Version No.			

ROLL NUMBER						

Answer Sheet No.____________

Sign. of Candidate___________

Sign. of Invigilator___________

PHYSICS HSSC–I (3^{rd} Set Solution)

SECTION – A (Marks 17)

Time allowed: 25 Minutes

Section – A is compulsory. All parts of this section are to be answered on this page and handed over to the Centre Superintendent. Deleting/overwriting is not allowed. Do not use lead pencil.

Q.1 Fill the relevant bubble for each part. Each part carries one mark.

(1) The percentage error in the measurement of mass and speed are 2% and 3% respectively. How much will be the maximum percentage error in the estimation of K.E obtained?

A. 1% ○ B. 4% ○
C. 5% ○ **D. 8%** ●

(2) A person first displaces 10 units towards North. After second displacement he is 7 units towards North. His 2^{nd} displacement was:

A. 3 units towards West ○ **B. 3 units towards South** ●
C. 3 units towards North ○ D. 3 units towards East ○

(3) For a projectile, if $g = 10ms^{-2}$ the ratio of maximum height reached to square of flight time will be:

A. 5 : 1 ○ B. 5 : 2 ○
C. 5 : 4 ● D. 10 : 1 ○

(4) What is the product of $(\hat{\imath} \times \hat{\jmath}).\hat{k}$ equal to:

A. $-\hat{k}$ ○ **B. 1** ●
C. -1 ○ D. $+\hat{k}$ ○

(5) When a force is applied on a body, which one of the following physical quantity will NOT change?

A. Mass ● B. Velocity ○
C. Position ○ D. Acceleration ○

6. K.E of a body is increased by 300%. What is the percentage increase in momentum?

A. 100% ● B. 200% ○
C. 300% ○ D. 400% ○

(7) When the speed of your car doubles, by what factor does its kinetic energy increase?

A. $\sqrt{2}$ ○ B. 2 ○
C. 4 ● D. 8 ○

(8) 1° is equal to:

A. 0.01745 rad ● B. 57 rad ○
C. 0.1745 rad ○ D. 2.9 rad ○

(9) The value of g at a height equal to the radius of earth from its surface is given as:

A. $g_h = g$ ○ B. $g_h = \frac{g}{4}$ ●
C. $g_h = \frac{g}{9}$ ○ D. $g_h = \frac{g}{2}$ ○

(10) The lift of an aeroplane is based on the principle of __________.

A. Torricelli's theorem ○ B. Equation of continuity ○
C. Bernoulli's theorem ● D. Stokes theorem ○

(11) If length of second pendulum is L, then the length of pendulum having a period of 1s will be:

A. $\frac{L}{2}$ ○ B. 2L ○
C. 4L ○ D. $\frac{L}{4}$ ●

(12) Which one of the following factor does not change during resonance?

A. Amplitude ○ B. Velocity ○
C. Acceleration ○ D. Time period ●

(13) A stretched string 4m long and it has 4 loops of stationary waves, then the wave length is:

A. 4m ○ B. 3m ○
C. 2m ○ D. 1m ●

(14) A sound source is moving towards stationary listener with $\frac{1}{10^{th}}$ of the speed of sound. The ratio of apparent to real frequency is:

A. $\frac{11}{10}$ ○ B. $\left[\frac{11}{10}\right]^2$ ○
C. $\left[\frac{9}{10}\right]^2$ ○ D. $\frac{10}{9}$ ●

(15) Signal from a remote control to the device operated by it travels with the speed of:

A. Sound ○ B. Light ●
C. Ultrasonic ○ D. Supersonics ○

(16) Light of wavelength λ is incident normally on a diffraction grating for which the split spacing is equal to 3λ. What is the sine of the angle [$\sin(\theta)$] between the second order maximum and the normal?

A. $\frac{1}{6}$ ○ B. $\frac{1}{3}$ ○
C. $\frac{2}{3}$ ● D. 1 ○

(17) Formation of clouds in atmosphere is due to ___________ process.

A. isothermal ○ B. isochoric ○
C. isobaric ○ D. adiabatic ●

Federal Board HSSC-I Examination
Physics Model Question Paper
(Curriculum 2006)

Time allowed: 2.35 hours   Total Marks: 68

Note: Answer any fourteen parts from Section 'B' and attempt any two questions from Section 'C' on the separately provided answer book. Write your answers neatly and legibly.

SECTION – B (Marks 42)

Q.2 Attempt any **FOURTEEN** parts. All parts carry equal marks. (14× 3 = 42)

i. Under what circumstances the *x*-component of a force is double of its *y*-component?

Answer:

$F_x = 2\,F_y$

$\theta = ?$

$\theta = \tan^{-1}(\frac{F_y}{F_x}) = \tan^{-1}(\frac{F_y}{2F_y})$

$\theta = \tan^{-1}(0.5) = 26.56\,°$

So x-component of force $\vec{F}$ can be double of y-component provided the force $\vec{F}$ makes an angle of 26.56° with horizontal.

ii. Find the work done if applied force $F = 3\hat{\imath} + 2\hat{\jmath}(N)$ moves a block from point (2, -1) to point (6, 4).

Answer:

Work = W = ? $\vec{F} = 3\hat{\imath} + 2\hat{\jmath}$ (N)

From points (2, -1) to (6, 4) in meters

So displacement = $\vec{d} = (6-2, 4+1) = (4,5) = (4\hat{\imath} + 5\hat{\jmath})m$

Work = W = $\vec{F}.\vec{d}$ = $(3\hat{\imath} + 2\hat{\jmath}).(4\hat{\imath} + 5\hat{\jmath})$

W= (3) (4) + (2) (5) = 12 + 10 = 22 J

iii. Calculate the angle of projection for which range of projectile becomes four times than height of projectile.

Answer:

$\theta = ?$ if R = 4H

$\frac{{V_i}^2 \sin(2\theta)}{g} = 4\,(\frac{{V_i}^2 \sin^2\theta}{2g})$

$2\sin\theta\cos\theta = 2\,sin^2\theta$

$\frac{\sin\theta}{cos\theta} = 1$

$\tan\theta = 1$, $\theta = \tan^{-1}(1) = 45°$

iv. If $m_2 = 2m_1$ and $v_2 = \frac{v_1}{2}$ then for elastic collision in one dimension, calculate velocities after collision.

Answer: $m_2 = 2\,m_1$, $v_2 = \frac{v_1}{2}$, $v_1{}' = ?,\ v_2{}' = ?$

$$v_1{}' = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) v_1 + \left(\frac{2m_2}{m_1 + m_2}\right) v_2$$
$$v_1{}' = \left(\frac{m_1 - 2m_1}{m_1 + 2m_1}\right) v_1 + \left(\frac{2 \times 2m_1}{m_1 + 2m_1}\right) \frac{v_1}{2}$$
$$v_1{}' = \left(\frac{-m_1}{3m_1}\right) v_1 + \left(\frac{4m_1}{3m_1}\right) \frac{v_1}{2} = -\frac{1}{3} v_1 + \frac{2}{3} v_1 = \frac{-v_1 + 2\,v_1}{3}$$

$$v_1{}' = \frac{v_1}{3}$$
$$v_2{}' = \left(\frac{2m_1}{m_1 + m_2}\right) v_1 - \left(\frac{m_1 - m_2}{m_1 + m_2}\right) v_2$$
$$v_2{}' = \left(\frac{2m_1}{m_1 + 2m_1}\right) v_1 - \left(\frac{m_1 - 2m_1}{m_1 + 2m_1}\right) \frac{v_1}{2}$$
$$v_2{}' = \left(\frac{2m_1}{3m_1}\right) v_1 - \left(\frac{-m_1}{3m_1}\right) \frac{v_1}{2} = \frac{2}{3} v_1 + \frac{1}{6}\, v_1 = \frac{4v_1 + v_1}{6}$$
$$v_2{}' = \frac{5}{6}\, v_1$$

v. The human pulse and the swing of a pendulum are possible time units. Why are they NOT often used?

Answer: Human pulse can't be taken time standard because it changes in rest, walking, running and in higher age, so time will not remain same. Time period of a pendulum is given by $T = 2\pi\sqrt{\frac{l}{g}}$ $T \propto \sqrt{l}$ but $T \propto \frac{1}{\sqrt{g}}$. Since length changes with temperature of seasons and g changes due to height, also frictional effects of air are also involved, so time does not remain same and can't be taken as time standard.

vi. The moon's radius is 16km, g_m = 1.6ms^{-2} on its surface. Calculate the escape velocity at moon surface.

Answer:
$$R_m = 16\ km = 16000m$$
$$g_m = 1.6\ ms^{-2}\ , V_{esc} = ?$$
$$V_{esc} = \sqrt{2 g_m R_m}$$
$$V_{esc} = \sqrt{2(1.6)(16000)} = 226.27\ ms^{-1}$$

vii. Why does a diver change its body position before and after diving in the pool? Explain.

Answer: A diver changes his body position before diving into pool. His moment of inertia I_1 becomes large but angular velocity ω_1 is small. According to law of conservation of angular momentum $I_1\omega_1 = I_2\omega_2$ = Constant i.e. $I \propto \frac{1}{\omega}$. He rotates his body position in a closed tuck position so that his moment of inertia I_2 becomes small but angular velocity $\omega_2$becomes large which helps him to take extra summer saults.

viii. Earth satellite is a gravity free system. Comment and justify.

Answer: An Earth satellite is a gravity free system. A satellite revolving close to surface of earth with critical velocity is actually a freely falling object. It is in a state of weightlessness that is objects inside it face no gravity. Due to Earth's surface curvature, its path becomes parallel to Earth but it does not hit Earth. Inside that satellite becomes a gravity free system so it is said that an Earth's satellite is a gravity free system.

ix. How large must a heating duct be if air moving 5 ms^{-1} along it can replenished in the air in a room of 200 m^3 volume every 1 hour? Assume the air density remains constant.

Answer: $v = 5\ ms^{-1}$, $V = 200\ m^3$

t = 1 hour = 3600s, r = ?

By equation of continuity $Av = \frac{V}{t}$

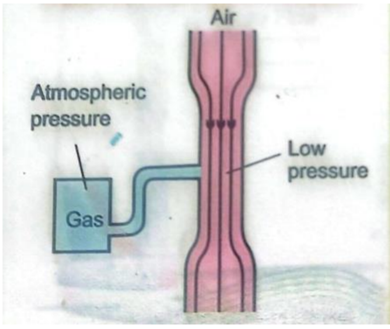
$$\pi r^2 \times v = \frac{V}{t}$$

$$(3.14)\, r^2 (5) = \frac{200}{3600}$$

$$r = \sqrt{\frac{200}{3600 \times 5 \times 3.14}} = 0.06\ m = 6\text{ cm}$$

x. How is a venturi duct used in the carburetor of a car engine?

Answer: A car carburetor has central portion as a thin constriction. When air passes through upper wider portion then it has large pressure P_1 but low speed v_1. But when air passes through central thin portion of tube it has low pressure P_2 and high speed v_2. Gas being at larger pressure forces the gas drops to moves towards central thinner portion of carburetor. In this way a proper mixture of air and gas drop is injected into the carburetor for its easy combustion.



xi. During S.H.M, in a mass-spring system, calculate the displacement at which K.E. becomes equal to P.E.

Answer: In a mass spring system of SHM

$$(P.E)_{inst} = \frac{1}{2}kx^2 \text{ and } (K.E)_{inst} = \frac{1}{2}k(x_0^2 - x^2)$$

If $(P.E)_{inst} = (K.E)_{inst}$

then $\frac{1}{2}kx^2 = \frac{1}{2}k(x_0^2 - x^2)$

$$x^2 = x_0^2 - x^2$$

$$2x^2 = x_0^2$$

$$x = \frac{x_0}{\sqrt{2}}$$

xii. Prove that $x = x_0\sqrt{1 - \frac{v^2}{v_0^2}}$ where $v = v_0\sqrt{1 - \frac{x^2}{x_0^2}}$ in SHM.

Answer: If $v = v_0\sqrt{1 - \frac{x^2}{x_0^2}}$

Then squaring both sides

$$v^2 = v_0^2\left(1 - \frac{x^2}{x_0^2}\right)$$

$$\frac{v^2}{v_0^2} = 1 - \frac{x^2}{x_0^2}$$

Re-arranging $\frac{x^2}{x_0^2} = 1 - \frac{v^2}{v_0^2}$

Taking square root on both sides

$$\frac{x}{x_0} = \sqrt{1 - \frac{v^2}{v_0^2}}$$

$$x = x_0\sqrt{1 - \frac{v^2}{v_0^2}}$$

xiii. Calculate the temperature at which speed of sound becomes $\frac{3}{2}$ times of its speed at 50°C.

Answer: T = ?, $T_0 = 50°C = 50 + 273 = 323\ K$

$v_t = \frac{3}{2}\ v_0$

Using $\frac{v_t}{v_0} = \sqrt{\frac{T}{T_0}}$

$$\frac{\frac{3}{2}\ v_0}{v_0} = \sqrt{\frac{T}{323}}$$

$$\frac{3}{2} = \sqrt{\frac{T}{323}}$$

Squaring both sides

$$\frac{9}{4} = \frac{T}{323}$$

4T = $9 \times 323 = 2907$

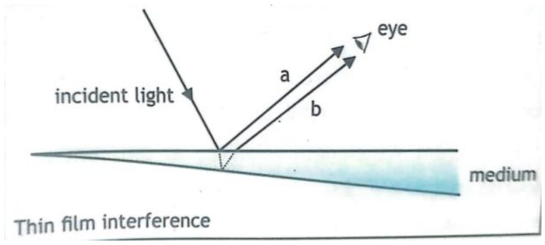
T = $\frac{2907}{4} = 726.75\ K$

Or T = 726.75 – 273 = 453.75°C

xiv. Explain why sound travels faster in warm air than in cold air.

Answer: Sounds travel faster in warm air than in cold air as $\frac{v_t}{v_0} = \sqrt{\frac{T}{T_0}}$ which shows that v $\alpha \sqrt{T}$ i.e. speed of sound depends directly upon square root of absolute temperature. As T for warm air is higher than cold air so speed of sound is greater through warm air as compared to its speed through cold air.

xv. A thin oil film on the surface of water shows different colors. Why?



Answer: This happened because of interference of light. A thin oil film is actually layer of some oil spread over a wet surface. When light falls on some angle then a part of it is reflected back from the upper surface of oil film while second part is reflected from the lower surface. Due to constructive interference, this oil film shows colors to observer's eye.

xvi. A beam of X-rays of wavelength 0.3 nm is incident on a crystal and gives a first order maximum when the glancing angle is 9°. Find the atomic spacing.

Answer:

$\lambda = 0.3\ nm = 0.3 \times 10^{-9}$ m , m = 1

$\theta = 9°,\ d = ?$

Using Bragg's law 2d $\sin\theta = m\lambda$

$$d = \frac{m\lambda}{2\sin\theta} = \frac{(1)(0.3\times10^{-9})}{2\ \sin 9^\circ}$$
$$d = \frac{0.3\times10^{-9}}{0.313} = 9.6\ \times\ 10^{-10}\ \text{m}$$

xvii. Check the homogeneity of equation $\frac{l}{g} = \frac{m}{k}$.

Answer: $\frac{l}{g} = \frac{m}{k}$

$$\frac{l}{g} = S.I\ units\ of\ L.H.S = \frac{m}{ms^{-2}} = \ s^2$$

Dimension of L.H.S = [T^2] ………(1)

$$\frac{m}{k} = S.I\ unit\ of\ R.H.S = \frac{kg}{N/m} = \frac{kg\ \times m}{N} = \frac{kg\ \times m}{kgms^{-2}} = s^2$$

Dimension of R.H.S. = [T^2] ………(2)

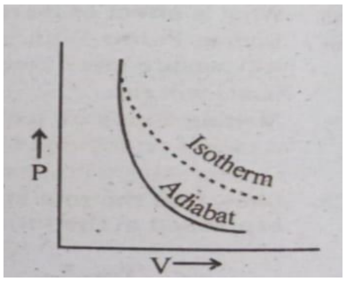
Comparing equations 1 and 2, we can see that the given equation $\frac{l}{g} = \frac{m}{k}$ is dimensionally correct.

xviii. Can we realize an ideal simple pendulum?

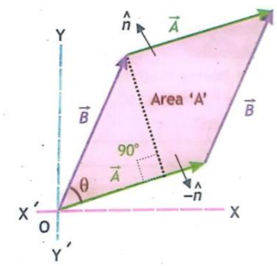
Answer: No we can't realize an ideal simple pendulum. For an ideal pendulum mass should be a point mass (very small in size but very large in value) and string or thread should be inextensible. Since both conditions practically does not exist, so we can't realize an ideal simple pendulum.

xix. Explain why adiabatic curve is more steeper than isothermal curve?

Answer: If an isotherm and an adiabatic are drawn on the same graph, it can be seen that adiabatic is steeper than the isotherm. This steepness is due to the reason that in an adiabatic expansion, the system does work at the cost of its own internal energy. While in an isothermal expansion energy is supplied by the heat reservoir. Also adiabatic process is faster than isothermal process. That is why adiabatic is steeper than an isotherm.



xx. If $\vec{A}$ and $\vec{B}$ are representing two adjacent sides of parallelogram then show that $|\vec{A}\times\vec{B}| = Area\ of\ parallelogram.$



Answer:

Area of parallelogram = (length)(height)

= (A) (Bsin θ)

= AB sin θ = magnitude of $\vec{A}\ \times\vec{B}$

= $|\vec{A}\times\vec{B}|$

SECTION – C (Marks 26)

Note: Attempt any TWO questions. All questions carry equal marks. (2 × 13 = 26)

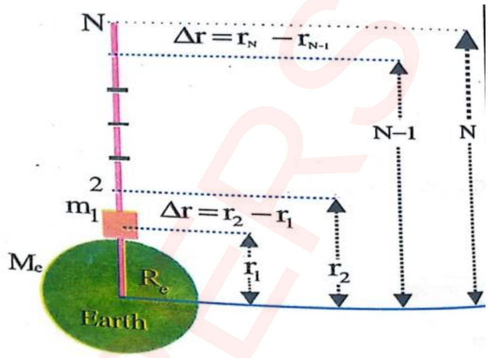
Q.3 a. What is absolute P.E? Derive an expression for it using diagram. (6)

Answer:

Absolute P.E: The work done by the gravitational force on a body in moving it from the surface of Earth to infinity where the force of gravity becomes zero is called Absolute P.E.

Explanation and Derivation:

Let a body of mass m is displaced from surface of Earth to an infinite distance at point N. The path is divided into small patches 1, 2, 3, ... N. We shall find work done between individual points as follows:



From diagram $\Delta r = r_2 - r_1$ ………(1)

$r_2 = r_1 + \Delta r$ ………(2)

Mid point $r = \frac{r_1 + r_2}{2}$ ………(3)

Using eq. (2) and eq. (3)

$$r = \frac{r_1 + r_1 + \Delta r}{2} = \frac{2r_1 + \Delta r}{2}$$

$$r = r_1 + \frac{\Delta r}{2} \text{ ……………. (4)}$$

Squaring both sides $r^2 = r_1^2 + 2(r_1)\left(\frac{\Delta r}{2}\right) + \left(\frac{\Delta r}{2}\right)^2$

here $\left(\frac{\Delta r}{2}\right)^2$ is very small, so it is neglected.

$$r^2 = r_1^2 + 2(r_1)\left(\frac{\Delta r}{2}\right)$$

Using eq. (1) in it

$$r^2 = r_1^2 + r_1(r_2 - r_1)$$

$$r^2 = r_1 r_2 \text{ …………….(5)}$$

Work done between points 1 and 2 = $\Delta W_{1\to2} = \vec{F} \cdot \Delta\vec{r}$

$\Delta W_{1\to2} = F\,\Delta r \cos 180$ (as we move against gravity)

$\Delta W_{1\to2} = F\Delta r\,(-1) = -F\Delta r$ ………(6)

where $F = \frac{Gm_1m_2}{r^2} = \frac{GMm}{r^2} = \frac{GMm}{r_1r_2}$ …………….(7)

using eq. (1) and (7) in eq. (6)

$$\Delta W_{1\to2} = -\frac{GMm}{r_1r_2}(r_2 - r_1)$$

$$= -GMm\left(\frac{r_2 - r_1}{r_1r_2}\right) = -GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \text{ ………(8)}$$

Similarly $\Delta W_{2\to3} = -GMm\left(\frac{1}{r_2} - \frac{1}{r_3}\right)$ ………………(9)

$$\Delta W_{(N-1)\to N} = -GMm\left(\frac{1}{r_{N-1}} - \frac{1}{r_N}\right) \text{ ………..(10)}$$

The total work done from point 1 to N is:

$$\Delta W_{1\to N} = \Delta W_{1\to2} + \Delta W_{2\to3} + \dots\dots\dots\dots \Delta W_{(N-1)\to N}$$

$$\Delta W_{1\to N} = -GMm\left(\frac{1}{r_1} - \frac{1}{r_2} + \frac{1}{r_2} - \frac{1}{r_3} + \dots\dots\dots\dots + \frac{1}{r_{N-1}} - \frac{1}{r_N}\right)$$

$$\Delta W_{1\to N} = -GMm\left(\frac{1}{r_1} - \frac{1}{r_N}\right)$$

If N lies at infinity than $r_N = \infty$

$$\frac{1}{r_N} = \frac{1}{\infty} = 0$$

So, $\Delta W_{1\to\infty} = -\frac{GMm}{r_1}$

If we displace body from surface of Earth

Then $\Delta W = -\frac{GMm}{R} = Absolute\ P.E$

Or $U = -\frac{GMm}{R}$ … … … … (11)

Gravitational potential is defined as potential energy per unit mass i.e.

$$V_r = \frac{U}{m} = -\frac{GMm}{m \times R}$$

$$V_r = -\frac{GM}{R} \text{ ……..(12)}$$

b. Show that $C_p - C_v = R$. (4)

Answer:

Specific heat is given by $\Delta Q = mC\Delta T$

For m = 1kg and at constant pressure

$$\Delta Q_P = C_P \Delta T \ldots\ldots\ldots\ldots(1)$$

And at constant volume $\Delta Q_V = C_V \Delta T \ldots\ldots\ldots(2)$

By 1st law of thermodynamics

$$\Delta Q = \Delta U + \Delta W \ldots\ldots\ldots(3)$$

At constant volume $\Delta V = 0$, $\Delta W = P(\Delta V) = P(O) = 0$

So equation (3) becomes $\Delta Q_V = \Delta U + O$

$$\Delta U = \Delta Q_V = C_V \Delta T \ldots\ldots\ldots(4) \qquad \text{\{by equation (2)\}}$$

At constant pressure: equation (3) becomes

$$\Delta Q_p = \Delta U + \Delta W$$

Or $\quad C_P \Delta T = C_v \Delta T + P(\Delta V) \ldots\ldots(5)$

Ideal gas equation is PV = nRT

For 1mole n = 1

PV = RT

For any change in temperature $P\Delta V = R\Delta T \ldots\ldots\ldots(6)$

Using equation (6) in equation (5)

$$C_P \Delta T = C_V \Delta T + R\Delta T$$

Dividing by ΔT; $\quad C_P = C_V + R$

Or $\quad C_P - C_V + R$

c. What is the effect on order of spectra of diffraction grating if the numbers of lines ruled in grating are increased? (3)

Answer:

Number of lines ruled in grating is related with grating element as $d = \frac{1}{N}$

Diffraction grating formula is:

$$d\sin\theta = m\lambda$$

or

$$\frac{1}{N}\sin\theta = m\lambda$$

$$m = \frac{\sin\theta}{N\lambda}$$

If N is increased, then order number of spectra (m) will decrease.

Q.4 a. What is the First Law of thermodynamics? Explain it. (6)

Answer: "In any thermodynamic process, when heat energy(ΔQ) is added to a system, this energy appears as an increase in the internal energy (ΔU) stored in the system plus the work done (ΔW) by the system on its surroundings. i.e.

$$\Delta Q = \Delta U + \Delta W \ldots\ldots\ldots\ldots(1)$$

$\Delta Q = +ve$ when heat is supplied to a system

$\Delta Q = -ve$ when heat is taken out of a system

$\Delta U = +ve$ internal energy of system increases

$\Delta U = -ve$ internal energy of system decreases

$\Delta W = +ve$ work is done by the system

$\Delta W = -ve$ work is done on the system

The internal energy is sum of K.E (translational, rotational and vibrational) and P.E associated with the random motion of actions of a system

By equation (1), we can write:

$$\Delta U = \Delta Q - \Delta W \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

It means that change in internal energy of a system is equal to the energy flowing in as heat minus the energy flowing out as work. This energy absorbed by the system changes the translational, vibrational and rotational K.E of molecules. It also changes P.E of molecules due to intermolecular forces. The change in internal energy of system depends on its initial and final states but it is independent of path between these states $\quad \Delta U = U_B - U_A$

and equation (2) becomes

$$U_B - U_A = \Delta Q - \Delta W$$

For a cyclic process $U_A = U_B$ and $U_B - U_A = 0$

So $\quad 0 = \Delta Q - \Delta W$

Or $\quad \Delta Q = \Delta W$

Thus in cyclic process all the heat energy absorbed by the system is used in doing some useful work by the system.

First law of thermodynamics is based on four processes:

(i) **<u>Isothermal Process:</u>** In which T = Constant and PV = Constant (Boyle's law) is applicable;

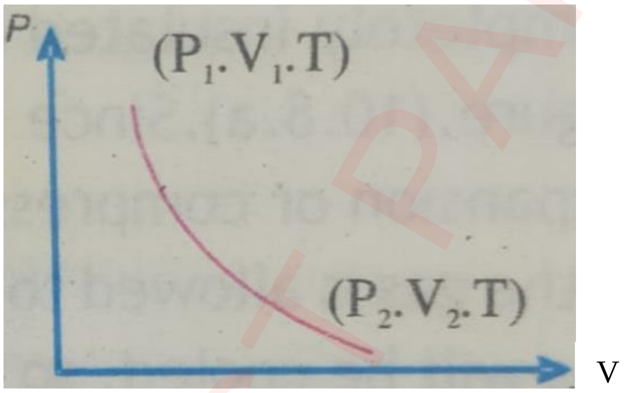
For T = constant, $\Delta T = O$ and $\Delta U = O$

So by equation (1) $\quad \Delta Q = O + \Delta W$

Either $+\Delta Q = +\Delta W$ or $-\Delta Q = -\Delta W$

i.e. when heat is supplied to a system under isothermal process, then work is done by the system	i.e. when heat is taken out of a system under isothermal process, then work is done on the system

It's P – V graph is shown below:



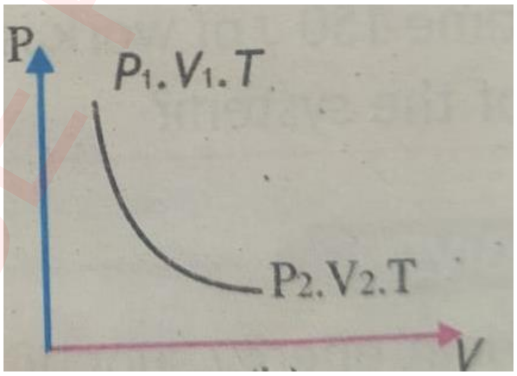
(ii) **<u>Adiabatic Process:</u>** In which no heat enters or leaves the system i.e. $\Delta Q = 0$

So by equation (1) $\quad O = \Delta U + \Delta W$

Either $-\Delta U = +\Delta W$ or $+\Delta U = -\Delta W$

i.e. under adiabatic process, when work is done by the system, then it decreases its internal energy	i.e. under adiabatic process, when work is done on the system then it increases its internal energy

It's P – V graph is shown below:



(iii) **<u>Isochoric Process:</u>** In which V = Constant then $\Delta V = 0$

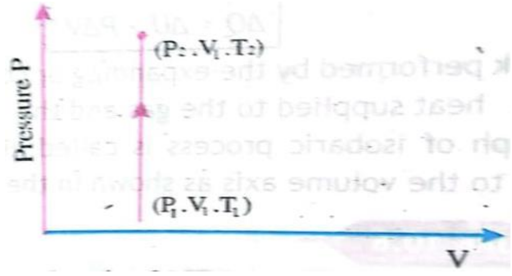
and work done by gas = $\Delta W = P(\Delta V) = P(0) = O$

So by equation (1) $\quad \Delta Q = \Delta U + O$

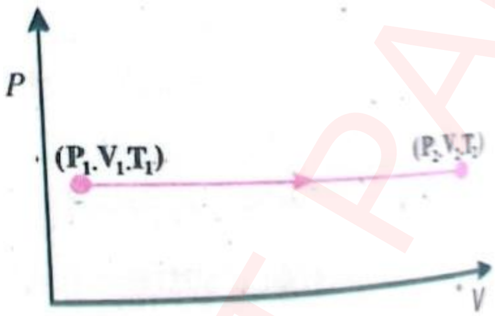
Either $+\Delta Q = +\Delta U$ or $-\Delta Q = -\Delta U$

i.e. when heat is supplied to system under isochoric process then internal energy of system increases	i.e. when heat is taken out of a system under isochoric process, then internal energy of system decreases

It’s P – V graph is shown below:



(iv) **Isobaric Process:** In which P = Constant
then work done by a gas is $\Delta W = P\Delta V$
Or $\Delta W = P(V_2 - V_1)$
So by equation (1) $\Delta Q = \Delta U + P\Delta V$
Or $\Delta Q = \Delta U + P(V_2 - V_1)$
It’s P – V graph is shown below:



b. The absorption spectrum of faint galaxy is measured and wave length of one of the lines identified as the calcium ∝ line is found to be 478 nm. The same line has a wavelength of 397 nm, when measured in laboratory. Calculate the speed of galaxy relative to Earth. (4)

Answer:
$\lambda' = 478\ nm$, $\lambda = 397$ nm
v = c = $3 \times 10^8\ ms^{-1}$
speed of galaxy = a = ?
using $f' = \left(\frac{v}{v+a}\right) f$ ……….(1) (as $\lambda' > \lambda, f' < f$ so galaxy is moving away)
First using c = $f\lambda$,

$$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{397 \times 10^{-9}} = 7.56 \times 10^{14}\ Hz$$

Similarly, $c' = f'\lambda'$,

$$f' = \frac{c'}{\lambda'} = \frac{3\times10^8}{478 \times 10^{-9}} = 6.28 \times 10^{14}\ Hz$$

using these in eq. (1)

$$6.28 \times 10^{14} = \left(\frac{v}{v+a}\right) \times 7.56 \times 10^{14}$$

$$\frac{v}{v+a} = \frac{6.28}{7.56} = 0.831$$

Since v = c

So, $\frac{c}{c+a} = 0.831$

c+a = $\frac{c}{0.831} = \frac{3 \times 10^8}{0.831} = 3.6101 \times 10^8$
a = 3.61×10^8 – c
a = $3.61 \times 10^8 - 3 \times 10^8 = 0.61 \times 10^8\ ms^{-1}$

c. Prove that $P = \vec{F}.\vec{v}$. (3)

Answer:

Work done = W = $\vec{F}.\vec{d}$

$$P_{inst} = \lim_{\Delta t \to 0} \frac{\Delta W}{\Delta t} = \lim_{\Delta t \to 0} \frac{\Delta(\vec{F}.\vec{d})}{\Delta t}$$

$$P_{inst} = \vec{F}.\lim_{\Delta t \to 0} \frac{\Delta \vec{d}}{\Delta t}$$

$$P_{inst} = \vec{F}.\vec{v}_{inst}$$

Or generally P = $\vec{F}.\vec{v}$

Q.5 a. What is angular momentum? Explain the law of conservation of angular momentum. (6)

Answer: **<u>Angular Momentum</u>**

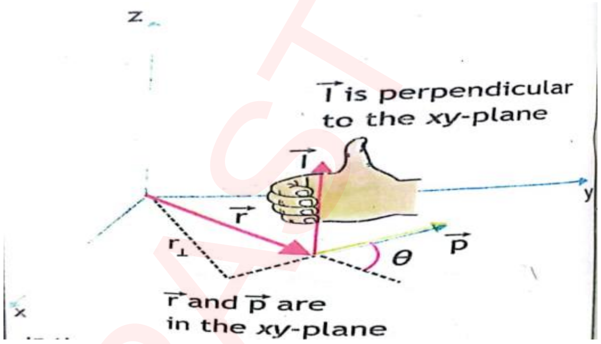
"A particle is said to possess an angular momentum about a reference axis if it so moves that its angular position changes relative to that reference axis."

OR

"The cross product of position vector $\vec{r}$ w.r.t. the axis of rotation and linear momentum $\vec{p}$ of an object is called angular momentum i.e.

$$\vec{L} = \vec{r} \times \vec{p} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

The direction of $\vec{L}$ is ⊥ to plane containing $\vec{r}$ and $\vec{p}$ and it is determined by Right Hand Rule.



$$\vec{L} = (rp\sin\theta)\hat{n}$$

Its magnitude is L = $rp\sin\theta$ …………..(2)

L= $rmv\sin\theta$

For maximum value $\theta = 90°$, $and \sin 90 = 1$

So L= rmv ……………. (3)

Its S.I. unit is m × $kg \times ms^{-1} = kg\,m^2s^{-1}$

Or J.s

Because $kg\,m^2s^{-1}$ = kg m $s^{-2} \times ms$

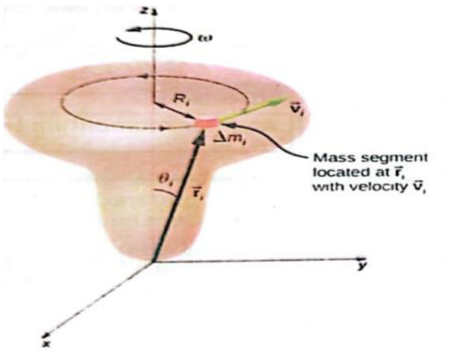
= N × ms

= $(N \times m)s = Js$

Since v = rw, so equation (3) becomes

L = $rm(rw)$

L = mr^2w ……………….(4)



In case of a rigid body of masses m_1, m_2 . . . m_n located at distances r_1, r_2 . . . . r_n from axis of rotation, by equation (4) their individual angular momentum will be:

$$L_1 = m_1r_1^2w \quad , \qquad L_2 = m_2r_2^2w\ , \ldots\ldots\ L_n = m_nr_n^2w$$

The total angular momentum of whole rigid body will be:

L = $L_1 + L_2 + \ldots\ldots + L_n$

$$L = m_1r_1^2w + m_2r_2^2w + \ldots\ldots\ldots + m_nr_n^2w$$
$$L = (m_1r_1^2 + m_2r_2^2 + \ldots\ldots\ldots + m_nr_n^2)w$$
$$L = (\sum_{i=1}^{N} m_i{r_i}^2)w$$
$$L = Iw \ldots\ldots\ldots\ldots(5)$$
where $I = \sum_{i=1}^{N} m_i{r_i}^{\mathbf{2}} = Moment\ of\ inertia\ of\ rigid\ body$

Conservation of Angular Momentum

"In any isolated system, if no net external torque acts on the system, then total angular momentum of system is conserved (remarks constant)."

Since $L = rp\text{Sin}90 = rp$

Then change in angular momentum is:
$$\Delta L = r\Delta p$$
Dividing both sides by Δt
$$\frac{\Delta L}{\Delta t} = r\frac{\Delta p}{\Delta t}$$
The rate of change of angular momentum is equal to torque i.e. $T = \frac{\Delta L}{\Delta t}$

An isolated system is that in which there are no external forces, so F acting on the system is zero;

Since $\frac{\Delta p}{\Delta t} = F = 0$

It follows $\frac{\Delta L}{\Delta t} = 0$ or $\Delta L = 0$

Or L = Constant

But L = Iw; so Iw = Constant

And $I \propto \frac{1}{w}$; For two states

We can write $I_1w_1 = I_2w_2$ = Constant

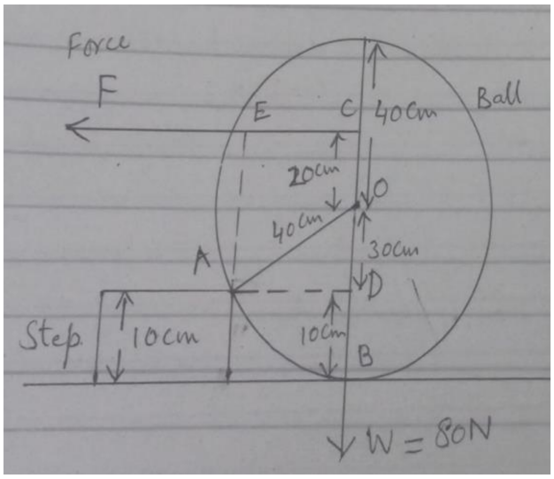
b. A spherical ball of weight 80 N and radius 40 cm is to be lifted over a 10 cm step. How much minimum force is required to lift it on step if force is applied at half of the radius of sphere from centre? (4)

Answer:

From the diagram $\overline{AE} = \overline{DC} = \overline{OD} + \overline{OC} = 30 + 20 = 50\ cm$

In right angled triangle AOD
$$\overline{AD} = \sqrt{(\overline{AO})^2 - (\overline{OD})^2}$$
$$= \sqrt{(40)^2 - (30)^2}$$
$$\overline{AD} = \sqrt{1600 - 900} = \sqrt{700}$$
$$\overline{AD} = 26.46 \text{ cm}$$
Taking A as pivot point

Anticlockwise torque = Clockwise torque
$$F \times \overline{AE} = W \times \overline{AD}$$
$$F = \frac{W \times \overline{AD}}{\overline{AE}} = \frac{80 \times 26.46}{50}$$
$$F = 42.34\ N$$



c. With the help of an example, show that impulsive force increases by decreasing the collision time. (3)

Answer: Impulse = (very large force) (very small time)
$$\vec{J} = \overrightarrow{F_{av}} \times \Delta t$$
Consider the example of helmet of a motor cyclist. Its outer surface is of plastic or metal sheet but inner side is packed with foam or thermopore sheet. When during a collision motor cyclist falls on road then this foam layer extends the time of collision of head on road, thus reducing the impulsive force and motor cyclist is saved from a severe head injury.