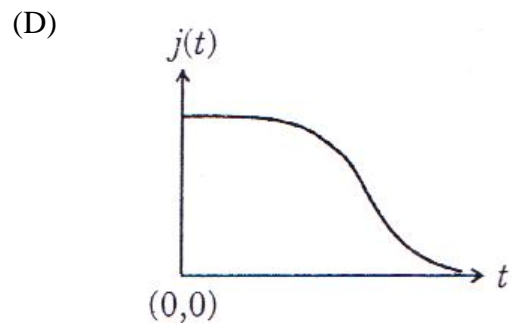
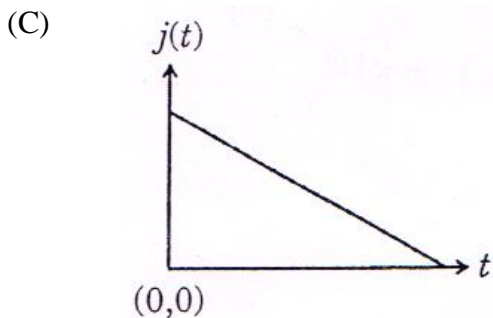
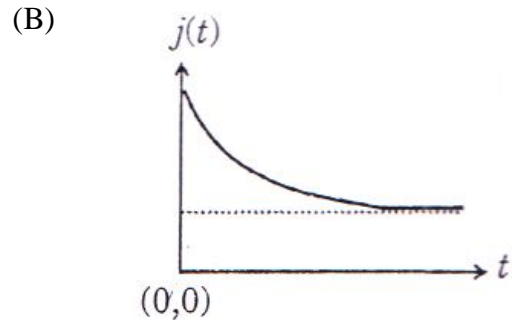
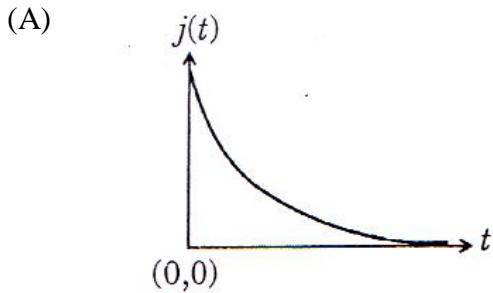


**SECTION – I (PHYSICS)**

1. An infinite line charge of uniform electric charge density  $\lambda$  lies along the axis of an electrically conducting infinite cylindrical shell of radius  $R$ . At time  $t = 0$ , the space inside the cylinder is filled with a material of permittivity  $\epsilon$  and electrical conductivity  $\sigma$ . The electrical conduction in the material follows Ohm's law. Which one of the following graphs best describes the subsequent variation of the magnitude of current density  $j(t)$  at any point in the material?



**Sol.** (A)  
 $E = JP$   
 $\frac{2K\lambda}{r} = JP$   
 $J = \frac{2K\lambda}{Pr}$   
 As  $t \uparrow J \downarrow$  and at  $t = \infty J \rightarrow 0$   
 And  $\frac{dJ}{dt} \propto \frac{dJ}{dt}$  hence option (A)  
 $\frac{dJ}{dt}$  is negative  $\therefore \frac{dJ}{dt} < 0$

2. In a historical experiment to determine Planck's constant, a metal surface was irradiated with light of different wavelengths. The emitted photoelectron energies were measured as a stopping potential. The relevant data for the wavelength ( $\lambda$ ) of incident light the corresponding stopping potential ( $V_0$ ) are given below :

$\lambda(\mu\text{m})$	$V_0(\text{Volt})$
0.3	2.0
0.4	1.0
0.5	0.4

Given that  $c = 3 \times 10^8 \text{ m s}^{-1}$  and  $e = 1.6 \times 10^{-19} \text{ C}$ , Planck's constant (in units of J s) found from such an experiment is

- (A)  $6.0 \times 10^{-34}$  (B)  $6.4 \times 10^{-34}$  (C)  $6.6 \times 10^{-34}$  (D)  $6.8 \times 10^{-34}$

**Sol. (B)**

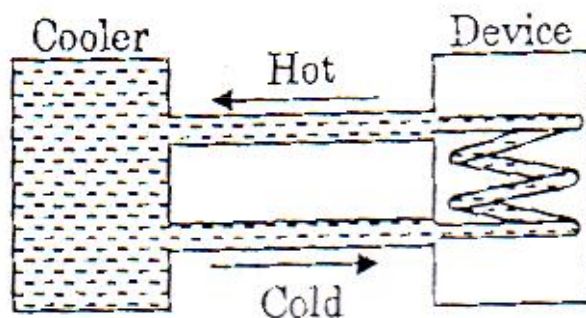
$$\frac{hc}{d} = \frac{hc}{\lambda_0} + 2 \times 1.6 \times 10^{-19}$$

$$h = \frac{B \times 10^8}{3 \times 10^{-7}} = \frac{hc}{\lambda_0} + 1.6 \times 10^{-19} \times 2$$

$$h = 10^{15} = 4 \times 1.6 \times 10^{-19}$$

$$h = 6.4 \times 10^{-34}$$

3. A water cooler of storage capacity 120 litres can cool water at a constant rate of P watts. In a closed circulation system (as shown schematically in the figure), the water from the cooler is used to cool an external device that generates constantly 3 kW of heat (thermal load). The temperature of water fed into the device cannot exceed  $30^\circ \text{C}$  and the entire stored 120 litres of water is initially cooled to  $10^\circ \text{C}$ . The entire system is thermally insulated. The minimum value of P (in watts) for which the device can be operated for 3 hours is



(Specific heat of water is  $4.2 \text{ kJ kg}^{-1}$  and the density of water is  $1000 \text{ kg m}^{-3}$ )

- (A) 1600 (B) 2067 (C) 2533 (D) 3933

**Sol. (B)**

heat product

$$3000 \text{ J/s} \times 3 \times 60 \times 60 = 32.4 \times 10^6 \text{ Joule}$$

$$120 \times 4.2 \times 10^3 \times 20 = 10.08 \times 10^6 \text{ Joules. Heat extracted}$$

$$P \times 3 \times 60 \times 60$$

$$32.4 \times 10^6 - 10.08 \times 10^6 = P \times 3 \times 60 \times 60$$

4. A uniform wooden stick of mass 1.6 kg and length  $l$  rests in an inclined manner on a smooth, vertical wall of height  $h$  ( $h < l$ ) such that a small portion of the stick extends beyond the wall. The reaction force of the wall on the stick is perpendicular to the stick. The stick makes an angle of  $30^\circ$  with the wall and the bottom of the stick is on a rough floor. The reaction of the wall on the stick is equal in magnitude to the reaction of the floor on the stick. The ratio  $h/l$  and the frictional force  $f$  at the bottom of the stick are ( $g = 10 \text{ m s}^{-2}$ )

(A)  $\frac{h}{l} = \frac{\sqrt{3}}{16}, f = \frac{16\sqrt{3}}{3} \text{ N}$

(B)  $\frac{h}{l} = \frac{3}{16}, f = \frac{16\sqrt{3}}{3} \text{ N}$

(C)  $\frac{h}{l} = \frac{3\sqrt{3}}{16}, f = \frac{8\sqrt{3}}{3} \text{ N}$

(D)  $\frac{h}{l} = \frac{3\sqrt{3}}{16}, f = \frac{16\sqrt{3}}{3} \text{ N}$

**Sol. (D)**

$$\cos 30^\circ = \frac{h}{\text{hyp}}$$

$$\text{hyp} = \frac{2h}{\sqrt{3}}$$

$$\frac{1}{\sqrt{3}} = \frac{x}{n}$$

x.

$$\frac{N}{2} + N = mg \quad \frac{N\sqrt{3}}{2} = f$$

$$\frac{3N}{2} = mg \quad \frac{2mg}{3} \cdot \frac{\sqrt{3}}{2} = f = \frac{mg}{\sqrt{3}} = \frac{16}{\sqrt{3}}$$

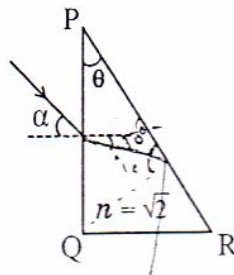
$$N = \frac{2mg}{3}$$

$$mg \cdot \frac{\ell}{2} \cdot \frac{1}{2} = N \cdot \frac{2h}{\sqrt{3}}$$

$$\frac{16}{4} \ell = \frac{216}{3} \cdot \frac{2h}{\sqrt{3}}$$

$$\frac{h}{\ell} = \frac{3\sqrt{9}}{16}$$

5. A parallel beam of light is incident from air at an angle  $\alpha$  on the side PQ of a right angled triangular prism of refractive index  $n = \sqrt{2}$ . Light undergoes total internal reflection in the prism at the face PR when  $\alpha$  has a minimum value of  $45^\circ$ . The angle  $\theta$  of the prism is



- (A)  $15^\circ$                       (B)  $22.5^\circ$                       (C)  $30^\circ$                       (D)  $45^\circ$

**Sol.**

$$n = \sqrt{2}$$

$$\sqrt{2} \sin i = 1$$

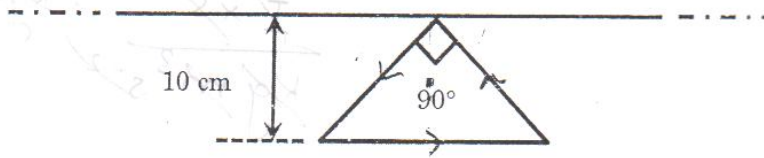
$$i = 45^\circ$$

$$\sin 45^\circ = \sqrt{2} \sin r$$

$$\sin r = \frac{1}{2}$$

$$\theta = 15^\circ$$

6. A conducting loop in the shape of a right angled isosceles triangle of height 10cm is kept such that the  $90^\circ$  vertex is very close to an infinitely long conducting wire (see the figure). The wire is electrically insulated from the loop. The hypotenuse of the triangle is parallel to the wire. The current in the triangular loop is in counterclockwise direction and increased at a constant rate of  $10 \text{ As}^{-1}$ . Which of the following statement(s) is (are) true?



- (A) The induced current in the wire is in opposite direction to the current along the hypotenuse  
 (B) There is a repulsive force between the wire and the loop  
 (C) The magnitude of induced *emf* in the wire is  $\left(\frac{\mu_0}{\pi}\right)$  volt  
 (D) If the loop is rotate at a constant angular speed about the wire, an additional *emf* of  $\left(\frac{\mu_0}{\pi}\right)$  volt is induced in the wire.

**Sol. (B, C)**

$$\phi = 2 \times dx \frac{\mu_0 i_1}{2\pi x}$$

$$\phi_2 = \frac{\mu_0 i_1 (10)}{\pi \times 100}$$

$$M = \frac{\mu_0 10}{\pi \times 100}$$

$$\phi = M i_2$$

$$\varepsilon_1 = \frac{d\phi}{dt} = M \frac{di_2}{dt} = \frac{\mu_0 10 (10)}{\pi \times 100}$$

$$\varepsilon_1 = \frac{\mu_0}{\pi}$$

7. A length-scale (*l*) depends on the permittivity ( $\varepsilon$ ) of a dielectric material, Boltzmann constant ( $k_B$ ), the absolute temperature (*T*), the number per unit volume (*n*) of certain charged particles, and the charge (*q*) carried by each of the particles. Which of the following expression (s) for *l* is (are) dimensionally correct?

(A)  $l = \sqrt{\left(\frac{nq^2}{\varepsilon k_B T}\right)}$

(B)  $l = \sqrt{\left(\frac{\varepsilon k_B T}{nq^2}\right)}$

(C)  $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{2/3} k_B T}\right)}$

(D)  $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{1/3} k_B T}\right)}$

**Sol. (BD)**

$$\frac{q^2}{\omega} = FL^2$$

$$K_B T = \text{Energy} = FL$$

$$n = L^{-3}$$

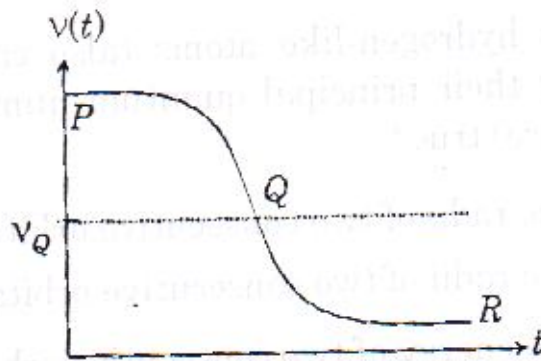
(A)  $\sqrt{n \frac{q^2}{\varepsilon_0 K_B T}} = \sqrt{\frac{L^{-3} FL^2}{FL}} = \frac{1}{L}$

(B)  $\sqrt{\frac{K_B T}{n \frac{q^2}{\epsilon^2}}} = \sqrt{\frac{FL}{L^{-3} FL^2}} = \sqrt{L^2} = L$

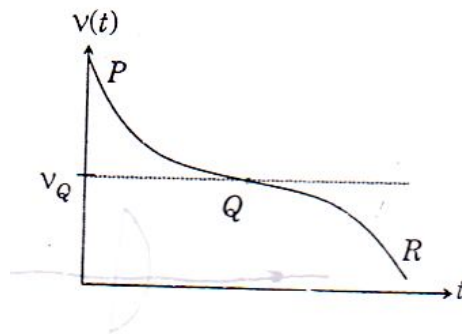
(C)  $\sqrt{\frac{q^2}{\epsilon} \cdot \frac{1}{h^{2/3}} \cdot \frac{1}{K_B T}} = \sqrt{\frac{FL^2}{L^2}} = \sqrt{L^3}$

(D)  $\sqrt{\frac{a^2}{\epsilon \frac{1}{ng}}} = \sqrt{\frac{FL^2}{L^{-1} FL}} = L$

8. Two loudspeakers M and N are located 20 m apart and emit sound at frequencies 118 Hz and 121 Hz, respectively. A car is initially at a point P, 1800 m away from the midpoint Q of the line MN and moves towards Q constantly at 60 km/hr along the perpendicular bisector of MN. It crosses Q and eventually reaches a point R, 1800 m away from Q. Let  $v(t)$  represent the beat frequency measured by a person sitting in the car at time  $t$ . Let  $v_P$ ,  $v_Q$  and  $v_R$  be the beat frequencies measured at locations P, Q and R, respectively. The speed of sound in air is  $330 \text{ m s}^{-1}$ . Which of the following statement(s) is(are) true regarding the sound heard by the person?
- (A) The plot below represents schematically the variation of beat frequency with time



- (B) The plot below represents schematically the variation of beat frequency with time



- (C)  $v_P + v_R = 2v_Q$
- (D) The rate of change in beat frequency is maximum when the car passes through Q

**Sol. (ACD)**

$$v(t) = \left( \frac{V + V_p \cos \theta}{V} \right) (121 - 118)$$

As  $v_p \cos \theta$  decreases so  $v(t)$  decreases. Initial rate of decrease will be small.

$$v_P = \frac{330 + \frac{50}{3}}{330} \times 3$$

$$v_Q = 3$$

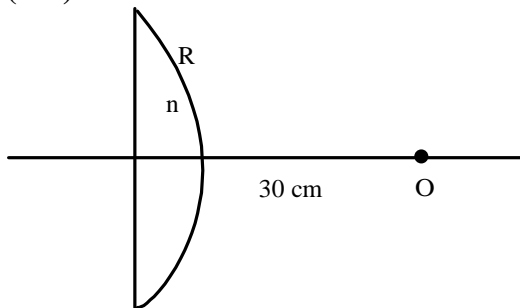
$$v_R = \left( \frac{330 - \frac{50}{3}}{330} \right) \times 3$$

$$v_P + v_R = 2v_Q$$

9. A plano-convex lens is made of refractive index  $n$ . When a small object is placed 30 cm away in front of the curved surface of the lens, an image of double the size of the object is produced. Due to reflection from the convex surface of the lens, another faint image is observed at a distance 10 cm away from the lens. Which of the following statement(s) is(are) true?

- (A) The refractive index of the lens is 2.5  
 (B) The radius of curvature of the convex surface is 45 cm  
 (C) The faint images is erect and real  
 (D) The focal length of the lens is 20 cm

Sol. (AD)



$$\frac{1}{v} - \frac{1}{u} = (n-1) \left[ \frac{1}{+R} - \frac{1}{\omega} \right] \quad \frac{v}{u} = -2$$

$$v = -24$$

$$\frac{1}{v} + \frac{1}{u} = \frac{2}{R}$$

$$\frac{1}{+10} + \frac{1}{-30} = \frac{2}{R}$$

$$\frac{3-1}{30} = \frac{2}{R} \Rightarrow \frac{2}{30} = \frac{2}{R} \Rightarrow R = 30 \text{ cm}$$

$$\frac{1}{v} - \frac{1}{u} = \frac{(n-1)}{30} \quad u = -30, v = +60$$

$$\therefore n = 2.5$$

$$\frac{1}{F} = (2.5-1) \left[ \frac{1}{+30} - \frac{1}{\omega} \right]$$

$$= \frac{1.5}{30} \Rightarrow F = 20 \text{ cm}$$

10. Highly excited states for hydrogen-like atoms (also called Rydberg states) with nuclear charge  $Ze$  are defined by their principal quantum number  $n$ , where  $n \gg 1$ . Which of the following statement(s) is(are) true?

- (A) Relative change in the radii of two consecutive orbitals does not depend on  $Z$   
 (B) Relative change in the radii of two consecutive orbitals varies as  $1/n$   
 (C) Relative change in the energy of two consecutive orbitals varies as  $1/n^3$   
 (D) Relative change in the angular momenta of two consecutive orbitals varies as  $1/n$

Sol. (A, B, D)

$$r = \frac{n^2}{z}$$

$$r + \Delta r = \frac{(n+1)^2}{z}$$

$$1 + \frac{\Delta r}{r} = \frac{(n+1)^2}{n^2} \Rightarrow 1 + \frac{\Delta r}{r} = \left(1 + \frac{2}{n}\right)$$

$$\frac{\Delta r}{r} = \frac{2}{n}$$

$$mvr = \frac{nh}{2\pi}$$

$$mv(r + \Delta r) = (n+1) \frac{h}{2\pi}$$

$$\frac{r + \Delta r}{r} = \frac{n+1}{n}$$

$$1 + \frac{\Delta r}{r} = 1 + \frac{1}{n}$$

$$\frac{\Delta r}{r} = \frac{1}{n}$$

$$E = \frac{z^2}{n^2}$$

$$E + \Delta E = \frac{z^2}{(n+1)^2}$$

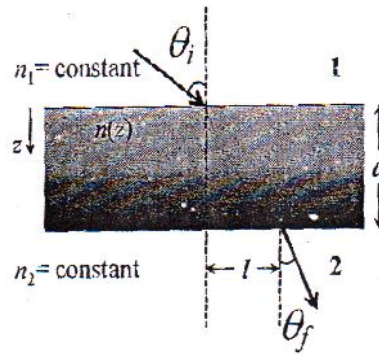
$$\frac{\Delta E}{E} + 1 = \frac{n^2}{(n+1)^2}$$

$$\frac{\Delta E}{E} + 1 = \frac{1}{\left(1 + \frac{1}{n}\right)^2}$$

$$\frac{\Delta E}{E} + \cancel{1} = \cancel{1} - \frac{2}{n}$$

$$\frac{\Delta E}{E} = -\frac{2}{n}$$

11. A transparent slab of thickness  $d$  has a refractive index  $n(z)$  that increases with  $z$ . Here  $z$  is the vertical distance inside the slab, measured from the top. The slab is placed between two media with uniform refractive indices  $n_1$  and  $n_2 (> n_1)$ , as shown in the figure. A ray of light is incident with angle  $\theta_i$  from medium 1 and emerges in medium 2 with refraction angle  $\theta_f$  with a lateral displacement  $l$ .



Which of the following statement(s) is(are) true?

- (A)  $l$  is independent of  $n_2$  (B)  $l$  is dependent on  $n(z)$   
(C)  $n_1 \sin \theta_i = n_2 \sin \theta_f$  (D)  $n_1 \sin \theta_i = (n_2 - n_1) \sin \theta_f$

11. (ABC)

12. An incandescent bulb has a thin filament of tungsten that is heated to high temperature by passing an electric current. The hot filament emits black-body radiation. The filament is observed to break up at random locations after a sufficiently long time of operation due to non-uniform evaporation of tungsten from the filament. If the bulb is powered at constant voltage, which of the following statement(s) is(are) true?

- (A) The temperature distribution over the filament is uniform  
(B) The resistance over small sections of the filament decreases with time  
(C) The filament emits more light at higher band of frequencies before it breaks up  
(D) The filament consumes less electrical power towards the end of the life of the bulb

12. (D)

Theoretical

13. The position vector  $\vec{r}$  of a particle of mass  $m$  is given by the following equation

$$\vec{r}(t) = \alpha t^3 \hat{i} + \beta t^2 \hat{j},$$

Where  $\alpha = 10/3 \text{ ms}^{-3}$ ,  $\beta = 5 \text{ ms}^{-2}$  and  $m = 0.1 \text{ kg}$ . At  $t = 1 \text{ s}$ , which of the following statement(s) is(are) true about the particle?

- (A) The velocity  $\vec{v}$  is given by  $\vec{u} = (10\hat{i} + 10\hat{j}) \text{ m s}^{-1}$   
(B) The angular momentum  $\vec{L}$  with respect to the origin is given by  $\vec{L} = -(5/3)\hat{k} \text{ N m s}$   
(C) The force  $\vec{F}$  is given by  $\vec{F} = (\hat{i} + 2\hat{j}) \text{ N}$   
(D) The torque  $\vec{\tau}$  with respect to the origin is given by  $\vec{\tau} = -(20/3)\hat{k} \text{ N m}$

Sol. (ABD)

$$\vec{v} = \frac{d\vec{r}}{dt} = 3\alpha t^2 \hat{i} + 2\beta t \hat{j}$$

At  $t = 1$

$$\vec{v} = 10\hat{i} + 10\hat{j}$$

$$\vec{L} = m(\vec{r} \times \vec{v})$$

$$= 0.1 \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 10 & 5 & 0 \\ 10 & 10 & 0 \end{vmatrix}$$



$$= -\frac{5}{3}\hat{k}$$

$$\vec{a} = \frac{d\vec{v}}{dt} = 6\alpha t\hat{i} + 2\beta\hat{j}$$

At  $t = 1$

$$= 20\hat{i} + 10\hat{j}$$

$$\vec{F} = m\vec{a} = 2\hat{i} + \hat{j}$$

$$\vec{\tau} = \vec{r} \times \vec{f}$$

$$= \alpha\hat{k} + 2\beta(-\hat{k}) = -\frac{20}{3}\hat{k}$$

- 14.** The isotope  ${}^{12}_5\text{B}$  having a mass 12.014 u undergoes  $\beta$ -decay to  ${}^{12}_6\text{C}$ .  ${}^{12}_6\text{C}$  has an excited state of the nucleus ( ${}^{12}_6\text{C}^*$ ) at 4.041 MeV above its ground state. If  ${}^{12}_5\text{B}$  decays to  ${}^{12}_6\text{C}^*$ , the maximum kinetic energy of the  $\beta$ -particle in units of MeV is (1u = 931.5 MeV/c<sup>2</sup>, where  $c$  is the speed of light in vacuum).

**Sol.** (9)

$${}^{12}_5\text{B} \rightarrow {}^{12}_6\text{C} + {}^0_{-1}\text{e} + \bar{\nu}$$

(excited state)

$$(12.014 \times 931.5) \text{ MeV} = (12 \times 931.5) \text{ MeV} + 4.041 + k$$

$$(12.014 - 12) 931.5 = 4.041 + k$$

$$(0.014) \times 931.5 - 4.041 = k$$

$$13.041 - 4.041 = k$$

$$k = 9 \text{ MeV}$$

- 15.** Two inductors  $L_1$  (inductance 1 mH, internal resistance  $3\Omega$ ) and  $L_2$  (inductance 2 mH, internal resistance  $4\Omega$ ), and a resistor  $R$  (resistance  $12\Omega$ ) are all connected in parallel across a 5 V battery. The circuit is switched on at time  $t = 0$ . The ratio of the maximum to the minimum current ( $I_{\max}/I_{\min}$ ) drawn from the battery is

**Sol.** (8)

$$L_1 = 10^{-3} \text{ H}, \quad r_1 = 3\Omega \quad L_2 = 2 \times 10^{-3} \text{ H}, \quad r_2 = 4\Omega \quad R = 12\Omega$$

At  $t = 0$   $i_1 = \frac{5}{12}$

At  $t = \infty$   $i_2 = \frac{5}{12} + \frac{5}{4} + \frac{5}{3} = \frac{40}{12}$

Required ratio  $\frac{i_2}{i_1} = 8$

- 16.** Consider two solid spheres P and Q each of density  $8 \text{ gm cm}^{-3}$  and diameters 1 cm and 0.5 cm, respectively. Sphere P is dropped into a liquid of density  $0.8 \text{ gm cm}^{-3}$  and viscosity  $\eta = 3$  poiseulles. Sphere Q is dropped into a liquid of density  $1.6 \text{ gm cm}^{-3}$  and viscosity  $\eta = 2$  poiseulles. The ratio of the terminal velocities of P and Q is

**Sol.** (3)

$$u = \frac{2\pi r^2 g (p - \sigma)}{9\pi\eta}$$

$$\frac{V_1}{V_2} = \frac{r_1^2 (P - \sigma_1) \eta_2}{r_2^2 (P - \sigma_2) \eta_1}$$

$$= \frac{(1 \times 10^{-2})^2 \times (8 - 0.8) \times 2}{(0.5 \times 10^{-2})^2 \times (8 - 1.6) \times 3}$$

$$= \frac{7.2 \times 2}{0.25 \times 6.4 \times 3}$$

$$= 3$$

17. A metal is heated in a furnace where a sensor is kept above the metal surface to read the power radiated ( $P$ ) by the metal. The sensor has a scale that displays  $\log_2 (P/P_0)$ , where  $P_0$  is a constant. When the metal surface is at a temperature of  $487^\circ\text{C}$ , the sensor shows a value 1. Assume that the emissivity of the metallic surface remains constant. What is the value displayed by the sensor when the temperature of the metal surface is raised to  $2767^\circ\text{C}$ ?

Sol. (9)

$$P = \sigma e A \tau^4$$

$$\log_2 \left( \frac{r e A (487 + 273)^4}{P_0} \right) = 1$$

$$\frac{\sigma e A}{P_0} = \frac{2}{(760)^4}$$

$$x = \log_2 \left\{ \frac{r e A (2767 + 273)}{P_0} \right\} = \log_2 \left\{ \frac{(3040)^4 \times 2}{(760)^4} \right\}$$

$$= \log_2 (4 \times 2) = 9$$

18. A hydrogen atom in its ground state is irradiated by light of wavelength  $970 \text{ \AA}$ . Taking  $hc/e = 1.237 \times 10^{-6} \text{ eV m}$  and the ground state energy of hydrogen atom as  $-13.6 \text{ eV}$ , the number of lines present in the emission spectrum is

Sol. (6)

$$E = \frac{12370}{970}$$

$$= 12.752 \text{ eV}$$

$$E_1 = -13.6 \text{ eV} = -13.6 \frac{Z^2}{n^2}$$

$$E_2 = -3.4 \text{ eV}$$

$$E_3 = -1.51 \text{ eV}$$

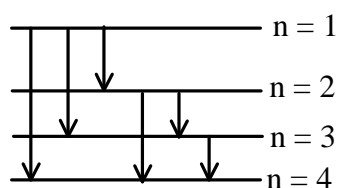
$$E_4 = -0.85 \text{ eV}$$

$$E_5 = -0.544 \text{ eV}$$

$$E_4 - E_1 < E$$

$$E_5 - E_1 > E$$

So, possible lines are



Total lines = 6

**SECTION – II (CHEMISTRY)**

- Q. 19** The increasing order of atomic radii of the following Group 13 elements is  
 (A) Al < Ga < In < Tl (B) Ga < Al < In < Tl  
 (C) Al < In < Ga < Tl (D) Al < Ga < Tl < In

Sol: **(B)**  
 Tl > In > Al > Ga  
 'Ga' size is small due to poor shielding of d- orbital.

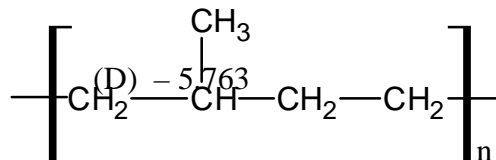
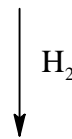
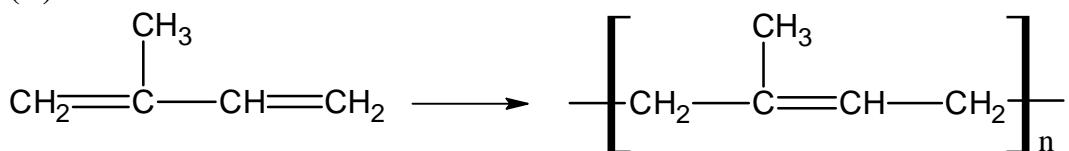
- Q. 20** Among  $[\text{Ni}(\text{CO})_4]$ ,  $[\text{NiCl}_4]^{2-}$ ,  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ ,  $\text{Na}_3[\text{CoF}_6]$ ,  $\text{Na}_2\text{O}_2$  and  $\text{CsO}_2$ , the total number of paramagnetic compounds is

- (A) 2 (B) 3 (C) 4 (D) 5

Sol: **(B)**  
 $[\text{Ni}(\text{CO})_4] sp^3 \mu = 0$   
 $[\text{NiCl}_4]^{2-} sp^3 \mu = \sqrt{8} \text{ B.M.}$   
 $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl} \mu = 0$   
 Most of the  $\text{Co}^{+3}$  complexes are low spin  
 $[\text{CoF}_6]^{3-} \mu = \sqrt{24} \text{ B.M.}$   
 $\text{Na}_2\text{O}_2$  diamagnetic  
 $\text{KO}_2$  paramagnetic one unpaired electron  
 So total three paramagnetic substances.

- Q. 21** On complete hydrogenation, natural rubber produces  
 (A) ethylene-propylene copolymer (B) vulcanized rubber  
 (C) polypropylene (D) polybutylene

Sol: **(A)**



1 L atm = 101.3 J)

- (A) 5.763 (B) 1.013 (C) -1.013 (D) -5.763

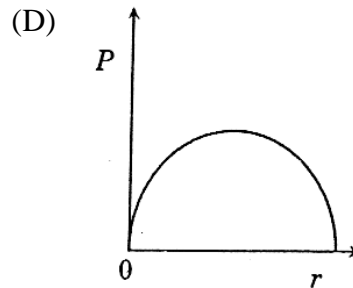
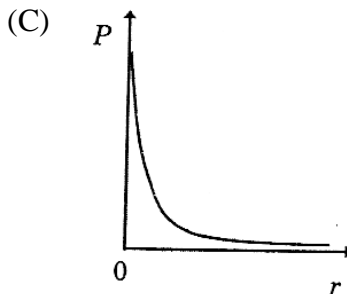
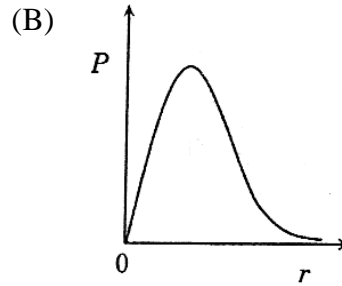
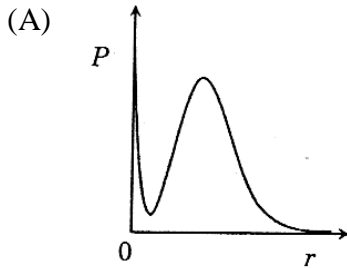
- Q. 22** One mole of an ideal gas at 300 K in thermal contact with surroundings expands isothermally from 1.0 L to 2.0 L against a constant pressure of 3.0 atm. In this process, the change in entropy of surroundings ( $\Delta S_{\text{surr}}$ ) in  $\text{JK}^{-1}$  is

$$Q_{\text{sys}} = +3(2-1) = 3L.\text{atm}$$

$$\Delta S_{\text{surr}} = \frac{-3 \times 101.325}{300}$$

$$= -1.01325$$

**Q. 23** P is the probability of finding the 1s electron of hydrogen atom in a spherical shell of infinitesimal thickness, dr, at a distance r from the nucleus. The volume of this shell is  $4\pi r^2 dr$ . The qualitative sketch of the dependence of P on r is

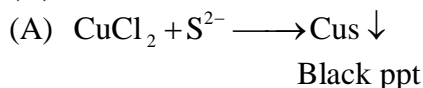


Sol: **(B)**

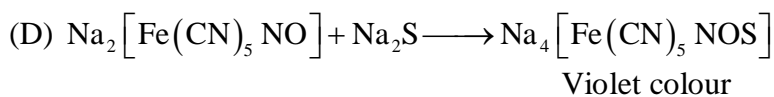
**Q. 24** The reagent(s) that can selectively precipitate  $S^{2-}$  from a mixture of  $S^{2-}$  and  $SO_4^{2-}$  in aqueous solution is (are)

- (A)  $CuCl_2$                       (B)  $BaCl_2$                       (C)  $Pb(OOCCH_3)_2$                       (D)  $Na_2[Fe(CN)_5NO]$

Sol: **(A)**



$CuSO_4$  is water soluble

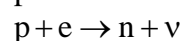
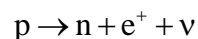


**Q. 25** A plot of the number of neutrons (N) against the number of protons (P) of stable nuclei exhibits upward deviation from linearity for atomic number,  $Z > 20$ . For an unstable nucleus having N/P ratio less than 1, the possible mode(s) of decay is (are)

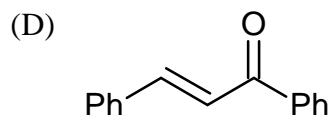
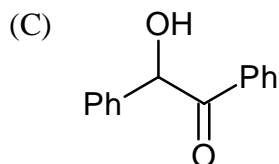
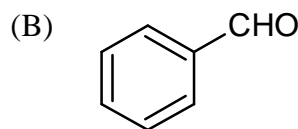
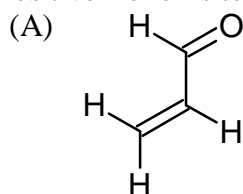
- (A)  $\beta^-$  - decay ( $\beta$  emission)                      (B) orbital or K-electron capture  
(C) neutron emission                      (D)  $\beta^+$  - decay (positron emission)

Sol: **(BD)**

No. of neutrons have to increased



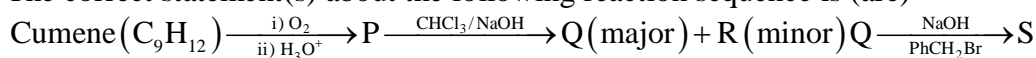
**Q. 26** Positive Tollen's test is observed for



Sol: **(AB)**

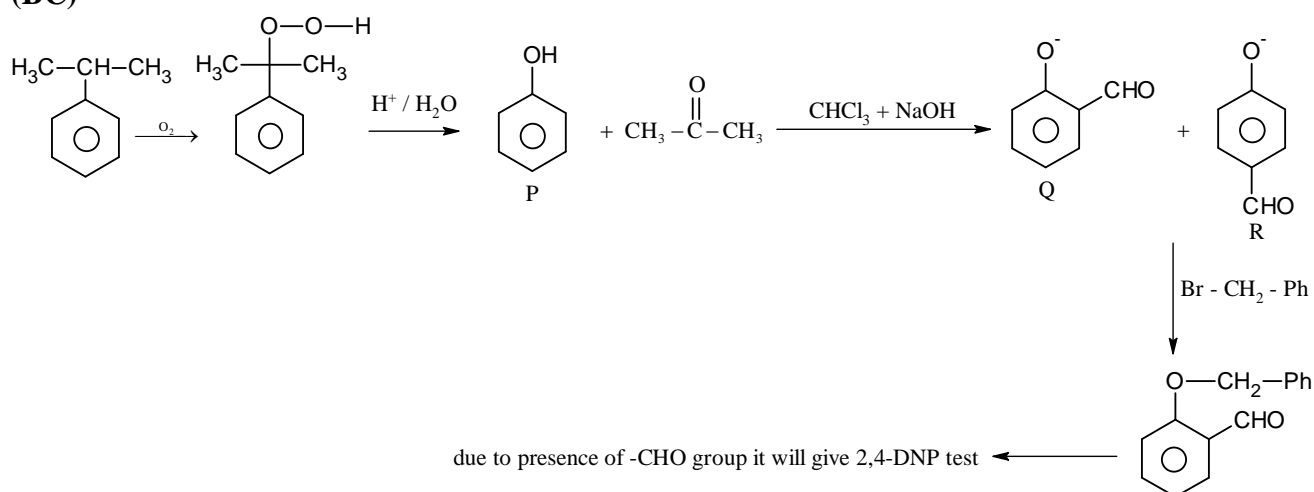
Give positive tollen's test

**Q. 27** The correct statement(s) about the following reaction sequence is (are)



- (A) R is steam volatile  
(B) Q gives dark violet coloration with 1% aqueous  $FeCl_3$  solution  
(C) S gives yellow precipitate with 2, 4-dinitrophenylhydrazine  
(D) S gives dark violet coloration with 1% aqueous  $FeCl_3$  solution

Sol: **(BC)**

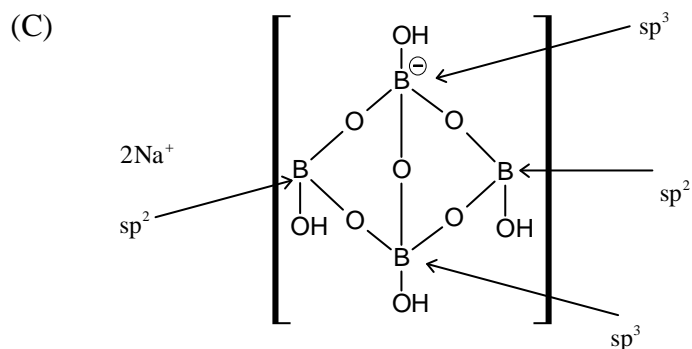


**Q. 28** The crystalline form of borax has

- (A) tetranuclear  $[B_4O_5(OH)_4]^{2-}$  unit  
(B) all boron atoms in the same plane  
(C) equal number of  $sp^2$  and  $sp^3$  hybridized boron atoms  
(D) one terminal hydroxide per boron atom

Sol: **(ACD)**

(A) Borax contains  $Na_2[B_4(OH)O_5]$



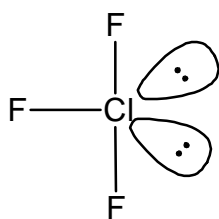
(D) each Boron contain one O–H

**Q. 29** The compound(s) with TWO lone pairs of electrons on the central atom is(are)

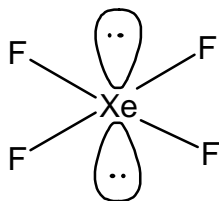
- (A)  $\text{BrF}_5$       (B)  $\text{ClF}_3$       (C)  $\text{XeF}_4$       (D)  $\text{SF}_4$

Sol: **(BC)**

(B)



(C)



**Q. 30** According to the Arrhenius equation,

- (A) a high activation energy usually implies a fast reaction.  
 (B) rate constant increases with increase in temperature. This is due to a greater number of collisions whose energy exceeds the activation energy.  
 (C) higher the magnitude of activation energy, stronger is the temperature dependence of the rate constant.  
 (D) the pre-exponential factor is a measure of the rate at which collisions occurs irrespective of their energy.

Sol: **(BCD)**

High  $E_a \Rightarrow$  slow reaction

$$\log \frac{K_2}{K_1} = \frac{E_a}{2.303R} \left[ \frac{1}{T_1} - \frac{1}{T_2} \right]$$

Higher  $E_a$  stronger temperature dependence

A depends on rate of collisions & temperature dependence is negligible.

**Q. 31** The product(s) of the following reaction sequence is (are)

