THINK NEET | THINK IIB

XIITH SCI THEORY 2023-24

XIIth 2023-24

Date : 30/10/2023

Physics Theory Round-01

Max.Marks :- 35

Time 90 Mins.

General Instructions : The question paper is divided into four sections.

(1) Section A : Q.No.1 contains Five Multiple choice type of question carrying **One** mark each.
Q.No.2 contains Five very short answer type of questions carrying **One** mark each.

(2) Section B : Q.No.3 to Q.9 are short answer type of question carrying **Two** marks each.

(3) Section C : Q.No.10 to Q. No.14 are short answer type of questions carrying **Three** marks each

(4) Section D: Q.No.15 to Q.No.18 are long answer type of questions carrying **Four** marks each.

(5) Figures to the right indicate full marks

MODEL ANSWER KEY

Section -A [05]

Q.1 Select and write the correct answer.

(i) The first law of thermodynamics is consistent with the law of conservation of ....

(1) Momentum (2) **Energy**

(3) Mass (4) Velocity

(ii) The average value of alternating current over a full cycle is always ....

(I_0 = peak value of the current)

(1) Zero (2) $\frac{I_0}{2}$

(3) $\frac{I_0}{\sqrt{2}}$ (4) $2I_0$

(iii) When the bob performs a vertical circular motion and string rotates in vertical plane, the difference in the tension in the string at horizontal position and uppermost position is ....

(1) mg (2) 2 mg

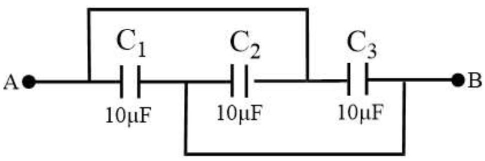
(3) 3 mg (4) 6 mg

(iv) A magnetic flux associated with the coil changes by 0.04 Wb in 0.2 second the induced emf with coil is ....

(1) 0.1 volt **(2) 0.2 volt**

(3) 0.3 volt (4) 0.4 volt

(v) The effective capacitor between A and B in the following circuit is ....



(1) $\frac{10}{3}\mu F$ (2) $\frac{3}{10}\mu F$

(3) 30μF (4) $\frac{1}{30}\mu F$

Q.2. Answer the following questions. **[05]**

(i) If friction is made zero for road, can a vehicle move safely on a road?

Ans : No, the vehicle can not move safely on this road.

(ii) State the formula giving relation between electric field intensity and potential gradient.

Ans : Relation between electric field intensity and potential gradient is

$$E = -\frac{dV}{dx}$$ where, $E \rightarrow$ electric intensity,

$\frac{dV}{dx} \rightarrow$ potential gradient.

(iii) What is the average value of alternating current over a complete cycle?

Ans : The average value of alternating current over a complete cycle is zero.

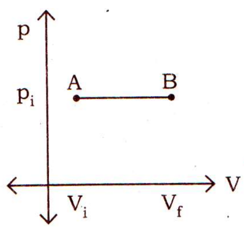
(iv) Two inductor coils with inductance 10 mH and 20 mH are connected in series what is the resultant inductance of the combination of the two coils?

Ans : $L_{total} = L_1 + L_2$

$= 10 + 20 = 30$ mH

(v) Write a short note on isobar.

Ans : (i) The p-V diagram for an isobaric process is called isobar. It is shown in figure below.



(ii) The different curves shown on the maps provided by the meteorology department are isobars. They indicate the locations having same pressure in a region.

Section -B : Attempt any 4 (Q.3 to 9) [08]

Answer the following questions :

Q.3. State and prove principle of conservation of angular momentum.

Ans : Principle of conservation of angular momentum : Angular momentum of an isolated system is conserved in the absence of an external balance torque.

Angular momentum (L) of a system is given by

$$\bar{L} = \bar{r} \times \bar{p} \qquad ....(i)$$

Where,

$\bar{r}$ is the position vector from the axis of rotation. $\bar{p}$ is the linear momentum.

Differentiating equation (i) with respect to time, we get

$$\frac{d\bar{L}}{dt} = \frac{d}{dt}(\bar{r} \times \bar{p})$$

$$= \bar{r} \times \frac{d\bar{p}}{dt} + \frac{d\bar{r}}{dt} \times \bar{p}$$

$$\therefore \frac{d\bar{L}}{dt} = \bar{r} \times \bar{F} + \bar{v} \times m\bar{v}$$

$$\ldots\left(\text{As } \frac{d\overline{p}}{dt}=\overline{F}, \frac{d\overline{r}}{dt}=\overline{v} \text{ and } p=mv\right)$$

$$= \overline{r}\times\overline{F}+m(\overline{v}+\overline{v})$$

$$\therefore \frac{d\overline{L}}{dt}=\overline{r}\times\overline{F}+0 \qquad \ldots(\text{As } \overline{v}\times\overline{v}=0)$$

But $\overline{r}\times\overline{F}$ is the torque ($\overline{\tau}$)

$$\therefore \frac{d\overline{L}}{dt}=\overline{r} \qquad \text{Thus, if } \overline{\tau}=0 \text{ then } \frac{d\overline{L}}{dt}=0$$

$\therefore$ $\overline{L}$ = constant

Hence, angular momentum $\overline{L}$ is conserved in the absence of external unbalanced torque (τ).

Q.4. A 100 Ω resistor is connected to a 220V, 50 Hz supply calculate

(a) r.m.s. value of the current

(b) net power consumed over a full cycle.

Ans : Given : R = 100 Ω, V = e_{rms} = 220 V, n = 50 Hz

To find : (a) i_{rms} = ? (b) Power = ?

(a) $i_{rms}=\frac{e_{rms}}{R}$

$$=\frac{220}{100}=2.2 \text{ A}$$

(b) Average power (P_{av})

$= i_{rms}\times e_{rms}$

= 220 × 2.2

= 484 watt

Q.5. An ideal mono-atomic gas is adiabatically compressed so that its final temperature is twice its initial temperature.

Ans : Given : Final temperature (T_f)

= 2 [Initial temperature (T_i)]

i.e. $T_f = 2T_i$

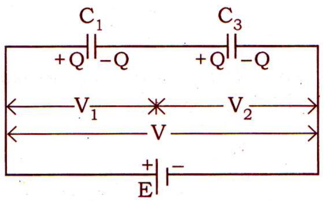
To find : $\frac{\text{Final Pressure } (P_f)}{\text{Initial Pressure } (P_i)} = ?$

We know, for monoatomic gas, $\gamma=\frac{5}{3}$

$$\left(\frac{P_i}{P_f}\right)^{1-\gamma}=\left(\frac{T_f}{T_i}\right)^{\gamma}$$

Q.6. Obtain an expression for equivalent capacitance of two capacitor C_1 and C_2 connected in series.

Ans :



Let C_1 and C_2 be capacitance are two capacitors connected in series as shown in the above figure.

Let V_1 be the potential difference across C_1,

V_2 be the potential difference across C_2,

V be the potential difference across series combination.

Let Q be the constant charge received by each capacitor.

Potential differences induced across capacitors is given by $V_1 = \frac{Q}{C_1}$ and $V_2 = \frac{Q}{C_2}$

The total P.D. across series combination is

$V = V_1 + V_2$

$$V = \frac{Q}{C_1} + \frac{Q}{C_2}$$

$$\therefore V = Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right) \qquad ....(i)$$

If C_s is the equivalent capacitance of combination and Q is the total charge, then

$$C_s = \frac{Q}{V} \quad \therefore V = \frac{Q}{C_s}$$

Substituting the value of V in eqn. (i), we get

$$\frac{Q}{C_s} = Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$$

$$\therefore \frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$$

Q.7. A 0.1 H inductor, a 25×10^{-6} F capacitor and 15 Ω resistor are connected in series to a 1250V, 50 Hz AC source. Calculate the resonant frequency.

Ans : L = 0.1 H, C = 25×10^{-6} F, f_r = ?

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$f_r = \frac{1}{2 \times 3.142\sqrt{0.1 \times 25 \times 10^{-6}}}$$

$$f_r = 100 \cdot 8 \, \text{Hz}$$

Q.8. State the factors on which magnetic coupling coefficient of two coil depends.

Ans : The coefficient of magnetic coupling between two coils depends on

(i) the permeability of the core on which the coils are wound.

(ii) the distance between the coils.

(iii) the angle between the coil axes.

Q.9. Define moment of inertia of a rigid body. State its SI units and dimensions.

Ans : Moment of Inertia : The moment of inertia of a body about a given axis of rotation is defined as the sum of the products of the masses of the particles of the body and the squares of their respective distances from the axis of rotations.

SI unit : kg m^2

Dimensions : $[M^1L^2T^0]$

Section -C : Attempt any 3 (Q.10 to 14) [09]

Q.10. A 25 watt lamp is connected to the a.c. potential of peak value 100 v. Calculate the r.m.s. value of the current.

Ans : Given : $\overline{p} = 25\text{ W},\ e_0 = 100\text{ V}$

To find : $I_{rms} = ?$

$$\because\ \overline{p} = \frac{e_0 I_0}{2}$$

$$\therefore\ I_0 = \frac{2\overline{p}}{e_0} = \frac{2\times 25}{100}$$

$$\therefore\ I_0 = 0.5\text{ A} \qquad \text{But } I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{0.5}{1.414} = 0.3536\text{ A}$$

Q.11. State and explain the limitations of the first law of thermodynamics.

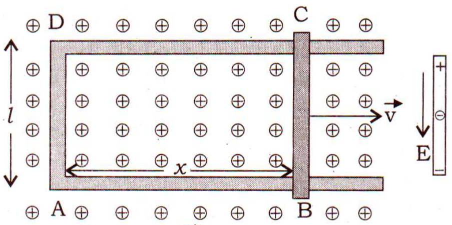
Ans : Limitations of first law of thermodynamics :

(i) First law of thermodynamics does not tell us whether any particular process can actually occur.

(ii) According to the first law of thermodynamics, heat may, on its own, flow from an object at higher temperature to one at lower.

Q.12. Derive an expression for emf (e) generated in a conductor of length (l) moving in a uniform magnetic field (B) with uniform velocity (V) along X-axis.

Ans :



⊕ Magnetic field $\vec{B}$ into plane of the paper

A loop is moving out of magnetic field with velocity $\vec{v}$ along X-axis.

As shown in figure, a rectangular frame ABCD of area (lx) is situated in a constant magnetic field ($\vec{B}$). As the wire BC of length l is moved out with the velocity $\vec{v}$ to increase x the area of the loop ABCD increases. Thus the flux of $\vec{B}$ through the loop increase with time.

According to the 'flux rule' the induced emf will be equal to the rate at which the magnetic flux through a conducting circuit is changing. Thus induced emf will cause a current in the loop.

As the flux ϕ through the frame ABCD is Blx, magnitude of the induced emf can be written as,

$$\therefore\ |e| = \frac{d\phi}{dt}$$

$$e = \frac{d\phi}{dt}(blx) = Bl\frac{dx}{dt}$$

$$e = Blv$$

Q.13. Find the ratio of potential differences that must be applied across the parallel and series combination of two capacitors C_1 and C_2 in the ratio 1 : 2 such that the energy stored in the two cases is the same.

Ans : Data : $\frac{C_1}{C_2} = \frac{1}{2}$, U_1 (for parallel) = U_2 (for series)

$$\because \frac{C_1}{C_2} = \frac{1}{2} \qquad \therefore \quad C_2 = 2C_1$$

For the parallel combination of C_1 and C_2, and charged to a potential V_1, the energy stored is

$$U_1 = \frac{1}{2} C_P V_1^2 = \frac{3}{2} C_1 V_1^2$$

For the series combination of C_1 and C_2 ,

$C_S = \frac{C_1 C_2}{C_1 + C_2} = \frac{2C_1^2}{3C_1} = \frac{2}{3} C_1$ and a charged to a potential V_2, the energy stored is,

$$U_2 = \frac{1}{2} C_S V_2^2 = \frac{1}{3} C_1 V_2^2$$

For $U_1 = U_2$,

$$\frac{3}{2} C_1 V_1^2 = \frac{1}{3} C_1 V_2^2$$

$$\therefore \left(\frac{V_1}{V_2}\right)^2 = \frac{2}{9}$$

$$\therefore \frac{V_1}{V_2} = \frac{\sqrt{2}}{3} = \frac{1.414}{3} = 0.471$$

This is the required ratio.

Q.14. Find the angular acceleration of a particle in circular motion which slows down from 300 r.p.m. to 0 r.p.m. in 20 second.

Ans : Given : n_1 = 300 rpm

$$\therefore \; n_1 = \frac{300}{60} = 5 \text{ rps} = 5 \text{ Hz}$$

$$n_2 = 0, \; t = 20\, s$$

Angular acceleration,

$$\alpha = \frac{\omega_2 - \omega_1}{t}$$

$$\alpha = \frac{2\pi n_2 - 2\pi n_1}{20}$$

$$\therefore \qquad \alpha = \frac{0 - 2\pi \times 5}{20} = \frac{-\pi}{2} \text{ rad/s}^2$$

$$\alpha = \frac{-3.14}{2} \text{ rad/s}^2$$

$$\therefore \qquad \alpha = -1.57 \text{ rad/s}^2$$

Section -D : Attempt any 2 (Q.15 to 18) [08]

Q.15. About radius of gyration, answer the following.

(a) Discuss the necessity of radius of gyration.

(b) Define it.

(c) On what factors does it depend?

(d) on what factors it does not depend?

(e) Can you locate some similarity between the centre of mass and radius of gyration?

(f) What can you infer if a uniform ring and a uniform disc have the same radius of gyration?

Ans : (a) The necessity of radius of gyration :

(i) The measure the distribution of masses in a body abut the given axis of rotation.

(ii) The measure moment of inertia of the body of any shape.

(b) **Definition :** Radius of gyration of a body about an axis of rotation is the distance between the axis of rotation and a point at which the whole mass of the body is supposed to be concentrated so as to have the same moment of inertia as that of the body about the same axis of rotation.

(c) Factors on which it depends :

(i) shape and size of the body.

(ii) Position and configuration of axis of rotation.

(iii) Distribution of masses in the body with respect to axis of rotation.

(iv) Moment of inertia of the body.

(d) Factors on which it does not depend :

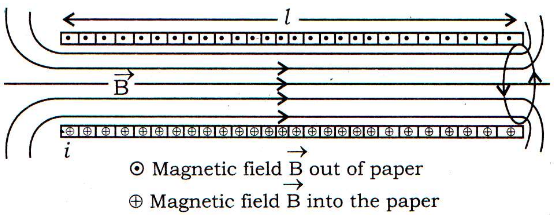
Mass of the body

(e) Axis, of rotation of a body passing through centre of mass and radius of gyration are parallel to each other.

(f) No, K is not same for a ring a disc.

Q.16. Obtain an expression for energy density of magnetic field.

Ans :



A current carrying solenoid produces uniform magnetic field in the interior region.

Consider a long solenoid having length and cross-section area A and B carrying a current. Volume associated with the solenoid = A × l. The energy stored will be uniformly distributed within the volume, as the magnetic field $\overline{B}$ is uniform every where inside the solenoid.

Thus, the energy stored, per unit volume in the magnetic field is,

$$u_B = \frac{U_B}{A \cdot l} \qquad ...(i)$$

We know energy stored in magnetic field is

$$U_B = \frac{1}{2} L I^2$$

$$\therefore\ u_B = \frac{1}{2} L I^2 \times \frac{1}{A \cdot l} = \left(\frac{L}{t}\right)\frac{I^2}{2A} \qquad ...(ii)$$

For a long solenoid, the inductance (L) per unit length is given by

$$\left(\frac{L}{l}\right) = \mu_0 n^2 A$$

Equation (ii) becomes

$$\therefore\ u_B = \mu_0 n^2 A \cdot \frac{l^2}{2A}$$

$$= \frac{1}{2}\mu_0 n^2 I^2 \qquad \text{...(iii)}$$

For a solenoid, the magnetic field at the interior points is

$B = \mu_0 n I$

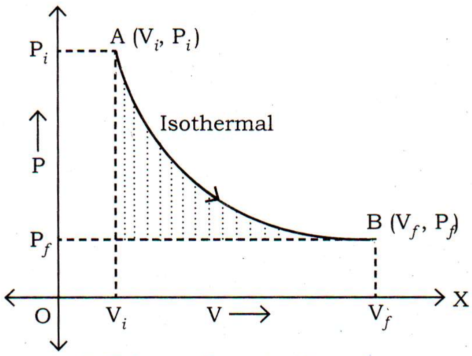
$$\therefore\ u_B = \frac{B^2}{2\mu_0} \qquad \text{...(iv)}$$

This gives the energy density stored at any point where magnetic field is B.

Q.17. Obtain an expression for the work done by the gas in an isothermal process. The molar specific heat of He at constant volume is 12.47 J/mol K. Two moles of He are heated at constant pressure so that the rise in temperature is 10 K. Find the increase in internal energy of the gas.

Ans : Work done by a gas in an isothermal process : Consider *n* moles of a gas enclosed in a cylinder fitted with a movable, light and frictionless piston. Let P_i, V_i and T be the initial pressure, volume and absolute temperature respectively of the gas.

Consider an isothermal expansion (or compression) of the gas in which P_f, V_f and T are respectively the final pressure, volume and absolute temperature of the gas.



P–V digram for an isothermal process

For an isothermal change,

$P_i V_i = P_f V_f$ = constant

Assuming the gas to behave as an ideal gas, its equation of state is

PV = nRT = constant ..... (i)

....(as T = constant, R is universal gas constant)

The work done in an infinitesimally small isothermal expansion is given by

dW = PdV

The total work done in bringing out the expansion from initial volume V_i to the final volume V_f is given by

$$W = \int_{V_i}^{V_f} P dV$$

$$\therefore W = nRT\int_{V_i}^{V_f}\frac{dV}{V} \quad \text{....([From (i)]}$$

$$\therefore W = nRT[\ln V_f - \ln V_i]$$

$$\therefore W = nRT\ln\frac{V_f}{V_i}$$

$$\therefore W = 2.303\ nRT\ \log_{01}\frac{V_f}{V_i}$$

Given, C_v = 12.47 J/mol. K, n = 2, $T_f - T_i$ = 10K

To find : The increase in the internal energy of the gas ((ΔU) = ?

$$\Delta U = nC_v(T_f - T_i)$$

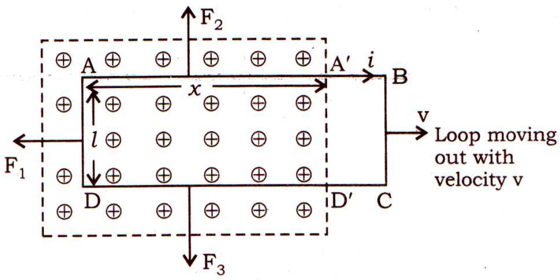
$$= 2\times 12.47\times 10$$

$$= 249.4 \text{ J}$$

Q.18. Show that the work done in pulling a loop through the magnetic field appears as heat energy in the loop.

Ans : Consider a loop ABCD moving with constant velocity in a uniform magnetic field B as shown in the figure.

A current i is induced in the loop in clockwise direction. Let F_1, F_2 and F_3 be the forces acting on side AD, AA' and DD' respectively. The dashed line shows limit of magnetic field.



⊕ Magnetic field $\vec{B}$ into plane of the paper

To pull the loop at constant velocity towards right, it is required to apply external force $\overline{F}$ on loop so as to over come the magnetic force of equal magnitude but opposite in direction.

The rate of work done on loop is

$$\text{Power} = \frac{\text{Work done}}{\text{Time}}$$

$$\therefore \text{Power} = \frac{\text{Force} \times \text{displacement}}{\text{Time}}$$

$$= \text{Force} = \text{Velocity}$$

$$\therefore \quad P = \overline{F}\cdot\overline{v}$$

Let us find the expression for P in terms of B, resistance, area and width. When the loop is moved to the right, the distance x decreases *i.e.* area of loop inside the field decreases, causing magnetic flux decreases and it reduces current in the loop.

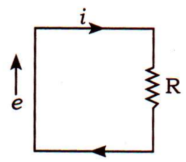
The magnitude of magnetic flux through loop is

$$\phi = BA$$

$$= Blx \quad \text{where } A = lx$$

By Faraday's law, the induced emf is

$$\therefore\ e = \frac{-d\phi}{dt}$$



$$\therefore\ e = \frac{-d}{dt}(Blx)$$

$$\therefore\ e = -Bl\frac{-dx}{dt}$$

$$\therefore\ e = -Bl(-v) \qquad \ldots\left(\text{As } -v = \frac{-dx}{dt}\right)$$

$$\therefore\ e = Blv \qquad \ldots\text{(i)}$$

v is negative, as time increases distance x decreases,
The magnitude of induced current is

$$i = \frac{|e|}{R} = \frac{Blv}{R} \qquad \ldots\text{(ii)}$$

The force acting on AA' and DD' i.e. F_2 and F_3 are equal in magnitude and opposite in direction. Therefore cancel each other.
The force F_1 is directed opposite to F.

$$\therefore \vec{F} = -\vec{F_1}$$

The magnitude of F_1 is
$F_1 = ilB \sin\theta$
$F_1 = ilB$ (As $F \perp l \perp B$, $\therefore\ \theta = 90^0$ and $\sin 90° = 1$)
$\therefore\ |F| = |F_l| = il\text{B}$
Putting the value of i in equation (ii) ,

$$|F| = \left(\frac{Blv}{R}\right)lB$$

$$|F| = \frac{B^2l^2v}{R} \qquad \ldots\text{(iii)}$$

The rate of mechanical work, i.e. power is
$P = Fv$

$$P = \frac{B^2l^2v^2}{R} \qquad \ldots\text{(iv)}$$

The rate of production of heat energy in the loop is
$P = i^2 R$

Putting $i = \dfrac{Blv}{R}$

$$P = \frac{B^2l^2v^2}{R} \qquad \ldots\text{(v)}$$

Comparing equations (iv) and (v) we find that the rate of doing mechanical work is exactly same as the rate of production of heat energy in the loop. Thus the work done in loop appears as heat energy in the loop.

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