Resonance®
Educating for better tomorrow

# INDIAN ASSOCIATION OF PHYSICS TEACHERS

## NATIONAL STANDARD EXAMINATION IN PHYSICS (NSEP) 2018-19

**Examination Date : 25-11-2018** | **Time: 2 Hrs.** | **Max. Marks : 240**

**Q. PAPER CODE : P160** | **HBCSE Olympiad (STAGE - 1)**

Write the question paper code mentioned above on YOUR answer sheet (in the space provided), otherwise your answer sheet will NOT be assessed. Note that the same Q. P. Code appears on each page of the question paper.

### INSTRUCTIONS TO CANDIDATES

1. Use of mobile phones, smartphones, ipads during examination is **STRICTLY PROHIBITED.**
2. In addition to this question paper, you are given answer sheet along with Candidate's copy.
3. On the answer sheet, make all the entries carefully in the space provided ONLY in **BLOCK** CAPITALS as well as by properly darkening the appropriate bubbles.
   **Incomplete/Incorrect/carelessly filled information may disqualify your candidature.**
4. On the answer sheet, use only **BLUE or BLACK BALL POINT PEN** for making entries and filling the bubbles.
5. The email ID and date birth entered in the answer sheet will be your login credentials for accessing performance report. Please take care while entering.
6. Question paper has two parts. In Part A1(Q. Nos 1 to 60) each question has four alternatives, Out of which only one is correct. Choose the correct alternative and fill the appropriate bubble, as shown.

   **Q. No.22** (a) ● (c) (d)

   In Part A2 *(Q.* Nos. 61 to 70) each question has four alternatives out of which **any number of alternatives** (1, 2, 3 or 4) may be correct. You have to choose ALL correct alternatives and fill the appropriate bubbles, as shown.

   **Q. No.64** (a) ● (c) ●

7. For Part A1, each correct answer carries 3 marks whereas 1 mark will be deducted for each wrong answer. In Part A2, you get
   6 marks if all the correct alternatives are marked. No negative marks in this part.
8. Any rough work should be done only in the space provided.
9. Use of **non-programmable** calculator is allowed.
10. No candidate should leave the examination hall before the completion of the examination.
11. After submitting your answer paper, take away the Candidate's copy for your reference.
    **Please DO NOT make any mark other than filling the appropriate bubbles properly in the space provided on the answer sheet.**
    **Answer sheets are evaluated using machine, hence CHANGE OF ENTRY IS NOT ALLOWED.**
    **Scratching or overwriting may result in a wrong score.**
    **DO NOT WRITE ON THE BACK SIDE OF THE ANSWER SHEET.**

**Read the following instructions after submitting the answer sheet**

12. Comments regarding this question paper, if any, may be filled in Google forms only at https://google/forms/9GP03NRgUVuhWJn52 till 28th November, 2017.
13. The answers/solutions to this question paper will be available on our website — www.iapt.org.in by 2nd December, 2017.
14. **CERTIFICATES and AWARDS –**
    Following certificates are awarded by the LAPT to students successful in NSEs
    (i) "Centre Top 10%" that will be sent to NSE centre by post.
    (ii) "Statewise Top 1%" that can be downloaded after Feb-15, 2019 from iapt.org.in.
    (iii) "National Top 1%" . Certificate can be downloaded after Feb-15th, 2019 iapt.org.in
15. Result sheets can be downloaded from our website in the month of February. The "Centre Top 10%" certificates will be dispatched to the Prof-in-charge of the centre by February, 2018**.**
16. List of students (with centre number and roll number only) having score above MAS will be displayed on our website (www.iapt.org.in) by 22nd December, 2017. See the Eligibility Clause in the Student's brochure on our website.
17. Students eligible for the INO Examination on the basis of selection criteria mentioned in Student's brochure will be informed accordingly.

## Total Time : 120 minutes (A–1 and A–2)

## A – 1

## ONLY ONE OUT OF FOUR OPTIONS IS CORRECT

**1.** The SI unit of permeability of free space is

(A) $\frac{\text{weber}}{\text{ampere}}$ (B) $\frac{\text{henery}}{\text{ampere}}$ (C) $\frac{\text{tesla}}{\text{ampere} - \text{meter}}$ (D) $\frac{\text{weber}}{\text{ampere} - \text{meter}}$

**Ans.** **(D)**

**Sol.** Permeability of free space

m kg $s^{-2}$ $A^{-2}$

$\mu_0 I = B.ds.$

$\mu_0 = \frac{B.ds}{I}$

$= \frac{\text{weber}}{m^2} \; \frac{m}{I} = \frac{\text{weber}}{\text{amper} - \text{meter}}$

**2.** A uniform solid drum of radius R and mass M rolls without slipping down a plane inclined at an angle $\theta$. Its acceleration along the plane is

(A) $\frac{1}{3} g \sin\theta$ (B) $\frac{1}{2} g \sin\theta$ (C) $\frac{2}{3} g \sin\theta$ (D) $\frac{5}{7} g \sin\theta$

**Ans.** **(C)**

**Sol.** $a = \frac{g \sin\theta}{1 + (k^2 / R^2)}$

$= \frac{g \sin\theta}{1 + 1/2} = \frac{2g \sin\theta}{3}$

**3.** A particle moves according to the law x = at, y = at (1 – $\alpha$t) where a and $\alpha$ are positive constants and t is time. The time instant at which velocity makes and angle $\frac{\pi}{4}$ with acceleration.

(A) $\frac{4}{\alpha}$ (B) $\frac{3}{\alpha}$ (C) $\frac{2}{\alpha}$ (D) $\frac{1}{\alpha}$

**Ans.** **(D)**

**Sol.** x = at

$v_y = a$

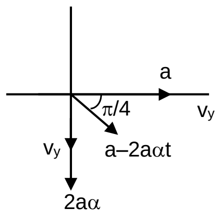
$a_y = 0$

$y = at - at - a\alpha t^2$

$v_y = a - 2a\alpha t$

$a_y = -2a\alpha$

$\tan\theta = 1$




$\frac{a}{-(a - 2a\alpha t)} = 1$

$a = -a + 2a\alpha t$

$2a = 2a\alpha t$

$t = \frac{1}{\alpha}$

**4.** The potential energy of a particle of mass m in conservative force field can be expressed as $U = \alpha x - \beta y$ where (x, y) denote the position coordinates of the body. The acceleration of the body is :

(A) $\frac{\alpha - \beta}{m}$ (B) $\frac{\alpha + \beta}{m}$ (C) $\frac{\sqrt{\alpha^2 - \beta^2}}{m}$ (D) $\frac{\sqrt{\alpha^2 + \beta^2}}{m}$

**Ans.** **(D)**

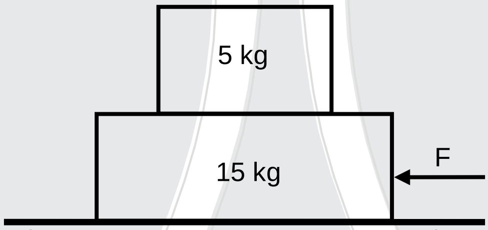
**Sol.** $U = ax - by$

$F_x = -a$

$F_y = b$

$F_{net} = \sqrt{a^2 + b^2}$ $a = \frac{\sqrt{a^2 + b^2}}{m}$

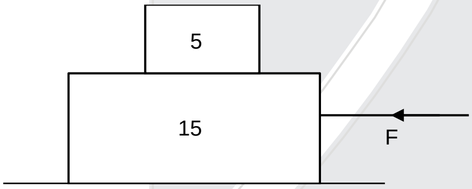
**5.** A constant force F applied to the lower block of mass 15 kg makes it slide between the upper block of mass 5 kg and the table below, as shown. The coefficients of static ($\mu_s$) and kinetic ($\mu_k$) friction between the lower block and the table are 0.5 and 0.4 respectively and those between the two blocks are 0.3 and 0.1. The accelerations of the upper and the lower blocks are respectively.




(A) 1.96 m/s² and 1.96 m/s² (B) 1.96 m/s² and 3.92 m/s²
(C) 0.98 m/s² and 0.49 m/s² (D) 0.98 m/s² and 1.96 m/s²

**Ans.** **(BONUS)**
**(CD)**

**Sol.**




$F - 80 = 20\ (3) \Rightarrow F = 140$

$a_{upper} = 1$ m/s², $a_2 = \frac{140 - 80 - 5}{15} = 3.67$m/s²

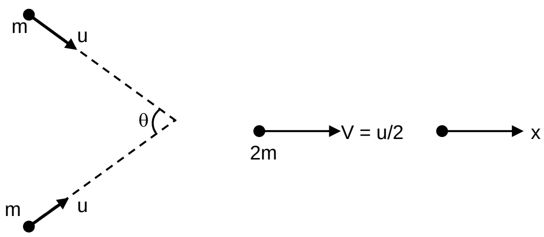
When slipping starts acceleration of upper block will be g/10 = 0.98 m/s². Acceleration of lower block will depend on F so answer may be (C) or (D)

**6.** Two bodies of equal masses moving with equal speeds make a perfectly inelastic collision. If the speed after the collision is reduced to half, the angle between their velocities of approach is.

(A) 30º (B) 60º (C) 90º (D) 120º

**Ans.** **(D)**

**Sol.**




According to linear momentum conservation along x-axis

$2mu\cos\frac{\theta}{2} = 2m\ \frac{u}{2}$ $\therefore \cos\frac{\theta}{2} = \frac{1}{2}$

$\frac{\theta}{2} = 60$

Hence $\theta = 120^\circ$

**7.** A student performs an experiment with a simple pendulum and records the time for 20 oscillations. If he would have recorded time for 100 oscillations, the error in the measurement of time priod would have reduced by a factor of

(A) 80 (B) 20 (C) 10 (D) 5

**Ans.** **(D)**

**Sol.** $T = \frac{t}{n}$

$\Delta T = \frac{\Delta t}{n}$

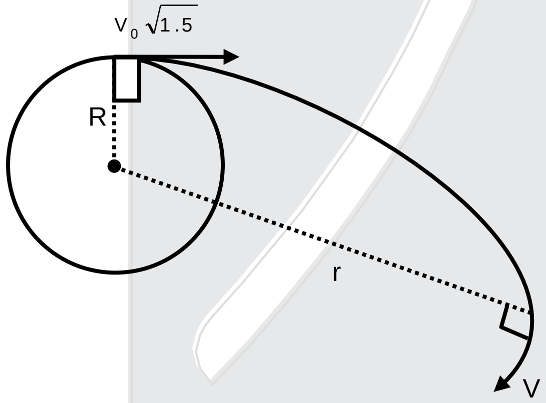
n is increased by a factor 5 so $\Delta T$ will decrease by a factor 5

**8.** A satellite is launched from a point close to the surface of the earth (radius R) with a velocity $v = v_0\sqrt{1.5}$ , where $v_0$ is the velocity in a circular orbit. If the initial velocity imparted to the satellite is horizontal, the maximum distance from the surface of the earth during its revolution is.

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

**Ans.** **(B)**

**Sol.**




**(B)**

Conservation of angular momentum

$mV_0\sqrt{1.5}R = mVr$

$V = \frac{V_0\sqrt{1.5}R}{r}$ ...........(i)

Conservation of energy

$\frac{1}{2}mV_0^2 1.5 - \frac{GMm}{R} = \frac{1}{2}mV^2 - \frac{GMm}{r}$

$\frac{3}{4}\frac{GM}{R} - \frac{GM}{R} = \frac{V_0^2 1.5R^2}{2r^2} - \frac{GM}{r}$

$-\frac{GM}{4R} = \frac{3GMR}{4r^2} - \frac{GM}{r}$

$\frac{3R}{4r^2} - \frac{1}{r} = \frac{-1}{4R}$

r = R, 3R $\Rightarrow$ taking r = 3R

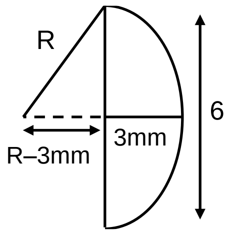
distance from surface = 2R

**9.** The aperture diameter of a plano-convex lens is 6 cm and its thickness is 3 mm. If the speed of light through its material is $v = 2 \times 10^8$ m/s. the focal length of the lens is

(A) 40 cm (B) 35 cm (C) 30 cm (D) 20 cm

**Ans.** **(C)**

**Sol.**




$\mu = 1.5$

Using Pythagoras theorem

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

$9 + R^2 + (.3)^2 - .6R = R^2$

$R = 15.15$

Using lens maker formula

$\frac{1}{f} = (1.5 - 1)\left(\frac{1}{R}\right)$

$= \frac{1}{2}\left(\frac{1}{15.15}\right)$

$f = 30.3$ cm

**10.** Under standard conditions of temperature and pressure a piece of ice melts completely on heating it. Obviously the increase in internal energy of the system (ice and water) is

(A) equal to the heat given (B) more than the heat given

(C) less than the heat given (D) zero.

**Ans.** **(B)**

**Sol.** On heating ice will convert into water and hence volume will decrease.
So change in internal energy will be more than heat supplied

**11.** Rocket fuel is capable of giving an exhaust velocity of $v_{rel} = 2.4$ km/s in the absence of any external forces. The fuel required per kg of the payload to provide an exhaust velocity of 12 km/s to the rocket is.

(A) 3670 kg (B) 8000 kg (C) 147.4 kg (D) 478.4 kg

**Ans.** **(C)**

**Sol.** $v = v_{rel}\,\ell n\left(\frac{m_0}{m}\right) = 12$ km/s

$\ell n\left(\frac{m_0}{m}\right) = 5$

$m_0 = me^5 = 148.41$ m kg

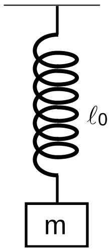
$m = 1$ kg, $m_0 = 148.41$kg

**12.** A vertical spring of length $\ell_0$ and force constant K is stretched by $\ell$ when a mass m is suspended from its lower end. By pulling the mass down a little the system is left off to oscillate. The time period of oscillation is.

(A) $2\pi\sqrt{\frac{\ell}{g}}$ (B) $2\pi\sqrt{\frac{\ell_0}{g}}$ (C) $\frac{1}{2\pi}\sqrt{\frac{m}{K}}$ (D) $2\pi\sqrt{\frac{\ell + \ell_0}{g}}$

**Ans.** **(A)**

**Sol.**




at eq. $mg = k\ell$

$\frac{m}{k} = \frac{\ell}{g}$

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

**13.** Let R be the radius of the earth. In general, the loss of gravitational potential energy of a body of mass m falling from a height h to the earth surface is

(A) mgh (B) $mgh\frac{R}{R+h}$ (C) $mgh\sqrt{\frac{R+h}{R}}$ (D) $mgh\sqrt{\frac{R}{R+h}}$

**Ans.** **(B)**

**Sol.** $\Delta U = -\frac{GMm}{R} + \frac{GMm}{R+h}$

$\frac{GM}{R^2} = g \qquad \Rightarrow GM = gR^2$

$\Delta U = -gmR + \frac{gmR^2}{R+h}$

$= -gmR\left(1 - \frac{R}{R+h}\right)$

Loss in P.E $= mgh\frac{R}{R+h}$

**14.** The velocity of a projectile at the highest point of its trajectory is $\sqrt{0.4}$ of its velocity at a point at half its maximum height. The angle of projection is.

(A) 30º (B) 45º (C) 60º (D) $\tan^{-1}\left(\sqrt{0.4}\right)$

**Ans.** **(C)**

**Sol.** $u_x = \sqrt{0.4}\sqrt{u_y^2 - 2g\frac{1}{2}\frac{u_y^2}{2g} + u_x^2}$

$\Rightarrow \frac{u_y}{u_x} = \sqrt{3} = \tan\theta \qquad \Rightarrow \theta = \frac{\pi}{3}$

**15.** The combination of a steel wire (length 80 cm, area of cross section 1 mm$^2$) and an aluminium wire (length 60 cm, area of cross section 3 mm$^2$) joined end to end is stretched by a tension of 160 N. If the densities of steel and aluminium are 7.8 g/cc and 2.6 g/cc respectively then, the minimum frequency of a tuning fork which can produce standing waves in the composite wire, with the joint as a node, is

(A) 179 Hz. (B) 358 Hz (C) 88 Hz (D) 118 Hz

**Ans.** **(B)**

**Sol.** Wave velocity in steel = $\sqrt{\frac{F}{\rho_s A_s}}$ $V_0 = 143.2$ m/s

Wave velocity in aluminum = $\sqrt{\frac{F}{\rho_a A_a}} = V_0 = 143.2$ m/s

Fundamental frequency in steel = $\frac{V_0}{1.6}$ = 89.5 hz

Fundamental frequency in aluminum = $\frac{V_0}{1.2}$ = 120 hz

Fundamental frequency of composite string = Lcm of both $\cong$ 358 Hz

**16.** In a stationary wave
(A) all the medium particles vibrate in the same phase
(B) all the particles between two consecutive nodes vibrate in the same phase
(C) any two consecutive nodes vibrate in the same phase
(D) all the particles between two consecutive antinodes vibrate in the same phase.

**Ans.** **(B)**

**Sol.** All the particles between two consecutive nodes vibrate in same phase.

**17.** An empty earthen pitcher is kept under a water tap and starts filling with water as the tap is opened. The pitch of the sound produced
(A) goes on decreasing
(B) goes on increasing
(C) first increases and then decreases after the pitcher is half filled
(D) does not change

**Ans.** **(B)**

**Sol.** Since frequency $\alpha \frac{1}{\ell}$ (here $\ell$ is empty space)

$\Rightarrow$ with time $\ell$ decreases and frequency increases so pitch also increases

**18.** The molar specific heat of an ideal gas in a certain thermodynamic process is $\frac{\alpha}{T}$ where $\alpha$ is a constant. If the adiabatic exponent is $\gamma = \frac{c_p}{c_v}$, the work done in heating the gas from $T_0$ to $nT_0$ is.

(A) $\frac{1}{\alpha}\ell nn$ (B) $\alpha \ell nn - \frac{(n-1)}{(\gamma-1)}RT_0$ (C) $\alpha \ell nn - (\gamma-1)RT_0$ (D) $\frac{(n-1)}{(\gamma-1)}RT_0$

**Ans.** **(B)**

**Sol.** $dQ = CdT = \frac{\alpha}{T}dT$

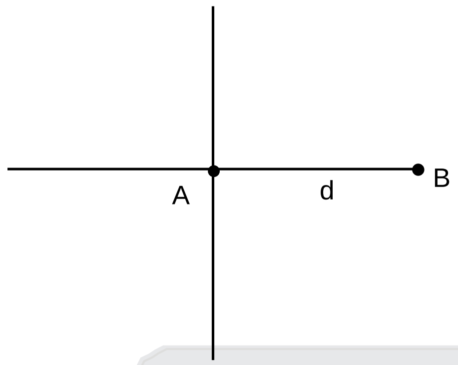
$\Delta Q = \alpha\, \ell n\, n$

$W = \Delta Q - \Delta u = \alpha\, \ell n\, n - \frac{R(n-1)T_0}{\gamma - 1}$

**19.** An aircraft flies at a speed v from city A to city B and back in time $t_0$. City B is to the east of city A at a distance d. The aircraft takes time $t_0$ for the round trip if wind blows with speed w along AB and time $t_2$ if the wind blows with the same speed perpendicular to AB. Then,
(A) $t_1 = t_2 = t_0$ (B) $t_1 > t_2 > t_0$ (C) $t_1 < t_2 < t_0$ (D) $t_1 > t_0 > t_2$

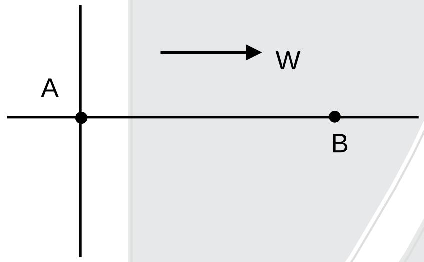
**Ans.** **(B)**

**Sol.** Case - 1




$t_0 = \frac{2d}{v}$

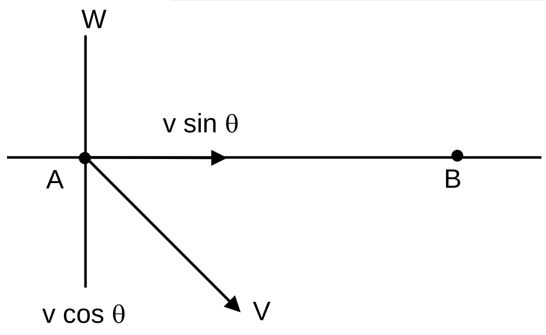
Case - 2




$t_1 = \frac{d}{v+w} + \frac{d}{v-w}$

$= \frac{2vd}{v^2 - w^2}$

Case - 3




$t_2 = \frac{2d}{v\sin\theta} = \frac{2d}{\sqrt{v^2 - w^2}}$

hence $t_2 > t_0$

$\Rightarrow t_1 > t_2 > t_0$

**20.** The Hubble telescope in orbit above the earth has a 2.4 m circular aperture. The telescope has equipment for detecting ultraviolet light. The minimum angular separation between two objects that the telescope can resolve in ultraviolet light of wavelength 95 mm is.

(A) $4.83 \times 10^{-8}$ rad (B) $4.03 \times 10^{-8}$ rad (C) $2.41 \times 10^{-8}$ rad (D) $2.00 \times 10^{-8}$ rad

**Ans. (A)**

**Sol.** 2.4 m circular aperture

$\lambda = 95$ nm

$$\theta = \frac{1.22\lambda}{D} = \frac{1.22 \times 95 \times 10^{-9}}{2.4\text{m}}$$

$= 4.83 \times 10^{-8}$ radius

**21.** A projectile is fired from ground with velocity u at an angle $\theta$ with the horizontal. It would be moving perpendicular to its initial direction of projection after a time t equal to

(A) $\frac{u\sin\theta}{g}$ (B) $\frac{2u\sin\theta}{g}$ (C) $\frac{u}{g\sin\theta}$ (D) $\frac{u}{2g\sin\theta}$

**Ans. (C)**

**Sol.** $\vec{u} = u\cos\theta\,\hat{i} + u\sin\theta\,\hat{j}$

$\vec{v} = u\cos\theta\,\hat{i} + (u\sin\theta - gt)\,\hat{j}$

$\vec{u} \cdot \vec{v} = 0$

$u^2\cos^2\theta + u^2\sin^2\theta - ug\sin\theta\, t = 0$

$$t = \frac{u}{g\sin\theta}$$

**22.** The critical angle for light passing from glass to air is minimum for the light of wavelength.

(A) 0.7 $\mu$m (B) 0.6 $\mu$m (C) 0.5 $\mu$m (D) 0.4 $\mu$m

**Ans. (D)**

**Sol.** $\text{Sin}\theta_c = \frac{\mu_{air}}{\mu_{glass}} = \frac{1}{\mu_{glass}}$

$\mu = a + \frac{b}{\lambda^2}$

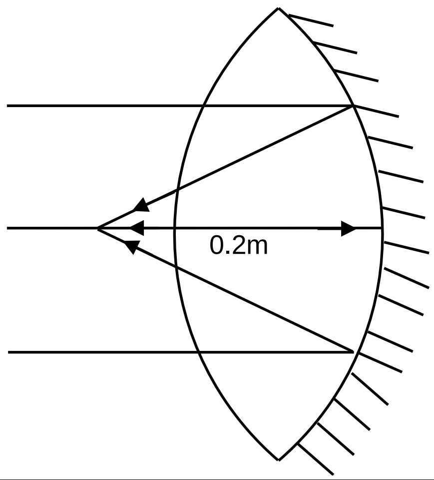
$\Rightarrow \theta_c$ will be minimum for $\lambda = 0.4\ \mu$m

**23.** A thin hollow equiconvex lens, silvered at the back, converges a beam of light parallel to the principal axis at a distance 0.2 m. When filled with water $\left(\mu = \frac{4}{3}\right)$, the same beam will be converged at a distance of

(A) 0.40 m (B) 0.20 m (C) 0.12 m (D) none of the above

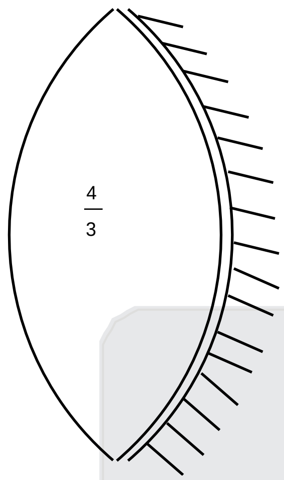
**Ans. (C)**

**Sol.**



R = 0.4 m = 40 cm

$$\frac{1}{f_{eq}} = \frac{1}{f_m} - \frac{2}{f_e}$$




$$= \frac{1}{-20} - 2 \times \left(\frac{4}{3} - 1\right)\left(\frac{1}{40} - \left(\frac{-1}{40}\right)\right)$$

$$= \frac{-1}{20} - 2 \times \frac{1}{3} \times \frac{1}{20}$$

$$= -\frac{1}{20} - \frac{1}{30} = -\left(\frac{3+2}{60}\right)$$

$$= \frac{-1}{12}$$

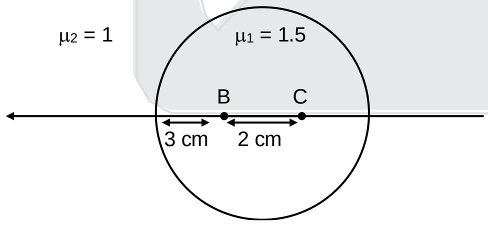
$f_{eq} = 12$

**24.** An air bubble is situated at a distance 2.0 cm from the centre of a spherical glass paper weight of radius 5.0 cm and refractive index 1.5. The bubble is seen through the nearest surface. If appears at a distance v from the centre. Therefore, v is

(A) 3.75 cm (B) 3.25 cm (C) 2.50 cm (D) 3.80 cm

**Ans.** **(C)**

**Sol.**




$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1}{v} - \frac{1.5}{-3} = \frac{1-1.5}{-5}$$

$$\frac{1}{v} + \frac{1}{2} = \frac{1}{10}$$

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{2} = \frac{1-5}{10} = \frac{-4}{10} = \frac{-2}{5}$$

$$v = \frac{-5}{2} = -2.5 \text{ cm}$$

**25.** A student while performing experiment with a sonometer with bridges separated by a distance of 80 cm missed out some of the observations. However, he claimed that the three resonant frequency for a given tuning fork were 84, 140 and 224 Hz. The speed of transverse waves on the wire is

(A) 33.30 m/s (B) 330. 0 m/s (C) 44.80 m/s (D) 448.0 m/s

**Ans.** **(C)**

**Sol.** f = fundamental frequency

$n_1^{th}$ harmonic = 84

$n_2^{th}$ harmonic = 140

$n_3^{th}$ harmonic = 224

$n_1f : n_2f : n_3f = 84 : 140 : 224$

$n_1 = 3$

$n_2 = 5$

$n_3 = 8$

$n_2f - n_1f = 140 - 84$

$(5 - 3)f = 56$

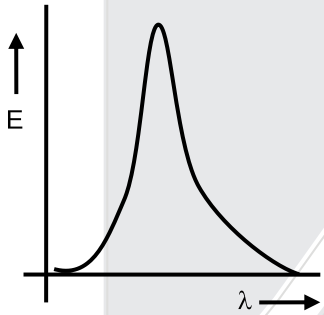
f = 28 Hz

$28 = \frac{v}{2\ell}$

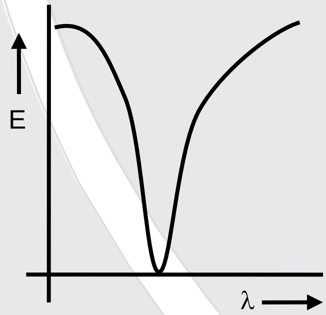
v = 44.80m/s

**26.** Which of the following curves represents spectral distribution of energy of black body radiation ?

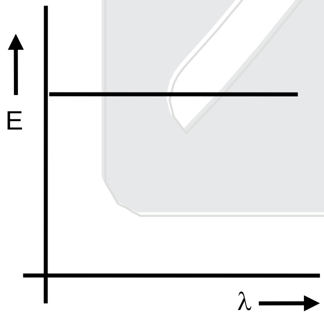
(A)



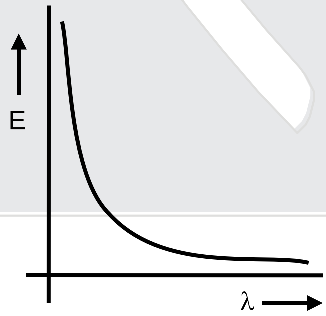

(B)




(C)




(D)




**Ans.** **(A)**

**Sol.** Self explanatory by theory

**27.** A sphere and a cube having equal surface area are made of the same material. The two are heated to the same temperature and kept in identical surrounding. The ratio of their initial rates of cooling is

(A) 1 : 1 (B) $\sqrt{\frac{\pi}{2}} : 1$ (C) $\sqrt{\frac{\pi}{3}} : 1$ (D) $\sqrt{\frac{\pi}{6}} : 1$

**Ans.** **(D)**

**Sol.** $\frac{dQ}{dt} = e\sigma AT^4$

$ms\frac{dQ}{dt} = e\sigma AT^4$

$$\frac{dQ}{dt} = \frac{e\sigma A}{ms}\left(T^4\right)$$

$$4\pi R^2 = 6a^2 \Rightarrow \sqrt{\frac{4\pi}{6}} = \frac{a}{R}$$

$M_S = \rho \frac{4}{3}\pi R^3$

$M_C = \rho a^3$

Ratio of Rate of cooling = $\frac{K_1}{K_2}$

$$= \frac{A_1/m_1}{A_2/m_2}$$

$$= \frac{m_2}{m_1} = \frac{\rho a^3}{\rho \frac{4}{3}\pi R^3}$$

$$= \frac{a^3}{\frac{4}{3}\pi R^3} = \frac{1}{4\frac{\pi}{3}}\left(\frac{4\pi}{6}\right)^{3/2}$$

$$= \frac{\sqrt{\frac{4\pi}{6}\frac{4\pi}{6}\frac{4\pi}{6}}}{\sqrt{\frac{4\pi}{3}\frac{4\pi}{3}}} = \sqrt{\frac{\pi}{6}} : 1$$

**28.** Consider the diffraction pattern due to a single slit. The first maximum for a certain monochromatic light coincides with the first minimum for red light or wavelength 660 nm. The wavelength of the monochromatic light is

(A) 660 nm (B) 550 nm (C) 440 nm. (D) 330 nm.

**Ans. (C)**

**Sol.** $(2n+1)\frac{\lambda'}{2} = n\lambda$

$\frac{3\lambda'}{2} = 660$

$\lambda' = \frac{660 \times 2}{3} = 440$ nm

**29.** A concave lens of focal length f produces an image (1/n) times the size of the object. The distance of the object from the lens is

(A) (n + 1)f (B) $\frac{(n-1)}{n}f$ (C) $\frac{(n+1)}{n}f$ (D) (n – 1)f

**Ans. (D)**

**Sol.**

$$\frac{h_i}{h_0} = \frac{1}{n} = \frac{v}{u} = \frac{f}{u+f}$$

u + f = nf

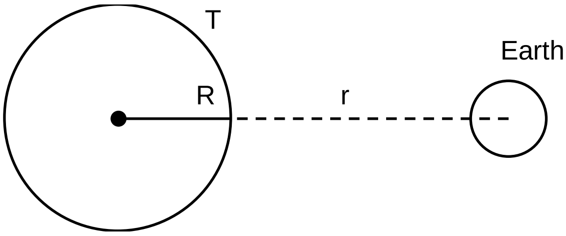
u = (n – 1)f

**30.** The Sun having radius R and surface temperature T, emits radiation as a perfect emitter. The distance of the earth from the sun is r and the radius of the earth is $R_e$. The total radiant power incident on the earth is

(A) $\frac{R_e^2 R^2 \sigma T^4}{4\pi r^2}$ (B) $\frac{R_e^2 R^2 \sigma T^4}{r^2}$ (C) $\frac{4\pi R_e^2 R^2 \sigma T^4}{r^2}$ (D) $\frac{\pi R_e^2 R^2 \sigma T^4}{r^2}$

**Ans. (D)**

**Sol.**




Intensity at distance r form sun

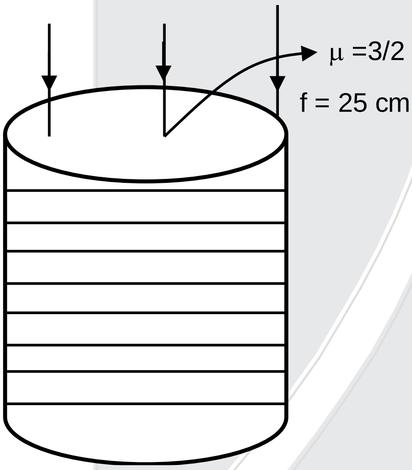
$$= \frac{\sigma T^4 4\pi R^2}{4nr^2}\,\pi\,R_e^2 \qquad = \frac{\sigma T^4 \pi R^2 R_e^2}{r^2}$$

**31.** A cylinder containing water (refractive index 4/3) is convered by an equiconvex glass (refractive idex 3/2) lens of focal length 25 cm. At the mid-day when the sun is just overhead, the image of the sun will be seen at a distance of

(A) 100 cm. (B) 50 cm. (C) 37.5 cm. (D) 25 cm.

**Ans.** **(B)**

**Sol.**




$$\frac{\mu_3}{v} - \frac{\mu_1}{u} = \frac{n_2 - 1}{R_1} + \frac{n_w - n_L}{R_2}$$

$$\frac{4}{3v} = \frac{\frac{3}{2} - 1}{R_1} + \frac{\frac{4}{3} - \frac{3}{2}}{R_2}$$

$$\frac{1}{f} = \left(\frac{3}{2} - 1\right)\frac{2}{R}$$

$$\frac{1}{25} = \frac{1}{R}$$

$$\frac{4}{3v} = \frac{1}{2(25)} + \frac{1}{6(25)}$$

$$\frac{4}{3v} = \frac{3}{150} + \frac{1}{150}$$

$$\frac{4}{150} = \frac{4}{3v}$$

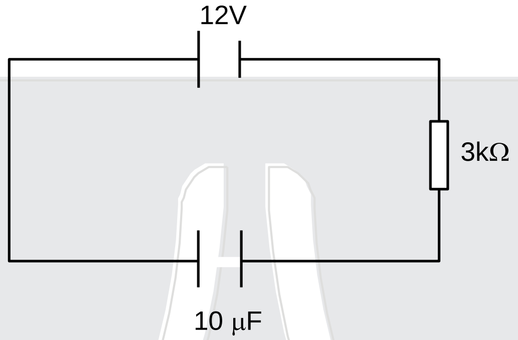
v = 50 cm

**32.** A rectangular loop carrying a current is placed in a uniform magnetic field. The net force acting on the loop
(A) depends on the direction and magnitude of the current
(B) depends on the direction and magnitude of the magnetic field
(C) depends on the area of the loop
(D) is zero

**Ans.** **(D)**

**Sol.** Force on a closed loop in uniform magnetic field is zero.

**33.** The capacitor in the circuit shown below carries a charge of 30 μC at a certain time instant. The rate at which energy is being dissipated in the 3KΩ resistor at the instant is




(A) 4 mW (B) 9 mW (C) 27 mW (D) 48 mW

**Ans.** **(C)**

**Sol.** $q = c\varepsilon(1 - e^{-t/\tau})$

$i = \frac{\varepsilon}{R} e^{-t/\tau}$

$P = i^2 R$

$P = \frac{\varepsilon^2}{R} e^{-2t/\tau}$ .......... (1)

$30 = 120(1 - e^{-t/\tau})$

$e^{-t/t} = \frac{3}{4}$ .......... (2)

From (1) & (2)

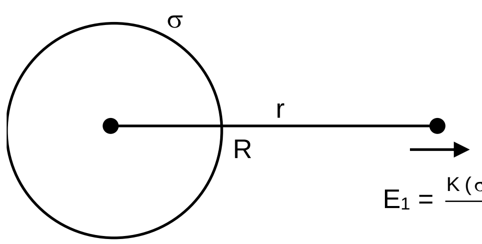
$P = \frac{144}{3000} \times \frac{9}{4}$

= 27 mw

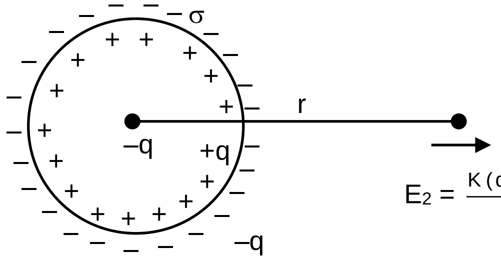
**34.** A hollow conducting sphere of radius 15 cm has a uniform surface charge density +3.2 μC/m$^2$. When a point charge q is placed at the centre of the sphere, the electric field at 25 cm from the centre just reverses its direction keeping the magnitude the same. Therefore, q is
(A) + 0.91 μC (B) –0.91 μC (C) +1.81 μC (D) –1.81 μC

**Ans.** **(D)**

**Sol.**




$E_1 = \frac{K(\sigma 4\pi R^2)}{r^2}$



$E_2 = \frac{K(q - \sigma 4\pi R^2)}{r^2}$

$E_1 = E_2$

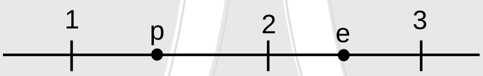
$\Rightarrow \frac{K\sigma.4\pi R^2}{r^2} = \frac{K}{r^2}(q - \sigma.\,4\pi R^2)$

$\Rightarrow q = 2 \times 4\pi R^2.\sigma$

$q = 8\pi R^2\,\sigma$

$= 1.81\ \mu c$

**35.** An electron e and a proton (p) are situated on the straight line as shown below. The directions of the electric field at the points 1,2 and 3 respectively, are shown as

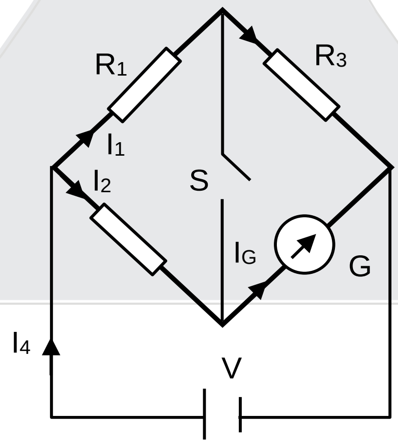


(A) $\rightarrow \leftarrow \rightarrow$ (B) $\leftarrow \rightarrow \leftarrow$ (C) $\leftarrow \rightarrow \rightarrow$ (D) $\rightarrow \leftarrow \leftarrow$

**Ans.** **(B)**

**Sol.** $E \propto \frac{1}{r^2}$

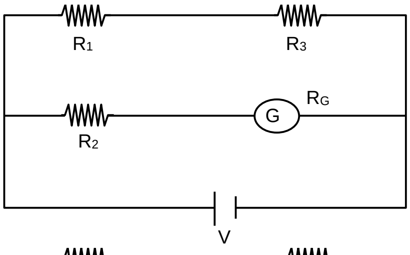
**36.** In the circuit shown $R_1 \neq R_2$. The reading in the galvanometer is the same with switch S open or closed. Then

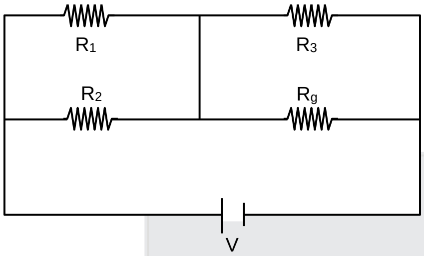


(A) $I_1 = I_G$ (B) $I_2 = I_G$ (C) $I_3 = I_G$ (D) $I_4 = I_G$

**Ans.** **(B)**

**Sol.**




$I_2 = I_G$

Circuit behaving $a_0$

Balanced Wheatstone network

**37.** A thin wire of length 1 m is placed perpendicular to the XY plane. If it is moved with velocity $\vec{v} = 4\hat{i} - \hat{j}$ m/s in the region of magnetic induction $\vec{B} = \hat{i} + 4\hat{j}$ Wb/m$^2$. The potential difference developed between the ends of the wire is

(A) zero (B) 3 V (C) 15 V (D) 17 V.

**Ans.** **(D)**

**Sol.** $E_{ind} = Bv\ell$

$= \sqrt{17} \,.\, \sqrt{17} \times 1$

$= 17$ V

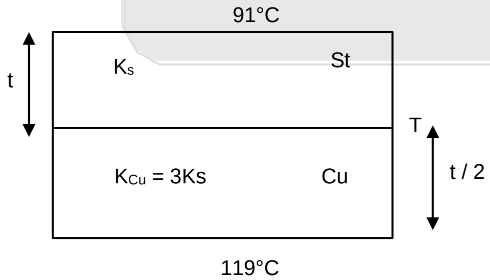
$\vec{B}$ is $\perp^r$ to $\vec{v}$ $\perp^r$ to $\vec{\ell}$

**38.** A steel cooking pan has copper coating at its bottom. The thickness of copper coating is half the thickness of steel bottom. The conductivity of copper is three times the of steel. If the temperature of blue flame is 119°C and that of the interior of the cooking pan is 91°C then the temperature at the interface between the steel bottom and the copper coating in the steady state is

(A) 98° C (B) 103° C (C) 115° C (D) 108°C

**Ans.** **(C)**

**Sol.**




$$3K_s A \frac{119 - T}{(t/2)} = \frac{AK_s.(T - 91)}{t}$$

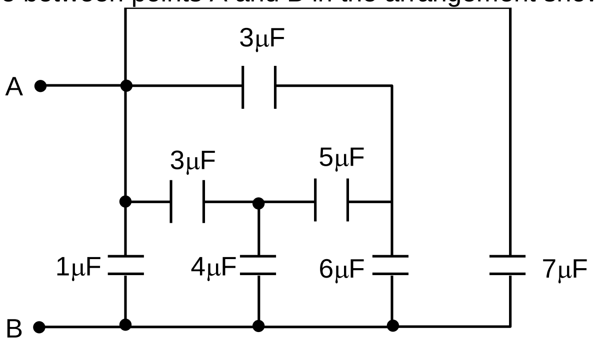
$\Rightarrow 2 \times (357 - 3T) = (T - 91)$

$\Rightarrow 714 - 6T = T - 91$

$\Rightarrow 714 + 91 = 7T$

$\Rightarrow T = \frac{805}{7} = 115°C$

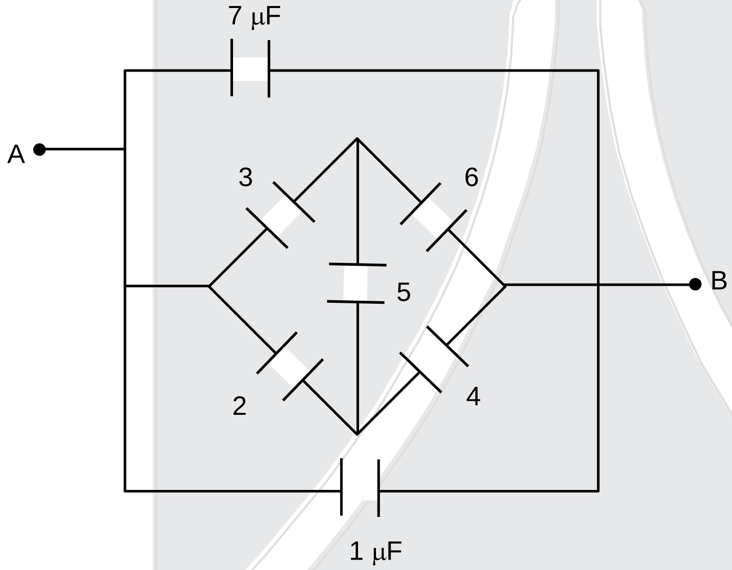
**39.** The total capacitance between points A and B in the arrangement shown below is




(A) 28 μF (B) $\frac{34}{7}$ μF (C) 23 μF (D) $\frac{34}{3}$ μF

**Ans.** **(D)**

**Sol.**




Note : - Midle Network is Balanced Wheatotone network

$C_{eq} = 7 + 1 + \left(2 + \frac{4}{3}\right)$

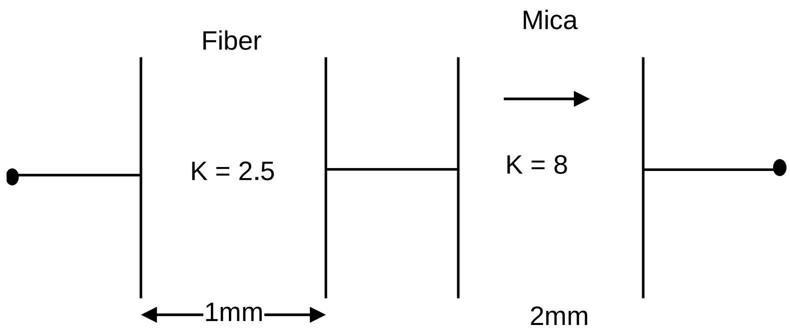
$= 10 + \frac{4}{3} = \frac{34}{3}$ μF

**40.** A fiber sheet of thickness 1 mm and a mica sheet of thickness 2 mm are introduced between two metallic parallel plates to form a capacitor. Given that the dielectric strength of fiber is 6400 kV/m and the dielectric constants of fiber and mica are 2.5 and 8 respectively, the electric field inside the mica sheet just at the breakdown of fiber will be

(A) 2000 kV/m (B) 2048 kV/m (C) 3200 kV/m (D) 6400 kV/m

**Ans.** **(A)**

**Sol.**




$E_1d_1 = V_1 = \frac{Q}{C_1} = \frac{Qd_1}{\varepsilon_0 AK_1}$

$E_2d_2 = \frac{Q}{C_2} = \frac{Qd_2}{\varepsilon_0 AK_2}$

$\Rightarrow \frac{E_1}{E_2} = \frac{K_2}{K}$

$\Rightarrow E_2 = \frac{K_2}{K_1}$

$\Rightarrow E_2 = \frac{K_1}{K_2} E_{1_{max}}$

$= \frac{5/2}{8} \times 6400$ kv/m

= 2000 kv / m

**41.** The position vector of a point mass is expressed as $\vec{r} = at\hat{i} + bt^2\hat{j}$. The trajectory of the particle is

(A) a straight line (B) a parabola (C) a hyperbola (D) none of the above

**Ans.** **(B)**

**Sol.** x = at

y = bt$^2$

y = b $\frac{x^2}{a^2}$ parabola

**42.** In a series LCR circuit fed with an alternating emf E = $E_0$ sin $\omega$t,

(A) the voltage across L is in phase with the applied emf E.

(B) the voltage across R is in phase with the applied emf E.

(C) the voltage across R is in phase with the applied emf E.

(D) the voltages across L, C and R are all in phase with the applied emf E.

**Ans.** **(BONUS)**

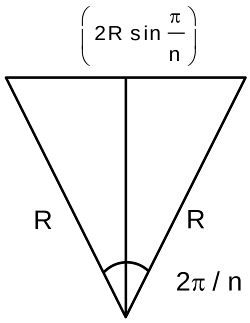
**Sol.** Voltage acros R may be in phase with source voltage provided circuit is Resistive $\left(\omega L = \frac{1}{\omega C}\right)$

**43.** A conducting wire is bent in the form of a n sided regular polygon enclosed by a circle of radius R. The magnetic field produced at its centre by a current I flowing through the wire is

(A) $\frac{\mu_0 i}{2R}\frac{\sin\frac{\pi}{n}}{\frac{\pi}{n}}$ (B) $\frac{\mu_0 i}{2R}\frac{\cos\frac{\pi}{n}}{\frac{\pi}{n}}$ (C) $\frac{\mu_0 i}{2R}\frac{\tan\frac{\pi}{n}}{\frac{\pi}{n}}$ (D) $\frac{\mu_0 i}{2R}\frac{\cot\frac{\pi}{n}}{\frac{\pi}{n}}$

**Ans.** **(C)**

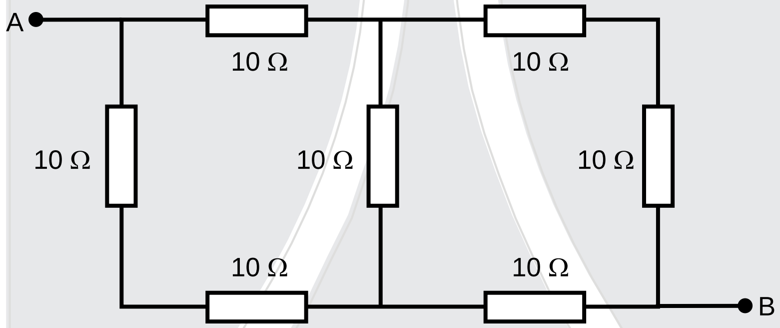
**Sol.**




$$\vec{B}_{Net} = n \cdot \frac{\mu_0 I}{4\pi(R\cos\pi/n)} \cdot \left(2\sin\cdot\frac{\pi}{n}\right)$$

$$= \frac{\mu_0 n I}{2\pi R}\tan\frac{\pi}{n}$$

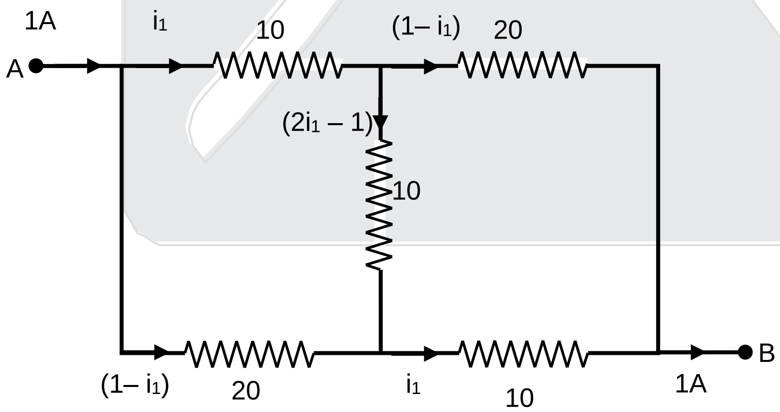
**44.** The effective resistance between points A and B in the circuit arrangement shown below is




(A) 14 Ω (B) 15 Ω (C) 30 Ω (D) None of these

**Ans.** **(A)**

**Sol.**




KVL : $10i_1 + (2i_1 - 1)\cdot 10 - 20(1 - i_1) = 0$

$\Rightarrow 50\ i_1 = 30$

$\Rightarrow i_1 = 3/5$

$$\therefore R_{eq} = \frac{V_{AB}}{I_{AB}} = \frac{10i_1 + 20(1-i_1)}{1A}$$

$$= 10\times\frac{3}{5} + 20\times\frac{2}{5} = 14\Omega$$

**45.** The magnetic dipole moment of an electron in the S state of hydrogen atom revolving in a circular orbit of radius 0.0527 nm with a speed $2.2 \times 10^6$ m/s is
(A) $4.64 \times 10^{-24}$ Am$^2$ (B) $9.28 \times 10^{-24}$ Am$^2$ (C) $18.56 \times 10^{-24}$ Am$^2$ (D) $2.32 \times 10^{-24}$ Am$^2$

**Ans.** **(B)**

**Sol.** $\vec{M} = I\vec{A}$

$= \frac{e.v}{2\pi r}\pi r^2$

$= \frac{evr}{2}$

$= \frac{1.6 \times 10^{-19} \times 2.2 \times 10^{6} \times 0.0527 \times 10^{-9}}{2}$

$= 9.2752 \times 10^{-24}$ Am$^2$

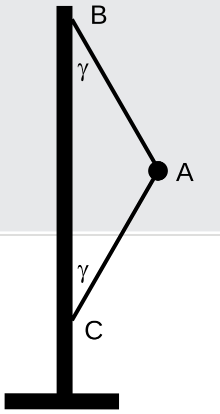
$= 9.28 \times 10^{-2}$ Am$^2$

**46.** A steel cable hanging vertically can support a maximum load W. The cable is cut to exactly half of its original length, the maximum load that is can support now is.
(A) W
(B) $\frac{W}{2}$
(C) 2W
(D) More than $\frac{W}{2}$ but less than W

**Ans.** **(A)**

**Sol.** Breaking strength remains same
$\Rightarrow$ Maximum load remain same

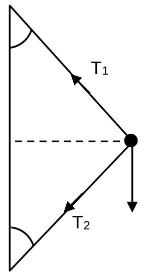
**47.** The strings AB and AC each of length 40 cm, connect a ball of mass 200 g to a vertical shaft as shown. When the shaft rotates a constant angular speed $\omega$, the ball travels in a horizontal circle with the strings inclined at $\gamma = 30^o$ to the shaft. If the tension in the string AC is 4N, that in the string AB and the angular speed $\omega$ respectively, are




(A) 6.26 N and 11.32 rad/s (B) 7.92 N and 14.32 rad/s
(C) 7.92 N and 11.32 rad/s (D) 6.26 N and 14.32 rad/s

**Ans.** **(A)**

**Sol.**




$\Rightarrow$ Mg + $T_2$ cos 30° = $T_1$ cos 30°

$\Rightarrow \frac{\sqrt{3}}{2} T_1 = 2 + \frac{4\sqrt{3}}{2} \Rightarrow T_1 = 4\left(\frac{1+\sqrt{3}}{\sqrt{3}}\right) \Rightarrow T_1 = 6.26$ N

# $T_1 \sin 30° + T_2 \sin 30° = M\omega^2 \times 0.4 \sin 30°$

$\Rightarrow 4\left(\frac{1+\sqrt{3}}{\sqrt{3}}\right) \times \frac{1}{2} + \frac{4}{2} = 0.2 \times \omega^2 \times 0.2$

$\Rightarrow \omega^2 = \frac{2}{0.2 \times 0.2}\left(\frac{1}{\sqrt{3}} + 2\right)$

$\Rightarrow \omega$ = 11.32 rad/sec

**48.** A tightly wound long solenoid carries a current 5A. An electing shot perpendicular to the solenoid axis inside it revolves at a frequency $10^8$ rev/s. The number of turns per meter length of the solenoid is

(A) 57 (B) 176 (C) 569 (D) 352

**Ans. (C)**

**Sol.** $\omega = \frac{qB}{m}$

$\Rightarrow \omega = \frac{q}{m} \mu_0 nI$

$\Rightarrow n = \frac{m\omega}{\mu_0 qI} = \frac{9.1 \times 10^{31} \times 2\pi \times 10^8}{4\pi \times 10^{-7} \times 1.6 \times 10^{-19} \times 5}$

$= \frac{9.1}{16} \times 10^3 = 569$

**49.** The same alternating voltage v = $V_0 \sin(\omega t)$ is applied in both the LCR circuits shown below. The current through the resistance R at resonance is

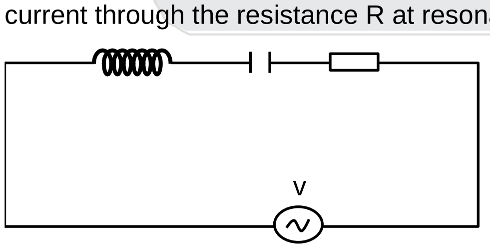



Figure -1

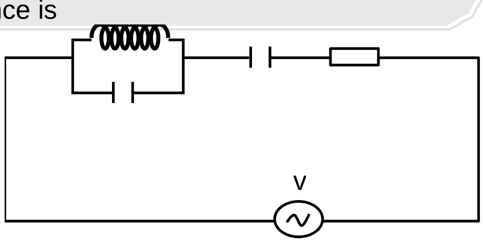


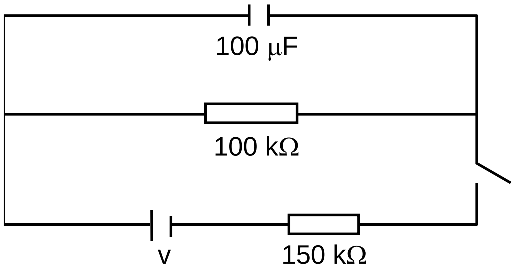

Figure -2

(A) Maximum in fig. (1) and maximum in fig. (2).
(B) Minimum in fig. (1) and maximum in fig. (2).
(C) Maximum in fig. (1) and minimum in fig. (2).
(D) Minimum in fig. (1) and minimum in fig. (2).

**Ans. (C)**

**Sol.** Circuit A behaves as an acceptor circuit (current maximizes at resonance) whereas circuit B behaves as a rejecter circuit (current minimizes at resonance).

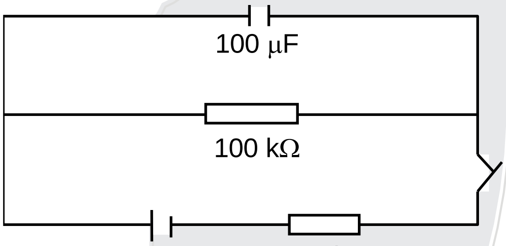
**50.** The switch S in the circuit shown is closed for a long time and then opened at time t = 0. The current in the 100 kΩ resistance at t = 3s is




(A) Zero (B) 48 μA (C) 35.5 μA (D) 16 μA

**Ans.** **(BONUS)**

**Sol.**




After very long time

$V_c = \frac{2v}{5}$

$\Rightarrow Q_c = \left(\frac{2v}{5} \times 100\right) \mu c$

$= (40\ v)\mu c$

$\frac{V_{100\ k\Omega}}{V_{150\ K\Omega}} = \frac{100}{150} = \frac{2}{3}$

Now from t = 0 discharging of capacitor will start time constant of discharging

$= RC = 100 \times 10^3 \times 100 \times 10^{-6}$

$= 100$ sec

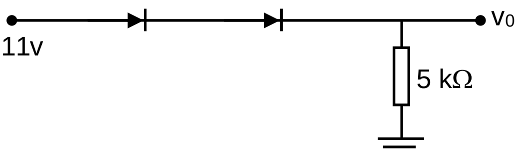
$v = v_0\, e^{-t/RC}$

$\Rightarrow v' = \frac{2v}{5} e^{-t/10}$

$\Rightarrow q = cv'$

$i = \frac{-dq}{dt}$

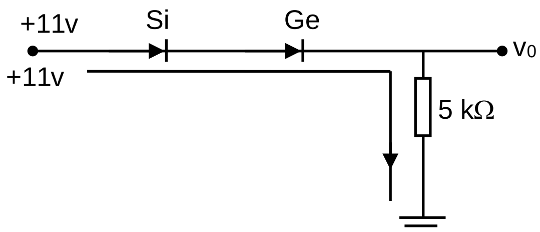
**51.** In the network shown below the voltage $V_0$ is is nearly




(A) 10 volt (B) 11 volt (C) 12 volt (D) Zero volt

**Ans.** **(A)**

**Sol.**




$V_{si}$ = 0.7 v
$V_{ac}$ = 0.3 v
$V_0$ = 11 – 0.7 – 0.3
$V_0$ = 10 volt

**52.** The energy of the characteristic X-ray photon in a Coolidge tube comes from
(A) The kinetic energy of striking electron.
(B) The kinetic energy of the free electrons of the target.
(C) The kinetic energy of the ions of the target.
(D) The electronic transition of the target atom.

**Ans.** **(D)**

**Sol.** Energy of x-rays in chracterstic x-ray photon comes from electronic transition of in the target atom

**53.** The maximum wavelength that can ionize a hydrogen atom initially in the ground state is
(A) 660.0 nm. (B) 364.5 nm. (C) 121.9 nm. (D) 91.4 nm.

**Ans.** **(D)**

**Sol.** Maximum wavelength $\Rightarrow$ minimum energy i.e transition takes place from n = 1 to n = $\infty$
$\Rightarrow \Delta E = 13.6$ eV
$\Rightarrow \lambda = 12400$ Å
= 914 Å = 91.4 nm

w

**54.** The wavelength of the waves associated with a proton and a photon are the same. Therefore, the two have equal
(A) Mass. (B) Velocity. (C) Momentum. (D) Kinetic energy.

**Ans.** **(C)**

**Sol.** $P = \frac{h}{\lambda}$

$E_{photon} = \frac{h}{\lambda}$

$E_{proton} = \frac{P^2}{2m}$

only momentum can be equal

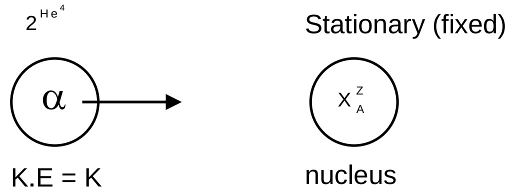
**55.** Which of the following sources emits light having highest degree of coherence?
(A) Light emitting diode. (B) LASER diode.
(C) Neon lamp. (D) Incandescent lamp.

**Ans..** **(B)**

**56.** An alpha particle with kinetic energy K approaches a stationary nucleus having atomic number Z. The distance of closest approach is b. Therefore the distance of closest approach for a nucleus of atomic number 2Z is
(A) b/2. (B) $\sqrt{2}$ b. (C) 2 b. (D) 4 b.

**Ans.** **(C)**

**Sol.**




$K = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{r}$

$r = \frac{2ze^2}{4\pi\varepsilon_0 K} \Rightarrow r = \frac{2Ze^2}{4\pi\varepsilon_0 K} = b$

$K = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(2Ze)}{r_{min}}$

$r_{min} = \frac{4Ze^2}{4\pi\varepsilon_0 K}$

$\Rightarrow r_{min} = 2b$

**57.** In a photodiode the reverse current increases when exposed to light of wavelength 620 nm or less. The band gap of the semiconductor used is

(A) 0.67 eV. (B) 1.12 eV. (C) 2.00 eV. (D) 2.42 eV.

**Ans.** **(C)**

**Sol.** $\Delta E = \frac{1240}{620} = 2eV$

**58.** An electron in hydrogen atom jumps from a level n = 4 to n = 1. The momentum of the recoiled atom is

(A) $6.8 \times 10^{-27}$ kg-m/s (B) $12.75 \times 10^{-19}$ kg-m/s (C) $13.6 \times 10^{-19}$ (D) zero

**Ans.** **(A)**

**Sol.** $\Delta E = 13.6\left(1 - \frac{1}{16}\right) = \frac{13.6 \times 15}{16} = \frac{51}{4}$

$= 12.75\text{ eV} = \frac{12.75 \times 1.6 \times 10^{-19}}{3 \times 10^8}$

Photon will take away almost all of the energy

$\frac{hc}{\lambda} = 12.75eV$

$\Rightarrow \frac{h}{\lambda} = \left(\frac{12.75}{c}\right) = P_{photon} = P_{revoled\ atom}$

$= 6.8 \times 10^{-27}$ kg m/s

**59.** For the Boolean equation $Y = AB + A(B + C) + B(B + C) + \overline{B}$ , which of the following statements is correct ?

(A) Y does not depend on A but depends on B
(B) Y does not depend on B but depends on A
(C) Y does not depend on B
(D) Y depends only on C

**Ans.** **(C)**

**Sol.** $Y = AB + A(B + C) + B(B + C) + \bar{B}$

$Y = AB + AB + AC + BB + BC + \bar{B}$

$Y = AB + AC + BC$

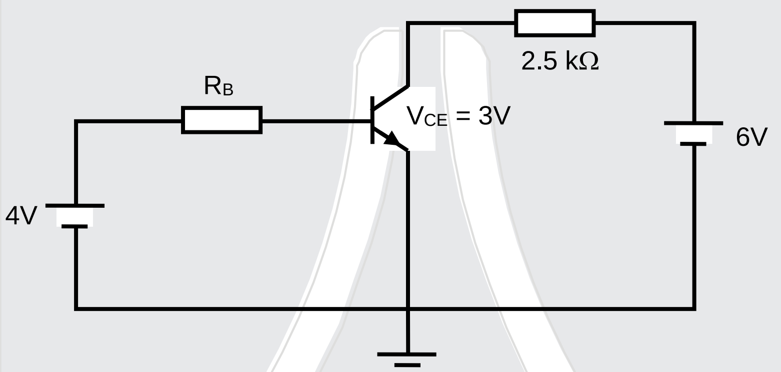
| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 |

$Y = AB + AB + AC + B + BC + \bar{B}$

$Y = AB + AC + BC + 1$

$Y = 1$

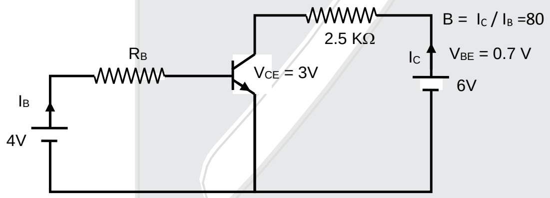
**60.** Refer to the common emitter amplifier circuit shown below, using a transistor with $\beta = 80$ and $V_{BE} = 0.7$ volt. The value of resistance $R_B$ is




(A) 330 Ω (B) 330 kΩ (C) 220 Ω (D) 220 kΩ

**Ans.** **(D)**

**Sol.**




$4 - I_BR_B - V_{BE} = 0$

$\Rightarrow I_B R_B = 4 - 0.7 = 3.3$ volt ...(i)

$6 - I_C = (2.5 \times 10^3) - 3V = 0$

$\Rightarrow I_C = \frac{3}{2.5 \times 10^3} = 1.2 \times 10^{-3}$

$= \frac{I_C}{I_B} = B \Rightarrow \frac{1.2 \times 10^{-3}}{I_B} = 80$

$\Rightarrow I_B = \frac{1.2 \times 10^{-3}}{800}$

$\Rightarrow I_B = 1.5 \times 10^{-5}$ A

Substitution in eq (i)

$1.5 \times 10^{-5} \times R_B = 3.3$

$R_B = \frac{3.3}{1.5 \times 10^{-5}}$

$= \frac{33}{15} \times 10^5$

$= 2.2 \times 10^5\ \Omega$

$R_B = 220\ K\Omega$

## A – 2

**In Q. Nos. 61 to 70 any number of options (1 or 2 or 3 or all 4) may be correct. You are to identify all of them correctly to get 6 marks. Even if one answer identified is incorrect or one correct answer is missed, you get zero marks.**

**61.** A horizontal insulated cylinder of volume V is divided into four identical compartments by stationary semi-permeable thin partitions as shown. The four compartments from left are initially filled with 28 g helium , 160 g oxygen, 28 g nitrogen and 20 g hydrogen respectively. The left partition lets through hydrogen, nitrogen and helium while the right partition lets through hydrogen sonly. The middle partition lets through hydrogen and nitrogen both. The temperature T inside sthe entire cylinder is maintained constant . After the system is set in equilibrium.

| | | | |
|---|---|---|---|
| He | $O_2$ | $N_2$ | $H_2$ |

(A) pressure of helium is $\frac{14\ RT}{V}$ (B)pressure of oxygen is $\frac{20\ RT}{V}$

(C) pressure of nitrogen is $\frac{4RT}{3V}$ (D) pressure of hydrogen is $\frac{10\ RT}{V}$

**Ans. (ABCD)**

**Sol.**

| | | | |
|---|---|---|---|
| 28 g He $n_1 = 7$ | 160 g $O_2$ $n_2 = 5$ | 28 g $N_2$ $n_3 = 1$ | 20 g $H_2$ $n_4 = 10$ |

After

| | | | |
|---|---|---|---|
| He $H_2$ $N_2$ | He $H_2$ $N_2$ | – $H_2$ $N_2$ | – $H_2$ |

$$P_{He} = \frac{n_1RT}{V/2} = \frac{7RT}{V/2} = \frac{14\ RT}{V}$$

$$P_{O_2} = \frac{n_2RT}{V/4} = \frac{5RT}{V/4} = \frac{20\ RT}{V}$$

$$P_{N_2} = \frac{n_3RT}{\frac{3}{4}V} = \frac{4}{3}\frac{RT}{V}$$

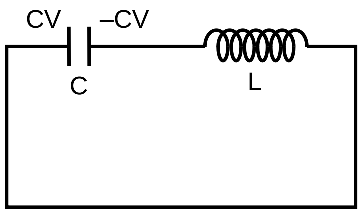
$$P_{H_2} = \frac{n_4RT}{V} = \frac{10\ RT}{V}$$

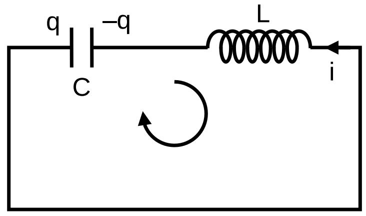
**62.** After charging a capacitor C to a potential V, it is connected across an ideal inductor L. The capacitor starts discharging simple harmonically at time t = 0. The charge on the capacitor at a later time instant is q and the periodic time of simple harmonic oscillations is T. Therefore,

(A) $q = CV \sin(\omega t)$ (B) $q = CV \cos(\omega t)$ (C) $T = 2\pi\sqrt{\frac{1}{LC}}$ (D) $T = 2\pi\sqrt{LC}$

**Ans. (BC)**

**Sol.**




t = 0 time 't'

Applying KVL

$-\frac{q}{C} + \frac{Ldi}{dt} = 0$

$i = \frac{-dq}{dt}$

$\therefore \frac{d^2q}{dt^2} = -\frac{1}{LC}q$ $\quad T = 2\pi\sqrt{LC}$ $\quad \omega = \frac{1}{\sqrt{LC}}$

$\therefore$ q = $q_0$sin ($\omega$t + $\phi$)

I = $q_0\omega$ cos ($\omega$t + $\phi$)

t = 0 i = 0

$\Rightarrow$ cos$\phi$ = 0

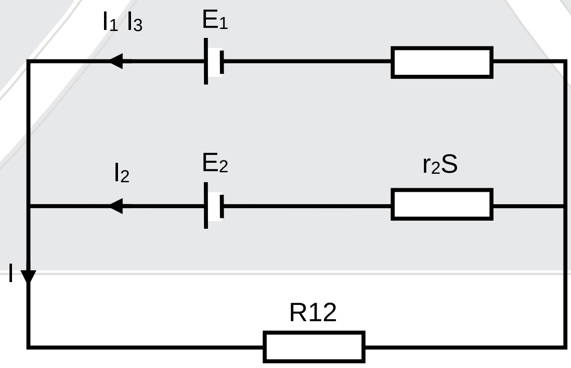
$\Rightarrow \phi = \frac{\pi}{2}$

$\therefore$ q = $q_0$ cos$\omega$t

t = 0 q = CV $\Rightarrow$ CV = $q_0$

$\therefore$ q = CV cos$\omega$t

**63.** In the circuit arrangement shown two cells supply a current I to a load resistance R = 9 Ω . One cell has an emf $E_1$ = 9V and internal resistance $r_1$ = 1 Ω and the other cell has an emf $E_2$ = 6V and internal resistance $r_2$ = 3 Ω . The currents are as shown. Then,



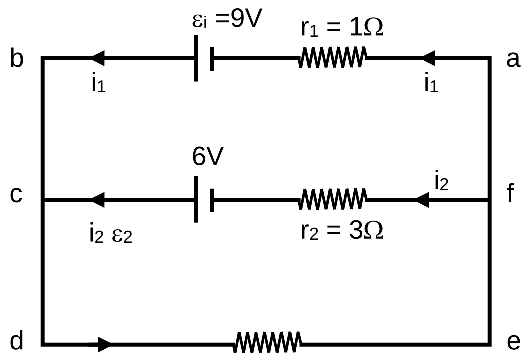

(A) $I_1$ = 0.9 A and $I_2$ = 0.5 A. (B) I ≅ 0.85 A

(C) if the cell of emf $E_1$ is removed, current I will be smaller.

(D) if the cell of emf $E_2$ is removed, current I will be smaller.

**Ans. (BD)**

**Sol.**




$i = i_1 + i_2$ 9

$$\varepsilon = \frac{\frac{9}{1}+\frac{6}{3}}{\frac{1}{1}+\frac{1}{3}} = \frac{11\times 3}{4} = \frac{33}{4}\text{V} \qquad r = \frac{3}{4}\Omega$$

$$i = i_1 + i_2 \qquad = \frac{33\ /\ 4}{9+\frac{3}{4}} = \frac{33}{39}\text{A}$$

KVL in abcdefa

$9 - (i_1 + i_2)\ 9 - i_1 = 0$

$\Rightarrow 10\ i_1 + 9i_2 = 9$ …(i)

KVL uin Fcdefc

$6 - (i_1 + i_2)9 - i_23 = 0$

$\Rightarrow 9i_1 + 12\ i_2 = 6$

$\Rightarrow 3i_1 + 4i_2 = 3$ …….(ii)

$10i_1 + 9i_2 = 9$ ….(i) × 3

$3i_1 + 4i_2 = 2$ …(ii) × 10

–

$0 - 13i_2 = 7$

$I_2 = -\frac{7}{13}$

from (ii) $i_1 = \frac{2+4\times\frac{7}{13}}{3} = \frac{54}{39}\text{A}$

$i = i_1 + i_2 = \frac{56}{35} - \frac{7}{13} = \frac{56-21}{39} = \frac{33}{39}\text{A} = 0.846\text{ A} = 0.85\text{ A}$

if $E_1$ = removed

$i = \frac{6}{13} = \frac{1}{2}\text{A}$ i decreases

if $E_2$ removed

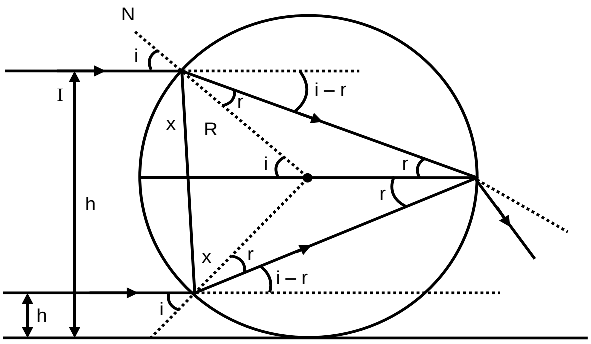
$\frac{i = 9}{10} = 0.9$ A i increases

**64.** A transparent cylindrical rod of length $\ell$ = 50 cm, radius R = 10 cm and refractive index $\mu = \sqrt{3}$ lies onto a horizontal plane surface. A ray of light moving perpendicular to its length is incident on the rod horizontally at a height h above the plane surface such that this ray emerges out of the rod at a height 10 cm above the plane surface. Therefore, h is

(A) 1.34 cm (B) 1.73 cm (C) 10.0 cm (D) 18.66 cm

**Ans.** **(ACD)**

**Sol.**




$r = i - r$

$\Rightarrow r = \frac{i}{2}$

$1 \sin i = \sqrt{3} \sin r$

$1 \sin i = \sqrt{3} \frac{\sin i}{2}$

$\Rightarrow 2 \sin(i/2) \cos(i/2) = \sqrt{3} \sin(i/2)$

$\Rightarrow \cos(i/2) = \frac{\sqrt{3}}{2}$

$\Rightarrow i = 60^\circ$

$\sin i = \frac{x}{R}$

$\Rightarrow \sin 60^\circ = \frac{x}{10}$

$\Rightarrow x = \frac{10\sqrt{3}}{2} = 8.66$ cm

| | | |
|---|---|---|
| Required | h = R + x | 8h = R – x |
| | = 10 + 8.66 cm | h = 10 – 8.66 |
| | = 18.66 cm | = 1.34 cm |

The correction ray will go undevided and among through the opposite end if it is incident at h = 10 cm.

**65.** Two point charges +1μC and –1μC are placed at points (0, – 0.1 m) and (0, +0.1 m) respectively in XY plane. Then, choose the correct statement/s from the following.

(A) The electric field at all points on the Y axis has the same direction.

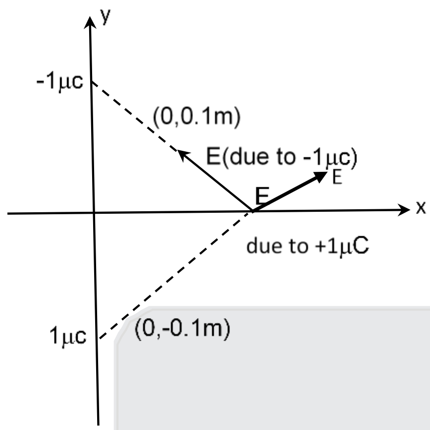
(B) The dipole moment is 0.2 μC-m along +X axis direction.

(C) No work has to be done in bringing a test charge infinity to the origin.

(D) Electric field at all points on the X axis is along +Y axis.

**Ans.** **(CD)**

**Sol.**




$V_O = 0$

$V_\infty = 0$ $\quad\quad \Delta U = q\Delta V = 0$

$\therefore$ C is correct.

From symmetry of the problem components of field by both charge cancel in x-axis and add up in y-axis.

**66.** An inductance L, a resistance R and a battery B are connect in series with a switch S. the voltages across L and R are $V_L$ and $V_R$ respectively. Just after closing the switch S,

(A) $V_L$ will be greater than $V_R$

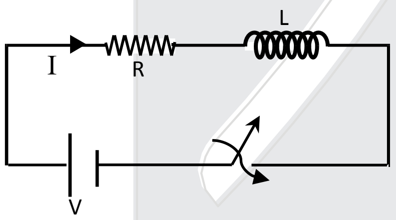
(B) $V_L$ will be less than $V_R$

(C) $V_L$ will be the same as $V_R$

(D) $V_L$ will decrease while $V_R$ will increase as time progresses.

**Ans.** **(AD)**

**Sol.**




$$I = \frac{V}{R}\left(1 - e^{-\frac{RT}{L}}\right)$$

At t = 0 $\quad\quad I = 0$

$\therefore$ $V_R = I R = 0$

$$V_L = \frac{L dI}{dt} = L \frac{V}{R} \times \frac{R}{L} e^{-\frac{Rt}{L}}$$

At t = 0 $V_L = V$

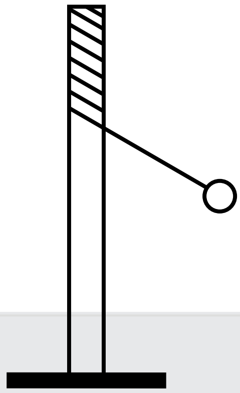
$\therefore$ (a) is correct at t = $\infty$ $\;I\;$ become constant

$\therefore$ $V_L = L\frac{dI}{dt} = 0$

& $V_R = IR = V$

$\therefore$ (d) is correct

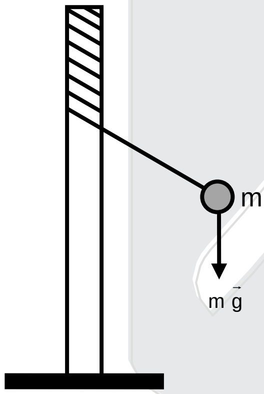
**67.** A string of length $\ell$ ties to the top of a pole, carries a ball at its other end as shows. On giving the ball a single hand blow perpendicular to the string, it acquires an initial velocity $v_0$ in the horizontal plane an moves in a spiral of decreasing radius by curling itself around the pole. Therefore,



(A) the instantaneous centre of revolution of the ball is the point of contact of the string with the pole at that instant.
(B) the instantaneous centre of revolution of the ball will be fixed at the point where the string was initially fixed.
(C) the angular momentum of the system will not be conserved.
(D) the angular momentum of the system will be conserved.

**Ans.** **(AC)**

**Sol.** Torque of $m\vec{g}$ is not zero m the plane perpendicular to it. Therefore angular momentum component in that plane is not conserved.
The Instantaneous axis revolution is instantaneously at rest.
$\therefore$ A is correct

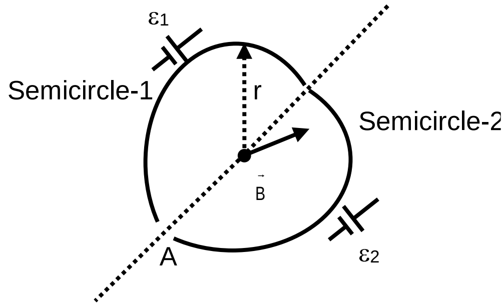


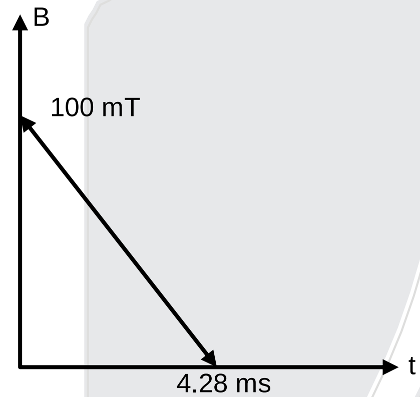

**68.** A circular loop of conducting wire of radius 1 cm is cut a a point A on its circumference. It is then folded along a diameter through A such that the two semicircular loops lie in two mutuially perpendicular planes. It this region a uniform magnetic field $\vec{B}$ of magnitude 100 mT is directed perpendicular to the diameter through A and makes angles of 30º and 60º with the planes of the two semicircles. The magnetic field reduces at a uniform rate from 100 mT to zero in a time interval of 4.28 ms. Therefore,

(A) instantaneous emf in the two loops are in the ratio $\sqrt{2}:1$
(B) instantaneous emf in the two loops are in the ratio $\sqrt{3}:1$
(C) the total emf between free ends at point A is 5 mV
(D) the total emf between free ends at point A is 1.4 mV

**Ans.** **(BC)**

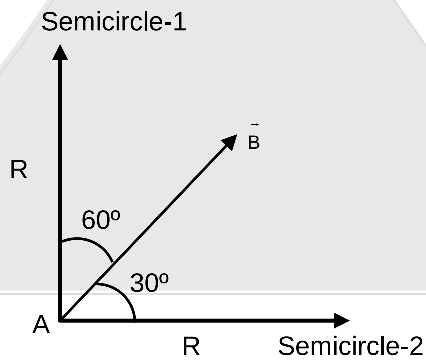
**Sol.**



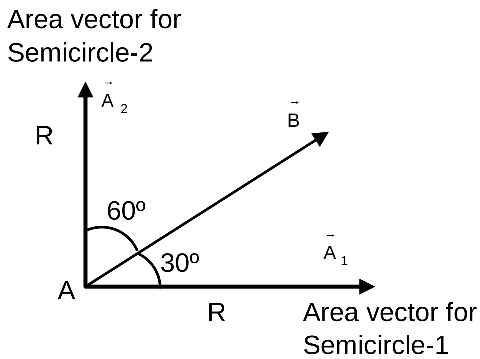




$$\left|\frac{dB}{dt}\right| = \frac{100 \times 10^{-3}}{4.28 \times 10^{-3}} = \frac{100}{4.28}\ T/s$$

Side view




$$A_1 = A_2 = a = \frac{\pi R^2}{2}$$



$\phi_1 = BA_1\cos30^o = \frac{\sqrt{3}}{2}Ba$

$\varepsilon_1 = \left|\frac{d\phi}{dt}\right| = \frac{\sqrt{3}}{2}a\left|\frac{dB}{dt}\right|$

$\phi_2 = BA_2 \cos60^o = \frac{1}{2}Ba$

$\varepsilon_2 = \left|\frac{d\phi_2}{dt}\right| = \frac{1}{2}a\left|\frac{dB}{dt}\right|$

$\frac{\varepsilon_1}{\varepsilon_2} = \frac{\sqrt{3}}{1}$ $\qquad\qquad \phi \;\; \therefore$ (a)

$\varepsilon_{total} = \varepsilon_1 + \varepsilon_2 = \left(\frac{\sqrt{3}}{2} + \frac{1}{2}\right) a \left|\frac{dB}{dt}\right|$

$= \left(\frac{2.732}{2}\right) \times \frac{\pi(.01)^2}{2} \times \frac{100}{4.28}$

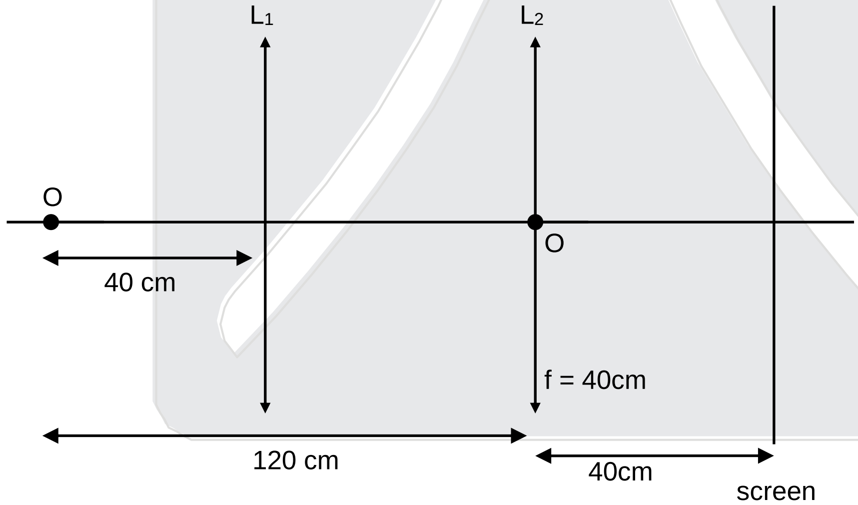
$= 5.01 \times 10^{-3}$ V = 5 mV

**69.** A converging lens of focal length 40 cm is fixed at 40 cm in front of a screen. An object placed 120 cm from the fixed lens is required to be focused on the screen by introducing another identical lens in between. The second lens should be placed at a distance x from the object where x is.

(A) 40 cm (B) 50 cm (C) 140 cm (D) 150 cm

**Ans.** **(AC)**

**Sol.**




For $L_2$ to form image on screen

v = 40 cm

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

$\Rightarrow \frac{1}{40} - \frac{1}{u} = \frac{1}{40}$ $\qquad\qquad \Rightarrow u = -\infty$

As the screen is in the focal plane of the lens $L_2$ the rays for image formation on the screen must be incident parallel on the lens. Therefore in order to create a parallel beam from the rays coming from the object the object must lie on the focal point of the other identical lens (call it $L_1$)

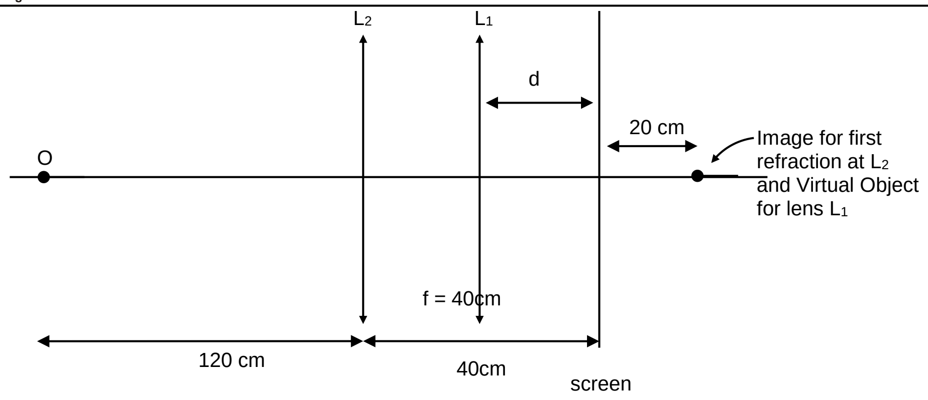
$\therefore$ x = 40 cm.

Another case

For lens to be b/w $L_2$ & screen. Refraction at $L_2$

u = –120 $\qquad$ f = 40

$v = \frac{fu}{u+f} = \frac{40 \times (-120)}{-80} = +60$




Continued
for ref. at $L_7$

$u = d + 20 \qquad v = d$

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

$$\Rightarrow \quad \frac{1}{d} - \frac{1}{d+20} = \frac{1}{40}$$

$$\Rightarrow \quad \frac{d+20-d}{d^2+20d} = \frac{1}{40}$$

$\Rightarrow \quad d^2 + 20d - 800 = 0$

$\Rightarrow \quad (d + 40)(d - 20) = 0$

$\Rightarrow \quad d = 20$

$x = 160 - d = 160 - 20 = 140$

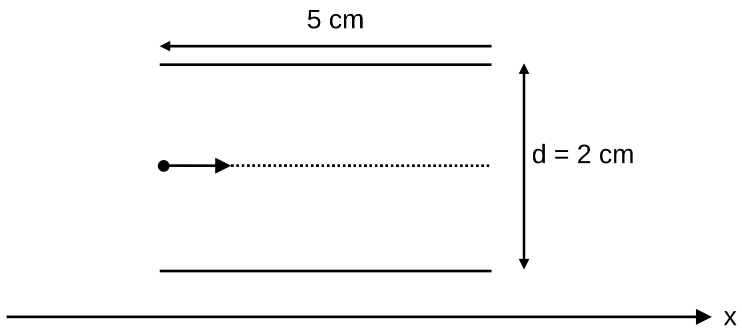
$\therefore$ (C) is also correct

**70.** Mysteriously a charged particle moving with velocity $\vec{v} = v_0\hat{i}$ entered the tube of Thomson's apparatus where the parallel metallic plates of length 5 cm along X axis are separated by 2 cm. Under the influence of a magnetic field $\vec{B} = (4.57 \times 10^{-2}\hat{k})$ T, the particle is found to deflect by an angle of 5.7º. When a potential of 2000 volt is applied between the two plates, the particle is found to move straight to the screen without any deflection. Then,

(A) the velocity $v_0 = 2.19 \times 10^6$ m/s
(B) the charge to mass ratio of the particle is $9.58 \times 10^7$ C/kg
(C) radius of the circular path in the magnetic field is 50 cm
(D) the particle is identified as a proton.

**Ans.** **(ABCD)**

**Sol.**

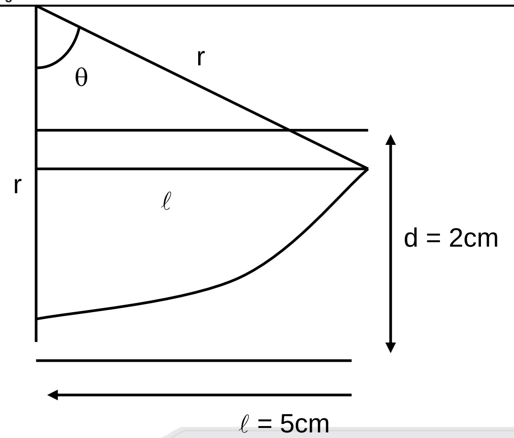



When voltage is applied and particle goes undeflected $qE = qv_0B$

$$V_0 = \frac{E}{B} = \frac{2000}{0.02} \; 4.57 \times 10^{-2}$$

$= 2.19 \times 10^6$ m/s

When only B is applied




$\frac{\ell}{r}$ = sinθ

$\frac{5}{r}$ = sin57º = 0.095

r = $\frac{5}{0.099}$ = 50.5cm

r = $\frac{mv_0}{qB}$ $\Rightarrow \frac{q}{m} = \frac{v_0}{rB} = \frac{2.19 \times 10^6}{\frac{1}{2} \times 4.57 \times 10^{-2}}$

= 957, 62967 ≈ 9.58 × 10⁷kg

Charge to mass ration of proton = $\frac{1.6 \times 10^{-19}}{1.6726219 \times 10^{-74}}$ = 9.58 × $10^7$ kg

∴ Identified particle is proton