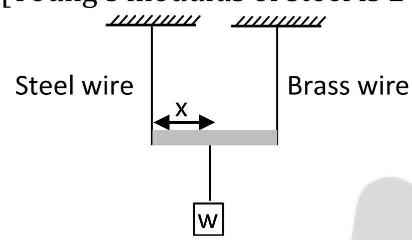
WB-JEE-2020 (Physics)

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

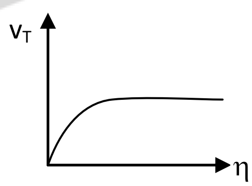
   a. $\frac{v_0^2}{2g}$
   b. $\frac{v_0^2}{g}$
   c. $\frac{v_0^2}{4g}$
   d. $\frac{gv_0^2}{4g}$

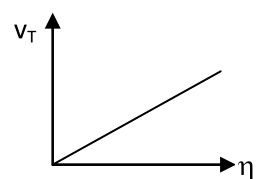
2. A steel and brass wire, each of length 50 cm and cross-sectional area 0.005 cm^2 hang from ceiling and are 15 cm apart. Lower ends of the wires are attached to a light horizontal bar. A suitable downward load is applied to the bar so that each of the wire extends in length by 0.1 cm. At what distance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

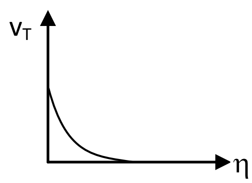


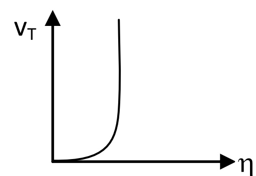
   a. 75 cm
   b. 5 cm
   c. 10 cm
   d. 3 cm

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 v of the liquid?

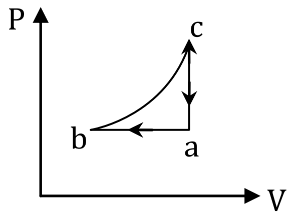
a. 

b. 

c. 

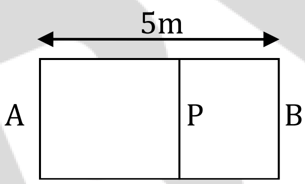
d. 

4. An ideal gas undergoes the cyclic process abca as shown in the given P.V diagram. It rejects 50 J of the 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

5. A container AB in the shape of a rectangular parallelepiped of length 5m 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?

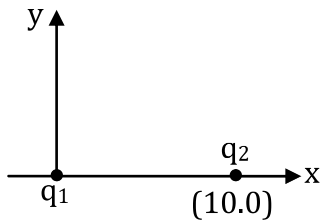


a. 2.5 m
b. 1.8 m
c. 3.2 m
d. 2.1 m

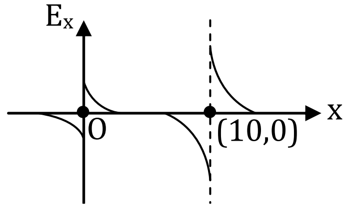
6. When 100 g of boiling water at 100°C is added into a calorimeter containing 300 g of cold water at 10°C, temperature of the mixture becomes 20°C. Then a metallic block of mass 1 kg at 10°C is dipped into the mixture in the calorimeter. After reaching thermal equilibrium, the final temperature becomes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

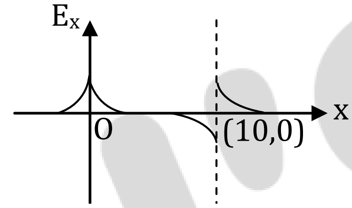
a. 0.01
b. 0.3
c. 0.09
d. 0.1

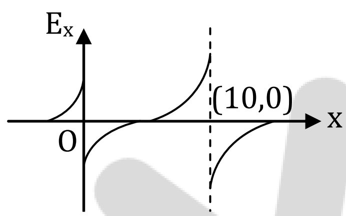
7.

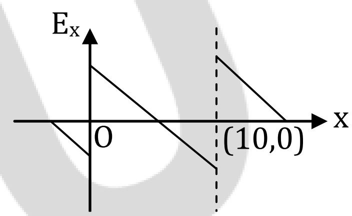


As shown in the figure, a point charge $q_1 = +1\times10^{-6}$ C is placed at the origin in x-y plane and another point charge $q_2 = +3\times10^{-6}$ is placed at the co-ordinate (10,0). In that case, which of the following graph(s) shown most correctly the electric field vector in E_x in x-direction?

a. 

b. 

c. 

d. 

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

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

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?

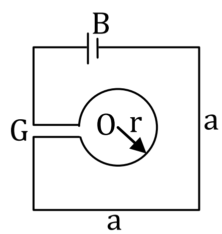
a. $\frac{V_0 - I_0R_2}{R_1 - R_2}$

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

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

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

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.

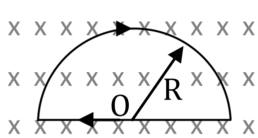
a. $\frac{\mu_0 I}{2\pi a}\sqrt{2}(\sqrt{2}-1)$

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

12. As shown in figure, a wire is bent to 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 B, which is directed into the plane of the paper. The magnetic force felt by the closed loop is



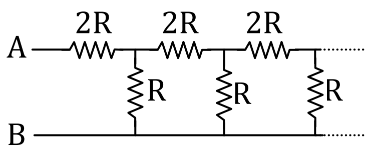
a. 0

b. IRB

c. 2IRB

d. $\frac{1}{2}$IRB

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



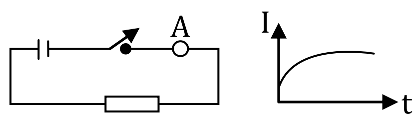
a. $\frac{(\sqrt{3}+1)}{2}$

b. $\frac{(\sqrt{3}-R)}{2}$

c. $3\frac{R}{2}$

d. $(\sqrt{3}+1)R$

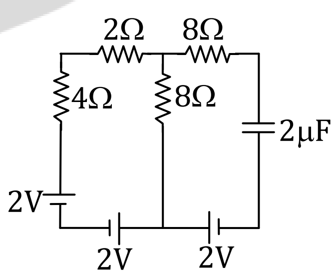
14.



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

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



a. 0.66 A

b. 0.29 A

c. 0 A

d. 0.14 A

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

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.

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

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

20. In a Fraundhofer 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

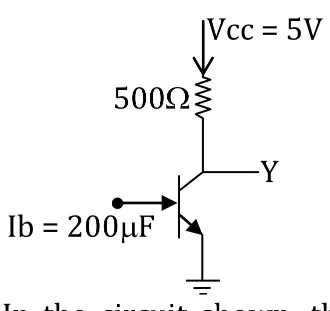
21. If R is the Rydberg constant in cm^{-1}, then hydrogen atom does not emit any radiation wavelength in the range of
   a. $\frac{1}{R}$ to $\frac{4}{3R}$ cm
   b. $\frac{7}{5R}$ to $\frac{19}{5R}$ cm
   c. $\frac{4}{R}$ to $\frac{36}{5R}$ cm
   d. $\frac{9}{R}$ to $\frac{144}{7R}$ cm

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

23. For nuclei with mass number close to 119 and 238, the binding energies per nucleon are approximately 7.6 MeV and 8.6 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

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

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

26. The frequency v of the radiation emitted by an atom when an electron jumps from one orbit to another is given by v = kδE, 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. $M^{-1}L^{-2}T$

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. $18\sqrt{5}$

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

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

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

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. When 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°C
    b. 0.0035°C
    c. 0.001°C
    d. 0.05°C

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 2J 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

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°
    b. 60°
    c. 45°
    d. 90°

34. A conducting circular loop of resistance 20Ω and cross sectional area 20×10^{-2} m^2 is placed perpendicular to a spatially uniform magnetic field B, which varies with time t as B = 2 sin(50πt) 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

35. A pair of parallel metal plates is kept with a separation'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. $\sin^{-1}\left[\frac{eVL}{mdv_0^2}\right]$

36. A simple pendulum of length l is displaced so that its taut 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. $\frac{2l}{3}$

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

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

a. 2μJ
b. 2.5μJ
c. 3.3μJ
d. 5μJ

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-electron will decrease
d. Stopping potential will increase slightly

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

WB-JEE-2020 (Physics)

ANSWER KEYS

1. (c)	2. (b)	3. (c)	4. (a)	5. (b)	6. (d)	7. (a)	8. (c)	9. (b)	10. (a)
11. (d)	12. (a)	13. (d)	14. (c)	15. (c)	16. (b)	17. (a)	18. (a)	19. (b)	20. (d)
21. (b)	22. (c)	23. (a)	24. (d)	25. (a)	26. (d)	27. (b)	28. (a)	29. (a)	30. (a)
31. (a)	32. (c)	33. (a)	34. (c)	35. (b)	36. (a)	37. (a,c,d)	38. (d)	39. (b)	40. (d)

WB-JEE-2020 (Physics)

Solution

1. (c)

Given:- Time period of swinging seconds pendulum is 2s.
It means it completes its one revolution in 2s.
So the bob will reach its lowest point after 2s.
As it is travelling further for ¼ sec. i.e. t = 2.5s

Hence, $v = A\omega\cos\omega t = v_0\cos\frac{\pi}{4} = \frac{v_0}{\sqrt{2}}\left\{\because A\omega = v_0 = v_{max}\right\}$

$$\left\{\begin{matrix}\because \text{displacement } x = A\sin\omega t \\ \text{velocity } v = \frac{dx}{dt} = A\omega\cos\omega t\end{matrix}\right\}$$

From law of conservation of energy

$$\frac{1}{2}mv_0^2 = \frac{1}{2}m\frac{v_0^2}{2} + mgh$$

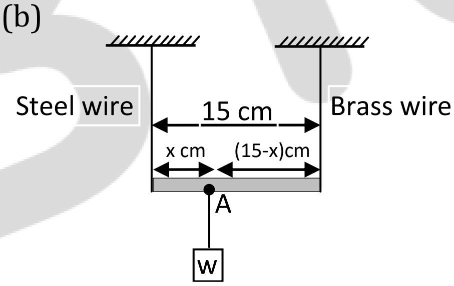
$$\frac{1}{2}v_0^2 - \frac{1}{2}\frac{v_0^2}{2} = gh$$

$$\frac{1}{2}v_0^2\left(1 - \frac{1}{2}\right) = gh$$

$$\frac{v_0^2}{4} = gh$$

$$\Rightarrow h = \frac{v_0^2}{4}$$

2. (b)



Given:-
Length of steel and Brass wire each =50 cm.
Cross sectional area = 0.005 cm^2
Distance between the wires = 15 cm.
Extension in wire = 0.1 cm.
(Y_s) Young's modulus of steel = 2×10^{12} dynes/cm^2
(Y_b) Young's modulus of brass = 1×10^{12} dynes/cm^2
As we know that Young's modulus is given by

$$Y = \frac{\text{Stress}}{\text{Strain}}$$

$\text{Stress} = \frac{\text{Force}}{\text{Area}}$, $\text{Strain} = \frac{\text{Change in length}}{\text{Original length}}$

$\therefore \quad Y = \frac{F/A}{\Delta\ell/\ell}$

$\Rightarrow \quad F = \frac{YA\Delta\ell}{\ell}$

$\because \quad A, \Delta\ell$ & ℓ are same for both the wires.

Taking moments about point A

$F_S(x) = F_b(15-x)$

$Y_S(x) = Y_b(15-x)$

Putting values of Y_s and Y_b

2×10^{12} (x) = (1×10^{12}) (15-x)

2x = (15 – x)

3x = 15

x = 5cm.

3. (c)

The force of viscosity acting on a smooth sphere in stream line motion can be expressed with Stock's formula -

$F = 6\pi\eta rv$

Where F = force (N)

η = viscosity of fluid

r = radius of sphere (m)

v = relative velocity between fluid and sphere (m/s) or terminal velocity.

$\therefore \quad v \propto \frac{1}{\eta}$

Velocity decreases for each terminal velocity.

4. (a)

From P – V diagram (given)

a b = Isobaric process

c a = Isochoric process

It is a cyclic process and for cyclic process abca, summation of heat will be equal to summation of work.

Now

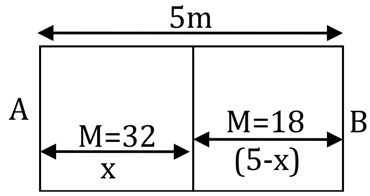
$\Delta Q = Q_{ab} + Q_{bc} + Q_{ca}$

= – 50 + 0 + 80

$\Delta Q = 30J$

{From Joule's law, $\Delta W = \Delta Q$ }

5. (b)



For equilibrium pressure on both sides should be equal.

$\because$ PV = nRT

Where P = Pressure $\left\{\because\ n = \frac{m}{M}\right\}$

n = no. of moles

V = volume

R = gas constant

T = Temperature

$\therefore$ $PV = \frac{m}{M}RT$

$\Rightarrow$ $P = \frac{mRT}{MV}$

$\Rightarrow$ MV = Constant

Putting the values

$\Rightarrow$ 32 x A = 15 (5 – x) A

$\Rightarrow$ 50 x = 90

$\Rightarrow$ x = 1.8 m

6. (d)

Initially

By energy conservation we can say that

Heat loss by boiling water = heat gained by cold water

$\because$ $Q = ms\Delta\theta$

s = Specific heat capacity

Q = heat

$\Delta\theta$ = Temperature difference

$100 \times 1 \times 80 = (300 + W)\ 1 \times 10$

Where W is the water equivalent of calorimeter

$\Rightarrow$ 8000 = 3000 + 10W

$\Rightarrow$ 5000 = 10W

$\Rightarrow$ W = 500 g

When block of mass 1 kg added at 10°C then

Total mass of water = 100 + 500 + 300 = 900 g

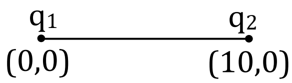
$\therefore$ $900 \times 1 \times (20-19) = 1000 \times s \times (19 - 10)$

$9 \times 1 = 10 \times s \times 9$

1 = 10 s

$\Rightarrow$ s = 0.1 CGS unit

7. (a)



$q_1 = 1\times10^{-6}$ C

$q_2 = 3\times10^{-6}$ C

Coulomb force between these charges will be

$$F = \frac{kq_1q_2}{r^2}$$

$$F = \frac{9\times10^{9}\times1\times10^{-6}\times3\times10^{-6}}{(10)^2}$$

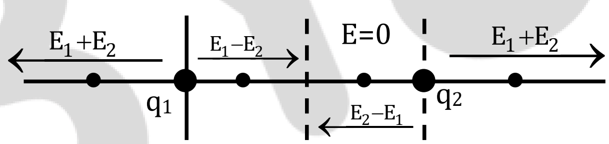
$$F = 27\times10^{-3-2} \quad = 27\times10^{-5}\text{N}$$

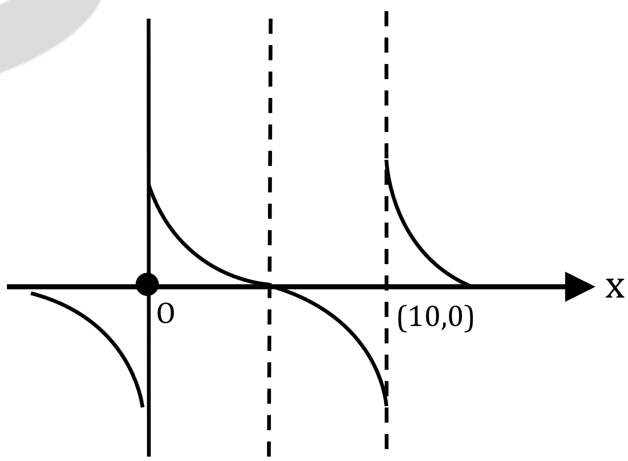
$\because$ Electric field $E = \dfrac{kq}{r^2}$

To the left of q_1 resultant $E_1 + E_2$ will be in –ve x-direction

To the right of q_2 resultant $E_1 + E_2$ will be in +ve x-direction

Also these is a neutral point in between the charges as they are both positive charges.





8. (c)

From energy conservation

$(K.E.)_i + (P.E.)_i = (K.E.)_f + (P.E.)_f$

$\because$ Electrostatic energy = $\frac{kq^2}{r}$

Here r = a

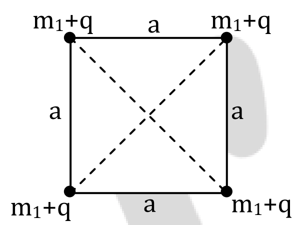
Initial electrostatic energy = $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{a}\times 4 + \frac{q^2\times 2}{4\pi\varepsilon_0 a\sqrt{2}}$

= $\frac{q^2}{4\pi\varepsilon_0 a}[4+\sqrt{2}]$

At infinity $U_\infty = 0$

(P.E. will be zero)

$\therefore$ ΔU = K.E. $\Rightarrow$ K.E. $\frac{q^2}{4\pi\varepsilon_0}[4+\sqrt{2}]$



It will be the kinetic energy of the system.

9. (b)

Using Gauss's law

$\oint E.dA = \frac{Q_{en}}{K\varepsilon_0}$ .... (1)

Q_{en}= enclosed charge

$Q_{en} = \rho\times\pi r^2\ell$

(Area) A = $2\pi r \times \ell$

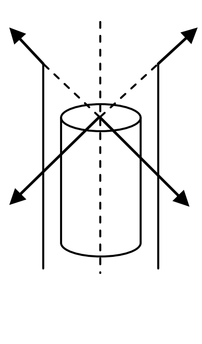
Here r = x

$\therefore$ A = $2px\ell$

So from equation .... (1)

$E . 2\pi x\ell = \frac{\rho\pi x^2\ell}{K\varepsilon_0}$

$\Rightarrow E = \frac{\rho x}{2K\varepsilon_0}$



10. (a)

When galvanometer is used or converted as a voltmeter, resistance is used in series with it

$I_g(G+R_1) = V_0$

$G+R_1 = \frac{V_0}{I_g} \quad \Rightarrow V_0 = I_g(G+R_1)$ .... (1)

$R_1 = \frac{V_0}{I_g} - G$ .... (A)

When galvanometer is used or converted as an ammeter, shunt is used in parallel with galvanometer.

$\therefore \quad I_g(G) = (I_0 - I_g)R_2$

$R_2 = \frac{I_gG}{I_0 - I_g}$ .... (2)

$\Rightarrow \quad G = \frac{R_2(I_0 - I_g)}{I_g}$ ....(3)

From equation (1), (2) & (3)

$V = G\,I_g + R_1I_g$

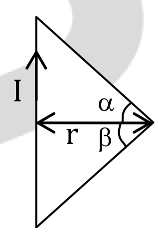
$V = R_2(I_0 - I_g) + R_1I_g$

$\Rightarrow I_g = \frac{V - I_0R_2}{R_1 - R_2}$

11. (d)

Magnetic field for square wire is given as –

$B = \frac{\mu_0 I}{4\pi r}(\sin\alpha + \sin\beta)$



$r = \frac{a}{2}$

$\therefore B = \frac{\mu_0 I}{4\pi\frac{a}{2}}(\sin 45^\circ + \sin 45^\circ)$ For one wire (out of the plane)

$\therefore B = \frac{\mu_0 I}{4\pi\frac{a}{2}}\left(\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right)$

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

$\therefore$ For four wires $B_1 = 4 \times \frac{\mu_0 I\sqrt{2}}{2\pi a}$

$\Rightarrow B_1 = \frac{2\sqrt{2}\mu_0 I}{\pi a}$

For circular loop, magnetic field is given as

$B_2 = \frac{\mu_0 I}{2r}$

Given that $\frac{a}{r} = \frac{8}{\pi} \Rightarrow r = \frac{\pi a}{8}$

$B_2 = \frac{\mu_0 I}{2\left(\frac{\pi a}{8}\right)} = \frac{4\mu_0 I}{\pi a}$ (Into the loop) (Into the plane)

Net magnetic field $B = B_2 - B_1$

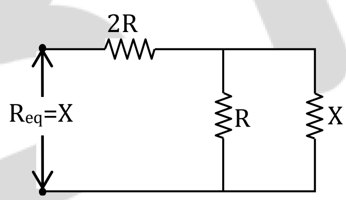
$B = \frac{\mu_0 I}{\pi a} 2\sqrt{2}\left(\sqrt{2} - 1\right)$

12. (a)

Figure forms a closed loop and the current completes the loop. Therefore, net force on the loop in uniform field should be zero.

13. (d)

Equivalent circuit



From figure we can see that resistance x and R in parallel and then connected with R in series.

So

$X = \frac{RX}{R+X} + 2R$

$X = \frac{RX + 2R(R+X)}{R+X}$

$X(R+X) = RX + 2R^2 + 2RX$

$XR + X^2 = RX + 2R^2 + 2RX$

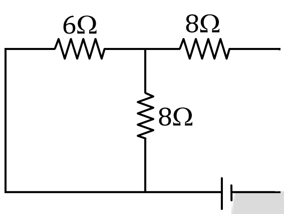
$X^2 - 2RX - 2R^2 = 0$

$\Rightarrow X = \left(1 + \sqrt{3}\right)R$

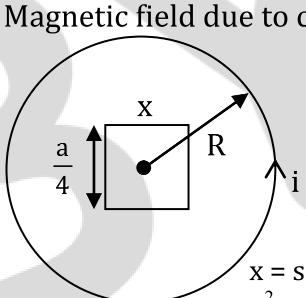
14. (c)

According to the graph, it is the condition of steady state. In this case the current gradually increases from zero to a certain value and then remains constant. It will occur in LR circuit transient.
In steady state, a capacitor behaves like an infinite resistance while an inductor will behave like a wire.
Hence current is constant with inductor and zero with capacitor.
Since DC current is given, that's why resistance in series is also necessary.

15. (c)
The equivalent emf of loop = 0
The capacitor is in steady state and in this state the capacitor draws no current from cell.
So the circuit is open. Hence no current passes through it.



16. (b)
Let i be the current flowing through the circular loop.
Magnetic field due to circular loop at the centre



x = side of the square loop.
x^2 = area of the square loop.

$B = \frac{\mu_0 i}{2R}$ .... (1)

Circumference of the loop $L = 2\pi R$

$\Rightarrow \quad R = \frac{L}{2\pi}$ .... (2)

Now flux through the square loop
$\phi = B\,A$
A = area of loop = x^2

$\therefore \quad \phi = B(x^2)$ .... (3)

Given $x = \frac{a}{4}$ .... (4)

∵ We know that $\phi = Mi$, where ϕ = flux, M = Mutual inductance, i = current

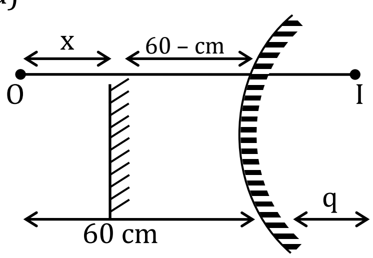
⇒ $Mi = Bx^2$ .... (5)

Putting the values from equation (1) , (2), (4) in equation (5)

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

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

17. (a)



Let light is incident from left to right

Given focal length of convex mirror (f) = 30 cm.

Object distance u = 60 cm

Image distance = (v) = q

From mirror formula

$$\frac{I}{f} = \frac{1}{v} + \frac{1}{u} \quad \text{........ (1)}$$

f = 30 cm. (+ve), u = -60 (taking direction is opposite to the incident light)

v= q (+ve) (distance of the image, as we know convex mirror always forms virtual erect and diminished image)

Substituting the values in equation (1)

$$\frac{1}{30} = \frac{1}{q} - \frac{1}{60} \quad \Rightarrow \quad \frac{1}{q} = \frac{1}{30} + \frac{1}{60}$$

$$\Rightarrow \quad \frac{1}{q} = \frac{2+1}{60}$$

$$\Rightarrow \quad q = \frac{60}{3} = 20 \text{ cm}$$

Plane mirror forms image at the same distance as the object is placed.

Hence, for the condition of no parallax

x = (60-x) + q

⇒ x = 60 – x + 20

⇒ x = 40 cm

18. (a)

Using the lens formula

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$$

For convex lens

Focal length f = +ve

Object distance u = –ve

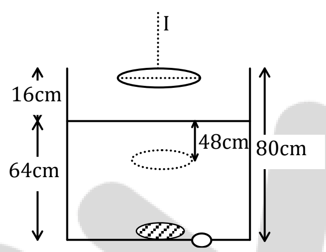
(∵ +ve and –ve sign considered according to the direction of incident ray)

So, $$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{20}+\frac{1}{80}=\frac{1}{f}$$

$$\Rightarrow \quad \frac{1}{f}=\frac{4+1}{80}$$

$$\Rightarrow \quad f = 16 \text{ cm}$$



Now when water is poured, the image will shift. Its distance from the surface of water

$$h'=\frac{h}{\mu}=\frac{64}{4/3}=\frac{64\times 3}{4}=48\text{cm}$$

Hence its distance from lens = 48 + 16 = 64 cm

This will be the new object distance.

Now we have to calculate the value of v, again using lens formula

$$\frac{1}{v}-\frac{1}{(-64)}=\frac{1}{16}$$

$$\frac{1}{v}=\frac{1}{16}-\frac{1}{64}$$

$$\frac{1}{v}=\frac{4-1}{64}$$

$$\Rightarrow v=\frac{64}{3} = 21.33 \text{ cm above the lens.}$$

19. (b)

$I_1 = 1.5\ I_2$

$\Rightarrow \quad \frac{I_1}{I_2} = 1.5$

Or $\quad \frac{I_1}{I_2} = \frac{3}{2}$

$\because \quad \frac{I_{max.}}{I_{min.}} = \left[\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right]^2 = \left[\frac{\sqrt{3}+\sqrt{2}}{\sqrt{3}-\sqrt{2}}\right]^2$

$= \frac{(\sqrt{3})^2+(\sqrt{2})^2+2\sqrt{3}(\sqrt{2})}{(\sqrt{3})^2+(\sqrt{2})^2-2\sqrt{3}(\sqrt{2})}$

$\frac{I_{max.}}{I_{min.}} = \frac{3+2+2\sqrt{6}}{3+2-2\sqrt{6}}$

$\frac{I_{max.}}{I_{min.}} = \frac{5+2\sqrt{6}}{5-2\sqrt{6}}$

$= \frac{5+2\sqrt{6}}{5-2\sqrt{6}} \times \frac{5+2\sqrt{6}}{5+2\sqrt{6}}$

$= \frac{\left(5+2\sqrt{6}\right)^2}{(5)^2-(2\sqrt{6})^2}$

$= \frac{25+24+20\sqrt{6}}{25-24}$

$= 97.8$

$\frac{I_{max.}}{I_{min.}} \approx 98$

20. (d)

Given d = 0.5 mm, D = 50 cm, λ = 600 nm

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

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

Substituting the values

$$x = \frac{2\times600\times10^{-9}\times50\times10^{-2}}{0.5\times10^{-3}} = 12\times10^{-4}$$

x = 1.2 mm

21. (b)

As we know that the wave number is given by

$$\frac{1}{\lambda}=R\left[\frac{1}{n_f^2}-\frac{1}{n_i^2}\right]$$

For range of wavelength:-

n_i = 1,2,3 …………..for Lyman, Balmer, Paschen ……

$n_f = n_i + 1$ and $n_f = \infty$ for upper and lower range

Thus, Lyman: $\left[\frac{1}{R}\text{to}\frac{4}{3R}\right]$

Balmer: $\left[\frac{4}{R}\text{to}\frac{36}{5R}\right]$

Paschen: $\left[\frac{9}{R}\text{to}\frac{144}{36R}\right]$

Bracket: $\left[\frac{16}{R}\text{to}\frac{400}{9R}\right]$

Pfund: $\left[\frac{25}{R}\text{to}\frac{900}{11R}\right]$

So Option A belongs to Lyman series

Option C belongs to Balmer series

Option D belongs to Paschen series

Option B does not belongs to any transition series.

Therefore hydrogen atom does not emit any radiation of wavelength in this range.

22. (c)

$${}_{z}X^{A} \longrightarrow {}_{z+1}Y^{A} + {}_{-1}e^{0} + \bar{\nu} + Q$$

Let M_x be the mass of the nucleus Xand

M_y be the mass of the nucleus Y.

Since mass change= $M_x - M_y$

This will be the mass reduced to β-particle.

Hence, energy $E = \Delta mc^2$

$E = (M_x - M_y)\, c^2$

23. (a)

Energy released = Total binding energy of reactant – Total binding energy of products.

E = 238 × 8.6 – 119×2×7.6

E = 238 ×(1) (MeV)

$$\left\{\begin{matrix} 119 \longrightarrow 7.6\text{MeV} \\ 238 \longrightarrow 119+119 \end{matrix}\right\}$$

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. (d)
Load resistance $R_L = 6k\Omega = 6000\Omega$

Base emitter voltage $V_{BE} = 15 \text{ mV} = 15\times10^{-3}V$

Base current $I_b = 20\mu A = 20\times10^{-6}A$

Collector current $I_c = 1.8 \text{ mA} = 1.8\times10^{-3} A$

Input resistance

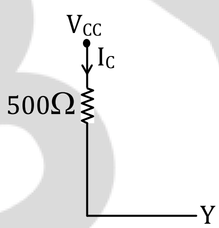
$$R_I = \frac{V_{BE}}{I_b} = \frac{15\times10^{-3}}{20\times10^{-6}} = \frac{3}{4}\times1000$$

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

$\because$ Voltage gain $(A_v) = \beta\frac{R_L}{R_I}$

$$= 90\times\frac{6000\times4}{3\times1000} = 720$$

25. (a)
$\beta = 48(\text{Given})$



$I_B = 200\mu A = 200\times10^{-6}A$

$\because \quad \beta = \frac{I_c}{I_b} \Rightarrow I_c = \beta I_B = 48\times200\times10^{-6} = 96\times10^{-4}A$

Now $V_{CC} = I_C I_R + V_{CE}$

$\therefore \quad V_{CE} = 5 - (96\times10^{-4})\times500$

(Voltage at terminal y)

$V_y = V_{CE} = 5 - 4.8 = 0.2$ volt

26. (d)

$v = k\delta E$

$\Rightarrow K = \left[\frac{\nu}{\delta E}\right] = \frac{[T^{-1}]}{[M^1L^2T^{-2}]}$

$\Rightarrow K = [M^{-1}L^{-2}T^1]$

{$\therefore$ Dimension of frequency = $\frac{1}{sec} = [T^{-1}]$

Dimension of energy = $= [M^1L^2T^{-2}]$

27. (b)

$\vec{A} = \hat{i} + \hat{j} - \hat{k}$, $\vec{B} = 2\hat{i} - \hat{j} + \hat{k}$, $\vec{C} = \frac{1}{\sqrt{5}}\left(\hat{i} - 2\hat{j} + 2\hat{k}\right)$

We have to find the value of $\vec{C}.(\vec{A}\times\vec{B})$

Now

$$\vec{A}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 1 & -1 \\ 2 & -1 & 1 \end{vmatrix}$$

$= \hat{i}[1-(+1)] - \hat{j}[1+2] + \hat{k}[-1-2]$

$= -3\hat{j} - 3\hat{k}$

Now

$\vec{C}\cdot(\vec{A}\times\vec{B}) = \left[\frac{1}{\sqrt{5}}(\hat{i} - 2\hat{j} + 2\hat{k})\right]\Box\left[-3\hat{j} - 3\hat{k}\right]$

$= \frac{1}{\sqrt{5}}(6-6) = 0$ $\left\{\begin{array}{l} \text{as } \hat{i}\cdot\hat{j} = 1 \\ \hat{j}\cdot\hat{j} = 1 \\ \hat{k}\cdot\hat{k} = 1 \end{array}\right\}$

28. (a)

$u = 360\frac{km}{hr} = 360 \times \frac{5}{18} = 100\ m/s$

h = 500 m

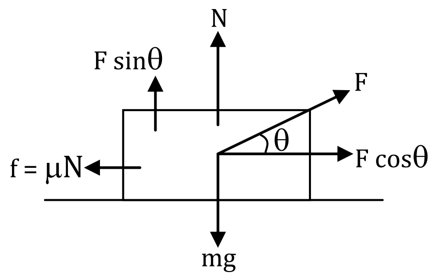
$\because R = u\sqrt{\frac{2h}{g}}$

$\therefore R = 100\sqrt{\frac{2\times 500}{10}}$

R = 100 ×10

R = 1000 m.

29. (a)



f = friction force

F cos θ = horizontal component of applied force

F sin θ = vertical component of applied force.

Now applying equilibrium in vertical direction

$F \sin\theta + N = mg$ ...... (1)

$N = mg - F \sin\theta$ ...... (2)

Applying equilibrium in horizontal direction

$F \cos\theta = \mu N$

$F \cos\theta = \mu (mg - F \sin\theta)$ {from equation (2)}

$F \cos\theta + \mu F \sin\theta = \mu mg$

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

$$F = \frac{\mu mg}{\cos\theta + \mu\sin\theta} \quad \text{...... (3)}$$

For F minimum, $(\cos\theta + \mu \sin\theta)$ should be maximum

$$\therefore \frac{d}{d\theta}(\cos\theta + \mu\sin\theta) = 0$$

$$-\sin\theta + \mu\cos\theta = 0$$

$$\mu\cos\theta = \sin\theta$$

$$\mu = \tan\theta \quad \text{...... (4)}$$

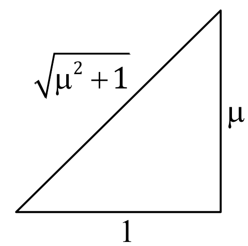
∴ from equation (3)

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

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

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

$\tan\theta = \mu$



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

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

30. (a)

Velocity of approach in the given case is the normal component of velocity.

Hence $v_n = v\cos\theta$

By definition of coefficient of restitution, velocity of reparation will be,

$$v_n' = \in v_n = \in v\cos\theta$$

Tangential component of velocity will not change

$$v_t' = v_t = v\sin\theta$$

Speed of reflected ball is

$$v' = \sqrt{v_n^2 + v_t^2}$$

$$= \sqrt{(\in v\cos\theta)^2 + (v\sin\theta)^2}$$

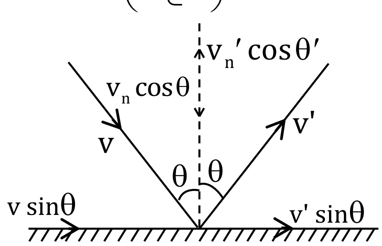
$$= v\sqrt{\in^2\cos^2\theta + \sin^2\theta}$$

Angle with normal is given by –

$$\theta' = \tan^{-1}\frac{v_t'}{v_n'}$$

$$\theta' = \tan^{-1}\left(\frac{v\sin\theta}{\in v\cos\theta}\right)$$

$$\theta = \tan^{-1}\left(\frac{\tan\theta}{\in}\right)$$



31. (a)

Mass $m = 20$ kg
Velocity $v = 0.5\ ms^{-1}$
Time = 2.1s, $\mu = 0.10$
Distance or displacement
$s = v \times t = 0.5\times2.1$
$s = 1.05$ m.
Friction force
$F = \mu mg$
$F = 0.1\times20\times10 = 20$
$\therefore$ Work done= F.s
$W = 20 \times 1.05 = 21$ J
This work done by friction is converted into heat energy.
$W = Q$
$W = ms\Delta T$
$\therefore$ $Q = ms\Delta T$
$21 = 20\times0.1\times4.2\times10^3.\ \Delta T$
$$\Delta T = \frac{21}{20\times0.1\times4.2\times10^3}$$
$\Rightarrow$ $\Delta T = 0.0025^\circ C$

32. (c)

Absorb heat = 130 Calorie from hot reservoir

Delivered heat = 30 Calorie to cold reservoir

Consume heat = 2J energy in each cycle

Engine works at 90 cycles per minute.

Work done per cycle = $(130-30)\times4.2-2$ {1 Calorie = 4.2 Joule}

$= 100 \times 4.2 - 2$

$= 420 - 2 = 418$ J

Total work done = 418×90

{$\because$ In each cycle work done = 418 J}

$$\text{Power} = \frac{\text{Workdone}}{\text{time}}$$

$$P = \frac{W}{t} = \frac{418\times90}{60} = \frac{418\times3}{2} = 627W$$

33. (a)

In first case

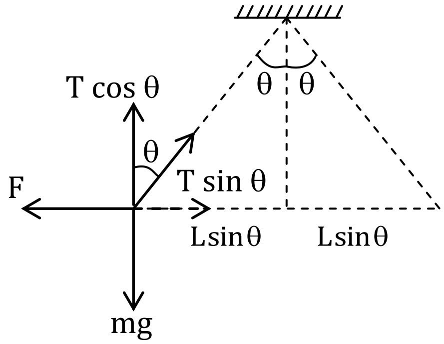
Applying equilibrium in horizontal direction

$T\sin\theta = F$ .... (1)

Applying equilibrium in vertical direction

$T\cos\theta = mg$ .... (2)

$\frac{\text{equation}(1)}{\text{equation}(2)}$ $\tan\theta = \frac{F}{mg}$ ...... (3)



$\tan\theta = \frac{kq^2}{(2L\sin\theta)} mg$ ...... (4) $\left\{\because \quad F = \frac{kq_1q_2}{r^2}\right.$

In second case $\rightarrow$ when each charge is tripled then q becomes 3q

$\tan 2\theta = \frac{kq\,q^2}{(2L\sin\theta)^2.mg}$ ...... (5)

Equation (5) divided by equation (4)

$$\frac{\tan 2\theta}{\tan\theta} = \frac{9\sin^2\theta}{\sin^2 2\theta}$$

$$\frac{2}{1-\tan^2\theta} = \frac{9}{4\cos^2\theta} = \frac{9}{4}\sec^2\theta$$

$$\frac{2}{1-\tan^2\theta} = \frac{9}{4}(1-\tan^2\theta)$$

$$\tan^2\theta = x, \quad \frac{2}{1-x} = \frac{9}{4}(1+x)$$

$\Rightarrow \quad 8 = 9 - 9x^2 \quad \Rightarrow \quad x = \frac{1}{3}$

$\Rightarrow \quad \tan^2\theta = \frac{1}{3} \quad \Rightarrow \quad \theta = 30^\circ$

$\therefore$ Initial angle between the strings = 30°

If it would have been asked final answer then angle would have been = 60°.

34. (c)

Given

R = 20Ω, A(area) = 20×10^{-2} m^2,

Magnetic field = B varies with time as B = 2 sin (50πt)T

q =?, time (t) = 20ms = 20×10^{-3}s.

Initial time t = 0

∵ Magnetic flux $\phi = B\cdot A$

emf $\varepsilon = \frac{d\phi}{dt} = A\frac{dB}{dt} = A\frac{d}{dt}\left(2\sin(50\pi t)T\right)$

$\varepsilon = A\times100\pi\ \cos(50\pi t)$ ...... (1)

$\because \text{current } I = \frac{dq}{dt} = \frac{\varepsilon}{R}$

$\Rightarrow$ $dq = \frac{\varepsilon}{R}dt$ ...... (2)

From equation (1) and (2)

$$dq = \frac{A}{R}[100\pi\cos50\pi t]dt$$

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

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

$$= \frac{A}{R}100\pi\left[\frac{\sin(50\pi t)}{50\pi}\right]_0^{20\times10^{-3}}$$

$$= \frac{A}{R}\frac{100\pi}{50\pi}\left[\sin\left(50\pi\times20\times10^{-3}\right)-0\right]$$

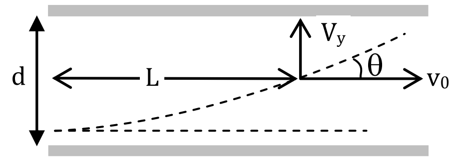
$$\frac{2A}{R}[\sin\pi-0]$$

q = 0 $\{\because [\sin\pi]=0\}$

35. (b)

$\because$ Time = $\dfrac{\text{distance}}{\text{speed}}$

$t = \dfrac{L}{v_0}$ ...... (1)



v_0 = velocity component along x – axis

v_y = velocity component along y – axis

$\because$ F = ma

F = qE = ma $\{\because F = qE\}$

Here q = e

$\Rightarrow a = \dfrac{eE}{m}$

$\because a = \dfrac{v}{t}$

$\therefore$ v = at

So $v = \dfrac{eE}{m}t$

Substituting the value of t from equation (1)

$v_y = \dfrac{eV}{md}\dfrac{L}{v_0}$ $\left[\because E = \dfrac{V}{d}\right]$

$\tan\theta = \dfrac{\text{velocity comonent of y}}{\text{velocity component of x}} = \dfrac{v_y}{v_x} = \dfrac{e}{m}\dfrac{V}{d}\dfrac{L}{v_0}.\dfrac{1}{v_0}$

$\Rightarrow \tan\theta = \dfrac{eVL}{mdv_0^2}$

$\Rightarrow \theta = \tan^{-1}\left(\dfrac{eVL}{mdv_0^2}\right)$

36. (a)

Time period of simple pendulum

$$T = 2\pi\sqrt{\frac{\ell}{g}},$$

ℓ = length of the string

g = acceleration due to gravity

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

$\therefore$ Time period $\quad T' = 2\pi\sqrt{\frac{I}{Mgd}}$

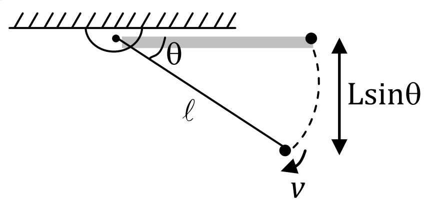
$$= 2\pi\sqrt{\frac{ML'^2}{3Mg\frac{L'}{2}}}, \qquad \text{where } d = \frac{3}{2}L'$$

$$T' = 2\pi\sqrt{\frac{2L'}{3g}}$$

$\because$ Motion is synchronous

$$T = T'$$

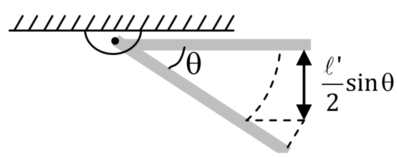
$$\Rightarrow \quad \sqrt{\frac{\ell}{g}} = \sqrt{\frac{2L'}{3g}}$$



Squaring both sides

$$\frac{\ell}{g} = \frac{2L'}{3g}$$

$$\frac{3}{2}\ell = L'$$



37. (a,c,d)

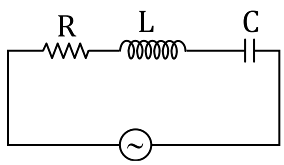
If a charged particle moves in a gravity free space without change in velocity then,

(1) Particle can move with constant velocity in any direction, so B = 0, E = 0

(2) Particle can move in a circle with constant speed. Magnetic force will provide the centripetal force that causes particle to move in a circle.

(3) If qE = qvB and magnetic & electric force in opposite direction, in this case also particle move with uniform speed.

38. (d)



Given values

R = 400Ω , L = 250 mH, C = 2.5μF

V_P = 5V, ω = 2KHz

Inductive reactance, $X_L = \omega L$

$= 2\times10^3 \times 250\times10^{-3}\Omega$

$X_L = 500\Omega$

Capacitive reactance $X_C = \frac{1}{\omega C} = \frac{1}{2\times10^3\times2.5\times10^{-6}}\Omega$

= 200Ω

Impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{(400)^2 + (500-200)^2}$

= 500 Ω

Peak current, $I_P = \frac{V_P}{Z} = \frac{5}{500} = \frac{1}{100}A$

∴ Voltage (Peak) drop in C

$$V_C = I_P \times X_C = \frac{1}{100}\times200 = 2V$$

∴ Peak electrostatic energy of the capacitor

$$E_C = \frac{1}{2}CV_C^2 = \frac{1}{2}\times2.5\times10^{-6}\times2^2$$

$E_C = 5\mu J$

39. (b)

$\because$ Intensity $(I) \propto \frac{1}{d^2}$

Where d = distance between the source and surface.

So

If the distance between the source and surface is doubled i.e. d'=2d, then the intensity of light falling on the surface becomes one fourth i.e., $I' = \frac{1}{(2d)^2} = \frac{1}{4}I$ and

photoelectric current $\propto$ intensity

$\therefore$ current will decrease

The stopping potential (V_S) in photoelectric effect is related with the incident light frequency (v) by the following equation.

$eV_s = hv - \phi$, where ϕ is the work function of the material. It does not depend on the distance of the light source from the emitting metal. So, the stopping potential will remain constant in this case.

40. (d)
To calculate kinetic energy when both the spheres are rotated with equal uniform angular speed about their diameters it will be given by

$$K.E. = \frac{1}{2}I\omega^2$$

$\because$ according to the question in option (d), ω is given same for both the spheres. In question it has already been mentioned that moment of inertia about their diameters is same. So we can say that their rotational kinetic energy will be constant.

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

As we already mentioned that in question only outer radius is given so to determine ratio of mass, inner radius is also required.

We can't comment on density of the sphere because information about inner radius not given.