6. Gravitation

1. State Kepler's three laws.

Law of orbits :

Each planet moves around the sun in an elliptical orbit with the sun at one of the foci.

- **Closet point of planet to sun ⟶ Perihelion**
- **Farthest point of planet to sun ⟶ Aphelion**

2. Law of area :

The radial vector (line joining the sun to a planet) sweeps equal areas in equal intervals of time.

- **The planets travel *faster* when they *nearer* to the sun.**
- **The planets travel *slower* when they *farther* to the sun.**
- **To cover equal area (Δ A) in equal in equal intervals of time (Δ t)**

3 Law of period :

The square of the time period of revolution of a planet around the sun in its elliptical orbit is directly proportional to the cube semi - major axis of the ellipse.

$$\boxed{T^2 \;\alpha\; a^3}$$

---

2. State Newtons Universal law of gravitation.

Newtons law of gravitation states that a particle of mass M_1 attracts any other particle of mass M_2 in the universe with an attractive force. The strength of this force of attraction was found to be directly proportional to the product of their masses and is inversely proportional to the square of the distance between them.

$$\boxed{\vec{F} = -\frac{G\,M_1\,M_2}{r^2}\hat{r}}$$

$$G = 6.67 \times 10^{-11}\ N\,m^2\,kg^{-2}$$

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3. Will the angular momentum of a planet be conserved ? Justify your answer.

The torque experienced by the Earth due to the gravitational force of the sun is given by

$$\vec{\tau} = \vec{r} \times \vec{F} = \vec{r} \times -\left(\frac{G M_S M_E \hat{r}}{r^2}\right) = 0$$

$$\tau = \frac{d\vec{L}}{dt} = 0 \quad \text{since } \vec{r} = r\hat{r}, \ \hat{r} \times \hat{r} = 0$$

- **Angular momentum $\vec{L}$ is a constant vector.**
- **Angular momentum of the Earth about the sun is constant throughout the motion.**

---

4. Define the gravitational field . Give its unit.

- **The gravitational field due to a mass m at a point which is at a distance r from mass m is given by ,**

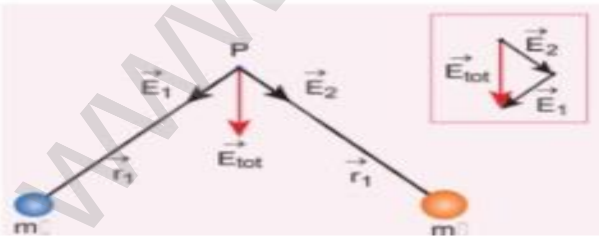
$$\boxed{\vec{E} = -\frac{G m}{r^2}\hat{r}}$$

- **The gravitational field is defined as the gravitational force experienced by unit mass placed at that point. It is a vector quantity.**

---

5. What is meant by superposition of gravitational field ?

Consider ' n ' particles of masses m_1 , m_2 ,….. m_n distributed in space at positions r_1 , r_2 ,….. r_n with respect to point P. The total gravitational field at a point P due to all the masses is given by the vector sum of the gravitational field due to the individual masses. This principle is known as superposition of gravitational fields.



$$\vec{E}_{total} = \vec{E}_1 + \vec{E}_2 + \dots \vec{E}_n$$

$$\vec{E}_{total} = -\frac{G m_1}{r_1^2}\hat{r}_1 - \frac{G m_1}{r_2^2}\hat{r}_2 \dots\dots \frac{G m_n}{r_n^2}\hat{r}_n = -\sum_{i=1}^{n} \frac{G m_i}{r_i^2}\hat{r}_i$$

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6. Define gravitational potential energy.

The gravitational potential energy of a system of two masses m_1 and m_2 separated by a distance r as the amount of work done to take the mass m_2 from a distance r to infinity assuming m_1 to be fixed in its position .

$$\boxed{U = -\frac{G\, m_1\, m_2}{r}}$$

---

7. Is potential energy the property of a single object ? Justify.

No , potential energy is a property of a system rather than of a single object due to its physical position. Because gravitation potential energy depends on relative position. So a reference level at which to set the potential energy equal to zero.

---

8. Define gravitational potential.

The gravitational potential at a distance r due to a mass m is defined as the amount of work required to bring unit mass from infinity to the distance r.

$$\boxed{V = -\frac{G\, m}{r}}$$

---

9. What is the difference between gravitational potential and gravitational potential energy .

S.NO	Gravitational potential	Gravitational potential energy
1.	The amount of work required to bring unit mass from infinity to the distance .	The amount of work done to take the mass m_2 from a distance r to infinity assuming m_1 to be fixed in its position .
2.	$V = -\frac{G\, m}{r}$	$U = -\frac{G\, m_1\, m_2}{r}$
3.	Unit : J kg^{-1}	Unit : Joule

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10. What is meant by escape speed in the case of the earth ?

The escape speed is defined as the minimum speed required by an object to escape from earth ' s gravitational field.

- **Escape speed of the earth is V_e = 11.2 km s^{-1}**
- **Radius of the earth is R_e = 6400 km**
- **Acceleration due to gravity 9.8 m s^{-2} .**

$$\boxed{V_e = \sqrt{2\ g\ R_e}}$$

---

11. Why is the energy of a satellite (or any other planet) negative ?

1. Implies that the satellite is bound to the Earth and it cannot escape from the Earth.

2. As h approaches ∞ the total energy tends to zero. Its physical meaning is that the satellite is completely free from the influence of Earth's gravity and is not bound to Earth at large distances.

---

12. What are geostationary and polar satellites ?

<u>Geostationary Satellite :</u>

1. Geostationary satellites appear to be stationary , when seen from Earth.

2. Distance h turns out be 36,000 km.

3. India uses the INSAT group of satellites that are basically geostationary satellite.

4. They are used for purpose of telecommunication.

<u>Polar Satellite :</u>

1. Another type satellite which is placed at a distance of 500 to 800 km.

2. This type satellite that orbits Earth from pole to south pole .

3. The time period of polar satellite is nearly 100 minutes.

4. The satellites completes many revolution in a day.

5. A polar satellite covers small strip of area from pole to pole during one revolution.

---

13. Define weight.

The weight of an object W is defined as the that of upward force that must be applied to the object to hold it at rest or at constant velocity relative to the earth.

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14. Why is there no lunar eclipse and solar eclipse every month ?

Moon's orbit is tilted 5^0 with respect to earths orbit. Due to this 5^0 tilt, only during certain periods of the year , the sun , earth and moon align in straight line leading to either lunar eclipse or solar eclipse depending on the alignment.

---

15. How will you prove that earth itself is spinning ?

The earth's spinning motion can be proved by observing star's position over a night. Due to earth's spinning motion , the stars in sky appear to move in circular motion about the pole star.

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7. Properties of Matter

1. Define stress and strain.

Stress :

The force per unit area is called " stress " . Stress = $\frac{\text{Force}}{\text{Area}}$

$$\sigma = \frac{F}{A}$$

SI Unit : $N\,m^{-2}$ Dimension : $M\,L^{-1}\,T^{-2}$

Strain :

The fractional change in the size of the object , when a force is applied , strain measures the degree of deformation.

Strain = $\frac{\text{Change in size}}{\text{Original size}}$

$$\varepsilon = \frac{\Delta l}{l}$$

---

2. State Hooke's law of elasticity.

Hooke's law is for a small deformation , when the stress and strain are proportional to each other.

$$\text{Stress} \ \alpha \ \text{strain}$$

---

3. Define Poisson's ratio.

It is defined as the of relative contraction (Lateral strain) to relative expansion (longitudinal strain) . It is denoted by the symbol μ .

Poisson's ratio = $\frac{\text{lateral strain}}{\text{Longitudinal strain}}$

$$\mu = \frac{d\,/\,D}{l\,/\,L} = -\frac{L}{l} \times \frac{d}{D}$$

---

4. Explain elasticity using intermolecular forces.

- In a solid , interatomic forces bind two or more atoms together and the atoms occupy the positions of stable equilibrium.
- When a deforming force is applied on a body ,atoms are pulled apart or pushed closer.
- When deforming force is removed , interatomic forces of attraction or repulsion restore the atoms to their equilibrium positions.
- If a body regains its original shape / size after the removal of deforming force is called elastic and the property is called " elasticity "

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5. Which one of these is more elastic , steel or rubber ? Why ?

- **Steel is more elastic than rubber .**
- **An equal stress is applied to both steel and rubber , the steel produces less strain .**
- **So the Young's modulus is higher for steel than rubber.**
- **The object which higher Young's modulus is more elastic.**

---

6. A spring balance shows wrong readings after using for a long time . Why ?

This is because of continuous usage , the wire loses its elasticity and does not regain it original dimension . (Length) Because of this , it shows wrong readings.

---

7. What is the effect of temperature on elasticity ?

As the temperature of substance increases , its elasticity decreases.

---

8. Write down the expression for the elastic potential energy of a stretched wire.

<u>Elastic Energy :</u>

When a body is stretched , work is done against the restoring force. This work done is stored in the body in the form of " Elastic energy "

<u>Explanation :</u>

Let us consider a unstretched wire.

- **Length of the wire** $\longrightarrow$ **L**
- **Force on the wire** $\longrightarrow$ **F**
- **Area of cross section** $\longrightarrow$ **A**
- **Extension in length** $\longrightarrow$ l

<u>Derivation :</u>

Work done by the force F is equal to the energy gained by the wire.

1. Work done : W $= \int_0^l F\, dl$

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2. **Young's Modulus :** $Y = \frac{F}{A} \times \frac{L}{l}$

3. **Force :** $F = \frac{Y A l}{L}$

4. **Work done :** $W = \int_0^l \frac{Y A l}{L} \, dl$

5. $W = \frac{Y A}{L} \int_0^l l \, dl$

6. $W = \frac{Y A}{L} \left(\frac{l}{2} \right)^2$

7. $W = \frac{1}{2} \frac{Y A l}{L} \, l$

8. $W = \frac{1}{2} F \, l$

9. **Work done = Elastic potential energy**

10. **Energy Density : Energy per unit volume** $= \frac{\text{Elastic potential energy}}{\text{Volume}}$

$$u = \frac{1}{2} \frac{F}{A} \frac{l}{L} \qquad \boxed{u = \frac{1}{2} \times \text{Stress} \times \text{Strain}}$$

---

9. State Pascal's law in fluids.

" If the pressure in a liquid is changed at a particular point , the change is transmitted to the entire liquid without being diminished in magnitude".

---

10. State Archimedes principle.

It states that when a body is partially or wholly immersed in a fluid , it experiences an upward thrust equal to weight of the fluid displaced by it and its upthrust acts through the centre of gravity of the liquid displaced.

Upthrust or Buoyant force = Weight of liquid displaced

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11. What do you mean by upthrust or buoyancy ?

The upward force exerted by a fluid that opposes the weight of an immersed object in a fluid is called upthrust.

---

12. State the law of floatation.

A body will float in a liquid if the weight of the liquid displaced by the immersed part of the body equals the weight of the body.

Example :

A wooden object 300 kg (about 3000 N) floats in water displaces 300 kg of water.

---

13. Define coefficient of viscosity of a liquid.

The viscous force acting tangentially per unit area of a liquid layer having a unit velocity gradient in a direction perpendicular of flow the liquid.

$$\boxed{F = -\eta A \frac{dv}{dx}}$$

---

14. Distinguish between streamlined flow and turbulent flow.

Streamlined Flow :

1. When a liquid flows such that each particle of the liquid passing through a point moves along the same path with the same velocity as it predecessor then the flow of liquid .

2. Velocity of the particle at any point is constant.

3. It is steady or laminar flow.

4. The actual path taken by the particle of the moving fluid is called a streamline , which is a curve , the tangent to which at any point gives the direction of the flow of the fluid at that point.

Turbulent Flow :

1. When the speed of the moving fluid exceeds the critical speed v_c the motion becomes turbulent.

2. The velocity changes both in magnitude and direction from particle to particle.

3. The path taken by the particles in turbulent flow becomes erratic and whirlpool like circles called eddy current or eddies.

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15. What is Reynold's number ? Give its significance .

Reynold's number is dimensionless number which is used to find out the nature of the liquid Whether it is streamline or turbulent.

- **Density of liquid - ρ**
- **Velocity of liquid - V**
- **Diameter of pipe - D**
- **Coefficient of viscosity - η**

$$R_C = \frac{\rho V D}{\eta}$$

---

16. Define terminal velocity.

The maximum constant velocity acquired by a body while falling freely through a viscous medium is called terminal velocity.

---

17. Write down the expression for the stoke's force and explain the symbols involved in it.

Viscous force F acting on a spherical body of radius r depends directly on

i) Radius (r) of the sphere

ii) Velocity (v) of the sphere

iii) Coefficient of viscosity (η)

$$F = 6 \pi \eta r v$$

---

18. State Bernoulli's theorem.

The sum of pressure energy , kinetic energy and potential energy , kinetic energy and potential energy per unit mass of an incompressible non – viscous fluid in a streamlined flow remains a constant.

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

19.What are the energies possessed by a liquid ? Write down their equations.

A liquid in a steady flow can possess three kinds of energy.

i) Kinetic Energy : $KE = \frac{1}{2} m v^2$ ii) Potential Energy : $PE = m g h$

iii) Pressure Energy : $E_P = \frac{P}{\rho} m$

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20. Two streamlines cannot cross each other . Why ?

If two streamlines cross each other , the fluid particle at the point of intersection will have two different directions of flow . This will destroy the steady nature of the fluid flow.

---

21. Define surface tension of a liquid . Mention its S.I unit and dimension.

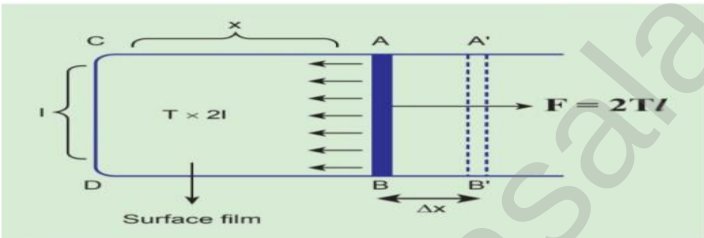
The surface tension of a liquid is defined as the energy per unit area of the surface of a liquid

$\boxed{T = F / l}$ **S . I Unit : N m^{-1} Dimension : M T^{-1}.**

---

22. How is surface tension related to surface energy ?

Consider a rectangular frame of wire ABCD in a solution. Let AB be the movable wire. Suppose the frame is dipped in soap solution , soap film is formed which pulls the wire AB inward due to surface tension . Let F be the force due to surface tension.



1. <u>Force</u> : $F = (2T)\,l$

Here , 2 is introduced because it has two free surfaces.

<u>2. Work done</u> : $W = (2T)\,l\,\Delta x$

<u>3. Increase in area :</u> $\Delta A = (2\,l)\,\Delta x$

<u>4. Surface Energy :</u> $\dfrac{W}{\Delta A} = \dfrac{(2T)\,l\,\Delta x}{(2\,l)\,\Delta x} = T$

5. Surface energy per unit area is numerically equal to surface tension.

---

23. Define angle of contact for a given pair of solid and liquid.

The angle between the tangent to the liquid surface at the point of contact and the solid surface inside the liquid is known as the angle of contact between the solid and the liquid.

---

24. Distinguish between cohesive and adhesive forces.

<u>Cohesive Force :</u>

The force between the like molecules which holds the liquid together is called " cohesive"

Adhesive Force :

When the liquid is in contact with a solid , the molecules of these solid and liquid will experience an attractive force which is called " Adhesive force "

---

25. What are the factors affecting the surface tension of a liquid ?

1. Presence of contamination or impurities :

- **Surface tension depends the degree of contamination.**

2. Presence of dissolved substances :

- **It can also affect the value of surface tension.**
- **When Nacl dissolved in H_2O increases the surface tension of water.**

3. Electrification :

- **When a liquid is electrified , surface tension decreases.**

4. Temperature :

- **The surface tension decreases linearly with the rise of temperature. $T_t = T_0 \ 1 - \alpha t)$**

---

26. What happens to the pressure inside a soap bubble when air is blown into it ?

Pressure is greater inside the small build.

---

27. What do you mean by capillarity or capillary action ?

The rise or fall of a liquid in a narrow tube is called capillarity or capillary action.

---

28. A drop of oil placed on the surface of water spreads out. But a drop of water place on oil contracts to a spherical shape. Why ?

i) A drop of oil placed on the surface of water spreads . Since the force of adhesion between the water molecules dominates the cohesive force of the oil molecule. So oil drop in water spreads.

ii) The cohesive force of water molecule dominate the adhesive force between water & oil molecules. So drop of water contracts to spherical shape.

---

29. State the principle and usage of Venturi meter.

This device is used to measure the rate of flow of the incompressible fluid flowing through pipe. It works on the principle of Bernoulli's theorem.

UNIT - 8

1. " An object contains more heat " - is it a right statement ? If not why ?

- Heat is the energy in transits and which flows from an object at higher temperature to an object at lower temperature.
- " An object has more heat " is wrong instead " object is hot " will be appropriate "

---

2. Obtain an ideal gas law from Boyle's and Charle's law.

Boyle's Law :

When the gas is kept at constant temperature , the pressure of the gas is inversely proportional to the volume. $\boxed{P \propto \frac{1}{V}}$

Charle's Law :

When the gas is kept at constant pressure , the volume of the gas is directly proportional to the absolute temperature. $\boxed{V \propto T}$

By combining these two equations : $PV = CT$

- The constant C as k times the number of particles N.
- K is the Boltzmann constant 1.381×10^{-23} J K^{-1}.

Ideal Gas Law : $PV = NkT$

---

3. Define one mole.

One mole of any substance is the amount of that substance which contains Avogadro's number (N_A) of particles . (Such as atoms or molecules)

---

4. Define specific heat capacity and give its unit.

Amount of heat energy required to raise the temperature of 1 kg of a substance by 1 kelvin

- or 1^0 C. S I Unit : J Kg^{-1} K^{-1}
  - Amount of heat energy ⟶ ΔQ
  - Change in temperature ⟶ ΔT
  - Mass of the substance ⟶ m

$$\boxed{S = \frac{1}{m}\left(\frac{\Delta Q}{\Delta T}\right)}$$

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5. Define molar specific heat capacity .

Amount of heat energy required to increase the temperature of 1 mole of a substance by 1 kelvin or 1^0 C. S I Unit : J mol^{-1} K^{-1}

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

---

6. What is a thermal expansion ?

- **The tendency of matter to change in shape , area and volume due to a change in temperature.**
- **All three states of matter (solid , liquid and gas) expand when heated.**
- **When solid is heated , its atoms vibrate with higher amplitude about their fixed points.**
- **The relative change in the size of solids is small.**

---

7. Give the expressions for linear , area and volume thermal expansions.

1. Linear Expansion : $\alpha_L = \frac{\Delta L}{L_0 \Delta T}$

2. Areal Expansion : $\alpha_A = \frac{\Delta A}{A_0 \Delta T}$

3. Volume Expansion: $\alpha_V = \frac{\Delta V}{V_0 \Delta T}$

4. Coefficient of expansion → α_L, α_A , α_V

5. Change in length , Area , Volume → ΔL , ΔA , ΔV

---

8. Define latent heat capacity . Give its unit.

The amount of heat energy required to change the state of a unit mass of the material.

- **Latent heat capacity → L**
- **Amount of heat → Q**
- **Mass of substance → m**

$$\boxed{L = \frac{Q}{m}}$$

S I Unit : J Kg^{-1}

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9. State Stefan - Boltzmann law.

Total amount of heat radiated per second per unit area of a black body is directly proportional to the fourth power of its absolute temperature.

$\boxed{E = \sigma T^4}$ $\sigma = 5.67 \times 10^{-8}\ W\ m^{-2}\ K^{-4}$

---

10. What is Wein's law ?

The wavelength of maximum intensity of emission of a black body radiation is inversely proportional to temperature of the black body.

$\boxed{\lambda_m = \frac{b}{T}}$ $b = 2.898 \times 10^{-3}\ m\ K$

---

11. Define thermal conductivity. Give its unit.

The quantity of heat transferred through a unit length of a material in a direction normal to unit surface area due to a unit temperature difference under steady state conditions is known as " thermal conductivity " of a material.

$$\boxed{\frac{Q}{t} = \frac{K\ A\ \Delta T}{L}}$$

- **Coefficient of thermal conductivity → K**
- **S I unit : $J\ s^{-1}\ m^{-1}\ K^{-1}$ or $W\ m^{-1}\ K^{-1}$**

---

12. What is a black body ?

- **A black body is an object that absorbs all electro magnetic radiations .**
- **It is a perfect absorber and radiator of energy with no reflecting power.**
- **The sun is approximately taken as a black body.**
- **Any object above 0 K will emit radiation , sun also emits radiation.**

---

13. What is a thermodynamic system ? Give examples.

A thermodynamic system is a finite part of the universe. It is a collection of large

number of particles (atoms and molecules) specified by certain parameters called pressure (P) , Volume (V) and temperature (T) . The remaining part of the universe is called surrounding . Both are separated by a boundary.

<u>Ex :</u> Bucket of water , Fish in the sea.

---

14. What are the different types of thermodynamic systems ?

<u>Open System :</u>

It can exchange both matter and energy with the environment.

<u>Closed System :</u>

It can exchange energy but not matter with the environment.

<u>Isolated System :</u>

It can exchange neither energy nor matter with the environment.

---

15. What is meant by " thermal equilibrium " ?

Two systems are said to be in thermal equilibrium with each other if they are at the same temperature , Which will not change with time.

---

16. What is meant by state variable ? Give example.

- **In thermodynamics , the state of a thermodynamic system is represented by a set of variables called thermodynamic variable.**
- **The values of these variables completely describe the equilibrium state of a thermodynamic system.**

<u>Ex :</u> Pressure , Temperature , Volume.

---

17. What are intensive and extensive variables ?

<u>Extensive Variable :</u>

It depends on the size or mass of the system.

<u>Ex :</u> Volume , Entropy , Total mass

<u>Intensive Variable :</u>

It do not depend on the size or mass of the system.

<u>Ex :</u> Density , Pressure , Temperature

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18. What is an equation of state ? Give an example.

- The equation which connects the state variables in a specific manner is called " equation of state "
- A thermodynamic equilibrium is completely specified by these state variables by the equation of state.
- If the system is not in thermodynamic equilibrium then these equation cannot specify the state of the system.

Ex : Equation of state of Van der Walls equation. Real gases obey this equation at thermodynamic equilibrium.

---

19. State Zeroth law of thermodynamic equilibrium.

If two systems A and B are in thermodynamic equilibrium with a third system C then A and B are in thermodynamic equilibrium with each other.

---

20 . Define the internal energy of the system.

- The internal energy of a thermodynamic system is the sum of kinetic and potential energies of all the molecules of the system with respect to the center of mass of the system.
- Energy due to molecular motion including translational , rotational and vibrational motion is called internal kinetic energy (E_K)
- Energy due to molecular interaction is called internal potential energy (E_P).

Ex : Bond energy $U = E_K + E_P$

---

21. Are internal energy and heat energy the same ? Explain .

- No , but they are related . If heat energy is added to substance , its internal energy will increase.
- Internal energy is a measure of kinetic & potential energy possessed by particles

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in a substance.

- Heat energy concerns only transfer of internal energy from the hotter to colder body.

---

22. Define one calorie.

One calorie is defined as the amount of heat required at a pressure of 1std atmosphere to raise the temperature of 1 g of water at 1^0 C.

---

23. Did Joule converted mechanical energy to heat energy ? Explain.

- Yes , in his experiment , two masses were attached with a rope and a paddle wheel. When these masses fall through a distance h due to gravity , both the masses lose potential energy equal to 2 m g h.
- When the masses fall , the paddle wheel turns . Due to the turning of wheel inside water , frictional force comes in between the water and paddle wheel.
- This cause a rise in temperature of the water. This implies that gravitational potential energy is converted to internal energy of water.
- The temperature of water increases due to the work done by the masses . Joule was able to show that the mechanical work has the same effect as giving heat.

---

24. State the first law of thermodynamics .

Change in internal energy (ΔU) of the system is equal to heat supplied to the system (Q) minus the work done by the system (W) on the surroundings.

$$\boxed{\Delta U = Q - W}$$

---

26. Give the sign convention for Q and W.

- System gains heat → Q is positive
- System loses heat → Q is negative
- Work done on the system → W is positive
- Work done by the system → W is negative

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27. Define the quasi - static process.

- **A quasi - static process is an *infinitely slow process* in which the system changes its variables (P , V , T) so slowly.**
- **Such that it remains in thermal , mechanical and chemical equilibrium with its surroundings through out.**
- **By this infinite slow variation the system is always almost close to equilibrium state.**

---

28. Give the expression for work done by the gas.

In general the work done by he gas by increasing the volume from V_i to V_f is given by

$$\boxed{W = \int_{V_i}^{V_f} P\, dV}$$

---

29. What is P V diagram ?

- **P V diagram is a graph between pressure P and volume V of the system .**
- **P V diagram is used to calculate the amount of work done by the gas during expansion or on the gas during compression.**

---

30. Explain why the specific heat capacity at constant pressure is greater than the specific heat capacity at constant volume.

- **Because when heat is added at constant pressure the substance expands & work.**
- **More amount of energy has to be supplied to a constant pressure to increase the system temperature by the same amount .**
- **Some of this energy is lost due to expansion work done by the system.**

---

31. Give the equation of state for an isothermal process.

The equation of state for isothermal process is given by P V = Constant

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32. Give an expression for work done in an isothermal process.

$$W = \mu R T \ln\left(\frac{V_f}{V_i}\right)$$

---

33. Express the change in internal energy in terms of molar specific heat capacity.

If Q is the heat supplied to mole of a gas at constant volume and if the temperature changes by an amount Δ T , We have

$$Q = \mu C_V \Delta T \quad \rightarrow \quad (1)$$

By applying the first law of thermodynamics for this constant volume process W = 0 since d V = 0 We have

$$Q = \Delta U - 0 \quad \rightarrow \quad (2)$$

Comparing the equations (1) and (2)

$$\Delta U = \mu C_V \Delta T$$

$$\mu C_V \Delta T = \Delta U$$

$$C_V = \frac{1}{\mu} \frac{\Delta U}{\Delta T}$$

$$\boxed{C_V = \frac{1}{\mu} \frac{dU}{dT}}$$

---

34. Apply first law for a) isothermal b) adiabatic c) isobaric processes.

S.No	Process	First Law
1.	Isothermal	$Q = W$
2.	Adiabatic	$\Delta U = W$
3.	Isobaric	$\Delta U = Q - P \Delta V$

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35. Give the equation of state for an adiabatic process.

$$P\,V^{\gamma} = \text{Constant}$$

- $\gamma \rightarrow$ **Adiabatic exponent** ($\gamma = C_P / C_V$)

---

36. Give an equation state for an isochoric process.

$$P = \left(\frac{\mu\,R}{V}\right) T$$

---

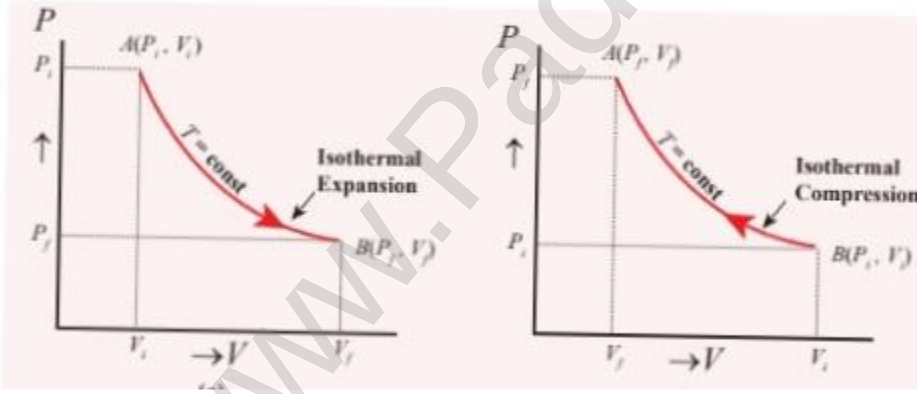
37. If the piston of a container is pushed fast inward . Will the ideal gas equation be valid in the intermediate stage ? If not , Why ?

- **Decrease in volume leading to increase in temperature work is done on the gas.**
- **Ideal gas equation $PV = RT$**
- **When piston be pushed further the parameters V & R are taken as constant.**
- **The equation becomes $P = KT$ i.e ., $P \alpha T$**

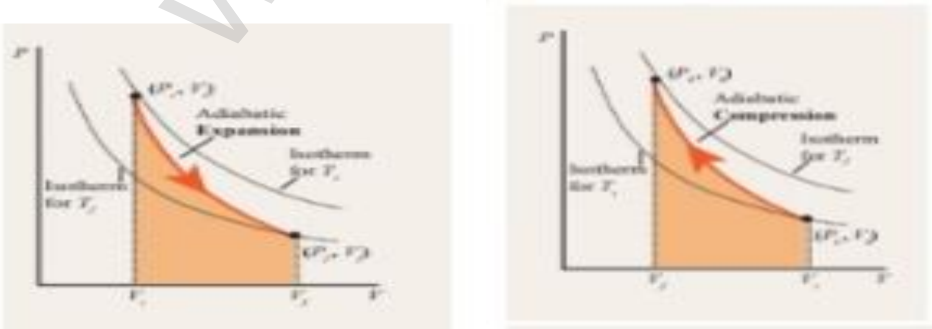
---

38. Draw the P V diagram for : a) Isothermal Process b) Adiabatic Process c) Isobaric Process d) Isochoric Process

a) Isothermal Process



b) Adiabatic Process



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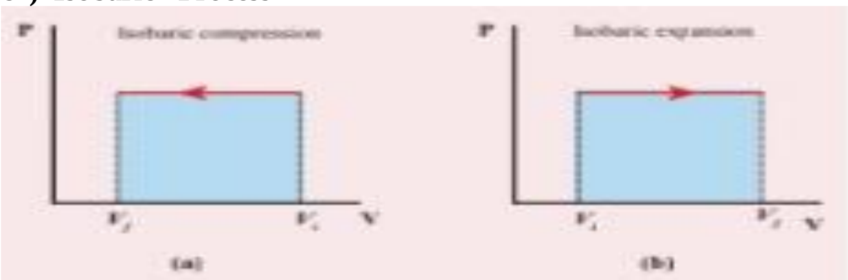
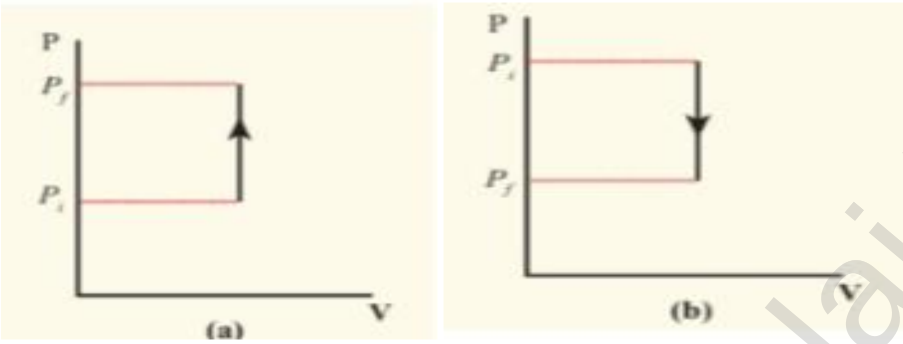
c) Isobaric Process



d) Isochoric Process



---

39. What is a cyclic process ?

- **The thermodynamic system returns to its initial state after undergoing a series of changes.**
- **The system comes back to initial state , change in the internal energy is zero.**
- **Heat can flow in to system and flow in to system and flow out of the system.**

---

40. What is meant by a reversible and irreversible processes ?

<u>Reversible Processs:</u>

- **If it possible to retrace the path in the opposite direction in such a way that the system and surroundings pass through the same as in the initial , direct process.**

<u>EX</u> : A quasi static isothermal expansion of gas , slow compression and expansion of a spring.

<u>Irreversible Process:</u>

- **All natural processes are irreversible.**
- **Irreversible process cannot be plotted in a P V diagram.**

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- **These process cannot have unique values of pressure , temperature at every stage of the process.**

---

41. State Clausius form of the second law of thermodynamics.

" Heat always flows from hotter object to colder object spontaneously " This is known as the Clausius form of the second law of thermodynamics.

---

42. State Kelvin - Planck statement of second law of thermodynamics.

It is impossible to construct a heat engine that operates in a cycle whose sole effect is to convert the heat completely into work . This implies that no heat engine in the universe can have 100 % efficiency.

---

43. Define heat engine .

Heat engine is a device which takes which takes heat as input and converts this heat in to work by undergoing a cyclic process.

---

44. What are processes involves in a Carnot engine ?

There are four reversible processes involved in Carnot's engine. There are

1. Step A to B : Quasi -static isothermal expansion from (P_1 , V_1 , T_H) to (P_2 , V_2 , T_H)

2. Step B to C : Quasi -static adiabatic expansion from (P_2 , V_2 , T_H) to (P_3 , V_3 , T_L)

#. Step C to D : Quasi -static isothermal compression from (P_3 , V_3 , T_L) to (P_4 , V_4 , T_L)

4. Step D to A : Quasi -static adiabatic compression from (P_4 , V_4 , T_L) to (P_1 , V_1 , T_H)

---

45. Can the given heat energy be completely converted to work in a cyclic process ? If not , when can the heat can completely converted to work ?

i) No , in a cyclic process the complete energy is not completely converted into work , as it violate second law of thermos dynamics.

ii) In an isothermal process the whole heat can be converted into work . For an isothermal process d Q = d T which shows that whole heat can be converted into work.

---

46. State the second law of thermodynamics in terms of entropy .

" For all the processes that occur in nature (Irreversible process) the entropy always increases . For reversible process entropy will not change " .

Entropy determines the direction in which natural process should occur.

---

47. Why does heat flow from a hot object to a cold object ?

Because entropy increases when heat flows from hot object to cold object.

---

48. Define the coefficient of performance .

It is defined as the ratio of heat extracted from the cold body to the external from the cold body to the external work done by the compressor .

$$\boxed{COP = \beta = \frac{Q_L}{W}}$$

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UNIT - 9

1. What is the microscopic origin of pressure ?

With the help of kinetic theory of gases , the pressure is linked to the velocity of molecules.

$$\boxed{P = \frac{1}{3}\frac{N}{V} m \overline{v}^2}$$

- **Mass of the molecule → m**
- **Avogadro number → N**
- **Average velocity → $\overline{v}$**
- **Volume of molecule → V**

---

2. What is the microscopic origin of temperature ?

Average K.E / molecule K.E = ε = $\frac{3}{2}$ N k T

---

3. Why moon has no atmosphere ?

The escape speed of gasses on the surface of moon is much less than the root mean square speeds of gases due to low gravity . Due to this , all the gases escape from the surface of the moon.

---

4. Write the expression for rms speed , average speed and most probable speed of a gas molecule.

RMS Speed : $V_{rms} = \sqrt{\frac{3KT}{m}} = 1.732\sqrt{\frac{KT}{m}}$

Average Speed : $\overline{V} = \sqrt{\frac{8KT}{m}} = 1.60\sqrt{\frac{KT}{m}}$

Most Probable Speed : $V_{mp} = \sqrt{\frac{2KT}{m}} = 1.414\sqrt{\frac{KT}{m}}$

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5. What is the relation between the average kinetic energy and pressure ?

The internal energy of the gas is given by

$$U = \frac{3}{2} N K T$$

$$U = \frac{3}{2} P V T \quad (P V = N K T)$$

$$P = \frac{2}{3} \frac{U}{V}$$

$$P = \frac{2}{3} u \quad (u = U / V)$$

Pressure of the gas is equal to two thirds of internal energy per unit volume or internal energy density.

Pressure of the gas :

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

$$P = \frac{1}{3} \rho \overline{v}^2 \quad (\rho = n m)$$

Multiply and divide R . H . S of eqn by 2

$$P = \frac{2}{3} \left(\frac{\rho \overline{v}^2}{2} \right)$$

$$\boxed{P = \frac{2}{3} \overline{K.E}}$$

---

6 . Define the term degrees of freedom.

The minimum number of independent coordinates needed to specify the position and configuration of a thermodynamical system in space is called the degree of freedom of the system.

---

7. State the law of equipartition of energy .

According to kinetic theory , the average kinetic energy of system of molecules in thermal equilibrium at temperature T is uniformly distributed to all degrees of freedom so that

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each degree of freedom will get 1 / 2 K T of energy . This is called law of equipartition of energy.

---

8. Define mean free path and write down its expression.

Average distance travelled by the molecule between collisions is called is called mean free path (λ)

$$\text{Mean free path} = \frac{\text{Distance travelled}}{\text{Number of collisions}}$$

$$\boxed{\lambda = \frac{1}{\sqrt{2}\,\pi\, d^2\, \rho}}$$

---

9. Deduce Charle's law based on kinetic theory .

From the equation ,

$$P = \frac{2}{3}\frac{U}{V}$$

$$P = \frac{2}{3}u \quad (u = U/V)$$

We get , $PV = \frac{2}{3}U$

For a fixed pressure , the volume of the gas is proportional to internal energy of the gas and the average kinetic energy of the gas and the average kinetic energy is directly proportional to absolute temperature .

$$\boxed{\begin{array}{l} V \;\alpha\; T \\ \frac{V}{T} = \text{Constant} \end{array}}$$

---

9. Deduce Boyle's law based on kinetic theory .

From the equation ,

$$P = \frac{2}{3}\frac{U}{V}$$

$$P = \frac{2}{3}u \quad (u = U/V)$$

We get , $P V = \frac{2}{3} U$

But the internal energy of an ideal gas is equal to N times the average kinetic energy (ε) of each molecule , $U = N\varepsilon$

For a fixed temperature , the average translational kinetic energy ε will remain constant. It implies that ,

$$\boxed{\begin{aligned} P V &= \frac{2}{3} N\varepsilon \\ P V &= \text{Constant} \end{aligned}}$$

---

11 . Deduce Avogadro's law based on kinetic theory.

- This law states that at constant temperature and pressure , equal volumes of all gases contain the same number of molecules . For two different gases at the same temperature and pressure .
- According to kinetic theory of gases ,

$$P = \frac{1}{3}\frac{N_1}{V} m_1 \overline{v_1}^2 = \frac{1}{3}\frac{N_2}{V} m_2 \overline{v_2}^2 \quad \text{--------} \quad (1)$$

Where $\overline{v_1}^2$ and $\overline{v_2}^2$ are the mean square speed for two gases and N_1 and N_2 are the number of gas molecules in two different gases.

- At the same temperature , average kinetic energy per molecule is the same for two gases.

$$\frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_2 v_2^2 \quad \text{--------} \quad (2)$$

- Dividing (1) by (2) We get $N_1 = N_2$. This is Avogadro's law.

---

12. List the factors affecting the mean free path.

1. Mean free path increases with increasing temperature . As the temperature increases , the average speed of each molecule will increase. It is the reason why the smell of hot sizzling food reaches several meter away than smell of cold food.
2. Mean free path increases with decreasing pressure of the gas and diameter of the gas molecule.

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13. What is the reason for Brownian motion ?

1. According to kinetic theory , any particle suspended in a liquid or gas is continuously bombarded from all the directions so that the mean free path is almost negligible.

2. This leads to the motion of the particles in a random and zig - zag manner.

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UNIT - 10

1. What is meant by periodic and non - periodic motion ? Give any two examples for each motion.

Periodic Motion :

Any motion which repeats itself in a fixed time interval is known as periodic motion.

EX : 1. Hands in pendulum clock 2. Heart beat of a person

Non - Periodic Motion :

Any motion which does not repeats itself after regular interval of time is known as Non - periodic motion.

EX : 1. Oscillations of loaded spring 2. Vibrations of tuning fork

---

2. What is meant by force constant of a spring ?

Force constant is defined as force per unit displacement.

Ex : 1. Oscillations of loaded spring 2. Vibrations of a tuning fork

---

3. Define time period of simple harmonic motion.

The time period is defined as the time taken by a particle to complete one oscillation . It is usually denoted by T . For one complete revolution , the time taken is t = T

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

---

4. Define frequency of simple harmonic motion.

- The number of oscillations produced by the particle per second is called frequency. $f = 1 / T$. S I Unit is hertz (Hz) or s^{-1}.
- The number of revolutions per sec is called angular frequency .
- Angular frequency and frequency are related by $\omega = 2 \pi f$. S I unit is rad s^{-1}.

---

5. What is an epoch.

The displacement time t = 0 s , the phase $\phi = \phi_0$ is called epoch (initial epoch)

ϕ_o is called the angle of epoch.

---

6. Write short notes on two springs connected in series.

Consider only two springs whose spring constant are k_1 and k_2 and which can be attached to a mass m. The results thus obtained can be generalized for any number of springs in series.

For springs in series connection : $-k_1 x_1 = -k_2 x_2 = F$

$$x_1 = -\frac{F}{k_1} \qquad x_1 = -\frac{F}{k_2}$$

Effective spring constant : $-\frac{F}{k_1} - \frac{F}{k_2} = -\frac{F}{k_s}$

$$\boxed{k_s = \frac{k_1 k_2}{k_1 + k_2}}$$

---

7. Write short notes on two springs connected in parallel.

Consider only two springs of spring constants k_1 and k_2 attached to a mass m. The results can be generalized to any number of springs in parallel.

$$F = -k_1 x - k_2 x$$

$$F = -k_p x$$

$$\boxed{K_p = k_1 + k_2}$$

---

8. Write down the time period of simple pendulum.

The angular frequency of this oscillator is ,

$$\omega^2 = \frac{g}{l} \qquad \omega = \sqrt{\frac{g}{l}} \qquad \text{rad s}^{-1}$$

Frequency of oscillation

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}} \qquad \text{in Hz}$$

Time period of oscillation

$$T = 2\pi\sqrt{\frac{l}{g}} \qquad \text{in sec}$$

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9. State the laws of simple pendulum.

i) Law of length :

For a given value of acceleration due to gravity , the time period of a simple pendulum is directly proportional to the square root of length of the pendulum.

$$\boxed{T \propto \sqrt{l}}$$

ii) Law of acceleration :

For a fixed length , the time period of a simple pendulum is inversely proportional to the square root of acceleration due to gravity.

$$\boxed{T \propto \frac{l}{\sqrt{g}}}$$

---

10. Write down the equation of time period for linear period for linear harmonic oscillator.

From Newton's second law , we can write the equation for the particle executing simple harmonic motion

$$m \frac{d^2 x}{d t^2} = - k x$$

$$\frac{d^2 x}{d t^2} = - \frac{k}{m} x$$

$$a = \frac{d^2 x}{d t^2} = - \omega^2 x$$

1. Angular Frequency : $\omega = \sqrt{\frac{k}{m}}$

2. Frequency : $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

3. Time Period : $T = 2\pi\sqrt{\frac{m}{K}}$

---

11. What is meant by free oscillation ?

When the oscillator is allowed to oscillate by displacing its position from equilibrium position , it oscillates with a frequency which is equal to the natural frequency which is equal to the oscillator . Such an oscillation is known as free oscillation .

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12. Explain damped oscillation . Give an example.

1. Due to the presence of friction and air drag , the amplitude of oscillation decreases as time progresses.

2. It implies that the oscillation is not sustained and the energy of the S H M decreases gradually indicating the loss of energy.

3. The energy lost is absorbed by the surrounding medium . This type of oscillatory motion is known as damped oscillation.

<u>Examples :</u>

1. Oscillation of a pendulum (including air friction)

2. Electromagnetic oscillation in a tank circuit.

3. Oscillations in a dead beat and ballistic galvanometers.

---

13. Define forced oscillation . Give an example.

In this type of vibration , the body executing vibration initially vibrates with its natural frequency and due to the presence of external periodic force , the body later vibrates with the frequency of the applied periodic force. Such vibrations are known as forced vibration.

<u>Ex :</u> Sound board of stringed instruments.

---

14. What is meant by maintained oscillations ? Give an example.

While playing in swing , the oscillations will stop after a few cycles , this is due to damping. To avoid damping we have to supply a push to sustained oscillations. By supplying energy from an external source , the amplitude of the oscillation can be made constant. Such vibrations are known maintained vibration.

<u>Ex</u> : The vibration of a tunning fork getting energy from a battery or from external power supply.

---

15. Explain resonance . Give an example.

The frequency of external periodic force matches with the natural frequency of the vibrating body. As a result the oscillating body begins to vibrate such that its amplitude increases at each step and ultimately it has a large amplitude.

Ex : **The breaking of glass due to sound.**

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UNIT - 11

1. What is meant by waves ?

The disturbance which carries energy and momentum from one point in space to another point in space without the transfer of the medium is known as a wave.

---

2. Write down the types of waves.

i) Mechanical Wave :

Waves which require a medium for propagation are known as mechanical wave.

EX : Sound waves , Ripples formed on water surface.

ii) Non - mechanical Wave :

Waves which do not require medium for propagation are known as mechanical wave.

EX : Light waves , Infra red rays

Waves can be classified into two types :

1. Transverse wave 2. Longitudinal wave

---

3. What are transverse wave ? Give one example.

In transverse wave motion , the constituent of the medium oscillate or vibrate about their mean position in a direction perpendicular to the direction of propagation of waves.

EX : Light (Electromagnetic wave)

---

4. What are longitudinal wave ? Give one example.

In longitudinal wave motion , the constituent of the medium oscillate or vibrate about their mean position in a direction parallel to the direction of propagation of waves.

Ex : Sound waves travelling in air

---

5. Define wavelength.

- **For transverse waves , the distance between two neighbouring crests or trough is known as the " wavelength ".**

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- **For longitudinal waves , the distance between two neighbouring compressions or rarefactions is known as the wavelength .**
- **S I unit of wave length is meter.**

---

6. Write down the relation between frequency , wavelength and velocity of a wave.

Dimension of wave length is $[\lambda] = L$

$$\text{Frequency} = \frac{1}{\text{Time period}}$$

Dimension of frequency is $[f] = \frac{1}{[T]} = T^{-1}$

Relation between frequency & wavelength :

$$[\lambda f] = [\lambda][f] = L\ T^{-1} = [\text{Velocity}]$$

$$\boxed{\lambda \ f = v}$$

- **Wave velocity is the distance travelled by a wave in one second.**
- **Wave velocity is called as " phase velocity "**

---

7. What is meant by interfere of waves ?

Interference is a phenomenon in which two waves superimpose to form a resultant wave of greater , lower or the same amplitude.

---

8. Explain the beat phenomenon.

- **When two or more waves superimpose each other with slightly different frequencies , then a sound of periodically varying amplitude at a point is observed . This phenomenon is known as beats .**
- **The number of amplitude maxima per second is called beat frequency.**
- **If we have two sources , then their difference in frequency gives the beat frequency.**
- **Number of beats per second** $n = |f_1 - f_2|$ **per second**

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9. Define intensity of sound and loudness of sound .

- **The sound power transmitted per unit area taken normal to the propagation of the sound wave.**
- **The loudness of sound is defined as " the degree of sensation of sound produced in the ear or the perception of sound by the listener .**

---

10. Explain Doppler effect.

When the source and the observer are in relative motion with respect to each other and to the medium in which sound propagates , the frequency of the sound wave observed is different from the frequency of the source. This phenomenon is called " Doppler effect ".

---

11. Explain red shift and blue shift in Doppler effect.

The spectral lines of the star are found to shift towards red end of the spectrum then the star is receding away from the earth. Similarly if the spectral lines of the star are found to shift towards the blue end of the spectrum then the star is approaching earth.

---

12. What is meant by end correction in resonance air column apparatus ?

The antinodes is not exactly formed at the open end , but a small distance above be open end. This is called " end correction "

To computer the end correction : $L_1 + e = \frac{\lambda}{4}$ **and** $L_2 + e = \frac{3\lambda}{4}$

---

13. Sketch the function y = x + a . Explain your sketch.

i) A combination of constant and direct.

ii) A fixed amount is added at regular intervals.

iii) y = x + a , a suitable conclusion statement would be that,

1. **y is linear with a**
2. **y varies linearly with x.**
3. **Y is a linear function of x y is the intercept.**

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14. Write down the factors affecting velocity of sound in gases.

1. Pressure 2. Temperature 3. Density 4. Humidity 5. Wind

---

15. What is meant by an echo ? Explain.

1. An echo is a reception of sound produced by the reflection of sound waves from a wall , mountain or other obstructing surfaces. The speed of sound in air at 20^0 C is 344 m s^{-1} .

2. If we shout at a wall which is at 344 m away , then the sound will take 1 second to reach the wall.

3. After reflection , the sound will take one more second to reach us.

4. We hear the echo after two seconds only.

5. Time gap or time interval between each sound is (1 / 10)th of second is 0.1 s

6. The minimum distance from a sound reflecting wall to hear an echo at 20^0 C is 17.2 m .

$$\text{Velocity} = \frac{\text{Distance Travelled}}{\text{Time taken}} = \frac{2d}{t}$$

$$2d = 344 \times 0.1 = 34.4$$

$$d = 17.2 \text{ m}$$

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