AIEEE 2009 Physics Solutions

Code (A)

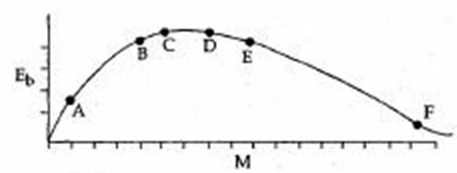
Physics

PART – A

1. This question contains Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.
Statement – 1: For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.
Statement-2: The net work done by a conservative force on an object moving along a closed loop is zero
(1) Statement-1 is true, Statement-2 is false
(2) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1.
(3) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1.
(4) Statement-1 is false, Statement-2 is true

Sol: **(2)**
Work done by conservative force does not depend on the path. Electrostatic force is a conservative force.

2. The above is a plot of binding energy per nucleon E_b, against the nuclear mass M; A, B, C, D, E, F correspond to different nuclei. Consider four reactions:

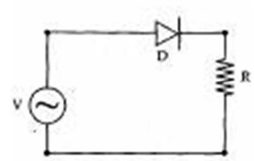


(i) $A + B \rightarrow C + \varepsilon$ (ii) $C \rightarrow A + B + \varepsilon$
(iii) $D + E \rightarrow F + \varepsilon$ and (iv) $F \rightarrow D + E + \varepsilon$
where ε is the energy released? In which reactions is ε positive?
(1) (i) and (iv) (2) (i) and (iii)
(3) (ii) and (iv) (4) (ii) and (iii)

Sol: **(1)**
1st reaction is fusion and 4th reaction is fission.

Trans Web Educational Services Pvt. Ltd
B – 147,1st Floor, Sec-6, NOIDA, UP-201301
Website:www.askiitians.com Email. info@askiitians.com
Tel:0120-4616500 Ext - 204

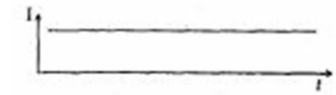
3. A p-n junction (D) shown in the figure can act as a rectifier. An alternating current source (V) is connected in the circuit.



(1) 

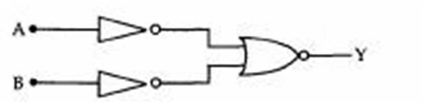
(2) 

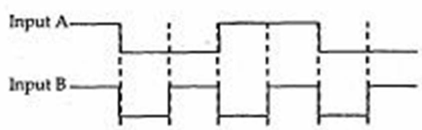
(3) 

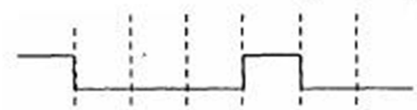
(4) 

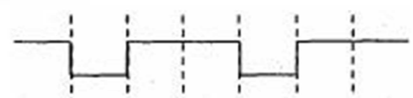
Sol: **(3)**
Given figure is half wave rectifier

4. The logic circuit shown below has the input waveforms 'A' and 'B' as shown. Pick out the correct output waveform.





(1) 

(2) 

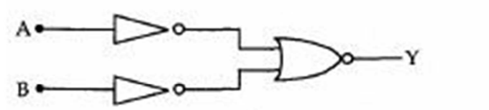
(3) 

(4) 

Sol: **(1)**

Truth Table

A	B	Y
1	1	1
1	0	0
0	1	0
0	0	0



*5. If x, v and a denote the displacement, the velocity and the acceleration of a particle executing simple harmonic motion of time period T, then, which of the following does not change with time?

(1) $a^2T^2 + 4\pi^2v^2$
(2) $\frac{aT}{x}$
(3) $aT + 2\pi v$
(4) $\frac{aT}{v}$

Sol: **(2)**

$$\frac{aT}{x} = \frac{\omega^2 xT}{x} = \frac{4\pi^2}{T^2}\times T = \frac{4\pi^2}{T} = \text{constant.}$$

6. In an optics experiment, with the position of the object fixed, a student varies the position of a convex lens and for each position, the screen is adjusted to get a clear image of the object. A graph between the object distance u and the image distance v, from the lens, is plotted using the same scale for the two axes. A straight line passing through the origin and making an angle of 45° with the x-axis meets the experimental curve at P. The coordinates of P will be

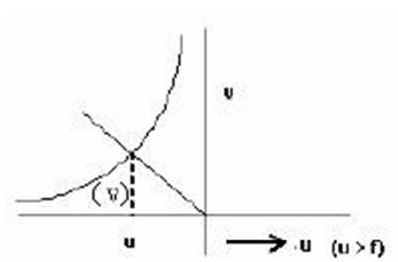
(1) (2f, 2f)
(2) $\left(\frac{f}{2}, \frac{f}{2}\right)$
(3) (f, f)
(4) (4f, 4f)

Sol: **(1)**

It is possible when object kept at centre of curvature.

u = v

u = 2f, v = 2f.



*7. A thin uniform rod of length ℓ and mass m is swinging freely about a horizontal axis passing through its end. Its maximum angular speed is ω. Its centre of mass rises to a maximum height of

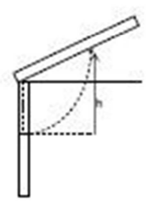
(1) $\frac{1}{3}\frac{\ell^2\omega^2}{g}$
(2) $\frac{1}{6}\frac{\ell\omega}{g}$
(3) $\frac{1}{2}\frac{\ell^2\omega^2}{g}$
(4) $\frac{1}{6}\frac{\ell^2\omega^2}{g}$

Sol: **(4)**

$T.E_i = T.E_f$

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

$$\frac{1}{2}\times\frac{1}{3}m\ell^2\omega^2 = mgh \Rightarrow h = \frac{1}{6}\frac{\ell^2\omega^2}{g}$$



8. Let $P(r) = \frac{Q}{\pi R^4} r$ be the charge density distribution for a solid sphere of radius R and total charge Q. for a point 'p' inside the sphere at distance r_1 from the centre of the sphere, the magnitude of electric field is

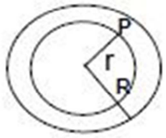
(1) 0

(2) $\frac{Q}{4\pi\varepsilon_0 r_1^2}$

(3) $\frac{Q r_1^2}{4\pi\varepsilon_0 R^4}$

(4) $\frac{Q r_1^2}{3\pi\varepsilon_0 R^4}$

Sol: **(4)**



$$\rho = \frac{Q}{\pi R^4} \times r_1$$

$$q_{in} = \frac{Q}{\pi R^4} r_1 \times \frac{4}{3} \times \pi r_1^3 = \frac{4}{3}\frac{Q}{R^4} r_1^4$$

By gauss law

$$\oint E.dA = \frac{1}{\varepsilon_0} q_{in} = \frac{4}{3\varepsilon_0}\frac{Q}{R^4} r_1^4 \Rightarrow E \times 4\pi r_1^2 = \frac{4}{3\varepsilon_0}\frac{Q}{R^4} r_1^4 \Rightarrow E = \frac{Q}{3\pi\varepsilon_0 R^4} r_1^2.$$

9. The transition from the state n = 4 to n = 3 in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition from

(1) $2 \rightarrow 1$ (2) $3 \rightarrow 2$
(3) $4 \rightarrow 2$ (4) $5 \rightarrow 4$

Sol: **(4)**

IR corresponds to least value of $\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

i.e. from Paschen, Bracket and Pfund series. Thus the transition corresponds to $5 \rightarrow 3$.

*10. One kg of a diatomic gas is at a pressure of 8×10^4 N/m^2. The density of the gas is 4 kg/m^3. What is the energy of the gas due to its thermal motion?

(1) 3×10^4 J (2) 5×10^4 J
(3) 6×10^4 J (4) 7×10^4 J

Sol: **(2)**

Thermal energy corresponds to internal energy
Mass = 1 kg
density = 8 kg/m^3

$\Rightarrow$ Volume = $\frac{\text{mass}}{\text{density}} = \frac{1}{8}$m^3

Pressure = 8×10^4 N/m^2

$\therefore$ Internal Energy = $\frac{5}{2}$ P $\times$ V = 5×10^4 J

11. This question contains Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.

Statement-1: The temperature dependence of resistance is usually given as R = $R_o(1 + \alpha\Delta t)$. The resistance of a wire changes from 100 Ω to 150 Ω when its temperature is increased from 27°C to 227°C. This implies that $\alpha = 2.5 \times 10^{-3}$ /° C.

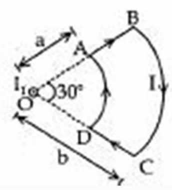
Statement 2: R = R_i (1 + $\alpha\Delta T$) is valid only when the change in the temperature ΔT is small and ΔR = (R - R_o) << R_o.

(1) Statement-1 is true, Statement-2 is false
(2) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1.
(3) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1.
(4) Statement-1 is false, Statement-2 is true

Sol: **(1)**

Directions: Question numbers 12 and 13 are based on the following paragraph.

A current loop ABCD is held fixed on the plane of the paper as shown in the figure. The arcs BC (radius = b) and DA (radius = a) of the loop are joined by two straight wires AB and CD. A steady current I is flowing in the loop. Angle made by AB and CD at the origin O is 30°. Another straight thin wire with steady current I_1 flowing out of the plane of the paper is kept at the origin.

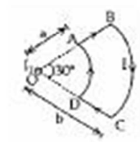


12. The magnitude of the magnetic field (B) due to loop ABCD at the origin (O) is

(1) zero
(2) $\frac{\mu_0(b-a)}{24ab}$
(3) $\frac{\mu_0 I}{4\pi}\left[\frac{b-a}{ab}\right]$
(4) $\frac{\mu_0 I}{4\pi}\left[2(b-a)+\frac{\pi}{3}(a+b)\right]$

Sol: **(2)**
Net magnetic field due to loop ABCD at O is
$B = B_{AB} + B_{BC} + B_{CD} + B_{DA}$

$$= 0+\frac{\mu_0 I}{4\pi a}\times\frac{\pi}{6}+0-\frac{\mu_0 I}{4\pi b}\times\frac{\pi}{6}=\frac{\mu_0 I}{24a}-\frac{\mu_0 I}{24b}=\frac{\mu_0 I}{24ab}(b-a)$$



13. Due to the presence of the current I_1 at the origin
(1) The forces on AB and DC are zero
(2) The forces on AD and BC are zero
(3) The magnitude of the net force on the loop is given by $\frac{\mu_0 I I_1}{4\pi}\left[2(b-a)+\frac{\pi}{3}(a+b)\right]$
(4) The magnitude of the net force on the loop is given by $\frac{\mu_0 I I_1}{24ab}(b-a)$

Sol: **(2)**
The forces on AD and BC are zero because magnetic field due to a straight wire on AD and BC is parallel to elementary length of the loop.

14. A mixture of light, consisting of wavelength 590 nm and an unknown wavelength, illuminates Young's double slit and gives rise to two overlapping interference patterns on the screen. The central maximum of both lights coincide. Further, it is observed that the third bright fringe of known light coincides with the 4^{th} bright fringe of the unknown light. From this data, the wavelength of the unknown light is
(1) 393.4 nm
(2) 885.0 nm
(3) 442.5 nm
(4) 776.8 nm

Sol: **(3)**
$3\lambda_1 = 4\lambda_2$

$$\Rightarrow \lambda_2 = \frac{3}{4}\lambda_1 = \frac{3}{4}\times 590 = \frac{1770}{4} = 442.5 \text{ nm}$$

15. Two points P and Q are maintained at the potentials of 10V and -4V respectively. The work done in moving 100 electrons from P to Q is

(1) -19×10^{-17} J
(2) 9.60×10^{-17} J
(3) -2.24×10^{-16} J
(4) 2.24×10^{-16} J

Sol: **(4)**
$W = QdV = Q(V_q - V_P) = -100 \times (1.6 \times 10^{-19}) \times (-4 - 10)$
$= +100 \times 1.6 \times 10^{-19} \times 14 = +2.24 \ \ 10^{-16}$ J.

16. The surface of a metal is illuminated with the light of 400 nm. The kinetic energy of the ejected photoelectrons was found to be 1.68 eV. The work function of the metal is (hc = 1240 eV nm)
(1) 3.09 eV (2) 1.41 eV
(3) 151 eV (4) 1.68 eV

Sol: **(2)**
$\frac{1}{2}mv^2 = eV_o = 1.68eV \Rightarrow \ h\nu = \frac{hc}{\lambda} = \frac{1240evnm}{400nm} = 3.1 \text{ eV} \Rightarrow 3.1 \text{ eV} = W_o + 1.6 \text{ eV}$
$\therefore \quad W_o = 1.42$ eV

*17. A particle has an initial velocity $3\hat{i} + 4\hat{j}$ and an acceleration of $0.4\hat{i} + 0.3\hat{j}$. Its speed after 10 s is

(1) 10 units
(2) $7\sqrt{2}$ units
(3) 7 units
(4) 8.5 units

Sol: **(2)**

$\vec{u} = 3\hat{i} + 4\hat{j}$; $\vec{a} = 0.4\hat{i} + 0.3\hat{j}$

$\vec{u} = \vec{u} + \vec{a}t$

$= 3\hat{i} + 4\hat{j} + (0.4\hat{i} + 0.3\hat{j})10 = 3\hat{i} + \hat{j} + 4\hat{i} + 3\hat{j} = 7\hat{i} + 7\hat{j}$

Speed is $\sqrt{7^2 + 7^2} = 7\sqrt{2}$ units

*18. A motor cycle starts from rest and accelerates along a straight path at 2 m/s^2. At the starting point of the motor cycle there is a stationary electric sire. How far has the motor cycle gone when the driver hears the frequency of the siren at 94% of its value when the motor cycle was at rest? (speed of sound = 330 ms^{-1}).

(1) 49 m
(2) 98 m
(3) 147 m
(4) 196 m

Sol: **(2)**

Motor cycle, u = 0, a = 2 m/s^2

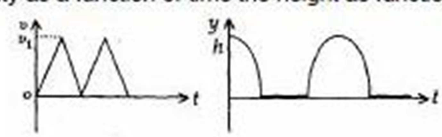
Observer is in motion and source is at rest.

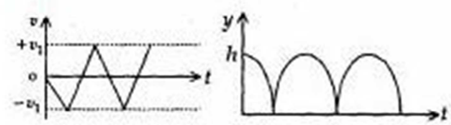
$$\Rightarrow n' = n\frac{v - v_O}{v + v_S} \Rightarrow \frac{94}{100}n = n\frac{330 - v_O}{330} \Rightarrow 330 - v_O = \frac{330 \times 94}{100}$$

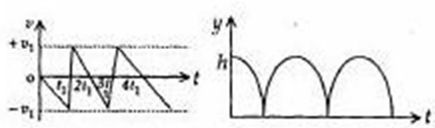
$$\Rightarrow v_O = 330 - \frac{94 \times 33}{10} = \frac{33 \times 6}{10}\ \text{m/s}$$

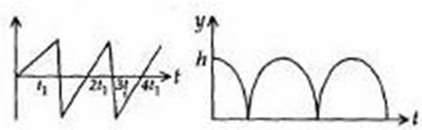
$$s = \frac{v^2 - u^2}{2a} = \frac{9 \times 33 \times 33}{100} = \frac{9 \times 1089}{100} \approx 98\ \text{m.}$$

*19. Consider a rubber ball freely falling from a height h = 4.9 m onto a horizontal elastic plate. Assume that the duration of collision is negligible and the collision with the plate is totally elastic. Then the velocity as a function of time the height as function of time will be

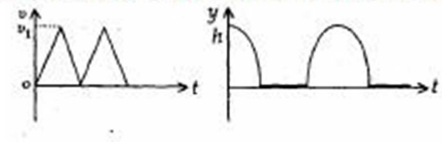
(1) 

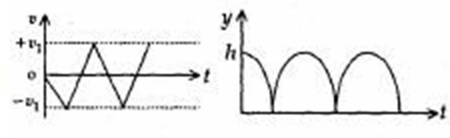
(2) 

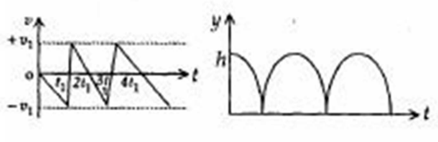
(3) 

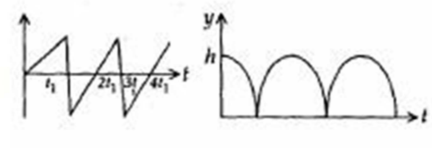
(4) 

*19. Consider a rubber ball freely falling from a height h = 4.9 m onto a horizontal elastic plate. Assume that the duration of collision is negligible and the collision with the plate is totally elastic. Then the velocity as a function of time the height as function of time will be

(1)


(2)


(3)


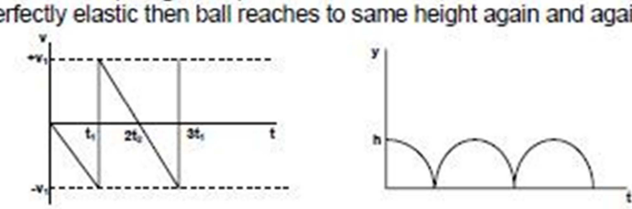
(4)


Sol: (3)

$h = \frac{1}{2}gt^2$, $v = -gt$ and after the collision, $v = gt$.

(parabolic) (straight line)

Collision is perfectly elastic then ball reaches to same height again and again with same velocity.

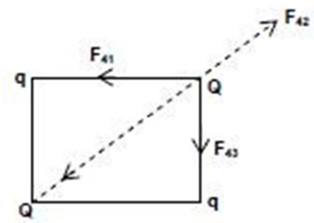


20. A charge Q is placed at each of the opposite corners of a square. A charge q is placed at each of the other two corners. If the net electrical force on Q is zero, then the Q/q equals

(1) $-2\sqrt{2}$ (2) -1

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

Sol: **(1)**



Three forces F_{41}, F_{42} and f_{43} acting on Q are shown

Resultant of $F_{41} + F_{43}$

$= \sqrt{2}\ F_{each}$

$= \sqrt{2}\frac{1}{4\pi\varepsilon_0}\frac{Qq}{d^2}$

Resultant on Q becomes zero only when 'q' charges are of negative nature.

$$F_{4,2} = \frac{1}{4\pi\varepsilon_0}\frac{Q\times Q}{\left(\sqrt{2}d\right)^2}$$

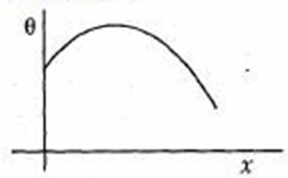
$$\Rightarrow \sqrt{2}\frac{dQ}{d^2} = \frac{Q\times Q}{2d^2}$$

$$\Rightarrow \sqrt{2}\times q = \frac{Q\times Q}{2}$$

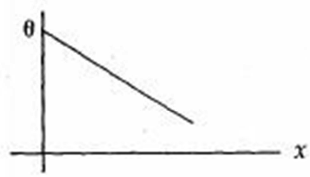
$$\therefore q = -\frac{Q}{2\sqrt{2}} \text{ or } \frac{Q}{q} = -2\sqrt{2}$$

*21. A long metallic bar is carrying heat from one of its ends to the other end under steady-state. The variation of temperature θ along the length x of the bar from its hot end is best described by which of the following figure.

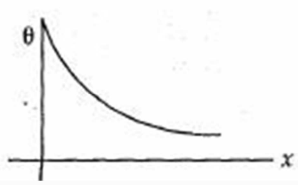
(1)



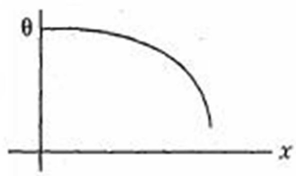
(2)



(3)



(4)



Sol: **(2)**

We know that $\frac{dQ}{dt} = KA\frac{d\theta}{dx}$

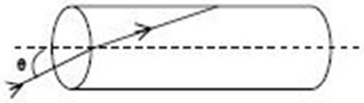
In steady state flow of heat

$d\theta = \frac{dQ}{dt}\cdot\frac{1}{kA}.dx$

$\Rightarrow \theta_H - \theta = k'x \Rightarrow \theta = \theta_H - k'x$

Equation $\theta = \theta_H - k'x$ represents a straight line.

22. A transparent solid cylindrical rod has a refractive index of $\frac{2}{\sqrt{3}}$. It is surrounded by air. A light ray is incident at the mid point of one end of the rod as shown in the figure.

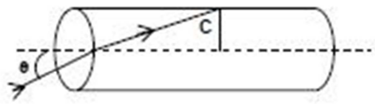


The incident angle θ for which the light ray grazes along the wall of the rod is

(1) $\sin^{-1}\left(\frac{1}{2}\right)$ (2) $\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$

(3) $\sin^{-1}\left(\frac{2}{\sqrt{3}}\right)$ (4) $\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

Sol: (4)



$\text{Sin}C = \frac{\sqrt{3}}{2}$ ..... (1)

$\text{Sin } r = \sin(90 - C) = \cos C = \frac{1}{2}$

$\frac{\sin\theta}{\sin r} = \frac{\mu_2}{\mu_1}$

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

$\theta = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

*23. Three sound waves of equal amplitudes have frequencies (ν – 1), ν, (ν + 1). They *superpose* to give beats. The number of beats produced per second will be

(1) 4 (2) 3

(3) 2 (4) 1

Sol: (3)

Maximum number of beats = $\nu + 1 - (\nu - 1) = 2$

*24. The height at which the acceleration due to gravity becomes $\frac{g}{9}$ (where g = the acceleration due to gravity on the surface of the earth) in terms of R, the radius of the earth is

(1) 2R (2) $\frac{R}{\sqrt{2}}$

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

Sol: (1)

$g' = \frac{GM}{(R+h)^2}$, acceleration due to gravity at height h

$\Rightarrow \frac{g}{9} = \frac{GM}{R^2} \cdot \frac{R^2}{(R+h)^2} = g\left(\frac{R}{R+h}\right)^2$

$\Rightarrow \frac{1}{9} = \left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{R}{R+h} = \frac{1}{3}$

$\Rightarrow 3R = R + h \Rightarrow 2R = h$

*25. Two wires are made of the same material and have the same volume. However wire 1 has cross-sectional area A and wire-2 has cross-sectional area 3A. If the length of wire 1 increases by Δx on applying force F, how much force is needed to stretch wire 2 by the same amount?

(1) F (2) 4F
(3) 6F (4) 9F

Sol: **(4)**

$$A_1\ell_1 = A_2\ell_2 \Rightarrow \ell_2 = \frac{A_1\ell_1}{A_2} = \frac{A \times \ell_1}{3A} = \frac{\ell_1}{3} \Rightarrow \frac{\ell_1}{\ell_2} = 3$$

$$\Delta x_1 = \frac{F_1}{A\gamma} \times \ell_1 \quad \text{..... (i)}$$

$$\Delta x_2 = \frac{F_2}{3A\gamma}\ell_2 \quad \text{.....(ii)}$$

Here $\Delta x_1 = \Delta x_2$

$$\frac{F_2}{3A\gamma}\ell_2 = \frac{F_1}{A\gamma}\ell_1$$

$$F_2 = 3F_1 \times \frac{\ell_1}{\ell_2} = 3F_1 \times 3 = 9F$$

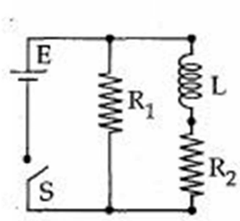
*26. In an experiment the angles are required to be measured using an instrument. 29 divisions of the main scale exactly coincide with the 30 divisions of the vernier scale. If the smallest division of the main scale is half-a-degree(=0.5°), then the least count of the instrument is

(1) one minute (2) half minute
(3) one degree (4) half degree

Sol: **(1)**

$$\text{Least count} = \frac{\text{value of main scale division}}{\text{No of divisions on vernier scale}} = \frac{1}{30}\text{MSD} = \frac{1}{30} \times \frac{1^\circ}{2} = \frac{1}{60}^\circ = 1 \text{ minute}$$

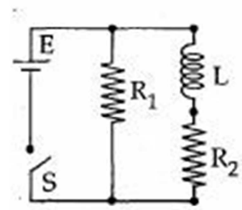
27. An inductor of inductance L = 400 mH and resistors of resistances $R_1 = 2\Omega$ and $R_2 = 2\Omega$ are connected to a battery of emf 12V as shown in the figure. The internal resistance of the battery is negligible. The switch S is closed at t = 0. The potential drop across L as a function of time is



(1) $6e^{-5t}V$ (2) $\frac{12}{t}e^{-3t}V$

(3) $6\left(1-e^{-t/0.2}\right)V$ (4) $12e^{-5t}V$

Sol: **(4)**



$$I_1 = \frac{F}{R_1} = \frac{12}{2} = 6A$$

$$E = L\frac{dI_2}{dt} + R_2 \times I_2$$

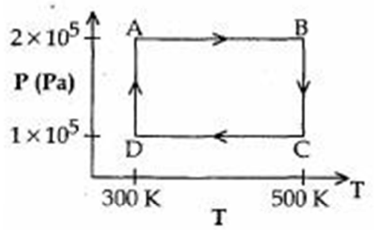
$$I_2 = I_0\left(1-e^{-t/t_c}\right) \Rightarrow I_0 = \frac{E}{R_2} = \frac{12}{2} = 6A$$

$$t_c = \frac{L}{R} = \frac{400\times10^{-3}}{2} = 0.2$$

$$I_2 = 6\left(1-e^{-t/0.2}\right)$$

Potential drop across L = $E - R_2I_2 = 12 - 2 \times 6\,(1 - e^{-5t}) = 12\,e^{-5t}$

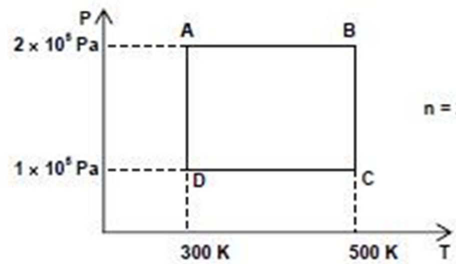
Directions: Question numbers 28, 29 and 30 are based on the following paragraph.
Two moles of helium gas are taken over the cycle ABCDA, as shown in the P – T diagram.



*28. Assuming the gas to be ideal the work done on the gas in taking it from A to B is
(1) 200 R (2) 300 R
(3) 400 R (4) 500 R

Sol: **(3)**

$W_{AB} = \Delta Q - \Delta U = nC_p dT - nC_v dT$ (at constant pressure)
$= n(C_p - C_v)dt$
$= nRdT = 2 \times R \times (500 - 300) = 400\ R$



n = 2, γ = 1.67

*29. The work done on the gas in taking it from D to A is
(1) – 414 R (2) + 414 R
(3) – 690 R (4) + 690 R

Sol: **(1)**
At constant temperature (isothermal process)

$$W_{DA} = nRT\ln\left(\frac{P_1}{P_2}\right) = 2.303 \times 2R \times 300\log\left(\frac{10^5}{2\times10^5}\right)$$
$$= 2.303 \times 600R\log\left(\frac{1}{2}\right)$$
$$= 0.693 \times 600\ R = -414\ R.$$

*30. The net work done on the gas in the cycle ABCDA is
(1) Zero (2) 276 R
(3) 1076 R (4) 1904 R

Sol: **(2)**

Net work done in a cycle $= W_{AB} + W_{Bc} + W_{CB} + W_{BA}$
$= 400\ R + 2 \times 2.303 \times 500\ R\ \ln 2 - 400R - 414\ R$
$= 1000R \times \ln 2 - 600R \times \ln 2 = 400R \times \ln 2 = 276R$