PHYSICS

1. A particle of mass M moves along a horizontal x axis from x=0 to x = L. The coefficient of kinetic friction varies as a function of x as $\mu_k(x) = \mu_0 - \alpha x$, where μ_0, α are constants of appropriate dimensions, so that $\mu_k(L)=0$. The total work done by the frictional force during the motion is $n\mu_0 MgL$, where g is the acceleration due to gravity. The value of n is :

(1) 3 (2) 1

(3) $\frac{1}{3}$ (4) $\frac{1}{2}$

Ans. (4)

Sol. $\mu_k = \mu_0 - \alpha x$

$\mu_0 - \alpha L = 0 \Rightarrow \alpha = \frac{\mu_0}{L}$

W.D. by kinetic friction = $\int f_k dx \cos 180°$

$= \int_0^L \mu_k mgdx(-1)$

$= -\int_0^L (\mu_0 - \alpha x) mg\,dx$

$= -\left[\mu_0 mgL - \alpha mg\frac{L^2}{2}\right]$

$= -\left[\mu_0 mgL - \frac{\mu_0}{L} mg\frac{L^2}{2}\right]$

$= -\left[\frac{\mu_0 mgL}{2}\right]$

on comparing magnitude with $n\mu_0 mgL$

$n = \frac{1}{2}$

2. The mean free path of molecules in an ideal gas A is half that of another ideal gas B. The diameter of the spherical molecules of gas A is twice the diameter of the molecules of B. If number densities of the gases A and B are n_A and n_B, respectively, then the correct option is :

(1) $n_A = n_B$ (2) $n_A = 2n_B$

(3) $n_A = \frac{1}{4}n_B$ (4) $n_A = \frac{1}{2}n_B$

Ans. (4)

Sol. $\lambda = \frac{1}{\sqrt{2}\pi d^2}\frac{1}{n}$

$n \propto \frac{1}{\lambda d^2}$

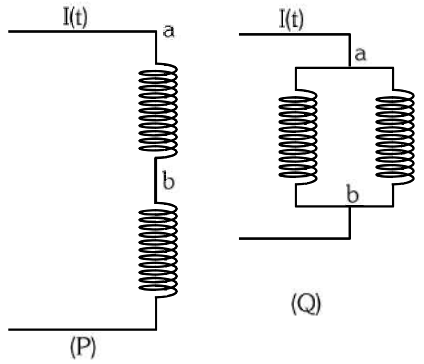
$\frac{n_A}{n_B} = \frac{\lambda_B}{\lambda_A} \times \left(\frac{d_B}{d_A}\right)^2$

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

$n_A = \frac{n_B}{2}$

3. Two identical inductors are connected in two different configurations P and Q, where a time varying current I(t) is flowing, as shown in the figure. The induced emf between points a and b for configuration P is E_P and that for configuration Q is E_Q. The ratio E_P/E_Q is :

[Neglect the effect of mutual inductance.]



(1) 1/4 (2) 1/2

(3) 1 (4) 2

Ans. (4)

Sol. $E_P = \frac{Ldi}{dt}$

$E_Q = L\frac{di/2}{dt}$

$E_Q = \frac{L}{2}\frac{di}{dt}$

$\frac{E_P}{E_Q} = \frac{\frac{Ldi}{dt}}{\frac{L}{2}\frac{di}{dt}} = 2$

4. For sound waves, if the number of nodes for the 5^{th} harmonic of an open-ended pipe is n and that for the 9^{th} harmonic of the same pipe with one of its ends closed is m, the ratio $\frac{n}{m}$ is :

(1) $\frac{5}{9}$ (2) $\frac{9}{5}$

(3) 1 (4) $\frac{3}{5}$

Ans. (3)

Sol. For COP and OOP → No. of nodes = m + 1

where m = No. of overtone

In OOP → 5^{th} Harmonic means 4^{th} OT

m = 4

so No. of nodes n = 4 + 1 = 5

In COP → 9^{th} Harmonic means 4^{th} OT

means m = 4

then no of nodes = m + 1 = 4 + 1 = 5

m = 5

So ratio $\frac{n}{m} = \frac{5}{5} = \frac{1}{1}$

5. Consider a long solenoid of length l and radius r. If n is the number of turns per unit length and μ_0 is the permeability of free space, the inductance of the solenoid is :

(1) $\mu_0 \pi n^2 r^2 l$ (2) $\mu_0 n^2 r^2 l$

(3) $(\mu_0/2\pi) n^2 r^2 l$ (4) $2\mu_0 \pi n^2 r^2 l$

Ans. (1)

Sol. $L = n^2 \mu_0 A l$

$L = n^2 \mu_0 \pi r^2 l$

option (1)

6. Consider a particle moving along a straight line, whose position as a function of time is given by $s(t) = \alpha t^2 - \beta t + \gamma$, where $\alpha = 1\ ms^{-2}$, $\beta = 6\ ms^{-1}$ and $\gamma = 5$ m. The average speed of the particle, in ms^{-1}, from t = 0 to t = 6 s is :

(1) 12 (2) 6

(3) 3 (4) 0

Ans. (3)

Sol. $S = \alpha t^2 - \beta t + \gamma$

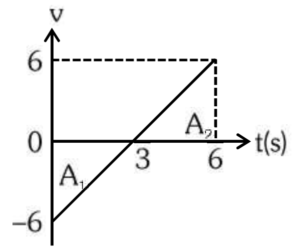
$S = t^2 - 6t + 5$

$\because v = \frac{ds}{dt} = (2t - 6)$ m/s

distance travelled = $|A_1| + |A_2|$

distance = $2\left[\frac{1}{2} \times 3 \times 6\right]$

distance = 18 m



$\therefore$ Average speed $\Rightarrow v_{avg} = \frac{\text{distance}}{\text{Time}}$

$v_{avg} = \frac{18}{6} = 3$ m/s

7. Consider the following nuclear reaction :

$$^{238}U \rightarrow {}^{234}Th + {}^{4}He$$

Take masses of ^{238}U, ^{234}Th and ^{4}He as 238.050 u, 234.043 u and 4.003 u, respectively. The Q value for the reaction, in keV, is :

[Given : 1 u = 931.5 MeV c^{-2}]

(1) 3726

(2) 3730

(3) 3736

(4) 3740

Ans. (1)

Sol. $Q = (m_i - m_f)C^2$

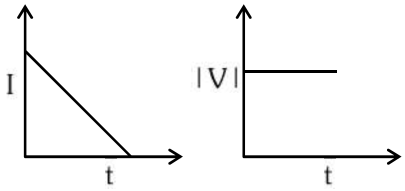
$= [238.050 - (234.043 + 4.003)]\ uC^2$

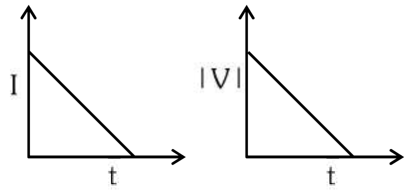
$= 0.004 \times 931.5$

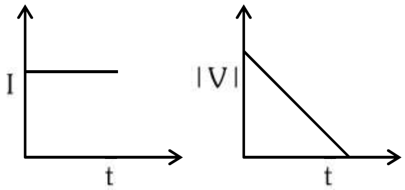
= 3.726 Mev

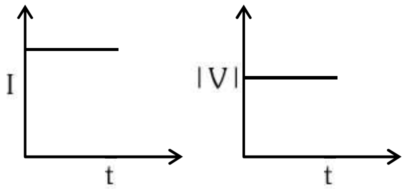
= 3726 Kev

8. A beam of light falls on a metal surface such that photo-electrons are generated. If power of the light source starts to decrease linearly with time t, then variation of the photocurrent I and magnitude of the stopping potential |V| with time is best represented by :

(1) 

(2) 

(3) 

(4) 

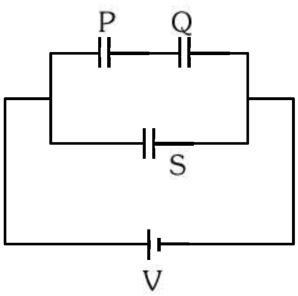
Ans. (1)

Sol. $P = \frac{nhC}{\lambda} = nh\nu$

If power decreases then n decreases but frequency remain same as source is same.

$\therefore$ Photocurrent will decrease & stopping potential remain same.

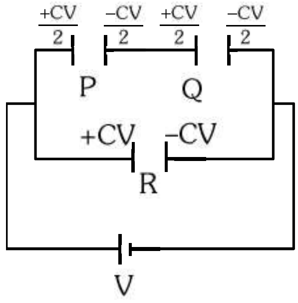
9. Three identical capacitors P, Q and S, each of the capacitance C, are connected to a battery of voltage V, as shown in the figure. If the energy stored in the capacitor P and total energy stored in the system are U_P and U_T, respectively, then the ratio $\frac{U_P}{U_T}$ is :



(1) 2/3 (2) 1/3 (3) 1/2 (4) 1/6

Ans. (4)

Sol.



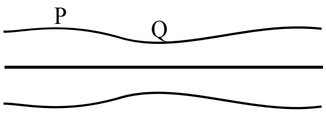
$$U_P = \frac{1}{2}\frac{\left(\frac{CV}{2}\right)^2}{C} = \frac{1}{8}CV^2$$

$$U_T = \frac{1}{2}\frac{\left(\frac{CV}{2}\right)^2}{C} + \frac{1}{2}\frac{\left(\frac{CV}{2}\right)^2}{C} + \frac{1}{2}CV^2$$

$$U_T = \frac{3}{4}CV^2$$

$$\frac{U_P}{U_T} = \frac{\frac{1}{8}CV^2}{\frac{3}{4}CV^2} = \frac{1}{6}$$

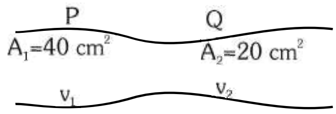
10. Water flows in a streamline motion through a horizontal pipe of circular cross-section as shown in the figure. The pressure difference of water between P and Q is 15 Nm^{-2}. The area of cross-section at P and Q are 40 cm^2 and 20 cm^2, respectively. The rate of flow of water through the pipe, in cm^3s^{-1}, is :
[Take density of water = 1000 kg m^{-3}]



(1) 100 (2) 200
(3) 300 (4) 400

Ans. (4)

Sol.



According to equation of continuity

$A_1v_1 = A_2v_2 \Rightarrow 40\, v_1 = 20v_2$

$v_2 = 2v_1$

Bernoulli's principle

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$P_1 - P_2 = \frac{1}{2}\rho[(2v_1)^2 - v_1^2]$$

$$\frac{15 \times 2}{10^3} = 3v_1^2$$

$v_1 = 0.1$ m/s

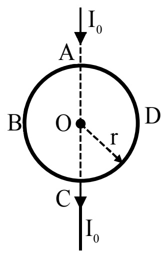
Now rate of flow $\frac{dV}{dt} = A_1v_1 = A_2v_2$

$$\frac{dV}{dt} = 40 \times 10^{-4} \times 0.1 = 4 \times 10^{-4} \text{ m}^3/\text{s}$$

$= 4 \times 10^{-4} \times 10^6$ cm^3/s

$= 400$ cm^3/s

11. A current I_0 flows through a metallic circular loop of radius r as shown in the figure. Resistance of the segment ABC is half that of ADC. Magnitude of magnetic field at the centre O of the loop is :

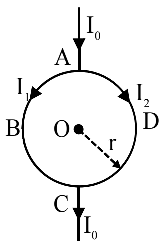


(1) $\frac{\mu_0 I_0}{12r}$ (2) $\frac{\mu_0 I_0}{4r}$

(3) $\frac{\mu_0 I_0}{2r}$ (4) $\frac{\mu_0 I_0}{2\pi r}$

Ans. (1)

Sol.



$R_1 : R_2 = 1 : 2$

From V = IR

$$I \propto \frac{1}{R}$$

$$\frac{I_1}{I_2} = \frac{R_2}{R_1} = \frac{2}{1}$$

$$I_1 = \frac{2}{3}I_0 \text{ and } I_2 = \frac{1}{3}I_0$$

$(B_0)_{net} = B_1 - B_2$

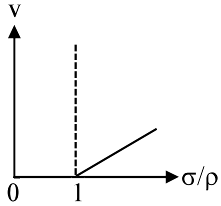
$$= \frac{\mu_0 I_1}{4r} - \frac{\mu_0 I_2}{4r}$$

$$= \frac{\mu_0}{4r}(I_1 - I_2) = \frac{\mu_0}{4r}\left(\frac{2I_0}{3} - \frac{I_0}{3}\right)$$

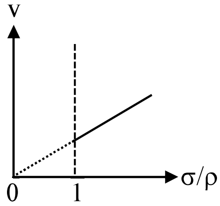
$$= \frac{\mu_0 I_0}{12r}$$

12. In the measurement of viscosity of liquids using terminal velocity experiment, spherical balls of same radius but having different densities are used. The variation of the terminal velocity (v) with the ratio of density of spherical ball (σ) to density of the liquid (ρ), is best represented by :

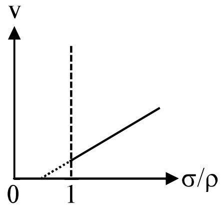
(1)



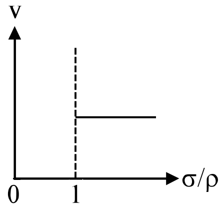
(2)



(3)



(4)



Ans. (1)

Sol. Given density of ball (solid) → σ

Density of liquid → ρ

So formula of terminal velocity

$$v = \frac{2r^2}{9\eta}(\sigma - \rho)g$$

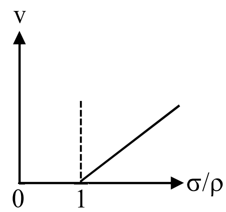
$$v = \frac{2r^2}{9\eta}\rho\left[\frac{\sigma}{\rho} - 1\right]g$$

$$v = \frac{2r^2\rho g}{9\eta}\left(\frac{\sigma}{\rho}\right) - \frac{2r^2\rho g}{9\eta}$$

It's equation of positive slope and negative straight line of intercept

If $\frac{\sigma}{\rho} = 1$ then v = 0

So, correct graph



13. Two planets P_1 and P_2 with equal mass have radii R_1 and R_2, respectively, where $R_2 = \frac{R_1}{2}$. The escape speeds of P_1 and P_2 are v_1 and v_2, respectively. Then $\frac{v_2}{v_1}$ is :

(1) $\frac{1}{\sqrt{2}}$ (2) 1

(3) $\sqrt{2}$ (4) 2

Ans. (3)

Sol. $V_{es} = \sqrt{\frac{2GM}{R}}$

$\frac{V_2}{V_1} = \sqrt{\frac{R_1}{R_2}} = \sqrt{2}$

14. In a solar system, the time-period of revolution of a planet tracing a circular orbit of radius R is proportional to :

(1) $R^{1/2}$ (2) $R^{3/2}$

(3) R^2 (4) R^3

Ans. (2)

Sol. By Kepler's III law-

$T^2 \propto R^3$

$T \propto R^{3/2}$

15. Two infinitely long parallel conducting wires A and B carry currents I and 2I, respectively, in the same direction. The wire A has uniform mass per unit length λ and lies on an insulated floor. The wire B is kept fixed at a height h above the floor. The minimum magnitude of h so that the wire A does not rise from the floor is :

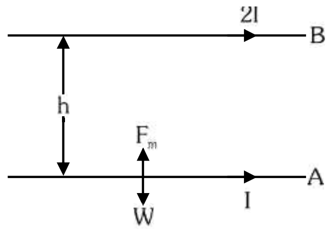
[g is the acceleration due to gravity and μ_0 is the permeability of free space]

(1) $\frac{\mu_0 I^2}{2\pi\lambda g}$ (2) $\frac{\mu_0 I^2}{\pi\lambda g}$

(3) $\frac{2\mu_0 I^2}{\pi\lambda g}$ (4) $\frac{4\mu_0 I^2}{\pi\lambda g}$

Ans. (2)

Sol.



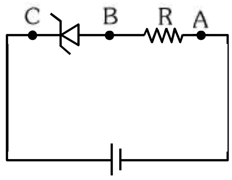
At equilibrium : $F_m = W$

$\frac{F_m}{\ell} = \frac{W}{\ell} = \frac{mg}{\ell} = \lambda g$

$\frac{\mu_0 (2I)(I)}{2\pi(h)} = \lambda g$

$h = \frac{\mu_0 I^2}{\pi\lambda g}$

16. An ideal Zener diode with breakdown voltage of –3V is reverse biased with a negative input voltage V_i = –5V. The magnitude of voltage difference between points B and A is :



(1) 3 V (2) 2 V

(3) 1 V (4) 0 V

Ans. (2)

Sol. Here Zener diode is in reverse biased so voltage drop across Zener diode is 3V.

Voltage difference across points B and A

$V_{BA} = 5 - 3 = 2V$

17. In an adiabatic expansion, the temperature of one mole of an ideal monatomic gas (γ=5/3) decreases from 60 K to 50 K. The work done by the gas in the process is :

(Take the universal gas constant as $R = 8.3\ J\ mol^{-1}\ K^{-1}$)

(1) 41.5 J (2) 83 J

(3) 124.5 J (4) 166 J

Ans. (3)

Sol. $W = \frac{\mu R \Delta T}{1-\gamma}$

$= \frac{1 \times 8.3 \times (-10)}{1 - \frac{5}{3}}$

$= \frac{3 \times 8.3 \times 10}{2} = 124.5\ J$

18. A ray of light with wavelength λ is incident on three different photo-electric cells namely 1, 2 and 3. The threshold wavelength of these photo-electric cells are λ_1, λ_2 and λ_3, respectively and the magnitude of stopping potentials of these cells are V_1, V_2 and V_3, respectively. The relation between λ and threshold wavelengths are $\lambda_1 < \lambda$, $\lambda_2 > \lambda$ and $\lambda_3 >> \lambda$. The correct option is :

(1) $V_1 = 0, V_2 < V_3$ (2) $V_1 = 0, V_2 > V_3$

(3) $V_1 > V_2, V_3 = 0$ (4) $V_1 < V_2, V_3 = 0$

Ans. (1)

Sol. For photo-electric effect wavelength of incident light should be less than threshold wavelength.

(i) $\lambda_1 < \lambda$

$\therefore$ No photoelectric effect take place.

(ii) $\lambda_2 > \lambda$, photoelectric effect take place.

(iii) $\lambda_3 >> \lambda$ photoelectric effect take place.

Frequency of 3 > frequency of 2

$\therefore V_3 > V_2$ & $V_1 = 0$

19. A photon and an electron, each of 20 eV energy, move in free space. The ratio of linear momentum of electron p_e to that of photon p_{Ph}, $\frac{p_e}{p_{Ph}}$ is :

(Take speed of light = 3×10^8 ms^{-1}, charge of electron = -1.6×10^{-19} C and mass of electron = 9×10^{-31} kg)

(1) $\frac{2}{450}$ (2) $\frac{1}{250}$

(3) 225 (4) 275

Ans. (3)

Sol. $\frac{p_e}{p_{Ph}} = \frac{\sqrt{2mE_e}}{\frac{E_{Ph}}{C}} \left(E_e = E_{Ph} = E\right)$

$$\frac{p_e}{p_{Ph}} = \sqrt{\frac{2m}{E}} \times C$$

$$= \sqrt{\frac{2 \times 9 \times 10^{-31}}{20 \times 1.6 \times 10^{-19}}} \times 3 \times 10^8$$

$$= \frac{3}{4} \times 10^{-6} \times 3 \times 10^8$$

$= 225$

20. Which of the following measurements require 'index correction'?

(1) Measurement of resistance of a wire using meter bridge

(2) Measurement of gravitational acceleration using simple pendulum

(3) Measurement of focal length of lenses using optical bench

(4) Measurement of speed of sound using resonance tube

Ans. (3)

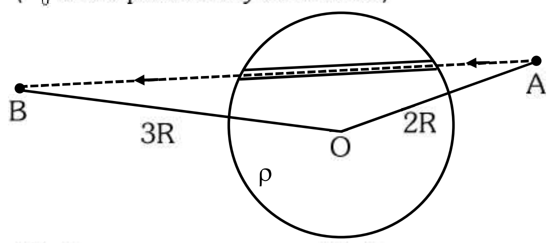
Sol. In an optical bench experiment, index correction also known as bench correction.

Optical bench experiment perform to calculate focal length of lenses.

21. A unit positive point charge is taken slowly through an infinitesimally thin tube that is inside a charged dielectric sphere of radius R, having uniform positive charge density ρ, as shown in the figure. The initial and final positions of the charge are marked by A and B at distances 2R and 3R respectively, from the centre of the sphere. In this process, the magnitude of the total work done on the point charge is $\frac{\rho R^2}{n \in_0}$.

The value of n is :

($\in_0$ is the permittivity of vacuum)



(1) 2 (2) 6

(3) 9 (4) 18

Ans. (4)

Sol. $W = q\Delta V$

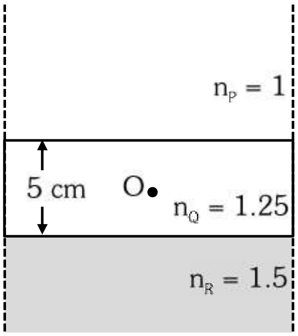
$= q(V_B - V_A)$

$$= 1\frac{kQ}{3R} - \frac{kQ}{2R} \quad = \frac{-kQ}{6R}$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{\rho \times \frac{4}{3}\pi R^3}{6R} \quad = \frac{\rho R^2}{18 \in_0}$$

$n = 18$

22. Consider three media P, Q and R with refractive indices 1, 1.25, and 1.5, respectively. The medium Q having a thickness of 5 cm is placed between extended media P and R as shown in the figure. An object O is placed at the centre of medium Q. If viewed from medium P near the normal direction, the apparent depth of O is h_1. For similar observation from medium R, the apparent depth is h_2. The value of $|h_1 - h_2|$, in cm, is :



(1) 0

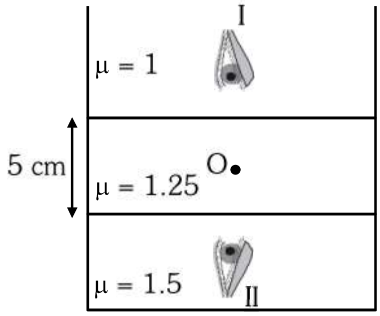
(2) 1

(3) 2

(4) 3

Ans. (2)

Sol.



For observer I

$$\frac{d'}{d} = \frac{\mu_2}{\mu_1}$$

$$\frac{d'}{2.5} = \frac{1}{1.25}$$

$d' = 2\text{ cm} = h_1$

For observer II

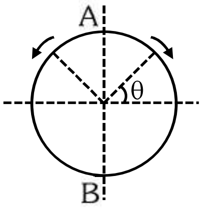
$$\frac{d'}{d} = \frac{\mu_2}{\mu_1}$$

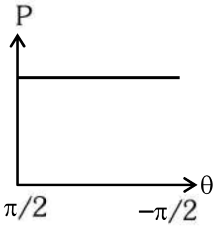
$$\frac{d'}{2.5} = \frac{1.5}{1.25}$$

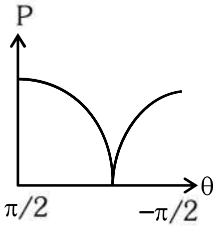
$d' = 3\text{cm} = h_2$

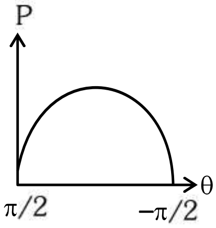
$|h_1 - h_2| = 1\text{ cm}$

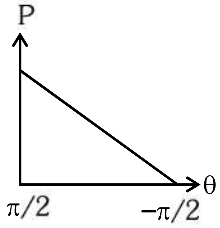
23. A frictionless circular wire of unit radius is fixed on the horizontal plane. Two point particles of unit mass start moving simultaneously from point $A\left(\theta=\frac{\pi}{2}\right)$ with identical uniform angular speeds in opposite directions, and meet again at point $B\left(\theta=-\frac{\pi}{2}\right)$. During this time, which of the following figures schematically represent the magnitude of the total linear momentum P of the system, as a function of θ ?



(1) 

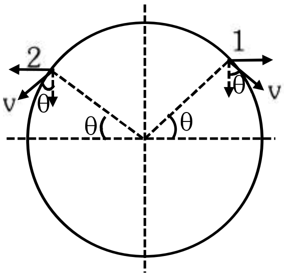
(2) 

(3) 

(4) 

Ans. (3)

Sol.



$$\vec{P}_1+\vec{P}_2 = mv\sin\theta\hat{i} - mv\cos\theta\hat{j} + \left(-mv\sin\theta\hat{i} - mv\cos\theta\hat{j}\right)$$

$$P_{Total} = \left|\vec{P}_1+\vec{P}_2\right| = 2mv\cos\theta$$

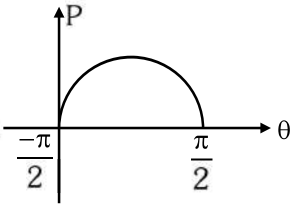
At $\theta=\frac{\pi}{2}$ At $\theta=-\frac{\pi}{2}$

$P_{Total} = 0$ $P_{Total} = 0$

At θ = 0

$P_{Total\ max} = 2mV$

So graph



24. The temperature of a metallic sphere of radius R is increased by a small amount ΔT. If the linear coefficient of thermal expansion of the metal is α, the approximate increase in the volume of the sphere is :

(1) $2\pi R^3\alpha\Delta T$ (2) $3\pi R^3\alpha\Delta T$

(3) $4\pi R^3\alpha\Delta T$ (4) $6\pi R^3\alpha\Delta T$

Ans. (3)

Sol. $\gamma = \frac{\Delta V}{V}\times\frac{1}{\Delta T}$

$3\alpha\,\Delta T\times V = \Delta V$

$\Delta V = \frac{4}{3}\pi R^3\times 3\alpha\Delta T$

$= 4\pi R^3\alpha\Delta T$

25. A cylindrical cork of uniform density floats in a liquid of density ρ_1. If the cork is depressed slightly and released, it oscillates harmonically with time period T. If the same cork floats in another liquid of density ρ_2, then the similar oscillation has time period 2T. The value of ρ_2/ρ_1 is :

(1) 4   (2) 2

(3) 1/2   (4) 1/4

Ans. (4)

Sol. Force on cork when cross section area is A

$F = -\rho gAx$

Compare with $F = -kx$

$k = \rho Ag$

$$T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow T = 2\pi\sqrt{\frac{m}{\rho Ag}} \Rightarrow T \propto \frac{1}{\sqrt{\rho}}$$

Now $\frac{T_1}{T_2} = \sqrt{\frac{\rho_2}{\rho_1}}$

$$\frac{T}{2T} = \sqrt{\frac{\rho_2}{\rho_1}} \Rightarrow \frac{\rho_2}{\rho_1} = \frac{1}{4}$$

26. One main scale division of a Vernier calliper is equal to 1 mm and the number of divisions on the Vernier scale is 10. When both the jaws touch each other, the Vernier scale shifts to the left of zero of the main scale in such a way that 4^{th} Vernier division coincides with a division of the main scale. If this Vernier calliper measures the length of a wire to be 1 cm, the actual length of the wire is :

(1) 0.60 cm (2) 0.96 cm
(3) 1.00 cm (4) 1.04 cm

Ans. (Bonus)

Sol. MSD = 1 mm

VSD = 0.9 mm

LC = 0.1 mm = 0.01 cm

ZE = – (Total – coinciding VSD) LC

= – (10 – 4) (0.01)

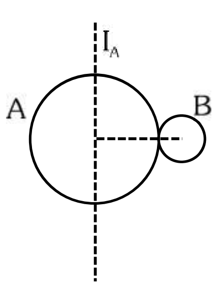
= –0.06 cm

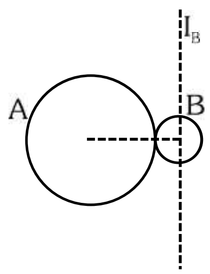
Actual reading = Measured reading – ZE

= 1 cm – (– 0.06) cm
= 1.06 cm

Bonus

27. A solid sphere A of radius R and mass M is attached at a point to a smaller solid sphere B of radius r < R and mass m < M. Assume that the line joining their centres lies along the horizontal. The moment of inertia of the system calculated about a vertical axis passing through the centre of A is I_A and that calculated about a vertical axis passing through the centre of B is I_B. The difference $I_A - I_B$ is :



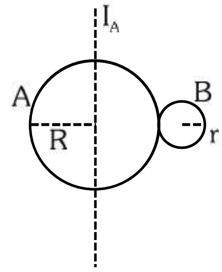


(1) $(M - m)(R + r)^2$ (2) $(m - M)(R + r)^2$

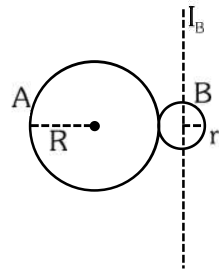
(3) $(m - M)(R - r)^2$ (4) 0

Ans. (2)

Sol.



$$I_A = \frac{2}{5}MR^2 + \frac{2}{5}mr^2 + m(R+r)^2$$



$$I_B = \frac{2}{5}mr^2 + \frac{2}{5}MR^2 + M(R+r)^2$$

$I_A - I_B = m(R + r)^2 - M(R + r)^2$

$= (R + r)^2 (m - M)$

28. Consider a spring mass simple harmonic oscillator in one dimension. The mass of the particle is m kg and the spring constant is k Nm^{-1}. At a given instant, the extension of the spring is x meter and the speed of the particle is v ms^{-1}. On the x-v plane, if the graph of v as a function of x is a circle, then the correct option is :

(1) $k = \frac{1}{m}$ (2) $k = m$

(3) $k = m^2$ (4) $k = \sqrt{m}$

Ans. (2)

Sol. In a spring mass system, the total energy is

$$E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$$

or $\frac{mv^2}{2E} + \frac{kx^2}{2E} = 1$

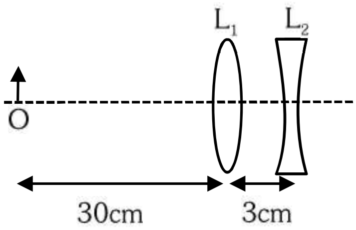
or $\frac{v^2}{\frac{2E}{m}} + \frac{x^2}{\frac{2E}{k}} = 1$

Compare with $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$

For circle $a^2 = b^2 \Rightarrow \frac{2E}{m} = \frac{2E}{k}$

$\Rightarrow m = k$

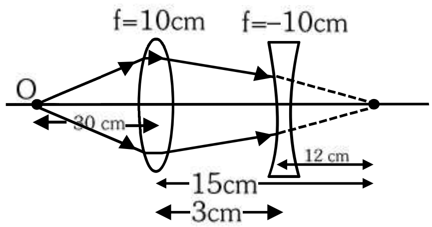
29. The lens combination as shown in the figure, consists of two lenses, L_1 and L_2, of the focal lengths +10 cm and –10 cm, respectively. The position of the image formed is :



(1) 20 cm to the left of the concave lens
(2) 60 cm to the left of the concave lens
(3) 30 cm to the right of the concave lens
(4) 60 cm to the right of the concave lens

Ans. (2)

Sol.



1^{st} lens $u = -30$ cm

$f = 10$ cm

$$v = \frac{uf}{u+f} = \frac{-30\times 10}{-30+10} = 15\text{cm}$$

Image of first lens act as a virtual object for second lens.

2^{nd} lens $u = 12$ cm

$f = -10$ cm

$$v = \frac{12\times(-10)}{12-10} = -60\text{cm (Virtual image)}$$

negative sign indicate left of the concave lens.

30. An ac voltage V=220 sin ($2 \times 10^3 t$) Volt is applied to a series LCR circuit. Then the current amplitude in this circuit is :
(Given : L = 10 mH, C = 25μF, R = 100 Ω)

(1) 2.2 A (2) 5.5 A
(3) 11.0 A (4) 22.0 A

Ans. (1)

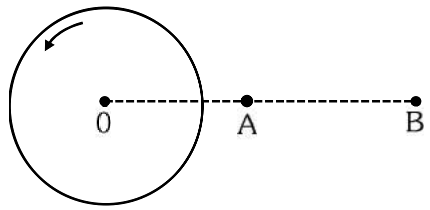
Sol. Here $X_L = \omega L = 2 \times 10^3 \times 10 \times 10^{-3} = 20\Omega$

$$X_C = \frac{1}{\omega C} = \frac{10^6}{2\times 10^3 \times 25} = 20\Omega$$

$\therefore X_L = X_C$; hence LCR circuit is in resonance

So Z = R ; $I_0 = \frac{V_0}{Z} = \frac{V_0}{R} = \frac{220}{100} = 2.2$ Amp

31. A thin horizontal disc is rotating about a vertical axis passing through its fixed centre O. Its angular momentum is L_A and L_B computed about points A and B, respectively, with OB = 2 × OA. The value of $\frac{L_A}{L_B}$ is :



(1) $\frac{1}{4}$ (2) $\frac{1}{2}$ (3) 1 (4) 2

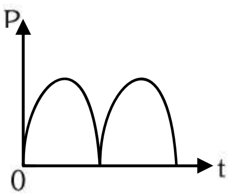
Ans. (3)

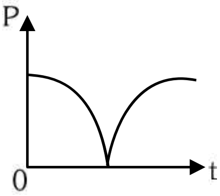
Sol. $L_{\text{of pure rotation body}} = I_{\text{about which body rotating}}\,\omega$

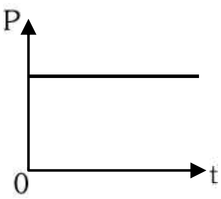
$$L_A = \frac{MR^2}{2}\omega \Rightarrow L_B = \frac{MR^2}{2}\omega$$

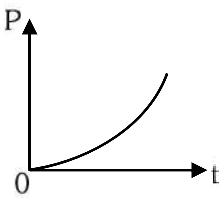
$$\frac{L_A}{L_B} = 1$$

32. A conducting loop of finite resistance lies on the x-y plane. There is a constant magnetic field in the z direction. The area of the loop varies with time t, as $A = A_0(1 + \sin t)$ in appropriate units. The figure that correctly indicates the qualitative behaviour of the power P dissipated in the loop as a function of time is :

(1)


(2)


(3)


(4)


Ans. (2)

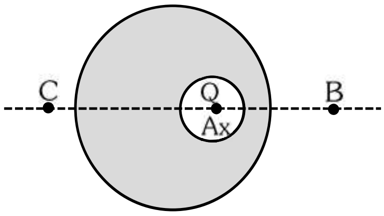
Sol. $\phi = BA$

$\phi = BA_0(1 + \sin t)$

$$e = \frac{-d\phi}{dt} = -BA_0\cos t \Rightarrow P = \frac{e^2}{R} = \frac{B^2A_0^2\cos^2 t}{R}$$

$P \propto \cos^2 t$

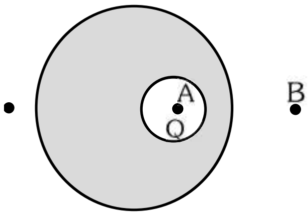
33. A point charge Q is placed inside a cavity within a solid isolated conducting sphere. Consider points A, B and C as shown in the figure, where the magnitudes of the electric fields are E_A, E_B and E_C, respectively. The points B and C are at the same distance from the center of the solid sphere. The correct option is :



(1) $E_A = 0, E_B = E_C$ (2) $E_A \neq 0, E_B = E_C$
(3) $E_A = 0, E_B > E_C$ (4) $E_A \neq 0, E_B < E_C$

Ans. (2)

Sol.



$$E_A = \frac{kQ}{r^2}$$

$$E_B = \frac{kQ}{r_B^2} = \frac{kQ}{r_C^2} = E_C$$

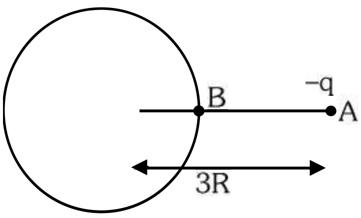
34. Consider a fixed uniformly charged insulating sphere with radius R and total charge +Q. A point charge –q (q<<Q) with mass m is released from rest at a distance of 3R from the centre of the charged sphere. When the point charge reaches the surface of the sphere, its speed is :
($\in_0$ is the permittivity of vacuum, neglect gravitational forces).

(1) $\sqrt{\dfrac{3Qq}{4\pi \in_0 mR}}$ (2) $\sqrt{\dfrac{2Qq}{3\pi \in_0 mR}}$

(3) $\sqrt{\dfrac{Qq}{3\pi \in_0 mR}}$ (4) $\sqrt{\dfrac{Qq}{4\pi \in_0 mR}}$

Ans. (3)

Sol.



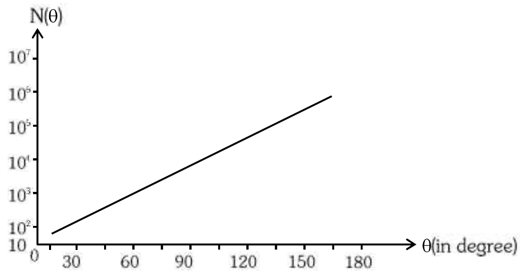
$$K_A + U_A = K_B + U_B$$

$$-qV_A = \frac{1}{2}mv^2 + -qV_B \Rightarrow -\frac{KQq}{3R} = \frac{1}{2}mv^2 - q\frac{KQ}{R}$$

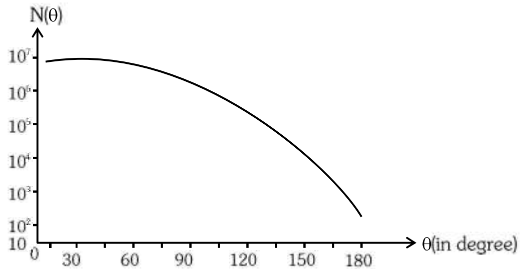
$$\frac{2}{3}\frac{KQq}{R} = \frac{1}{2}mv^2 \Rightarrow \sqrt{\frac{Qq}{3\pi \in_0 R}} = v$$

35. In Geiger-Marsden experiment, the number of scattered α-particles N(θ) is plotted as a function of scattering angle θ. Which of the following options represents the correct plot ?

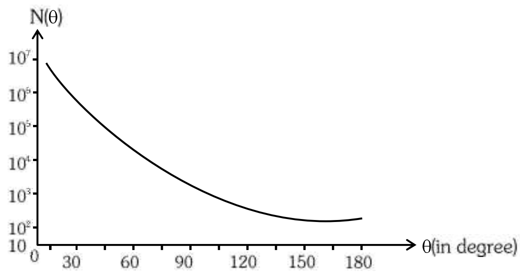
(1)



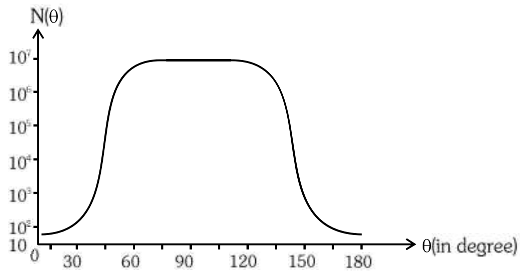
(2)



(3)



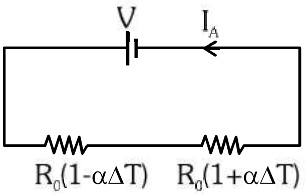
(4)



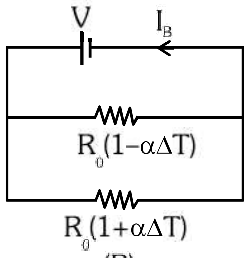
Ans. (3)

Sol. $N \propto \dfrac{1}{\sin^4(\theta/2)}$

36. Consider two circuits, (A) and (B), each having two resistors. One of them has a positive temperature coefficient of resistance, $+\alpha$, while the other one has a negative temperature of coefficient, $-\alpha$, as shown in the figure. The current through these circuits are denoted by I_A and I_B. At initial temperature, the resistance of the two resistors is R_0. As the temperature is increased, the correct option that describes the variation of current in these circuits is :



(A)



(B)

(1) I_A remains constant while I_B increases

(2) I_A decreases while I_B increases

(3) I_A increases while I_B decreases

(4) both I_A and I_B remain constant

Ans. (1)

Sol. $R_A = R_1 + R_2$

$= R_0(1 + \alpha\Delta T) + R_0(1 - \alpha\Delta T) = 2R_0$

$$I_A = \frac{V}{R_A} = \frac{V}{2R_0}$$

does not depends on temperature

$$R_B = \frac{R_1R_2}{R_1 + R_2} = \frac{R_0^2(1+\alpha\Delta t)(1-\alpha\Delta t)}{R_0(1+\alpha\Delta t) + R_0(1-\alpha\Delta t)}$$

$$= \frac{R_0^2(1-\alpha^2\Delta t^2)}{2R_0}$$

$$R_B = \frac{R_0}{2}(1-\alpha^2\Delta t^2)$$

as $\Delta t \uparrow R_B \downarrow I_B \uparrow$

37. Consider that σ_S, k_B, b represent Stefan-Boltzmann constant, Boltzmann constant and Wien's displacement law constant, respectively. The dimension of $\sigma_S k_B^{-1}$ b is :

(1) $[L^{-1}T^{-1}K^{-2}]$ (2) $[L^{-1}K^{-2}]$

(3) $[L^{-1}T^{-1}K^{-3}]$ (4) $[L^{-1}T^{-1}K^{-4}]$

Ans. (1)

Sol. $[\sigma_S][k_B^{-1}][b] = \left[\frac{\text{Intensity}}{(\text{Temp})^4}\right]\left[\frac{\text{Energy}}{\text{Temp}}\right]^{-1}[\lambda_{max}\text{ Temp}]$

$$= \left[\frac{MT^{-3}}{K^4}\right]\left[\frac{ML^2T^{-2}}{K}\right]^{-1}[LK]$$

$= [M^0L^{-1}T^{-1}K^{-2}]$

38. An electromagnetic wave travelling in a lossless dielectric medium having a dielectric constant $\in_r = 9$, has the electric field, $E_x = E_0 \sin(kz - 2\pi \times 10^6 t)\ Vm^{-1}$ where E_0 is the amplitude and k is the wave vector. Among the following options, the **incorrect** choice is :

(1) The speed of the electromagnetic wave inside the medium is $10^8\ ms^{-1}$

(2) The wavelength of the electromagnetic wave inside the medium is 300 m

(3) The magnetic field is given by the relation $B_y = \frac{B_0}{v}\sin(kz - 2\pi\times10^6 t)$ where v is the speed of the electromagnetic wave inside the medium

(4) The direction of propagation of the electromagnetic wave is along +z

Ans. (2,3)

Sol. Speed of EMW in a medium

$$C_m = \frac{C}{\sqrt{\mu_r\varepsilon_r}}$$

Here, $\mu_r = 1$, $\varepsilon_r = 9$

$$C_m = \frac{C}{\sqrt{1\times9}} = \frac{3\times10^8}{3} = 10^8 \text{ m/sec. (Correct)}$$

(2) $v = f\lambda \Rightarrow \lambda_m = \frac{C_m}{f}$

Here $2\pi f = \omega = 2\pi \times 10^6 \Rightarrow f = 10^6$

$$\lambda_m = \frac{C_m}{f} = \frac{10^8}{10^6} = 100 \text{ m (Incorrect)}$$

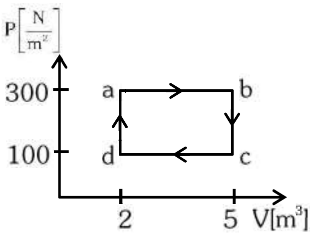
(3) $\frac{E_0}{B_0} = v \Rightarrow B_0 = \frac{E_0}{v}$

$$B_y = \frac{E_0}{v}\sin(kz - 2\pi\times10^6 t) \text{ (Incorrect)}$$

(4) Here EMW is propagating in +z (from eq.) (correct)

so incorrect statement $\rightarrow$ 2, 3

39. One mole of an ideal monatomic gas undergoes a cyclic process as shown in the figure. The total heat supplied to the gas is :



(1) 400 J (2) 500 J

(3) 600 J (4) 800 J

Ans. (3)

Sol. W = Q = Area of rectangle

Q = (300 – 100) (5 – 2)

= 200 × 3 = 600 J

40. Consider that an electron is revolving in an excited state of Hydrogen atom with velocity $\sqrt{25.6} \times 10^5\ ms^{-1}$. The radius of the orbit is x × 10^{-9} m. The value of x is :

[Take the mass of electron to be 9 × 10^{-31} kg, charge of electron = – 1.6 × 10^{-19} C and $\frac{1}{4\pi \in_0} = 9 \times 10^9\ N\ m^2\ C^{-2}$]

(1) 4 (2) 3

(3) 2 (4) 1

Ans. (4)

Sol. $\frac{mv^2}{r} = \frac{1}{4\pi \in_0}\frac{e^2}{r^2}$

$$\frac{9\times10^{-31}\times25.6\times10^5\times10^5}{r} = 9\times10^9\times\frac{1.6\times10^{-19}\times1.6\times10^{-19}}{r^2}$$

$$r = \frac{256\times10^{-40}}{256\times10^4\times10^5}\times\frac{10^9}{10^{-31}}$$

r = 1 × 1^{-9} m = x × 10^{-9} m

x = 1

41. A car travels on a circular racetrack of radius 50 m, which is banked at an angle θ. If the car travels at a speed 10 ms^{-1}, then the wear and tear on its tyres is minimum. Taking the acceleration due to gravity to be 10 ms^{-2}, the value of θ is :

(1) $\tan^{-1}\left(\frac{1}{5}\right)$ (2) $\tan^{-1}\left(\frac{2}{5}\right)$

(3) $\tan^{-1}\left(\sqrt{3}/2\right)$ (4) $\tan^{-1}\left(2\sqrt{3}\right)$

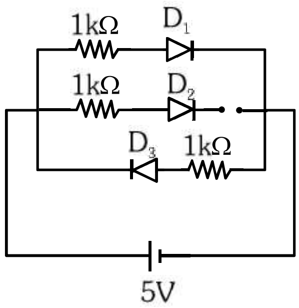
Ans. (1)

Sol. $\tan\theta = \frac{V^2}{Rg}$

$\tan\theta = \frac{(10)^2}{50\times10} = \frac{1}{5}$

$\theta = \tan^{-1}\left(\frac{1}{5}\right)$

42. Three identical p-n junction diodes D_1, D_2 and D_3 are connected across a battery as shown in the figure. If the width of the depletion regions of D_1, D_2 and D_3 are W_1, W_2 and W_3, respectively, then the correct option is :



(1) $W_1 > W_2 > W_3$ (2) $W_3 = W_1 > W_2$

(3) $W_3 > W_2 > W_1$ (4) $W_2 > W_1 = W_3$

Ans. (3)

Sol. Here diode D_1 is F.B. diode D_2 is unbias and diode D_3 is R.B.

In F.B width of depletion region decreases and in R.B width of depletion region increases so order of width of depletion region is

$W_3 > W_2 > W_1$

43. The following table presents the part of the electromagnetic spectrum and their corresponding major applications.

	Part of the electromagnetic spectrum		Applications
P	Microwave	I	For purifying the water
Q	UV rays	II	For warming the food
R	Gamma rays	III	For AM and FM communication systems
S	Radio wave	IV	For treating the Cancer cells

The **correct** option is :

(1) P-I, Q-II, R-III, S-IV (2) P-I, Q-IV, R-II, S-III

(3) P-II, Q-I, R-IV, S-III (4) P-II, Q-IV, R-III, S-I

Ans. (3)

Sol. * Microwaves are used for warming the food P-II

* UV rays are used for purifying the water Q-I

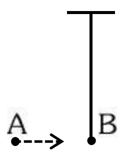
* Gamma rays are used for treating the cancer cells. (R-IV)

* Radio wave are used for AM and FM communication system (S-III)

(From NCERT)

Ans. P-II, Q-I, R-IV, S-III

44. Bob B of mass m at rest is hanging vertically from the ceiling via a massless string of length 10 m, as shown in the figure. Point mass A of mass m travelling horizontally with speed 10 ms^{-1} hits bob B elastically. The bob B rises h meter after the collision. Taking the acceleration due to gravity g = 10 ms^{-2} and neglecting the size of the bob, the value of h is :

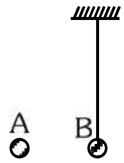


(1) 8 (2) 7

(3) 5 (4) 2.5

Ans. (3)

Sol.



* Mass same
* Collision → Head on elastic
* Velocity will interchange
* After that by COME

$$\frac{1}{2}mv^2 = mgh$$

$$h = \frac{v^2}{2g}$$

$$h = \frac{100}{20}$$

* h = 5 m

45. An ideal gas is made of polyatomic molecules. Each of the molecules has three translational, three rotational and *f* number of vibrational modes. If the ratio of heat capacities C_P/C_V of the gas is 8/7, then the value of *f* is :

(1) 4

(2) 3

(3) 3

(4) 1

Ans. (1)

Sol. Total degree of freedom = $\frac{2}{\gamma - 1}$

$$6 + 2f = \frac{2}{\frac{8}{7} - 1}$$

6 + 2f = 14

2f = 8

f = 4