JEE Main September 2020

Question Paper With Text Solution

4 September| Shift-2

PHYSICS

MATRIX

JEE Main & Advanced | XI-XII Foundation| VI-X Pre-Foundation

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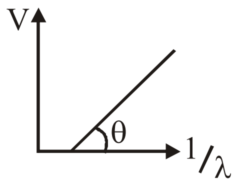
JEE MAIN SEP 2020 | 4 SEP SHIFT-2

1. In a photoelectric effect experiment, the graph of stopping potential V versus reciprocal of wavelength obtained is shown in the figure. As the intensity of incident radiation is increased:



(1) Straight line shifts to right (2) Straight line shifts to left

(3) Graph does not change (4) Slope of the straight line gets more steep

Ans. (3)

Sol. $eV_s = h\nu - \phi$

$$V_s = \frac{h\nu}{e} - \frac{\phi}{e}$$

Frequency and work function are constant therefore graph does not change.

2. Match the thermodynamic processes taking place in a system with the correct conditions. In the table : ΔQ is the heat supplied, ΔW Is the work done and ΔU is change in internal energy of the system.

Process	**Condition**
(I) Adiabatic	(A) $\Delta W = 0$
(II) Isothermal	(B) $\Delta Q = 0$
(III) Isochoric	(C) $\Delta U \neq 0, \Delta W \neq 0, \Delta Q \neq 0$
(IV) Isobaric	(D) $\Delta U \neq 0$

(1) (I)-(B), (II)-(D), (III)-(A), (IV)-(C)

(2) (I) -(A), (II)-(A), (III)- (B), (IV)- (C)

(3) (I) -(A), (II)-(B), (III)- (D), (IV)- (D)

(4) (I) -(B), (II)-(A), (III)- (D), (IV)- (C)

Ans. (1)

Sol. for Adiabatic $\rightarrow \Delta Q = 0 \quad I \rightarrow (B)$

for Isothermal $\rightarrow \Delta U = 0 \quad II \rightarrow (D)$

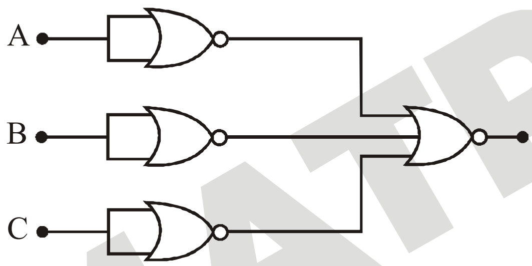
for Isochoric $\rightarrow \Delta W = 0 \quad III \rightarrow (A)$

for Isobaric $\rightarrow \Delta U + 0$

$\Delta W + 0 \quad \rightarrow IV \rightarrow (C)$

$\Delta Q + 0$

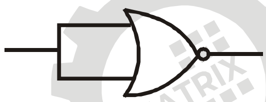
3. Identify the operation performed by the circuit given below :



(1) AND (2) NOT (3) OR (4) NAND

Ans. (1)

Sol.



Behaves like a not gate so boolean equation will be

$$y = \overline{\overline{A} + \overline{B} + \overline{C}}$$

$$y = A.B.C$$

whole arrangement behaves like an AND gate

4. A body is moving in a low circular orbit about a planet of mass M and radius R. The radius of the orbit can be taken to be R itself. Then the ratio of the speed of this body in the orbit to the escape velocity from the planet is:

(1) 1 (2) $\frac{1}{\sqrt{2}}$ (3) $\sqrt{2}$ (4) 2

Ans. (2)

Sol. Orbital speed $V_0 = \sqrt{\dfrac{GM}{r}}$

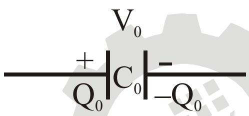
Escape speed $V_e = \sqrt{\dfrac{2GM}{r}}$

$$\frac{v_0}{v_e} = \frac{\sqrt{\dfrac{Gm}{r}}}{\sqrt{\dfrac{2Gm}{r}}} = \frac{1}{\sqrt{2}}$$

5. A capacitor C is fully charged with voltage V_0. After disconnecting the voltage source, it is connected in parallel with another uncharged capacitor of capacitance $\dfrac{C}{2}$. The energy loss in the process after the charge is distributed between the two capacitors is :

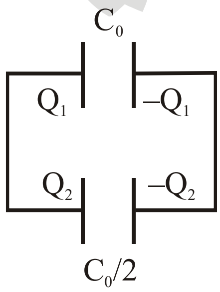
(1) $\frac{1}{4}CV_0^2$ (2) $\frac{1}{2}CV_0^2$ (3) $\frac{1}{3}CV_0^2$ (4) $\frac{1}{6}CV_0^2$

Ans. (4)

Sol.


Charge on capacitor before connecting it with another capacitor = $Q_0 = C_0V_0$

Now, connecting this capacitor with another capacitor of capacitance $C_0/2$



Total charge remains constant so $Q_1 + Q_2 = Q_0$ .....(i)

also $\dfrac{Q_1}{C_0} = \dfrac{Q_2}{C_0/2} \Rightarrow Q_1 = 2Q_2$ .....(ii)

By solving equation (i) and (ii)

$$Q_1 = \frac{2Q_0}{3}, \quad Q_2 = \frac{Q_0}{3}$$

$$\text{Loss} = U_i - U_f = \frac{Q_0^{\,2}}{2C_0} - \left[\frac{Q_1^{\,2}}{2C_0} + \frac{Q_2^{\,2}}{2\left(\frac{C_0}{2}\right)}\right]$$

$$= \frac{Q_0^{\,2}}{2C_0} - \left[\frac{\left(2\frac{Q_0}{3}\right)^2}{2C_0} + \frac{\left(\frac{Q_0}{3}\right)^2}{2\left(\frac{C_0}{2}\right)}\right]$$

$$= \frac{Q_0^{\,2}}{6C_0} = \frac{(C_0V_0)^2}{6C_0} = \frac{1}{6}C_0V_0^{\,2}$$

6. A cube of metal is subjected to a hydrostatic pressure of 4 GPa. The percentage change in the length of the side of the cube is close to :

(Given bulk modulus of metal, $B = 8 \times 10^{10}$ Pa)

(1) 0.6 (2) 20 (3) 1.67 (4) 5

Ans. (3)

Sol. As $B = \frac{\Delta P}{-\left(\frac{\Delta v}{v}\right)}$

$$\frac{\Delta v}{v} = -\frac{\Delta P}{B} = \frac{4\times10^9}{8\times10^{10}} = \frac{1}{20}$$

$$\frac{\Delta v}{v} = 5\%$$

Also $\frac{\Delta v}{v} = 3\frac{\Delta L}{L}$

$$\frac{\Delta L}{L} = \left(\frac{5}{3}\right)\% = 1.67\%$$

7. A particle of charge q and mass m is subjected to an electric field $E = E_0(1 - ax^2)$ in the x-direction, where a and E_0 are constants. Initially the particle was at rest at x = 0. Other than the initial position the kinetic energy of the particle becomes zero when the distance of the particle from the origin is :

(1) a (2) $\sqrt{\frac{2}{a}}$ (3) $\sqrt{\frac{3}{a}}$ (4) $\sqrt{\frac{1}{a}}$

Ans. (3)

Sol. $W_{ext} = \Delta K \qquad K_f - K_i = 0$

$$\int_0^x qE\,dx = 0$$

$$q\int_0^x E_0(1 - a\,x^2)dx = 0$$

$$qE_0\int_0^x (1 - a\,x^2)dx = 0$$

$$x - \frac{ax^3}{3} = 0$$

$$1 - \frac{ax^2}{3} = 0$$

$$\frac{ax^2}{3} = 1$$

$$x^2 = \frac{3}{a}$$

$$x = \pm\sqrt{\frac{3}{a}}$$

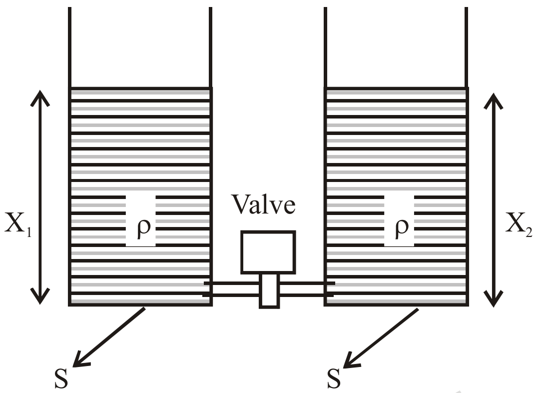
So distance from origin = $\sqrt{\frac{3}{a}}$

8. Two identical cylindrical vessels are kept on the ground and each contains the same liquid of density d. The area of the base of both vessels is S but the height of liquid in one vessel is x_1 and in the other, x_2. When both cylinders are connected through a pipe of negligible volume very close to the bottom, the liquid flows from one vessel to the other until it comes to equilibrium at a new height. The change in energy of the system in the process is :

(1) $\frac{1}{4}gdS(x_2 - x_1)^2$ (2) $\frac{3}{4}gdS(x_2 - x_1)^2$ (3) $gdS(x_2 + x_1)^2$ (4) $gdS(x_2^2 + x_1^2)$

Ans. (1)

Sol.



Initial height of liquid in container's of same cross section are x_1 and x_2 respectively. Now valve is opened find loss in potential energy when water level become same

loss in PE = $U_i - U_f$

$$U = mgh = (\rho(S)(x))g\left(\frac{x}{2}\right)$$

x is level of liquid in container
where h is height of COM of liquid

New level is $x = \frac{x_1 + x_2}{2}$

and new height of COM = $h = \frac{x}{2} = \left(\frac{x_1 + x_2}{4}\right)$

$$U_i = \left[\rho(S)x_1\frac{x_1}{2} + \rho S x_2 \frac{x_2}{2}\right]g$$

$$U_f = 2 \times \left[\rho S\left(\frac{x_1 + x_2}{2}\right) \times \left(\frac{x_1 + x_2}{4}\right)\right]g$$

Loss in gravitational potential energy = $U_i - U_f = \frac{\rho Sg(x_1 - x_2)^2}{4}$

9. The electric field of a plane electromagnetic wave is given by

$$\vec{E} = E_0(\hat{x}+\hat{y})\sin(kz-\omega t)$$

Its magnetic field will be given by :

(1) $\frac{E_0}{c}(-\hat{x}+\hat{y})\sin(kz-\omega t)$ (2) $\frac{E_0}{c}(\hat{x}-\hat{y})\cos(kz-\omega t)$

(3) $\frac{E_0}{c}(\hat{x}+\hat{y})\sin(kz-\omega t)$ (4) $\frac{E_0}{c}(\hat{x}-\hat{y})\sin(kz-\omega t)$

Ans. (1)

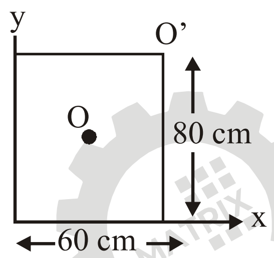
Sol. $\frac{E_0}{B_0} = C \Rightarrow B_0 = \frac{E_0}{C}$

Wave is propagating in +z direction

$\vec{E}\times\vec{B}$ must be in +z direction

hence, $\vec{B}$ must be parallel to vector $(-\hat{i}+\hat{j})$

$$\vec{B} = \frac{E_0}{C}\sin(kz-\omega t)(-\hat{i}+\hat{j})$$

10. 

For a uniform rectangular sheet shown in the figure, the ratio of moments of inertia about the axes perpendicular to the sheet and passing through O (the centre of mass) and O' (corner point) is :

(1) 2/3 (2) 1/8 (3) 1/4 (4) 1/2

Ans. (3)

Sol. $$\frac{I_O}{I_{O'}} = \frac{\frac{M}{12}(a^2+b^2)}{\frac{M}{12}(a^2+b^2)+M\left(\left(\frac{a}{2}\right)^2+\left(\frac{b}{2}\right)^2\right)}$$

$$\frac{\frac{M}{12}(a^2+b^2)}{\frac{M}{3}(a^2+b^2)} = \frac{1}{4} \qquad \frac{I_O}{I_{O'}} = \frac{1}{4}$$

11. Consider two uniform discs of the same thickness and different radii $R_1 = R$ and $R_2, = \alpha R$ made of the same material. If the ratio of their moments of inertia I_1 and I_2, respectively, about their axes is $I_1 : I_2 = 1 : 16$ then the value of α is :

(1) $2\sqrt{2}$ (2) 4 (3) $\sqrt{2}$ (4) 2

Ans. (4)

Sol. Moment of inertia of disc is given by $I = \frac{MR^2}{2} = \frac{[\rho(\pi R^2)]R^2}{2}$

$$I \propto R^4$$

$$\frac{I_2}{I_1} = \left(\frac{R_2}{R_1}\right)^4 = \left(\frac{\alpha R}{R}\right)^4$$

$$\frac{16}{1} = \alpha^4$$

$$\alpha = 2$$

12. A paramagnetic sample shows a net magnetisation of 6 A/m when it is placed in an external magnetic field of 0.4 T at a temperature of 4 K. When the sample is placed in an external magnetic field of 0.3 T at a temperature of 24 K, then the magnetisation will be :

(1) 4 A/m (2) 2.25 A/m (3) 1 A/m (4) 0.75 A/m

Ans. (4)

Sol. given $\Rightarrow$ at, T = 6k, B = 0.4 T $\Rightarrow$ Magnetization(M) = 6

at, T = 24k, B = 0.3 T, M = ?

as we know magnetisation $M = \frac{CB_{ext}}{T}$

$$M \propto \frac{B_{ext}}{T}$$

$$\frac{M}{6} = \left(\frac{0.3}{24}\right) \div \left(\frac{0.4}{4}\right)$$

$\Rightarrow$ M = 0.75

13. A series L-R circuit is connected to a battery of emf V. If the circuit is switched on at t=0, then the time at which the energy stored in the inductor reaches $\left(\frac{1}{n}\right)$ times of its maximum value, is:

(1) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}+1}\right)$ (2) $\frac{L}{R}\ln\left(\frac{\sqrt{n}-1}{\sqrt{n}}\right)$ (3) $\frac{L}{R}\ln\left(\frac{\sqrt{n}+1}{\sqrt{n}-1}\right)$ (4) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}-1}\right)$

Ans. (4)

Sol. Energy stored in inductor is given by $U=\frac{1}{2}LI^2$

$U \propto I^2$

$\frac{U}{U_0}=\left(\frac{I}{I_0}\right)^2$, where U_0 is maximum energy stored

$\frac{1}{n}=\left(\frac{I}{I_0}\right)^2 \Rightarrow \frac{I}{I_0}=\frac{1}{\sqrt{n}}$

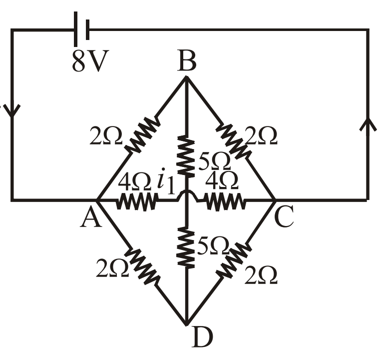
Current at time 't' through inductor

$I = I_0(1-e^{-t/\tau})$

$\frac{I}{I_0}=1-e^{-Rt/L}=\frac{1}{\sqrt{n}}$

$t=\frac{L}{R}\ln\frac{\sqrt{n}}{\sqrt{n}-1}$

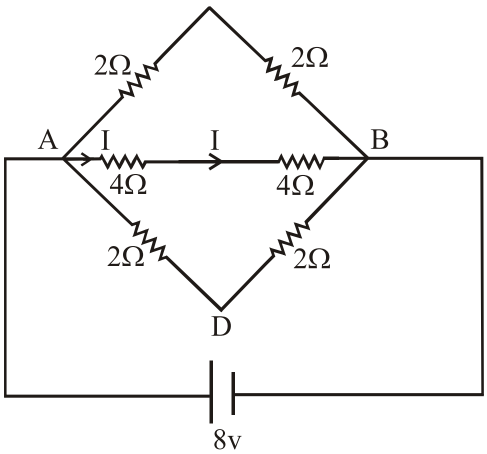
14. The value of current i_1 flowing from A to C in the circuit diagram is :



(1) 5 A (2) 2 A (3) 1 A (4) 4 A

Ans. (3)

Sol.



$$I = \frac{8}{4+4} = 1\,\text{Amp}$$

15. A circular coil has moment of inertia 0.8 kg m^2 around any diameter and is carrying current to produce a magnetic moment of 20 Am^2. The coil is kept initially in a vertical position and it can rotate freely around a horizontal diameter. When a uniform magnetic field of 4 T is applied along the vertical, it starts rotating around its horizontal diameter. The angular speed the coil acquires after rotating by 60° will be :

(1) 20π rad s^{-1} (2) 10 rad s^{-1} (3) 20 rad s^{-1} (4) 10π rad s^{-1}

Ans. (2)

Sol. From energy conservation

$$\frac{1}{2}I\omega^2 = U_{in} - U_f$$

$$= -MB\cos 60° - (-MB\cos(0°))$$

$$\frac{MB}{2} = \frac{1}{2}I\omega^2$$

$$\frac{20\times 4}{2} = \frac{1}{4}(0.8)\omega^2$$

$$100 = \omega^2$$

$$\omega = 10\,\text{rad}$$

16. A quantity x is given by (IFv^2/WL^4)in terms of moment of inertia I, force F, velocity v, work W and Length L. The dimensional formula for x is same as that of :

(1) force constant (2) planck's constant (3) energy density (4) coefficient of viscosity

Ans. (3)

Sol. $X = \frac{IFv^2}{wLu}$

$$[X] = \frac{(M^1 M^2)(M^1L^1T^{-2})(L^2T^{-2})}{(M^1L^2T^{-2})\,L^4}$$

$$= M^1L^{-1}T^{-2}$$

energy density

17. A small ball of mass m is thrown upward with velocity u from the ground. The ball experiences a resistive force mkv^2 where v is its speed. The maximum height attained by the ball is :

(1) $\frac{1}{2k}\ln\left(1+\frac{ku^2}{g}\right)$ (2) $\frac{1}{k}\ln\left(1+\frac{ku^2}{2g}\right)$ (3) $\frac{1}{2k}\tan^{-1}\frac{ku^2}{g}$ (4) $\frac{1}{k}\tan^{-1}\frac{ku^2}{2g}$

Ans. (1)

Sol. $F_{net} = ma$

$$-mg - mkv^2 = mv\frac{dv}{ds}$$

$$v\frac{dv}{ds} = -g - kv^2$$

$$-\int_{v_0}^{0}\frac{vdv}{g+kv^2} = \int_0^{h_{max}} ds = h_{max}$$

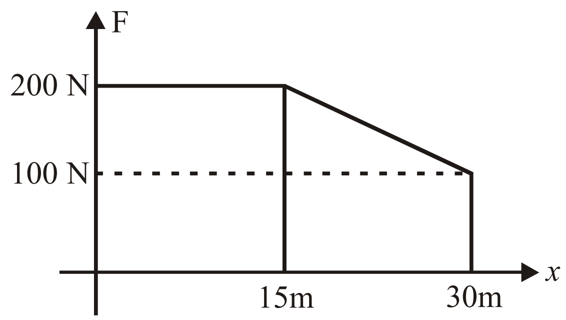
$$h_{max} = \frac{1}{2k}\, l\,n\left(\frac{g+kv_0^2}{g}\right)$$

18. A person pushes a box on a rough horizontal platform surface. He applies a force of 200 N over a distance of 15 m. Thereafter, he gets progressively tired and his applied force reduces linearly with distance to 100 N. The total distance through which the box has been moved is 30 m. What is the work done by the person during the total movement of the box ?

(1) 5250 J (2) 5690 J (3) 2780 J (4) 3280 J

Ans. (1)

Sol.



$W = \text{area} = (200 \times 15) + \frac{1}{2}(100+200)\times 15$

$= 3000 + 2250$

$W = 5250$ J

19. The driver of a bus approaching a big wall notices that the frequency of his bus' s horn changes from 420 Hz to 490 Hz when he hears it after it gets reflected from the wall. Find the speed of the bus if speed of the sound is 330 ms^{-1}.

(1) 81 kmh^{-1} (2) 71 kmh^{-1} (3) 61 kmh^{-1} (4) 91 kmh^{-1}

Ans. (4)

Sol. Frequency appeared at wall

$f_w = \frac{330}{330-v}.f \quad ...(1)$

$f' = \frac{330+v}{330}.f_w = \frac{330+v}{330-v}.f$

$490 = \frac{330+v}{330-v}.420$

$v = \frac{330\times 7}{91} \approx 25.38 m/s = 91 km/hr$

20. Find the Binding energy per neucleon for ${}^{120}_{50}Sn$. Mass of proton m_p = 1.00783 U, mass of neutron m_n = = 1.00867 U and mass of tin nucleus m_{Sn} = 119.902199 U. (take 1U = 931 MeV)

(1) 8.0 MeV (2) 9.0 MeV (3) 8.5 MeV (4) 7.5 MeV

Ans. (3)

Sol. Binding energy = [50 × 1.00783 + 70 × 1.00867 - 119.902199]U

= [50.3915 + 70.6069 - 119.902199]

= [120.9984 - 119.902199]U

Binding energy = 1.096 × 931 MeV

= 1020.56 MeV

$$\frac{\text{BE}}{\text{nucleon}} = \frac{1020.56}{120} = 8.504\,\text{MeV}$$

21. Orange light of wavelength 6000×10^{-10} m illuminates a single slit of width 0.6×10^{-4} m. The maximum possible number of diffraction minima produced on both sides of the central maximum is _________.

Ans. 160

Sol. $d\sin\theta = m$

$\sin\theta = \frac{\lambda n}{d} \le 1 \qquad n \le \left[\frac{d}{\lambda}\right]$

$n \le 100$

So total number of minima on one side = 99

So total number of minima = 198

22. The distance between an object and a screen is 100 cm. A lens can produce real image of the object on the screen for two different positions between the screen and the object. The distance between these two positions is 40 cm. If the power of the lens is close to $\left(\frac{N}{100}\right)$D where N is an integer, the value of N is ___________ .

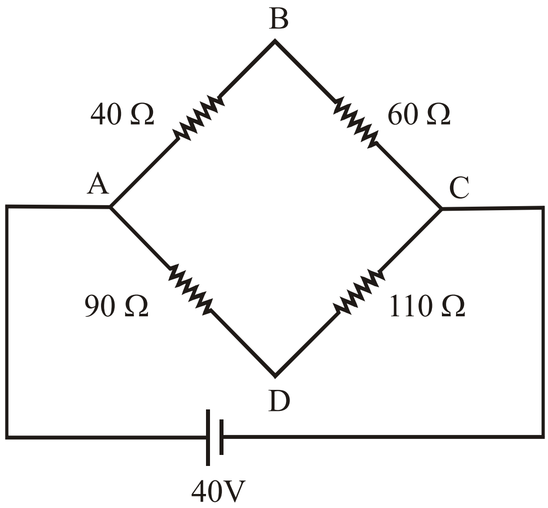
Ans. 476

Sol. Focal length of lens = $f = \frac{D^2 - d^2}{4D} = \frac{100^2 - 40^2}{4(100)} = \frac{(100+40)(100-40)}{4(100)}$

$= \frac{140 \times 60}{4 \times 100} = \frac{14 \times 6}{4} = 21\text{cm}$

Power = $\frac{100}{f(\text{in cm})} = \frac{100}{21} = \frac{100}{21}\text{D} = \left(\frac{N}{100}\right) \Rightarrow N = 476$

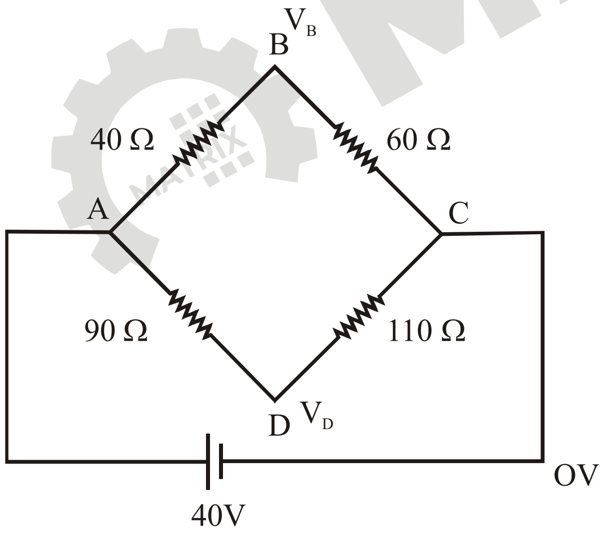
23.



Four resistances 40 Ω, 60 Ω, 90 Ω and 110 Ω make the arms of a quadrilateral ABCD. Across AC is a battery of emf 40 V and internal resistance negligible. The potential difference across BD in V is __________ .

Ans. 2V

Sol.



Using junction law

$$\frac{(V_B-40)}{40}+\frac{(V_B-0)}{60}=0$$

$$\rightarrow 6V_B-2u_0+4V_B=0$$

$$V_B=24V$$

Also $\frac{V_D - 440}{90} + \frac{V_D - 0}{110} = 0$

$\Rightarrow 11V_D - U_{40} + 9V_D = 0$

$\rightarrow V_D = \frac{44}{2} = 22v$ so $V_B - V_D = 2V$

24. The change in the magnitude of the volume of an ideal gas when a small additional pressure ΔP is applied at a constant temperature, is the same as the change when the temperature is reduced by a small quantity ΔT at constant pressure. The initial temperature and pressure of the gas were 300 K and 2 atm. respectively. If $|\Delta T| = C|\Delta P|$ then value of C in (K/atm.) is _________ .

Ans. 150

Sol. PV = nRT

differentiate both side →

(1) when Temp (T) is constant ⇒

$P\Delta V + V\Delta P = nR(0)$

$\Delta V = -\left(\frac{V}{P}\right)\Delta P$...........(i)

(2) when pressure is constant

$P\Delta V = nR\Delta T$

$\Rightarrow \Delta V = \left(\frac{nR}{P}\right)\Delta T$............(ii)

by solving (1) and (2)

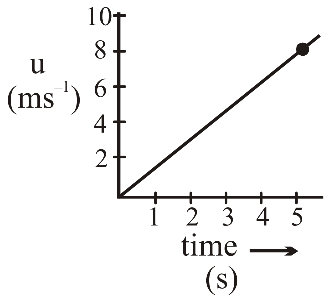
$\Rightarrow -\frac{V}{P}\Delta P = \frac{nR\Delta T}{P}$

$\Rightarrow |\Delta T| = \frac{V}{nR}|\Delta P|$

Compairing $\Rightarrow C = \frac{V}{nR} = \frac{V}{\frac{PV}{T}}$

$C = \frac{T}{P} = \frac{300}{2} = 150$

25. The speed versus time graph for a particle is shown in the figure. The distance travelled (in m) by the particle during the time interval t = 0 to t = 5 s will be __________ .



Ans. 20

Sol. Distance = Area of |v| – t graph

$= 1/2 \times 8 \times 5 = 20$ m