|JEE MAIN 2025 | DATE : 24 JANUARY 2025 (SHIFT-1) MORNING

PHYSICS

SECTION-1

[:Q.1] A car of mass 'm' moves on a banked road having radius 'r' and banking angle θ. To avoid slipping from banked road, the maximum permissible speed of the car is v_0. The coefficient of friction μ between the wheels of the car and the banked road is

[:A] $\mu = \frac{v_o^2 - rg\tan\theta}{rg - v_o^2\tan\theta}$

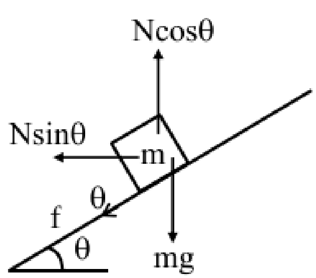
[:B] $\mu = \frac{v_o^2 + rg\tan\theta}{rg - v_o^2\tan\theta}$

[:C] $\mu = \frac{v_o^2 + rg\tan\theta}{rg + v_o^2\tan\theta}$

[:D] $\mu = \frac{v_o^2 - rg\tan\theta}{rg + v_o^2\tan\theta}$

[:ANS] **D**

[:SOLN]



$$N\sin\theta + f\cos\theta = \frac{mv^2}{R}$$

$$N\cos\theta - f\sin\theta = mg$$

$$\frac{\sin\theta + \mu\cos\theta}{\cos\theta - \mu\sin\theta} = \frac{v^2}{Rg}$$

$$Rg\tan\theta + \mu Rg = v^2 - v^2\mu\tan\theta$$

$$\mu = \frac{v^2 - Rg\tan\theta}{Rg + v^2\tan\theta}$$

[:Q.2] 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

[:A] y = 1326.2

[:B] y = 1326.186

[:C] y = 1330

[:D] y = 1326.19

[:ANS] **C**

[:SOLN] $y = \frac{32.3 \times 1125}{27.4} = 1326.186$

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

$\therefore\ y = 1330$

[:Q.3] An alternating current is given by $I = I_A \sin\omega t + I_B \cos\omega t$. The r.m.s current will be

[:A] $\sqrt{I_A^2 + I_B^2}$

[:B] $\sqrt{\frac{I_A^2 + I_B^2}{2}}$

[:C] $\frac{\sqrt{I_A^2 + I_B^2}}{2}$

[:D] $\frac{|I_A + I_B|}{\sqrt{2}}$

[:ANS] **B**

[:SOLN] $i_{rms} = \sqrt{\frac{\int I^2 dt}{\int dt}}$

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

[:Q.4] 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

[:A] 2 : 3

[:B] 3 : 5

[:C] 1 : 2

[:D] 1 : 3

[:ANS] **D**

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

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

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

$f_2 = 12$

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

[:Q.5] A satellite is launched into a circular orbit of radius 'R' around the earth. A second satellite is launcehed into an orbit of radius 1.03 R. The time period of revolution of the second satellite is large than the first one approximately by

[:A] 3%

[:B] 4.5%

[:C] 2..5%

[:D] 9%

[:ANS] **B**

[:SOLN] $T^2 = KR^3$

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

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

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

[:Q.6] 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

[:A] $\frac{1}{2}\varepsilon_0 E^2 Ad$

[:B] $\frac{1}{4}\varepsilon_0 E^2 Ad$

[:C] $\frac{3}{4}\varepsilon_0 E^2 Ad$

[:D] $\varepsilon_0 E^2 Ad$

[:ANS] **A**

[:SOLN] $\frac{U}{V} = \frac{1}{2}\epsilon_0 E^2$

$U = \frac{1}{2}\epsilon_0 E^2 V$

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

[:Q.7] A force F = $\alpha + \beta x^2$ acts on an object in the x-direction. The work done by the force is 5 J when the object is displaced by 1m. If the constant $\alpha = 1N$ then β will be

[:A] $15\ N/m^2$

[:B] $8N/m^2$

[:C] $10N/m^2$

[:D] $12N/m^2$

[:ANS] **D**

[:SOLN] $F = \alpha + \beta x^2$

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

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

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

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

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

[:Q.8] 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 the origin, when it reaches at the maximum height, will be [g is acceleration due to gravity]

[:A] $\frac{mv_o^3}{4\sqrt{2}g}$ along negative z-axis

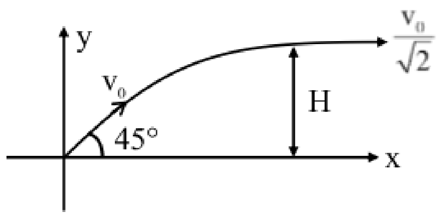
[:B] $\frac{mv_o^3}{2\sqrt{2}g}$ along negative z-axis

[:C] $\frac{mv_o^3}{4\sqrt{2}g}$ along positive z-axis

[:D] $\frac{mv_o^3}{2\sqrt{2}g}$ along positive z-axis

[:ANS] **A**

[:SOLN]



$$H = \frac{\left(\frac{v_0}{\sqrt{2}}\right)^2}{2g} = \frac{v_0^2}{4g}$$

$$L = mvh$$

$$L = m\frac{v_0}{\sqrt{2}}\frac{v_0^2}{4g}$$

[:Q.9] A thin plano convex lens made of glass of refractive index 1.5 is immersed in a liquid of refractive index 1.2. When the plane side of the lens is silver coated for complete reflection. the lens immersed in the liquid behaves like a concave mirror of focal length 0.2 m. The radius of curvature of the curved surface of the lens is

[:A] 0.15 m

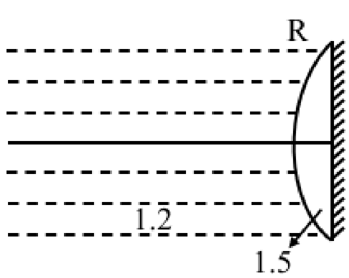
[:B] 0.20 m

[:C] 0.10 m

[:D] 0.25 m

[:ANS] **3**

[:SOLN]



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

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

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

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

[:Q.10] What is the relative decrease in focal length of a lens for an increase in optical power by 0.1D from 2.5D? ['D' stands for dioptre]

[:A] 0.01

[:B] 0.04

[:C] 0.40

[:D] 0.1

[:ANS] **B**

[:SOLN] 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

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

[:Q.11] 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.

Choose the correct answer from the options given below:

[:A] b, e only

[:B] b, d, e only

[:C] a, c, e only

[:D] a, c only

[:ANS] **A**

[:SOLN] Conceptual

[:Q.12] 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/m^3. If the pressure inside the bubble is 2100 N/m^2 greater than the atmosphere pressure, then the surface tension of the liquid in SI unit is (use g = $10m/s^2$)

[:A] 0.05

[:B] 0.25

[:C] 0.1

[:D] 0.02

[:ANS] **A**

[:SOLN] T is surface tension

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

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

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

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

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

$$= 0.05$$

[:Q.13] 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

[:A] 15 J

[:B] 10 J

[:C] 20 J

[:D] 5 J

[:ANS] **A**

[:SOLN] $W = \Delta U = S\Delta A$

One drop to n drop

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

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

So $W = S\left(n4\pi r^2 - 4\pi R^2\right)$

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

For on drop to 27 drops

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

For one drop to 64 drops

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

(ii)/(i)

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

$W' = \frac{3}{2}W = 155$

[:Q.14] During the transition of electron from state A to state C of a Bohr atom, the wavelength of emitted radiation is 2000Å and it becomes 6000Å 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

[:A] 3000Å

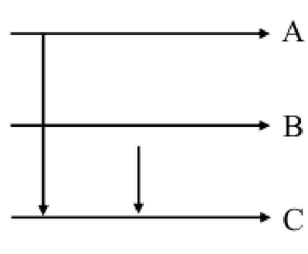
[:B] 6000Å

[:C] 2000Å

[:D] 4000Å

[:ANS] **A**

[:SOLN]



$E_A - E_C = \frac{hc}{2000Å}$ ….. (i)

and $E_B - E_C = \frac{hc}{6000Å}$ ….. (ii)

Now $E_A - E_B = (E_A - E_C) - (E_B - E_C)$

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

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

$$\lambda_{AB} = 3000\text{Å}$$

[:Q.15] A parallel plate capacitor was made with two rectangular plates, each with a length of $\ell = 3$ cm and breath of b = 1 cm. The distance between the plates is 3 μm. Out of the following, which the ways to increase the capacitance by a factor of 10?

a. $\ell = 30$ cm, b = 1 cm, d = 1 μm

b. $\ell = 3$ cm, b = 1 cm, d = 30 μm

c. $\ell = 6$ cm, b = 5 cm d = 3 μm

d. $\ell = 1$ cm, b = 1 cm , d = 10 μm

e. $\ell = 5$ cm, b = 2 cm, d = 1 μm

Choose the correct answer from the options given below:

[:A] A only

[:B] C and E only

[:C] C and E only

[:D] C only

[:ANS] **C**

[:SOLN] $C = \frac{A\epsilon_0}{d}$

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 = $10 \in_0$ units

$\therefore$ Ans is option (1)

[:Q.16] A uniform solid cylinder of mass 'm' and radius 'r' rolls along an inclined rough plane of inclination 45°. If it starts to roll from rest from the top of the plane then the linear acceleration of the cylinder's axis will be

[:A] $\frac{\sqrt{2}g}{3}$

[:B] $\sqrt{2}g$

[:C] $\frac{1}{\sqrt{2}}g$

[:D] $\frac{1}{3\sqrt{2}}g$

[:ANS] **A**

[:SOLN] $a = \frac{g\sin\theta}{1+\frac{I}{mR^2}}$

$a = \frac{\frac{g}{\sqrt{2}}}{1+\frac{1}{2}} = \frac{2\frac{g}{\sqrt{2}}}{3} = \frac{\sqrt{2}g}{3}$

[:Q.17] A particle is executing simple harmonic motion with time period 2 s 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

[:A] $\frac{16}{5}$

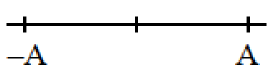
[:B] 10

[:C] 25

[:D] $\frac{15}{4}$

[:ANS] **C**

[:SOLN] A = 1 cm



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

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

d = 1

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

[:Q.18] The Young's double slit interference experiment is performed using light consisting of 480 nm and 600 nm wavelengths to form interference patterns. The least number of the bright fringes of 480 nm light that are required for the first coincidence with the bright fringes formed by 600 mm light is

[:A] 5

[:B] 4

[:C] 8

[:D] 6

[:ANS] **A**

[:SOLN] $\frac{n_1\lambda_1 D}{d} = \frac{n_2\lambda_2 D}{d}$

n 480 = m 600

$n_{min} = 5$

[:Q.19] 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:

[:A] a, c only

[:B] a, d, e only

[:C] a, b, c, d only

[:D] e only

[:ANS] **B**

[:SOLN] Given that

P = kT

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

$\therefore$ Volume is constant or isochoric process.

$\therefore W_D = 0$

$\therefore Q = \Delta U$

Also temperature increases hence internal energy increases.

[:Q.20] An electron of mass 'm' with an initial velocity $\vec{v} = v_0\hat{i}\,(v_0 > 0)$ enters an electric field $\vec{E} = -E_o\hat{k}$.

If the initial de Broglie wavelength is λ_0 the value after time t would be

[:A] $\lambda_0\sqrt{1+\frac{e^2E_o^{\,2}t^2}{m^2v_o^2}}$

[:B] $\frac{\lambda_o}{\sqrt{1+\frac{e^2E_o^2t^2}{m^2v_o^2}}}$

[:C] λ_o

[:D] $\frac{\lambda_o}{\sqrt{1-\frac{e^2E_o^2t^2}{m^2v_o^2}}}$

[:ANS] **B**

[:SOLN] $\vec{v} = v_0\hat{i} - \frac{E_0 e}{m}t\hat{k}$

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

$\lambda_0 = \frac{h}{mv_0}$

$\lambda' = \frac{h}{mv_0\sqrt{1+\frac{E_0^2e^2t^2}{v_0^2m^2}}}$

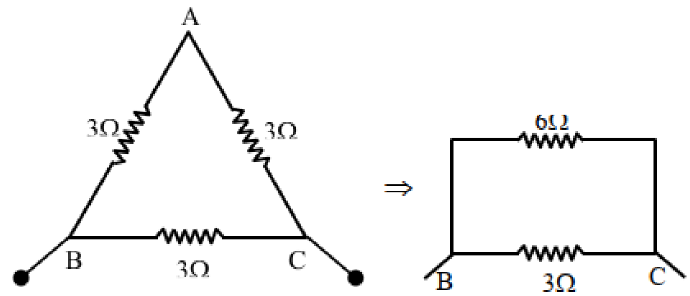
$\lambda' = \frac{\lambda_0}{\sqrt{1+\frac{E_0^2e^2t^2}{v_0^2m^2}}}$

SECTION-2

[:Q.21] A wire of resistance 9Ω is bent to form an equilateral triangle. Then the equivalent resistance across any two vertices will be _____ohm.

[:ANS] **2**

[:SOLN]



9Ω is the resistance of whole wire

∴ resistance of each wire = 3Ω.

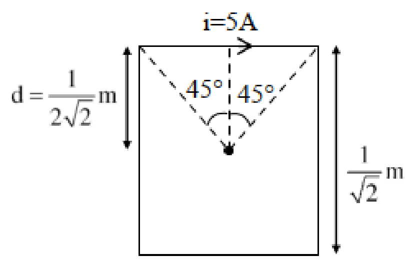
∴ Equivalent resistance = 2Ω

[:Q.22] A current of 5A exists in a square loop of side $\frac{1}{\sqrt{2}}$ m. Then the magnitude of the magnetic field B at the centre of teh square loop will be $p \times 10^{-6}$ T. where, value of p is ____.

[Take $\mu_0 = 4\pi \times 10^{-7} TmA^{-1}$]

[:ANS] **2**

[:SOLN]



Square loop

Let B be the magnetic field due to single side

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

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

∴ B_{net} at centre O = 4B

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

∴ P = 8 Ans.

[:Q.23] 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 _______ x10^{-3}mm

[:ANS] **35**

[:SOLN] Given least count of Screw Gauge = 0.01 mm

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

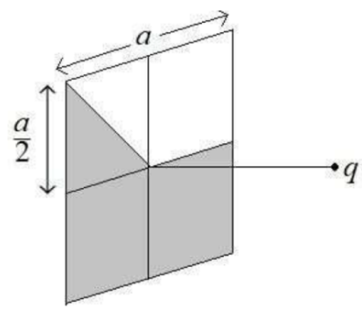
$$\text{New pitch} = \frac{P(1+0.75)}{N(1-0.5)} = \frac{P}{N}\left[\frac{1.75}{0.5}\right]$$

= (0.01) 3.5

= 0.035 mm

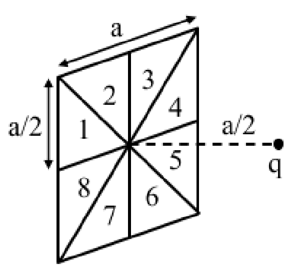
= 35×10^{-3} mm = 35

[:Q.24] A square loop of sides a = 1 m is held normally in front of a point charge q = 1C. The flux of the electric field through the shaded region is $\frac{5}{p} \times \frac{1}{\varepsilon_0} \frac{Nm^2}{C}$, where the value of p is _____.



[:ANS] **BONUS**

[:SOLN]



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

Lets divide square is 8 equal parts.

Flux is same for each part.

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

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

required Ans. is 48

Note : Distnace of charge from square loop is not mentioned

we have assume it as $\frac{a}{2}$.

[:Q.25] The temperature of 1 mole of an ideal monoatomic gas is increased by 50ºC 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**

[:SOLN] Given that process is isobaric $\Delta T = 50°C$

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.

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

$x = 15$