

JEE-MAIN EXAMINATION – JANUARY 2025

(HELD ON FRIDAY 24th JANUARY 2025)

TIME : 9 : 00 AM TO 12 : 00 NOON

PHYSICS

TEST PAPER WITH SOLUTION

SECTION-A

26. Consider a parallel plate capacitor of area A (of each plate) and separation 'd' between the plates. If E is the electric field and ϵ_0 is the permittivity of free space between the plates, then potential energy stored in the capacitor is :-

(1) $\frac{1}{2} \epsilon_0 E^2 Ad$ (2) $\frac{3}{4} \epsilon_0 E^2 Ad$

(3) $\frac{1}{4} \epsilon_0 E^2 Ad$ (4) $\epsilon_0 E^2 Ad$

Ans. (1)

Sol. $\frac{U}{V} = \frac{1}{2} \epsilon_0 E^2$
 $U = \frac{1}{2} \epsilon_0 E^2 V$
 $= \frac{1}{2} \epsilon_0 E^2 (Ad)$

Ans. (1)

27. What is the relative decrease in focal length of a lens for an increase in optical power by 0.1 D from 2.5 D ? ['D' stands for dioptre]

(1) 0.04 (2) 0.40

(3) 0.1 (4) 0.01

Ans. (1)

Sol. When P = 2.5 D

$$F = \frac{1}{P} = \frac{1}{2.5}$$

When P' = 2.6 D

$$F' = \frac{1}{P'} = \frac{1}{2.6}$$

Relative decrease in focal length

$$\frac{F - F'}{F} = \frac{\frac{2}{5} - \frac{5}{13}}{\frac{2}{5}} = 1 - \frac{25}{26} = \frac{1}{26} = \frac{1}{26} = 0.04$$

Ans. (1)

28. An air bubble of radius 0.1 cm lies at a depth of 20 cm below the free surface of a liquid of density 1000 kg/m³. If the pressure inside the bubble is 2100 N/m² greater than the atmospheric pressure, then the surface tension of the liquid in SI unit is (use g = 10 m/s²)

(1) 0.02 (2) 0.1

(3) 0.25 (4) 0.05

Ans. (4)

Sol. T is surface tension

$$P \text{ in air bubble} = P_0 + \rho gh + \frac{2T}{R}$$

$$P_{in} - P_0 = \rho gh + \frac{2T}{R} = 2100$$

$$\frac{2T}{R} = 2100 - \rho gh$$

$$T = \frac{R}{2} (2100 - 10^3 \times 10 \times 0.2)$$

$$= \frac{1}{20} (2100 - 2000) \times 10^{-2}$$

$$= 0.05$$

Ans. (4)

29. For an experimental expression $y = \frac{32.3 \times 1125}{27.4}$,

where all the digits are significant. Then to report the value of y we should write :-

(1) y = 1326.2 (2) y = 1326.19

(3) y = 1326.186 (4) y = 1330

Ans. (4)

Sol. $y = \frac{32.3 \times 1125}{27.4} = 1326.186$

Last significant digits are 3 in operands so results should rounded off to 3 digits.

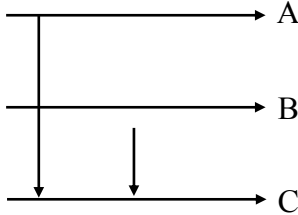
$$\therefore y = 1330$$

Ans. (4)

30. During the transition of electron from state A to state C of a Bohr atom, the wavelength of emitted radiation is 2000 \AA and it becomes 6000 \AA when the electron jumps from state B to state C. Then the wavelength of the radiation emitted during the transition of electrons from state A to state B is :-

- (1) 3000 \AA (2) 6000 \AA
 (3) 4000 \AA (4) 2000 \AA

Ans. (1)



Sol.

$$E_A - E_C = \frac{hc}{2000\text{\AA}} \dots\dots (i)$$

$$\text{and } E_B - E_C = \frac{hc}{6000\text{\AA}} \dots\dots (ii)$$

$$\text{Now } E_A - E_B = (E_A - E_C) - (E_B - E_C)$$

$$\frac{hc}{\lambda_{AB}} = \frac{hc}{2000} - \frac{hc}{6000}$$

$$\frac{1}{\lambda_{AB}} = \frac{1}{3000\text{\AA}}$$

$$\lambda_{AB} = 3000\text{\AA}$$

Ans. (1)

31. Consider the following statements :

- A. The junction area of solar cell is made very narrow compared to a photo diode.
 B. Solar cells are not connected with any external bias.
 C. LED is made of lightly doped p-n junction.
 D. Increase of forward current results in continuous increase of LED light intensity.
 E. LEDs have to be connected in forward bias for emission of light.

- (1) B, D, E Only (2) A, C Only
 (3) A, C, E Only (4) B, E Only

Ans. (4)

Sol. Conceptual

Ans. (4)

32. The amount of work done to break a big water drop of radius 'R' into 27 small drops of equal radius is 10 J. The work done required to break the same big drop into 64 small drops of equal radius will be :-

- (1) 15 J (2) 10 J
 (3) 20 J (4) 5 J

Ans. (1)

Sol. $W = \Delta U = S\Delta A$

One drop to n drop

$$\frac{4}{3}\lambda R^3 = n \frac{4}{3}\lambda r^3$$

$$r = \frac{R}{n^{\frac{1}{3}}}$$

$$\text{So } W = S(n4\pi r^2 - 4\pi R^2)$$

$$= S4\pi R^2 \left(n^{\frac{1}{3}} - 1 \right)$$

For on drop to 27 drops

$$W = S4\pi R^2 \left(27^{\frac{1}{3}} - 1 \right) = 10 \dots\dots (i)$$

For one drop to 64 drops

$$W' = S4\pi R^2 \left(64^{\frac{1}{3}} - 1 \right) \dots\dots (ii)$$

(ii)/(i)

$$\frac{W'}{W} = \frac{4-1}{3-1} = \frac{3}{2}$$

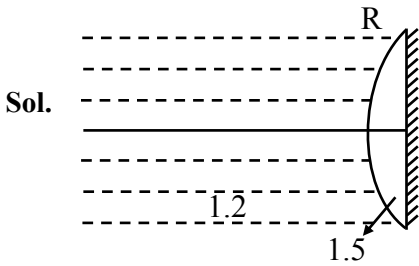
$$W' = \frac{3}{2} W = 15$$

Ans. (1)

33. An object of mass 'm' is projected from origin in a vertical xy plane at an angle 45° with the x-axis with an initial velocity v_0 . The magnitude and direction of the angular momentum of the object with respect to origin, when it reaches at the maximum height, will be [g is acceleration due to gravity]

- (1) $\frac{mv_0^3}{2\sqrt{2}g}$ along negative z-axis
 (2) $\frac{mv_0^3}{2\sqrt{2}g}$ along positive z-axis
 (3) $\frac{mv_0^3}{4\sqrt{2}g}$ along positive z-axis
 (4) $\frac{mv_0^3}{4\sqrt{2}g}$ along negative z-axis

Ans. (4)



$$\frac{1.5}{v} = \frac{1.5 - 1.2}{R}$$

$$v = \frac{1.5R}{0.3} = 5R$$

$$\frac{1.2}{f} - \frac{1.5}{5R} = \frac{1.2 - 1.5}{-R}$$

$$\frac{1.2}{f} = \frac{0.3}{R} \times 2 \Rightarrow f = 2R \Rightarrow R = 0.1$$

Ans (2)

38. A particle is executing simple harmonic motion with time period 2s and amplitude 1 cm. If D and d are the total distance and displacement covered by

the particle in 12.5 s, then $\frac{D}{d}$ is :-

(1) $\frac{15}{4}$

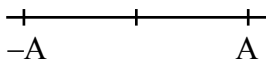
(2) 25

(3) 10

(4) $\frac{16}{5}$

Ans. (2)

Sol. $A = 1$ cm



$$n = \frac{12.5}{2} = 6.25 \text{ cycles}$$

$$\therefore D = 4 \times 6 + 1 = 25$$

$$d = 1$$

$$\frac{D}{d} = 25$$

Ans. (2)

39. A satellite is launched into a circular orbit of radius 'R' around the earth. A second satellite is launched into an orbit of radius 1.03 R. The time period of revolution of the second satellite is larger than the first one approximately by :-

(1) 3 %

(2) 4.5 %

(3) 9 %

(4) 2.5 %

Ans. (2)

Sol. $T^2 = KR^3$

$$\frac{2\Delta T}{T} = \frac{3\Delta R}{R}$$

$$\frac{2\Delta T}{T} = \frac{3 \times 0.03R}{R}$$

$$\frac{\Delta T}{T} = \frac{3 \times 0.03}{2} \times 100 = 4.5\%$$

Ans. (2)

40. A plano-convex lens having radius of curvature of first surface 2 cm exhibits focal length of f_1 in air. Another plano-convex lens with first surface radius of curvature 3 cm has focal length of f_2 when it is immersed in a liquid of refractive index 1.2. If both the lenses are made of same glass of refractive index 1.5, the ratio of f_1 and f_2 will be :-

(1) 3 : 5

(2) 1 : 3

(3) 1 : 2

(4) 2 : 3

Ans. (2)

Sol. $\frac{1}{f_1} = (1.5 - 1) \left[\frac{1}{2} - 0 \right] \Rightarrow f_1 = 4$ cm

$$\frac{1}{f_2} = \left(\frac{1.5}{1.2} - 1 \right) \left(\frac{1}{3} - 0 \right)$$

$$\frac{1}{f_2} = \frac{0.3}{1.2} \times \frac{1}{3}$$

$$f_2 = 12$$

$$f_1 : f_2 = 4 : 12 = 1 : 3$$

Ans. (2)

41. An alternating current is given by

$$I = I_A \sin \omega t + I_B \cos \omega t.$$

The r.m.s. current will be :-

(1) $\sqrt{I_A^2 + I_B^2}$

(2) $\frac{\sqrt{I_A^2 + I_B^2}}{2}$

(3) $\sqrt{\frac{I_A^2 + I_B^2}{2}}$

(4) $\frac{|I_A + I_B|}{\sqrt{2}}$

Ans. (3)

Sol. $i_{\text{rms}} = \sqrt{\frac{\int I^2 dt}{\int dt}}$

$$\sqrt{\frac{I_A^2 + I_B^2}{2}} = i_{\text{rms}}$$

42. An electron of mass 'm' with an initial velocity $\vec{v} = v_0 \hat{i}$ ($v_0 > 0$) enters an electric field $\vec{E} = -E_0 \hat{k}$. If the initial de Broglie wavelength is λ_0 , the value after time t would be :-

- (1) $\frac{\lambda_0}{\sqrt{1 + \frac{e^2 E_0^2 t^2}{m^2 v_0^2}}}$ (2) $\frac{\lambda_0}{\sqrt{1 - \frac{e^2 E_0^2 t^2}{m^2 v_0^2}}}$
 (3) λ_0 (4) $\lambda_0 \sqrt{1 + \frac{e^2 E_0^2 t^2}{m^2 v_0^2}}$

Ans. (1)

Sol. $\vec{v} = v_0 \hat{i} - \frac{E_0 e}{m} t \hat{k}$

$$|\vec{v}| = \sqrt{v_0^2 + \frac{E_0^2 e^2 t^2}{m^2}}$$

$$\lambda_0 = \frac{h}{m v_0}$$

$$\lambda' = \frac{h}{m v_0 \sqrt{1 + \frac{E_0^2 e^2 t^2}{v_0^2 m^2}}}$$

$$\lambda' = \frac{\lambda_0}{\sqrt{1 + \frac{E_0^2 e^2 t^2}{v_0^2 m^2}}}$$

Ans. (1)

43. A parallel plate capacitor was made with two rectangular plates, each with a length of $l = 3$ cm and breadth of $b = 1$ cm. The distance between the plates is $3 \mu\text{m}$. Out of the following, which are the ways to increase the capacitance by a factor of 10 ?

- A. $l = 30$ cm, $b = 1$ cm, $d = 1 \mu\text{m}$
 B. $l = 3$ cm, $b = 1$ cm, $d = 30 \mu\text{m}$
 C. $l = 6$ cm, $b = 5$ cm, $d = 3 \mu\text{m}$
 D. $l = 1$ cm, $b = 1$ cm, $d = 10 \mu\text{m}$
 E. $l = 5$ cm, $b = 2$ cm, $d = 1 \mu\text{m}$

Choose the correct answer from the options given below :

- (1) C and E only (2) B and D only
 (3) A only (4) C only

Ans. (1)

Sol. $C = \frac{A \epsilon_0}{d}$

A : plate area

d : distance between the plates.

Capacitance initial

$$= \frac{\epsilon_0 \ell b}{d} = \epsilon_0 \text{ units}$$

Option 'C' $\ell = 6$ cm

$b = 5$ cm

$d = 3$ cm

Capacitance = $10 \epsilon_0$ units

Option 'E' $\ell = 5$ cm

$b = 2$ cm

$d = 1$ cm

Capacitance = $10 \epsilon_0$ units

\therefore Ans is option (1)

44. A force $F = \alpha + \beta x^2$ acts on an object in the x-direction. The work done by the force is 5J when the object is displaced by 1 m. If the constant $\alpha = 1\text{N}$ then β will be

- (1) 15 N/m^2 (2) 10 N/m^2
 (3) 12 N/m^2 (4) 8 N/m^2

Ans. (3)

Sol. $F = \alpha + \beta x^2$

$$\text{Work done} = \int F dx$$

$$5 = \int (\alpha + \beta x^2) dx$$

$$5 = \alpha x + \frac{\beta x^3}{3} \Big|_0^1$$

$$5 = \alpha + \frac{\beta}{3} [\alpha = 1]$$

$$4 = \frac{\beta}{3} \Rightarrow \beta = 12 \text{ N/m}^2$$

45. An ideal gas goes from an initial state to final state. During the process, the pressure of gas increases linearly with temperature.

- A. The work done by gas during the process is zero.
- B. The heat added to gas is different from change in its internal energy.
- C. The volume of the gas is increased.
- D. The internal energy of the gas is increased.
- E. The process is isochoric (constant volume process)

Choose the **correct** answer from the options given below :-

- (1) A, B, C, D Only
- (2) A, D, E Only
- (3) E Only
- (4) A, C Only

Ans. (2)

Sol. Given that

$$P = kT$$

$$\frac{P}{T} = \text{constant}$$

∴ Volume is constant or isochoric process.

$$\therefore W_D = 0$$

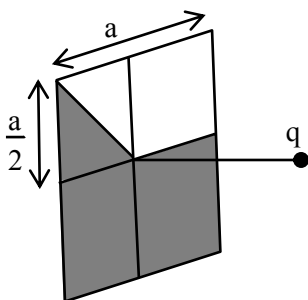
$$\therefore Q = \Delta U$$

Also temperature increases hence internal energy increases.

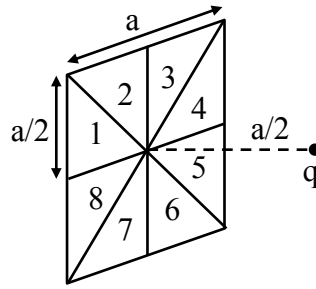
SECTION-B

46. A square loop of sides $a = 1 \text{ m}$ is held normally in front of a point charge $q = 1 \text{ C}$. The flux of the electric field through the shaded region is

$$\frac{5}{p} \times \frac{1}{\epsilon_0} \frac{\text{Nm}^2}{\text{C}}, \text{ where the value of } p \text{ is } \underline{\hspace{2cm}}.$$



Ans. (48)



Sol.

$$\text{Total flux through square} = \frac{q}{\epsilon_0} \left(\frac{1}{6} \right)$$

Lets divide square is 8 equal parts.

Flux is same for each part.

$$\therefore \text{Flux through shaded portion is } \frac{5}{8} \text{ (Total flux)}$$

$$= \frac{5}{8} \times \frac{q}{\epsilon_0} \frac{1}{6} = \frac{5}{48} \frac{q}{\epsilon_0}$$

∴ required Ans. is 48

Note : Distnace of charge from square loop is

not mentioned we have assume it as $\frac{a}{2}$.

47. The least count of a screw guage is 0.01 mm. If the pitch is increased by 75% and number of divisions on the circular scale is reduced by 50%, the new least count will be $\underline{\hspace{2cm}} \times 10^{-3} \text{ mm}$.

Ans. (35)

Sol. Given least count of Screw Gauge = 0.01 mm

$$\text{L.C} = \frac{(\text{pitch})}{\text{No. of circular turn}} = \frac{P}{N} = 0.01 \text{ mm}$$

$$\text{New pitch} = \frac{P(1+0.75)}{N(1-0.5)} = \frac{P}{N} \left[\frac{1.75}{0.5} \right]$$

$$= (0.01) 3.5$$

$$= 0.035 \text{ mm}$$

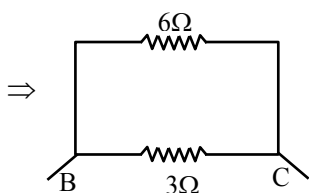
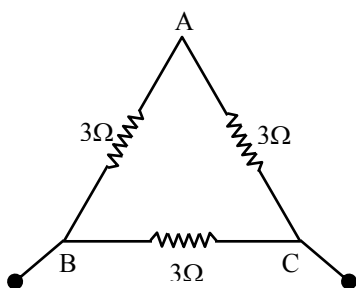
$$= 35 \times 10^{-3} \text{ mm}$$

∴ Ans. is 35

48. A wire of resistance $9\ \Omega$ is bent to form an equilateral triangle. Then the equivalent resistance across any two vertices will be ___ohm.

Ans. (2)

Sol.



$9\ \Omega$ is the resistance of whole wire

\therefore resistance of each wire = $3\ \Omega$.

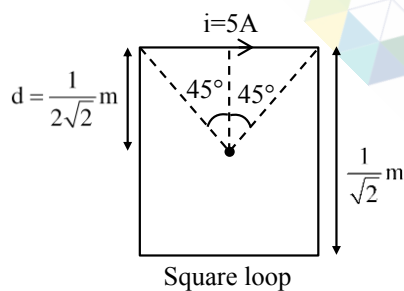
\therefore Equivalent resistance = $2\ \Omega$

49. A current of 5A exists in a square loop of side $\frac{1}{\sqrt{2}}\text{m}$. Then the magnitude of the magnetic field

B at the centre of the square loop will be $p \times 10^{-6}\text{ T}$. where, value of p is _____.

[Take $\mu_0 = 4\pi \times 10^{-7}\text{ T mA}^{-1}$].

Ans. (8)



Sol.

Let B be the magnetic field due to single side

$$\text{then } B = \frac{\mu_0 i}{4\pi d} (\sin\theta_1 + \sin\theta_2)$$

$$= \frac{10^{-7} \times 5 \times 2}{\frac{1}{2\sqrt{2}}} \times \frac{1}{\sqrt{2}} = 2 \times 10^{-6}$$

$\therefore B_{\text{net}}$ at centre $O = 4B$

$$= 8 \times 10^{-6}$$

$\therefore P = 8$ Ans.

50. The temperature of 1 mole of an ideal monoatomic gas is increased by 50°C at constant pressure. The total heat added and change in internal energy are

E_1 and E_2 , respectively. If $\frac{E_1}{E_2} = \frac{x}{9}$ then the value

of x is _____.

Ans. (15)

Sol. Given that process is isobaric $\Delta T = 50^\circ\text{C}$

Q in isobaric process = $nC_p\Delta T = E_1$

ΔU in isobaric process = $nC_v\Delta T = E_2$

$$\therefore \frac{E_1}{E_2} = \frac{C_p}{C_v} = \gamma$$

Given, gas is monoatomic

$$\therefore \gamma = 1 + \frac{2}{f}$$

$$= 1 + \frac{2}{3}$$

$$= \frac{5}{3}$$

Now, as per question.

$$\frac{5}{3} = \frac{x}{9}$$

$$x = 15$$