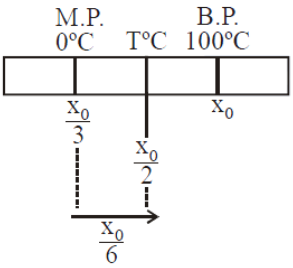
PHYSICS
JEE-MAIN (January-Attempt) 11 January (Shift-2) Paper

SECTION - A

1. A thermometer graduated according to a linear scale reads a value x_0 when in contact with boiling water, and $x_0/3$ when in contact with ice. What is the temperature of an object in ºC, if this thermometer in the contact with the object reads $x_0/2$?

(A) 60 (B) 40 (C) 35 (D) 25

sol. **D**



$\Rightarrow T^0C = \frac{x_0}{6}$ & $\left(x_0 - \frac{x_0}{3}\right) = (100 - 0°C)$

$x_0 = \frac{300}{2}$

$\Rightarrow T°C = \frac{150}{6} = 25°C$

2. The region between y = 0 and y = d contains a magnetic field $\vec{B} = B\hat{z}$. A aprticle of mass m and charge q enters the region with a velocity $\vec{v} = v\hat{i}$. If d = $\frac{mv}{2qB}$, the acceleration of the charged particle at the point of its emergence at the other side is -

(A) $\frac{qvB}{m}\left(\frac{-\hat{j}+\hat{i}}{\sqrt{2}}\right)$ (B) $\frac{qvB}{m}\left(\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j}\right)$ (C) $\frac{qvB}{m}\left(\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right)$ (D) $\frac{qvB}{m}\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)$

Sol. **Bonus**

3. A paramagnetic substance in the form of a cube with sides 1 cm has a magnetic dipole moment of 20×10^{-6} J/T when a magnetic intensity of 60×10^3 A/m is applied. Its magnetic susceptibility is :

(1) 4.3×10^{-2} (B) 3.3×10^{-4} (C) 2.3×10^{-2} (D) 3.3×10^{-2}

Sol. **B**

$X = \frac{I}{H}$

$I = \frac{\text{Magnetic Moment}}{\text{Volume}}$

$I = \frac{20\times10^{-6}}{10^{-6}} = 20 \text{ N/m}^2$

$X = \frac{20}{60\times10^{+3}} = \frac{1}{3} \times 10^{-3}$

$= 0.33 \times 10^{-3} = 3.3 \times 10^{-4}$

4. The mass and the diameter of a planet are three times the respective values for the Earth. The period of oscillation of a simple Pendulum on the Earth is 2 s. The period of oscillation of the same pendulum on the planet would be :

(A) $\frac{\sqrt{3}}{2}$ s (B) $2\sqrt{3}$s (C) $\frac{2}{\sqrt{3}}$ s (D) $\frac{3}{2}$ s

Sol. **B**

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

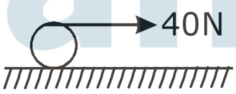
$\frac{g_p}{g_e} = \frac{M_e}{M_e}\left(\frac{R_e}{R_p}\right)^2 = 3\left(\frac{1}{3}\right)^2 = \frac{1}{3}$

Also, $T \propto \frac{1}{\sqrt{g}}$

$\frac{T_p}{T_e} = \sqrt{\frac{g_e}{g_p}} = \sqrt{3}$

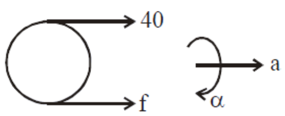
$\Rightarrow T_p = 2\sqrt{3}$ s

5. A string is wound around a hollow cylinder of mass 5kg and radius 0.5m. If the string is now pulled with a horizontal force of 40 N, and the cylinder is rolling without slipping on a horizontal surface (seee figure), then the angular acceleration of the cylinder will be (Neglect the mass and thickness of the string):



(A) 20 rad/s² (B) 16 rad/s² (C) 10 rad/s² (D) 12.rad/s²

Sol. **B**



$40 + f = m(R\alpha)$ ....(i)

$40 \times R - f \times R = mR^2\alpha$

$40 - f = mR\alpha$ ....(ii)

From (i) and (ii)

$\alpha = \frac{40}{mR} = 16$

6. A particle of mass m is moving in a straight line with momentum p. Starting at time t = 0, a force F = kt acts in the same direction on the moving particle during time interval T so that its mometum changes from p to 3p. Here k is a constant. The value of T is :

(A) $2\sqrt{\frac{p}{k}}$ (B) $2\sqrt{\frac{k}{p}}$ (C) $\sqrt{\frac{2k}{p}}$ (D) $\sqrt{\frac{2p}{k}}$

Sol. **A**

$$\frac{dp}{dt} = F = kt$$

$$\int_P^{3P} dP = \int_0^T Ptdt$$

$$2p = \frac{KT^2}{2}$$

$$T = 2\sqrt{\frac{P}{K}}$$

7. A 27 mW laser beam has a cross-sectional area of 10 mm^2. The magnitude of the maximum electric field in this electromagnetic wave is given by:
[Given permittivity of space $\varepsilon_0 = 9\times10^{-12}$ SI units, Speed of light $c = 3 \times 10^8$ m/s]
(A) 0.7kV/m (B) 1.4kV/m (C) 2kV/m (D) 1 kV/m

Sol. **B**

Intensity of EM wave is given by

$$I = \frac{\text{Power}}{\text{Area}} = \frac{1}{2}\varepsilon_0 E_0^2 C$$

$$= \frac{27\times10^{-3}}{10\times10^{-6}} = \frac{1}{2} \times 9 \times 10^{-12} \times E^2 \times 3 \times 10^8$$

$E = \sqrt{2} \times 10^3$ kv/m

= 1.4 kv/m

8. A simple pendulum of length 1 m is oscillating with an angular frequency 10 rad/s. The support of the pendulum starts oscillating up and down with a small angular frequency of 1 rad/s and an amplitude of 10^{-2} m . The relative change in the angular frequency of the pendulum is best given by :
(A) 10^{-1} rad/s (B) 10^{-3} rad/s (C) 10^{-5} rad/s (D) 1rad/s

Sol. **B**

Angular frequency of pendulum

$$\omega = \sqrt{\frac{g_{eff}}{\ell}}$$

$$\therefore \frac{\Delta\omega}{\omega} = \frac{1}{2}\frac{\Delta g_{eff}}{g_{eff}}$$

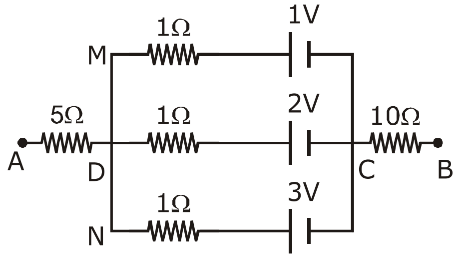
$$\Delta\omega = \frac{1}{2}\frac{\Delta g}{g} \times \omega$$

[ω_s = angular frequency of support]

$$\Delta\omega = \frac{1}{2} \times \frac{2Aw_s^2}{100} \times 100$$

$\Delta\omega = 10^{-3}$ rad/sec

9. In the circuit shown, the potential difference between A and B is :



(A) 3V (B) 6V (C) 2V (D) 1V

Sol. **C**

Potential difference across AB will be equal to battery equivalent across CD

$$V_{AB} = V_{CD} = \frac{\frac{E_1}{r_1}+\frac{E_2}{r_2}+\frac{E_3}{r_3}}{\frac{1}{r_1}+\frac{1}{r_2}+\frac{1}{r_3}} = \frac{\frac{1}{1}+\frac{2}{1}+\frac{3}{1}}{\frac{1}{1}+\frac{1}{1}+\frac{1}{1}}$$

$$= \frac{6}{3} = 2\text{ V}$$

10. A metal ball of mass 0.1 kg is heated upto 500ºC and dropped into a vessel of heat capacity 800 JK^{-1} and containing 0.5 kg water. The initial temperature of water and vessel is 30ºC. What is the approximate percentage increment in the temperature of the water ? [Specific Heat Capacities of water and metal are, respectively, 4200Jkg^{-1} K^{-1} and 400 $Jkg^{-1}K^{-1}$]

(A) 20 % (B) 25 % (C) 15 % (D) 30 %

sol. **A**

$0.1 \times 400 \times (500 - T) = 0.5 \times 4200 \times (T - 30) + 800\,(T - 30)$

$\Rightarrow 40\,(500 - T) = (T - 30)\,(2100 + 800)$

$\Rightarrow 20000 - 40\,T = 2900\,T - 30 \times 2900$

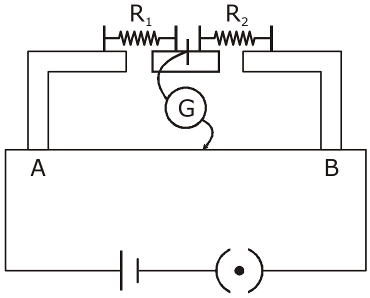
$\Rightarrow 20000 + 30 \times 2900 = T\,(2940)$

$T = 30.4°C$

$$\frac{\Delta T}{T} \times 100 = \frac{6.4}{30} \times 100$$

$\simeq$ 20%

11. In the experimental set up of metre bridge shown in the figure, the null point is obtained at a distance of 40cm from A. If a 10Ω resistor is connected in series with R_1, the null point shifts by 10 cm. The resistance that should be connected in parallel with $(R_1 + 10)\Omega$ such that the null point shifts back to its initial position is:



(A) 60Ω (B) 30Ω (C) 20Ω (D) 40Ω

Sol. **A**

$\frac{R_1}{R_2} = \frac{2}{3}$ ....(i)

$\frac{R_1 + 10}{R_2} = 1 \Rightarrow R_1 + 10 = R_2$ ....(ii)

$\frac{2R_2}{3} + 10 = R_2$

$10 = \frac{R_2}{3} \Rightarrow R_2 = 30\ \Omega$

& $R_1 = 20\ \Omega$

$\frac{\frac{30 \times R}{30 + R}}{30} = \frac{2}{3}$

$R = 60\ \Omega$

12. If speed (V), acceleration (A) and force (F) are considered as fundamental units, the dimension of Young's modulus will be :

(A) $V^{-2}A^{2}F^{2}$ (B) $V^{-2}A^{2}F^{-2}$ (C) $V^{-4}A^{-2}F$ (D) $V^{-4}A^{2}F$

Sol. **D**

$\frac{F}{A} = y.\ \frac{\Delta\ell}{\ell}$

$[Y] = \frac{F}{A}$

Now from dimension

$F = \frac{ML}{T^2}$

$L = \frac{F}{M} . T^2$

$L^2 = \frac{F^2}{M^2}\left(\frac{V}{A}\right)^4 \quad \because T = \frac{V}{A}$

$L^2 = \frac{F^2}{M^2A^2}\ \frac{V^4}{A^2}\ F = MA$

$L^2 = \frac{V^4}{A^2}$

$[Y] = \frac{[F]}{[A]} = F^1\ V^{-4}\ A^2$

13. A particle moves from the point $\left(2.0\hat{i} + 4.0\hat{j}\right)m$, at t=0, with an initial velocity $\left(5.0\hat{i} + 4.0\hat{j}\right)ms^{-1}$. It is acted upon by a constant force which produces a constant acceleration $\left(4.0\hat{i} + 4.0\hat{j}\right)ms^{-2}$. What is the distance of the particle from the origin at time 2s ?

(A) $10\sqrt{2}m$ (B) 5m (C) $20\sqrt{2}m$ (D) 15m

Sol. **C**

$\vec{S} = (5\hat{i} + 4\hat{j})2 + \frac{1}{2}(4\hat{i} + 4\hat{j})4$

$= 10\hat{i} + 8\hat{j} + 8\hat{i} + 8\hat{j}$

$\vec{r}_f - \vec{r}_i = 18\hat{i} + 16\hat{j}$

$\vec{r}_f = 20\hat{i} + 20\hat{j}$

$|\vec{r}_f| = 20\sqrt{2}$

14. Two rods A and B of identical dimensions are at temperature 30°C. If A is heated upto 180°C and B upto T°C, then the new lengths are the same. If the ratio of the coefficients of linear expansion of A and B is 4:3, then the value of T is :

(A) 270°C (B) 230°C (C) 200°C (D) 250°C

Sol. **B**

$\Delta l_1 = \Delta l_2$

$l\alpha_1 \Delta T_1 = l\alpha_2 \Delta T_2$

$\frac{\alpha_1}{\alpha_2} = \frac{\Delta T_1}{\Delta T_2}$

$\frac{4}{3} = \frac{T - 30}{180 - 30}$

T = 230°C

15. A monochromatic light is incident at a certain angle on an equilateral triangular prism and suffers minimum deviation. If the refractive index of the martial of the prism is $\sqrt{3}$, then the angle of incidence is

(A) 90° (B) 30° (C) 45° (D) 60°

Sol. **D**

i = e

$r_1 = r_2 = \frac{A}{2} = 30°$

by Snell's law

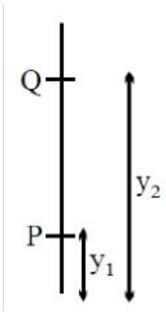
$1 \times \sin i = \sqrt{3} \times \frac{1}{2} = \frac{\sqrt{3}}{2}$

i = 60

16. In a double-slit experiment, green light (5303Å) falls on a double slit having a separation of 19.44 μm and a width of 4.05μm. The number of bright fringes between the first and the second diffraction minima is :

(A) 09 (B) 05 (C) 10 (D) 04

Sol. **B**



For diffraction location of first minima

$y_1 = \frac{\Delta\lambda}{a} = 0.2469\ D\lambda$

Location of 2nd minima

$y_2 = \frac{2\Delta\lambda}{a} = 0.4938\ D\lambda$

Now for interference

Path difference at P.

$\frac{dy}{D} = 4.8\lambda$

Path difference at Q

$\frac{dy}{D} = 9.6\ \lambda$

So orders of maxima in between P and Q is 5,6,7,8,9

So 5 bright fringes all present between P & Q.

17. A galvanometer having a resistance of 20Ω and 30 divisions on both sides has figure of merit 0.005 ampere/division. The resistance that should be connected in series such that it can be used as a voltameter upto 15 volt, is :

(A) 80 Ω (B) 120 Ω (C) 125 Ω (D) 100 Ω

Sol. **A**

$R_g = 20\ \Omega$

$N_L = N_R = N = 30$

$FOM = \frac{I}{\phi} = 0.005\ A/Div.$

Current sensitivity = CS = $\left(\frac{1}{0.005}\right) = \frac{\phi}{I}$

$Ig_{max} = 0.005 \times 30$

$= 15 \times 10^{-2} = 0.15$

$15 = 0.15\ [20 + R]$

$100 = 20 + R$

$R = 80$

18. In a photoelectric experiment, the wavelength of the light incident on a metal is changed from 300 nm to 400 nm. The decrease in the stopping potential is close to : ($\frac{hc}{e}$ =1240 nm–V)

(A) 1.0 V (B) 1.5 V (C) 0.5 V (D) 2.0 V

Sol. **A**

$\frac{hc}{\lambda_1} = \phi + eV_1$ ....(i)

$\frac{hc}{\lambda_2} = \phi + eV_2$ ...(ii)

(i) - (ii)

$hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = e\ (V_1 - V_2)$

$\Rightarrow V_1 - V_2 = \frac{hc}{e}\left(\frac{\lambda_2 - \lambda_1}{\lambda_1 - \lambda_2}\right)$

$= (12540 \text{ nm - V}) \dfrac{100\text{nm}}{300\text{nm} \times 400\text{nm}}$

$= 1 \text{ V}$

19. An electric field of 1000 V/m is applied to an electric dipole at angle of 45°. The value of electric dipole moment is 10^{-29} C.m. What is the potential energy of the electric dipole?

(A) -10×10^{-29} J (B) -9×10^{-20} J (C) -20×10^{-18} J (D) -7×10^{-27} J

Sol. **D**

$U = -\vec{P}.\vec{E}$

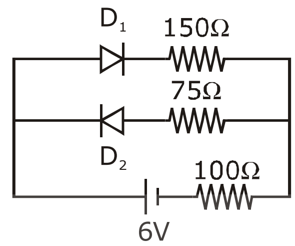
$= -\, PE \cos \theta$

$= -(10^{-29})\,(10^{3}) \cos 45°$

$= -\,0.707 \times 10^{-26}$ J

$= -7 \times 10^{-27}$ J

20. The circuit shown below contains two ideal diodes, each with a forward resistance of 50Ω. If the battery voltage is 6V, the current through the 100Ω resistance (in Amperes) is :

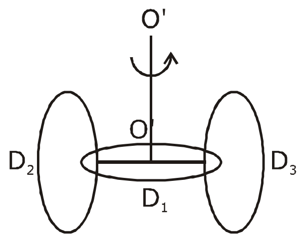


(A) 0.020 (B) 0.030 (C) 0.036 (D) 0.027

Sol. **A**

$I = \dfrac{6}{300} = 0.002$ (D_2 is in reverse bias)

21. A circular disc D_1 of mass M and radius R has two identical discs D_2 and D_3 of the same mass M and radius R attached rigidly at its opposite ends (see figure). The moment of inertia of the system about the axis OO', passing through the centre of D_1, as shown inthe figure, will be :



(A) $\dfrac{4}{5}MR^2$ (B) MR^2 (C) $\dfrac{2}{3}MR^2$ (D) $3MR^2$

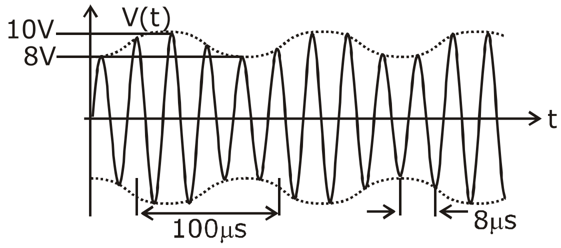
Sol. **D**

$I = \dfrac{MR^2}{2} + 2\left(\dfrac{MR^2}{4} + MR^2\right)$

$= \dfrac{MR^2}{2} + \dfrac{MR^2}{2} + 2MR^2$

$= 3\, MR^2$

22. An amplitude modulated signal is plotted below :



Which one of the following best describes the above signal ?
(A) $(9 + \sin(2.5\pi \times 10^5 t)) \sin(2\pi \times 10^4 t)$ V
(B) $(9 + \sin(2\pi \times 10^4 t)) \sin(2.5\pi \times 10^5 t)$ V
(C) $(1 + 9\sin(2\pi \times 10^4 t)) \sin(2.5\pi \times 10^5 t)$ V
(D) $(9 + \sin(4\pi \times 10^4 t)) \sin(5\pi \times 10^5 t)$ V

Sol. **B**
Analysis of graph says
(1) Amplitude varies as 8 – 10 V or 9 ± 1
(2) Two time period as
100 μs (signal wave) & 8 μs (carrier wave)

Hence signal is $\left[9 \pm 1\sin\left(\frac{2\pi t}{T_1}\right)\right] \sin\left(\frac{2\pi t}{T_2}\right)$

$= 9 \pm 1 \sin(2\pi \times 10^4 t) \sin 2.5\pi \times 10^5 t$

23 A particle of mass m and charge q is in an electric and magnetic field given by

$\vec{E} = 2\hat{i} + 3\hat{j}; \vec{B} = 4\hat{j} + 6\hat{k}$

The charged particle is shifted from the origin to the point P (x = 1; y = 1) along a straight path. The magnitude of the total work done is -
(A) (0.35) q (B) (0.15) q (C) 5q (D) (2.5) q

Sol. **C**

$\vec{F}_{net} = q\vec{E} + q(\vec{v} \times \vec{B})$

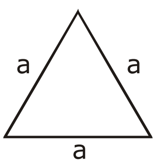
$= (2q\hat{i} + 3q\hat{j}) + q(\vec{v} \times \vec{B})$

$W = \vec{F}_{net}.\vec{S}$
$= 2q + 3q$
$= 5q$

24. A copper wire is wound on a wooden frame, whose shape is that of an equilateral triangle. If the linear dimension of each side of the frame is increased by a factor of 3, keeping the number of turns of the coil per unit length of the frame the same, then the self inductance of the coil :

(A) decreases by a factor of $9\sqrt{3}$ (B) decreases by a factor of 9
(C) increases by a factor of 27 (D) increases by a factor of 3

Sol. **D**
Total length L will remain constnat L = (3a) N (N = total turns)
and length fo winding = (d) N
(d = diameter of wire)



self inductance = $\mu_0 n^2 A\ell$

$= \mu_0 n^2 \left(\frac{\sqrt{3}a^2}{4}\right) dN$

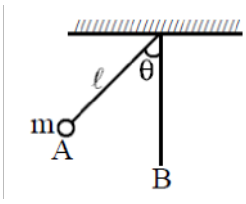
$\propto a^2 \; N \propto a$

So self inductance will become 3 times

25. A pendulum is executing simple harmonic motion and its maximum kinetic energy is K_1. If the length of the pendulum is doubled and it performs simple harmonic motion with the same amplitude as in the first case its maximum kinetic energy is K_2. Then -

(A) $K_2 = \frac{k_1}{2}$ (B) $K_2 = 2K_1$ (C) $K_2 = K_1$ (D) $K_2 = \frac{k_1}{4}$

Sol. **B**



Maximum kinetic energy at lowest point B is given by

$K = mg\,l\,(1 - \cos\theta)$

Where θ = angular amp.

$K_1 = mg\,l\,(1 - \cos\theta)$

$K_2 = mg\,(2\ell)\,(1 - \cos\theta)$

$K_2 = 2K_1$

26. When 100 g of a liquid A at 100°C is added to 50 g of a liquid B at temperature 75°C, the temperature of the mixture becomes 90°C. The temperature of the mixture, if 100g of liquid A at 100°C is added to 50 g of liquid B at 50°C, will be -

(A) 60°C (B) 70°C (C) 80°C (D) 85°C

Sol. **C**

$100 \times S_A \times [100 - 90] = 50 \times S_B \times (90 - 75)$

$2S_A = 1.5\,S_B$

$S_A = \frac{3}{4}\,S_B$

Now, $100 \times S_A \times [100 - T] = 50 \times S_B\,(T - 50)$

$2 \times \left(\frac{3}{4}\right)(100 - T) = (T - 50)$

$300 - 3T = 2T - 100$

$T = 80$

27. The magnitude of torque on a particle of mass 1 kg is 2.5 Nm about the origin. If the force acting on it is 1N, and the distance of the particle from the origin is 5m, the angle between the force and the position vector is (in radians) -

(A) $\frac{\pi}{4}$ (B) $\frac{\pi}{3}$ (C) $\frac{\pi}{6}$ (D) $\frac{\pi}{8}$

Sol. **C**

$2.5 = 1 \times 5 \sin\theta$

$\sin\theta = 0.5 = \frac{1}{2}$

$\theta = \frac{\pi}{6}$

28. In a process, temperature and volume of one mole of an ideal monoatomic gas are varied according to the relation VT = K, where K is a constant. In this process the temperature of the gas is increased by ΔT. The amount of heat absorbed by gas is (R is gas constant);

(A) $\frac{2K}{3}\ \Delta T$ (B) $\frac{1}{2}\ R\Delta T$ (C) $\frac{3}{2}\ R\Delta T$ (D) $\frac{1}{2}\ KR\Delta T$

Sol. **B**

VT = K

$\Rightarrow V\left(\frac{PV}{nR}\right) = k \Rightarrow PV^2 = K$

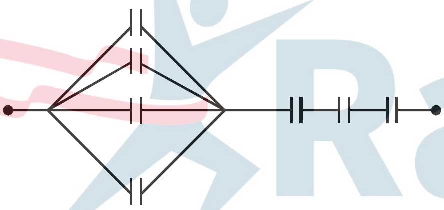
$\because C = \frac{R}{1-x} + C_v$ (For polytropic process)

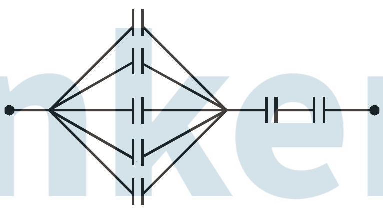
$C = \frac{R}{1-2} + \frac{3R}{2} = \frac{R}{2}$

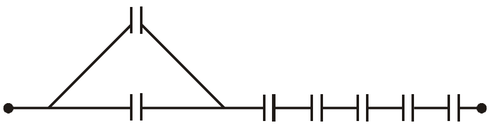
$\therefore \Delta Q = nC\ \Delta T$

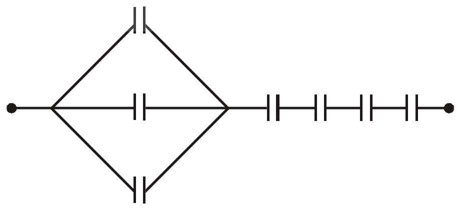
$= \frac{R}{2} \times \Delta T$

29. Seven capacitors, each of capacitance $2\mu F$, are to be connected in a configuration to obtain an effective capacitance of $\left(\frac{6}{13}\right)\ \mu F$. Which of the combinations, shown in figures below, will achieve the desired value ?

(A)


(B)


(C)


(D)


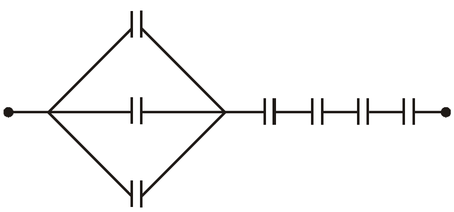
Sol. **D**

$C_{eq} = \frac{6}{13}\ \mu F$

Therefore three capacitors most be in parallel to get 6 in

$\frac{1}{C_{eq}} = \frac{1}{3C} + \frac{1}{C} + \frac{1}{C} + \frac{1}{C} + \frac{1}{C}$

$C_{eq} = \frac{3C}{13} = \frac{6}{13}\ \mu F$



30. In a hydrogen like atom, when an electron jumps from the M - shell to the L -shell, the wavelength of emitted radiation is λ. If an electron jumps from N-shell to the L-shell, the wavelength of emitted radiation will be -

(A) $\frac{27}{20}\lambda$ (B) $\frac{25}{16}\lambda$ (C) $\frac{20}{27}\lambda$ (D) $\frac{16}{25}\lambda$

Sol. **C**

For M $\rightarrow$ L steel

$$\frac{1}{\lambda} = K\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{K \times 5}{36}$$

for N $\rightarrow$ L

$$\frac{1}{\lambda'} = K\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{K \times 3}{16}$$

$$\lambda' = \frac{20}{27}\lambda$$