body
- ii. Do not include any force that the chosen body exerts on any other body.

18. Free body equations represent the two equations of motion framed along two perpendicular axes.

19. Maximum value of Static friction

$$f_{s,\max} \propto R$$

$$f_{s,\max} = \mu_s \cdot R$$

Here $f_{s,\max}$ is the limiting value of the static friction, R is the normal reaction and μ_s is the coefficient of static friction.

20. Static friction increases with the applied force till it reaches a maximum value of $F_{s,\max}$.

21. Kinetic friction

$$f_k \propto R$$

$$f_k = \mu_k \cdot R$$

Here f_k is the limiting value of the static friction, R is the normal reaction and μ_k is the coefficient of kinetic friction.

22. The force required to start a motion is more than the force required to maintain a constant motion in a body.

23. Horizontal component of contact force equals force of friction.

24. Limiting value of static friction is greater than kinetic friction.

25. Force required to initiate the motion in a body should be greater than then the force required to maintain the motion with uniform velocity.

26. The direction of frictional force is always directed in the direction opposite to the relative motion between the two surfaces.

Top Formulae:

1. Momentum (p) = mass (m) x velocity (v)

2. Net external force $F = \frac{dp}{dt} = ma$

3. Impulse = Force x time duration
= Change in momentum

4. According to Newton's third law of motion
Force on A by B = - Force on B by A

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

5. According to conservation of linear momentum

Total initial momentum of an isolated system = Total final momentum of an isolated system

$$\vec{P}'_A + \vec{P}'_B = \vec{P}_A + \vec{P}_B$$

6. Equilibrium under three concurrent forces requires

$$\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0$$

7. Maximum value of Static friction

$$f_{s,\max} = \mu_s \cdot R$$

8. Kinetic friction

$$f_k = \mu_k \cdot R$$

9. In Circular Motion

$$f_c = \frac{mv^2}{R}$$

10. Maximum permissible speed limit for car to take a turn along a rough road:

$$v = \sqrt{\mu_s rg} \quad \text{along the unbanked road}$$

$$v_{\max} = \left(Rg \frac{\mu_s + \tan\theta}{1 - \mu_s \tan\theta} \right)^{\frac{1}{2}} \quad \text{along the banked road.}$$

Class XI: Physics
Chapter 7: Systems of Particles and Rotational Motion
Chapter Notes

Key Learnings

1. Rigid body is a solid body of finite size in which deformation is negligible under the effect of deforming forces.
2. A rigid body is one for which the distances between different particles of the body do not change.
3. Centre of mass (COM) of rigid body is the point in or near an object at which the whole mass of the object may be considered to be concentrated.
4. A rigid object can be substituted with a single particle with mass equal to the total mass of the system located at the COM of the rigid object.
5. In pure translational motion all particles of the body move with the same velocities in the same direction.
6. In pure translation, every particle of the body moves with the same velocity at any instant of time.
7. In rotational motion each particle of the body moves along the circular path in a plane perpendicular to the axis of rotation.
8. In rotation about a fixed axis, every particle of the rigid body moves in a circle with same angular velocity at any instant of time.
9. Irrespective of where the object is struck, the COM always moves in translational motion.

10. Motion of the COM is the resultant of the motions of all the constituent particles of a system.

11. Velocity of the centre of mass of a system of particles is given by

$$\vec{V} = \frac{\vec{P}}{M}, \text{ where } \vec{P} \text{ is the linear momentum of the system.}$$

12. The translational motion of the centre of mass of a system is, as if, all the mass of the system is concentrated at this point and all the external forces act at this point.

If the net external force on the system is zero, then the total linear momentum of the system is constant and the center of mass moves at a constant velocity.

13. Torque is the rotational analogue of force in translational motion.

14. The torque or moment of force on a system of n particles about the origin is the cross product of radius vectors and force acting on the particles.

$$\vec{\tau} = \sum_{i=1}^n \vec{r}_i \times \vec{F}_i$$

15. Angular velocity in rotational motion is analogous to linear velocity in linear motion.

16. Conditions for equilibrium:

- i. Resultant of all the external forces must be zero. Resultant of all the external torques must be zero.
- ii. Centre of gravity is the location in the extended body where we can assume the whole weight of the body to be concentrated.

17. When a body acted by gravity is supported or balanced at a single point, the centre of gravity is always at and directly above or below the point of suspension.

18. The moment of inertia of a rigid body about an axis is defined by the formula $I = \sum m_i r_i^2$ where r_i is the perpendicular distance of the i th point of the body from the axis. The kinetic energy of rotation is $K = \frac{1}{2} I \omega^2$

19. Theorem of perpendicular axis:

It states that the moment of inertia of a planar body (lamina) about an axis perpendicular to its plane is equal to the sum of its moments of inertia about two perpendicular axes concurrent with perpendicular axis and lying in the plane of the body.

$$I = I_x + I_y$$

Here

I_x : Moment of inertia about x axis in the plane of the lamina.

I_y : Moment of inertia about y axis in the plane of the lamina.

20. Theorem of parallel Axes:

This theorem states that the moment of inertia of a body about any axis is equal to its moment of inertia I_{cm} about a parallel axis through its center of mass, plus the product of the mass M of the body and the square of the distanced between the two axes.

$$I_p = I_{cm} + Md^2$$

21. Work done on the rigid body by the external torque is equal to the change in its kinetic energy.

22. Pure Rolling implies rolling without slipping which occurs when there is no relative motion at the point of contact where the rolling object touches the ground.

23. For a a rolling wheel of radius r which is accelerating, the acceleration of centre of mass -

$$a_{cm} = R\alpha$$

24. Law of conservation of angular momentum: If the net resultant external torque acting on an isolated system is zero, then total angular momentum L of system should be conserved.

25. The relation between the arc length S covered by a particle on a rotating rigid body at a distance r from the axis and the displacement θ in radians is given by $S=r \theta$.

Top Formulae

1. The position vector of COM of a system:

$$\vec{R} = \frac{m_1 \vec{r}_1 + m_2 \vec{r}_2 + m_3 \vec{r}_3 + \dots}{m_1 + m_2 + m_3 + \dots}$$

2. The coordinates of COM

$$x = \frac{m_1 x_1 + m_2 x_2 + m_3 x_3 + \dots}{m_1 + m_2 + m_3 + \dots}, \quad y = \frac{m_1 y_1 + m_2 y_2 + m_3 y_3 + \dots}{m_1 + m_2 + m_3 + \dots}, \quad z = \frac{m_1 z_1 + m_2 z_2 + m_3 z_3 + \dots}{m_1 + m_2 + m_3 + \dots}$$

3. Velocity of COM of a system of two two particles

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

4. Equations of rotational motion

i. $\omega_2 = \omega_1 + \alpha t$

ii. $\theta = \omega_1 t + \frac{1}{2} \alpha t^2$

iii. $\omega_2^2 - \omega_1^2 = 2\alpha\theta$

5. Centripetal acceleration = $\frac{v^2}{r} = r\omega^2$

6. Linear acceleration $a = r\alpha$

7. Angular momentum $\vec{L} = \vec{r} \times \vec{p}$

8. Torque $\vec{\tau} = \vec{r} \times \vec{F}$

9. Kinetic energy of rotation = $\frac{1}{2}I\omega^2$

10. Kinetic energy of translation = $\frac{1}{2}mv^2$

11. Total K. E. = $\frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$

12. Angular momentum $L = I\omega$

13. Torque $\tau = I\alpha$

14. Relation between torque and angular momentum $\vec{\tau} = \frac{d\vec{L}}{dt}$

15. Moment of inertia in terms of radius of gyration $I = \sum_{i=1}^{i=n} m_i r_i^2 = MK^2$

16. Moment of inertia of a uniform circular ring about an axis passing through the centre and perpendicular to the plane of the ring, $I = MR^2$

17. For a uniform circular disc, $I = \frac{1}{2}MR^2$

18. For a thin uniform rod = $\frac{1}{12}M\ell^2$

19. For a hollow cylinder about its axis = MR^2

20. For a solid cylinder about its axis = $\frac{1}{2}MR^2$

21. For a hollow sphere about its diameter = $\frac{2}{3}MR^2$

22. For a solid sphere about its diameter = $\frac{2}{5}MR^2$

23. Power of a torque

24. Coefficient of friction for rolling of solid cylinder without slipping down the rough inclined plane $\mu = \frac{1}{3} \tan \theta$

Class XI: Physics
Chapter 8: Gravitation
Chapter Notes

Key Learnings:

1. Newton's law of universal gravitation states that the gravitational force of attraction between any two particles of masses m_1 and m_2 separated by a distance r has the magnitude

$$F = G \frac{m_1 m_2}{r^2}$$

Where G , the universal gravitational constant, has the value $6.672 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}$.

2. From the principle of superposition each force acts independently and uninfluenced by the other bodies. The resultant force F_R is then found by vector addition.

$$F_R = F_1 + F_2 + \dots + F_n = \sum_{i=1}^n F_i$$

2. Acceleration due to gravity: $g = \frac{GM}{r^2}$
3. For small heights h above the earth's surface the value of g decreases by a factor $(1-2h/R)$.
4. The gravitational potential energy of two masses separated by a distance r is inversely proportional to r .
5. The potential energy is never positive; it is zero only when the two bodies are infinitely far apart.
6. The gravitational potential energy associated with two particles separated by a distance r is given by

$$V = -\frac{Gm_1 m_2}{r}$$

Where V is taken to be zero at $r \rightarrow \infty$.

7. The total mechanical energy is the sum of the kinetic and potential energies. The total energy is a constant of motion.

8. If an isolated system consists of a particle of mass m moving with a speed v in the vicinity of a massive body of mass M , the total mechanical energy of the particle is given by

$$E = \frac{1}{2} m v^2 - \frac{GMm}{r}$$

If m moves in circular orbit of radius a about M , where $M \gg m$, the total energy of the system is

$$E = -\frac{GMm}{2a}$$

9. The escape speed from the surface of the Earth is

$$v_e = \sqrt{\frac{2GM_E}{R_E}} = \sqrt{2gR_E}$$

And has a value of 11.2 km s^{-1}

10. Kepler's law of planetary motion:

- i. The orbit of the planet is elliptical with sun at one of the focus -
LAW OF ORBITS.
- ii. The line joining the planet to the sun sweeps out equal area in equal interval of time - LAW OF AREAS.
- iii. The square of the planet's time period of revolution T , is proportional to the cube of semi major axis a .

11. A geostationary satellite moves in a circular orbit in the equatorial plane at an approximate distance of 36,000 km.

Top Formulae:

1. Newton's Law of Gravitation

$$F = \frac{Gm_1m_2}{r^2}, \quad G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$$

2. Acceleration due to Gravity

$$g = \frac{GM}{R^2} = \frac{4}{3} \pi GR\rho$$

3. Variation of g

(a) Altitude (height) effect $g' = g \left(1 + \frac{h}{R}\right)^{-2}$

If $h \ll R$ then $g' = g \left(1 - \frac{2h}{R}\right)$

(b) Effect of depth $g'' = \left(1 - \frac{d}{R}\right)g$

(c) Latitude effect

4. Intensity of Gravitational Field

$$\vec{E}_g = \frac{GM}{r^2}(-\vec{r})$$

For earth $E_g = g = 9.86 \text{ m/s}^2$

5. Gravitational Potential

$$v_g = -\int_{\infty}^r \vec{E}_g \cdot d\vec{r}$$

For points on outside ($r > R$)

$$v_g = -\frac{GM}{r}$$

For points inside it, $r < R$

$$v_g = -GM \left[\frac{3R^2 - r^2}{2R^3} \right]$$

6. Change in Potential Energy (P. E.) on going height h above the surface

$$\Delta U_g = mgh \quad \text{if } h \ll R_e$$

In general $\Delta U_g = \frac{mgh}{\left(1 + \frac{h}{R}\right)}$

7. Orbital Velocity of a Satellite

$$\frac{mv_0^2}{r} = \frac{GMm}{r^2}$$

$$v_0 = \sqrt{\frac{GM}{R+h}} \quad r = h + R$$

If $h \ll R \quad v_0 = \sqrt{\frac{GM}{R}} = \sqrt{gR} = 8 \text{ Km/sec.}$

8. Velocity of Projection

Loss of K. E. = gain in P. E.

$$\frac{1}{2}mv_p^2 = -\frac{gMm}{(R+h)} - \left(-\frac{GMm}{R}\right)$$

$$v_p = \left[\frac{2GMh}{R(R+h)} \right]^{1/2} = \left[\frac{2gh}{1 + \frac{h}{R}} \right]^{1/2} \quad (\because GM = gR^2)$$

9. Period of Revolution

$$T = \frac{2\pi r}{v_0} = \frac{2\pi(R+h)^{3/2}}{R\sqrt{g}}$$

Or $T^2 = \frac{4\pi^2 r^3}{GM}$

If $h \ll R \quad T = \frac{2\pi R^{3/2}}{R\sqrt{g}} = 1\frac{1}{2} \text{ hr.}$

10. Kinetic Energy of Satellite

$$\text{K.E.} = \frac{GMm}{2r} = \frac{1}{2}mv_0^2$$

11. P.E. of Satellite

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

12. Binding energy of Satellite = $\frac{1}{2} \frac{GMm}{r}$

13. Escape Velocity

$$v_e = \sqrt{\frac{2GM}{R}} = \sqrt{2gR} = R\sqrt{\frac{8\pi Gd}{3}}$$

$$v_e = v_0 \sqrt{2}$$

14. Effective Weight in a Satellite

$$w = 0$$

Satellite behaves like a free fall body

15. Kepler's Laws for Planetary Motion

- (a) Elliptical orbit with sun at one focus
- (b) Areal velocity constant $dA/dt = \text{constant}$
- (c) $T^2 \propto r^3$. $r = (r_1 + r_2)/2$

Class XI : Physics
Chapter 10: Mechanical Properties of Fluids

Key Learning:

1. Fluid has a property that is flow. The fluid does not have any resistance to change of its shape. The shape of a fluid governed by the shape of its container.
2. A liquid is incompressible and has a free surface of its own. A gas is compressible and it expands to occupy all the space available to it.
3. Liquids and gases together are known as fluids.
4. Pressure at a point is force upon area, and it is a scalar quantity. Unit of pressure is pascal. Its SI unit is N m^{-2} .
5. Average pressure P_{av} is defined as the ratio of the force to area

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

6. Pascal is the unit of the pressure. It is the same as N m^{-2} . Other common units of pressure are

$$1 \text{ atm} = 1.01 \times 10^5 \text{ Pa}$$

$$1 \text{ bar} = 10^5 \text{ Pa}$$

$$1 \text{ torr} = 133 \text{ Pa} = 0.133 \text{ kPa}$$

$$1 \text{ mm of Hg} = 1 \text{ torr} = 133 \text{ Pa}$$

5. Pressure is defined as normal force per unit area.

$$P = \frac{dF_{\perp}}{dA}$$

6. The pressure difference between two points in a static fluid of uniform density ρ is proportional to the depth h .

7. Pascal's law states that a change in pressure at any point in an enclosed fluid at rest is transmitted undiminished to all points in the fluid.
8. Gauge pressure measures the excess pressure above the atmospheric pressure.
9. Flow of a fluid whose density is independent of both position and time is said to be incompressible.
10. If the frictional forces in a moving fluid are negligible, the flow is called non viscous.
11. If a fluid element has a nonzero angular velocity at every point, the flow is said to be non-rotational.
12. Orderly flow of a fluid is called streamlined or steady flow.
13. In streamlined flow, every liquid element crossing a point has the same velocity.
14. Disorderly flow of fluid is called turbulent Flow.
15. A streamline is defined as a curve such that the tangent to any point on the curve gives the direction of fluid flow at that point.
16. Like in a steady or streamline flow, no two streamlines ever cross each other.
17. The greater is the spacing between streamlines in a region, the smaller is the fluid velocity there.
18. A bundle of streamlines forming a tubular region is called a tube of flow.
19. When the flow is incompressible, non-viscous, steady and non-rotational, it is called ideal fluid flow.
20. Equation of continuity says that the product of area of cross section and velocity remains constant through out the flow.

21. In case of varying density or compressible liquids, the equation of continuity modifies to product of the density, area of cross section and velocity of the flow remaining constant as opposed to $Av = \text{constant}$.
22. If the fluid velocity is less than a certain limiting value called critical velocity, the flow is steady or streamlined; as its speed exceeds the critical velocity it becomes turbulent.
23. Equation of continuity tells us that fluid speed is greater in narrow regions as compared to wider regions.
24. If the speed of a fluid element increases as it flows, the pressure of the fluid must decrease and vice versa – This is one implication of Bernoulli's Principle.
25. Bernoulli was the first one to relate this pressure difference to velocity changes.
26. Bernoulli also explained the relation between the height of a fluid and changes in pressure and speed of fluid.
27. Along a streamline, the sum of the pressure, the kinetic energy per unit volume and the potential energy per unit volume remains constant. This is the statement of Bernoulli's Principle.
28. Bernoulli's principle holds true in case of ideal fluid flow which is incompressible; irrotational and streamlined.
29. Bernoulli's principle, which results from conservation of energy, relates the height, pressure, and speed of an ideal fluid whether it is a liquid or a gas.
30. The speed of outflow of a liquid from a hole in an open tank is called the speed of efflux.
31. Velocity of fluid flowing out through end B as $v_B = \sqrt{2gh}$. This is called Torricelli's Law.
32. Venturimeter is the device used to measure the flow speed of an incompressible liquid.
33. As per Bernoulli's principle, the pressure above the wing is lower than the pressure below it because the air is moving faster above the wing. This higher pressure at the bottom compared to the top, applies an upward force to the wing to lift it upwards. This is called dynamic lift.

34. Magnus effect is the curving in the path of the ball introduced due to the difference in pressure above and below the ball.
35. The speed of efflux from a hole in an open tank is given by $\sqrt{2gh}$.
36. Ideal fluid is incompressible and nonviscous.
37. Viscosity describes a fluid's internal resistance to flow and may be thought of as a measure of fluid friction.
38. Viscous fluid flows fastest at the center of the cylindrical pipe and is at rest at the surface of the cylinder.
39. Viscosity is internal friction in a fluid.
40. Surface tension is due to molecular forces.
41. The difference in energy of the bulk molecules and the surface molecules gives rise to surface tension.
42. Drops have a spherical shape because spherical shape has the minimum surface area for a given volume of a free liquid.
43. Surface tension is also responsible for the wiggling of soap bubbles. Greater is the attractive force between molecules of a liquid, greater is its surface tension and greater is its resistance to the increase in surface area.
44. Surface tension can be quantitatively defined as the energy required per unit increase in surface area.
45. Angle of contact is the angle formed between the solid/liquid interface and the liquid/vapor interface and it has a vertex where the three interfaces meet.
46. When the contact angle is acute, the liquid wets the solid, like water on a glass surface.
47. When the contact angle is obtuse, the liquid does not wet the solid like water on these flower petals.
48. Angle of contact is a good measure of Cleanliness of a surface. Organic Contamination increases the angle of contact.
49. Surface tension of a liquid decreases with the rise in temperature because molecules get extra energy to overcome their mutual attraction.

50. Due to surface tension, the liquid surface squeezes itself to minimum surface area.

51. The greater is the surface tension of the liquid, greater is the excess pressure required for bubble formation inside it.

52. Capillary action is the tendency of a liquid to rise in narrow tubes due to surface tension,

53. Height of liquid column rising in a capillary tube depends upon:

- On its contact angle θ
- directly on its surface tension S
- Inversely on its density ρ
- Inversely on radius r of the tube

54. Addition of detergent in water lowers the surface tension which helps with the cleansing action.

Top Formulae:

1. Pressure of a fluid having density ρ at height h , $P = h\rho g$
2. Gauge pressure = total pressure – atmospheric pressure
3. For hydraulic lift

$$\frac{F_1}{a_1} = \frac{F_2}{a_2}$$

4. Surface tension, $S = F / \ell$
5. Work done = surface tension x increase in area
6. Excess of pressure inside the liquid drop $p = P_i - P_o = \frac{2S}{r}$
7. Excess of pressure inside the soap bubble $p = P_i - P_o = \frac{4S}{r}$
8. Total pressure in the air bubble at a depth h below the surface of liquid of density ρ is

$$P = P_o + h\rho g + \frac{2S}{r}$$

9. In case of capillary, ascent / descent formula, $h = \frac{2S \cos \theta}{r \rho g}$, where θ is the angle of contact.

10. Newton's viscous dragging force, $F = \eta A \frac{dv}{dx}$, where η is coefficient of viscosity, A is the area of layer of liquid and $\frac{dv}{dx}$ is the velocity gradient.

11. According to Poisseuille, the volume of the liquid flowing per second through the tube $V = \frac{\pi P r^4}{8 \eta \ell}$

12. Stoke's law, $F = 6 \pi \eta r v$

13. Terminal velocity, $v = \frac{2r^2(\rho - \sigma)g}{9\eta}$, where ρ and σ are the densities of spherical body and medium respectively; r is the radius of spherical body.

14. Reynold's number, $R_N = \frac{\rho D v}{\eta}$, where D is the diameter of the tube and v is the velocity of liquid flow through tube.

15. Volume of liquid flowing per second through a tube, $V = a v$, where a is the area of cross section and v is the velocity of liquid through tube.

16. Bernoulli's theorem:

Pressure energy per unit mass + potential energy per unit mass + kinetic energy per unit mass = constant

$$\frac{P}{\rho} + gh + \frac{1}{2}v^2 = \text{constant}$$

17. Venturimeter, volume of liquid flowing per second

$$V = a_1 a_2 \sqrt{\frac{2 \rho_m g h}{\rho(a_1^2 - a_2^2)}}$$

Where a_1 and a_2 are the areas of cross-section of bigger and smaller tube; h is the difference of pressure head at two tubes of venturimeter.

18. Velocity of efflux, $v = \sqrt{2gh}$

Class XI: Physics
Chapter 9, Mechanical Properties of Solids

Points to remember

Key Learning:

1. Stress is the restoring force per unit area and strain is the fractional change in dimension.
2. Types of stresses (a) tensile stress — longitudinal stress (b) shearing stress, and (c) hydraulic stress.
3. Hooke's law states that the extension is proportional to the force or tension in a wire if the proportional limit is not exceeded. The constant of proportionality is called modulus of elasticity.
4. Three elastic moduli viz., Young's modulus, shear modulus and bulk modulus are used to describe the elastic behaviour of objects as they respond to deforming forces that act on them.
5. Strain is fractional deformation.
6. Elastic deformations, stress is proportional to strain. The proportionality constant is called the elastic modulus.

$$\frac{\text{Stress}}{\text{Strain}} = \text{Elastic modulus}$$

7. Elastomers, a new class of solid, do not obey Hooke's law.
8. Tensile stress = force per unit area = F/A
9. Tensile strain is extension per unit length = e/l .
10. Shearing stress is possible only in solids.
11. In elastic behaviour, metal returns to original length after load is removed. In this situation the energy is then recovered.
12. In plastic behaviour, metal permanently strained after load is removed. In this case the energy transferred to heat after elastic limit exceeded.

Top Formulae:

1. Normal stress, $S = F / a$; where $a = \pi r^2$
2. Longitudinal strain $= \frac{\Delta \ell}{\ell}$
3. *Young's* modulus $Y = \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{F / A}{\Delta L / L_0} = \frac{F}{A} \frac{L_0}{\Delta L}$
4. Breaking force = breaking stress x area of cross section
5. Volumetric strain $= \frac{\Delta V}{V}$
6. *Bulk* modulus, $B = \frac{\text{Bulk stress}}{\text{Bulk strain}} = -\frac{\Delta p}{\Delta V / V_0} = -\frac{\Delta p V_0}{\Delta V}$
7. Shearing strain $= \frac{\Delta L}{L} = \theta$
8. *Shear* modulus, $S = \frac{\text{Shear stress}}{\text{Shear strain}} = \frac{F / A}{x / h} = \frac{F}{A} \frac{h}{x}$
9. Modulus of rigidity, $G = \frac{F}{a\theta}$
10. Elastic potential energy of a stretched wire

$$= (1/2) \times \text{stress} \times \text{strain} \times \text{volume}$$

Class XI: Physics
Chapter 11: Thermal Properties of Matter

Key Learning

1. Heat is a form of energy that brings about changes in temperature.
2. Temperature is that quality of an object which determines the sensation of hotness or coldness felt when there is contact with the object.
3. Heat is the transfer of energy between two systems or a system and its surroundings.
4. Heat flows from body at higher temperature to body at lower temperature.
5. Thermometer uses a measurable property that changes with temperature.
6. In constant volume gas thermometer, $P \propto T$
7. When two objects achieve the same temperature and there is no net transfer of heat between them they are in thermal equilibrium.
8. Heat capacity is the quantity of heat required to raise the temperature of a body by one degree. Its unit is joules per kelvin or J K^{-1}
9. The specific heat capacity is the amount of heat required to raise the temperature of 1kg of a substance by one degree. SI unit is joules per kilogram per kelvin or $\text{J kg}^{-1} \text{K}^{-1}$ and the symbol is c .
10. Calorimeter is a device used for heat measurement.
11. In an isolated system, heat lost = heat gained.
12. Matter exists in three states: solid, liquid and gas.
13. Different phases of a substance at a fixed temperature have different internal energies.

14. Latent heat of fusion is the heat required to change unit mass of a substance from solid to liquid at same temperature and pressure.
15. Latent heat of vaporization is the heat required to change unit mass of a substance from liquid to vapor state at same temperature and pressure.
16. The three mechanisms of heat transfer are – Conduction, Convection and Radiation.
17. Radiation is energy transfer through electromagnetic radiation.
18. Newton's law of cooling states that the rate of loss of heat is proportional to the excess temperature over the surroundings.

$$-dQ/dt = k (T_2 - T_1)$$

19. In conduction, heat is transferred between neighbouring parts of a body through molecular collisions, without any flow of matter.

Top Formulae

1. The ideal gas equation connecting pressure (P), volume (V), and absolute temperature (T) is:

$$PV = \mu RT$$

where μ is the number of moles and R is the universal gas constant.

2. If T_C , T_F and T_K are temperature values of body on Celcius scale, Fahrenheit scale and Kelvin scale, then

$$\frac{T_C - 0}{100} = \frac{T_F - 32}{180} = \frac{T_K - 273.15}{100}$$

3. If triple point of water is chosen as the reference point, then

$$T_K = 273.16 \left(\frac{P}{P_{tr}} \right)$$

where P: pressure at unknown temperature T

P_{tr} : pressure at triple point.

4. (i) Coeff. of linear expansion, $\alpha = \frac{\Delta L}{L(\Delta T)}$

(ii) Coeff. of area expansion, $\beta = \frac{\Delta S}{S(\Delta T)}$

(iii) Coeff. of volume expansion, $\gamma = \frac{\Delta V}{V(\Delta T)}$

5. $\beta = 2 \alpha ; \gamma = 3 \alpha$

6. Variation of density with temperature is given by

$$\rho = \rho_0 (1 - \gamma \Delta T)$$

7. The specific heat capacity of a substance is defined by

$$s = \frac{1}{m} \frac{\Delta Q}{\Delta T}$$

Where m is the mass of the substance and ΔQ is the heat required to change its temperature by ΔT .

8. The molar specific heat capacity of a substance is defined by

$$C = \frac{1}{\mu} \frac{\Delta Q}{\Delta T}$$

Where μ is the number of moles of the substance.

9. Change of heat, $\Delta Q = m s \Delta T$, where c is specific heat of the substance.

10. Molar specific heat of substance, $C = m \times s$,

11. In the method of mixtures,

Heat gained = Heat lost

i.e. mass \times specific heat \times rise in temperature

= mass \times sp. heat \times fall in temperature

12. For Change of state, $\Delta Q = mL$ where L is latent heat of the substance

13. $C_p - C_v = \frac{R}{J}$, where $R = \frac{PV}{T}$ = gas constant for one gram mole of the gas.

14. For mono-atomic gases, $C_v = \frac{3}{2} R$; $C_p = \frac{5}{2} R$

15. For diatomic gases, $C_v = \frac{5}{2} R$, $C_p = \frac{7}{2} R$
16. For tri-atomic gases (non linear molecule), $C_v = 3 R$, $C_p = 4 R$
17. For tri-atomic gases (linear molecule) $C_p = \frac{7}{2} R$, $C_v = \frac{5}{2} R$
18. Rate of conduction of heat, $\frac{\Delta Q}{\Delta t} = KA \frac{\Delta T}{\Delta x}$

Where $\frac{\Delta T}{\Delta x}$ = temperature gradient = rate of fall of temperature with distance, A = area of the hot surface, K = coefficient of thermal conductivity.

19. If heat so conducted is used in changing the state of m gram of the substance, then $\Delta Q = mL = KA \left(\frac{\Delta T}{\Delta x} \right) \Delta t$, where L is latent heat of the substance.
20. If heat so conducted is used in increasing the temp. of the substance through range $\Delta \theta$, then $\Delta Q = sm \Delta \theta = KA \left(\frac{\Delta T}{\Delta x} \right) \Delta t$

Class XI: Physics
Chapter 12: Thermodynamics

Key Learning

1. The nature of heat and its relationship to mechanical work was studied by Joule.
2. Thermal equilibrium implies that systems are at the same temperature.
3. Internal energy of a system is the sum of kinetic energies and potential energies of the molecular constituents of the system. It does not include the over – all kinetic energy of the system.
4. Equilibrium states of a thermodynamics system are described by state variables. The value of a state variable depends only on the particular state, not on the path used to arrive at that state.
5. Examples of state variables are pressure (P), volume (V), temperature (T) and mass (m). Heat and work are not state variables.
6. Zeroth law of thermodynamics states that two systems in thermal equilibrium with a third system, are in thermal equilibrium with each other.
7. The first law of thermodynamics is based on the principle of conservation of energy. It states that $\Delta U = \Delta Q - P\Delta V$
8. The efficiency of a heat engine is defined as the ratio of the work done by the engine to the input heat.

$$\eta = \frac{\text{Work done}}{\text{Input heat}} = \frac{W}{Q_H}$$

9. If all the input heat is converted entirely into heat, the engine would have an efficiency of 1.
10. In a reversible process both the system and its environment can be returned to their initial states.
11. Spontaneous processes of nature are irreversible. The idealized reversible process is a quasi – static process with no dissipative factors such as friction viscosity, etc.
12. A quasi – static process is an infinitely slow process such that the system remains in thermal and mechanical equilibrium with the surroundings throughout. In a quasi – static process, the pressure and temperature of the environment can differ from those of the system only infinitesimally.
13. Heat engine is a device in which a system undergoes a cyclic process resulting in conversion of heat into work.
14. Carnot engine is a reversible engine operating between two temperatures T_1 (source) and T_2 (sink). The Carnot cycle consists of two isothermal processes connected by two adiabatic processes.
15. The efficiency of the Carnot engine is independent of the working substance of the engine. It only depends on the temperatures of the hot and cold reservoirs.
16. Efficiency of Carnot engine is $\eta = 1 - T_C / T_H = 1 - (\text{Temperature of cold reservoir} / \text{Temperature of hot reservoir})$.
17. No engine can have efficiency more than that of a Carnot engine.

18. Implications of First law of thermodynamics:
 - i. Heat lost by hot body = heat gained by the cold body.
 - ii. Heat can flow from cooler surroundings into the hotter body like coffee to make it hotter.
19. Kelvin's Statement of second law of thermodynamics:

No heat engine can convert heat into work with 100 % efficiency.
20. Clausius's Statement: No process is possible whose sole result is the transfer of heat from a colder to a hotter body.
21. Kelvin's Statement: No process is possible whose sole result is the complete conversion of heat into work.
22. The co-efficient of performance of a refrigerator is $\alpha = Q_c/W$.
23. A heat pump, is called so, because it pumps heat from the cold outdoors (cold reservoir) into the warm house (hot reservoir).
24. If $Q > 0$, heat is added to the system
 If $Q < 0$, heat is removed to the system
 If $W > 0$, Work is done by the system
 If $W < 0$, Work is done on the system

Top Formulae

1. Equation of isothermal changes $PV = \text{constant}$ or $P_2 V_2 = P_1 V_1$
2. Equation of adiabatic changes
 - (i) $P_2 V_2^\gamma = P_1 V_1^\gamma$
 - (ii) $P_2^{1-\gamma} T_2^\gamma = P_1^{1-\gamma} T_1^\gamma$
 - (iii) $T_2 V_2^{\gamma-1} = T_1 V_1^{\gamma-1}$, where $\gamma = C_p / C_v$
3. Work done by the gas in isothermal expansion

$$W = 2.3026 RT \log_{10} \frac{V_2}{V_1},$$

$$W = 2.3026 RT \log_{10} \frac{P_1}{P_2}$$
4. Work done in adiabatic expansion

$$W = \frac{R}{(1-\gamma)}(T_2 - T_1)$$

5. $dQ = dU + dW$

Here $dW = P (dV)$, small amount of work done

$dQ = m L$, for change of state and

$dQ = mc \Delta T$ for rise in temperature

dU = change in internal energy

6. $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

Where T_1 = temperature of source, T_2 = temperature of sink ; Q_1 is amount of heat absorbed/cycle from the source, Q_2 is the amount of heat rejected/cycle to the sink.

7. Useful work done/cycle $W = Q_1 - Q_2$

8. Efficiency of Carnot engine is also given by $\eta = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1}$

9. Coefficient of performance of a refrigerator

$$\beta = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}; W = Q_1 - Q_2,$$

Where Q_2 is amount of heat drawn/cycle from the sink (at T_2) and W is Work done/cycle on the refrigerator. Q_1 is amount of heat rejected/cycle to the source (air at room temp. T_1)

10. $\beta = \frac{1-\eta}{\eta}$

Class XI: Physics
Chapter 13: Kinetic Theory

Key Learning:

1. Kinetic theory of gases relates the macroscopic properties of gases like pressure, temperature etc. to the microscopic properties of its gas molecules example speed, kinetic energy etc.
2. Ideal gas is one for which the pressure p , volume V and temperature T are related by $pV = nRT$ where R is called the gas constant.
3. Real gases satisfy the ideal gas equations only approximately, more so at low pressures and high temperatures.
4. Kinetic theory of an ideal gas gives the relation

$$P = \frac{1}{3} n m \overline{v^2}$$

Where n is number density of molecules, m the mass of the molecule and $\overline{v^2}$ is the mean of squared speed.

5. The temperature of a gas is a measure of the average kinetic energy of molecules, independent of the nature of the gas or molecule. In a mixture of gases at a fixed temperature the heavier molecule has the lower average speed.
6. The pressure exerted by n moles of an ideal gas, in terms of the speed of its molecules is $P = \frac{1}{3} n m v_{\text{rms}}^2$.
7. The average kinetic energy of a molecule is proportional to the absolute temperature of the gas.
8. Degrees of freedom of a gas molecule are independent ways in which the molecule can store energy.
9. Law of equipartition of energy states that every degree of freedom of a molecule has associated with it, on average, an internal energy of $(\frac{1}{2})kT$ per molecule.

10. Monoatomic gases only have three translational degrees of freedom.
11. Diatomic gases in general have three translational, two rotational and two vibrational degrees of freedom.
12. The molar specific heat at constant volume C_v can be written as $(f/2)R$ where f is the number of degrees of freedom of the ideal gas molecule.

Top Formulae:

1. Boyle's law, $PV = \text{constant}$.
2. Charle's law, $V/T = \text{a constant}$
3. Gaylussac's law, $P/T = \text{a constant}$,
4. Gas equation, $PV = \mu RT$, where μ is the no. of moles of the given gas.
5. Pressure exerted by gas, $P = \frac{1}{3} \frac{M}{V} C^2 = \frac{1}{3} \rho C^2$
6. Mean K.E. of translation per molecule of a gas $= \frac{1}{2} m C^2 = \frac{3}{2} kT$
7. Mean K.E. of translation per mole of gas $= \frac{1}{2} M C^2 = \frac{3}{2} RT = \frac{3}{2} NkT$,
8. Total K.E. per mole of gas $= \frac{n}{2} RT$, where n is number of degrees of freedom of each molecule.
9.
$$C_{\text{rms}} = \sqrt{\frac{C_1^2 + C_2^2 + \dots + C_n^2}{n}}$$
10. Effect of temperature: $\frac{C_2}{C_1} = \sqrt{\frac{T_2}{T_1}}$
11. Mean free path, $\lambda = \frac{k_B T}{\sqrt{2} \pi d^2 p} = \frac{1}{\sqrt{2} \pi d^2 n}$ where n = number of molecules per unit volume of the gas.
12. Collision frequency $f = v / \lambda$

Class XI: Physics
Chapter 14: Oscillations

Key Learning:

1. The motion which repeats itself is called periodic motion.
2. The period T is the time required for one complete oscillation, or cycle. It is related to the frequency ν by, $\nu = 1/T$.
3. The frequency ν of periodic or oscillatory motion is the number of oscillations per unit time.
4. The force acting in simple harmonic motion is proportional to the displacement and is always directed towards the centre of motion.
5. In Simple harmonic motion, the displacement $x(t)$ of a particle from its equilibrium position is given by,

$$x(t) = A \cos(\omega t + \Phi)$$

6. $(\omega t + \Phi)$ is the phase of the motion and Φ is the phase constant. The angular frequency ω is related to the period and frequency of the motion by,

$$\omega = \frac{2\pi}{T} = 2\pi\nu$$

7. Two perpendicular projections of uniform circular motion will give simple harmonic motion for projection along each direction with center of the circle as the mean position.
8. The motion of a simple pendulum swinging through small angles is approximately simple harmonic. The period of oscillation is given by

$$T = 2\pi\sqrt{\frac{l}{g}}$$

9. The motion of a simple pendulum is simple harmonic for small angular displacement.

10. A particle of mass m oscillating under the influence of a Hooke's law restoring force given by $F = -kx$ exhibits simple harmonic motion with

$$\omega = \sqrt{\frac{k}{m}} = \text{Angular frequency}$$

$$T = 2\pi\sqrt{\frac{m}{k}} = \text{Period}$$

11. The restoring force in case of wooden cylinder floating on water is due to increase in up thrust as it is pressed into the water.
12. The restoring force in case of Liquid in U tube arises due to excess pressure in the liquid column when the liquid levels in the two arms are not equal.
13. A simple pendulum undergoing SHM in the plane parallel to the length of the wire is due to restoring force that arises due to increase in tension in the wire
14. The mechanical energy in a real oscillating system decreases during oscillations because external forces, such as drag, inhibit the oscillations and transfer mechanical energy to thermal energy. The real oscillator and its motion are then said to be damped.
15. If an external force with angular frequency ω_d acts on an oscillating system with natural angular frequency ω , the system oscillates with angular frequency ω_d . The amplitude of oscillations is the greatest when

$$\omega_d = \omega$$

This condition is called resonance.

Top Formulae:

1. Displacement in S.H.M., $y = a \sin (\omega t \pm \phi_0)$
2. Velocity in S.H.M., $V = \omega \sqrt{a^2 - y^2}$
3. Acceleration in S.H.M., $A = -\omega^2 y$ and $\omega = 2\pi v = 2\pi/T$
4. Potential energy in S. H. M., $U = \frac{1}{2} m \omega^2 a^2 = \frac{1}{2} k y^2$
5. Kinetic energy in S. H. M., $K = \frac{1}{2} m \omega^2 (a^2 - y^2) = \frac{1}{2} k (a^2 - y^2)$
6. Total energy, $E = \frac{1}{2} m \omega^2 a^2 = \frac{1}{2} k a^2$
7. Spring constant $k = F/y$
8. Spring constant of parallel combination of springs

$$K = k_1 + k_2$$
9. Spring constant of series combination of spring $\frac{1}{K} = \frac{1}{k_1} + \frac{1}{k_2}$
10. Time period, $T = 2\pi \sqrt{\frac{m}{K}}$
11. If the damping force is given by $F_d = -b v$, where v is the velocity of the oscillator and b is its damping constant, then the displacement of the oscillator is given by

$$x(t) = A e^{-bt/2m} \cos (\omega' t + \Phi)$$

where ω' the angular frequency of the damped oscillator, is given by

$$\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$$

12. The mechanical energy E of damped oscillator is given by

$$E(t) = \frac{1}{2} k A^2 e^{-bt/m}$$

Class XI: Physics Waves

Key Learning:

1. Waves carry energy from one place to another.
2. The amplitude is the magnitude of the maximum displacement of the elements from their equilibrium positions as the wave passes through them.
3. The wavelength λ of a wave is the distance between repetitions of the shape of the wave. In a stationary wave, it is twice the distance between two consecutive nodes or anti nodes.
4. The period T of oscillation of a wave is the time any string element takes to move through one full oscillation.
5. A mechanical wave travels in some material called the medium. Mechanical waves are governed by Newton's Laws.
6. The speed of the wave depends on the type of wave and the properties of the medium.
7. The product of wavelength and frequency equals the wave speed.
8. $y = A \sin(kx - \omega t)$ is an equation that describes a traveling wave
9. In transverse waves the particles of the medium oscillate perpendicular to the direction of wave propagation.
10. In longitudinal waves the particles of the medium oscillate along the direction of wave propagation.

11. Progressive wave is a wave that moves from one point of medium to another.
12. The speed of a transverse wave on a stretched string is set by the properties of the string. The speed on a string with tension T and linear mass density μ is $v = \sqrt{\frac{T}{\mu}}$.

11. Sound waves are longitudinal mechanical waves that can travel through solids, liquids, or gases. The speed v of sound wave in a fluid having bulk modulus B and density ρ is

$$v = \sqrt{\frac{B}{\rho}}$$

The speed of longitudinal waves in a metallic bar of Young's modulus Y and density ρ is

$$v = \sqrt{\frac{Y}{\rho}}$$

For gases, since $B = \gamma P$, the speed of sound is

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

12. When two or more waves traverse the same medium, the displacement of any element of the medium is the algebraic sum of the displacements due to each wave. This is known as the principle of superposition of waves
13. Two sinusoidal waves on the same string exhibit interference, adding or canceling according to the principle of superposition.
14. A traveling wave, at a rigid boundary or a closed end, is reflected with a phase reversal but the reflection at an open boundary takes place without any phase change.

For an incident wave

$$y_i(x, t) = a \sin(kx - \omega t)$$

The reflected wave at a rigid boundary is

$$y_r(x, t) = -a \sin(kx + \omega t)$$

For reflection at an open boundary

$$y_r(x, t) = a \sin(kx + \omega t)$$

15. The interference of two identical waves moving in opposite directions produces standing waves. For a string with fixed ends, the standing wave is given by

$$y(x, t) = [2a \sin kx] \cos \omega t$$

16. Standing waves are characterized by fixed locations of zero displacement called nodes and fixed locations of maximum displacements called antinodes. The separation between two consecutive nodes or antinodes is $\lambda/2$.

17. A stretched string of length L fixed at both the ends vibrates with frequencies given by

$$\nu = \frac{1}{2} \frac{v}{L}, \quad n = 1, 2, 3, \dots$$

The set of frequencies given by the above relation are called the normal modes of oscillation of the system. The oscillation mode with lowest frequency is called the fundamental mode or the first harmonic. The second harmonic is the oscillation mode with $n = 2$ and so on.

16. A string of length L fixed at both ends or an air column closed at one end and open at the other end, vibrates with frequencies called its normal modes. Each of these frequencies is a resonant frequency of the system.

17. Beats arise when two waves having slightly different frequencies, ν_1 and ν_2 and comparable amplitudes, are superposed.
The beat frequency, $\nu_{\text{beat}} = \nu_1 \sim \nu_2$
18. The Doppler's effect is a change in the observed frequency of a wave when the source and the observer move relative to the medium.
5. The velocity of sound changes with change in pressure, provided temperature remains constant.
16. The plus/minus sign is decided by loading/filling any of the prongs of either tuning fork.
17. on loading a fork, its frequency decrease and on filling its frequency increases.

Top Formulae

1. Velocity of wave motion, $v = \nu \lambda = \lambda / T$, where λ is wavelength, T is period, ν is frequency.
2. Angular wave number $k = \frac{2\pi}{\lambda}$
3. Angular frequency $\omega = \frac{2\pi}{T}$
4. Newton's formula (corrected) for velocity of sound in air is

$$v = \sqrt{\frac{B_a}{\rho}} = \sqrt{\frac{\gamma P}{\rho}},$$

Where B_a is coefficient of volume elasticity of air under adiabatic conditions, P is pressure and ρ is density of air.

5. Velocity of transverse waves in stretched string, $v = \sqrt{T/m}$, where T is tension in string and m is mass/ length of string.
6. Phase difference between two points separated by distance $\lambda = 2 \pi$ radian.
7. Equation of a plane progressive harmonic wave traveling along positive direction of X – axis is

$$y = r \sin \frac{2\pi}{\lambda} (vt - x)$$

Where, y = displacement of particle at time t, r = amplitude of vibration of particle, v = velocity of wave, λ = wavelength of wave,

x = distance of starting point (or wave) from the origin.

8. Velocity of particle at time t = dy/dt
9. Acceleration of particle at time t = $\frac{d^2y}{dt^2}$

10. Acceleration of wave = 0.

11. Equation of a stationary wave is

$$y = 2r \sin \frac{2\pi}{\lambda} x \cos \frac{2\pi}{\lambda} vt$$

12. Fundamental frequency

$$v_1 = \frac{v}{2L} = \frac{1}{2L} \sqrt{\frac{T}{m}} = \frac{1}{\ell D} \sqrt{\frac{T}{\pi \rho}}$$

13. Second harmonic or 1st overtone $v_2 = 2v_1$
14. Third harmonic or 2nd overtone $v_3 = 3v_1$ and so on.

15. Closed organ pipes.

i. Fundamental note $v_1 = \frac{v}{4L}$

ii. First overtone or 3rd harmonic $v_2 = 3v_1$.

iii. Second overtone or 5th harmonic $v_3 = 5v_1$

16. Open organ pipes.

i. Fundamental note $v_1 = \frac{v}{2L}$

ii. First overtone or 2nd harmonic $v_2 = 2v_1$

iii. Second overtone or 3rd harmonic $v_3 = 3v_1$

17. Beat frequency, $m = (n_1 - n_2)$ or $(n_2 - n_1)$

18. Doppler's effect

$$v' = \frac{[(v + v_m) - v_L]}{(v + v_m) - v_s} v$$

Where, v = actual frequency of sound emitted by the source,

v' = apparent frequency of sound heard,

v = velocity of sound in air,

v_m = velocity of medium (air) in the direction of sound,

v_s = velocity of source, along SL

v_L = velocity of listener, along SL