QNO: 19

1) **State and prove law of conservation of energy in case of a freely falling body.**

Statement: "Energy can neither be created nor be destroyed, but it can be converted from one form to another form. The total mechanical energy in the universe remains constant."

Proof: Consider a freely falling body of mass 'm' dropped from a height 'h'. Its potential energy decreases and kinetic energy increases but the total mechanical energy remains constant.

$$\textbf{Total energy} = \boldsymbol{K.E + P.E}$$

At point A:

Initial velocity$(u) = 0$
Height = h

$K.E = \frac{1}{2}mu^2 = 0$
$P.E = mgh$

∴Total energy, $T.E = K.E + P.E$
$T.E = 0 + mgh$
$T.E = mgh$ ------→ (1)

At point B($A \to B$):

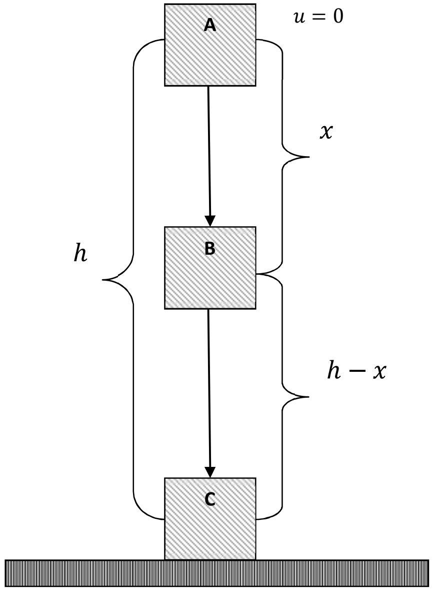
Initial velocity $(u) = 0$
Final velocity $(v) = v_B(say)$
Acceleration $(a) = g$
Displacement $(S) = x$
Height $(H) = h - x$

Using $v^2 - u^2 = 2aS$
$v_B^2 = 2gx$
$\therefore K.E = \frac{1}{2}mv_B^2 = \frac{1}{2}m.2gx = mgx$
$P.E = mg(h-x) = mgh - mgx$

∴Total energy, $T.E = K.E + P.E$

$T.E = mgx + mgh - mgx$

$T.E = mgh$ -------→ (2)



At point C($A \to C$):
Initial velocity $(u) = 0$
Final velocity $(v) = v_C(say)$
Acceleration $(a) = g$
Displacement $(S) = h$
Height $(H) = 0$

Using $v^2 - u^2 = 2aS$
$v_C^2 = 2gh$

$\therefore K.E = \frac{1}{2}mv_C^2 = \frac{1}{2}m.2gh = mgh$
$P.E = 0$

∴Total energy, $T.E = K.E + P.E$

$T.E = mgh + 0$

$T.E = mgh$ ---------→ (3)

From (1), (2) and (3), the total mechanical energy remains constant.
Hence the law of conservation of energy is proved

2) **Develop the notions of work and kinetic energy and show that it leads to work – energy theorem.**

Work done: It is defined as the product of component of force in the direction of displacement and magnitude of the displacement.

(Or)

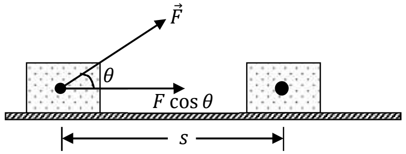
It is defined as the dot product of force and displacement vectors.

$W = F\cos\theta\, S = FS\cos\theta$

$W = \vec{F}.\vec{S}$

* It is a scalar quantity.
* It may be positive, negative or zero

Unit: Joule



Kinetic energy: The energy possessed by a body by virtue of its motion is called kinetic energy.

$$K.E = \frac{1}{2}mv^2$$

Ex: A bullet in motion, flowing water.

Work – energy theorem:

"The work done by the force on a body is equal to the change in its kinetic energy."

$$\boxed{W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2}$$

Proof: Consider a body of mass 'm' moving with velocity 'u'. Let a constant force F is applied on a body; its velocity changes to 'v' after covering a displacement 's' in time 't'.

From the equation of motion,

$$v^2 - u^2 = 2as$$

Multiplying both sides by $\frac{1}{2}m$, we get

$$\frac{1}{2}m(v^2 - u^2) = \frac{1}{2}m.2as$$

$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mas$$

By Newton's Second law, F = ma

$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$$

But $W = Fs$

$$\boxed{W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2}$$

(or)

$$\boxed{W = K_f - K_i}$$

Hence work – energy theorem is proved.

3) What are collisions? Explain the possible types of collisions? Develop the theory of one dimensional elastic collision.

Collision: The strong interaction between the bodies involving exchange of their momentum in a small interval of time is called collision.
Collisions are two types 1).Elastic collision 2).Inelastic collision

Elastic collision: The collision in which both momentum and kinetic energy are conserved is known as elastic collision.

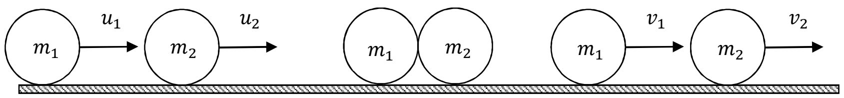
Ex: Collisions between nuclei and fundamental particles

Inelastic collision: The collision in which only momentum is conserved but not kinetic energy is known as inelastic collision.

Ex: Collisions between two vehicles

One dimensional elastic collision:

Consider two spheres of masses m_1 and m_2 moving along the same straight line in the same direction.
Let u_1 and u_2 be the initial velocities before collision($u_1 > u_2$.).
v_1 and v_2 be the final velocities after collision.



Before collision During collision After collision

According to law of conservation of linear momentum
Total momentum before collision = Total momentum after collsion

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \quad ---------\rightarrow (1)$$
$$m_1u_1 - m_1v_1 = m_2v_2 - m_2u_2$$
$$m_1(u_1 - v_1) = m_2(v_2 - u_2) \quad --------- (2)$$

According to law of conservation of kinetic energy
Total K.E before collision = Total K.E after collsion

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$
$$m_1u_1^2 + m_2u_2^2 = m_1v_1^2 + m_2v_2^2$$
$$m_1u_1^2 - m_1v_1^2 = m_2v_2^2 - m_2u_2^2$$
$$m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2)$$
$$m_1(u_1 + v_1)(u_1 - v_1) = m_2(v_2 + u_2)(v_2 - u_2) \quad ------(3)$$

Dividing Eq (3) by Eq (2)

$$\frac{(3)}{(2)} \Rightarrow \frac{m_1(u_1 + v_1)(u_1 - v_1)}{m_1(u_1 - v_1)} = \frac{m_2(v_2 + u_2)(v_2 - u_2)}{m_2(v_2 - u_2)}$$
$$u_1 + v_1 = v_2 + u_2$$
$$\boxed{\boldsymbol{u_1 - u_2 = v_2 - v_1}} \quad --------\rightarrow (4)$$

Hence, $\left(\begin{matrix}\text{relative velocity of approach}\\ \text{before collision}\end{matrix}\right) = \left(\begin{matrix}\text{relative velocity of separation}\\ \text{after collision}\end{matrix}\right)$

Final velocities: From equation (4), we get
$$v_2 = u_1 - u_2 + v_1$$

Putting this value in equation (1), we get
$$m_1u_1 + m_2u_2 = m_1v_1 + m_2(u_1 - u_2 + v_1)$$

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2u_1 - m_2u_2 + m_2v_1$$
$$(m_1 - m_2)u_1 + 2m_2u_2 = (m_1 + m_2)v_1$$
$$\boxed{v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \left(\frac{2m_2}{m_1 + m_2}\right)u_2}$$

Interchanging the subscripts 1 and 2 in the above equation, we get
$$\boxed{v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \left(\frac{2m_1}{m_1 + m_2}\right)u_1}$$

Cases: (1) If $m_1 = m_2$, then we get
$$v_1 = u_2$$
$$v_2 = u_1$$

(2) If $u_2 = 0$, then we get
$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1$$
$$v_2 = \left(\frac{2m_1}{m_1 + m_2}\right)u_1$$

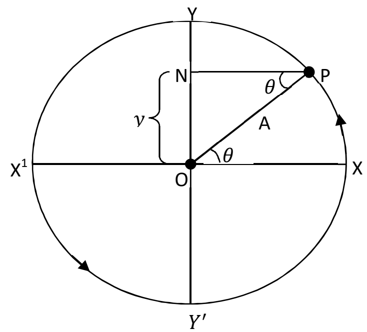
QNO: 20

4) Define simple harmonic motion. Show that the motion of projection of a particle performing uniform circular motion on any diameter is simple harmonic.

SHM: A particle is said to be in SHM, if it moves to and fro about its mean position such that its acceleration is directly proportional to displacement in magnitude but opposite in direction and is always directed towards the mean position.
If 'a' is acceleration and 'y' is displacement, then
$$\boxed{a \propto -y}$$
– Sign indicates that 'a' and 'y' are in opposite direction

Show that the projection of uniform circular motion on any diameter is SHM:
Consider a particle 'P' moving along a circle of radius A with uniform angular velocity ω in anti-clock wise direction.
Let O be the centre of the circle
XX^1 and YY^1 are the diameters of the circle
N be the projection of P on the diameter YY^1.

As the particle P moves on the circumference of the circle, N moves to and fro about a fixed point O along the diameter YY^1.



Displacement:
Let y be the displacement of the projection N at any instant
From $\Delta^{le}ONP$,
$$\sin\theta = \frac{y}{A}$$
$$y = A\sin\theta \qquad [\because \theta = \omega t]$$
$$y = A\sin\omega t$$

Velocity:
The rate of displacement is called velocity.
$$\therefore v = \frac{dy}{dt} = A\omega\cos\omega t$$

Acceleration:
The rate of change of velocity is called acceleration.
$$\therefore a = \frac{dv}{dt} = -A\omega^2\sin\omega t$$
$$a = -\omega^2 A\sin\omega t$$
$$a = -\omega^2 y$$
$$\boxed{a \propto -y}$$
∴ The projection of uniform circular motion on any diameter is SHM.

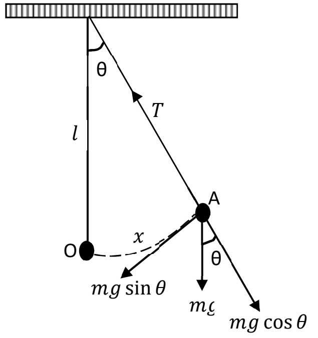
5) Show that the motion of a simple pendulum is simple harmonic and hence derive an equation for its time period. What is second's pendulum?

Consider a simple pendulum of length 'l' suspended from a rigid support. If the pendulum is pulled aside through a small angular displacement θ and released, then it begins to oscillate to and fro about its mean position.

Let the bob is at position A. The weight mg has two rectangular components

i) $mg\cos\theta$, balances the tension in the string

ii) $mg\sin\theta$, provides the restoring force.



The restoring force acting on the bob is

$$F = -mg\ \sin\theta$$
$$ma = -mg\ \sin\theta$$
$$a = -g\ \sin\theta$$

If θ is very small, then $\sin\theta \approx \theta$

$$\therefore a = -g\,\theta$$

If l is length of the simple pendulum, then

$$\theta = \frac{x}{l}$$
$$\therefore a = -g\,\frac{x}{l}$$
$$a = -\frac{g}{l}x \quad -------\rightarrow (1)$$
$$\boxed{a \propto -x}$$

Hence the motion of the bob is S.H.M

The standard equation of S.H.M is

$$a = -\omega^2 x \quad ------\rightarrow (2)$$

From (1) and (2), we get

$$\omega^2 = \frac{g}{l} \quad\Rightarrow\quad \omega = \sqrt{\frac{g}{l}}$$

The time period of the pendulum is

$$T = \frac{2\pi}{\omega} \quad \boxed{\therefore T = 2\pi\sqrt{\frac{l}{g}}}$$

Second's pendulum: A pendulum whose time period is 2 sec is called seconds pendulum.

6) Derive the equation for the kinetic energy and potential energy of a simple harmonic oscillator and show that the total energy of a particle in simple harmonic motion is constant at any point on its path.

Kinetic energy: The displacement of a particle executing SHM is given by

$$y = A\sin\omega t$$

The velocity of a particle executing SHM is given by

$$v = \omega\sqrt{A^2 - y^2}$$

The kinetic energy of a particle at any displacement 'y' is given by

$$K.E = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2(A^2 - y^2)$$
$$\boxed{K.E = \frac{1}{2}m\omega^2(A^2 - y^2)}$$

Potential energy: Work done against the restoring force to produce a displacement of y in simple harmonic oscillation is given by

$$Work\ done = Average\ force \times displacement$$
$$W = \frac{F}{2}\times y \qquad \left[\because F_{avg} = \frac{0+F}{2} = \frac{F}{2}\right]$$
$$W = \frac{1}{2}\times ma \times y$$

$$W = \frac{1}{2}\times m(\omega^2 y)\times y \qquad [\because a = \omega^2 y]$$
$$W = \frac{1}{2}m\omega^2 y^2$$

This work done is stored as potential energy.

$$\boxed{\therefore P.E = \frac{1}{2}m\omega^2 y^2}$$

Total energy: The total energy of a particle at any displacement 'y' is

$$T.E = K.E + P.E$$
$$T.E = \frac{1}{2}m\omega^2(A^2 - y^2) + \frac{1}{2}m\omega^2 y^2$$
$$\boxed{T.E = \frac{1}{2}m\omega^2 A^2}$$

At mean position, $y = 0$

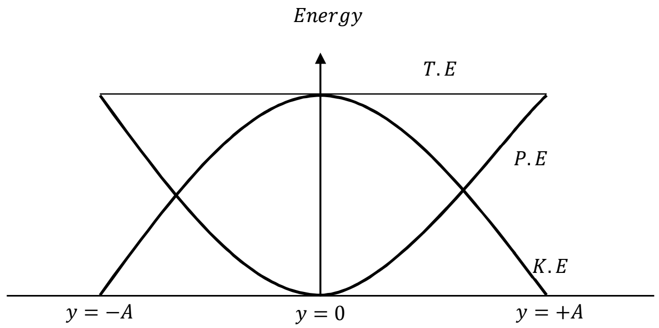
$$K.E = \frac{1}{2}m\omega^2(A^2 - y^2) = \frac{1}{2}m\omega^2 A^2$$
$$P.E = \frac{1}{2}m\omega^2 y^2 = 0$$
$$T.E = K.E + P.E = \frac{1}{2}m\omega^2 A^2$$

At extreme position, $y = \pm A$

$$K.E = \frac{1}{2}m\omega^2(A^2 - y^2) = 0$$
$$P.E = \frac{1}{2}m\omega^2 y^2 = \frac{1}{2}m\omega^2 A^2$$
$$T.E = K.E + P.E = \frac{1}{2}m\omega^2 A^2$$

∴ The total energy is same at all points. Hence law of conservation of energy is proved.

The variation of P.E and K.E with displacement y is shown below.



7) Explain reversible and irreversible processes. Describe the working of Carnot engine. Obtain an expression for the efficiency

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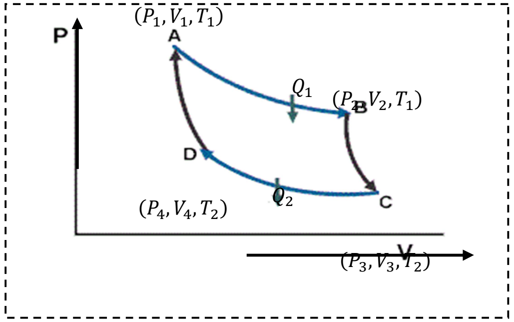
Reversible process: A process that can be retraced back in the opposite direction so that it passes through the same states as in the direct process, and finally the system and surroundings return to their original state is called *reversible process*.
Ex: Fusion of ice and vaporization of water

Irreversible process: A process that cannot be retraced back in the opposite direction is called *irreversible process*.
EX: Work done against friction, Diffusion of gases, Joule heating effect

Working of Carnot engine: A reversible heat engine operating between two temperatures is called a Carnot engine. The working of Carnot's engine is called Carnot cycle.
The Carnot's cycle has the followings four steps.



Isothermal expansion: When the gas expand isothermally at T_1, then its state changes from (P_1, V_1, T_1) to (P_2, V_2, T_1)
Work done by the gas is equal to heat absorbed from the source. $\therefore W_1 = Q_1 = nRT_1 \log\left(\frac{V_2}{V_1}\right)$

Adiabatic expansion: When the gas expand adiabatically, then its state changes from (P_2, V_2, T_1) to (P_3, V_3, T_2)
Work done by the gas is $W_2 = \frac{nR}{\gamma - 1}[T_1 - T_2]$

Isothermal compression: When the gas compress isothermally at T_2, then its state changes from (P_3, V_3, T_2) to (P_4, V_4, T_2)
Work done on the gas is equal to the heat rejected to the sink.

$$\therefore W_3 = Q_2 = -nRT_2 \log\left(\frac{V_4}{V_3}\right) = nRT_2 \log\left(\frac{V_3}{V_4}\right)$$

Adiabatic compression: When the gas compress adiabatically, then its state changes from (P_4, V_4, T_2) to (P_1, V_1, T_1)
Work done on the gas is

$$W_4 = \frac{-nR}{\gamma - 1}[T_2 - T_1] = \frac{nR}{\gamma - 1}[T_1 - T_2]$$

Net work done by the gas in one complete cycle is,

$$W = W_1 + W_2 - W_3 - W_4$$
$$W = W_1 - W_3 \qquad [\because W_2 = W_4]$$
$$W = Q_1 - Q_2$$

Efficiency is,

$$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \left[\frac{Q_2}{Q_1}\right]$$

In adiabatic expansion, (P_2, V_2, T_1) to (P_3, V_3, T_2)
$$T_1 V_2^{\gamma-1} = T_2 V_3^{\gamma-1} \quad ---\to (i)$$
In adiabatic compression, (P_4, V_4, T_2) to (P_1, V_1, T_1)
$$T_1 V_1^{\gamma-1} = T_2 V_4^{\gamma-1} \quad ---\to (ii)$$
On dividing (i) and (ii), we get
$$\left(\frac{V_2}{V_1}\right)^{\gamma-1} = \left(\frac{V_3}{V_4}\right)^{\gamma-1}$$
$$\boxed{\frac{V_2}{V_1} = \frac{V_3}{V_4}}$$

$$\eta = 1 - \left[\frac{nRT_2 \log\left(\frac{V_3}{V_4}\right)}{nRT_1 \log\left(\frac{V_2}{V_1}\right)}\right] \qquad \left[From\ adiabatic\ relation, \frac{V_3}{V_4} = \frac{V_2}{V_1}\right]$$

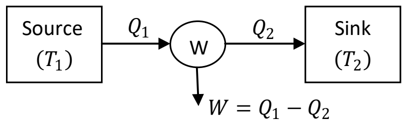
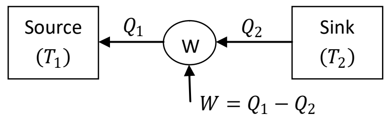
$$\boxed{\therefore \eta = 1 - \frac{T_2}{T_1}}$$

8) State second law of thermodynamics. How is heat engine different from a refrigerator?

Second law of thermodynamics:

Kelvin statement: "It is impossible to construct a heat engine which completely converts the heat energy into mechanical work"
(Or)
"100% conversion of heat energy into mechanical work is impossible"

Clausius statement: "It is impossible to transfer the heat energy from cold body to hot body without use of any external agency"
(Or)
"Heat energy by itself cannot flow from cold body to hot body"

Heat engine	Refrigerator
Heat engine is a device used to convert heat energy into mechanical work.	The refrigerator is a heat engine working in backward direction.
	
Working: The working substance absorbs heat (Q_1) from the source, converts a part of it into work and rejects remaining heat (Q_2) to the sink. $\therefore$ Work done by the system, $W = Q_1 - Q_2$	**Working:** The working substance absorbs heat (Q_2) from the sink and some work is done on it by external agency and finally rejects heat (Q_1) to the source. $\therefore$ Work done on the system, $W = Q_1 - Q_2$
Efficiency (η): It is defined as the ratio of work done by the engine to the heat absorbed by it. $\therefore \eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$ $\boxed{\eta = 1 - \frac{Q_2}{Q_1}}$ (or) $\boxed{\eta = 1 - \frac{T_2}{T_1}}$	**Coefficient of performance (β):** The efficiency of refrigerator is called coefficient of performance. $\therefore \beta = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$ $\boxed{\beta = \frac{Q_2}{Q_1 - Q_2}}$ (or) $\boxed{\beta = \frac{T_2}{T_1 - T_2}}$
$\eta < 1$	$\beta > 1$

9) State and explain Newton's law of cooling. State the conditions under which Newton's law of cooling is applicable

Newton's law of cooling: The rate of loss of heat of a hot body is directly proportional to the temperature difference between the hot body and its surroundings.

Explanation:

If $-\frac{dQ}{dt}$ is the rate of loss of heat of a hot body,

θ is the temperature of hot body and

θ_0 is the temperature of surroundings, then

$$-\frac{dQ}{dt} \propto (\theta - \theta_0)$$
$$-\frac{dQ}{dt} = K(\theta - \theta_0) \quad ----\rightarrow (1)$$

If 'm' is mass and 's' is specific heat of the body, then

$$dQ = ms\, d\theta \quad -----\rightarrow (2)$$

Substitute (2) in (1), we get

$$-\frac{msd\theta}{dt} = K(\theta - \theta_0)$$
$$-\frac{d\theta}{dt} = \frac{K}{ms}(\theta - \theta_0)$$
$$\boxed{-\frac{d\theta}{dt} = C(\theta - \theta_0)}$$

Where C is called cooling constant

Conditions:

i) Loss of heat is negligible by conduction and only when it is due to convection.
ii) Temperature difference is moderate.
iii) Temperature of every part of the body is same.
iv) Loss of heat occurs in a stream lined flow of air.

10) Define two principal specific heats of a gas. Which is greater and why? Derive a relation between the two specific heat capacities of gas on the basis of first law of thermodynamics.

EXTRA++

Molar specific heat at constant volume: At constant volume, the amount of heat required to raise the temperature of 1 mole of a gas through 1°C is called molar specific heat at constant volume.

$$C_V = \frac{1}{n}\frac{dQ}{dT}$$

Units: $J/mole - K$

Molar specific heat at constant pressure: At constant pressure, the amount of heat required to raise the temperature of 1 mole of a gas through 1°C is called molar specific heat at constant pressure.

$$C_P = \frac{1}{n}\frac{dQ}{dT}$$

Units: $J/mole - K$

Reason for $C_P > C_V$:

i) At constant volume, supplied heat is utilized only to increase internal energy. $[(dQ)_v = du]$

ii) At constant pressure, supplied heat is utilized to increase internal energy and to do external work done. $[(dQ)_p = du + dw]$

iii) For the same rise in temperature, more heat is given to the gas at constant pressure compared to at constant volume.

$$Therefore, C_P > C_V$$

To show $C_P - C_V = R$:

Consider 1 mole of an ideal gas contained in a cylinder with movable piston. Let P, V and T be the pressure, volume and temperature of gas.

At constant volume: Supplied heat is utilized only to increase the internal energy

$$(dQ)_V = dU = C_V dT \quad ------\rightarrow (1)$$

At constant pressure: Supplied heat is utilized to increase the internal energy and to do the external work.

$$(dQ)_P = C_P dT \quad -----\rightarrow (2)$$

Work done, $dW = P.dV \quad ------\rightarrow (3)$

From first law of thermodynamics,

$$(dQ)_P = dU + dW$$

Substitute (1), (2)and (3)in above equation, we get

$$C_P dT = C_V dT + P\,dV \quad -----\rightarrow (4)$$

From ideal gas equation,

$$PV = RT$$

On differentiating, we get

$$P\,dV = R\,dT \quad ------\rightarrow (5)$$

From Eq (4) and Eq (5)

$$\therefore C_P dT = C_V dT + RdT$$
$$C_P dT - C_V dT = RdT$$
$$[C_P - C_V]dT = RdT$$
$$\boxed{C_P - C_V = R}$$

11) State Boyle's law and Charles law. Derive an ideal gas equation. Which of the two laws is better for the purpose of thermometry and why?

Boyle's law: At constant temperature, the volume of a given mass of gas is inversely proportional to its pressure.

$$\therefore V \propto \frac{1}{P}$$

$$\boxed{PV = constant}$$

Charles law at constant pressure: At constant pressure, the volume of a given mass of gas is directly proportional to its absolute temperature.

$$\therefore V \propto T$$

$$\boxed{\frac{V}{T} = constant}$$

Charles law at constant volume: At constant volume, the pressure of a given mass of gas is directly proportional to its absolute temperature.

$$\therefore P \propto T$$

$$\boxed{\frac{P}{T} = constant}$$

Ideal gas: A gas which obeys gas laws at all temperatures and pressures is called ideal gas

Derivation for Ideal gas equation:

According to Boyle's law,

$$V \propto \frac{1}{P}$$

According to Charles law,

$$V \propto T$$

Combining above two laws,

$$V \propto \frac{T}{P}$$

$$V = constant \times \frac{T}{P}$$

$$\frac{PV}{T} = constant$$

For one mole of a gas, the constant has same value for all gases and is called *universal gas constant(R)*. So the above equation becomes

$$\frac{PV}{T} = R$$

$$PV = RT$$

For n mole of a gas,

$$\boxed{PV = nRT}$$

This is ideal gas equation.

b) Charles is better for the purpose of thermometry, because in Charles law volume varies linearly with temperature.

12) Explain thermal conductivity and coefficient of thermal conductivity.

Thermal conductivity: The ability to conduct heat in solids by conduction is called thermal conductivity.

Coefficient of thermal conductivity(K):

Consider a rectangular slab of cross-sectional area A and thickness d. Suppose its opposite faces are maintained at different temperatures θ_1 and $\theta_2 (\theta_1 > \theta_2)$.

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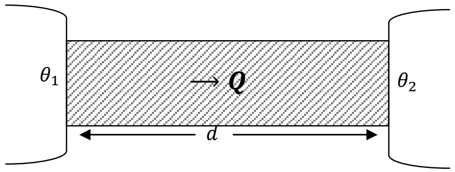


The amount of heat Q transmitted between these two faces depends upon the following factors:

i) It is directly proportional to the cross-sectional area

$$Q \propto A$$

ii) It is directly proportional to the temperature difference between the two faces

$$Q \propto (\theta_1 - \theta_2)$$

iii) It is directly proportional to the time of flow of heat.

$$Q \propto t$$

iv) It is inversely proportional to the thickness of the slab

$$Q \propto \frac{1}{d}$$

Combining above factors, we get

$$Q \propto \frac{A(\theta_1 - \theta_2)t}{d}$$

$$\boxed{Q = K\frac{A(\theta_1 - \theta_2)t}{d}} \quad and \quad \boxed{K = \frac{Q}{A\left(\frac{\theta_1 - \theta_2}{d}\right)t}}$$

The proportionality constant K is called coefficient of thermal conductivity of the given material.

If $A = 1$; $\left(\frac{\theta_1 - \theta_2}{d}\right) = 1$; $t = 1$ then

$$\boxed{Q = K}$$

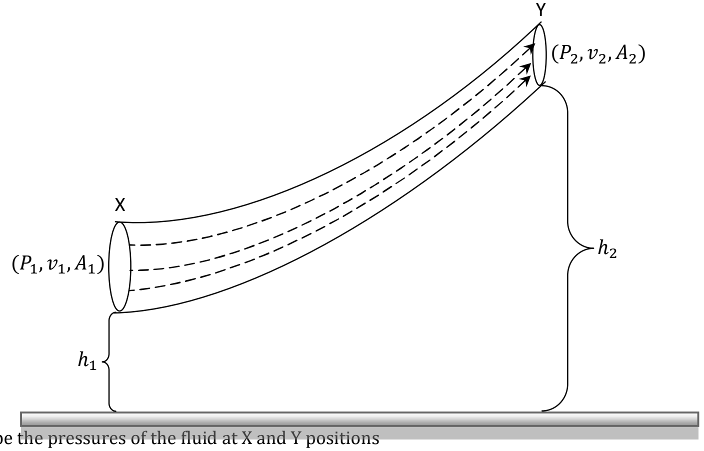
Definition of K: The coefficient of thermal conductivity is defined as the quantity of heat flowing through a conductor of unit cross-sectional area per second per unit temperature gradient.

13) State Bernoulli's principle. From conservation of energy in a fluid flow through a tube, arrive at Bernoulli's equation. Give an application of Bernoulli's theorem.

Statement: "For an ideal fluid flow, the sum of pressure energy, kinetic energy and potential energy per unit volume remains constant"

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

Proof: Consider an ideal fluid flowing through a non uniform cross-sectional tube XY.



Let P_1 and P_2 be the pressures of the fluid at X and Y positions
v_1 and v_2 be the velocities of the fluid at X and Y positions
A_1 and A_2 be the cross − sectional areas of the tube at X and Y positions
h_1 and h_2 be the heights of the tube at X and Y positions

Kinetic energy: The energy possessed by a fluid by virtue of its motions is called kinetic energy.

$$\text{Kinetic energy} = \frac{1}{2}mv^2$$

$$\text{Kinetic energy per unit volume} = \frac{1}{2}\frac{m}{V}v^2 = \frac{1}{2}\rho v^2$$

∴ Change in kinetic energy of the fluid at X and Y positions is

$$\Delta E = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2$$

Potential energy: The energy possessed by a fluid by virtue of its position is called potential energy.

$$\text{Potential energy} = mgh$$

$$\text{Potential energy per unit volume} = \frac{mgh}{V} = \rho g h$$

∴ Change in potential energy of the fluid at X and Y positions is

$$\Delta U = \rho g h_2 - \rho g h_1$$

Pressure energy: The energy possessed by a fluid by virtue of its pressure is called pressure energy.

$$\text{Pressure energy} = PV$$

$$\text{Pressure energy per unit volume} = \frac{PV}{V} = P$$

∴ Change in pressure energy of the fluid at X and Y positions is

$$\Delta P = P_1 - P_2$$

By law of conservation of energy,

$$\Delta P = \Delta E + \Delta U$$

$$P_1 - P_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 + \rho g h_2 - \rho g h_1$$

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

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

Applications:

i) Aerofoil
ii) Spinning of a ball
iii) Venturimeter

14) a) State Newton's second law of motion. Hence derive the equation of motion $F = ma$ from it.
b) A body is moving along a circular path such that its speed always remains constant. Should there be force acting on the body.

Newton's second law: "The rate of change of linear momentum of a body is directly proportional to the applied force and the change in momentum takes place in the direction of the applied force."

Derivation: Consider a body of mass 'm' moving with velocity $\vec{v}$, its momentum is

$$\vec{P} = m\vec{v}$$

According to Newton's second law,
Applied force ∝ Rate of change of momentum

$$\vec{F} \propto \frac{d\vec{P}}{dt}$$

$$\vec{F} \propto \frac{d(m\vec{v})}{dt}$$

$$\vec{F} \propto m\frac{d\vec{v}}{dt} \qquad \left[\because \vec{a} = \frac{d\vec{v}}{dt}\right]$$

$$\vec{F} \propto m\vec{a}$$

$$\vec{F} = k\, m\vec{a}$$

Where k is called proportionality constant and assume k = 1

$$\vec{F} = m\vec{a}$$

b) When a body moving along a circular path, its velocity changes (due to direction) continuously. Hence the body will have acceleration. So the body is subjected to centripetal force.

15) Define angle of friction and angle of repose. Show that angle of friction is equal to angle of repose for a rough inclined plane.

A block of mass 4kg is resting on a rough horizontal plane and is about to move when a horizontal force of 30N is applied on it. If g = 10m/s², find the total contact force exerted by the plane on the block?

Angle of friction (φ): The angle made by the resultant of limiting friction and normal reaction with normal reaction is called angle of friction.

Consider a block on a rough horizontal surface.

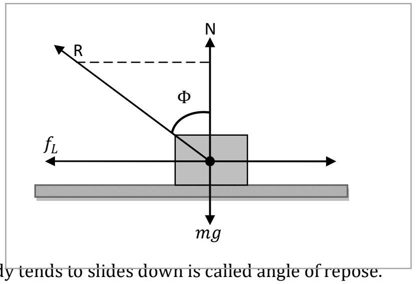
Let

N is normal reaction

f_L is limiting friction

R is resultant of f_L and N

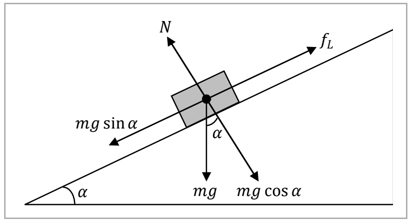
ϕ is angle made by R with N



$$\tan\phi = \frac{f_L}{N} = \frac{\mu_s N}{N} \quad [\because f_L = \mu_s N]$$

$$\boxed{\tan\phi = \mu_s} \longrightarrow (1)$$

Angle of repose (α): The angle of inclination at which the body tends to slides down is called angle of repose.



Consider a body of mass 'm' placed on a rough inclined plane with angle of repose (α).

The weight of the body mg acts vertically downwards. The weight mg can be resolved into two components.

a) $mg\ \cos\alpha$ balances the normal reaction

$$N = mg\cos\alpha$$

b) $mg\ \sin\alpha$ acts along the inclined plane and balances the frictional force

∴The coefficient of static friction is

$$\mu_s = \frac{f_L}{N} = \frac{mg\sin\alpha}{mg\cos\alpha} = \tan\alpha$$

$$\boxed{\mu_s = \tan\alpha} \longrightarrow (2)$$

From (1) and (2)

$$\tan\phi = \tan\alpha$$

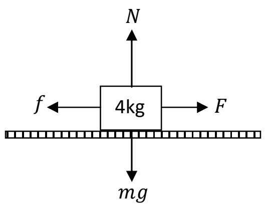
$$\boxed{\phi = \alpha}$$

∴ Angle of friction is equal to angle of repose

Problem:

Given,

$m = 4\,kg;\quad F = 30N;\quad g = 10m/sec^2$



Total contact force $= \sqrt{f^2 + N^2} = \sqrt{F^2 + (mg)^2}$

$$= \sqrt{30^2 + (4\times 10)^2} = \sqrt{900 + 1600} = \sqrt{2500} = 50\,N$$

Total contact force $= 50\,N$

16) Define Hooke's law of elasticity and describe an experiment to determine the Young's modulus of the material of a wire.

Hooke's law: Within elastic limit, the stress is directly proportional to strain.

Thus within elastic limit,

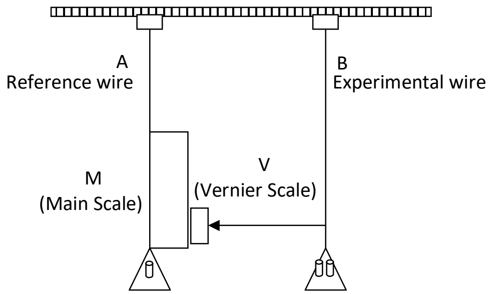
$$\text{Stress} \propto \text{Strain}$$

$$\text{Stress} = \text{Constant} \times \text{Strain}$$

$$\frac{\text{Stress}}{\text{Strain}} = \text{Constant}$$

The constant of proportionality is called modulus of elasticity

Determination of Young's modulus of the material of a wire:



Description:

a) The apparatus consists of two similar wires A and B of same length and equal radius suspended side by side from a fixed rigid support.

b) The wire A is called reference wire and the wire B is called experimental wire.

c) The wire A carries a main millimeter scale M and a pan.

d) The wire B carries a Vernier scale V and a pan. The Vernier scale can slide against the main scale attached to the reference wire.

Procedure:

a) The length L and radius r of the experimental wire is measured using scale and screw gauge.

b) Initially small and equal load is given to both wires to keep the wires straight and the Vernier scale reading is noted.

c) The load given to reference wire is kept constant. The load given to experimental wire is gradually increased and corresponding Vernier readings are noted.

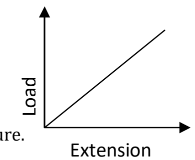
d) The difference between two Vernier scale readings gives the extension produced in the wire.

e) Let M be the mass that produced an extension ΔL in the wire.

f) The young's modulus of the material of the experimental wire is given by

$$Y = \frac{\text{Stress}}{\text{Strain}} = \frac{\left(Mg/\pi r^2\right)}{\left(\Delta L/L\right)} = \frac{Mg}{\pi r^2}\cdot\frac{L}{\Delta L}$$

g) A graph is plotted between the load applied and Extension produced. It will be a Straight line passing through the origin as shown in figure.



JR INTER SHORT ANSWER QUESTIONS

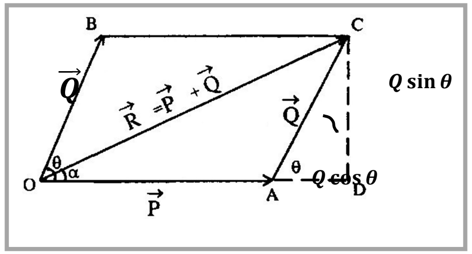
1) State parallelogram law of vectors. Derive an expression for the magnitude and direction of the resultant vector

Statement: *"If two vectors are represented by the two adjacent sides of a parallelogram drawn from a point, then their resultant is represented by the diagonal passing through the same point (both in magnitude and direction)"*

Explanation: Let $\vec{P}$ *and* $\vec{Q}$ are two vectors inclined at an angle θ.

$\vec{R}$ represents the resultant of two vectors $\vec{P}$ *and* $\vec{Q}$

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



Magnitude of resultant vector:

From diagram,

$$\overline{OA} = \vec{P},\ \overline{AC} = \vec{Q},\ \overline{OC} = \vec{R}$$

From right angle ΔADC,

$$CD = Q\sin\theta,\ AD = Q\cos\theta$$

From right angle ΔODC,

$$OC^2 = OD^2 + CD^2 = (OA + AD)^2 + CD^2$$

$$OC^2 = (P + Q\cos\theta)^2 + (Q\sin\theta)^2$$

$$R^2 = P^2 + Q^2\cos^2\theta + 2PQ\cos\theta + Q^2\sin^2\theta$$

$$R^2 = P^2 + Q^2(\cos^2\theta + \sin^2\theta) + 2PQ\cos\theta$$

$$R^2 = P^2 + Q^2 + 2PQ\cos\theta$$

$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

Direction of resultant vector: Let $\vec{R}$ makes an angle α with $\vec{P}$.

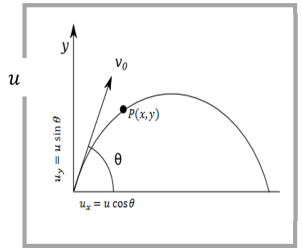
From right angle ΔODC,

$$\tan\alpha = \frac{CD}{OD} = \frac{CD}{OA + AD}$$

$$\tan\alpha = \frac{Q\sin\theta}{P + Q\cos\theta} \qquad \boxed{\alpha = \tan^{-1}\left[\frac{Q\sin\theta}{P + Q\cos\theta}\right]}$$

2) Show that the trajectory of an object thrown at certain angle with the horizontal is parabola.

Consider a body projected into air with an initial velocity $'u'$ at an angle θ with the horizontal.



The velocity $'u'$ can be resolved into two rectangular components.

* Horizontal component = $u\cos\theta$
* Vertical component = $u\sin\theta$

Let the body reaches the point P (x, y) after time t.

In horizontal direction: The displacement of the projectile along X – direction is

$$x = u\cos\theta \times t$$

$$t = \frac{x}{u\cos\theta}$$

In Vertical direction: The displacement of the projectile along Y – direction is

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

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

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

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

let $\tan\theta = A$ and $\frac{g}{2u^2\cos^2\theta} = B$ $\qquad \boxed{y = Ax - Bx^2}$

Hence trajectory of projectile is a parabola.

3) Show that for a projectile launched at an angle 45° the maximum height of a projectile is one quarter of range?

Given θ = 45°

Range, $(R) = \frac{u^2 \sin 2\theta}{g}$

$R = \frac{u^2 \sin 90}{g}$

$R = \frac{u^2}{g}$

Maximum height, $(H) = \frac{u^2 \sin^2 \theta}{2g}$

$H = \frac{u^2 \sin^2 45}{2g} = \frac{u^2 \left(\frac{1}{2}\right)}{2g} = \frac{u^2}{4g}$

$\boxed{H = \frac{R}{4}}$

4) Explain the advantages and disadvantages of friction.

Advantages:

- We can walk safely without slipping due to friction.
- We can hold any object due to friction.
- A match stick is lightened due to friction.
- Friction stops the vehicles by using brakes
- Nails can be fixed to the walls due to friction.

Disadvantages:

- Due to friction, the wear and tear of machines increases
- Due to friction, large amount of energy is wasted in the form of heat.
- Friction results in the large amount of power loss in engine.

5) Mention the methods used to decrease friction.

Polishing: Friction between two surfaces in contact can be reduced by polishing the surfaces to some extent.

Lubricants: Lubricants like oil (or) grease is used between the surfaces in contact to reduce the friction.

Ball bearings: The hard steel balls placed between the moving parts converts sliding friction into rolling friction. Hence friction is reduced.

Streamlining: The automobiles and aero planes are streamlined to reduce the air friction.

6) State Newton's second law of motion. Hence derive the equation of motion $F = ma$ from it.

Newton's second law: "The rate of change of linear momentum of a body is directly proportional to the applied force and the change in momentum takes place in the direction of the applied force."

Derivation: Consider a body of mass 'm' moving with velocity $\vec{v}$, its momentum is

$\vec{P} = m\vec{v}$

According to Newton's second law,

Applied force ∝ Rate of change of momentum

$\vec{F} \propto \frac{d\vec{P}}{dt}$

$\vec{F} \propto \frac{d(m\vec{v})}{dt}$

$\vec{F} \propto m\frac{d\vec{v}}{dt}$ $\left[\because \vec{a} = \frac{d\vec{v}}{dt}\right]$

$\vec{F} \propto m\vec{a}$

$\vec{F} = k\, m\vec{a}$

Where k is called proportionality constant and assume k = 1

$\boxed{\vec{F} = m\vec{a}}$

7) Distinguish between centre of mass and centre of gravity.

Centre of mass	Centre of gravity
It is a point at which the whole mass of the body is supposed to be concentrated.	It is a point though which the whole weight of the body acts.
It describes motion of body	It describes stability of body
It is related to the distribution of mass of the body.	It is related to weights of all particles of the body.
It is independent of 'g'	It depends on 'g'
It may (or) may not lie inside the body	It is always lie inside the body
In case of small bodies, C.M and C.G coincide	In case of very large bodies, C.M and C.G do not coincide.

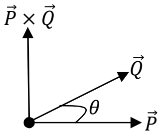
8) Define vector product. Explain the properties of a vector product with two examples.

Vector product: The vector product of two vectors is a vector whose magnitude is equal to the product of magnitudes of two vectors and sine of angle between them. The direction is perpendicular to both the vectors.

If $\vec{P}$ and $\vec{Q}$ are two vectors, then the vector product is defined as

$\vec{P} \times \vec{Q} = PQ \sin\theta\ \hat{n}$

$|\vec{P} \times \vec{Q}| = PQ \sin\theta$



Where $\hat{n}$ is the unit vector perpendicular to plane containing both $\vec{P}$ and $\vec{Q}$

Properties:

1) It does not obey commutative law

$\vec{P} \times \vec{Q} \neq \vec{Q} \times \vec{P}$

2) It obeys distributive law

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

3) If two vectors are parallel, i.e. $\theta = 0°$,then

$|\vec{P} \times \vec{Q}| = 0$

4) If two vectors are perpendicular, i.e. $\theta = 90°$, then

$|\vec{P} \times \vec{Q}| = PQ$

5) If $\hat{\imath}, \hat{\jmath}$ and $\hat{k}$ are unit vectors along x, y and z axes, then

$\hat{\imath} \times \hat{\imath} = \hat{\jmath} \times \hat{\jmath} = \hat{k} \times \hat{k} = 0$

$\hat{\imath} \times \hat{\jmath} = \hat{k};\ \hat{\jmath} \times \hat{k} = \hat{\imath};\ \hat{k} \times \hat{\imath} = \hat{\jmath}$

Examples:

* Torque, $\vec{\tau} = \vec{r} \times \vec{F}$
* Angular momentum, $\vec{L} = \vec{r} \times \vec{P}$

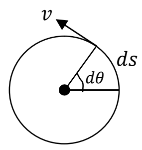
9) Define angular velocity. Derive $v = r\omega$

Angular velocity: The rate of change of angular displacement is called angular velocity.

$$\omega = \frac{d\theta}{dt}\ rad/sec$$

Derivation of $v = r\omega$

Let a particle P be displaced by ds in a time interval dt on the circumference of a circle of radius r through an angle $d\theta$.



We know that, $arc = radius \times angle$

$$ds = r \times d\theta$$

Differentiating w.r.to time

$$\frac{ds}{dt} = r \times \frac{d\theta}{dt} \qquad \left(\because v = \frac{ds}{dt}\right)$$

$$\boxed{\therefore v = rw}$$

10) Define angular acceleration and torque. Establish the relation between angular acceleration and torque.

Angular acceleration: The rate of change of angular velocity is called angular acceleration.

$$\boxed{\alpha = \frac{d\omega}{dt}}$$

Torque: The product of force and perpendicular distance of line of action of force from the axis of rotation is called torque.

(OR)

The rate of change of angular momentum is called torque.

Derivation of $\tau = I\alpha$:

From definition of torque,

$$\tau = r \times F$$
$$\tau = r \times ma \qquad [\because F = ma]$$
$$\tau = r \times m \times r\alpha \qquad [\because a = r\alpha]$$
$$\tau = mr^2 \times \alpha \qquad [\because I = mr^2]$$
$$\boxed{\tau = I\alpha}$$

11) State and prove the principle of conservation of angular momentum. Explain the principle of conservation of angular momentum with examples.

Statement: "In the absence of an external torque the total angular momentum of a system remains constant"

Explanation:

We know that, $\tau = \frac{dL}{dt}$

If $\tau = 0 \implies \frac{dL}{dt} = 0$

$$L = constant$$

$$I\omega = constant$$

$$\boxed{I \propto \frac{1}{\omega}}$$

Examples:

a) The angular velocity of a planet revolving in an elliptical orbit around the sun increases, when it comes closer to the sun and vice -versa.

b) A diver jumping from a spring board exhibits somersaults in air before touching the water surface.

c) A ballet dancer decreases or increases her angular velocity by stretching the hands or bringing the hands closer to the body.

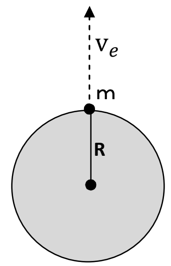
12) What is escape velocity? Obtain an expression for it.

Escape velocity: The minimum velocity required for an object to escape from the gravitational influence of the planet is called escape velocity.

Expression: Consider an object of mass m on the surface of the earth of mass M and radius R.

Gravitational potential energy= $-\frac{GMm}{R}$

When an object is projected with escape velocity V_e, then



$$K.E = -P.E$$
$$\frac{1}{2}mv_e^2 = \frac{GMm}{R}$$
$$\frac{1}{2}v_e^2 = \frac{GM}{R}$$
$$v_e^2 = \frac{2GM}{R} \times \frac{R}{R}$$
$$v_e^2 = 2 \times \frac{GM}{R^2} \times R$$
$$v_e^2 = 2gR \qquad \left[\because \frac{GM}{R^2} = g\right]$$
$$\boxed{v_e = \sqrt{2gR}}$$

13) What is geostationary satellite? State its uses.

Geo-stationary satellite: A satellite whose time period of revolution is equal to the time period of rotation of the earth is called geo-stationary satellite.

(Or)

If the period of revolution of an artificial satellite is equal to the period of rotation of the earth, then it is called geo-stationary satellite.

* Time period of geo-stationary satellite is 24 hours.

Uses:

- To study the upper layers atmosphere
- To know the size and shape of the earth
- To forecast the changes in atmosphere
- To identify the minerals and natural resources present inside the earth.
- To transmit the T.V programs to the distant places.

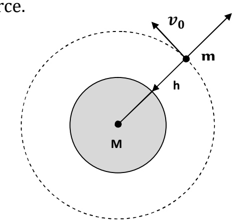
14) What is orbital velocity? Obtain an expression for it.

Orbital velocity: The minimum velocity required for an object to revolve around a planet in a circular orbit is called orbital velocity.

Expression: Consider an object of mass m revolving around the earth at a height h.

Let v_0 be the orbital velocity on the surface of the earth.

The Gravitational force between earth and object provides necessary centripetal force.



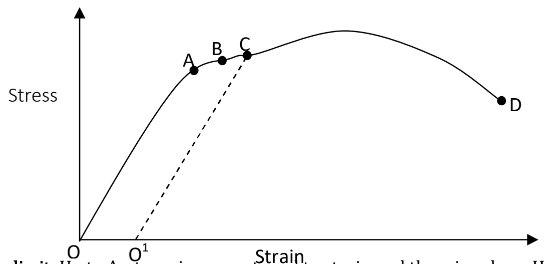
$$\therefore \frac{mV_0^2}{(R+h)} = \frac{GMm}{(R+h)^2}$$
$$v_0^2 = \frac{GM}{(R+h)}$$

As $R \gg h$, $R + h \approx R$

$$v_0^2 = \frac{GM}{R} \times \frac{R}{R}$$
$$v_0^2 = \frac{GM}{R^2} \times R \qquad \left[\because \frac{GM}{R^2} = g\right]$$
$$v_0^2 = gR$$
$$\boxed{v_0 = \sqrt{gR}}$$

15) Describe the behavior of wire under gradually increasing load.

The behavior of a wire under gradually increasing load can be explained by using stress – strain curve.



Proportionality limit: Up to A, stress is proportional to strain and the wire obeys Hooke's law. The point A is called proportionality limit.

Elastic limit : From A to B, stress is not proportional to strain and the wire does not obey Hooke's law but elastic nature exists. The point B is called elastic limit.

Yield point: If the stress is further increased beyond the point B, yielding starts. The starting point of yielding is called yield point

Permanent set (OO^1): Permanent deformation is produced in the wire when it is stretched beyond elastic limit.

Breaking point (D): The stress at which the wire breaks is called breaking point. The point D is called breaking point.

16) Define strain energy and derive the equation for the same

(OR)

Explain the concept of elastic potential energy is a stretched wire and hence obtain the expression for it

Strain energy: The energy stored in a body due to its deformation is called strain energy.

Expression: Suppose a force F is applied on a wire of length 'L'. Let 'e' be the extension of the wire, when force increases from zero to F

Average force on the wire $= \frac{0+F}{2} = \frac{F}{2}$

Work done on the wire is

$$W = \text{average force} \times \text{extension}$$

$$W = \frac{F}{2} \times e$$

$$W = \frac{1}{2} \times \left(\frac{F}{A}\right) \times \left(\frac{e}{L}\right) \times (AL)$$

$$W = \frac{1}{2} \times stress \times strain \times volume$$

This work done is stores as elastic potential energy called strain energy.

$$U = \frac{1}{2} \times stress \times strain \times volume$$

∴ Strain energy per unit volume is

$$\boxed{U = \frac{1}{2} \times stress \times strain}$$

AIMSTUTORIAL Physics-1

17) Pendulum clocks generally go fast in winter and slow in summer. Why?

The time period of the pendulum is given as

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

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

Where,

l = Length of the pendulum clock

g = Acceleration due to gravity

a) In winter, due to decrease in temperature the length of the pendulum decreases and its time period also decreases. So the pendulum clocks go fast in winter (gains the time).

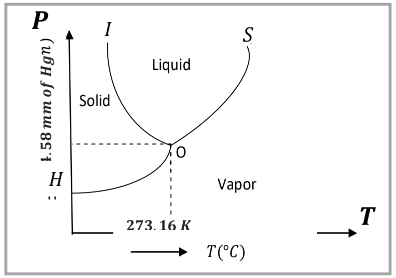
b) In summer, due to increase in temperature the length of the pendulum increase and its time period also increases. So the pendulum clocks go slow in summer (loses the time).

18) Write short notes on triple point of water.

Definition: The temperature and pressure at which the three phases of a substance (solid, liquid and vapour) are in equilibrium is called triple point.

The values of triple point of water is ($\mathbf{273.16\ K,\ 4.58\ mm\ of\ Hg}$)

Pressure – Temperature phase diagram:



Ice line:

- ♣ OI is called ice line.
- ♣ Along this line ice and water are in equilibrium.
- ♣ It has negative slope

Steam line:

- ♣ OS is called steam line.
- ♣ Along this line water and steam are in equilibrium.
- ♣ It has positive slope.

Hoar frost line:

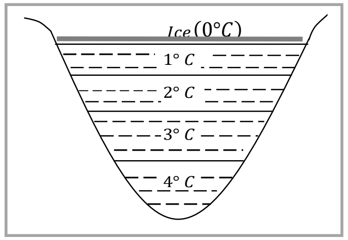
- ♣ OH is called Hoar frost line.
- ♣ Along this line steam and ice are in equilibrium.
- ♣ It has positive slope.

The three curves meet at a point 'O'. This point is called triple point.

19) In what way is the anomalous expansion behavior of water advantageous to aquatic animals?

Anomalous expansion of water: Generally liquids expand on heating and contract on cooling. But water contracts from 0°C to 4°C and expands from 4°C to 0°C. This behavior of water is called anomalous expansion of water.

Significance:



a) In cold countries, during winter the temperature of water in lakes and ponds decrease much below 0°C.

b) Due to this the top most layers of the water gets cooled, becomes denser and sink to the bottom.

c) At the same time water at the bottom which is lighter, goes up. This process continues till the entire water gets 4°C.

d) When the water at the top of the lake attains 0°C, it becomes ice and forms a layer at the top. Since ice is a bad conductor of heat, the lower layers of water protected against freezing.

e) Hence the water inside the lake will be at 4°C, so that the aquatic animals can survive in severe winter also.

20) Explain conduction, convection and radiation with examples.

Conduction: The process in which the heat energy is transmitted from one place to another without actual movement of the particles of the medium is called conduction.
Ex: Flow of heat in solids

Convection: The process in which the heat energy is transmitted from one place to another with actual movement of the particles of the medium is called convection.
Ex: Flow of heat in fluids

Radiation: The process in which the heat energy is transmitted from one place to another without help of any material medium is called radiation.
Ex: Earth receives heat from the sun

21) Derive the equation $x = v_0 t + \frac{1}{2}at^2$ using graphical.

Suppose a body moving with uniform acceleration 'a'.
Let
u = intial velocity
v = final velocity
The area under velocity – time graph gives the displacement
Displacement = area of OABCD

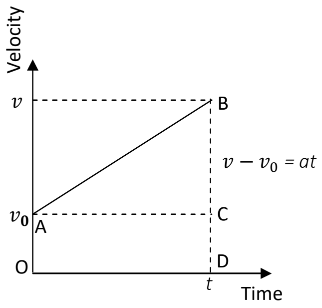
$$x = \text{area of rectangle OACD} + \text{area of triangle ABC}$$

$$x = \text{OA.OD} + \frac{1}{2}.\text{AC.BC}$$

$$x = v_0 t + \frac{1}{2}t(v - v_0)$$

but $(v - v_0) = at$

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



22) Define unit vector, null vector and position vector

Unit vector: A vector whose magnitude is equal to one is called a unit vector. It has no units and no dimensions.
If $\vec{A}$ is a vector, then the unit vector of $\vec{A}$ is

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

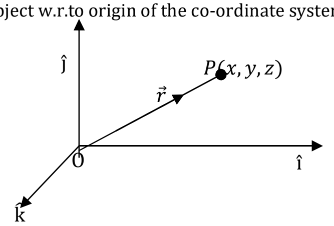
Null vector: A vector whose magnitude is equal to zero called a null vector. Its direction is indeterminate.
Ex: The velocity of a particle at rest.

Position vector: A vector which gives the position of an object w.r.to origin of the co-ordinate system is called position vector.
The position vector of the particle P is

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

The magnitude of position vector is

$$|\vec{r}| = \sqrt{x^2 + y^2 + z^2}$$



23) Explain the terms average velocity and instantaneous velocity. When they are equal?

Average velocity: The ratio of total displacement to the total time taken is called average velocity. (or) the velocity of a body at a particular period of time is called average velocity.

$$\text{Average velocity} = \frac{\text{total displacement}}{\text{total time taken}}$$

$$\vec{V}_{avg} = \frac{\Delta\vec{s}}{\Delta t}$$

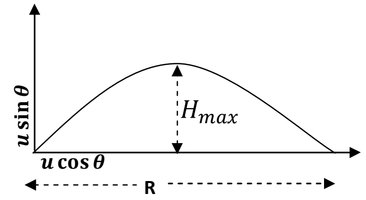
Instantaneous velocity: The velocity of a body at a particular instant of time is called instantaneous velocity.

$$\vec{V}_{inst} = \lim_{\Delta t \to 0}\frac{\Delta\vec{s}}{\Delta t} = \frac{d\vec{s}}{dt}$$

- In uniform motion, average velocity is equal to instantaneous velocity
-

24) Show that the maximum height and range of a projectile are $\frac{u^2\sin^2\theta}{2g}$ and $\frac{u^2\sin 2\theta}{g}$

Maximum height: The maximum vertical displacement of a projectile is called maximum height.
Here
Vertical initial velocity, $u_y = u\sin\theta$
Vertical final velocity, $v_y = 0$
Vertical acceleration, $a = -g$
Vertical displacement, $s = H_{max}$



Using $v_y{}^2 - u_y{}^2 = 2as$

$$0 - u^2\sin^2\theta = -2gH_{max}$$

$$u^2\sin^2\theta = 2gH_{max}$$

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

Range: The maximum horizontal displacement of a projectile is called range (R).
Here
Horizontal velocity, $u_x = u\cos\theta$
Time of flight, $T = \frac{2u\sin\theta}{g}$

∴ Range = Horizontal velocity × time of flight

$$R = u_x \times T$$

$$R = u\cos\theta \times \frac{2u\sin\theta}{g}$$

$$R = \frac{u^2(2\sin\theta\cos\theta)}{g} \quad [\because \sin 2\theta = 2\sin\theta\cos\theta]$$

$$\boxed{R = \frac{u^2\sin 2\theta}{g}}$$

25) Define the terms momentum and impulse. State and explain the law of conservation of linear momentum. Give examples

Momentum (P): Momentum of a body is defined as the product of mass and velocity of the body.

Momentum = mass × velocity

$$\vec{P} = m\vec{v}$$

* It is a vector quantity.

SI unit: $kg - m/sec$ (or) $N - sec$

Impulse (J): The product of force and time that produce a finite change in momentum of a body is called impulse

Impulse = force × time = change in momentum

$$J = F \times t = mv - mu$$

* It is a vector quantity.

SI unit: $kg - m/sec$ (or) $N - sec$

Law of conservation of linear momentum: "In the absence of any external force, the total linear momentum of the system remains constant"

Proof: If $\vec{F}$ is the external force acting on the system, then according to Newton's second law

$$\vec{F} = \frac{d\vec{p}}{dt}$$

For isolated system, $\vec{F} = 0$

$$\therefore \frac{d\vec{p}}{dt} = 0$$

As the derivative of a constant is zero, so

$$\vec{P} = constant$$

This proves law of conservation of linear momentum.

Examples:

- **Recoil of a gun:** When a bullet is fired from a gun, the bullet moves in forward direction and the gun moves in backward direction (backward kick).
- **Explosion of a bomb:** When a bomb explodes into two parts, they move in opposite directions with equal momenta.
- Rocket and jet planes works on the principle of conservation of momentum.
- When a man jumps out of a boat to the shore, then the boat slightly moves away from the shore

26) Why are shock absorbers used in motor cycles and cars?

When a vehicle moves on an uneven road, it receives a jerk. So the vehicle receives the impulsive force. To minimize this impact shock absorbers are used.

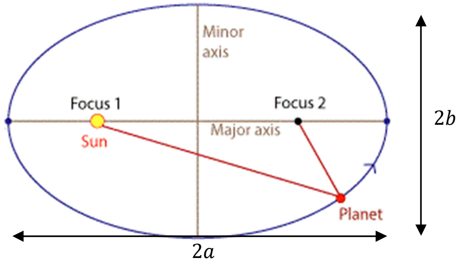
Impulse = F × Δt

$$F \propto \frac{1}{\Delta t}$$

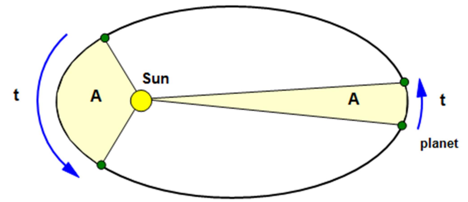
The function of shock absorbers is to increase the time of jerk, thereby reducing the impulsive force (jerk). This minimizes the damage to the vehicles.

27) State Kepler's laws of planetary motion.

I Law: All planets move in elliptical orbits with the sun at one of the foci.



II Law: The line joining the planet to the sun sweeps equal areas in equal intervals of time.



III Law: The Square of the period of revolution of a planet is directly proportional to the cube of the semi major axis of the ellipse.

$$T^2 \propto a^3$$

28) Explain surface tension and surface energy.

Surface Tension: The tangential force acting per unit length of an imaginary line drawn on the free liquid surface is called surface tension.

$$\therefore S = \frac{F}{l}$$

Units: N/m

Dimensional formula: MT^{-2}

Surface Energy: The excess potential energy per unit area of the surface film is called surface energy.

Units: J/m^2

* Surface energy of liquid is numerically equal to its surface tension.

29) Explain Celsius and Fahrenheit scales of temperatures. Obtain the relation between Celsius and Fahrenheit scales of temperatures.

Celsius scale of temperature:

- Lower fixed point is taken as 0°C
- Upper fixed point is taken as 100°C
- The interval between two fixed points is divided into 100 equal parts
- Each part represents 1°C

Fahrenheit scale of temperature:

- Lower fixed point is taken as 32°F
- Upper fixed point is taken as 212°F
- The interval between two fixed points is divided into 180 equal parts
- Each part represents 1°F

Relation: The relation between Celsius and Fahrenheit scales is

$$\frac{C-0}{100}=\frac{F-32}{180}$$

$$\frac{C}{5}=\frac{F-32}{9}$$

$$\boxed{C=\frac{5}{9}(F-32)} \quad (Or) \quad \boxed{F=\frac{9C}{5}+32}$$

30) Two identical rectangular strips, one of copper and the other of steel, are riveted together to form a compound bar. What will happen on heating?

A bimetallic strip is formed by riveting two identical rectangular strips, one of copper and the other of steel.

Fig: At Room temperature

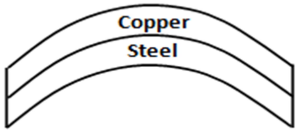


Fig: At Higher temperature

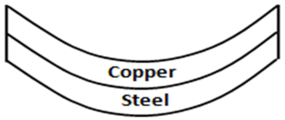


Fig: At Lower temperature

Since $\alpha_{copper} > \alpha_{steel}$

a) When a bimetallic strip is heated then copper expand more than steel. So the bimetallic strip bends with copper on outer side (i.e Convex side).

b) When a bimetallic strip is cooled then copper contract more than steel. So the bimetallic strip bends with copper on inner side (i.e Concave side).

31) How specific heat capacity of mono atomic, diatomic and poly atomic gases can be explained on the basis of law of equipartition of energy?

According to law of equipartition of energy, the energy associated with each molecule per degree of freedom is $\frac{1}{2}K_BT$

For one mole of gas,

* Total internal energy, $U=f\left(\frac{1}{2}K_BT\right)N=\frac{f}{2}RT$ $\quad [\because R=K_BN]$
* Specific heat at constant volume, $C_V=\frac{dU}{dT}=\frac{f}{2}R$
* Specific heat at constant pressure, $C_P=C_V+R=\left(\frac{f}{2}+1\right)R$
* Specific heat ratio, $\gamma=\frac{C_P}{C_V}$

Atomic gas	Degrees of freedom	C_v	C_P	γ
Mono atomic gas	3	$\frac{3R}{2}$	$\frac{5R}{2}$	$\frac{5}{3}$
Dia atomic gas	5	$\frac{5R}{2}$	$\frac{7R}{2}$	$\frac{7}{5}$
Poly atomic gas	6	$3R$	$4R$	$\frac{4}{3}$

32) What is the ratio of r.m.s speed of oxygen and hydrogen molecules at the same temperature?

The r.m.s speed of gas molecule is given by

$$V_{rms}=\sqrt{\frac{3RT}{M}}$$

$$V_{rms}\propto\frac{1}{\sqrt{M}}$$

$$\therefore \frac{V_O}{V_H}=\sqrt{\frac{M_H}{M_O}}=\sqrt{\frac{2}{32}}=\sqrt{\frac{1}{16}}=\frac{1}{4}$$

33) Four molecules of a gas have speeds 1, 2, 3 and 4 km/sec. find the r.m.s speed of the gas molecule?

$$V_{rms}=\sqrt{\frac{V_1{}^2+V_2{}^2+V_3{}^2+V_4{}^2}{4}}$$

$$V_{rms}=\sqrt{\frac{1^2+2^2+3^2+4^2}{4}}=\sqrt{\frac{1+4+9+16}{4}}=\sqrt{\frac{30}{4}}=\sqrt{7.5}=2.7km/sec$$

34) Derive a relation between the two specific heat capacities of gas on the basis of first law of thermodynamics (OR) show that $C_P-C_V=R$ (Mayer's equation)

Consider 1 mole of an ideal gas contained in a cylinder with movable piston. Let P, V and T be the pressure, volume and temperature of gas.

At constant volume: Supplied heat is utilized only to increase the internal energy

$$(dQ)_V=dU=C_VdT \quad ------\rightarrow (1)$$

At constant pressure: Supplied heat is utilized to increase the internal energy and to do the external work.

$$(dQ)_P=C_PdT \quad -----\rightarrow (2)$$

Work done, $dW=P.dV \quad ------\rightarrow (3)$

From first law of thermodynamics,

$$(dQ)_P=dU+dW$$

Substitute (1), (2)and (3)in above equation, we get

$$C_PdT=C_VdT+P\,dV \quad -----\rightarrow (4)$$

From ideal gas equation,

$$PV=RT$$

On differentiating, we get

$$P\,dV=R\,dT \quad ------\rightarrow (5)$$

From Eq (4) and Eq (5)

$$\therefore C_PdT=C_VdT+RdT$$

$$\therefore C_PdT-C_VdT=RdT$$

$$[C_P-C_V]dT=RdT$$

$$\boxed{C_P-C_V=R}$$

35) Define two principal specific heats of a gas. Which is greater and why?

Molar specific heat at constant volume: At constant volume, the amount of heat required to raise the temperature of 1 mole of a gas through 1°C is called molar specific heat at constant volume.

$$C_V = \frac{1}{n}\frac{dQ}{dT}$$

Units: $J/_{mole-K}$

Molar specific heat at constant pressure: At constant pressure, the amount of heat required to raise the temperature of 1 mole of a gas through 1°C is called molar specific heat at constant pressure.

$$C_P = \frac{1}{n}\frac{dQ}{dT}$$

Units: $J/_{mole-K}$

Reason for $C_P > C_V$:

iv) At constant volume, supplied heat is utilized only to increase internal energy. $[(dQ)_v = du]$

v) At constant pressure, supplied heat is utilized to increase internal energy and to do external work done.$[(dQ)_p = du + dw]$

vi) For the same rise in temperature, more heat is given to the gas at constant pressure compared to at constant volume.

$Therefore, C_P > C_V$

36) State and explain first law of thermodynamics.

Statement: *The amount of heat given to a system is equal to the sum of increase in internal energy and external work done by the system.*

Let

dQ = heat supplied to the system
dU = increase in its internal energy
dW = external work done by the system

Then according to the first law of thermodynamics,

$$\boxed{dQ = dU + dW}$$

This law is the consequence of law of conservation of energy.
This law gives the concept of internal energy

Sign convection:

a) dW is +ve, when work is done by the system
b) dW is – ve, when work is done on the system
c) dQ is +ve, when heat is given to the system
d) dQ is – ve, when heat is taken out from the system

Limitation:

a) It does not explain about the direction of heat flow.
b) It does not explain us about the efficiency with which heat can be converted into work.

AIMSTUTORIAL Physics-1

37) Compare isothermal and adiabatic process.

Isothermal process	Adiabatic process
The process in which pressure and volume variations takes place at constant temperature	The process in which pressure, volume and temperature variations takes place in thermally isolated system
Internal energy is constant	Internal energy changes
It takes place in good conducting vessel	It takes place in bad conducting vessel
$du = 0$	$dQ = 0$
$PV = constant$	$PV^\gamma = constant$
Specific heat is infinity	Specific heat is zero
It is slow process	It is quick process

38) Obtain an expression for the work done by an ideal gas during isothermal change?

Consider n moles of an ideal gas expand isothermally from initial state(P_1, V_1) to the final state (P_2, V_2)at constant temperature T.

Work done during small change in volume dV is $dW = P\,dV$

Total work done during the process is given by

$$W = \int_{V_1}^{V_2} P\,dV \; ---\rightarrow (1)$$

From ideal gas equation,

$$PV = nRT$$

$$P = \frac{nRT}{V} \; ---\rightarrow (2)$$

From (1) and (2)

$$\therefore W = \int_{V_1}^{V_2} \frac{nRT}{V} dV = nRT \int_{V_1}^{V_2} \frac{1}{V} dV = nRT[\log_e V]_{V_1}^{V_2}$$

$$W = nRT[\log_e V_2 - \log_e V_2] = nRT \log_e \left(\frac{V_2}{V_1}\right) \qquad \boxed{W = 2.303\,nRT\,\log_{10}\left(\frac{V_2}{V_1}\right)}$$

39) Derive the relation between acceleration due to gravity (g) at the surface of a planet and gravitational constant (G).

Relation between g and G: Consider a body of mass m on the surface of a planet of mass M and radius R

The gravitational force acting on the body is

$$F = mg \; ----\rightarrow (1)$$

Where g is the acceleration due to gravity

According to Newton's universal law of gravitation

$$F = \frac{GMm}{R^2} \; ----\rightarrow (2)$$

Where G is universal gravitational constant

From (1) and (2) $\quad mg = \frac{GMm}{R^2}$

$$\boxed{g = \frac{GM}{R^2}}$$

JR INTER VERY SHORT ANSWER QUESTIONS

PHYSICAL WORLD

1) **What is physics?**(1 time)
Physics is the study of basic laws of nature and their manifestation in different natural phenomena.

2) **What is the discovery of C.V.Raman?**(5 times)
C.V Raman discovered Raman Effect. It deals with scattering of light by molecules of a medium when they are excited to vibrational energy levels.

3) **What are the fundamental forces in nature?**
   a) Gravitational force
   b) Electromagnetic force
   c) Strong nuclear force
   d) Weak nuclear force

4) **Which of the following has symmetry a) Acceleration due to gravity b) Law of gravitation?**
Law of gravitation

5) **What is the contribution of S.ChandraSekhar to physics?**(8 times)
Chandrasekhar limit. He worked on structure and evolution of stars.

6) **What is beta (β)decay? Which force is a function of it?** (1 time)
   * A radioactive decay in which an electron is emitted is called beta decay.
   * Weak nuclear force

UNITS AND MEASUREMENTS

7) **Distinguish between accuracy and precision.** (7 times)

Accuracy	Precision
It is the closeness of a measured value to the true value.	It is the closeness among several measured values.
It depends on errors.	It does not depend on errors.

8) **What are the different types of errors that can occur in a measurement?**
   a) Systematic errors
   b) Random errors

9) **How can systematic errors be minimized or eliminated?** (3 time)
Systematic errors can be minimized
   * By improving experimental techniques,
   * selecting better instruments and
   * removing personal bias as far as possible

10) **Illustrate how the result of a measurement is to be reported indicating the error involved.**
A physical quantity 'A' is measured as $A \pm \Delta A$, where ΔA is the error in measuring 'A'
Ex: Reported value= $(50.5 \pm 0.1)cm$
Where, **50.5** is the measured length
0.1 is the error in the measurement

11) **What are the significant figures and what do they represent when reporting the result of a measurement?**

Significant figures: The reliable digits plus the first uncertain digit are known as significant figures.
   * They represent the precision of measurement when reporting the result

12) **Distinguish between fundamental units and derived units.** (2 times)

Fundamental units	Derived units
The units of fundamental physical quantities are called fundamental units.	The units of derived physical quantities are called derived units.
Ex: metre, kilogram, second etc	Ex: newton, joule etc

13) **Why do we have different units for the same physical quantity?** (2 times)
The physical quantity has wide range of magnitudes. Hence we have different units for the same physical quantity.
(OR)
We have different systems of measurements like CGS and MKS systems. Hence we have different units for the same physical quantity.

14) **How many orders of magnitude greater is the radius of the atom as compared to that of the nucleus?**
The radius of the atom is greater by 10^5 times as compared to that of the nucleus (OR) 10^5

15) **What is dimensional analysis?**
The analysis in which a physical quantity is represented as mathematical powers of fundamental physical quantities is called dimensional analysis.
   * It is used to check the correctness of the given formula

16) **Express unified atomic mass unit in kg.**
$1\ Unified\ atomic\ mass\ unit\ (a.m.u) = 1.66\ X\ 10^{-2}$ kg

17) **Write the dimensional formulae for the following quantities.(Board model paper)**
(a) Gravitational constant **(b) Surface tension**
Gravitational constant: $M^{-1}L^3T^{-2}$
Surface tension: $M\,T^{-2}$

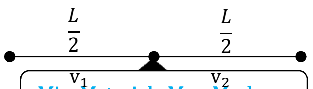
MOTION IN A STRAIGHT LINE

18) **The states of motion and rest are relative. Explain.**
A man sitting in a moving bus is at rest w.r.to his co-passenger but he is in motion w.r.to observer outside the bus. Hence rest and motion are relative.

19) **How is the average velocity different from instantaneous velocity?** (1 time)
Average velocity: It is defined as the ratio of total displacement to the total time taken.
Instantaneous velocity: It is the velocity of a body at particular instant of time.
   * Only In uniform motion, $average\ velocity = instantaneous\ velocity$.

20) **Give an example where the velocity of an object is zero but the acceleration is not zero.** (1 time)
At maximum height of a vertically projected body, velocity is zero but acceleration is not zero.

21) **A vehicle travels half of the distance L with speed $v_1$and the other half with speed v_2. What is the average speed?**
$$\text{Total time} = t_1 + t_2 = \frac{L}{2v_1} + \frac{L}{2v_2} = \frac{L}{2}\left[\frac{v_1 + v_2}{v_1 v_2}\right]$$



$$\text{Average speed} = \frac{\text{total distance}}{\text{total time}} = \frac{L}{\frac{L}{2}\left[\frac{v_1+v_2}{v_1 v_2}\right]} = \frac{2v_1v_2}{v_1+v_2}$$

$$\text{Average speed} = \frac{2v_1v_2}{v_1+v_2}$$

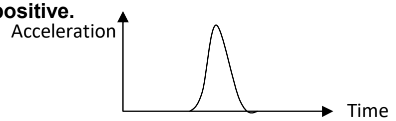
22) A lift coming down is just about to reach the ground floor. Taking the ground floor as origin and positive direction upwards for all quantities, which one of the following is correct.

a) x<0, v<0, a>0 **b) x>0, v<0, a<0**

c) x>0, v<0, a>0 **d) x>0, v>0, a>0**

a) x<0, v<0, a>0 is correct

23) A uniformly moving cricket ball is hit with a bat for a very short time and is turned back. Show the variation of its acceleration with time taking the acceleration in the backward direction as positive.



24) Give an example of one dimensional motion where a particle moving along the positive X – direction comes to rest periodically and moves forward.

A particle is moving according to the equation $x(t) = t - \sin t$, moving along the positive x – direction comes to rest periodically and moves forward.

25) An object falling through a fluid is observed to have an acceleration given by $a = g - bv$ where g is the gravitational acceleration and b is a constant. After a long time it is observed to fall with a constant velocity. What would be the value of this constant velocity?

Given $a = g - bv$

For constant velocity, $a = 0$

$$\therefore g - bv = 0$$

$$g = bv$$

$$\boxed{v = \frac{g}{b}}$$

26) If the trajectory of a body is parabolic in one frame, can it be parabolic in another frame that moves with a constant velocity with respect to the first frame? If not, what can it be?

No. it will be a straight line.

27) A spring with one end attached to a mass and the other to a rigid support is stretched and released. When is the magnitude of acceleration a maximum?

The magnitude of acceleration is maximum at extreme position **(OR)** At extreme position

MOTION IN A PLANE

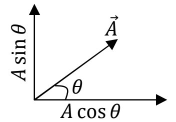
28) The vertical component of a vector is equal to its horizontal component. What is the angle made by the vector with x – axis?

Vertical component of $\vec{A}$ = Horizontal component of $\vec{A}$

$$A\sin\theta = A\cos\theta$$

$$\tan\theta = 1$$

$$\boxed{\theta = 45^\circ}$$



29) A vector v makes an angle θ with the horizontal. The velocity is rotated through an angle α. Does this rotation change the vector $\vec{v}$?

Yes,

Because due to rotation of the vector, magnitude remains constant but direction changes other than $2\pi, 4\pi, 6\pi, \ldots\ldots\ldots$

30) Two forces of magnitudes 3 units and 5 units act at 60° with each other. What is the magnitude of their resultant? (3 times)

Given $P = 3;\ Q = 5;\ \theta = 60^\circ$

$$\therefore R = \sqrt{P^2+Q^2+2PQ\cos\theta} = \sqrt{9+25+\left(2\times3\times5\times\frac{1}{2}\right)} = \sqrt{9+25+15} = \sqrt{49} = 7$$

R = 7 units

31) $A = \vec{i}+\vec{j}$ What is the angle between the vector and x – axis? (4 times)

Given $\vec{A} = \vec{i}+\vec{j}$

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

$$\therefore A_x = 1;\quad A_y = 1$$

$$\tan\theta = \frac{A_y}{A_x} = 1 = \tan 45^\circ$$

$$\boxed{\theta = 45^\circ}$$

32) When two right angled vectors of magnitudes 7 units and 24 units combine, what is the magnitude of their resultant? (2 times)

Given P = 7; Q = 24; θ = 90°

$$\therefore R = \sqrt{P^2+Q^2+2PQ\cos\theta}$$

$$R = \sqrt{7^2+24^2+(7\times24\times\cos 90^\circ)} = \sqrt{49+576+0} = \sqrt{625} = 25 \text{ units}$$

33) If $\vec{P} = 2\hat{\imath}+4\hat{\jmath}+14\hat{k}$ and $\vec{Q} = 4\hat{\imath}+4\hat{\jmath}+10\hat{k}$, find the magnitude of $\vec{P}+\vec{Q}$? (2 times)

Given, $\vec{P} = 2\hat{\imath}+4\hat{\jmath}+14\hat{k}$; $\vec{Q} = 4\hat{\imath}+4\hat{\jmath}+10\hat{k}$

$$\therefore \vec{P}+\vec{Q} = 6\hat{\imath}+8\hat{\jmath}+24\hat{k}$$

$$|\vec{P}+\vec{Q}| = \sqrt{6^2+8^2+24^2} = \sqrt{36+64+576} = \sqrt{676} = 26$$

$$|\vec{P}+\vec{Q}| = 26\ units$$

34) Can a vector of magnitude zero have non zero components?

No, a vector of magnitude can never be zero with non zero components.

35) What is the acceleration of a projectile at the top of its trajectory?

$a = g, in\ downwards$

36) Can two vectors of unequal magnitude, add up to give the zero vector? Can three vectors of unequal magnitude, add up to give the zero vector?

a) No, addition of two vectors of unequal magnitude cannot give a zero vector.

b) Yes, addition of three vectors of unequal magnitude may give a zero vector.

37) Write the equation for the horizontal range covered by a projectile and specify when it will be maximum?

* Range of projectile $= \dfrac{u^2\sin 2\theta}{g}$
* Range will be maximum when $\theta = 45^\circ$

LAWS OF MOTION

38) What is inertia? What gives the measure of inertia? (2 time)

Inertia: The inability of a body to change its state by itself is called inertia.

* *Mass* is the measure of inertia.

39) According to Newton's third law, every force is accompanied by an equal and opposite force. How can a movement ever take place? (1 time)

Action and reaction forces acts on two different bodies. Hence they do not cancel each other. Hence, movement takes place.

40) When a bullet is fired from a gun, the gun gives a kick in the backward direction. Explain. (1 time)

According to law of conservation of linear momentum,

$$Momentum\ before\ firing = Momentum\ after\ firing$$

$$0 = P_{gun} + P_{bullet}$$

$$\boxed{P_{gun} = -P_{bullet}}$$

Hence the gun gives a kick in the backward direction.

41) Why does a heavy rifle not recoil as strongly as a light rifle using the same cartridge?

According to law of conservation of linear momentum,

$$Velocity \propto \frac{1}{Mass}$$

Hence a heavy rifle does not recoil as strongly as a light rifle because of its heavy mass.

42) If a bomb at rest explodes into two pieces, the pieces must travel in opposite directions. Explain. (3 times)

According to law of conservation of linear momentum,

$$Momentum\ before\ explosion = Momentum\ after\ explosion$$

$$0 = P_1 + P_2$$

$$\boxed{P_1 = -P_2}$$

Hence two pieces travels in opposite directions.

43) Define force. What are the basic forces in nature?

Force: A physical quantity which changes or tries to change the state of a body is called force.

* The basic forces in nature are
  - Gravitational force
  - Electromagnetic force
  - Strong nuclear force
  - Weak nuclear force

44) Can the coefficient of friction be greater than one?

Yes. In the case of heavily polished surfaces $\mu > 1$

45) Why does the car with a flattened tyre stop sooner than the one with inflated tyres? (1 time)

In the case of flattened tyres, the rolling friction is more due to greater deformation of tyres.

(OR)

Flattened tyre has more area of contact. Hence rolling friction increases and there by a car with flattened tyre stop sooner.

46) What happens to the coefficient of friction if the weight of the body is doubled? (2 times)

Remains same, because it is independent of weight of the body

47) A horse has to pull harder during the start of the motion than later. Explain. (2 times)

Before starting the motion, a horse has static friction and later it is converted into kinetic friction. Static friction is greater than kinetic friction. Hence the horse has to pull harder during start of the motion than later.

WORK, ENERGY AND POWER

48) State the conditions under which a force does no work.

- ♣ The displacement is zero.
- ♣ The force is perpendicular to the displacement ($\theta = 90°$).

49) Define work, power and energy. State their SI units.

Work: It is defined as the dot product of force and displacement vectors.
SI unit: joule (J)

Energy: The capacity to do work is called energy
SI unit: joule (J)

Power: The rate of work done is called power
SI units: joule/sec (or) watt (W)

50) State the relation between the kinetic energy and momentum of a body.

$$\text{Kinetic energy} = \frac{1}{2}mv^2 \quad \& \quad \text{Momentum(P)} = mv$$

$$\text{K.E} = \frac{1}{2}mv^2 = \frac{m^2v^2}{2m} = \frac{p^2}{2m}$$

$$\boxed{\text{K.E} = \frac{p^2}{2m}}$$

51) State the sign of work done by a force in the following

a) Work done by a man in lifting a bucket out of a well by means of rope tied to the bucket.

b) Work done by gravitational force in the above case.

a) Work done is positive
b) Work done is negative

52) State the sign of the work done by a force in the following

a) Work done by a friction on a body sliding down in an inclined plane.

b) Work done by gravitational force in the above case.

a) Work done is negative
b) Work done is positive

53) State the sign of the work done by a force in the following

c) Work done by an applied force on a body moving of a rough horizontal plane with uniform velocity.

d) Work done by the resistive force of air on vibrating pendulum in bringing it to rest.

c) Work done is positive
d) Work done is negative

54) State if each of the following statements is true or false. Give reasons for your answer.

a) Total energy of a system is always conserved, no matter what internal and external forces on the body are present.

b) The work done by the earth's gravitational force in keeping the moon in its orbit for its one revolution is zero.

a) False, the external forces affect the energy of the system.
b) True, Gravitational force is a conservative force.

55) Which physical quantity remains constant a) In an elastic collision and b) In an inelastic collision?

a) In an elastic collision, both momentum and kinetic energy remains constant
b) In an inelastic collision, only momentum is constant

56) A body freely falling from a certain height 'h' after striking a smooth floor rebounds and h rises to height h/2. What is the coefficient of restitution between the floor and the body?

Given $h_1 = h$, $h_2 = h/2$

$$e = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{h/2}{h}} = \frac{1}{\sqrt{2}}$$

57) What is the total displacement of a freely falling body, after successive rebounds from the place of ground, before it comes to stop?

Total displacement = Height of freely falling body

SYSTEM OF PARTICLES AND ROTATIONAL MOTION

58) Is it necessary that a mass should be present at the centre of mass of any system? (1 time)

No, it is not necessary that a mass should be present at the centre of mass of any system

Ex: circular ring, hollow sphere

59) What is the difference in the positions of a girl carrying a bag in one of her hands and another girl carrying a bag in each of her two hands?

- When a girl carrying a bag in one of her hands, centre of mass shifts towards the hand with bag
- When a girl carrying a bag in each of her two hands, centre of mass does not change

60) Two rigid bodies have same moment of inertia about their axes of symmetry. Of the two, which body will have greater kinetic energy?

Rotational $K.E = \frac{L^2}{2I}$

Given moment of inertia (I) is same

$$\Rightarrow \boldsymbol{K.E \propto L^2}$$

∴ A body with greater angular momentum will have greater kinetic energy.

61) Why are spokes provided in a bicycle wheel? (2 times)

To increase the moment of inertia without large increase in its mass and thereby it increase the rotational inertia.

(OR)

To ensure uniform speed of the cycle wheel, it should possess large moment of inertia. To increase moment of inertia of the wheel without large increase in its mass, it is provided with spokes.

62) We cannot open or close the door by applying force at the hinges. Why? (1 time)

We know that torque, $\tau = rF\sin\theta$

At hings, $r = 0$

$\therefore \tau = 0$

So we cannot open or close the door by applying force at the hinges.

63) Why do we prefer a spanner of longer arm as compared to the spanner of shorter arm?

We know that torque, $\tau = rF\sin\theta$

For constant force, $\tau \propto r$

With less applied force, more torque acts on a spanner of longer arm compared to spanner of shorter arm. Hence we prefer a spanner of larges arm.

64) By spinning eggs on a table top, how will you distinguish a hardboiled egg from a raw egg? (2 time)

According to law of conservation of angular momentum,

$I\omega = constant$

$\therefore \omega \propto \frac{1}{I}$

Since $I_r > I_b$, so $\omega_r < \omega_b$

So the raw egg comes to rest quickly.

65) Why should a helicopter necessarily have two propellers?

If the helicopter had only one propeller, then helicopter itself will rotate in the opposite direction to conserve angular momentum. To avoid this, the helicopter should have two propellers.

66) If the polar ice caps of the earth were to melt, what would the effect of the length of the day be?

As polar ice caps melts, moment of inertia increases. To conserve the angular momentum, angular velocity(ω) decreases, thereby increasing the length of the day.

(OR)

Length of the day increases

67) Why is it easier to balance a bicycle in motion?

Due to law of conservation of angular momentum the bicycle is easier to balance in motion.

OSCILLATIONS

68) Give two examples of periodic motion which are not oscillatory.

- Motion of planets around the sun
- Motion of seconds hand in a clock

69) The displacement in SHM is given by $y = a\sin(20t + 4)$. What is the displacement when it is increased by 2π/ω?

Displacement doesn't change because after every $\frac{2\pi}{\omega}$ second the motion is repeating.

70) A girl is swinging seated in a swing. What is the effect on the frequency of oscillation if she stands?

Frequecy, $n \propto \frac{1}{\sqrt{l}}$

When the girl stands up, the effective length decreases. So the frequency increases.

71) The bob of a simple pendulum is a hollow sphere filled with water. How will the period of oscillation change, if the water begins to drain out of the hollow sphere?

Time period first increases and then decreases to original value.

72) The bob of a simple pendulum is made of wood. What will be the effect on the time period if the wooden bob is replaced by an identical bob of aluminum?

Time period remains same, because it is independent of material of the bob.

73) Will a pendulum clock gain or lose time when taken to the top of a mountain?

Since period of oscillation, $T \propto \frac{1}{\sqrt{g}}$

On the top of mountain 'g' decreases and 'T' increases. So pendulum clock loses time.

74) A pendulum clock gives correct time at the equator. Will it gain or lose time if it is taken to the poles? If so. Why?

Since period of oscillation, $T \propto \frac{1}{\sqrt{g}}$

At the poles, 'g' increases and 'T' decreases. So it will gain time.

75) What fraction of the total energy in K.E when the displacement is one half of amplitude of particle executing S.H.M?

Given $y = \frac{A}{2}$

$$\frac{\text{Kinetic energy}}{\text{Total energy}} = \frac{\frac{1}{2}m\omega^2(A^2 - y^2)}{\frac{1}{2}m\omega^2 A^2} = \frac{\left(A^2 - \frac{A^2}{4}\right)}{A^2} = \frac{\frac{3A^2}{4}}{A^2} = \frac{3}{4}$$

$$\therefore Kinetic\ energy = \frac{3}{4} \times Total\ energy$$

76) What happens to the energy of a simple harmonic oscillator it its amplitude is doubled?

Energy of simple harmonic oscillator is given by

$$E = \frac{1}{2}mA^2\omega^2$$

$$E \propto A^2$$

∴ If the amplitude is doubled, then energy becomes four times.

77) Can a simple pendulum be used in an artificial satellite?

No. In artificial satellite acceleration due to gravity is zero.

GRAVITATION

78) State the unit and dimension of the universal gravitational constant.

Units: Nm^2/kg^2

D.F: $M^{-1}L^3T^{-2}$

79) State the vector form of Newton's law of gravitation.

$$\vec{F} = \frac{Gm_1m_2}{r^2}\hat{r} \quad (or) \quad \vec{F} = \frac{Gm_1m_2}{r^3}\vec{r} \qquad \left(\because \hat{r} = \frac{\vec{r}}{r}\right)$$

80) If the gravitational force of earth on the moon is F, what is the gravitational force of moon on earth? Do these forces form an action – reaction pair?

- ♣ The gravitational force of the moon on the earth is also F
- ♣ Yes, these forces form an action – reaction pair.

81) What would be the change in acceleration due to gravity (g) at the surface, if the radius of earth decreases by 2% keeping the mass of earth constant?

Given $\left(\frac{dR}{R} \times 100\right) = -2\%$

We know that,

$$g \propto \frac{1}{R^2}$$

$$\left(\frac{dg}{g} \times 100\right) = -2\left(\frac{dR}{R} \times 100\right)$$

$$\left(\frac{dg}{g} \times 100\right) = -2 \times (-2) = 4\%$$

∴'g' Increased by 4%

82) As we go from one planet to another, how will a) The mass and b) The weight of a body change?

a) Mass remains same

b) Weight of the body changes, because g changes from planet to planet.

83) Keeping the length of a simple pendulum constant, will the time period be the same on all planets? Support your answer with reason.

No,

As 'g' changes from planet to planet, the time period also changes.

84) Give the equation for the value of 'g' at a depth 'd' from the surface of earth. What is the value of 'g' at the centre of earth?

- ♣ $g_d = g\left(1 - \frac{d}{R}\right)$
- ♣ At the centre of the earth, $d = R$

$\therefore g_d = 0$

85) What are the factors that make 'g' the least at the equator and maximum at the poles?

$We\ know\ that\ g_\varphi = g - R\omega^2\cos^2\varphi$

a) The factors that make 'g' the least at the equator are

- ∗ Equatorial radius of the earth is maximum
- ∗ Latitude, $\varphi = 0^\circ$

b) The factors that make 'g' the maximum at the poles are

- ∗ Polar radius of the earth is minimum
- ∗ Latitude, $\varphi = 90^\circ$

86) "Hydrogen is in abundance around the sun and not around earth". Explain.

The escape velocity on the sun is greater than the rms velocity of the hydrogen. But the escape velocity on the earth is less than the rms velocity of the hydrogen. Hence hydrogen is abundance around the sun and not around earth.

87) What is the time period of revolution of geostationary satellite? Does it rotate from west to east or from east to west?

T = 24hours. It rotates from west to east.

88) What are polar satellites?

- ∗ The satellites which revolve in polar orbits ($N - S\ direction$) are called polar satellites.
- ∗ Polar satellites are low altitude satellites.

MECHANICAL PROPERTIES OF SOLIDS

89) Sate Hooke's law of elasticity.

Hooke's law: Within elastic limit, stress is directly proportional to strain

Stress α Strain

Stress = K Strain

Where K is called modulus of elasticity

90) State the units and dimensions of stress. (Or)
State the units and dimensions of modulus of elasticity. (Or)
State the units and dimensions of young's modulus. (Or)
State the units and dimensions of modulus of rigidity. (Or)
State the units and dimensions of bulk modulus.

Units: N/m^2 (or) Pascal

D.F: $M\,L^{-1}T^{-2}$

91) What are the theoretical and practical limits of Poisson's ratio? (1 time)

Theoretical limits: – 1 to 0.5

Practical limits: 0 to 0.5

92) What is elastic fatigue?
The state of temporary loss of elastic nature of a body due to repeated stress is called elastic fatigue.

93) Define Poisson's ratio
The ratio of lateral strain to longitudinal strain is called Poisson's ratio.

94) "steel exhibits more elastic nature than rubber" explain
Young's modulus of steel is more than rubber. Hence steel is more elastic than rubber.

95) State the examples of nearly perfect elastic and plastic bodies.
Nearly perfectly elastic body: Quartz fibre, Phosphor bronze
Nearly perfectly plastic body: Putty, wax

MECHANICAL PROPERTIES OF FLUIDS

96) Define average pressure. Mention its unit and dimensional formula. Is it a scalar or a vector?
The normal force acting per unit area is called average pressure.

$$P_{avg} = \frac{F}{A}$$

Units: N/m^2 (or) Pascal **D.F:** $M L^{-1}T^{-2}$
It is a scalar quantity.

97) Define coefficient of viscosity. What are its units and dimensions?
The tangential viscous force acting per unit area per unit velocity gradient normal to the direction of fluid flow is called coefficient of viscosity.
SI Unit: Pascal-second (or) N – Sec/m^2 **CGS Unit:** poise
D.F: $M L^{-1}T^{-1}$

98) Define viscosity. What are its units? (3 times)
Viscosity: The property of a fluid which opposes the relative motion between its layers is called viscosity.
SI Unit: Pascal-second (or) N – Sec/m^2 **CGS Unit:** poise

99) Define viscosity and coefficient of viscosity.
Viscosity: The property of a fluid which opposes the relative motion between its layers is called viscosity.
Coefficient of viscosity: The tangential viscous force acting per unit area per unit velocity gradient normal to the direction of flow is called coefficient of viscosity.

100) What is the principle behind the carburetor of an automobile? (3 times)
Carburetor works on Bernoulli's principle.
The carburetor of automobile has a venturi channel (nozzle) through which air flows with a large speed. The pressure is then lowered at the narrow neck and the petrol is sucked up in the chamber to provide the correct mixture of air to fuel for combustion.

101) What is Magnus effect? (2 times)

When a ball is spinning and moving in the air, it experiences a net upward force called dynamic lift. This dynamic lift due to spinning is called Magnus effect
(Or)
The difference in the velocities of air results in the pressure difference between the lower and upper faces and there is a net upward force on the ball. This dynamic lift due to spinning is called Magnus effect.

102) Why are drops and bubbles spherical? (7 times)
Due to surface tension
(Or)
Due to surface tension, the free surface of the liquid tends to acquire minimum surface area. For a given volume sphere possess minimum surface area. Hence drops and bubbles are spherical.

103) Give the expression for the excess pressure in a liquid drop. (2 time)
Excess pressure, $P = \frac{2S}{r}$ Where 'S' is surface tension
'r' is radius of liquid drop

104) Give the expression for the excess pressure in an air bubble inside the liquid.
Excess pressure, $P = \frac{2S}{r}$ Where 'S' is surface tension
'r' is radius of air bubble

105) Give the expression for the soap bubble in air. (1 times)
Excess pressure, $P = \frac{4S}{r}$ Where 'S' is surface tension
'r' is radius of soap bubble

106) What are water proofing agents and water wetting agents? What do they do?
Water proofing agents: The substances which are used to increase the angle of contact are called Water proofing agents.
* Water proofing agents decreases the wetting nature of the surface.
* **Ex:** Wax

Water wetting agents: The substances which are used to decrease the angle of contact are called Water wetting agents.
* Water wetting agents increases the wetting nature of the surface.
* **Ex:** Soaps, detergents

107) What is angle of contact? (2 times)
Angle of contact: The angle between tangent drawn to the liquid surface at the point of contact and the solid surface inside the liquid is called angle of contact.
For pure mercury with glass, θ = 140°
For pure water with glass, θ = 0°

108) Mention any two examples that obey Bernoulli's theorem and justify them. (1 time)
* 1) Dynamic lift on aero plane wing 2) Magnus effect
* Pressure is low at large velocity and vice versa.

109) When water flows through a pipe, which of the layers moves fast and slowest? (1 time)
The layers in contact with the walls of the pipe moves slowly and the central layer moves fast.

110) "Terminal velocity is more if surface area of the body is more". Give reasons in support your answer?

Terminal velocity is

$$V_t = \frac{2r^2(\rho - \sigma)g}{9\eta}$$

$$V_t \propto r^2$$

$$\text{Surface area, } A = 4\pi r^2 \Rightarrow A \propto r^2$$

$$\boxed{\therefore V_t \propto A}$$

∴ Terminal velocity is more if surface area of the body is more.

111)Why a water droplet wet the glass surface and does not wet the lotus leaf? (1 time)
For glass – water pair, angle of contact is acute($\theta < 90°$). So water wet the glass surface.
For water – lotus leaf, angle of contact is obtuse($\theta > 90°$). So water does not wet the lotus leaf.

112)Explain the effect of temperature on the viscosity of liquids.
Viscosity of a liquid decreases with increase in temperature

113)Explain how viscosity of a gas changes with temperature.
Viscosity of a gas increases with increase in temperature.

114)What is the effect of temperature on surface tension?
Surface tension decreases with increase in temperature.

115)What are cohesive and adhesive forces?
Cohesive force: The force of attraction between the molecules of the same substance is called cohesive force.
Adhesive force: The force of attraction between the molecules of different substances is called adhesive force.

116)Define the velocity gradient and give its units.
The change in velocity per unit distance is called velocity gradient.
SI unit: sec^{-1}

117)Hot liquid flows faster than cold liquids. Explain. (1 time)
Viscosity of hot liquids is less than viscosity of cold liquids. Hence hot liquids flow faster than cold liquids.

THERMAL PROPERTIES OF MATTER

118)Distinguish between heat and temperature. (1 time)

Heat	Temperature
Heat is a form of energy	Temperature is the degree of hotness or coldness of a body
Heat is a cause	Temperature is effect
Units: calorie (or) Joule	**Units:** °C, °F, (or) K

119)What are the lower and upper fixing points in Celsius and Fahrenheit scales? (2 times)
Celsius scale:
Lower fixed point = 0°C
Upper fixed point =100°C
Fahrenheit scale:
Lower fixed point =32°F

Upper fixed point = 212°F

120)Do the values of coefficients of expansion differ, when the temperature is measured on Centigrade scale or on Fahrenheit scale?
Yes,
Because (α in Celsius scale) $= \frac{9}{5} \times$ (α in Fahrenheit scale)

121)Can a substance contract on heating? Give an example. (1 time)
Yes,
Ex: Indian rubber, water from 0°C to 4°C, cast iron, type metal

122)Why gaps are left between rails on a railway track? (4 times)
To allow linear expansion in summer

123)Why do liquids have no linear and areal expansions?
Liquids have no shape of their own. They do not have individual length and area. Hence liquids have no linear and areal expansions.

124)What is latent heat of fusion?
Latent heat of fusion: The amount of heat required to convert unit mass of substance from solid state to liquid state at constant temperature is called latent heat of fusion.

125)What is latent heat of vaporization? (1 time)
Latent heat of vaporization: The amount of heat required to convert unit mass of substance from liquid state to gaseous state at constant temperature is called latent heat of vaporization.

126)What is specific gas constant? Is it same for all gases?
Gas constant per unit mass is called specific gas constant. $\left(r = \frac{R}{M}\right)$

* It changes from gas to gas.

(OR)

For 1 gram of ideal gas, the ratio $\frac{PV}{T}$ is called specific gas constant

* It changes from gas to gas.

127)What are the units and dimensions of specific gas constant? (1 time)
Units: $J\,Kg^{-1}\,K^{-1}$
Dimensions: $L^2T^{-2}K^{-1}$

128)Why utensils are coated black? Why the bottom of the utensils is made of copper?

* Black is a good absorber and good emitter. Hence utensils are coated with black.
* Copper is a good conductor of heat. Hence copper is used at bottom of utensils.

129)State Wien's displacement law. (1 time)
The wavelength corresponding to maximum energy emitted by a black body is inversely proportional to its absolute temperature.

$$\lambda_{max} \propto \frac{1}{T} \quad (or) \quad \lambda_{max}T = constant$$

130)Ventilators are provided in rooms just below the roof. Why? (2 time)
Because to escape hot air from the room due to convection
(Or)

Ventilators are provided in rooms just below the roof, because the hot air escapes out and fresh air enters into the rooms due to convection.

131) Does a body radiate heat at 0K? Does it radiate heat at 0°C?

* No, a body does not radiate heat at 0 K.
* Yes, a body radiate heat at 0°C

132) State the different modes of transmission of heat. Which of these modes require medium?

a) Modes of transmission of heat are
  * Conduction
  * Convection
  * Radiation

b) For conduction and convection, medium is necessary

133) Define coefficient of thermal conductivity and temperature gradient.

Coefficient of thermal conductivity: It is defined as the amount of heat flowing through a conductor of unit area of cross section per second per unit temperature gradient.

$$K = \frac{Q}{A\left(\frac{\theta_2-\theta_1}{l}\right)t}$$

Temperature gradient: The change in temperature per unit distance in the direction of heat flow is called temperature gradient.

$$\text{Temperature gradient} = \frac{(\theta_2-\theta_1)}{l}$$

134) What is thermal resistance of a conductor? On what factors does it depend?

The resistance offered by the conductor for the flow of heat is called thermal resistance.

$$R = \frac{l}{KA}$$

It depends on

a) The nature of the material
b) Length and area of cross-section of the conductor

135) State the units and dimensions of coefficient of convection.

Units: $Wm^{-2}K^{-1}$

Dimensions: $M^1T^{-3}K^{-1}$

136) Define emissive power and emissivity.

Emissive power: The energy emitted by a body per second per unit surface area at a given temperature and wavelength range is called emissive power.

Emissivity: The ratio of the emissive power of the body to that of black body at the same temperature is called emissivity.

137) What is greenhouse effect? Explain global warming. (4 times)

Greenhouse effect: The surface of the earth and atmosphere gets heated up due to green house gases like CO_2, CH_4, N_2O etc., (Carbon dioxide, methane, nitrous oxide). This is called as Green house effect.

Global warming: As greenhouse gases content increases, more heat is retained in the atmosphere and the temperatures all over the world increase. This is called global warming.

138) Define absorptive power of a body. What is the absorptive power of a perfect black body?

Absorptive power: The ratio of energy absorbed to the energy incident on the body at a given temperature and wavelength range is called absorptive power.

For a perfect black body, the absorptive power is 1.

AIMSTUTORIAL Physics-1

139) State Newton's law of cooling. (2 times)

Newton's law of cooling: The rate of loss of heat of a hot body is directly proportional to the temperature difference between the hot body and its surroundings.

$$-\frac{dQ}{dt} \propto (T_2 - T_1)$$

140) State the conditions under which Newton's law of cooling is applicable? (2 times)

* Loss of heat is negligible by conduction and only when it is due to convection.
* Loss of heat occurs in a steam lined flow of air.
* Temperature of the body is uniformly distributed over it.
* Temperature difference is small.

141) Why is it easier to perform the skating on the snow? (1 time)

Skating is possible on snow due to the formation of water below the skates. Water is formed due to the increase of pressure and it acts as a lubricant.

142) The roofs of building are often painted white during summer. Why? (2 times)

Because white paint is a good reflector (or) bad absorber of heat

THERMODYNAMICS

143) Define thermal equilibrium. How does it lead to Zeroth law of thermodynamics? (1 time)

Thermal equilibrium: If two systems are at the same temperature, then they are said to be in thermal equilibrium.

Zeroth law of thermodynamics: If two systems A and B are in thermal equilibrium separately with a third system C, then the two systems must be in thermal equilibrium with each other

144) Define calorie. What is the relation between calorie and mechanical equivalent of heat?

Calorie: The amount of heat required to raise the temperature of one gram of water through 1°C at a pressure of 1atm is called Calorie.

$$J = 4.186\ \frac{Joule}{Calorie}$$

Where J is called mechanical equivalent of heat

145) What thermodynamic variables can be defined by a) Zeroth law b) First law?

a) Zeroth law defines **temperature**
b) First law defines **internal energy**

146) Define specific heat capacity of the substance. On what factors does it depend?

The amount of heat required to raise the temperature of unit mass of substance through 1°C is called specific heat capacity.

$$s = \frac{1}{m}\frac{dQ}{dT}$$

It depends on the nature of the substance and scale of temperature.

147) Define molar specific heat capacity. (1 time)

The amount of heat required to raise the temperature of one mole of substance through 1°C is called molar specific heat capacity.

$$s = \frac{1}{n}\frac{dQ}{dT}$$

Where n is the number of moles of gas

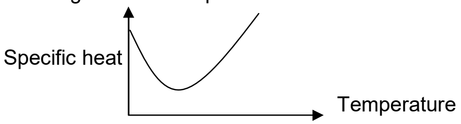
148) For a solid, what is the total energy of an oscillator?

$$Total\ energy = Potential\ energy + Kinetic\ energy = 3RT$$

Target ⇨ 60 Min. Material –Max. Marks

149)Indicate the graph showing the variation of specific heat of water with temperature. What does it signify?

The graph showing variation of specific heat of water with temperature is shown in figure.



It signifies that for a precise definition of calorie, the unit temperature interval should be taken as 14.5°C to 15.5°C.

150)Define state variables and equation of state.

State variables: The quantities like pressure, volume, temperature and mass used to study the behavior of thermodynamic system are called state variables.

Equation of state: The mathematical relation between the state variables (Thermodynamic variables) is called equation of state.

151)Why a heat engine with 100% efficiency can never be realized in practice?

$$Efficiency, \eta = 1 - \frac{T_2}{T_1}$$

For 100% efficiency, $T_2 = 0K$, which is not possible.

So 100% efficiency can never be realized in practice.

152)In summer, when the valve of a bicycle tube is opened, the escaping air appears cold. Why?

When the valve of a bicycle tube is opened, the air expands adiabatically. In adiabatic expansion, temperature decreases and hence escaping air appears cold.

153)Why does the brake drum of an automobile get heated up while moving down at constant speed?

Due to increase in internal energy

154)Can a room be cooled by leaving the door of an electric refrigerator open?

No, because the refrigerator is a heat engine works in backward direction.

155)Which of the two will increase the pressure more, an adiabatic or an isothermal process, in reducing the volume to 50%?

In isothermal process, $PV = constant$	In adiabatic process, $PV^{\gamma} = constant$
$P_2V_2 = P_1V_1$ $P_2 \times \frac{V_1}{2} = P_1V_1$ $P_2 = 2P_1$	$P_2{V_2}^{\gamma} = P_1{V_1}^{\gamma}$ $P_2 \times \left(\frac{V_1}{2}\right)^{\gamma} = P_1{V_1}^{\gamma}$ $P_2 = 2^{\gamma}P_1$
∴ Pressure in adiabatic process is greater than the pressure in isothermal process.	

(OR)

Adiabatic process

156)A thermo flask containing a liquid is shaken vigorously. What happens to its temperature?

Temperature of the liquid increases due to increase in internal energy

157)A sound wave is sent into a gas pipe. Does its internal energy change?

Yes, propagation of sound in a gas pipe is an adiabatic process and hence the internal energy changes.

158)How much will be the internal energy change in a) Isothermal process b) Adiabatic process?

a) Internal energy remains constant

b) Internal energy changes with temperature

159)The coolant in a chemical or a nuclear plant should have high specific heat. Why?

The coolant in a chemical or a nuclear plant should absorb large amount of heat for a small rise in temperature. Hence the specific heat of the coolant must be high.

160)Explain the following processes. a) Isochoric process b) Isobaric process

Isochoric process: A process that takes place at constant volume is called isochoric process.

Isobaric process: A process that takes place at constant pressure is called isobaric process

161)What is specific heat of a gas in a) isothermal process and b) adiabatic process? (1 time)

a) In isothermal process, specific heat is infinity

b) In adiabatic process, specific heat is zero

KINETIC THEORY

162)Define mean free path. (4 times)

Mean free path: The average distance covered by a molecule between two successive collisions is called mean free path.

163)Name two prominent phenomena which provide conclusive evidence of molecular motion.

* Diffusion of gases
* Brownian motion

164)How does kinetic theory justify Avogadro's hypothesis and show that Avogadro number in different gases is same?

Avogadro's law: At the same temperature and pressure, equal volumes of all gases contain equal number of molecules.

According to kinetic theory,

For 1st gas, $P_1V_1 = \frac{1}{3}N_1m_1V_1^2$ For 2nd gas, $P_2V_2 = \frac{1}{3}N_2m_2V_2^2$

If two gases are at same pressure and volume,

$$P_1V_1 = P_2V_2$$

$$\frac{1}{3}N_1m_1V_1^2 = \frac{1}{3}N_2m_2V_2^2 \quad ---\rightarrow (1)$$

If two gases are at same temperature, then kinetic energies of gas molecules are same.

$$\therefore \frac{1}{2}m_1V_1^2 = \frac{1}{2}m_2V_2^2$$

$$m_1V_1^2 = m_2V_2^2 \quad ---\rightarrow (2)$$

From (1) and (2) we get

$$\boxed{N_1 = N_2}$$

165)When does a real gas behave like an ideal gas? (4 times)
At low pressure and high temperature real gas behaves like an ideal gas.

166)State Boyle's law and Charles law. (3 times)
Boyle's law: At constant temperature, the volume of a given mass of gas is inversely proportional to its pressure.

$$V \propto \frac{1}{P} \implies PV = \text{constant}$$

Charles law: At constant pressure, the volume of a given mass of gas is directly proportional to its absolute temperature.

$$V \propto T \implies \frac{V}{T} = \text{constant}$$

167)State Dalton's law of partial pressure. (3 times)
The total pressure exerted by a mixture of non-reacting gases is equal to the sum of the partial pressures of the individual gases.

$$\therefore P = P_1 + P_2 + P_3 + ------$$

168)Pressure of an ideal gas in container is independent of shape of the container. Explain(1 time)
The pressure of an ideal gas in a container is given by

$$P = \frac{1}{3} nm\bar{v}^2$$

From the above equation, shape of the container is immaterial (Irrelevant). Hence pressure of an ideal gas is independent of shape of the container.

169)Explain the concept of degrees of freedom for molecules of a gas.
Degrees of freedom: The total number of independent ways in which a system can possess energy is called degree of freedom.

* Monoatomic gas has 3 degrees of freedom
* Diatomic gas has 5 degrees of freedom
* Triatomic gas has 6 degrees of freedom

170)What is the expression between pressure and kinetic energy of a gas molecule? (3 times)

$$P = \frac{2}{3} K$$

Where K is the average kinetic energy of gas molecule per unit volume of the gas

171)The absolute temperature of a gas is increased 3 times. What will be the increase in rms velocity of the gas molecule? (1 time)

$$v_{rms} \propto \sqrt{T}$$

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$$

$$Given\ T_2 = 3T_1$$

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{3T_1}} = \frac{1}{\sqrt{3}}$$

$$v_2 = \sqrt{3} v_1$$

$$\text{increase in rms velocity} = \sqrt{3}v_1 - v_1 = (1.732 - 1)v_1 = 0.732v_1$$

172)State the law of equipartition of energy. (1 time)
Law of equipartition of energy: For any dynamical system in thermal equilibrium, the total energy is equally divided among its various degrees of freedom and the energy associated with each degree of freedom is $\frac{1}{2} K_B T$.
Where
K_B = Boltzmann's constant
T = Absolute temperature of the system

JUNIOR INTERMEDIATE - PROBLEMS (LAQ)

WORK, ENERGY AND POWER:

1) A machine gun fires 360 bullets per minute and each bullet travels with a velocity of 600 ms^{-1}. If the mass of each bullet is 5gm, find the power of the machine gun?
Given,

$$\frac{N}{t} = 360\ bullets/sec = \frac{360}{60} = 6\ bullets/sec$$

$$v = 600\ m/s$$

$$m = 5\ gm = 5 \times 10^{-3}\ kg$$

Power of the machine gun is

$$P = \frac{w}{t} = \frac{N\left(\frac{1}{2}mv^2\right)}{t}$$

$$P = 6 \times \frac{1}{2} \times (5 \times 10^{-3}) \times 600^2$$

$$P = 3 \times 5 \times 10^{-3} \times 36 \times 10^4$$

$$P = 5400\ W = 5.4\ KW$$

2) A pump is required to lift 600kg of water per minute from a well 25m deep and to eject it with a speed of 50*ms*$^{-1}$. Calculate the power required to perform the above task?
Given, $m = 600\ kg$
$t = 1\ min = 60\ sec$
$h = 25\ m$
$v = 50\ m/s$

Power required is

$$P = \frac{mgh + \frac{1}{2}mv^2}{t} = \frac{(600 \times 10 \times 25) + \left(\frac{1}{2} \times 600 \times 50^2\right)}{60}$$

$$= \frac{600\left(250 + \frac{1}{2} \times 2500\right)}{60}$$

$$P = 10(250 + 1250) = 10 \times 1500$$

$$P = 15000\ W = 15\ KW$$

3) In a ballistics demonstration a police officer fires a bullet of mass 50.0 gm with speed 200 m s^{-1} on soft plywood of thickness 2.00 cm. The bullet emerges with only 10% of its initial kinetic energy. What is the emergent speed of the bullet?

Given, $m = 50\ gm = 50 \times 10^{-3}\ kg$

$u = 200\ m/s$

If v is the emergent speed of the bullet, then

$$\frac{1}{2}mv^2 = (10\%) \times \frac{1}{2}mu^2$$
$$v^2 = \frac{10}{100} \times u^2$$
$$v^2 = \frac{1}{10} \times 200^2 = \frac{40000}{10} = 4000$$
$$v = \sqrt{4000}$$
$$v = 63.2\ m/s$$

4) Consider a drop of mass1.00 g falling from a height 1.00 km. It hits the ground with a speed of 50.0 m s^{-1}. (a) What is the work done by the gravitational force? What is the work done by the unknown resistive force?

Given, $m = 1.00\ gm = 10^{-3} kg$

$h = 1.00\ km = 10^3 km$

$v = 50\ m/s$

a) Work done by the gravitational force:

$$W_g = mgh = 10^{-3} \times 10 \times 10^3 = 10\ J$$

b) Work done by the unknown resistive force:

From work – energy theorem,

$$W_g + W_r = \Delta K$$
$$W_g + W_r = \frac{1}{2}mv^2$$
$$10 + W_r = \frac{1}{2} \times 10^{-3} \times 50^2 = \frac{1}{2} \times 10^{-3} \times 2500 = \frac{2.5}{2} = 1.25$$
$$W_r = 1.25 - 10$$
$$W_r = -8.75\ J$$

5) Find the angle between force $\vec{F} = (3\,\hat{\imath} + 4\hat{\jmath} - 5\,\hat{k})$ unit and displacement $\vec{d} = (5\,\hat{\imath} + 4\,\hat{\jmath} + 3\,\hat{k})$ unit. Also find the projection of F on d?

Given,

$F = (3\,\hat{\imath} + 4\hat{\jmath} - 5\,\hat{k})$

$d = (5\,\hat{\imath} + 4\,\hat{\jmath} + 3\,\hat{k})$

Angle between $\vec{F}$ and $\vec{d}$ is

$$\cos\theta = \frac{\vec{F}.\vec{d}}{Fd} = \frac{(3\,\hat{\imath} + 4\hat{\jmath} - 5\,\hat{k}).(5\,\hat{\imath} + 4\,\hat{\jmath} + 3\,\hat{k})}{\sqrt{9+16+25}\sqrt{25+16+9}} = \frac{15+16-15}{\sqrt{50}\sqrt{50}} = \frac{16}{50} = 0.32$$
$$\theta = \cos^{-1}(0.32)$$

Projection of $\vec{F}$ on $\vec{d} = F\cos\theta = \sqrt{50} \times \frac{16}{50} = \frac{16}{\sqrt{50}}$

6) A cyclist comes to a skidding stop in 10 m. During this process, the force on the cycle due to the road is 200 N and is directly opposed to the motion. (a) How much work does the road do on the cycle? (b) How much work does the cycle do on the road?

a) The stopping force 200 N and displacement 10 m makes and angle of 180° with each other.

∴ Work done by the road, $W = Fs\cos 180° = -200 \times 10 = -2000\ J$

b) Road undergo no displacement. Thus work done by cycle on the road is zero.

7) Find the useful power used in pumping 3425m^3 of water per hour from a well 8m deep to the surface, supposing 40% of the horse power during pumping is wasted. What is the horse power of the engine?

Given, $V = 3425\ m^3$

$m = volume \times desity = 3425 \times 10^3\ kg$

$t = 1\ hour = 60 \times 60\ sec$

$h = 8\ m$

Formula:

$$\frac{60}{100}P = \frac{mgh}{t}$$
$$\frac{60}{100}P = \frac{(3425 \times 10^3) \times 9.8 \times 8}{60 \times 60}$$
$$P = \frac{(3425 \times 10^3) \times 9.8 \times 8 \times 100}{60 \times 60 \times 60}\ W$$
$$P = \frac{(3425 \times 10^3) \times 9.8 \times 8 \times 100}{60 \times 60 \times 60 \times 746}\ HP$$
$$P = 1.66 \times 10^2\ HP$$

8) Find total energy of a body of 5 kg mass which is at a height of 10m from the earth and falling downwards straightly with a velocity of 20 m/s ?(Take g = 10ms^{-2})

Given, $h = 10\ m;\quad m = 5kg;\quad v = 20\ m/s;\quad g = 10\ m/s^2$

$$K = \frac{1}{2}mv^2 = \frac{1}{2} \times 5 \times 20 \times 20 = 1000\ J$$
$$U = mgh = 5 \times 10 \times 10 = 500\ J$$

Total energy is

$$E = K + U = 1000 + 500$$
$$E = 1500\ J.$$

9) If $\vec{v} = 3\hat{\imath} + 4\hat{\jmath} + 5\hat{k}$ is the instantaneous velocity of a body of mass 1.5 kg. Calculate its kinetic energy.

Given,

$m = 1.5\ kg$

$\vec{v} = 3\hat{\imath} + 4\hat{\jmath} + 5\hat{k}$

$v = \sqrt{9+16+25} = \sqrt{50}\ m/s$

Kinetic energy is

$$K = \frac{1}{2}mv^2 = \frac{1}{2} \times 1.5 \times 50 = 37.5\ J$$

10) A ball falls from a height of 10m on to a hard horizontal floor and repeatedly bounces. If the coefficient of restitution is $1/\sqrt{2}$, what is the total distance travelled by the before it ceases to rebound?

Given,

$$h = 10\,m$$
$$e = \frac{1}{\sqrt{2}}$$

Total distance travelled is

$$d = h\left[\frac{1+e^2}{1-e^2}\right] = 10\left[\frac{1+\frac{1}{2}}{1-\frac{1}{2}}\right] = 10\left[\frac{\left(\frac{3}{2}\right)}{\left(\frac{1}{2}\right)}\right] = 10 \times 3 = 30\,m$$
$$d = 30\,m$$

11) A block of mass 5kg initially at rest at the origin is acted on by a force along the X – Positive direction represented by *F* = (20 + 5*x*)*N* . Calculate the work done by the force during the displacement of the block from x = 0 to x = 4m.

Given,

$$m = 5\,kg$$
$$F = (20+5x)N$$
$$x = 0 \; to \; x = 4\,m$$

Work done by the force is

$$W = \int_{x=0}^{x=4} F\,dx$$
$$W = \int_{x=0}^{x=4} (20+5x)\,dx = \left[20x + 5\frac{x^2}{2}\right]_0^4 = \left[80 + 5\times\frac{16}{2}\right] - 0 = 80 + 40 = 120$$
$$W = 120\,J$$

12) A force $F = -\frac{K}{x^2}(x \neq 0)$ acts on a particle along the X-axis. Find the work done by the force in displacing the particle from $x = +a \; to \; x = +2a$. Take K as a positive constant?

Given,

$$F = -\frac{K}{x^2}(x \neq 0)$$
$$x = +a \; to \; x = +2a.$$

Work done by the force is

$$W = \int_{x=a}^{x=2a} F\,dx = \int_a^{2a}\left(-\frac{K}{x^2}\right)dx = -K\int_a^{2a}\left(\frac{1}{x^2}\right)dx = -K\left[-\frac{1}{x}\right]_a^{2a}$$
$$W = K\left[\frac{1}{x}\right]_a^{2a} = K\left[\frac{1}{2a} - \frac{1}{a}\right] = K\left[-\frac{1}{2a}\right]$$
$$W = -\frac{K}{2a}\;J$$

OSCILLATIONS:

13) What is the length of a simple pendulum, which ticks seconds?

Given, T = 2 sec

Time period of a simple pendulum is

$$T = 2\pi\sqrt{\frac{L}{g}}$$
$$T^2 = 4\pi^2 \times \frac{L}{g}$$
$$4 = 4(9.8) \times \frac{L}{9.8}$$
$$L = 1\,m \quad (or) \quad L = 100\,cm$$

14) On an average a human heart is found to beat 75 times in a minute. Calculate its frequency and period.

$$\text{Beat frequency of heart}, n = \frac{75}{1\,min} = \frac{75}{60\,sec} = \frac{5}{4}\,sec^{-1} = 1.25\,Hz$$
$$\text{Time period}, T = \frac{1}{n} = \frac{4}{5}\,sec = 0.8\,sec$$

15) A particle executes SHM such that, the maximum velocity during the oscillation is numerically equal to half the maximum acceleration. What is the time period?

We know that $v_{max} = \omega A$; $a_{max} = \omega^2 A$

Given condition is

$$v_{max} = \frac{a_{max}}{2}$$
$$\omega A = \frac{\omega^2 A}{2}$$
$$\omega = 2$$
$$\text{Time period}, T = \frac{2\pi}{w} = \frac{2\pi}{2} = \pi\,sec$$

16) What are physical quantities having maximum value at the mean position in SHM?

Velocity and kinetic energy

17) A particle executing SHM has amplitude of 4cm and its acceleration at a distance of 1cm from the mean position is 2*cms*$^{-2}$. What will be its velocity when it is at a distance of 2cm from its mean position?

Given,

$$A = 4\,cm; \quad y_1 = 1\,cm; \quad a_1 = 3\,cm\,s^{-2};$$
$$y_2 = 2\,cm;$$
$$v_2 = ?$$

From $a_1 = \omega^2 y_1$

$$3 = \omega^2 \times 1$$
$$\omega = \sqrt{3}$$

From $V = \omega\sqrt{A^2 - y_2^2}$

$$V = \sqrt{3}\sqrt{16-4} = \sqrt{3}\sqrt{12} = \sqrt{36} = 6\,cm/s$$

18) A simple harmonic oscillator has a time period of 2s.What will be the change in the phase 0.25 s after leaving the mean position?

Given, $T = 2\ sec;\quad t = 0.25\ sec$

Phase change, $\Phi = \omega t = \frac{2\pi}{T}t$

$$\Phi = \frac{2\pi}{2} \times 0.25 = \frac{\pi}{4}\ radian$$

19) Calculate the change in the length of a simple pendulum of length 1m, when its period of oscillation changes from 2s to 1.5s?

Given,

$$L_1 = 1\ m;\quad T_1 = 2\ sec;\quad T_2 = 1.5\ sec = \frac{3}{2}\ sec$$

$$L_2 = ?\quad L_2 - L_1 = ?$$

Time period of a simple pendulum, $T = 2\pi\sqrt{\frac{L}{g}}$

$$T \propto \sqrt{L}$$

$$T^2 \propto L$$

$$\frac{T_2^2}{T_1^2} = \frac{L_2}{L_1} \Rightarrow \frac{\left(\frac{9}{4}\right)}{4} = \frac{L_2}{1}$$

$$L_2 = \frac{9}{16}$$

change in length, $L_2 - L_1 = \frac{9}{16} - 1 = \frac{-7}{16}$

∴ Change in length is decreased by $\frac{7}{16}\ m$

20) What happens to the time period of a simple pendulum if its length is increased up to four times?

Given, $l_2 = 4l_1$

We know that, $T = 2\pi\sqrt{\frac{l}{g}}$

$$T \propto \sqrt{L}$$

$$\frac{T_2}{T_1} = \sqrt{\frac{l_2}{l_1}} = \sqrt{4} = 2$$

$$T_2 = 2T_1$$

∴ Time period increased by 2 times

21) The mass and radius of a planet are double that of the earth. If the time period of a simple pendulum on the earth is T, Find the time period on the planet?

Given,

$$M_P = 2M_e \Rightarrow \frac{M_P}{M_e} = 2$$

$$R_P = 2R_e \Rightarrow \frac{R_P}{R_e} = 2$$

$$T_e = T;\quad T_P = ?$$

Time period of a simple pendulum, $T = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\frac{L}{\left(\frac{GM}{R^2}\right)}}$ $\left[\because g = \frac{GM}{R^2}\right]$

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

$$T \propto \sqrt{\frac{R^2}{M}}$$

$$\frac{T_P}{T_e} = \sqrt{\left(\frac{R_P}{R_e}\right)^2 \times \frac{M_e}{M_P}} = \sqrt{4 \times \frac{1}{2}} = \sqrt{2}$$

$$T_P = \sqrt{2}\ T$$

22) A freely falling body takes 2 seconds to reach the ground on a planet, when it is dropped from a height of 8m. If the period of a simple pendulum is π seconds on the planet, calculate the length of the pendulum?

Given,

$$t = 2\ sec;\quad h = 8\ m;\quad T = \pi\ sec;\quad L = ?$$

For a freel falling body, $h = \frac{1}{2}g_p t^2$

$$8 = \frac{1}{2}(g_p) \times 4$$

$$g_p = 4\ ms^{-2}$$

Time period of a simple pendulum on planet is

$$T = 2\pi\sqrt{\frac{L}{g_p}}$$

$$T^2 = 4\pi^2 \times \frac{L}{g_p}$$

$$\pi^2 = 4\pi^2 \times \frac{L}{4}$$

$$L = 1\ m$$

23) The bob of a pendulum is made of a hollow brass sphere. What happens to the time period of the pendulum, if the bob is filled with water completely? Why?

Time period, $T = 2\pi\sqrt{\frac{L}{g_p}}$

Where L = Length of the pendulum

When hollow brass sphere is completely filled with water, centre of mass does not change. Hence length of the pendulum remains same.

Therefore, time period of hollow brass sphere filled with water completely has 'no change'.

24) Two identical springs of force constant 'K' are joined one at the end of the other (in series). Find the effective force constant of the combination.

Total elongation, $e = e_1 + e_2$

$$\frac{F}{K_{eff}} = \frac{F}{K} + \frac{F}{K} = \frac{2F}{K}$$

$$K_{eff} = \frac{K}{2}$$

Effective force constant of combination, $K_{eff} = \frac{K}{2}$

THERMODYNAMICS:

25) A refrigerator is to maintain eatables kept inside at 9°C. If room temperature is 36°C, calculate the coefficient of performance?

Given,

$T_1 = 273 + 36 = 309\ K$

$T_2 = 273 + 9 = 282\ K$

Coefficient of performance is

$$\beta = \frac{T_2}{T_2 - T_1} = \frac{282}{309 - 282} = \frac{282}{27} = 10.4$$

26) An electric heater supplies heat to a system at a rate of 100W. If system performs work at a rate of 75 joules per second. At what rate is the internal energy increasing?

Given,

$\Delta Q = 100\ W$

$\Delta W = 75\ J/s$

We know that,

$\Delta Q = \Delta U + \Delta W$

$\Delta U = \Delta Q - \Delta W = 100 - 75 = 25\ W$

JUNIOR INTERMEDIATE – PROBLEMS (VSAQ)

UNITS AND DIMENSIONS:

1) The vernier scale of an instrument has 50 divisions which coincide with 49 main scale divisions. If each main scale division is 0.5 mm, then using this instrument what would be the minimum inaccuracy in the measurement of distance?

Given $50\ VSD = 49\ MSD$

$1\ VSD = \frac{49}{50}\ MSD$

And $1\ MSD = 0.5\ mm$

Formula:

Least count, $L.C = 1MSD - 1VSD$

$$= 1MSD - \frac{49}{50}\ MSD = \frac{1}{50} MSD = \frac{0.5}{50}\ mm = 0.01 mm$$

$L.C = 0.01\ mm$

∴Minimum inaccuracy in the measurement of distance is 0.01 mm

2) In a system of units, the unit of force is 100 N, unit of length 10 m and the unit of time is 100 s. What is the unit of mass in this system?

Unit of force, F = 100 N

Unit of length, L = 10 m

Unit of time, T = 100 s

We know that, $[F] = [MLT^{-2}]$

$$\therefore \text{Unit of mass}, M = \frac{F}{LT^{-2}} = \frac{100}{(10)(100)^{-2}} = 10^5\ kg$$

3) A physical quantity X is related to four measurable quantities a, b, c and d as follows: $X = a^2b^3c^{5/2}d^{-2}$. The percentage error in the measurement of a, b, c and d are 1%, 2%, 3% and 4% respectively. What is the percentage error in X?

Given,

$X = a^2b^3c^{5/2}d^{-2}$

The percentage error in X is

$$\frac{\Delta X}{X} \times 100 = 2\left(\frac{\Delta a}{a} \times 100\right) + 3\left(\frac{\Delta b}{b} \times 100\right) + \frac{5}{2}\left(\frac{\Delta c}{c} \times 100\right) + 2\left(\frac{\Delta d}{d} \times 100\right)$$

$$= 2(1) + 3(2) + \frac{5}{2}(3) + 2(4)$$

$$= 2 + 6 + 7.5 + 8$$

$$= 23.5\%$$

4) The velocity of a body is given by $v = At^2 + Bt + C$. If v and t are expressed in SI what are the units of A, B and C?

Given $v = At^2 + Bt + C$.

$Unit\ of\ A = \frac{v}{t^2} = \frac{ms^{-1}}{s^2} = ms^{-3}$

$Unit\ of\ B = \frac{v}{t} = \frac{ms^{-1}}{s} = ms^{-2}$

$Unit\ of\ C = v = ms^{-1}$

5) The error in measurement of radius of a sphere is 1%. What is the error in the measurement of volume?

Given,

$$\frac{\Delta r}{r} \times 100 = 1\%$$

Error in the measurement of volume is

$$\frac{\Delta V}{V} \times 100 = 3\left(\frac{\Delta r}{r} \times 100\right) = 3(1) = 3\%$$

6) The percentage error in the mass and speed are 2% and 3% respectively. What is the maximum error in kinetic energy calculated using these quantities?

Given,

$$\frac{\Delta m}{m} \times 100 = 2\%$$

$$\frac{\Delta v}{v} \times 100 = 3\%$$

We know that, $K = \frac{1}{2}mv^2$

Maximum error in kinetic energy is

$$\frac{\Delta K}{K} \times 100 = \left(\frac{\Delta m}{m} \times 100\right) + 2\left(\frac{\Delta v}{v} \times 100\right)$$

$$= 2 + 2(3) = 2 + 6$$

$$= 8\%$$

7) Find the relative error in Z, if $Z = A^4B^{1/3}/CD^{3/2}$

Given, $Z = A^4B^{1/3}/CD^{3/2}$

Relative error in Z is

$$\frac{\Delta Z}{Z} = 4\left(\frac{\Delta A}{A}\right) + \frac{1}{3}\left(\frac{\Delta B}{B}\right) + \frac{\Delta C}{C} + \frac{3}{2}\left(\frac{\Delta D}{D}\right)$$

8) The temperatures of two bodies measured by a thermometer are $t_1 = 20°C \pm 0.5°C$ and $t_2 = 50°C \pm 0.5\ °C$. Calculate the temperature difference and the error therein.

$$t' = t_2 - t_1 = (50°C \pm 0.5\ °C) - (20°C \pm 0.5°C)$$
$$t' = 30°C \pm 1°C$$

9) The resistance R = V/I where V = (100 ± 5) V and I = (10 ± 0.2) A. Find the percentage error in R.

We know that,

$$R = \frac{V}{I}$$

Percentage error in R is

$$\therefore \frac{\Delta R}{R} \times 100 = \left(\frac{\Delta V}{V} \times 100\right) + \left(\frac{\Delta I}{I} \times 100\right)$$
$$= \left(\frac{5}{100} \times 100\right) + \left(\frac{0.2}{10} \times 100\right)$$
$$= 5 + 2$$
$$\frac{\Delta R}{R} \times 100 = 7\%$$

10) State the number of significant figures in the following.

a)6729 **b)0.024** **c)0.08240** **d)6.032** **e)4.57×10^8**

a)4 b)2 c)4 d)4 e)3

11) The measured mass and volume of a body are 2.42 g and 4.7 cm^3 respectively with possible errors 0.01 g and 0.1cm^3. Find the maximum error in density?

Given,

$$m = 2.42\ gm; \quad V = 4.7\ cm^3$$
$$\Delta m = 0.01\ gm; \quad \Delta V = 0.1\ cm^3$$

We know that

$$\rho = \frac{m}{V}$$
$$\frac{\Delta\rho}{\rho} \times 100 = \left(\frac{\Delta m}{m} \times 100\right) + \left(\frac{\Delta V}{V} \times 100\right)$$
$$\frac{\Delta\rho}{\rho} \times 100 = \left(\frac{0.01}{2.42} \times 100\right) + \left(\frac{0.1}{4.7} \times 100\right) = 2.54\%$$

12) Each side of a cube is measured to be 7.203 m. What are the total surface area and the volume of the cube to appropriate significant figures?

Given each side of a cube, a = 7.203 m

i) Total surface area of the cube $= 6a^2\ m^2$
$$= 6 \times (7.203)^2$$
$$= 311.299254$$
$$= 311.3\ m^2$$

ii) Volume of the cube $= a^3\ m^3$
$$= (7.203)^3 = 373.714754$$
$$= 373.7\ m^3$$

13) 5.74 g of a substance occupies 1.2 cm³. Express its density by keeping the significant figures in view.

Given, m = 5.74 g

V = 1.2 cm³

$$\therefore \text{density}, \rho = \frac{m}{V} = \frac{5.74}{1.2} = 4.78333$$
$$\rho = 4.8\ g/cm^3$$

14) Three measurements of the time for 20 oscillations of a pendulum give t_1 = 39.6 s, t_2 = 39.9 s and t_3 = 39.5 s. What is the precision in the measurement? What is the accuracy of the measurement?

Given, t1 = 39.6 s, t_2 = 39.9 s and t_3 = 39.5 s

$$T_{Mean\ value} = \frac{t_1 + t_2 + t_3}{3}$$
$$= \frac{39.6 + 39.9 + 39.5}{3} = \frac{119}{3} = 39.666$$
$$= 39.7\ sec$$

Precision: 0.1 sec

Accuracy: 39.6 sec

15) The distance of galaxy from earth is of the order of 10^{25}m. Calculate the order of magnitude of the time taken by the light to reach us from the galaxy?

Given, Order of distance = 10^{25} m

Order of velocity of light = 10^8 m

Order of magnitude of the time taken by the light to reach us from the galaxy is

$$t = \frac{d}{v} = \frac{10^{25}}{10^8} = 10^{17} sec$$

16) The Earth – Moon distance is about 60 Earth radius. What will be the approximate diameter of the earth as seen from the moon?

Given, Earth – moon distance = 60 R

Earth radius = R

Angular diameter of the earth as seen from the moon is

$$\theta = \frac{Diameter}{Distance} = \frac{2R}{60R} = \frac{1}{30}\ radian = \frac{1}{30} \times \frac{180^\circ}{\pi} = \frac{6^\circ}{\pi} \approx 2^\circ$$

17) A new unit of length is chosen so that the speed of light in vacuum is 1 ms^{-1}. If light takes 8 min 20 s to cover this distance, what is the distance between the sun and earth in terms of the new unit?

In new system, c = 1m/s

t = 8 min 20 sec = 500 sec

Distance between the sun and the earth in new system is

$$d = c \times t$$
$$d = 1 \times 500$$
$$d = 500\ m$$

18) A student measures the thickness of a human hair using a microscope of magnification 100. He takes 20 observations and finds that the average thickness is 3.5 mm. What is the estimate of the thickness of hair?

Given, magnification = 100
Observed thickness = 3.5 mm
Real thickness = ?

Formula:

$$Magnification = \frac{Observed\ thickness}{Real\ thickness}$$

$$Real\ thickness = \frac{Observed\ thickness}{Magnification} = \frac{3.5\ mm}{100} = 0.035\ mm$$

19) In the expression $P = El^2m^{-5}G^{-2}$ the quantities E, l, m and G denote energy angular momentum, mass and gravitational constant respectively. Show that P is a dimensionless quantity?

$Energy, E = [ML^2T^{-2}]$
$Angular\ momentum, l = [ML^2T^{-1}]$
$mass, m = [M]$
$Gravitational\ constant, G = [M^{-1}L^3T^{-2}]$

Given condition is

$$P = El^2m^{-5}G^{-2}$$
$$P = [ML^2T^{-2}][ML^2T^{-1}]^2[M]^{-5}[M^{-1}L^3T^{-2}]^{-2}$$
$$P = [ML^2T^{-2}][M^2L^4T^{-2}]\ [M]^{-5}[M^2L^{-6}T^4]$$
$$P = [M^{1+2-5+2}L^{2+4-6}T^{-2-2+4}]$$
$P = [M^0L^0T^0]$ ∴ P is a dimensional quantity.

20) Calculate the angle of a) 1° (degree) b) 1' (minute) and c) 1'' (second) in radians.

We Know that $180° = \pi\ radian \Rightarrow 1° = \frac{\pi}{180} radian$

$$1° = 60' \Rightarrow 1' = \frac{1°}{60}$$
$$1' = 60'' \Rightarrow 1'' = \frac{1'}{60}$$

a) $1° = \frac{\pi}{180} radian = 1.745 \times 10^{-2}\ radian$

b) $1' = \frac{1°}{60} = \frac{1.745\times10^{-2}}{60} = 2.908 \times 10^{-4}\ radian$

c) $1'' = \frac{1'}{60} = \frac{1°}{60\times60} = \frac{1.745\times10^{-2}}{60\times60} = 4.85 \times 10^{-6}\ radian$

21) The sun's angular diameter is measured to be 1920''. The distance D of the sun from the earth is $1.496 \times 10^{11} m$. what is the diameter of the sun?

Given $\theta = 1920'' = 1920 \times 4.85 \times 10^{-6}\ radian = 9.31 \times 10^{-3}\ radian$
$D = 1.496 \times 10^{11} m$

Diameter of the sun is

$$d = \theta D = 9.31 \times 10^{-3} \times 1.496 \times 10^{11}$$
$$d = 13.93 \times 10^{8}$$
$$d = 1.39 \times 10^{9}\ m$$

MOTION IN A PLANE:

22) A force $2i + j - k$ newton acts on a body which is initially at rest. At the end of 20 seconds the velocity of the body is $4i + 2j - 2k$ ms^{-1}. What is the mass of the body?

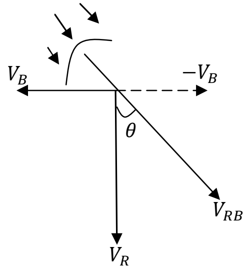
Given,

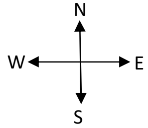
$\vec{F} = 2i + j - k;\quad F = \sqrt{4+1+1} = \sqrt{6}\,N$
Initial velocity, $u = 0$
$\vec{v} = 4i + 2j - 2k;\quad v = \sqrt{16+4+4} = \sqrt{24} = 2\sqrt{6}\,m/s$
Time, $t = 20\ sec$

We know that, $F = ma$

$$F = m\left(\frac{v-u}{t}\right)$$
$$\sqrt{6} = m\left(\frac{2\sqrt{6}}{20}\right) = m\left(\frac{\sqrt{6}}{10}\right)$$
$$m = 10\ kg$$

23) Rain is falling vertically with a speed of 35 ms^{-1}. A woman rides a bicycle with a speed of 12 ms^{-1} in east to west direction. What is the direction in which she should hold her umbrella?





Given,

$V_R = 35\ m/sec$
$V_B = 12\ m/sec$

Let V_{RB} is the velocity of rain w.r.to bicycle.

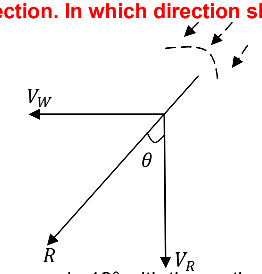
$$\therefore \overrightarrow{V_{RB}} = \overrightarrow{V_R} - \overrightarrow{V_B}$$

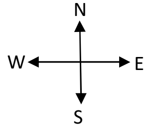
Direction of V_{RB} is

$$\tan\theta = \frac{V_B}{V_R} = \frac{12}{35} = 0.343$$
$$\theta = \tan^{-1}(0.343)$$
$$\theta = 19°$$

Therefore, the woman should hold her umbrella at an angle 19° with the vertical towards the west.

24) Rain is falling vertically with a speed of 35 ms^{-1}. Winds starts blowing after sometime with a speed of 12 ms^{-1} in east to west direction. In which direction should a boy waiting at a bus stop hold his umbrella?





Given,

$V_R = 35\ m/sec$
$V_W = 12\ m/sec$

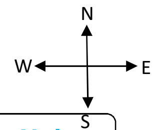
Let R is the resultant of V_R and V_W

Direction of R is

$$\tan\theta = \frac{V_W}{V_R} = \frac{12}{35} = 0.343$$
$$\theta = \tan^{-1}(0.343)$$
$$\theta = 19°$$

Therefore, the boy should hold his umbrella at an angle 19° with the vertical towards the east.

25) Wind is blowing from the south at 5m/s. To a cyclist it appears to be blowing from the east at 5m/s. Find the velocity of the cyclist?



Given,

$\overrightarrow{V_W} = (5j)\ m/s$
$\overrightarrow{V_{WC}} = (-5i) m/s$

But $\overrightarrow{V_{WC}} = \overrightarrow{V_W} - \overrightarrow{V_C}$

$\vec{V_C} = \vec{V_W} - \vec{V_{WC}} = 5j - (-5i) = (5i + 5j)\ m/s$

$V_c = \sqrt{25 + 25} = \sqrt{50} = 2\sqrt{5}\ m/s$

Therefore, velocity of cyclist is $2\sqrt{5}\ m/s$ towards N – E.

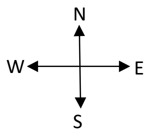
26) O is a point on the ground chosen as origin. A body first suffers a displacement of $10\sqrt{2}$ m north – east, next 10m north and finally $10\sqrt{2}$ m north – west. How far is the body from the origin?

Given,

$\vec{S_1} = 10\sqrt{2}\,m\ due\ N - E = (10i + 10j)m$

$\vec{S_2} = 10\,m\ due\ N = (10j)m$

$\vec{S_3} = 10\sqrt{2}\,m\ due\ N - W = (-10i + 10j)m$



$\therefore \vec{S} = \vec{S_1} + \vec{S_2} + \vec{S_3} = 10i + 10j + 10j - 10i + 10j = 30j$

Therefore, the body is at a distance of 30m from the origin towards north.

LAWS OF MOTION:

27) A batsman hits back a ball straight in the direction of the bowler without changing its initial speed of 12 ms^{-1}. If the mass of the ball is 0.15 kg, determine the impulse imparted to the ball.

Given,

$m = 0.15\ kg$

$v = 12\ m/s$

Impulse, $J = 2mv$

$J = 2 \times 0.15 \times 12$

$J = 3.6\ Ns$

28) Calculate the time needed for a net force of 5N to change the velocity of a 10kg mass by 2m/s.

Given,

$F = 5\ N$

$m = 10\ kg$

$(v - u) = 2\ m/s$

We know that,

$F = m\left(\frac{v-u}{t}\right)$

$5 = 10\left(\frac{2}{t}\right)$

$t = \frac{20}{5} = 4\ sec$

29) An astronaut accidentally gets separated out of his small spaceship accelerating in inter stellar space at a constant rate of 100 ms^{-2}. What is the acceleration of the astronaut the instant after he is outside the spaceship?

The acceleration of the astronaut is zero.

30) A bullet of mass 0.04 kg moving with a speed of 90 ms^{-1} enters a heavy wooden block and is stopped after a distance of 60 cm. What is the average resistive force exerted by the block on the bullet?

$m = 0.04kg = 4 \times 10^{-2}kg$

$v = 90m/s$

$s = 60cm = 60 \times 10^{-2}m$

Average resistive force is

$F = \frac{mv^2}{2s} = \frac{4 \times 10^{-2} \times 81 \times 10^2}{2 \times 60 \times 10^{-2}}$

$F = 270N$

31) The motion of a particle of mass m is described by $y = ut + \frac{1}{2}gt^2$. Find the force acting on the particle?

Given $y = ut + \frac{1}{2}gt^2$

Now

$v = \frac{dy}{dt} = u + gt$

$a = \frac{dv}{dt} = g$

Then the force is given

$F = ma = mg$

32) Determine the maximum acceleration of the train in which a box lying on its floor will remain stationary, given that the co-efficient of static friction between the box and the train's floor is 0.15.

Given $\mu_s = 0.15$

$\therefore\ a_{max} = \mu_s g = 0.15 \times 10 = 1.5\ m/s^2$

33) A mass of 4 kg rests on a horizontal plane. The plane is gradually inclined until at an angle θ = 15° with the horizontal, the mass just begins to slide. What is the coefficient of static friction between the block and the surface?

Given $\theta_{max} = 15°$

Coefficient of static friction is

$\mu_s = \tan(\theta_{max}) = \tan 15° = 0.27$

34) A cyclist speeding at 18 km/h on a level road takes a sharp circular turn of radius 3 m without reducing the speed. The coefficient of static friction between the tyres and the road is 0.1. Will the cyclist slip while taking the turn?

Given,

$v = 18\ kmph = 18 \times \left(\frac{5}{18}\right) m/s = 5\ m/s$

$r = 3\ m$

Condition for cyclist not to slip is given by

$v_{max} = \sqrt{\mu_s g r}$

$v_{max} = \sqrt{0.1 \times 10 \times 3}$

$v_{max} = \sqrt{3} = 1.732\ m/s$

But given v = 5 m/s

$\therefore v > v_{max}$

Therefore the cyclist will slip while taking the circular turn.

35) The linear momentum of a particle as a function of time t is given by $p = a + bt$, where a and b are positive constants. What is the force acting on the particle?

Given,

$p = a + bt,$

The force acting on the particle is

$$F = \frac{dp}{dt} = \frac{d}{dt}(a + bt) = b$$
$$F = b$$

36) A constant force acting on a body of mass 3.0kg changes its speed from 2.0m/s to 3.5m/s in 25s. The direction of motion of the body remains unchanged. What is the magnitude and direction of the force?

Given,

$m = 3\,kg$
$v - u = 1.5\,m/s$
$t = 25\,s$

We know that,

$$F = m\left(\frac{v-u}{t}\right) = 3 \times \frac{1.5}{25} = \frac{4.5}{25} = 0.18\,N$$

Therefore, the force will be in the direction of motion of the body.

37) A ball of mass m is thrown vertically upward from the ground and reaches a height h before momentarily coming to rest. If g is acceleration due to gravity, what is the impulse received by the ball due to gravity force during its flight?

Impulse, $J = 2mv$

But $v = \sqrt{2gh}$

$\therefore J = 2m\sqrt{2gh} = \sqrt{4m^2 2gh} = \sqrt{8m^2 gh}$

38) A container of mass 200 kg rests on the back of an open truck. If the truck accelerates at 1.5 m/s^2, what is the minimum coefficient of static friction between the container and the bed of the truck required to prevent the container from sliding off the back of the truck?

Given,

$m = 200kg$
$a = 1.5\,m/s^2$

We know that, $a = \mu g$

$$u = \frac{a}{g} = \frac{1.5}{10} = 0.15$$

SYSTEM OF PARTICLES AND ROTATIONAL MOTION:

39) Find the torque of a force $7i + 3j - 5k$ about the origin. The force acts on a particle whose position vector is $i - j + k$

Given,

$\vec{F} = 7i + 3j - 5k$
$\vec{r} = i - j + k$

We know that,

$$\vec{\tau} = \vec{r} \times \vec{F}$$
$$\vec{\tau} = \begin{vmatrix} i & j & k \\ 1 & -1 & 1 \\ 7 & 3 & -5 \end{vmatrix} = i(5-3) - j(-5-7) + k(3+7)$$
$$= 2i + 12j + 10k$$

40) When 100 J of work is done on a fly wheel, its angular velocity is increased from 60rpm to 180rpm. What is the moment of inertia of the wheel?

Given,

$$n_1 = 60rpm = \frac{60}{60}rps = 1\,rps\,;$$
$$n_2 = 180rpm = \frac{180}{60}rps = 3\,rps$$
$$\omega_1 = 2\pi n_1 = 2\pi \times 1 = 2\pi$$
$$\omega_2 = 2\pi n_2 = 2\pi \times 3 = 6\pi$$
$$W = 100\,J$$

We know that,

$$W = \frac{1}{2}I(\omega_2^2 - \omega_1^2)$$
$$100 = \frac{1}{2}I(36\pi^2 - 4\pi^2) = \frac{1}{2}I \times 32\pi^2 = 16I \times \pi^2$$
$$I = \frac{100}{16\pi^2} = 0.63\,kgm^2$$

41) Find the scalar and vector product of two vectors $\vec{a} = (3i - 4j + 5k)$ and $\vec{b} = (-2i + j - 3k)$?

1) $\vec{a}.\vec{b} = (3i - 4j + 5k).(-2i + j - 3k) = -6 - 4 - 15 = -25$

2) $\vec{a} \times \vec{b} = \begin{vmatrix} i & j & k \\ 3 & -4 & 5 \\ -2 & 1 & -3 \end{vmatrix} = i(12-5) - j(-9+10) + k(3-8)$

$$= 7i - i - 5k$$

42) The moment of inertia of a fly wheel making 300 revolutions per minute is 0.3 kgm^2. Find the torque required to bring it to rest in 20s?

Given,

$$n_1 = 300rpm = \frac{300}{60}rps = 5\,rps$$
$$\omega_1 = 2\pi n_1 = 2\pi \times 5 = 10\pi$$
$$I = 0.3\,kgm^2$$
$$\omega_2 = 0$$
$$t = 20\,s$$

We know that,

$$\tau = I\alpha = I\left(\frac{\omega_2 - \omega_1}{t}\right)$$
$$\tau = 0.3\left(\frac{-10\pi}{20}\right) = -\frac{0.3 \times 3.14}{2} = -\frac{0.942}{2} = -0.471\,Nm$$

Torque required to bring it to rest is 0.471 Nm.

43) What is the moment of inertia of a disc about one of its diameter?

$$I = \frac{MR^2}{4}$$

44) What is the moment of inertia of a rod of mass M, length l about an axis perpendicular to it through one end?

$$I = \frac{Ml^2}{3}$$

45) What is the moment of inertia of a ring about a tangent to the circle of the ring?

$I = \frac{3}{4}MR^2$

46) To maintain a rotor at a uniform angular speed of 200 rad s[-1], an engine needs to transmit a torque of 180 Nm. What is the power required by the engine?

Given,

$\omega = 200\,rad\,s^{-1}; \qquad \tau = 180\,Nm$

Power, $P = \tau\omega$

$P = 180 \times 200$

$P = 36000\,W$

GRAVITATION:

47) Two spherical balls each of mass 1 kg are placed 1 cm apart. Find the gravitational force of attraction between them?

Given

$m_1 = m_2 = 1\,kg$

$r = 1\,cm = 10^{-2}\,m$

$G = 6.67 \times 10^{-11}\,Nm^3/kg^2$

Gravitational force of attraction between them is

$$F = \frac{Gm_1m_2}{r^2} = \frac{6.67 \times 10^{-1} \times 1 \times 1}{10^{-4}} = 6.67 \times 10^{-7}\,N$$

MECHANICAL PROPERITES OF SOLIDS:

48) A copper wire of 1 mm diameter is stretched by applying a force of 10 N. find the stress in the wire?

Given,

$D = 1mm$

$r = \frac{D}{2} = \frac{1}{2}mm = \frac{1}{2} \times 10^{-3}m$

$F = 10\,N$

$$\therefore Stress = \frac{F}{A} = \frac{F}{\pi r^2} = \frac{10}{\left(\frac{22}{7}\right) \times \frac{1}{4} \times 10^{-6}} = \frac{280}{22} \times 10^6 = 12.73 \times 10^6 = 1.273 \times 10^7 N/m^2$$

49) A tungsten wire of length 20cm is stretched by 0.1cm. Find the strain on the wire?

Given,

$l = 20\,cm$

$\Delta l = 0.1\,cm$

$\therefore Strain = \frac{\Delta l}{l} = \frac{0.1}{20} = 0.005$

50) If an iron wire is stretched by 1%, what is the strain on the wire?

Given,

$\frac{\Delta l}{l} = 1\% = \frac{1}{100} = 0.01$

$\therefore Strain = \frac{\Delta l}{l} = 0.01$

AIMSTUTORIAL Physics-1

51) Determine the pressure required to reduce the given volume of water by 2%. Bull modulus of water is $2.2 \times 10^9\,N/m^2$

Given,

$\frac{\Delta V}{V} = -2\% = -\frac{2}{100}$

$K = 2.2 \times 10^9\,N/m^2$

We know that,

$K = \frac{P}{\left(-\frac{\Delta V}{V}\right)}$

$P = K\left(-\frac{\Delta V}{V}\right) = 2.2 \times 10^9 \left(\frac{2}{100}\right) = 4.4 \times 10^7\,N/m^2$

52) A steel wire of length 20cm is stretched to increase its length by 0.2cm. Find the lateral strain in the wire if the Poisson's ratio for steel is 0.19?

Given,

$\text{Longitudinal strain} = \frac{\Delta l}{l} = \frac{0.2}{20} = 0.01$

$\text{Poisson's ratio} = 0.19$

We know that,

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

$\text{Lateral strain} = \text{Poisson's ratio} \times \text{Longitudinal strain}$

$\text{Lateral strain} = 0.19 \times 0.01 = 0.0019$

MECHANICAL PROPERTIES OF FLUIDS:

53) If the diameter of a soap bubble 10mm and its surface tension is 0.04 Nm[-1], find the excess pressure inside the bubble?

Given,

$D = 10mm$

$R = \frac{D}{2} = 5mm = 5 \times 10^{-3}m$

$S = 0.04\,N/m$

Excess pressure inside the bubble is

$$P = \frac{4S}{R} = \frac{4 \times 0.04}{5 \times 10^{-3}} = \frac{0.16}{5} \times 10^3 = \frac{160}{5} = 32\,\,N/m^2$$

54) Find the excess pressure inside a soap bubble of radius 5 mm (surface tension is 0.04 N/m)?

Given,

$R = 5mm = 5 \times 10^{-3}m$

$S = 0.04\,N/m$

Excess pressure inside the bubble is

$$P = \frac{4S}{R} = \frac{4 \times 0.04}{5 \times 10^{-3}} = \frac{0.16}{5} \times 10^3 = \frac{160}{5} = 32\,\,N/m^2$$

Target ⇨ 60 Min. Material –Max. Marks

55) Calculate the work done in blowing a soap bubble of diameter 0.6cm against the surface tension force. (Surface tension of soap solution $= 2.5 \times 10^{-2}\ N/m$)

Given,

$$S = 2.5 \times 10^{-2}\ N/m$$
$$D = 0.6\ cm$$
$$R = \frac{D}{2} = 0.3\ cm = 0.3 \times 10^{-2}\ m$$

Work done in blowing a soap bubble is

$$W = 8\pi R^2 S = 8 \times 3.14 \times (0.3 \times 10^{-2})^2 \times 2.5 \times 10^{-2}$$
$$W = 5.652 \times 10^{-6}\ J$$

56) If work done by an agent to form a bubble of radius R is W, then how much energy is required to increase its radius to 2R?

Given,

Work done to form a bubble of radius R is W

$$W = 8\pi R^2 S$$

Energy required to increase its radius from R to 2R is

$$E = 8\pi[(2R)^2 - R^2]S = 8\pi[4R^2 - R^2]S = 8\pi(3R^2)S$$
$$E = 3(8\pi R^2 S) = 3W$$

57) If two soap bubbles of radii R_1 and R_2 (in vacuum) coalesce under isothermal conditions, what is the radius of the new bubble?

Work done to form bubble of radius R

= Work done to form bubble of radius R_1

+ Work done to form bubble of radius R_2

$$8\pi R^2 S = 8\pi {R_1}^2 S + 8\pi {R_2}^2 S$$
$$R^2 = {R_1}^2 + {R_2}^2$$
$$R = \sqrt{{R_1}^2 + {R_2}^2}$$

58) The two thigh bones (femurs), each of cross-sectional area10 cm^2 support the upper part of a human body of mass 40 kg. Estimate the average pressure sustained by the femurs.

Given $A = 2 \times 10\ cm^2 = 20 \times 10^{-4}\ m^2$

$m = 40\ kg$

Average pressure is

$$P_{av} = \frac{F}{A} = \frac{mg}{A} = \frac{40 \times 10}{20 \times 10^{-4}}$$
$$P_{av} = 2 \times 10^5 \frac{N}{m^2}$$

59) What is the pressure on a swimmer 10 m below the surface of a lake?

Given $h = 10\ m$

$P_a = 1.01 \times 10^5\ Pa$

$$\therefore P = P_a + \rho g h$$
$$= (1.01 \times 10^5) + (10^3 \times 10 \times 10)$$
$$= (1.01 \times 10^5) + 10^5$$
$$= 2.01 \times 10^5\ Pa$$
$$\approx 2\ atm$$

60) The density of the atmosphere at sea level is 1.29 kg/m^3. Assume that it does not change with altitude. Then how high would the atmosphere extend?

Given $\rho = 1.29$ kg/m^3

$P_a = 1.01 \times 10^5\ Pa$

$$\therefore P_{atm} = \rho g h$$
$$1.01 \times 10^5 = 1.29 \times 9.8 \times h$$
$$h = \frac{1.01 \times 10^5}{1.29 \times 9.8} = \frac{1.01 \times 10^5}{12.642} = 7989\ m$$
$$h \approx 8\ km$$

61) Show that Reynold's number is dimensionless.

We know that Reynold's number is

$$R_e = \frac{\rho v D}{\eta}$$

Where $\rho = density\ of\ fluid = [ML^{-3}]$

$v = velocity\ of\ fluid = [LT^{-1}]$

$D = diameter\ of\ tube = [L]$

$\eta = coefficient\ of\ viscosity = [ML^{-1}T^{-1}]$

$$\therefore R_e = \frac{\rho v D}{\eta} = \frac{[ML^{-3}][LT^{-1}][L]}{[ML^{-1}T^{-1}]} = \frac{[ML^{-1}T^{-1}]}{[ML^{-1}T^{-1}]} = 1$$

Therefore, Reynold's number is dimensionless.

62) What should be the radius of a capillary tube if water has to rise to a height of 6 cm in it? (Surface tension of water $= 7.2 \times 10^{-2}\ Nm^{-1}$)

Given,

$$h = 6cm = 6 \times 10^{-2} m$$
$$S = 7.2 \times 10^{-2}\ Nm^{-1}$$
$$\rho = 10^3\ kg/m^3$$

Radius of the capillary tube is

$$r = \frac{2S}{\rho g h} = \frac{2 \times 7.2 \times 10^{-2}}{10^3 \times 10 \times 6 \times 10^{-2}} = 2.4 \times 10^{-4} = 0.00024\ m$$

THERMAL PROPERTIES OF MATTER:

63) Find the increase in temperature of aluminium rod if its length is to be increased by 1%? (α for aluminium $= 25 \times 10^{-6}\ /°C$)

Given,

$$\alpha = 25 \times 10^{-6}\ /°C$$
$$\frac{\Delta l}{l} = 1\% = \frac{1}{100}$$

We know that,

$$\alpha = \frac{\Delta l}{l \times \Delta t}$$
$$\Delta t = \frac{\Delta l}{l} \times \frac{1}{\alpha} = \frac{1}{100} \times \frac{1}{25 \times 10^{-6}} = \frac{1}{25 \times 10^{-4}} = \frac{10000}{25} = 400°C$$
$$\Delta t = 400°C$$

64) What is the temperature for which the readings on Kelvin and Fahrenheit scales are same?

$K = F = x(say)$

We know that,

$$\frac{K-27.015}{100} = \frac{F-32}{180}$$
$$\frac{x-273.15}{5} = \frac{x-32}{9}$$
$$9x - 2458.35 = 5x - 160$$
$$4x = 2458.35 - 160 = 2298.35$$
$$x = 574.58$$
$$\therefore x = 574.6°F = 574.6K$$

65) If the maximum intensity of radiation for a black body is found at 2.65μm what is the temperature of the radiating body? (Wein's constant = $2.9 \times 10^{-3} mK$)

Given,

$\lambda_{max} = 2.65\mu m = 2.65 \times 10^{-6}\ m$

Wein's constant, b = $2.9 \times 10^{-3} mK$

We know that,

$$\lambda_{max} T = constant\ (b)$$
$$T = \frac{b}{\lambda_{max}} = \frac{2.9 \times 10^{-3}}{2.65 \times 10^{-6}} = 1094\ K$$

66) If the volume of nitrogen of mass 14 kg is 0.4 m^3 at 30°C; calculate the pressure.

Given,

$$m = 14kg = 14 \times 10^3 gm$$
$$M = 28$$
$$V = 0.4\ m^3$$
$$T = 30 + 273 = 303K$$

We know that,

$$PV = \frac{m}{M}RT$$
$$P = \frac{mRT}{MV} = \frac{14 \times 10^3 \times 8.314 \times 303}{28 \times 0.4} = 31.5 \times 10^5\ N/m^2$$

67) The volume of a mass of gas at 37°C and a pressure of 75 cm of mercury is 620 cc. Find the volume at N.T.P?

Given,

$T_1 = 273 + 37 = 310K$ $\quad$ $T_2 = 273K$

$P_1 = 75\ cm\ of\ Hg$ $\quad$ $P_2 = 76\ cm\ of\ Hg$

$V_1 = 620\ cc$ $\quad$ $V_2 = ?$

We know that,

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$
$$\frac{75 \times 620}{310} = \frac{76 \times V_2}{273} \Longrightarrow 150 = \frac{76 \times V_2}{273}$$
$$V_2 = \frac{150 \times 273}{76} = 538.81\ cc$$

AIMSTUTORIAL Physics-1

68) Two absoluting scales A and B have triple points of water defined to be 200A and 350B. What is the relation between T_A and T_B?

$$\frac{T_A}{T_B} = \frac{200}{350} = \frac{4}{7}$$

KINETIC THEORY:

69) What is the ratio of rms speed of oxygen and hydrogen molecules at the same temperature?

The rms speed of gas molecule is given by

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$
$$V_{rms} \propto \frac{1}{\sqrt{M}}$$
$$\therefore \frac{V_O}{V_H} = \sqrt{\frac{M_H}{M_O}} = \sqrt{\frac{2}{32}} = \sqrt{\frac{1}{16}} = \frac{1}{4}$$

70) Four molecules of a gas have speeds 1, 2, 3 and 4 km/s. find the rms speed of the gas molecule?

$$V_{rms} = \sqrt{\frac{{V_1}^2 + {V_2}^2 + {V_3}^2 + {V_4}^2}{4}}$$
$$V_{rms} = \sqrt{\frac{1^2 + 2^2 + 3^2 + 4^2}{4}} = \sqrt{\frac{1+4+9+16}{4}} = \sqrt{\frac{30}{4}} = \sqrt{7.5} = 2.7km/sec$$

71) If a gas has f degrees of freedom, find the ratio of C_P and C_V?

If a gas has f degrees of freedom, then

$$C_V = \frac{f}{2}R \quad and$$
$$C_P = C_V + R = \frac{f}{2}R + R = \left(\frac{f}{2} + 1\right)R$$
$$\therefore \frac{C_P}{C_V} = \frac{\left(\frac{f}{2} + 1\right)R}{\frac{f}{2}R} = 1 + \frac{2}{f}$$

72) Calculate the molecular K.E of 1 gram of Helium (Molecular weight 4) at 127°C. Given $R = 8.31\ J\ mol^{-1}\ K^{-1}$

$$T = (127 + 273)K = 400K$$
$$n = \frac{m}{M} = \frac{1}{4}\ mole$$

Molecular kinetic energy is

$$K.E = \frac{3}{2}nRT = \frac{3}{2} \times \frac{1}{4} \times 8.31 \times 400 = 3 \times 8.31 \times 50 = 1246.5\ J$$

73) When pressure increases by 2%, what is the percentage decrease in the volume of a gas, assuming Boyle's law is obeyed?

$$\frac{\Delta P}{P} \times 100 = 2\%$$

According to Boyle's law, $V \propto \frac{1}{P}$

$$\therefore \frac{\Delta V}{V} \times 100 = -\frac{\Delta P}{P} \times 100 = -2\%$$

∴ Volume decreases by 2%