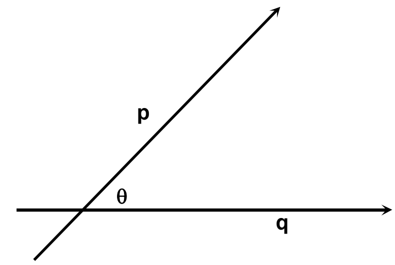
1. Motion of a particle in a plane is described by the non-orthogonal set of coordinates (p, q) with unit vectors $(\hat{p}, \hat{q})$ inclined at an angle θ as shown in the diagram. If the mass of the particle is m, its kinetic energy is given by $\left(\dot{x} = \frac{dx}{dt}\right)$

(A) $\frac{1}{2}m\left(\dot{p}^2 + \dot{q}^2 + \dot{p}\dot{q}\cos\theta\right)$

(B) $\frac{1}{2}m\left(\dot{p}^2 + \dot{q}^2 - \dot{p}\dot{q}(1-\sin\theta)\right)$

(C) $\frac{1}{2}m\left(\dot{p}^2 + \dot{q}^2 + 2\dot{p}\dot{q}\cos\theta\right)$

(D) $\frac{1}{2}m\left(\dot{p}^2 + \dot{q}^2 + \dot{p}\dot{q}\cot\theta\right)$



1. **C**

1. $\vec{v} = p\hat{p} + q\hat{q}$

$K = \frac{1}{2}m(\vec{v}\cdot\vec{v}) = \frac{1}{2}m(p^2 + q^2 + 2pq\hat{p}\cdot\hat{q})$

$= \frac{1}{2}m(p^2 + q^2 + 2pq\cos\theta)$

2. A man is going up in a lift (open at the top) moving with a constant velocity 3 m/s. He throws a ball up at 5 m/sec relative to the lift when the lift is 50 m above the ground. Height of the lift when the ball meets it during its downward journey is (g = 10 m/s^2)

(A) 53 m (B) 58 m
(C) 63 m (D) 68 m

2. **A**

2. $\Delta y_{b\ell} = u_{b\ell(y)}t + \frac{1}{2}a_{b\ell(y)}t^2 = 0$

∴ t = 1 sec
After t = 1 sec, the ball will be again caught by the man.
H = 50 + 3 × 1

3. Two cells each of emf E and internal resistances r_1 and r_2 respectively are connected in series with an external resistance R. The potential difference between the terminals of the first cell will be zero when R is equal to

(A) $\frac{r_1 + r_2}{2}$ (B) $\sqrt{r_1^2 - r_2^2}$

(C) $r_1 - r_2$ (D) $\frac{r_1 r_2}{r_1 + r_2}$

3. **C**

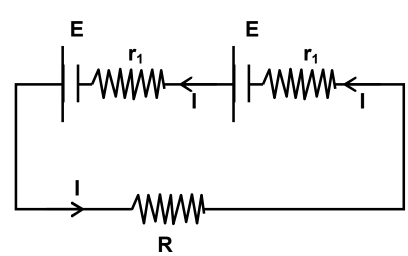
3. $2E - I(r_1 + r_2 + R) = 0$

From question

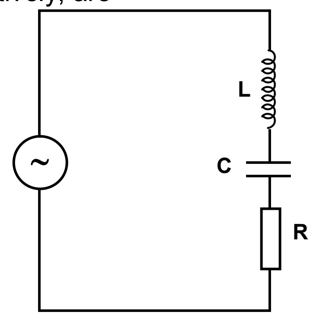
$E - Ir_1 = 0$

$r_1 + r_2 + R = 2r_1$

∴ $R = r_1 - r_2$



4. In the following circuit the current is in phase with the applied voltage. Therefore, the current in the circuit and the frequency of the source voltage respectively, are



(A) $\frac{v_i}{R}$ and $\frac{1}{2\pi\sqrt{LC}}$

(B) Zero and $\frac{1}{\sqrt{LC}}$

(C) $\sqrt{\frac{C}{L}}v_i$ and $\frac{2}{\pi\sqrt{LC}}$

(D) $\sqrt[4]{\frac{C}{LR^2}}$ and $\frac{2}{\sqrt{LC}}$

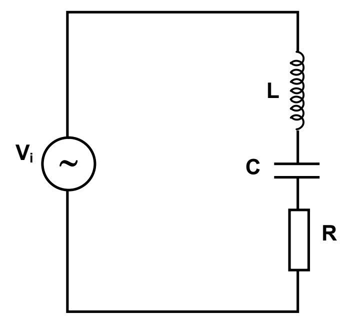
4. **A**

4. $X_L = X_C$

$$\omega L = \frac{1}{\omega C}$$

$$\omega = \frac{1}{\sqrt{LC}} \Rightarrow f = \frac{\omega}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$

$$I = \frac{V_c}{R}$$



5. The photoelectric threshold wavelength of tungsten is 230 nm. The energy of electrons ejected from its surface by ultraviolet light of wavelength 180 nm is

(A) 0.15 eV
(B) 1.5 eV
(C) 15 eV
(D) 1.5 keV

5. **B**

5. Work function of tungsten, $\phi = \frac{hC}{\lambda_0} = \frac{1242}{230} = 5.4\,eV$

$\therefore$ Energy of each photon, $E = \frac{hC}{\lambda} = \frac{1242}{180} = 6.9\,eV$

$\therefore$ $K = E - \phi = 1.5$ eV

6. Consider two point masses m_1 and m_2 connected by a light rigid rod of length r_0. The moment of inertia of the system about an axis passing through their centre of mass and perpendicular to the rigid rod is given by

(A) $\frac{m_1m_2}{2(m_1+m_2)}r_0^2$
(B) $\frac{m_1m_2}{m_1+m_2}r_0^2$
(C) $\frac{2m_1m_2}{m_1+m_2}r_0^2$
(D) $\frac{m_1^2+m_2^2}{m_1+m_2}r_0^2$

6. **B**

6. $I = \mu r_0^2$

$$\mu = \left(\frac{m_1m_2}{m_1+m_2}\right)$$

7. The fraction of the original number of nuclei of a radioactive atom having a mean life of 10 days, that decays during the 5th day is
(A) 0.15 (B) 0.30
(C) 0.045 (D) 0.064

7. **D**

7. $t_{(mean)} = \frac{1}{\lambda}$
$\Delta N = N_0\left[e^{-0.4} - e^{-0.5}\right] = 0.064$

8. A point source of light is viewed through a plate of glass of thickness t and of refractive index 1.5. The source appears
(A) closer by a distance 2t/3 (B) closer by a distance t/3
(C) farther by a distance t/3 (D) farther by a distance 2t/3

8. **B**

8. Normal shift, $\Delta t = t\left(1 - \frac{1}{\mu}\right)$

9. A particle performs simple harmonic motion at a frequency f. The frequency at which its kinetic energy varies is
(A) f (B) 2f
(C) 4f (D) f/2

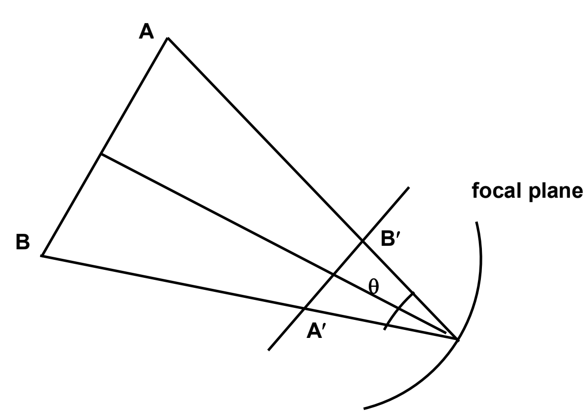
9. **B**

9. frequency of kinetic energy is twice the frequency of motion.

10. When observed from the earth the angular diameter of the sun is 0.5 degree. The diameter of the image of the sun when formed in a concave minor of focal length 0.5 m will be about
(A) 3.0 mm (B) 4.4 mm
(C) 5.6 mm (D) 8.8 mm

10. **B**

10. Diameter of the image of the sun formed by the concave mirror is
$d = f\theta = 0.5 \times 0.5 \times \frac{\pi}{180}$meter
= 4.4 mm



11. Two particles A and B of equal masses have velocities $\overrightarrow{v_A} = 2\hat{i} + \hat{j}$ and $\overrightarrow{v_B} = -\hat{i} + 2\hat{j}$. The particles move with accelerations $\overrightarrow{a_A} = -4\hat{i} - \hat{j}$ and $\overrightarrow{a_B} = -2\hat{i} + 3\hat{j}$ respectively. The centre of mass of the two particles moves along
(A) a straight line (B) a parabola
(C) a circle (D) an ellipse

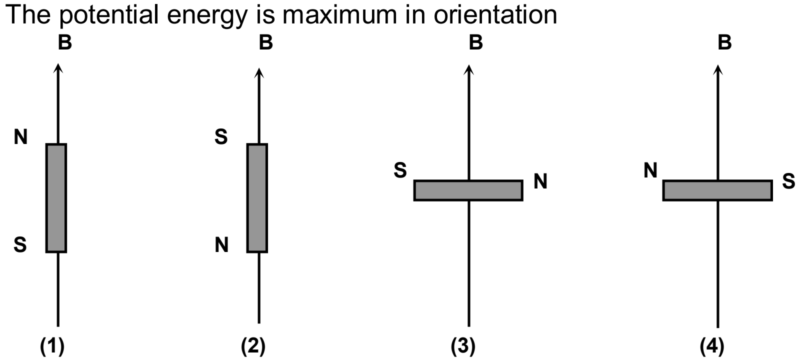
11. **B**

11. $\vec{v}_{CM} = \dfrac{2\hat{i}+\hat{j}-\hat{i}+2\hat{j}}{2} = \dfrac{\hat{i}+3\hat{j}}{2}$

and $\vec{v}_{CM} \perp \vec{a}_{CM}$

So path of centre of mass be parabolic

12. Consider different orientations of a bar magnet lying in a uniform magnetic field as shown below. The potential energy is maximum in orientation



(A) 1
(B) 2
(C) 3
(D) 4

12. **B**

12. $U = -\vec{M}.\vec{B}$

13. Acidified water from certain reservoir kept at a potential V falls in the form of small droplets each of radius r through a hole into a hollow conducting sphere of radius a. The sphere is insulated and is initially at zero potential. If the drops continue to fall until the sphere is half full, the potential acquired by the sphere is

(A) $\dfrac{a^2V}{2r^2}$
(B) $\sqrt{\dfrac{a}{r}}\dfrac{V}{2}$
(C) $\dfrac{a^3V}{2r^3}$
(D) $\dfrac{aV}{r}$

13. **A**

13. Charge on a droplet = $4\lambda\varepsilon_0 rV$

Total no. of droplets = $\dfrac{\frac{2}{3}\pi a^3}{\frac{4}{3}\pi r^3} = \dfrac{a^3}{2r^3}$

So potential of the sphere = $\dfrac{1}{4x\varepsilon_0 a}\dfrac{a^3}{2r^3}4\pi\varepsilon_0 rV = \dfrac{a^2V}{2r^2}$

14. A small fish, 4 cm below the surface of a lake, is viewed through a thin converging lens of focal length 30 cm held 2 cm above the water surface. Refractive index of water is 1.33. The image of the fish from the lens is at a distance of

(A) 10 cm
(B) 8 cm
(C) 6 cm
(D) 4 cm

14. **C**

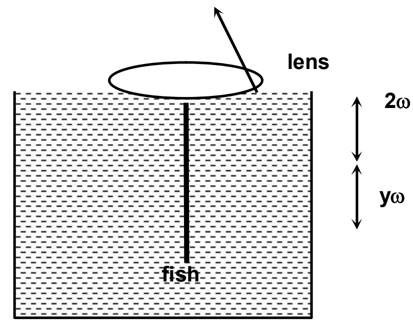
14. Object distance for the long

$= 2 + \frac{4}{4/3} = 5$ cm

$\therefore \quad \frac{1}{v} - = \frac{1}{30}$

$\therefore \quad \frac{1}{v} = \frac{1}{30} - \frac{1}{5} = -\frac{5}{30}$

v = – 6 cm



15. In case of real images formed by a thin convex lens, the linear magnification is (I) directly proportional to the image distance, (II) inversely proportional to the object distance, (III) directly proportional to the distance of image from the nearest principal focus, (IV) inversely proportional to the distance of the object from the nearest principal focus. From these the correct statements are

(A) (I) and (II) only
(B) (III) and (IV) only
(C) (I), (II), (III) and (IV) all
(D) None of (I), (II), (III) and (IV)

15. **C**

15. $m = \frac{v}{u} = \frac{f}{f+u} = \frac{f-v}{v}$

16. If Newton's inverse square law of gravitation had some dependence on radial distance other than r^{-2}, which one of Kepler's three laws of planetary motion would remain unchanged?

(A) First law on nature of orbits
(B) Second law on constant areal velocity
(C) Third law on dependence of orbital time period on orbit's semi major axis
(D) None of the above

16. **B**

16. Angular momentum of a planet is still conserved about centre of sun

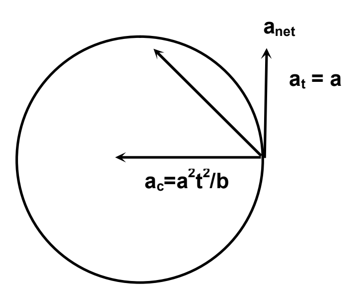
17. A racing car moves along circular track of radius b. The car starts from rest and its speed increases at a constant rate α. Let the angle between the velocity and the acceleration be θ at time t. Then ($\cos\theta$) is

(A) 0
(B) αt+/b
(C) b/(b + αt^2)
(D) $b\left(b^2 + \alpha^2 t^4\right)^{1/2}$

17. **D**

17. $\cos\theta = \frac{a}{\sqrt{a^2 + \frac{a^4 t^4}{b^2}}}$

$= \frac{b}{\sqrt{b^2 + a^2 t^4}}$



18. A small pond of depth 0.5 m deep is exposed to a cold winter with outside temperature of 263 K. Thermal conductivity of ice is K = 2.2 $Wm^{-1}K^{-1}$, latent heat L = 3.4 × 10^5 Jk g^{-1} and density ρ= 0.9 × 10^3 kgm^{-3}. Take the temperature of the pond to be 273 K. The time taken for the whole pond to freeze is about

(A) 20 days (B) 25 days
(C) 30 days (D) 35 days

18. **A**

18. $$\frac{KA(273-263)}{y}dt = \rho AdyL$$

$$\therefore \quad 10\times 2.2\int_0^t dt = 0.9\times 10^3\times 3.4\times 10^5\int_0^{0.5} y\,dy$$

$$\therefore \quad 22t = 306\times 10^8\times \frac{1}{8}$$

$$\therefore \quad t = \frac{3.06\times 10^8}{22\times 8}\text{sec} = 20\,\text{days}(\text{approx})$$

19. Two identical charged spheres suspended from a common point by two light strings of length l. are initially at a distance d(<<l) apart due to their mutual repulsion. The charges begin to leak from both the spheres at a constant rate. As a result, the spheres approach each other with a velocity v. If x denotes the distance between the spheres, then v varies as

(A) x^{-1} (B) $x^{1/2}$
(C) $x^{-1/2}$ (D) x

19. **C**

19. $$\frac{Kq^2}{mgx^2} = \tan\theta = \frac{x}{2\ell}$$

$$\therefore \quad q \propto x^{3/2}v$$

$$\frac{dq}{dt} \propto x^{1/2}v$$

$$\therefore \quad v \propto x^{-\frac{1}{2}}$$

20. The physical quantity that has unit volt-second is

(A) energy (B) electric flux
(C) magnetic flux (D) inductance

20. **C**

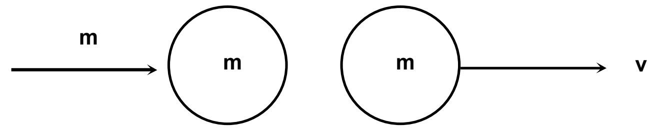
20. $$L\frac{di}{dt} = \frac{d\phi}{dt}$$

21. A ball of mass m hits directly another ball of mass M at rest and is brought to rest by the impact. One third of the kinetic energy of the ball is lost due to the collision. The coefficient of restitution is

(A) 1/3 (B) 1/2
(C) 2/3 (D) $\sqrt{\frac{2}{3}}$

21. **C**

21. So $\frac{1}{2}mv^2 = \frac{1}{2}mu^2\left(\frac{2}{3}\right)$



Before collison

After collison

$\therefore \quad v = \sqrt{\frac{2m}{3M}}u$

and $\quad mu = mv$

$\therefore \quad \frac{m}{M} = \sqrt{\frac{2m}{3M}} \quad \therefore \quad \frac{v}{u} = \frac{2}{3}$

22. Consider a parallel plate capacitor. When half of the space between the plates is filled with some dielectric material of dielectric constant K as shown in Fig. (1) below, the capacitance is C_1. However, if the same dielectric material fills half the space as shown in Fig. (2), the capacitance is C_2. Therefore, the ratio $C_1 : C_2$ is

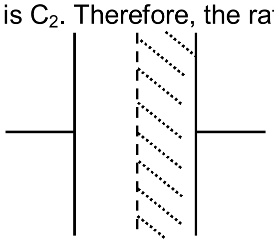


Fig. (1)

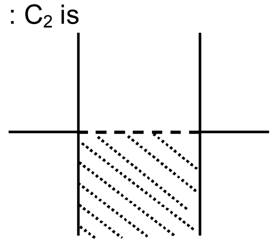


Fig. (2)

(A) 1

(B) $\frac{2K}{K+1}$

(C) $\frac{4K}{(K+1)^2}$

(D) $\frac{K+1}{2}$

22. **C**

22. $C_1 = \frac{\varepsilon_0 A}{d - \frac{d}{2} + \frac{d}{2k}} = \frac{2\varepsilon_0 At}{d(k+1)}$

$C_2 = \frac{\varepsilon_0 A}{2d}(1+k)$

$\therefore \quad \frac{C_1}{C_2} = \frac{4x}{(k+1)^2}$

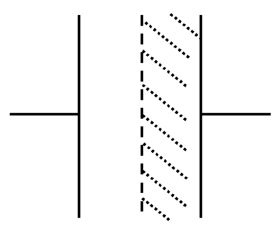


Fig. (1)

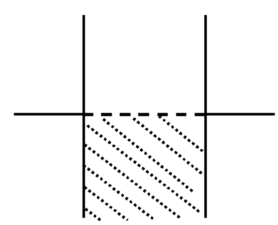


Fig. (2)

23. The excess pressure inside a soap bubble is equal to 2 mm of kerosene (density 0.8 g cm^{-3}). If the diameter of the bubble is 3.0 cm, the surface tension of soap solution is

(A) 39.2 dyne cm^{-1}

(B) 45.0 dyne cm^{-1}

(C) 51.1 dyne cm^{-1}

(D) 58.8 dyne cm^{-1}

23. **D**

23. $\frac{8T}{D} = 0.2 \times 0.8 \times 980$

$\therefore \quad T = \frac{0.2 \times 0.8 \times 980 \times 3}{8} = 58.8 \text{ dyne / a}$

24. A body of mass 4 kg moves under the action of a force $\vec{F} = \left(4\hat{i} + 12t^2\hat{j}\right)N,$ where t is the time in second. The initial velocity of the particle is $\left(2\hat{i} + \hat{j} + 2\hat{k}\right)ms^{-1}$. If the force is applied for 1s, work done is

(A) 4J (B) 8J
(C) 12J (D) 16J

24. **D**

24. $\vec{J} = \int_0^1 \left(4\hat{i} + 12t^2\hat{j}\right)dt = 4\vec{v} - 4\left(2\hat{i} + \hat{j} + 2\hat{k}\right)$

$4\hat{i} + 4\hat{j} = 4\vec{v} - u\left(2\hat{i} + \hat{j} + 2\hat{k}\right)$

$\therefore \quad \vec{v} = 3\hat{i} + 2\hat{j} + 2\hat{k}$

$\therefore \quad \Delta\omega = \frac{1}{2} \times 4\left[9 + 4 + 4 - 4 - 1 - 4\right] = 16J$

25. Which one of the following devices does not respond to the intensity of light incident on it?

(A) Photoresistor (LDR) (B) Photodiode
(C) Light Emitting Diode (D) Solar Cell

25. **C**

26. Two moles of hydrogen are mixed with n moles of helium. The root mean square speed of gas molecules in the mixture is $\sqrt{2}$ times the speed of sound in the mixture. Then n is

(A) 3 (B) 2
(C) 1.5 (D) 2.5

26. **B**

26. $\sqrt{\frac{3RT}{M_{min}}} = \sqrt{2}\sqrt{\frac{rRT}{M_{min}}}$

$\therefore \quad \frac{3}{2} = Y = \frac{2}{\frac{7}{5} - 1} + \frac{n}{\frac{5}{3} - 1} = \frac{n + 2}{\frac{3}{2} - 1}$

$\therefore \quad n = 2$

27. In an X ray tube the electrons are expected to strike the target with a velocity that is 10% of the velocity of light. The applied voltage should be

(A) 517.6 V (B) 1052 V
(C) 2.559 kV (D) 5.680 kV

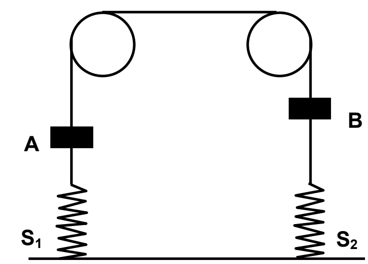
27. **C**

27. $ev' = \frac{1}{2}m\left(0.1C\right)^2$

$\therefore \quad v = \frac{1}{2}\frac{9.1 \times 10^{0-31} \times 10^{-2} \times 9 \times 10^{16}}{1.6 \times 10^{-19}}$

$= \frac{9.1 \times 9}{3.2} \times 10^2 = 2.559kV$

28. In the figure shown below masses of blocks A and B are 3 kg and 6 kg respectively. The force constants of springs S_1 and S_2 are 160 N/m and 40 N/m respectively. Length of the light string connecting the blocks is 8 m. The system is released from rest with the springs at their natural lengths. The maximum elongation of spring S_1 will be



(A) 0.294 m (B) 0.490 m
(C) 0.588 m (D) 0.882 m

28. **A**

28. $6gx - 3gx = \frac{1}{2}(160 + 40)x^2$

$\therefore$ x = 0.294 m

29. A quantity α is defined as $\alpha = e^2/4\pi\varepsilon_0 c\hbar$, where e is electric charge, $\hbar = h/2\pi$ is the reduced Planck's constant and c is the speed of light. The dimensions of α are

(A) $\left[M^0L^0T^0I^0\right]$ (B) $\left[M^1L^{-1}T^2I^{-2}\right]$
(C) $\left[M^2L^1T^{-1}I^0\right]$ (D) $\left[M^0L^3T^1I^{-2}\right]$

29. **A**

29. $\alpha = \left(\frac{e^2}{4\pi\varepsilon_0}\right)\left(\frac{1}{C\hbar}\right)$

$= \left(MLT^{-2}L^2\right)\left(\frac{1}{LmL^2T^{-2}}\right)$

30. A student uses a convex lens to determine the width of a slit. For this he fixes the positions of the object and the screen and moves the lens to get a real image on the screen. The images of the slit width are found to be 2.1 cm and 0.48 cm wide respectively when the lens is moved through 15 cm. Therefore, the slit width and the focal length of the lens respectively are

(A) 1 cm, 9.3 cm (B) 1 cm, 10.5 cm
(C) 2 cm, 12.8 cm (D) 2 cm, 15.2 cm

30. **A**

30. $x - y = 15$

and $y = 0.48x$

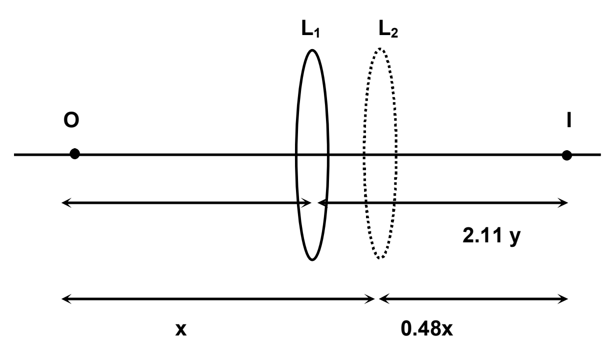
$\therefore$ $x - 0.48x = 15 \Rightarrow x = \frac{15}{0.52}\omega$

from lens equation $\frac{1}{0.48x} - \frac{1}{-x} = \frac{1}{f}$

$\frac{0.52}{(0.48)(15)} + \frac{0.52}{15} = \frac{1}{f}$

$\therefore$ f = 9.3 cm

Object length = $\sqrt{L_1L_2} = \sqrt{(2.1)(0.48)} = 1$ cm



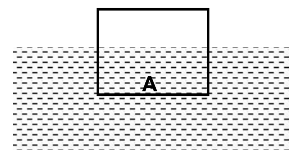
31. Two identical solid blocks A and B are made of two different materials. Block A floats in a liquid with half of its volume submerged. When block B is pasted over A, the combination is found to just float in the liquid. The ratio of the densities of the liquid, material of A and material of B is given by

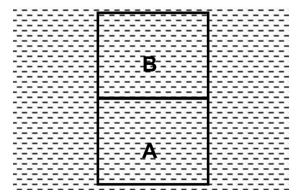
(A) 1 : 2 : 3 (B) 2 : 1 : 4
(C) 2 : 1 : 3 (D) 1 : 3 : 2

31. **C**

31. $v\rho_A g = \frac{v}{2}\rho_\omega g$

$\frac{\rho_\omega}{2} = \rho_A$





$V(\rho_A + \rho_B)g = 2v\rho_\omega g$

$\rho_A + \rho_B = 2\rho_\omega$

$\rho_B = \frac{3\rho_\omega}{2}$

$\rho_\omega : \rho_A : \rho_B = \rho_\omega : \frac{\rho_\omega}{2} : \frac{3\rho_\omega}{2} = 2 : 1 : 3$

32. The decimal number that is represented by the binary number $(100011.101)_2$ is

(A) 23.350 (B) 35.625
(C) 39.245 (D) 42.455

32. **B**

32. $(100011.\ 101)_2 = 1 \times 2^5 + 0 \times 2^4 + 0 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 + 1 \times 2^{-1} + 0 \times 2^{-2} + 1 \times 2^{-3}$

$= 32 + 0 + 0 + 0 + 2 + 1 + \frac{1}{2} + 0 + \frac{1}{\delta}$

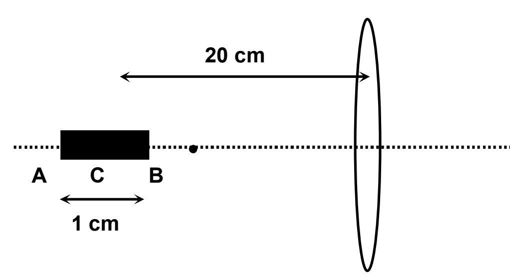
= 35.625

33. An object 1 cm long lies along the principal axis of a convex lens of focal length 15 cm, the centre of the object being at a distance of 20 cm from the lens. Therefore, the size of the image is

(A) 0.3 cm (B) 3 cm
(C) 9 cm (D) 12 cm

33. **C**

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



$\frac{1}{15} = \frac{1}{v} - \frac{1}{-20}$

$\Rightarrow \frac{1}{v} = \frac{1}{15} - \frac{1}{20} = \frac{3-2}{60} = \frac{1}{60}$

$\Rightarrow$ v = 60 cm

$\Rightarrow -\frac{v}{u} = 3$

$$0 = \frac{-1}{v^2}\Delta v + \frac{1}{u^2}\Delta u$$

$$\Rightarrow \quad \Delta v = -\left(\frac{v}{u}\right)^2 \Delta u = 9 \times 1 = \text{cm}$$

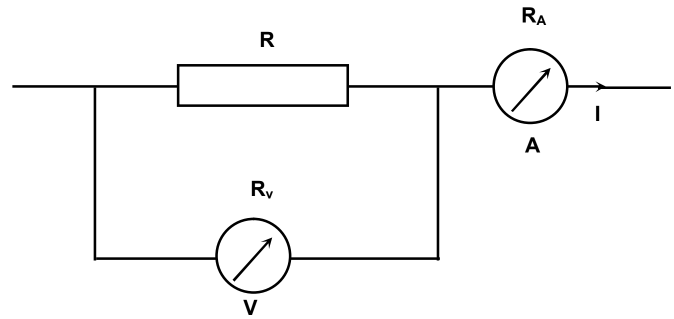
34. Let V and I be the readings of the voltmeter and the ammeter respectively as shown in the figure. Let R_V and R_A be their corresponding resistances. Therefore,

(A) $R = \frac{V}{I}$

(B) $R = \frac{V}{I - \left(\frac{V}{R_V}\right)}$

(C) $R = R_V - V_A$

(D) $R = \frac{V(R + R_A)}{IR_A}$



34. **B**

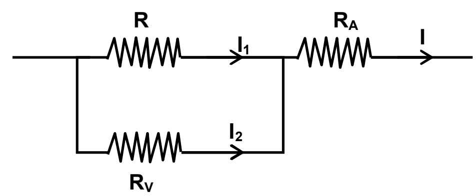
34. $I_2 = \frac{R}{R + R_V} I$

$$V = R_V I_2 = \frac{R R_V I}{R + R_V}$$

$$\Rightarrow \quad RV + R_v V = R R_V I$$

$$\Rightarrow \quad R[R_V I - V] = R_V V$$

$$\Rightarrow \quad R = \frac{VR_V}{R_V I - V} = \frac{V}{I - \left(\frac{V}{R_V}\right)}$$

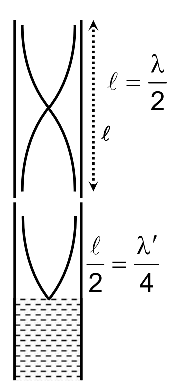


35. A whistle whose air column is open at both ends has a fundamental frequency 500 Hz. The whistle is dipped in water such that half of it remains out of water. What will be the fundamental frequency now? (speed of sound in air is 340 ms^{-1})

(A) 250 Hz
(B) 125 Hz
(C) 500 Hz
(D) 1000 Hz

35. **C**

35. $f_0 = \frac{v}{2\ell}$



$$\frac{\lambda'}{4} = \frac{\ell}{2} \Rightarrow \lambda' = 2\ell$$

$$f_0' - \frac{v}{\lambda'} = \frac{v}{2\ell} = f_0 = 500\,\text{Hz}$$

36. An isolated metallic object is charged in vacuum to a potential V_0 using a suitable source, its electrostatic energy being W_0. It is then disconnected from the source and immersed in a large volume of dielectric with dielectric constant K. The electrostatic energy of the sphere in the dielectric is

(A) K^2W_0 (B) $K W_0$
(C) W_0/K^2 (D) W_0/K

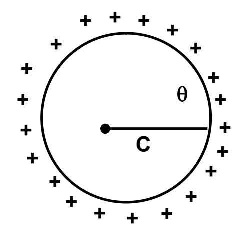
36. **D**

36. $Q = CV,\ U = \frac{1}{2}CV^2 = W_0$

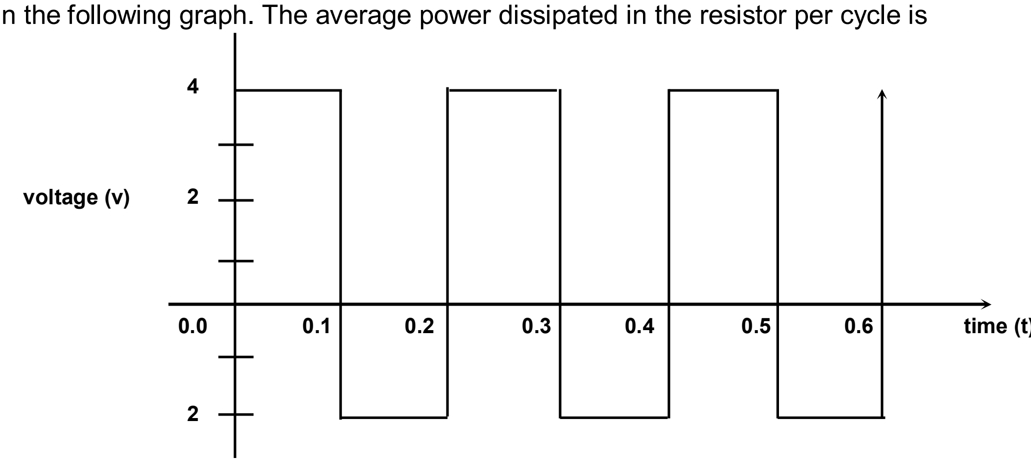
In presence of dielectric, charge is fixed

$C' = CK$

$$U = \frac{Q^2}{2C'} = \frac{(CV)^2}{2KC} = \left(\frac{CV^2}{2}\right)\frac{1}{K} = \frac{W_0}{K}$$



37. A 10 ohm resistor is connected to a supply voltage alternating between + 4V and – 2V as shown in the following graph. The average power dissipated in the resistor per cycle is



(A) 1.0 W (B) 1.2 W
(C) 1.4 W (D) 1.6 W

37. **A**

37. If $0 \le t \le 0.1$ sec

$-0.2A$ If $0.1 \le t \le 0.2$ sec

$$I_{rms}^2 = \frac{0.16 \times 0.1 + 0.04 \times 0.1}{0.2} = 0.1A$$

$$P_{AV} = RI_{rms}^2 = 10 \times 0.1 = 1\omega$$

38. A coil 2.0 cm in diameter has 300 turns. If the coil carries a current of 10 mA and lies in a magnetic field 5×10^{-2} T, the maximum torque experienced by the coil is

(A) 4.7×10^{-2} N-m (B) 4.7×10^{-4} N-m
(C) 4.7×10^{-5} N-m (D) 4.7×10^{-8} N-m

38. **C**

38. $\vec{M} = \pi \times (1 \times 10^{-2})^2 \times 10 \times 10^{-3} \times 300 = 3\pi \times 10^{-4}\ Am^2$

$\tau = MB = 15\pi \times 10^{-6}\ N-m = 4.7 \times 10^{-5}\ Nm$

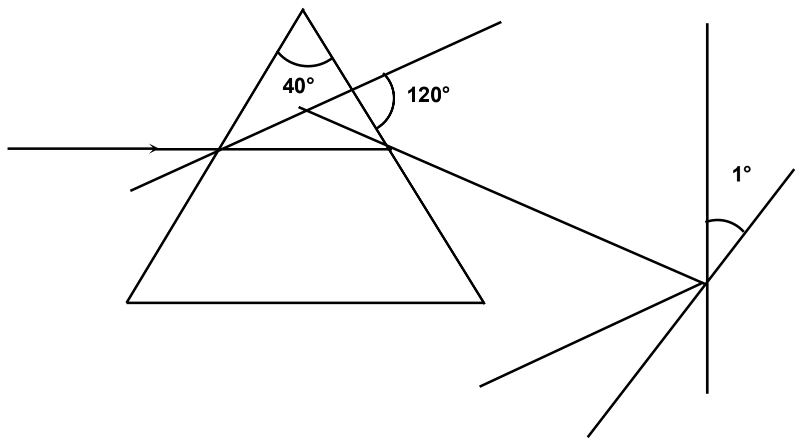
39. A horizontal ray of light passes through a prism of refractive index 1.5 and apex angle 4° and then strikes a vertical plane mirror placed to the right of the prism. If after reflection, the ray is to be horizontal, then the mirror must be rotated through an angle

(A) 1° clockwise
(B) 1° anticlockwise
(C) 2° clockwise
(D) 2° anticlockwise

39. **A**

39. $\delta = (\mu - 1)A = 0.5 \times 4° = 2°$

Ans will 1° clockwise

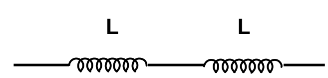


40. Two identical coils each of self-inductance L, are connected in series and are placed so close to each other that all the flux from one coil links with the other. The total self-inductance of the system is

(A) L
(B) 2L
(C) 3L
(D) 4L

40. **D**

40. $M = \sqrt{L \times L} = L$



$L_S = 4 + l_2 + 2M = L + L + 2L = 4L$

$V_{CD} = 16mv = 1l$

$V_{AB} = 12mv = R_g I$

I = 10 dω

x $\Rightarrow$ value of each division

$\frac{16}{12} = \frac{100}{R_g} \Rightarrow R_g = 75\Omega$

$I = \frac{16 \times 10^{-3}}{100} = 16 \times 10^{-15} A = 10d\omega$

$\Rightarrow \quad x = 1.6 \times 10^{-5} A / dive = 16x / A / div$

$\Rightarrow \quad 30\,dive = 48 \times 10^{-5} A = I_g$

Group of question Nos 41 to 45 are based on the following paragraph and its subsequent continuation after some questions

The following questions are concerned with experiments on the characterization and use of a moving coil galvanometer.

The series combination of a variable resistance R, one 100 Ω resistor and a moving coil galvanometer is connected to a mobile phone charger having negligible internal resistance. The zero of the galvanometer lies at the centre and the pointer can move 30 divisions full scale on either side depending on the direction of current. The reading of the galvanometer is 10 divisions and the voltage across the galvanometer and 100 Ω resistor are respectively 12 mV and 16 mV.

41. The figure of merit of the galvanometer in microampere per division is
(A) 16 (B) 20
(C) 32 (D) 10

41. **A**

42. The resistance of the galvanometer in ohm is
(A) 50 Ω (B) 75 Ω
(C) 100 Ω (D) 80 Ω

42. **B**

41-42. $V_{CD} = 10\text{ mV} = 100\text{ I}$

$V_{AB} = 12\text{ mV} = R_g I$

$I \equiv 10\text{ div}$

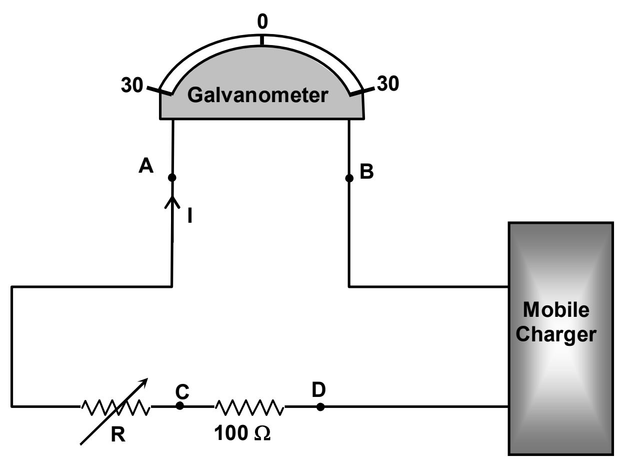
$x \Rightarrow$ value of each division

$\frac{16}{12} = \frac{100}{R_g} \Rightarrow R_g = 75\ \Omega$

$I = \frac{16\times10^{-3}}{100} = 16\times10^{-5} = 10\text{ div}$

$\Rightarrow x = 1.6\ \ 10^{-5}$ A/div = 16 μA/div

$\Rightarrow 30\text{ div} = 48 \times 10^{-5}\text{ A} = I_g$



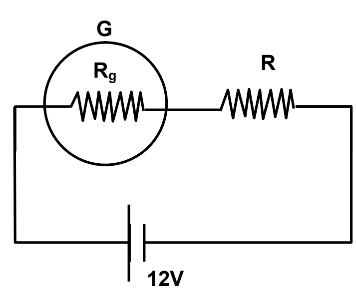
The series combination of the galvanometer with resistance of R is connected across an ideal voltage supply of 12 V and this time the galvanometer shows full scale deflection of 30 divisions.

43. The value of R is nearly
(A) 12.5 kΩ (B) 25 kΩ
(C) 75 kΩ (D) 100 kΩ

43. B

43. $I_g(R + R_g) = 12\text{ V}$

$R + R_g = \frac{12\times10^5}{48} = \frac{100}{4}\times10^3 = 25\text{K}\Omega$



44. A 24 Ω resistance is connected to a 5 V battery with internal resistance of 1 Ω. A 25 kΩ resistance is connected in series with the galvanometer and this combination is used to measure the voltage across the 24 Ω resistance. The number of divisions shown in the galvanometer is

(A) 6 (B) 8
(C) 10 (D) 12

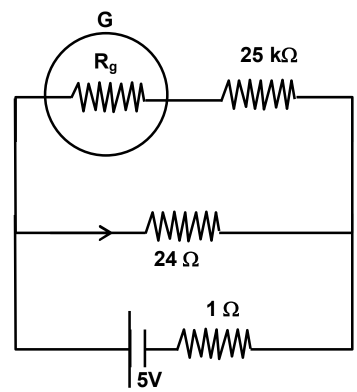
44. D

44. $V = \frac{1}{5} \times 24 = 4.8\ V$

$4.8 = 25 \times 10^3 \times I'$

$\Rightarrow I' = \frac{4.8}{25 \times 10^3} = 4.8 \times 4 \times 10^{-5}$ amp

No. of division = $\frac{4.8 \times 4 \times 10^{-5}}{1.6 \times \times 10^{-5}} = 12$



45. Now a 1000 μF capacitor is charged using the 12 V supply and is discharged through the galvanometer-resistance combination used in the previous question. The current i (in ampere) at different time t (in second) are recorded. A graph of (ℓn i) against (t) is plotted. The slope of the graph is

(A) $-0.02\ s^{-1}$ (B) $-0.01\ s^{-1}$
(C) $-0.04\ s^{-1}$ (D) $+0.04\ s^{-1}$

45. C

45. $Q = Q_0 e^{-\frac{t}{\tau}} \Rightarrow I = \frac{Q_0}{\tau} e^{-\frac{t}{\tau}} \Rightarrow \ell n I = \ell n \frac{Q_0}{\tau} - \frac{1}{\tau} t$

$\tau = 1000 \times 10^{-6} \times 25 \times 10^3$ = 25 sec

Slope = $-\frac{1}{\tau} = -\frac{1}{25} \times \frac{4}{4} = -\frac{4}{100} = 0.04\ s^{-1}$

46. A particle rests in equilibrium under two forces of repulsion whose centres are at distances of a and b from the particle. The forces vary as the cube of the distance. The forces per unit mass are k and k′ respectively. If the particle be slightly displaced towards one of them the motion is simple harmonic with the time period equal to

(A) $\frac{2\pi}{\sqrt{3\left(\frac{k}{a^3} + \frac{k'}{b^3}\right)}}$ (B) $\frac{2\pi}{\sqrt{\left(\frac{k}{a^3} + \frac{k'}{b^3}\right)}}$

(C) $\frac{2\pi}{\sqrt{\left(\frac{k}{a^4} + \frac{k'}{b^4}\right)}}$ (D) $\frac{2\pi}{\sqrt{3\left(\frac{k}{a^4} + \frac{k'}{b^4}\right)}}$

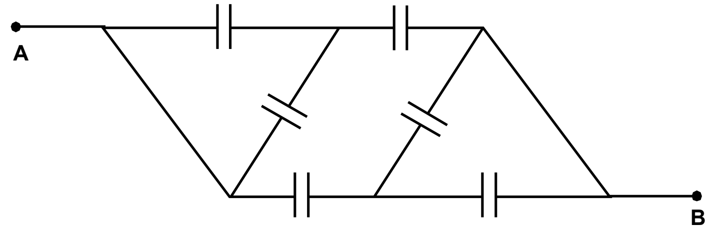
46. Particle can't perform SHM with given forces.

47. A slit of width a is illuminated by parallel monochromatic light of wavelength λ. The value of a at which the first minimum of the diffraction pattern will form at $\theta = 30^o$ is
(A) $\lambda/2$
(B) λ
(C) 2λ
(D) 3λ

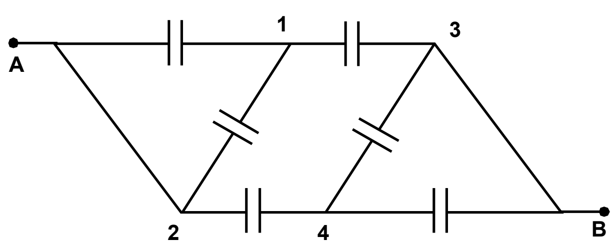
47. C

47. For minima, a sin $\theta = n\lambda$
For first minima, a sin $\theta = \lambda$
$$\Rightarrow a = \frac{\lambda}{\sin\theta} = \frac{\lambda}{\sin 30^\circ} = 2\lambda$$

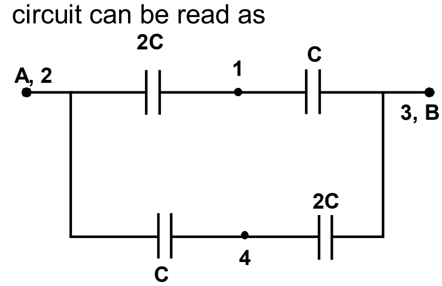
48. A network of six identical capacitors, each of capacitance C is formed as shown below. The equivalent capacitance between the points A and B is
(A) 3C
(B) 6C
(C) 3C/2
(D) 4C/3



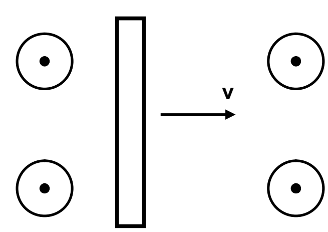
48. D

48. 

circuit can be read as



49. A neutral metal bar moves at a constant velocity v to the right through a region of uniform magnetic field directed out of the page, as shown. Therefore,
(A) positive charges accumulate to the left side and negative charges to the right side of the rod.
(B) negative charges accumulate to the left side and positive charges to the right side of the rod.
(C) positive charges accumulate to the top end and negative charges to the bottom end of the rod.
(D) negative charges accumulate to the top end and positive charges to the bottom end of the rod.



49. D

49. $$\varepsilon = \left[\int_{\text{lower end}}^{\text{upper end}} (\vec{v} \times \vec{B}) \cdot d\vec{\ell}\right] < 0$$

50. In an atom an electron excites to the fourth orbit. When it jumps back to the lower energy levels a spectrum is formed. Total number of spectrum lines in this spectrum would be
(A) 3
(B) 4
(C) 5
(D) 6

50. A

50. For one atom with one electron in 4th level, possible transition for maximum lines in spectrum would be $4 \rightarrow 3$, $3 \rightarrow 2$ and $2 \rightarrow 1$.

51. A hollow sphere of inner radius 9 cm and outer radius 10 cm floats half submerged in a liquid of specific gravity 0.8. The density of the material of the sphere is
(A) 0.84 g cm^{-3}
(B) 1.48 g cm^{-3}
(C) 1.84 g cm^{-3}
(D) 1.24 g cm^{-3}

51. B

51. Weight = Up thrust

$$\frac{4}{3}\pi\left[a^3 - b^2\right]\rho g = \frac{2}{3}\pi a^3 \rho_\ell g$$

$$\Rightarrow \rho = \frac{a^3}{2(a^3 - b^3)}\rho_\ell$$ [a = outer radius, b = inner radius]

$= 1.48$ g/cm^3

52. The earth's magnetic field at a certain point is 7.0 10^{-5} T. This field is to be balanced by a magnetic field at the centre of circular current carrying coil of radius 5.0 cm by suitably orienting it. If the coil has 100 turns then the required current is about.
(A) 28 mA
(B) 56 mA
(C) 100 mA
(D) 560 mA

52. B

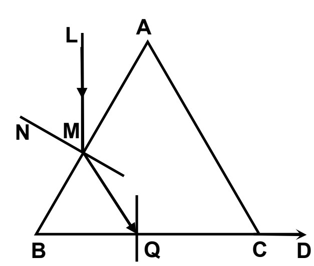
52. $$B_H = N\left[\frac{\mu_0 I}{2R}\right]$$

$$100 \times \frac{\mu_0 I}{2R} = 7 \times 10^{-5}$$

$$\Rightarrow \quad 100 \times \frac{4\pi \times 10^{-7} \times I}{2 \times 5 \times 10^{-2}} = 7 \times 10^{-5}$$

$\Rightarrow$ I = 56 mA

53. The following figure shows the section ABC of an equilateral triangular prism. A ray of light enters the prism along LM and emerges along QD. If the refractive index of the material of the prism is 1.6, angle LMN is
(A) 35.6°
(B) 37.4°
(C) 39.4°
(D) 41.3°



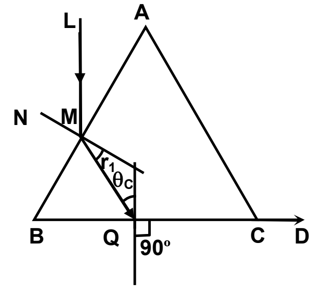
53. A

53. $\theta_C = \sin^{-1}\left(\frac{1}{1.6}\right) = 38.7°$

$r_2 = 60° - \theta_C = 21.3°$

$1 \times \sin i = 1.6 \sin(21.3^o)$

$\Rightarrow i = 35.6$



54. An infinitely long straight non-magnetic conducting wire of radius a carries a dc current I. The magnetic field B, at a distance r (r < a) from axis of wire is

(A) $\mu_0 I/2\pi a$
(B) $\mu_0 Ir/2\pi a^2$
(C) $2\mu_0 Ir/\pi a^2$
(D) $\mu_0 Ir^2/2\pi a^3$

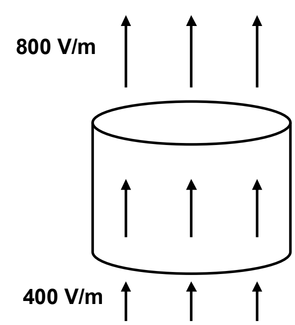
54. B

54. $B \times 2\pi r = \mu_0 I \frac{r^2}{a^2}$

$\Rightarrow B = \frac{\mu_0 Ir}{2\pi a^2}$

55. A cylinder on whose surfaces there is vertical electric field of varying magnitude as shown. The electric field is uniform on the top surface as well as on the bottom surface. Therefore, this cylinder encloses

(A) no net charge.
(B) net positive charge
(C) net negative charge.
(D) There is not enough information to determine whether or not there is net charge inside the cylinder.



55. B

55. $\phi = E_T A - E_B A$

$800 \times A - 400\ A = + 400\ A$

Hence system contains positive charge.

56. When a body is suspended from a fixed point by a spring, the angular frequency of its vertical oscillations is ω_1: When a different spring is used, the angular frequency is ω_2. The angular frequency of vertical oscillations when both the springs are used together in series is given by

(A) $\omega = \left[\omega_1^2 + \omega_2^2\right]^{1/2}$
(B) $\omega = \left[\left(\omega_1^2 + \omega_2^2\right)/2\right]^{1/2}$
(C) $\omega = \left[\omega_1^2\omega_2^2/\left(\omega_1^2 + \omega_2^2\right)\right]^{1/2}$
(D) $\omega = \left[\omega_1^2\omega_2^2/2\left(\omega_1^2 + \omega_2^2\right)\right]^{1/2}$

56. C

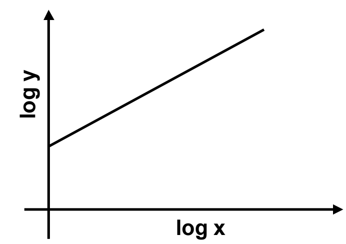
56. $\omega_1^2 = \frac{k_1}{m}$, $\omega_2^2 = \frac{k_2}{m}$

$\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2} \Rightarrow \omega^2 = \frac{k_{eq}}{m}$

$$\Rightarrow \frac{1}{\omega^2 m} = \frac{1}{\omega_1^2 m} + \frac{1}{\omega_2^2 m} \Rightarrow \frac{1}{\omega^2} = \frac{1}{\omega_1^2} + \frac{1}{\omega_2^2}$$

$$\Rightarrow \omega = \left[\frac{\omega_1^2\omega_2^2}{\omega_1^2 + \omega_2^2}\right]^{1/2}$$

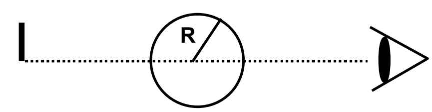
57. The equation correctly represented by the following graph is (a and b are constants)
(A) x + y = b
(B) $ax^2 + by^2 = 0$
(C) x + y = ab
(D) $y = ax^b$



57. D

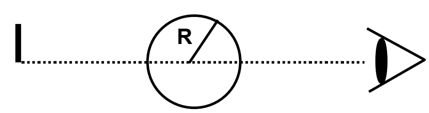
57. $\ell n\, y = \ell n\, a + b\, \ell n\, x$

58. Rays from an object immersed in water (μ = 1.33) traverse a spherical air bubble of radius R. If the object is located far away from the bubble, its image as seen by the observer located on the other side of the bubble will be
(A) virtual, erect and diminished
(B) real, inverted and magnified
(C) virtual, erect and magnified
(D) real, inverted and diminished



58. A

58. for first refraction $\frac{1}{v_1} - \frac{4}{-3(\infty)} = \frac{1-(4/3)}{R}$



$\Rightarrow v_1 = -3R$

for 2nd refraction $\frac{4}{3v_2} + \frac{1}{5R} = -\frac{1}{3}\left(\frac{1}{R}\right)$

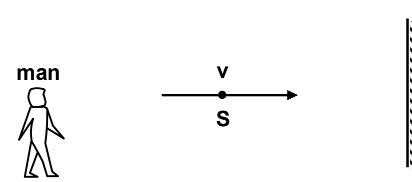
$\Rightarrow v_2 = -\frac{5}{2}R$

59. A man stands at rest in front of a large wall. A sound source of frequency 400 Hz is placed between him and the wall. The source is now moved towards the wall at a speed of 1 m/s. The number of beats heard per second will be (speed of sound in air is 345 m/s)
(A) 0.8 (B) 0.58
(C) 1.16 (D) 2.32

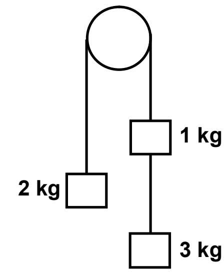
59. D

59. Beat frequency $= v_s f\left[\frac{1}{v_s - v} - \frac{1}{v + v_s}\right] \approx 2.32$

v_s = velocity of sound
v = velocity of source



60. In the following arrangement the pulley is assumed to be light and the strings inextensible. The acceleration of the system can be determined by considering conservation of certain physical quantity. The physical quantity conserved and the acceleration respectively, are
(A) energy and g/3
(B) linear momentum and g/2
(C) angular momentum and g/3
(D) mass and g/2



60. A

60. $\text{Acceleration} = \left(\frac{4-2}{4+2}\right)g = \frac{g}{3}$

A2
QUESTIONS WITH MORE THAN ONE OPTION CORRECT

61. Two identical rods made of two different metals A and B with thermal conductivities K_A and K_B respectively are joined end to end. The free end of A is kept at a temperature T_1 while the free end of B is kept at a temperature T_2 ($<T_1$). Therefore, in the steady state
(A) the temperature of the junction will be determined only by K_A and K_B.
(B) if the length of the rods are doubled the rate of heat flow will be halved.
(C) If the temperatures at the two free ends are interchanged the junction temperature will change.
(D) the composite rod has an equivalent thermal conductivity of $\frac{2K_AK_B}{K_A+K_B}$

61. A, B, C, D

61. $K_A(T_1 - T) = K_B(T - T_2)$

$T = \frac{K_AT_1 + K_BT_2}{K_A + K_B} \Rightarrow$ Hence option (A) is correct.

$$\frac{dQ}{dT} = \frac{T_1 - T_2}{\frac{r}{K_aA} + \frac{r}{K_BA}}$$

$K_m = \frac{2K_1K_2}{K_1 + K_2} \Rightarrow$ Hence option (D) is correct.

62. If a system is made to undergo a change from an initial state to a final state by adiabatic process only, then
(A) the work done is different for different paths connecting the two states.
(B) there is no work done since there is no transfer of heat.
(C) the internal energy of the system will change.
(D) the work done is the same for all adiabatic paths.

62. A, C

63. A small bar magnet is suspended by a thread. A torque is applied and the magnet is found to execute angular oscillations. The time period of oscillations.
(A) decreases with the moment of magnet.
(B) increases with the increase of the horizontal component of the earth's magnetic field.
(C) will remain unchanged even if another magnet is ketp at a distance.
(D) depends on the mass of the magnet.

63. A, D

63. Time period $T = 2\pi\sqrt{\frac{I}{mB}}$

64. A body of mass 1.0 kg moves in X-Y plane under the influence of the conservative force. Its potential energy is given by U = 2x + 3y where (x, y) denote the coordinates of the body. The body is at rest at (2, –4) initially. All the quantities have SI units. Therefore, the body
(A) moves along a parabolic path.
(B) moves with a constant acceleration.
(C) never crosses the X-axis.
(D) has a speed of $2\sqrt{13}$ m/s at time t = 2 s.

64. B, C, D

64. $\vec{a} = -2\hat{i} - 3\hat{j}$
$v = \sqrt{4^2 + 6^2} = 2\sqrt{13}$

65. Two balls A and B moving in the same direction collide. The mass of B is p times that of A. Before the collision the velocity of A was q times that of B. After the collision A comes to rest. If e be the coefficient of restitution then which of the following conclusion/s is/are correct?
(A) $e = \frac{p+q}{pq-p}$
(B) $q = \frac{p+q}{pq+p}$
(C) $p \geq \frac{q}{q-2}$
(D) $p \geq 1$

65. A, C, D

65. $v_1 = 0$
$e = \frac{p+q}{pq-p}$
$e \geq 0$
$p \geq \frac{q}{q-2}$

66. A ray is incident on a refracting surface of RI μ at an angle of incidence i and the corresponding angle of refraction is r. The deviation of the ray after refraction is given by $\delta = i - r$. Then, one may conclude that
(A) r increases with i
(B) δ increases with i
(C) δ decreases with i
(D) the maximum value of δ is $\cos^{-1}\left(\frac{1}{\mu}\right)$

66. A, B, D

66. $\delta_{max} = 90° - \sin^{-1}\left(\frac{1}{\mu}\right) = \cos^{-1}\left(\frac{1}{\mu}\right)$

67. In a bipolar junction transistor
(A) the most heavily doped region is the emitter.
(B) the level of doping is the same in both the emitter the collector.
(C) its base is the thinnest part.
(D) when connected in common emitter configuration a base current is generally of the order of μA.

67. A, C, D

68. A convex lens and a concave lens are kept in contact and the combination is used for the formation of image of a body by keeping it at different places on the principal axis. The image formed by this combination of lenses can be
(A) Magnified, inverted and real (B)Diminished, inverted and real
(C) Diminished, erect and virtual (D) Magnified, erect and virtual

68. A, B, C, D

69. In a series R-C circuit the supply voltage (V_S) is kept constant at 2V and the frequency f of the sinusoidal voltage is varied from 500 Hz to 2000 Hz. The voltage across the resistance R = 1000 ohm is measured each time as V_R. For the determination of the C a student wants to draw a linear graph and try to get C from the slope. Then she may draw a graph of
(A) f^2 against V_R^2 (B) $\frac{1}{f^2}$ against $\frac{V_S^2}{V_R^2}$
(C) $\frac{1}{f^2}$ against $\frac{1}{V_R^2}$ (D) f against $\frac{V_R}{\sqrt{V_S^2 - V_R^2}}$

69. B, C, D

69. $$V_R^2 = \frac{V_s^2 R^2}{R^2 + \frac{1}{4\pi^2 f^2 C^2}}$$
$$\frac{1}{4\pi^2 f^2 C^2} = R^2\left(\frac{V_s^2 - V_R^2}{V_R^2}\right)$$

70. A particle starting from rest at the highest point slides down the outside of a smooth vertical circular track of radius 0.3 m. When it leaves the track its vertical fall is h and the linear velocity is v. the angle made by the radius at the position of the particle with the vertical is θ. Now consider the following observations: (g = 10 m/s^2)
(I) h = 0.1 m and cos θ = 2/3. (II) h = 0.2 m and cos θ = 1/3 (III) $v = \sqrt{2}$ ms^{-1} (V) After leaving the circular track the particle will describe a parabolic path.
Therefore,
(A) (I) and (III) both are correct (B) only (II) is incorrect
(C) only (III) is correct (D) (IV) is correct

70. A, D

70. $$mgR(1-\cos\theta) = \frac{1}{2}mv^2$$
$$mg\cos\theta = \frac{mv^2}{r}$$
$$\therefore \cos\theta = \frac{2}{3},\ h = 0.1,\ v = \sqrt{2}$$