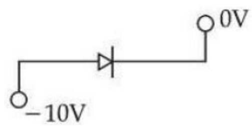
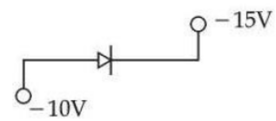
|JEE MAIN 2025 | DATE : 22 JANUARY 2025 (SHIFT-1) MORNING

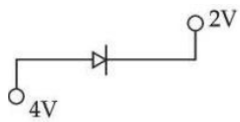
PHYSICS

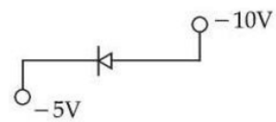
SECTION-1

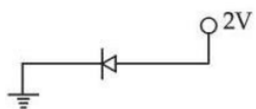
[:Q.1] Which of the following circuits represents a forward biased diode?

(a) 

(b) 

(c) 

(d) 

(e) 

Choose the correct answer from the options given below:

[:A] (b), (c) and (e) only

[:B] (a) and (d) only

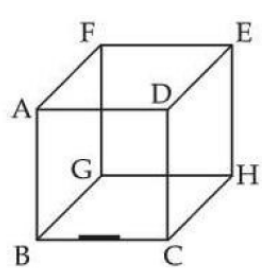
[:C] (b), (d) and (e) only

[:D] (c) and (e) only

[:ANS] **A**

[:SOLN] For diode to be forward biased p-type is connected to higher potential and n-type is connected to lower potential.

[:Q.2] A line charge of length $\frac{'a'}{2}$ is kept at the center of an edge BC of a cube ABCDEFGH having edge length 'a' as shown in the figure. If the density of line charge is λ C per unit length, then the total electric flux through all the faces of the cube will be _______. (Take, ϵ_0 as the free space permittivity)



[:A] $\frac{\lambda_a}{4 \in_0}$

[:B] $\frac{\lambda_a}{16 \in_0}$

[:C] $\frac{\lambda_a}{2 \in_0}$

[:D] $\frac{\lambda_a}{8 \in_0}$

[:ANS] **D**

[:SOLN] Total charge inside the cube

$$= \frac{\lambda \frac{a}{2}}{4} = \frac{\lambda a}{8}$$

$$\therefore \ \phi = \frac{q_{in}}{\varepsilon_0} = \frac{\lambda a}{8\varepsilon_0}$$

[:Q.3] An electron is made to enter symmetrically between two parallel and equally but oppositely charged metal plates, each of 10 cm length. The electron emerges out of the electric field region with a horizontal component of velocity 10^6 m/s.If the magnitude of the electric field between the plates is 9.1 V/cm, then the vertical component of velocity of electron is (mass of electron = 9.1×10^{-31} kg and charge of electron = 1.6×10^{-19} C)

[:A] $16 \times 10^4 m / s$

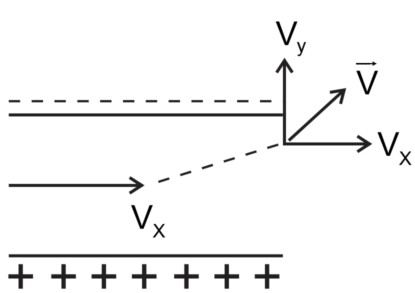
[:B] $16 \times 10^6 m / s$

[:C] $1 \times 10^6 m / s$

[:D] 0

[:ANS] **B**

[:SOLN]



$E = 9.1 \times 10^2 \ V / m$

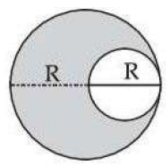
$$t=\frac{l}{v_x}=\frac{10\times10^{-2}}{10^{6}}=10^{-7}\text{ sec}$$

$$a=\frac{eE}{m}=\frac{1.6\times10^{-19}\times9.1\times10^{2}}{9.1\times10^{-31}}$$

$$v_y=u_y+at=0+\frac{1.6\times10^{-19}\times9.1\times10^{2}}{9.1\times10^{-31}}$$

$$V_y=16\times10^{6}\text{ m / s}$$

[:Q.4] A uniform circular disc of radius 'R' and mass 'M' is rotating about an axis perpendicular to its plane and passing through its centre. A small circular part of radius R/2 is removed from the original disc as shown in the figure. Find the moment of inertia of the remaining part of the original disc about the axis as given above.



[:A] $\frac{7}{32}MR^2$

[:B] $\frac{9}{32}MR^2$

[:C] $\frac{13}{32}MR^2$

[:D] $\frac{17}{32}MR^2$

[:ANS] **C**

[:SOLN] $I=I_1-I_2$

$$I_1=\frac{MR^2}{2}$$

$$I_2=\frac{\frac{M}{4}\left(\frac{R}{2}\right)^2}{2}+\frac{M}{4}\left(\frac{R}{2}\right)^2$$

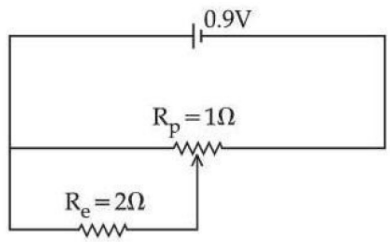
$$=\frac{MR^2}{32}+\frac{MR^2}{16}=\frac{3MR^2}{32}$$

$$I=I_1-I_2$$

$$=\frac{16MR^2}{32}-\frac{3MR^2}{32}$$

$= \frac{13MR^2}{32}$

[:Q.5] Sliding contact of a potentiometer is in the middle of the potentiometer wire having resistance $R_p = 1\Omega$ as shown in the figure. An external resistance of $R_e = 2\Omega$ is connected via the sliding contact. The electric current in the circuit is :



[:A] 1.35

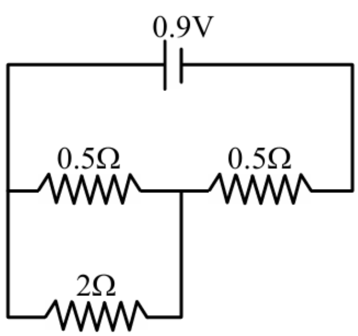
[:B] 1.0 A

[:C] 0.9 A

[:D] 0.3 A

[:ANS] **B**

[:SOLN] The circuit can be considered as

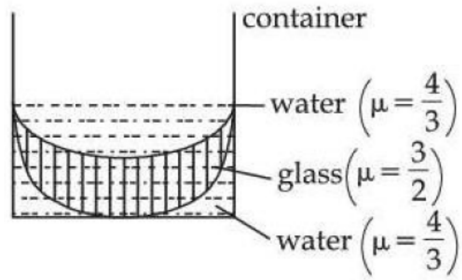


$$\therefore\ R_{eq} = 0.5 + \frac{0.5 \times 2}{2 + 0.5} = \left(\frac{5}{10} + \frac{10}{25}\right)\Omega$$

$$= \frac{45}{50} = \frac{9}{10} = 0.9$$

$$\therefore\ i = \frac{0.9}{0.9} = 1A$$

[:Q.6] In the diagram given below, there are three lenses formed. Considering negligible thickness of each of them as compared to $|R_1|$ and $|R_2|$, i.e., the radii of curvature for upper and lower surfaces of the glass lens, the power of the combination is



[:A] $-\frac{1}{6}\left(\frac{1}{|R_1|} - \frac{1}{|R_2|}\right)$

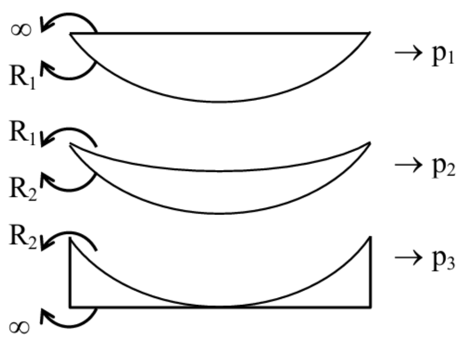
[:B] $\frac{1}{6}\left(\frac{1}{|R_1|} - \frac{1}{|R_2|}\right)$

[:C] $\frac{1}{6}\left(\frac{1}{|R_1|} + \frac{1}{|R_2|}\right)$

[:D] $-\frac{1}{6}\left(\frac{1}{|R_1|} + \frac{1}{|R_2|}\right)$

[:ANS] A

[:SOLN]



$$\Rightarrow p_{eq} = p_1 + p_2 + p_3$$

$$\Rightarrow p_1 = \left(\frac{4}{3} - 1\right)\left(\frac{1}{\infty} - \frac{1}{-|R_1|}\right)$$

$$\Rightarrow p_1 = \left(\frac{1}{3|R_1|}\right)$$

$$\Rightarrow p_2 = \frac{1}{2}\left(\frac{1}{|R_2|} - \frac{1}{|R_1|}\right)$$

$$\Rightarrow p_3 = \left(\frac{1}{3}\right)\left(\frac{1}{-|R_2|} - \frac{1}{\infty}\right) = -\frac{1}{3|R_2|}$$

$$\Rightarrow p_{eq} = \frac{1}{3}\left(\frac{1}{|R_1|} - \frac{1}{|R_2|}\right) - \frac{1}{2}\left(\frac{1}{|R_1|} - \frac{1}{|R_2|}\right)$$

$$= -\frac{1}{6}\left(\frac{1}{|R_1|} - \frac{1}{|R_2|}\right)$$

[:Q.7] Given below are two statements :

Statement - I : The equivalent emf of two non-ideal batteries connected in parallel is smaller than either of the two emfs

Statement - II : The equivalent internal resistance of two non-ideal batteries connected in parallel is smaller than the internal resistance of either of the two batteries.

In the light of the above statements, choose the correct answer from the options given below.

[:A] Both Statement - I and Statement - II are false

[:B] Statement - I is strue but Statement - II is false

[:C] Statement - I is false but Statement - II is true

[:D] Both Statement - I and Statement - II are true

[:ANS] **C**

[:SOLN] $$E_{eq} = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}}$$

$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2}$$

[:Q.8] Two spherical bodies of same materials having radii 0.2 m and 0.8 m are placed in same atmosphere. The temperature of the smaller body is 800 K and temperature of the bigger body is 400 K. If the energy radiated from the smaller body is E, the energy radiated from the bigger body is (assume, effect of the surrounding temperature to be negligible),

[:A] 64 E

[:B] E

[:C] 16 E

[:D] 256 E

[:ANS] **B**

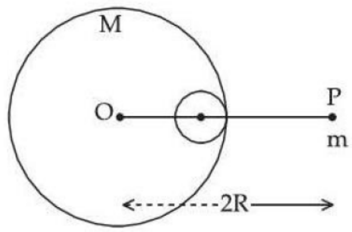
[:SOLN] $$\frac{d\theta}{dt} = \sigma e A T^4 \Rightarrow P \propto AT^4$$

$$\frac{P_{smaller}}{P_{larger}} = \frac{(0.2)^2 \times 800^4}{(0.8)^2 \times 400^4}$$

$$\frac{1}{16}\times 16 = 1$$

$\therefore\ P_{larger} = P_{smaller}$ = E

[:Q.9] A small point of mass m is placed at a distance 2R from the centre 'O' of a big uniform solid sphere of mass M and radius R. The gravitational force on 'm' due to M is F_1. A spherical part of radius R/3 is removed from the big sphere as shown in the figure and the gravitational force on m due to remaining part of M is found to be F_2. The value of ratio $F_1 : F_2$ is



[:A] 11 : 10

[:B] 12 : 11

[:C] 16 : 9

[:D] 12 : 9

[:ANS] **B**

[:SOLN] $F_1 = \frac{GMm}{(2R)^2}$ ...(1)

$$F_2 = \frac{GMm}{(2R)^2} - \left(\frac{G\left(\frac{M}{27}\right)m}{\left(\frac{4R}{3}\right)^2}\right)$$

$$F_2 = \frac{11}{48}\frac{GMm}{R^2} \quad \ldots(2)$$

$F_1 : F_2 = 12 : 11$

[:Q.10] Given below are two statements : one is labelled as Assertion (A) and the other is labelled as Reason (R)

Assertion (A) : If Young's double slit experiment is performed in an optically denser medium than air, then the consecutive fringes come closer.

Reason (R) : The speed of light reduces in an optically denser medium than air while its frequency does not change.

In the light of the above statements, choose the most appropriate answer from the options given below:

[A] Both (A) and (R) are true and (R) is the correct explanation of (A)

[B] Both (A) and (R) are true but (R) is not the correct explanation of (A)

[C] (A) is true but (R) is false

[D] (A) is false but (R) is true

[:ANS] **A**

[:SOLN] $\beta(\text{fringe width}) = \dfrac{\lambda D}{d}$

In denser medium, $\lambda \downarrow \Rightarrow \beta \downarrow$

$\Rightarrow$ fringe come closer

Also, $\mu = \dfrac{c}{V} \Rightarrow V = \dfrac{c}{\mu}$

Frequency remains same,

$\Rightarrow \mu = \dfrac{\lambda_{vac.} f}{\lambda_{med} f} \Rightarrow \lambda_{med} = \dfrac{\lambda_{vac.}}{\mu}$

[:Q.11] A closed organ and an open organ tube are filled by two different gases having same bulk modulus but different densities ρ_1 and ρ_2, respectively. The frequency of 9^{th} harmonic of closed tube is identical with 4^{th} harmonic of open tube. If the length of the closed tube is 10 cm and the density ratio of the gases is $\rho_1 : \rho_2 = 1 : 16$, then the length of the open tube is :

[:A] $\dfrac{20}{7}$ cm

[:B] $\dfrac{20}{9}$ cm

[:C] $\dfrac{15}{7}$ cm

[:D] $\dfrac{15}{9}$ cm

[:ANS] **B**

[:SOLN] 9^{th} harmonic of closed pipe $= \dfrac{9V_1}{4\ell_1}$

4^{th} harmonic of open pipe $= \dfrac{2V_2}{\ell_2}$

$\therefore \dfrac{9V_1}{4\ell_1} = \dfrac{2V_2}{\ell_2}$

$$\therefore \frac{9}{4\ell_1}\sqrt{\frac{B}{\rho_1}} = \frac{2}{\ell_2}\sqrt{\frac{B}{\rho_2}} \Rightarrow \frac{\ell_2}{\ell_1} = \frac{8}{9}\sqrt{\frac{\rho_1}{\rho_2}}$$

$$\ell_2 = \ell_1 \times \frac{8}{9} \times \frac{1}{4} = \frac{20}{9}\text{cm}$$

[:Q.12] The work functions of cesium (Cs) and lithium (Li) metals are 1.9 eV and 2.5 eV, respectively. If we incident a light of wavelength 550 nm on these two metal surfaces, then photo-electric effect is possible for the case of

[:A] Li only

[:B] Cs only

[:C] Both Cs and Li

[:D] Neither Cs nor Li

[:ANS] **B**

[:SOLN] $E = \frac{12400}{5500} = 2.25\,\text{eV}.$

For Cs, $E > \phi \quad \therefore$ P.E.E. takes place

[:Q.13] An amount of ice of mass 10^{-3} kg and temperature -10°C is transformed to vapour of temperature 110ºC by applying heat. The total amount of work required for this conversion is ,

(Take, specific heat of ice = 2100 $\text{Jkg}^{-1}\text{K}^{-1}$, specific heat of water = 4180 $\text{Jkg}^{-1}\text{K}^{-1}$, specific heat of steam = 1920 $\text{Jkg}^{-1}\text{K}^{-1}$, Latent heat of ice = 3.35 × 10^5 Jkg^{-1} and Latent heat of steam = 2.25 × 10^6 Jkg^{-1})

[:A] 3043 J

[:B] 3003 J

[:C] 3022 J

[:D] 3024 J

[:ANS] **A**

[:SOLN] $Q_{net} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5$

$= mC,\Delta T + mL_f + mC_{cv}\Delta T + mL_v + mC_v\Delta T$

$= 10^{-3} \times 2100 \times 10 + 10^{-3} \times 3.35 \times 10^5 + 4180 \times 10^{-3} \times 100 + 10^{-3} \times 2.25 \times 10^6 + 10^{-3} \times 1920 \times 10$

$= 21 + 335 + 418 + 2250 + 19.2$

=3043.2J

[:Q.14] An electron in the ground state of the hydrogen atom has the orbital radius of 5.3×10^{-11} m while that for the electron in third excited state is 8.48×10^{-10} m. The ratio of the de Broglie wavelengths of electron in the ground state to that in the excited state is

[:A] 3

[:B] 16

[:C] 4

[:D] 9

[:ANS] **BONUS**

[:SOLN]

$$\lambda=\frac{h}{mv}$$

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

$$mv=\frac{nh}{2\pi r}$$

$$\lambda=\frac{2\pi rh}{nh}$$

$$\lambda\propto\frac{r}{n}$$

$$\frac{\lambda_1}{\lambda_4}=\frac{r_1n_4}{n_1r_4}=\frac{5.3\times10^{-11}\times4}{1\times84.8\times10^{-11}}$$

$$\frac{\lambda_1}{\lambda_4}=\frac{1}{4}$$

[:Q.15] Given is a thin convex lens of glass (refractive index μ) and each side having radius of curvature R. One side is polished for complete reflection. At what distance from the lens, an object be placed on the optic axis so that the image gets formed on the object itself?

[:A] R/μ

[:B] μR

[:C] $R/(2\mu-3)$

[:D] $R/(2\mu-1)$

[:ANS] **D**

[:SOLN] $P_{eq}=2P_{\ell}+P_m$

$$-\frac{1}{f_Q}=\frac{2}{f_\ell}-\frac{1}{f_m}$$

$$=\frac{4(\mu-1)}{R}-\frac{2}{-R}=\frac{1}{R}(4\mu-4+2)$$

$$-\frac{1}{f_{eq}}=\frac{1}{R}(4\mu-2)$$

$$\Rightarrow\frac{1}{f_{eq}}=\frac{-1}{R}(4\mu-2)$$

$$u = 2f_{eq}=-2\left(\frac{R}{4\mu-2}\right)=\frac{-R}{(2\mu-1)}$$

[:Q.16] If B is magnetic field and μ_0 is permeability of free space, then the dimensions of (B/μ_0) is

[:A] $MT^{-2}A^{-1}$

[:B] $LT^{-2}A^{-1}$

[:C] $L^{-1}A$

[:D] $ML^2T^{-2}A^{-1}$

[:ANS] **C**

[:SOLN] $B=\frac{\mu_0 I}{2r}$

$$\frac{B}{\mu_0}=\frac{I}{2r}$$

$$\left[\frac{B}{\mu_0}\right]=\left[\frac{A}{L}\right]=\left[L^{-1}A\right]$$

[:Q.17] Given below are two statements :

Statement I : In a vernier calliper, one vernier scale division is always smaller than one main scale division.

Statement II : The vernier constant is given by one main scale division multiplied by the number of vernier scale divisions.

In the light of the above statements, choose the correct answer from the options given below.

[:A] Both statement I and Statement II are ture.

[:B] Both statement I and statement II are false.

[:C] Statement I is correct but statement II is false

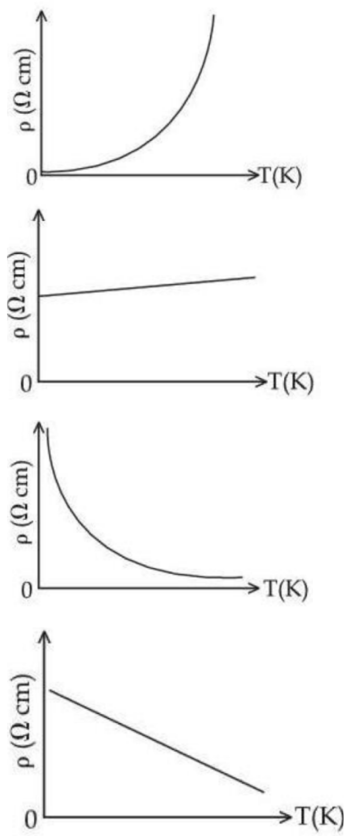
[:D] Statement I is incorrect but statement II is true.

[:ANS] **B**

[:SOLN] Vernier Constant = MSD – VSD = $\frac{MSD}{n}$

[:Q.18] Which of the following resistivity (ρ) v/s temperature (T) curves is most suitable to be used in wire bound standard resistors?

[:A] [:B] [:C] [:D]



[:ANS] **B**

[:SOLN] Resistivity is independent of temperature for wire bound resistor.

[:Q.19] A parallel-plate capacitor of capacitance $40\mu F$ is connected to a 100 V power supply. Now the intermediate space between the plates is filled with a dielectric material of dielectric constant K = 2. Due to the introduction of dielectric material, the extra charge and the change in the electrostatic energy in the capacitor, respectively, are

[:A] 2mC and 0.2 J

[:B] 4 mC and 0.2 J

[:C] 2 mC and 0.4 J

[:D] 8 mC and 2.0 J

[:ANS] **B**

[:SOLN] $\Delta Q = (KC - C)V$

$= 40 \times 10^{-6} \times 100$

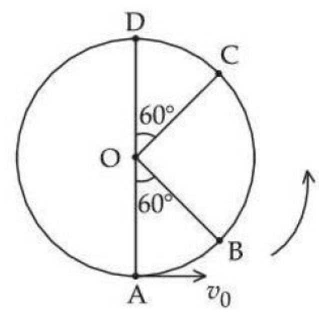
$= 4 \times 10^{-3} C = 4\ mC$

$\Delta U = \frac{1}{2}C'V^2 - \frac{1}{2}CV^2 = \frac{1}{2}(K-1)CV^2$

$= \frac{1}{2}CV^2 = \frac{1}{2} \times 40 \times 10^{-6} \times 10^4$

=0.2 J

[:Q.20] A bob of mass m is suspended at a point O by light string of length ℓ and left to perform vertical motion (circular) as shown in figure. Initially, by applying horizontal velocity υ_0 at the point 'A' the string becomes slack when, the bob reaches at the point 'D'. The ratio of the kinetic energy of the bob at the points B and C is ______



[:A] 2

[:B] 1

[:C] 4

[:D] 3

[:ANS] **A**

[:SOLN] $E_A = E_B$

$\Rightarrow \frac{1}{2} \times m \times 5g\ell = \frac{1}{2}mV_B^2 + mg\frac{\ell}{2}$

$\therefore K_B = \frac{5mgl}{2} - \frac{mgl}{2} = 2mgl$

$E_D = E_C$

$\Rightarrow \frac{1}{2} \times m \times V_c^2 = \frac{1}{2}mV_D^2 + mg\frac{l}{2}$

$K_c = \frac{mgl}{2} + \frac{mgl}{2} = mgl$

$$\therefore \frac{K_B}{K_C} = \frac{2mgl}{mgl} = 2$$

SECTION-2

[:Q.21] The driver sitting inside a parked car is watching vehicles approaching from behind with the help of his side view mirror, which is a convex mirror with radius of curvature R = 2m. Another car approaches him from behind with a uniform speed of 90 km/hr. When the car is at a distance of 24 m from him, the magnitude of the acceleration of the image of the car in the side view mirror is 'a'. The value of 100a is ______m/s^2.

[:ANS] **8**

[:SOLN] $v = \frac{uf}{u-f} = \frac{24}{25}$

$$m = \frac{-v}{u} = \frac{24/25}{24} = \frac{1}{25}$$

$$V_I = -m^2 V_0 = -\left(\frac{1}{25}\right)^2 \times 25 = \frac{-1}{25}$$

$$\Rightarrow \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\Rightarrow -\frac{1}{v^2}\left(\frac{dv}{dt}\right) + \frac{1}{u^2}\left(\frac{du}{dt}\right) = 0$$

$$\Rightarrow a_i = \frac{2}{v}\left(v_i^2\right) - \frac{2v^2}{u^3}\left(v_0^2\right)$$

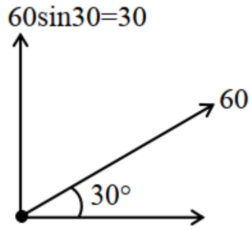
$$= \frac{2}{(24)(25)} - \frac{2}{24} = -\frac{2}{25}$$

Now, $100a = \frac{2}{25} \times 100 = 8$

[:Q.22] A particle is projected at an angle of 30° from horizontal at a speed of 60 m/s. The height traversed by the particle in the first second is h_0 and height traversed in the last second, before it reaches the maximum height, is h_1. The ratio $h_0 : h_1$ is ______. [Take, g = 10 m/s^2]

[:ANS] **5**

[:SOLN]



$$S_1 = 30\times1-\frac{1}{2}\times10\times1 = 25$$

$$S_3 = 30+\left(\frac{-10}{2}\right)\times(2\times3-1) = 5$$

$$\frac{S_1}{S_3} = \frac{25}{5} = 5$$

[:Q.23] The position vectors of two 1 kg particles, (A) and (B), are given by

$\vec{r}_A = \left(\alpha_1 t^2\hat{i} + \alpha_2 t\hat{j} + \alpha_3 t\hat{k}\right)$ m and $\vec{r}_B = \left(\beta_1 t\hat{i} + \beta_2 t^2\hat{j} + \beta_3 t\hat{k}\right)$ m, respectively;

$\left(\alpha_1 = 1 m/s^2, \alpha_2 = 3n m/s, \alpha_3 = 2 m/s, \beta_1 = 2 m/s, \beta_2 = -1 m/s^2, \beta_3 = 4p m/s\right)$, where t is time, n and p are constants. At t = 1 s, $|\vec{V}_A| = |\vec{V}_B|$ and velocities $\vec{V}_A$ and $\vec{V}_B$ of the particles are orthogonal to each other. At t = 1 s, the magnitude of angular momentum of particle (A) with respect to the position of particle (B) is $\sqrt{L}\, kgm^2s^{-1}$. The value of L is _____.

[:ANS] **90**

[:SOLN] $\vec{V}_A = (2t\hat{i} + 3n\hat{j} + 2\hat{k})$

$\vec{V}_B = (2\hat{i} - 2t\hat{j} + 4p\hat{k})$

At t = 1 s $\vec{V}_A \cdot \vec{V}_B = 0$

$4 - 6n + 8p = 0$

$2 - 3n + 4p = 0$

$3n = 2 + 4p$

Also, $|\vec{V}_A| = |\vec{V}_B|$

$4 + 9n^2 + 4 = 4 + 4 + 16p^2$

$p = \frac{-1}{4} \quad \Rightarrow n = \frac{1}{3}$

$$\vec{L} = m_A\left(\vec{r}_{A/B} \times \vec{V}_A\right)$$

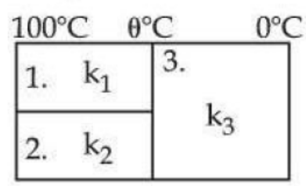
$$\vec{r}_{A/B} = (\alpha_1 - \beta_1)\hat{i} + (\alpha_2 - \beta_2)\hat{j} + (\alpha_3 - \beta_3)$$

$$= (1-2)\hat{i} + (1+1)\hat{j} + 3\hat{k}$$

$$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -1 & 2 & 3 \\ 2 & 1 & 2 \end{vmatrix} = \hat{i} + 8\hat{j} - 5\hat{k}$$

$$= \sqrt{1+64+25} = \sqrt{90}$$

[:Q.24] Three conductors of same length having thermal conductivity k_1, k_2 and k_3 are connected as shown in figure.

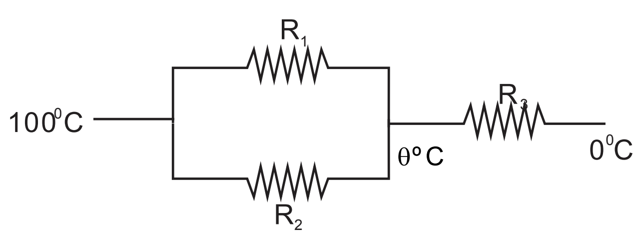


Area of cross sections of 1st and 2nd conductor are same and for 3rd conductor it is double of the 1st conductor. The temperatures are given in the figure. In steady state condition, the value of θ is ________ºC.

(Given : $k_1 = 60\ Js^{-1}m^{-1}K^{-1}, k_2 = 120 Js^{-1}m^{-1}K^{-1}, k_3 = 135 Js^{-1}m^{-1}K^{-1}$)

[:ANS] **40**

[:SOLN]



$$R_1 = \frac{2L}{K_1 A}$$

$$R_2 = \frac{2L}{K_2 A}$$

$$R_3 = \frac{L}{K_3 A}$$

$$\frac{\theta-100}{\frac{R_1R_2}{R_1+R_2}}+\frac{\theta-0}{R_3}=0$$

$\theta = 40°C$

[:Q.25] Two soap bubbles of radius 2 cm and 4 cm, respectively, are in contact with each other. The radius of curvature of the common surface, in cm, is _______.

[:ANS] **4**

[:SOLN] $r=\frac{r_1\cdot r_2}{r_1-r_2}=\frac{2\cdot 4}{4-2}=4\text{cm}$