West Bengal JEE 2020 Physics Question Paper.

1 The bob of a swinging seconds pendulum (one whose time period is $2\ s$) has a small speed v_0 at its lowest point. Its height from this lowest point, $2.25\ s$ after passing through it is

A. $\frac{v_0^2}{2g}$

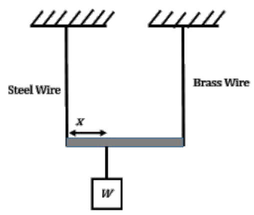
B. $\frac{v_0^2}{g}$

C. $\frac{v_0^2}{4g}$

D. $\frac{9v_0^2}{4g}$

The bob will reach its lowest point after $2\ s$.
As it is traveling further for $\frac{1}{4}$sec, i.e., $t = 2.25\ s$
Hence $v = A\omega cos\omega t = v_0 cos\frac{\pi}{4} = \frac{v_0}{\sqrt{2}}$. $(\because A\omega = v_0 = v_{max})$.
Applying law of conservation of energy
$\Rightarrow \frac{1}{2}mv_0^2 = \frac{1}{2}m\frac{v_0^2}{2} + mgh$
$\Rightarrow h = \frac{v_0^2}{4g}$

2 A steel and a brass wire, each of length 50 cm and cross-sectional area $0.005\ cm^2$ hang from a ceiling and are 15 cm apart. Lower ends of the wires are attached to a light horizontal bar. A suitable downward load is applied to the bar so that each of the wires extends in length by 0.1 cm. At what distance from the steel wire the load must be appied?
[Young's modulus of steel is $2 \times 10^{12}\ dynes/cm^2$] and that of brass is $1 \times 10^{12}\ dynes/cm^2$



A. 7.5 cm

B. 5 cm

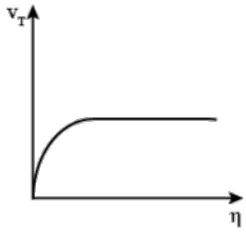
C. 10 cm

D. 3 cm

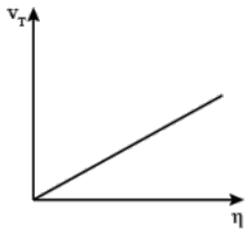
$F = \frac{AYe}{L}$;
As A, Y, e are same for both wires and taking moments about A $F_s(x) = F_b(15 - x)$
$\Rightarrow Y_s(x) = Y_b(15 - x) \Rightarrow 2x = (15 - x) \Rightarrow x = 5\ cm$

3 Which of the following diagrams correctly shows the relation between the terminal velocity V_T of a spherical body falling in a liquid and viscosity ν of the liquid?

A.



B.



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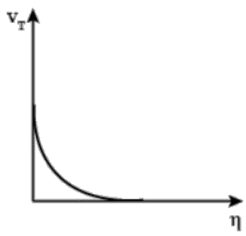
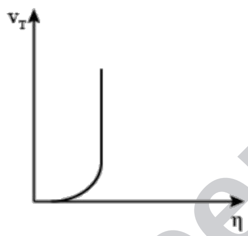


D.



$f_t = 6\pi\eta r V \Rightarrow V \propto \frac{1}{\eta}$

& Velocity decreases for each terminal velocity.

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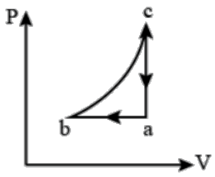

An ideal gas undergoes the cyclic process abca as shown in the given P-V diagram. It rejects 50 J of heat during ab and absorbs 80J of heat during ca. During bc, there is no transfer of heat and 40J of work is done by the gas. What should be the area of the closed curve abca?

- **A.** 30 J
- **B.** 40 J
- **C.** 10 J
- **D.** 90 J

For cyclic process abca, summation of heat will be equal to summation of work.
Now $\Delta Q = Q_{ab} + Q_{bc} + Q_{ca}$
$= -50 + 80 + 0 = 30\ J$

$\therefore \Delta W = 30\ J$

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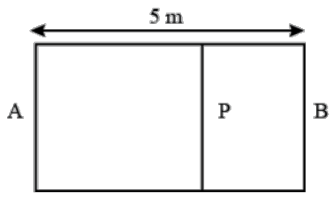
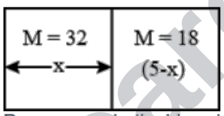


A container AB in the shape of a rectangular parallelopiped of length 5 m is divided internally by a movable partition P as shown in the figure. The left compartment is filled with a given mass of an ideal gas of molar mass 32 while the right compartment is filled with an equal mass of another ideal gas of molar mass 18 at same temperature. What will be the distance of P from the left wall A when equilibrium is established?

- **A.** 2.5 m
- **B.** 1.8 m
- **C.** 3.2 m
- **D.** 2.1 m



Pressure on both sides should be equal.
$PV = \frac{m}{M}RT \Rightarrow P = \frac{mRT}{MV}$
$\Rightarrow MV$ = constant
$\Rightarrow 32xA = 18(5-x)A$
$\Rightarrow x = 1.8m$

6 When 100 g of boiling water at $100^\circ C$ is added into a calorimeter containing 300 g of cold water at $10^\circ C$, temperature of the mixture becomes $20^\circ C$. Then a metallic block of mass 1 kg at $10^\circ C$ is dipped into the mixture in the calorimeter. After reaching thermal equilibrium, the final temperature becomes $19^\circ C$. What is the specific heat of the metal in C.G.S. units?

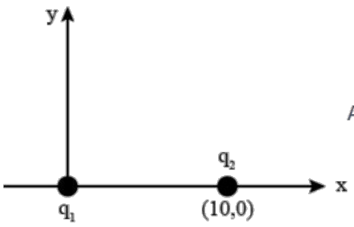
A. 0.01

B. 0.3

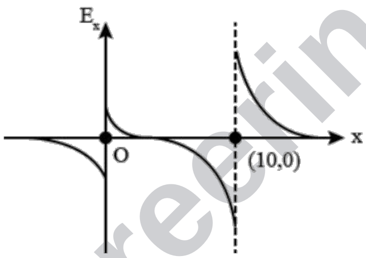
C. 0.09

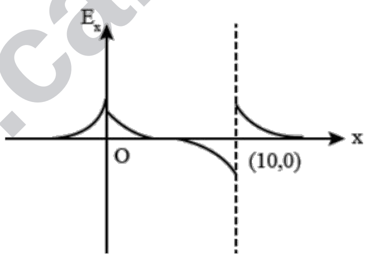
D. 0.1

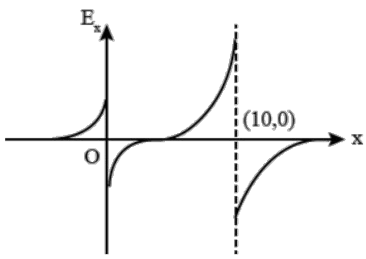
Initially
Heat lost by boiling water = Heat gained by cold water
$100 \times 1 \times 80 = (300 + w)1 \times 10$
Where w is the water equivalent of calorimeter
$\Rightarrow w = 500\ g$
When block is added
Total mass of water =100+500+300 = 900 g
$\therefore 900 \times 1 \times (20 - 19) = 1000 \times s(19 - 10)$
$\Rightarrow s = 0.1\ CGS\ Units.$

7 

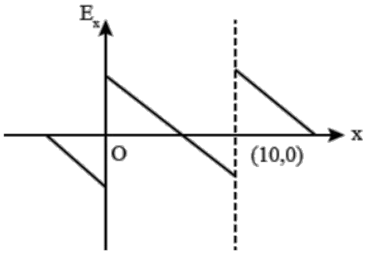
As shown in the figure, a point charge $q_1 = +1 \times 10^{-6} C$ is placed at the origin in x-y plane and another point charge $q_2 = +3 \times 10^{-6}$ is placed at the co-ordinate (10, 0). In that case, which of the following graph(s) shows most correctly the eletric field vector in E_x in x-direction?

A.


B.


C.


D.



To the left of q_1 : $\vec{E}$ is - ve and to the right of q_2 : $\vec{E}$ is the + ve. Also there is a neutral point in between the charges as they are both positive charges.

8 Four identical point masses, each of mass m and carrying charge +q are placed at the corners of a square of sides 'a' on a frictionless plain surface. If the particles are released simultaneously, the kinetic energy of the system when they are infinitely far apart is

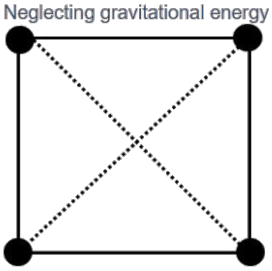
A. $\frac{q^2}{4\pi\epsilon_0 a}(2\sqrt{2}+1)$

B. $\frac{q^2}{4\pi\epsilon_0 a}(\sqrt{2}+2)$

C. $\frac{q^2}{4\pi\epsilon_0 a}(\sqrt{2}+4)$

D. $\frac{q^2}{4\pi\epsilon_0 a}(\sqrt{2}+1)$

Neglecting gravitational energy



Initial total electrostatic energy = $\frac{q^2}{4\pi\epsilon_0 a}\times 4+\frac{q^2\times 2}{4\pi\epsilon_0 a\sqrt{2}}$

$=\frac{q^2}{4\pi\epsilon_0 a}[4+\sqrt{2}]$

At infinity $U_\infty = 0$

$\therefore \Delta U = K.E \Rightarrow K.E = \frac{q^2}{4\pi\epsilon_0 a}[4+\sqrt{2}]$

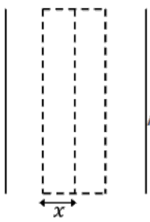
9 A very long charged solid cylinder of radius 'a' contains a uniform charge density ρ. Dielectric constant of the material of the cylinder is k. What will be the magnitude of electric field at a radial distance 'x' ($x < a$) from the axis of the cylinder?

A. $\rho\frac{x}{\epsilon_0}$

B. $\rho\frac{x}{2k\epsilon_0}$

C. $\rho\frac{x^2}{2a\epsilon_0}$

D. $\rho\frac{x}{2k}$



Applying gauss law

$E\,2\pi x l = \frac{\rho\pi x^2 l}{k\epsilon_0}$

$\Rightarrow E = \frac{\rho x}{2k\epsilon_0}$

10 A galvanometer can be converted to a voltmeter of full-scale deflection V_0 by connecting a series resistance R_1 and can be converted to an ammeter of full -scale deflection I_0 by connecting a shunt resistance R_2. What is the current flowing through the galvanometer at its full-scale deflection?

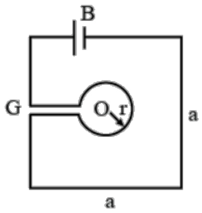
A. $\frac{V_0-I_0R_2}{R_1-R_2}$

B. $\frac{V_0+I_0R_2}{R_1+R_2}$

C. $\frac{V_0-I_0R_1}{R_1-R_2}$

D. $\frac{V_0+I_0R_1}{R_1+R_2}$

For voltmeter ---(1)
$V=(G+R_1)i_g$ where i_g is the current through galvanometer
& For Ammeter Shunt S = R_2
$R_2=\frac{G}{\frac{i_0}{i_g}-1}=\frac{Gi_g}{i_0-i_g}\ldots(2)$
Solving (1) & (2)
$V=Gi_g+R_1i_g$
$=R_2(i_0-i_g)+R_1i_g$
$\Rightarrow i_g=\frac{V-I_0R_2}{R_1-R_2}$

11 

As shown in the figure, a single conducting wire is bent to form a loop in the form of a circle of radius 'r' concentrically inside a square of side 'a', where a: r = 8 : π. A battery B drives a current through the wire. If the battery B and the gap G are of negligible sizes, determine the strength of magnetic field at the common centre O.

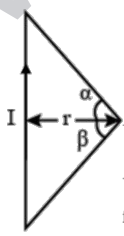
A. $\frac{\mu_0 I}{2\pi a}\sqrt{2}(\sqrt{2}-1)$

B. $\frac{\mu_0 I}{2\pi a}(\sqrt{2}+1)$

C. $\frac{\mu_0 I}{\pi a}2\sqrt{2}(\sqrt{2}+1)$

D. $\frac{\mu_0 I}{\pi a}2\sqrt{2}(\sqrt{2}-1)$

For square wire
$B=\frac{\mu_0 I}{2\pi r}(sin\alpha+sin\beta)$



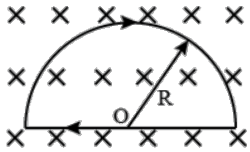
$B=\frac{\mu_0}{4\pi}\frac{I}{\frac{a}{2}}(sin45^\circ+sin45^\circ)$ for one wire (Out of the plane)

$B=\frac{\mu_0 I\sqrt{2}}{2\pi a}$

for four wires $B_1=\frac{\mu_0 I2\sqrt{2}}{\pi a}$

For circular wire
$B_2=\frac{\mu_0 I}{2r}\Rightarrow\frac{\mu_0 I\times 8}{2\pi a}$ (Into the loop) (Into the plane)
$as\ \frac{a}{r}=\frac{8}{\pi}\Rightarrow r=\frac{\pi a}{8}$
$Net\ B=B_2-B_1=\frac{\mu_0 I}{\pi a}2\sqrt{2}(\sqrt{2}-1)$

12

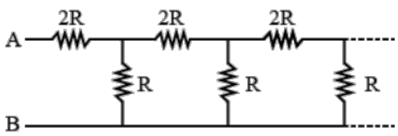


As shown in figure, a wire is bent to form a D-shaped closed loop, carrying current I, where the curved part is a semi-circle of radius R. The loop is placed in a uniform magnetic field $\vec{B}$, which is directed into the plane of the paper. The magnetic force felt by the closed loop is

- A. 0
- B. IRB
- C. $2IRB$
- D. $\frac{1}{2}IRB$

Force on a closed loop placed in a uniform magnetic field is always zero.

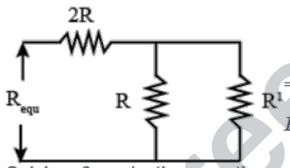
13



What will be the equivalent resistance between the terminals A and B of the infinite resistive network shown in figure ?

- A. $\frac{(\sqrt{3}+1)}{2}$
- B. $\frac{(\sqrt{3}-R)}{2}$
- C. $3\frac{R}{2}$
- D. $(\sqrt{3}+1)R$

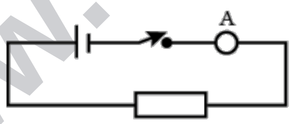
Let R' be the equivalent resistance
The circuit can be redrawn as

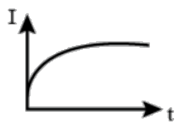


$\Rightarrow R_{equ} = \frac{RR'}{R+R'} + 2R$
$R' = \frac{RR'}{R+R'} + 2R$

Solving & neglecting negative value
$R' = R(\sqrt{3}+1)$

14



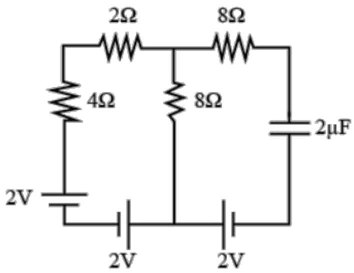


When a DC voltage is applied at the two ends of a circuit kept in a closed box, it is observed that the current gradually increases from zero to a certain value and then remains constant. What do you think that the circuit contains?

- A. A resistor alone
- B. A capacitor alone
- C. A resistor and a inductor in series
- D. A resistor and a capacitor in series

In steady state, , a capacitor behaves like an infinite resistance while an inductor will behave like a wire. Hence current is constant with inductor & zero with capacitor.
Since DC current is given, thats why resistance in series is also necessary.

15 Consider the circuit shown. If all the cells have negligible internal resistance, what will be the current through the $2\ \Omega$ resistor when steady state is reached ?



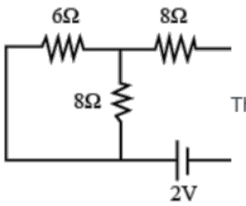
A. 0.66 A

B. 0.29 A

C. 0 A

D. 0.14 A

The emfs due to two of the cells cancel out. The circuit can be redrawn as



The capacitor is in steady state. The circuit is open. Hence no current passes through it.

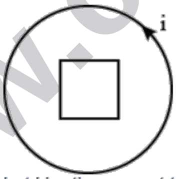
16 Consider a conducting wire of length L bent in the form of a circle of radius R and another conductor of length 'a' ($a << R$) bent in the form of a square. The two loops are then placed in the same plane such that the square loop is exactly at the centre of the circular loop. What will be the mutual inductance between the two loops?

A. $\mu_0 \frac{\pi a^2}{L}$

B. $\mu_0 \frac{\pi a^2}{16L}$

C. $\mu_0 \frac{\pi a^2}{4L}$

D. $\mu_0 \frac{a^2}{4\pi L}$



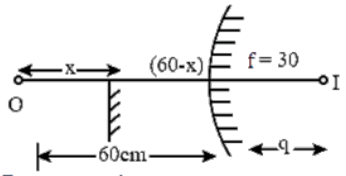
Let i be the current through the circular loop.
Magnetic field due to the current,
$\vec{B} = \frac{\mu_0 i}{2R}$ where $2\pi R = L$
Hence flux through square loop,
$\Phi = B \times$ (Area of loop) $= B \times (x)^2$
where x is the side of the square loop.
Given, $x = \frac{a}{4}$
Also, $\Phi = Mi$

$$\Rightarrow Mi = \frac{\mu_0 i}{2\left(\frac{L}{2\pi}\right)}\left(\frac{a}{4}\right)^2 = \frac{\mu_0 i a^2 \pi}{16L}$$

$$\Rightarrow M = \frac{\mu_0 \pi a^2}{16L}$$

17 An object is placed $60\ cm$ in front of a convex mirror of focal length $30\ cm$. A plane mirror is now placed facing the object in between the object and the convex mirror such that it covers lower half of the convex mirror. What should be the distance of the plane mirror from the object so that there will be no parallax between the images formed by the two mirrors?

- A. $40\ cm$ ✓
- B. $30\ cm$ ✗
- C. $20\ cm$ ✗
- D. $15\ cm$ ✗



For convex mirror,
$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{q}-\frac{1}{60}=\frac{1}{30}$
$\Rightarrow q=20\ cm$
Plane mirror forms image at the same distance as the object
Hence, for condition of no parallax,
$x=(60-x)+q$
$\Rightarrow x=60-x+20\Rightarrow x=40\ cm$

18 A thin convex lens is placed just above an empty vessel of depth $80\ cm$. The image of a coin kept at the bottom of the vessel is thus formed $20\ cm$ above the lens. If now, water is poured in the vessel up to a height of $64\ cm$, what will be the approximate new position of the image? Assume that refractive index of water is 4/3.

- A. $21.33\ cm$ above the lens ✓
- B. $6.67\ cm$ below the lens ✗
- C. $33.67\ cm$ above the lens ✗
- D. $24\ cm$ above the lens ✗

For convex lens,
$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}\Rightarrow\frac{1}{20}+\frac{1}{80}=\frac{1}{f}$
$\Rightarrow f=16\ cm$
Now when water is poured, the image will shift. Its distance from the surface of water
$\frac{t}{m}=\frac{64\times 3}{4}=48\ cm$
Hence its distance from lens $=48+16=64\ cm$. This will be the new object distance.
$\frac{1}{v}-\frac{1}{(-64)}=\frac{1}{16}$
Hence, $v=\frac{64}{3}=21.33\ cm$ above the lens.

19 The intensity of light emerging from one of the slits in a Young's double slit experiment is found to be 1.5 times the intensity of light emerging from the other slit. What will be the approximate ratio of intensity of an interference maximum to that of an interference minimum?

- A. 2.25 ✗
- B. 98 ✓
- C. 5 ✗
- D. 9.9 ✗

$I_2=1.5I_1$
$$\frac{I_{max}}{I_{min}}=\left[\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right]^2=\left[\frac{\sqrt{3}+\sqrt{2}}{\sqrt{3}-\sqrt{2}}\right]^2$$
≈ 98

20 In a Fraunhofer diffraction experiment, a single slit of width $0.5\ mm$ is illuminated by a monochromatic light of wavelength $600\ nm$. The diffraction pattern is observed on a screen at a distance of $50\ cm$ from the slit. What will be the linear separation of the first order minima?

A. $1.0\ mm$

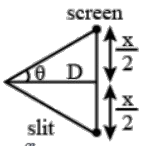
B. $1.1\ mm$

C. $0.6\ mm$

D. $1.2\ mm$

Let x be the distance between the first order minima's.

$d sin\theta = 2 \times \lambda/2$



$d\frac{x}{2D} = \lambda$

$\frac{0.5 \times x \times 10^{-3}}{2 \times 50 \times 10^{-2}} = 1 \times 600 \times 10^{-9}$

$\Rightarrow x = 1.2\ mm$

21 If R is the Rydberg Constant in cm^{-1}, then hydrogen atom does not emit any radiation of wavelength in the range of

A. $\frac{1}{R} to \ \frac{4}{3R} cm$

B. $\frac{7}{5R} to \ \frac{19}{5R} cm$

C. $\frac{4}{R} to \ \frac{36}{5R} cm$

D. $\frac{9}{R} to \ \frac{144}{7R} cm$

Option a belongs to Lyman series where transition is from first orbit to any other orbits upto infinity.
Option c belongs to Balman series where transition is from second orbit to any other orbits upto infinity.
Option d belongs to Paschen series where transition is from third orbit to any other orbits upto infinity.

Option (b) does not belong to any transition series. Therefore, hydrogen atom does not emit any radiation of wavelength in this range.

22 A nucleus X emits a beta particle to produce a nucleus Y. If their atomic masses are M_x and M_y respectively. The maximum energy of the beta particle emitted is
(where m_e is the mass of an electron and c is the velocity of light)

A. $(M_x - M_y - m_e)c^2$

B. $(M_x - M_y + m_e)c^2$

C. $(M_x - M_y)c^2$

D. $(M_x - M_y - 2m_e)c^2$

For $\beta - decay$
Energy is given by
$E = \Delta m\ c^2$
$= (M_x - M_y)c^2$

23 For nuclei with mass number close to 119 and 238, the binding energies per nucleon are approximately 7.6 MeV and 8.6 MeV respectively. If a nucleus of mass number 238 breaks into two nuclei of nearly equal masses, what will be the approximate amount of energy released in the process of fission?

- **A.** 214 MeV
- **B.** 119 MeV
- **C.** 2047 MeV
- **D.** 1142 MeV

Total B.E of reactant-Total B.E of products = Energy released
$E = 238 \times 8.6 - 119 \times 2 \times 7.6$
$= 238 \times 1 (MeV)$

Since, the energy released will also be transferred as kinetic energy of the daughter nuclei. Therefore the answer closest to $238\ MeV$ from option should be chosen.

24 A common emitter transistor amplifier is connected with a load resistance of $6\ k\Omega$. When a small a.c. signal of 15 mV is added to the base emitter voltage, the alternating base current is $20\ \mu A$ and the alternating collector current is 1.8 mA. What is the voltage gain of the amplifier?

- **A.** 90
- **B.** 640
- **C.** 900
- **D.** 720

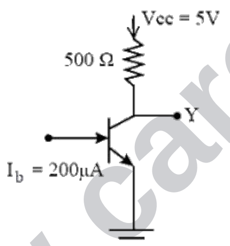
$R_I = \frac{V_{BE}}{I_b} = \frac{15\times10^{-3}}{20\times10^{-6}} = \frac{3}{4} \times 1000$

$\beta = \frac{\Delta I_c}{\Delta I_b} = \frac{1.8\times10^{-3}}{20\times10^{-6}} = 90$

Voltage gain = $\beta \times \frac{R_0}{R_I}$

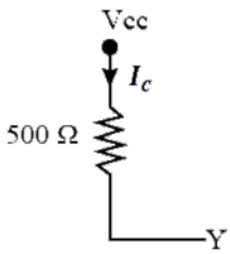
$= \frac{90\times6\times10^3\times4}{3\times1000} = 720$

25



In the circuit shown, the value of β of the transistor is 48. If the base current supplied $200\ \mu A$, what is the voltage at the terminal Y?

- **A.** 0.2 V
- **B.** 0.5 V
- **C.** 4 V
- **D.** 4.8 V



$\beta = \frac{I_c}{I_b} \Rightarrow I_c = 48 \times 200 \times 10^{-6}$
$= 96 \times 10^{-4}\ A$
$\therefore\ V_{cc} - I_c R_c = V_y$
$\Rightarrow 5 - 96 \times 10^{-4} \times 500 = V_y$
$\Rightarrow V_y = 0.2\ V$

26 The frequency ν of the radiation emitted by an atom when an electron jumps from one orbit to another is given by $\nu = k\delta E$, where k is a constant and δE is the change in energy level due to the transition. Then dimension of k is

- A. ML^2T^{-2}
- B. The same dimension of angular momentum.
- C. ML^2T^{-1}
- D. $M^{-1}L^{-2}T$

$v = k\delta E$
$\Rightarrow T^{-1} = k[M^1L^2T^{-2}]$
$\Rightarrow k = [M^{-1}L^{-2}T^1]$

27 Consider the vectors $\vec{A} = \hat{i} + \hat{j} - \hat{k}, \vec{B} = 2\hat{i} - \hat{j} + \hat{k}, \vec{C} = \frac{1}{\sqrt{5}}(\hat{i} - 2\hat{j} + 2\hat{k})$. What is the value of $\vec{C}.(\vec{A} \times \vec{B})$?

- A. 1
- B. 0
- C. $3\sqrt{2}$
- D. $18\sqrt{5}$

$\vec{A} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 1 & -1 \\ 2 & -1 & 1 \end{vmatrix}$
$= -3\hat{j} - 3\hat{k}$
$\vec{C}.(\vec{A} \times \vec{B}) = \frac{1}{\sqrt{5}}(0 + 6 - 6) = 0$

28 A fighter plane, flying horizontally with a speed of 360 km/h at an altitude of 500 m drops a bomb for a target straight ahead of it on the ground. At what approximate distance, the bomb should be dropped ahead of the target, so that it hits the target ? Assume that acceleration due to gravity, g is $10\ ms^{-2}$. Also neglect air drag.

A. $1000\ m$

B. $50\sqrt{5}\ m$

C. $500\sqrt{5}\ m$

D. $866\ m$

$x = u\sqrt{\frac{2y}{g}}$

$= 100\sqrt{\frac{2\times500}{10}} = 1000\ m$

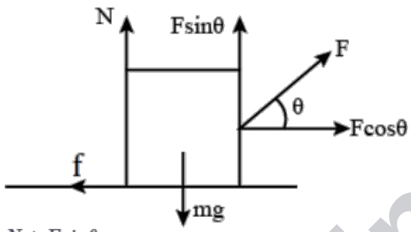
29 A block of mass m rests on a horizontal table with coefficient of static friction μ. What minimum force must be applied on the block to drag it on the table?

A. $\frac{\mu}{\sqrt{1+\mu^2}}mg$

B. $\frac{\mu-1}{\mu+1}mg$

C. $\frac{\mu}{\sqrt{1-\mu^2}}mg$

D. μmg



$N + F sin\theta = mg$

$\Rightarrow N = mg - F sin\theta$

$F cos\theta = \mu(mg - F sin\theta)$

$\Rightarrow F = \frac{\mu mg}{cos\theta + \mu sin\theta}$ ___(1)

F is minimum when $cos\theta + \mu sin\theta$ is maximum.

Hence $Y = cos\theta + \mu sin\theta$

$\frac{dy}{d\theta} = 0 \Rightarrow \mu = \tan\theta$ ___(2)

From (1) and (2)

$F_{min} = \frac{\mu}{\sqrt{\mu^2+1}}mg$

as $cos\theta = \frac{1}{\sqrt{\mu^2+1}}$

and $sin\theta = \frac{\mu}{\sqrt{\mu^2+1}}$

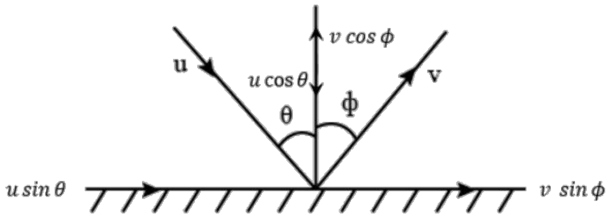
30 A tennis ball hits the floor with a speed v at an angle θ with the normal to the floor. If the collision is inelastic and the coefficient of restitution is ε, what will be the angle of reflection?

A. $tan^{-1}\left[\frac{tan\,\theta}{\varepsilon}\right]$

B. $sin^{-1}\left[\frac{sin\,\theta}{\varepsilon}\right]$

C. $\theta\varepsilon$

D. $\theta\frac{2\varepsilon}{\varepsilon+1}$



Along horizontal direction momentum is conserved,
$v\ sin\,\phi = u\ sin\,\theta$ ___(1)
Along the vertical,
$\varepsilon = \frac{v\cos\phi}{u\cos\theta} = \left(\frac{sin\,\theta}{sin\,\phi}\right)\left(\frac{cos\,\phi}{cos\,\theta}\right)$
$\varepsilon = \frac{tan\,\theta}{tan\,\phi}$
$tan\,\phi = \frac{tan\,\theta}{\varepsilon}$
$\Rightarrow \phi = tan^{-1}\left[\frac{tan\,\theta}{\varepsilon}\right]$

31 A metallic block of mass $20\ kg$ is dragged with a uniform velocity of $0.5\ ms^{-1}$ on a horizontal table for $2.1\ s$. The coefficient of static friction between the block and the table is 0.10. What will be the maximum possible rise in temperature of the metal block, if the specific heat of the block is 0.1 C.G.S. unit? Assume $g = 10\ ms^{-1}$ and uniform rise in temperature throughout the whole block. [Ignore absorption of heat by the table]

A. $0.0025\ ^oC$

B. $0.0035\ ^oC$

C. $0.001\ ^oC$

D. $0.05\ ^oC$

$W = FS = (\mu mg)vt$
$W = 0.1 \times 20 \times 10 \times 0.5 \times 2.1 = 21\ J$

This work done by friction is converted into heat energy:
$\therefore Q = 21\ J$
$Q = 20 \times 10^3 \times 4200 \times \Delta\theta$
$[as\ S = 0.1 \times 4200\ J/kg - K]$
$\Rightarrow \Delta\theta = 0.0025\ K = 0.0025\ ^oC$

32

Consider an engine that absorbs 130 cal of heat from a hot reservoir and delivers 30 cal heat to a cold reservoir in each cycle. The engine also consumes 2 J energy in each cycle to overcome friction. If the engine works at 90 cycles per minute, what will be the maximum power delivered to the load?

- A. 816 W
- B. 819 W
- C. 627 W
- D. 630 W

Total workdone in one cycle$= [(130-30)\times 4.2-2]\ J$

$= (420-2)\ J = 418\ J$

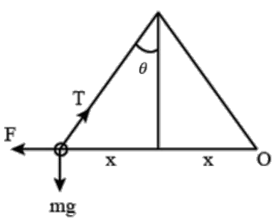
For 90 cycles; $W = 90\times 418\ J$

$P = \frac{W}{t} = \frac{90\times418}{60} = 627\ W$

33

Two pith balls, each carrying charge +q are hung from a hook by two strings. It is found that when each charge is tripled, angle between the strings double. What was the initial angle between the strings?

- A. 30^o
- B. 60^o
- C. 45^o
- D. 90^o



$tan\ \theta = \frac{F}{mg} = \frac{q^2}{4\pi\varepsilon_0(2x)^2mg}$

Also, $sin\ \theta = \frac{X}{L}$

$\therefore tan\ \theta = \frac{q^2}{4\pi\varepsilon_0(4x^2)mg}$

$= \frac{q^2}{16\pi\varepsilon_0(\sin\theta)^2L^2mg}$

$\Rightarrow sin^2\theta\ tan\ \theta \propto q^2$

Substituting the option, $\theta = 30^\circ$ as initial angle and accordingly $\theta = 60^\circ$ as final angle, it satisfies the propotionality found.

Hence, the angle between the strings initially $= 30^\circ$

If it would have been asked final answer then angle would have been $= 60^\circ$

34 A conducting circular loop of resistance $20\ \Omega$ and cross-sectional area $20 \times 10^{-2}\ m^2$ is placed perpendicular to a spatially uniform magnetic field B, which varies with time t as $B = 2\sin(50\pi t)\ T$. Find the net charge flowing through the loop in $20\ ms$ starting from $t = 0$.

- **A.** 0.5 C
- **B.** 0.2 C
- **C.** $0\ C$
- **D.** 0.14 C

$\phi = B.A$

$\varepsilon = \frac{d\phi}{dt} = A\frac{dB}{dt} = A \times 100\pi\cos(50\pi t)$

$\Rightarrow I = \frac{dq}{dt} = \frac{\varepsilon}{R}$

$\Rightarrow dq = \frac{\varepsilon}{R}dt$

$= \frac{A}{R}[100\pi\ cos\ 50\pi t]dt$

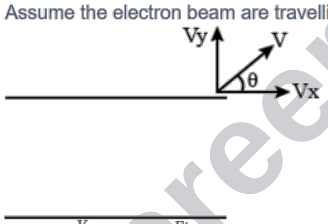
$\Rightarrow q = \int_0^{20\times10^{-3}} \frac{A}{R} \times 100\pi\ cos(50\pi t)dt$

$\Rightarrow q = 0\ C$

35 A pair of parallel metal plates are kept with a seperation 'd'. One plate is at a potential $+V$ and the other is at ground potential. A narrow beam of electrons enters the space between the plates with a velocity v_0 and in a direction parallel to the plates. What will be the angle of the beam with the plates after it travels an axial distance L?

- **A.** $tan^{-1}\left[\frac{eVL}{mdv_0}\right]$
- **B.** $tan^{-1}\left[\frac{eVL}{mdv_0^2}\right]$
- **C.** $sin^{-1}\left[\frac{eVL}{mdv_0}\right]$
- **D.** $cos^{-1}\left[\frac{eVL}{mdv_0^2}\right]$

Assume the electron beam are travelling close to one of the plate.



$tan\ \theta = \frac{V_y}{V_x} = \frac{at}{V_x} = \frac{qEt}{mV_x}$

Also, $E = \frac{V}{d}$

$\Rightarrow \tan\theta = \left(\frac{q}{m}\right)\left(\frac{V}{d}\right)\frac{t}{V_x}$

Now, $L = V_x t$

Where, $V_x = v_0$

$\Rightarrow \tan\theta = \left(\frac{q}{m}\right)\left(\frac{V}{d}\right)\frac{L}{v_0^2}$

Where, $q = e$

$\therefore \theta = tan^{-1}\left[\frac{eVL}{mdv_0^2}\right]$

36 A simple pendulum of length l is displaced so that its taught string is horizontal and then released. A uniform bar pivoted at one end is simultaneously released from its horizontal position. If their motions are synchronous, what is the length of the bar?

A. $\frac{3l}{2}$

B. l

C. $2l$

D. $\frac{2l}{3}$

For a simple pendulum

$T = 2\pi\sqrt{\frac{l}{g}}$

For a compound pendulum, let L' be the length, I be the moment of inertia about the pivot.

$T' = 2\pi\sqrt{\frac{I}{Mgd}} = 2\pi\sqrt{\frac{ML'^2}{3Mg\frac{L'}{2}}}$

$= 2\pi\sqrt{\frac{2L'}{3g}}$

$T = T'$ as the motion is synchronous.

$\Rightarrow \sqrt{\frac{l}{g}} = \sqrt{\frac{2L'}{3g}}$

$\Rightarrow L' = \frac{3l}{2}$

37 A charged particle moves with constant velocity in a region where no effect of gravity is felt but an electrostatic field $\vec{E}$ together with a magnetic field $\vec{B}$ may be present. Then which of the following cases are possible?

A $\vec{E} \neq 0, \vec{B} \neq 0$

B $\vec{E} \neq 0, \vec{B} = 0$

C $\vec{E} = 0, \vec{B} = 0$

D $\vec{E} = 0, \vec{B} \neq 0$

If a charged particle is moving in a gravity-free space without changing its velocity, then three cases possible

(i) Particle can move with constant velocity in any direction, if $\vec{E} = 0, \vec{B} = 0$.

(ii) If $\vec{E}$,$\vec{B}$ are having values such that $qE = qvB$ and hence both forces (Force due to magnetic field and force due to electric field) acts in such a way that they cancel each other, in this case also particle can move with uniform velocity.

(iii) If $\vec{E} = 0, \vec{B} \neq 0$ and $\vec{B}$ is such that it acts in the direction of velocity then magnetic force would be zero and hence velocity can remain constant.

38 A 400 Ω resistor, a 250 mH inductor and a 2.5 μF capacitor are connected in series with an AC source of peak voltage 5 V and angular frequency $2\ kHz$. What is the peak value of the electrostatic energy of the capacitor?

A. $2\ \mu J$
B. $2.5\ \mu J$
C. $3.33\ \mu J$
D. $5\ \mu J$

From given,
$X_C = \frac{1}{\omega C} = 200\ \Omega$
$X_L = \omega L = 500\ \Omega$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{400^2 + 300^2} = 500\ \Omega$$

$V_C = iX_C = \frac{5}{500} \times 200 = 2\ V$
$U_C = \frac{1}{2} C V_C^2 = \frac{1}{2} \times 2.5 \times 10^{-6} \times (2)^2 = 5\ \mu J$

39 A point source of light is used in an experiment of photoelectric effects. If the distance between the source and the photo-electric surface is doubled, which of the following may result ?

A. Stopping potential will be halved
B. Photoelectric current will decrease.
C. Maximum kinetic energy of photo-electrons will decrease.
D. Stopping potential will increase slightly.

If the distance between source and surface doubled, the intensity of light falling on surface becomes one-fourth.

So as the intensity is decreasing, the photoelectric current will decrease.

Maximum kinetic energy depends only on frequency of incident light.

40 Two metallic spheres of equal outer radii are found to have same moment of inertia about their respective diameters. Then which of the following statement(s) is/are true ?

A. Two spheres have equal mass
B. The ratio of masses is nearly 1.67 : 1
C. The spheres are made of different materials
D. Their rotational kinetic energies will be equal when rotated with equal uniform angular speed about their respective diameters

$K.E = \frac{1}{2} I \omega^2$
Since in option d, ω is given same and as already mentioned moment of inertia about their respective diameters is also same, therefore $K.E$ is constant.

Although, moment of inertia of sphere contains term of mass as well as terms of outer radius and inner radius of sphere. As, only outer radius is given same, so masses need not be equal as change in inner radius can cancel out effect of change in mass to maintain same moment of inertia of both spheres.

Also, we can't determine ratio of mass untill information about inner radius is also given.

Even to comment on density of sphere (material they are made up of), information about inner radius is needed.