Answers to RPH/Set-3

1. (*d*)
2. (*c*)
3. (*b*)
4. (*c*)
5. (*a*) Given: Capacitance of each capacitor = 3 μF

   Equivalent capacitance between A and B

$$C_{AB} = \frac{1}{\frac{1}{3}+\frac{1}{3}+\frac{1}{3}} + 3$$

$$= \frac{1}{\frac{3}{3}} + 3 = 1 + 3 = 4\ \mu F$$

   And equivalent capacitance between A and C

$$C_{AC} = \frac{1}{\frac{1}{3}+\frac{1}{3}} + \frac{1}{\frac{1}{3}+\frac{1}{3}}$$

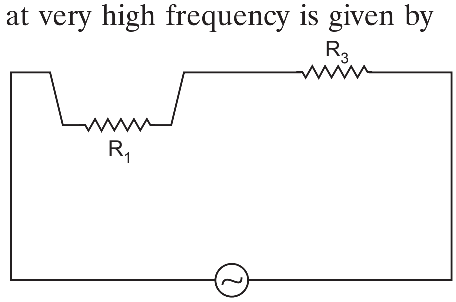
$$= \frac{3}{2} + \frac{3}{2} = \frac{6}{2} = 3\ \mu F$$

   Now, $\frac{C_{AB}}{C_{AC}} = \frac{4}{3}$

   ∴ Ratio = 4 : 3

6. (*c*) Since the frequency is very high therefore, 'C' behave as short circuit and 'L' will behave as an open circuit

   So, equivalent circuit at very high frequency is given by



   ∴ Equivalent resistance,

$$R' = R_1 + R_3$$

$$= 10 + 30 = 40\ \Omega$$

   and $I_0 = \frac{E_0}{R'} = \frac{200}{40} = 5$ A

7. (*d*)
8. (*c*)

9. (*c*)

10. (*b*)

11. (*d*)

12. (*a*)

13. (*d*) If both Assertion and Reason are false.

14. (*a*) If both Assertion and Reason are true and Reason is the correct explanation of Assertion.

15. (*b*) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

16. (*c*) If Assertion is true but Reason is false.

17. By Einstein's Photoelectric equation,

$$h(\nu - \nu_0) = \frac{1}{2}mv_{\max}^2$$

or

$$\nu_0 = \nu - \frac{mv_{\max}^2}{2h}$$

$$= 8 \times 10^{14} - \frac{9.1 \times 10^{-31} \times (7 \times 10^5)^2}{2 \times 6.63 \times 10^{-34}}$$

$$= 4.64 \times 10^{14} \text{ Hz}$$

18. Given: $\lambda = 600 \text{ nm} = 600 \times 10^{-9}$ m. $D = 0.8$ m, $n = 2$,

$\therefore \quad y_2 = 1.5 \text{ mm} = 1.5\ 10^{-3}$ m

Position of nth maximum in diffraction of a single slit.

$$y_n = \left(n + \frac{1}{2}\right)\frac{\lambda D}{a}$$

or.

$$a = \left(n + \frac{1}{2}\right)\frac{\lambda D}{y_n}$$

$$= \left(2 + \frac{1}{2}\right) \times \frac{600 \times 10^{-9} \times 0.8}{1.5 \times 10^{-3}}$$

$$= \frac{5}{2} \times \frac{200 \times 10^{-9} \times 8}{5 \times 10^{-3}} = 8 \times 10^{-4} = 0.8 \text{ mm}$$

Or

Let the n_1^{th} bright fringe of the 750 nm pattern and the n_2^{th} bright fringe of the 900 nm pattern are situated at

$$y_{n_1} = n_1\frac{D\lambda_1}{d}$$

And

$$y_{n_2} = n_2\frac{D\lambda_2}{d}$$

As they coincide,

$$y_{n_1} = y_{n_2}$$

$$\Rightarrow \qquad \frac{n_1 D\lambda_1}{d} = \frac{n_2 D\lambda_2}{d}$$

or

$$\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} = \frac{900}{750} = \frac{6}{5}$$

∴ The first position where the overlapping occurs at

$$y_5 = y_6 = \frac{6D\lambda}{d}$$

$$= \frac{6 \times 2 \times 750 \times 10^{-9}}{2 \times 10^{-3}}$$

$$= 4.5 \times 10^{-3} \text{ m} = 4.5 \text{ mm}$$

19. When radius of circular loop = r

∴ Magnetic field at its centre

$$B = \frac{\mu_0 I}{2r} \qquad \ldots(i)$$

When the radius is doubled, the resistance in the circuit is also doubled. Therefore, the current in the circuit becomes halved.

∴ Magnetic field at its centre

$$B' = \frac{\mu_0 I'}{2r'}$$

Here, $I' = \frac{I}{2}$ and $r' = 2r$

$$\therefore \qquad B' = \frac{\mu_0 \left(\frac{I}{2}\right)}{2(2r)} = \frac{1}{4}\left[\frac{\mu_0 I}{2r}\right]$$

Using equation (i), we get

$$B' = \frac{B}{4}$$

20. Mass defect in the process

$$\Delta m = 235.0439 + 1.00867 - (139.9054 + 93.9063 + 2.01734)$$

$$= 0.22353 \text{ u}$$

The corresponding energy released $= \Delta mc^2$

$= 0.22353\text{u} \times 931 = 208$ MeV $\quad (\because 1 \text{ u} = 931 \text{ MeV/c}^2)$

21. Let r_0 = Bohr radius, v_0 = Velocity of electron in first orbit

∴ Time taken by electron to complete one revolution,

$$T = \frac{2\pi r_0}{v_0}$$

∴ Current created by electron,

$$I = \frac{e}{T}$$

$$= \frac{e}{\left(\frac{2\pi r_0}{v_0}\right)} = \frac{ev_0}{2\pi r_0}$$

$$I = \frac{ev_0}{2\pi r_0}$$

22. Given: $I_{min} = 1$ mA

For minimum current of 1 mA, the potential drop of 0.7 V occurs across the diode for a forward bias of 5 V

(*a*) Given: $V_B = 5$ V, $V_d = 0.7$

$$\therefore \quad V_B = V_d + V_R$$
$$5 = 0.7 + I_{min} \times R_{max}$$
$$5 = 0.7 + 10^{-3} R_{max}$$

or $$R_{max} = \frac{5 - 0.7}{10^{-3}} = 4.3 \times 10^3 \ \Omega$$

(*b*) Given: $V_B = 5$ V, $I = 5$ mA $= 5 \times 10^{-3}$ A, $V_d = 0.7$ V

Here, $$V_B = V_R + V_d$$

or $$V_B = IR + V_d$$

or $$5 = 5 \times 10^{-3} R + 0.7$$

or $$R = \frac{5 - 0.7}{5 \times 10^{-3}} = \frac{4.3}{5} \times 10^3$$
$$= 0.86 \times 10^3 = 860 \ \Omega$$

Or

This behaviour is observed due to the nature of the *p-n* junction in forward and reverse bias conditions.

(*i*) **Forward bias:** When the positive terminal is connected to the *p*-side and the negative terminal to the *n*-side the *p-n* junction is forward biased.

This reduces the potential barrier at the junction, allowing charge carriers (electrons and holes) to move across the junction resulting in conduction.

(*ii*) **Reverse bias:** When the polarity is reversed (positive terminal connected to the n-side and negative terminal to p-side), the *p-n* junction is reverse biased.

This increases the potential barrier, preventing the movement of charge carriers across the junction and as a result, no conduction occurs.

23. Let the charges on C_1, C_2 and C_3 are q_1, q_2 and q_3 respectively

Then from diagram: $$V_A - V_O = \frac{q_1}{C_1}$$

or $$q_1 = C_1(V_A - V_O)$$

Similarly, $$V_B - V_O = \frac{q_2}{C_2}$$

or $$q_2 = C_2(V_B - V_O)$$

And, $V_D - V_O = \frac{q_3}{C_3}$

or $q_3 = C_2(V_D - V_O)$

By conservation of charge, at 'O'

$$q_1 + q_2 + q_3 = 0$$

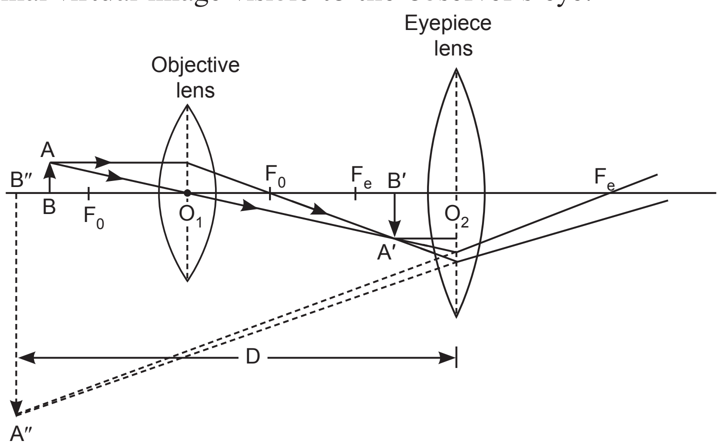
$\therefore$ $(V_A - V_O)C_1 + (V_B - V_O)C_2 + (V_D - V_O)C_3 = 0$

or $V_AC_1 - V_OC_1 + V_BC_2 - V_OC_2 + V_DC_3 - V_OC_3 = 0$

or $-V_O(C_1 + C_2 + C_3) + V_AC_1 + V_BC_2 + V_DC_3 = 0$

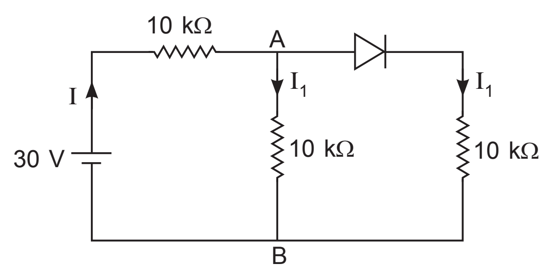
or $V_O = \frac{V_AC_1 + V_BC_2 + V_DC_3}{C_1 + C_2 + C_3}$

24. In a compound microscope, the eyepiece lens should have a greater focal length and a larger aperture compared to the objective lens to further magnify the image formed by the objective and make the final virtual image visible to the observer's eye.



25. $R_{eq} = 10 + \frac{10 \times 10}{10 + 10}$

$= 10 + \frac{100}{20} = 15\ k\Omega$



$\therefore$ $I = \frac{V}{R_{eq}}$

$= \frac{30}{15 \times 10^3} = 2 \times 10^{-3}$ A

$\therefore$ $I_1 = \frac{I}{2} = \frac{2 \times 10^{-3}}{2} = 1 \times 10^{-3}$ A

$\therefore$ $V_{AB} = I_1R$

$= 1 \times 10^{-3} \times 10^3 \times 10 = 10$ V

26. (*a*) Torque on the loop, $\tau = MB \sin \theta$

As M and B are parallel,

$\therefore$ $\theta = 0$

$\therefore$ $\tau = 0$

(*b*) Magnitude of force, $|\vec{F}| = \dfrac{\mu_0 I_1 I_2 l}{2\pi}\left(\dfrac{1}{r_1} - \dfrac{1}{r_2}\right)$

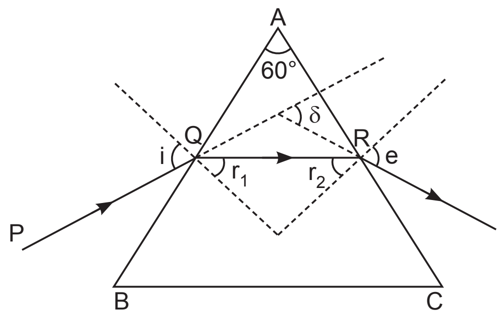
$$= 2 \times 10^{-7} \times 2 \times 1 \times 4 \times 10^{-2}\left[\frac{1}{2\times10^{-2}} - \frac{1}{4.5\times10^{-2}}\right]$$

$$= 16 \times 10^{-7}\left[\frac{4.5-2}{2\times4.5}\right] = \frac{8\times5\times10^{-7}}{9} = 4.44 \times 10^{-7}\text{ N}$$

Direction of force is towards conductor, i.e. attractive in nature.

27. Given: $A = 60°$, $\mu = \sqrt{3}$, $AQ = AR \Rightarrow QR||BC$

Hence in this case, there will be minimum deviation



$\therefore \quad r_1 = r_2 = r$

Using, $\quad r_1 + r_2 = A$

or $\quad 2r = A$

or $\quad r = \dfrac{A}{2}$

or $\quad r = \dfrac{60}{2} = 30°$

Now, using $\quad \mu = \dfrac{\sin i}{\sin r}$

or $\quad \sqrt{3} = \dfrac{\sin i}{\sin 30°}$

or $\quad \sin i = \sqrt{3}\sin 30° = \dfrac{\sqrt{3}}{2}$

or $\quad i = 60°$

Now, using $\quad i + e = A + \delta$

For minimum deviation, $i = e$, $\delta = \delta_m$

$\therefore \quad i + i = A + \delta_m$

or $\quad \delta_m = 2i - A$

Putting the values, $\quad \delta_m = 2 \times 60° - 60°$

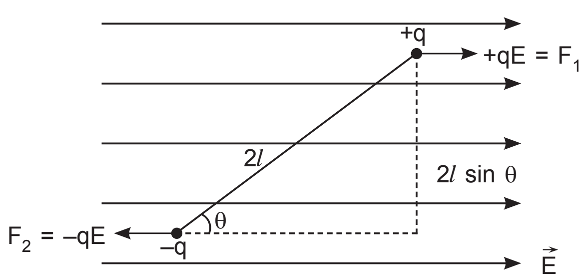
$= 120° - 60° = 60°$

or $\quad \sin e = \mu \sin 30°$

or $\quad \sin e = \sqrt{3} \times \dfrac{1}{2}$

or $\quad e = 60°$

28.



Force: The force on charge $+q$ is

$$\vec{F}_1 = q\vec{E}, \text{ the direction of } \vec{E} \text{ along}$$

The force on charge $-q$ is

$$\vec{F}_2 = q\vec{E}, \text{ opposite to the direction } \vec{E}$$

∴ Net force on electric dipole in uniform electric field is

$$\vec{F} = \vec{F}_1 - \vec{F}_2 = q\vec{E} - q\vec{E} = 0$$

Torque: As the forces F_1 and F_2 are equal and opposite in direction with different lines of action, they form a couple which tends to rotate and align the dipole along the direction of electric field. This couple is called torque (τ).

∴ τ = Magnitude of either force × Perpendicular distance between lines of action of force

$$= (qE)(2l \sin\theta)$$

$$= q(2l) E \sin\theta$$

$$\tau = PE \sin\theta$$

Where $P = q(2l)$, dipole moment

In vector from, $\vec{\tau} = \vec{P} \times \vec{E}$

29. (*i*) (*a*)

(*ii*) (*c*) Given: $E = 200$ N/C, $B = 25$ T

Using, $v = \dfrac{E}{B}$

We get, $v = \dfrac{200}{25} = 8$ m/s

∴ Option (*c*) is correct.

(*iii*) (*b*)

(*iv*) (*d*) Given: $B = 25$ T, $v = 10$ m/s

Using, $v = \dfrac{E}{B}$

or $10 = \dfrac{E}{25}$

or $E = 250$ N/C

Now electric field between two oppositely charged plates,

$$E = \frac{\sigma}{\varepsilon_0}$$

or $\sigma = E\varepsilon_0 = 250 \times 8.85 \times 10^{-12}$

$= 2222.5 \times 10^{-12} = 2.22 \times 10^{-9}$ Cm^{-2}

Or

(*iv*) (*b*)

30. (*i*) (*a*)

(*ii*) (*d*)

(*iii*) (*c*)

(*iv*) (*b*)

$$\lambda = \frac{12.27}{\sqrt{V}} \text{ Å} = \frac{12.27}{\sqrt{100}} \text{ Å}$$

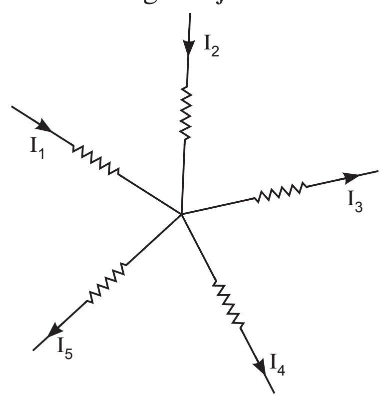
$$= \frac{12.27}{10} = 1.227 \text{ Å} = 0.123 \text{ nm}$$

Or

(*iv*) (*d*)

31. (*a*) Kirchhoff's laws are fundamental in electrical circuit theory and consist of two main rules.

(*i*) **Kirchhoff's current law:** The total current entering a junction in an electrical circuit equals the total current leaving the junction.



i.e., $I_1 + I_2 = I_3 + I_4 + I_5$

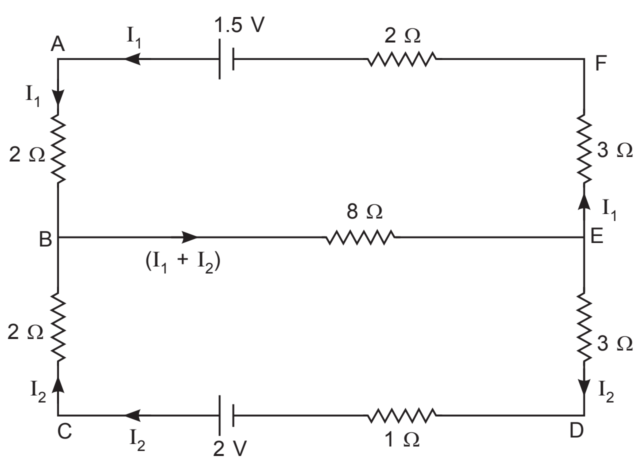
This law is based on the conservation of charge.

(*ii*) **Kirchhoff's voltage law:** The total sum of electrical potential differences around any closed loop or circuit is zero.

i.e., $\Sigma V = 0$

This law is based on the conservation of energy.

(*b*)



Applying Kirchhoff's rule in closed loop *ABEFA*,

$2I_1 + 8(I_1 + I_2) + 3I_1 + 2I_1 - 1.5 = 0$

or $15I_1 + 8I_2 = 1.5$ ...(*i*)

Now, applying Kirchhoff's rule in closed loop *BCDEB*,

$-2I_2 - I_2 - 3I_2 - 8(I_1 + I_2) + 2 = 0$

or $8I_1 + 14I_2 = 2$

or $4I_1 + 7I_2 = 1$ ...(*ii*)

Solving equation (*i*) and (*ii*), we get

$I_1 = \frac{5}{146}$ A, $I_2 = \frac{9}{73}$ A

Current flowing through 8 Ω resistance $= I_1 + I_2 = \frac{5}{146} + \frac{9}{73} = \frac{23}{146}$ A

∴ Potential difference across 8 Ω resistance $= (I_1 + I_2)R = \frac{23}{146} \times 8 = 1.26$ V

Or

(*a*) If *I* is the current flowing through a conductor of cross-sectional area '*A*' then the current density is given by

$$J = \frac{I}{A}$$

∵ $$I = neAv_d \quad \text{...}(i)$$

Where e = Electronic charge, n = Number of electron per unit volume

And $$v_d = \frac{eE}{m}\tau \quad \text{...}(ii)$$

Where m is mass of electron, E is electric field and τ is relaxation time

Then, $$I = neA\left(\frac{eE}{m}\tau\right) \quad \text{[Using equation } (ii)]$$

or $$= \frac{ne^2A\tau}{m}E \quad \text{...}(iii)$$

If l is length of conductor and V is applied voltage

then, $$E = \frac{V}{l}$$

∴ $$I = \frac{ne^2A\tau}{m}\left(\frac{V}{l}\right)$$

or $$V = \left(\frac{ml}{ne^2A\tau}\right)I$$

Comparing it with Ohm's law

$$V = IR, \text{ we get}$$

$$R = \frac{ml}{ne^2 A\tau}$$

$\because$ $$R = \rho\frac{l}{A}$$

$\therefore$ $$\rho = \frac{m}{ne^2\tau}$$

$\therefore$ Conductivity $$\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m}$$

Using this in equation (*iii*), we get

$$I = \sigma AE$$

or $$\frac{I}{A} = \sigma E$$

or $$J = \sigma E$$

(*b*) Mobility is given by

$$\mu = \frac{v_d}{E} = \frac{e\tau}{m}$$

As the temperature is constant, relaxation time will be same and if we double the potential difference, the mobility will change accordingly.

32. (*a*) Given: $E_P = 200$ V, $E_S = 20$ V, $R_L = 20\ \Omega$, $\eta = 80\%$

Now, $$I_S = \frac{E_S}{R_L} = \frac{20}{20} = 1 \text{ A}$$

$$\eta = \frac{\text{Power output}}{\text{Power input}} = \frac{E_S I_S}{E_P I_P}$$

$\therefore$ $$I_P = \frac{E_S I_S}{\eta E_P} = \frac{20\times 1}{\frac{80}{100}\times 200} = \frac{1}{8} = 0.125 \text{ A}$$

(*b*) (*i*) Current is maximum at resonance in a LCR circuit.

As resonant frequency, $\omega_r = \frac{1}{\sqrt{LC}}$

Since ω is same for the two circuits

$\therefore$ $$\sqrt{L_1C_1} = \sqrt{L_2C_2}$$

or $$L_1C_1 = L_2C_2$$

(*ii*) At resonance, $Z = R$

$\therefore$ Power factor $= \cos\phi$

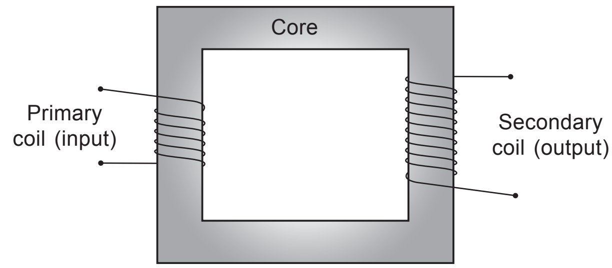
$$= \frac{R}{Z} = 1$$

Power factor is same for both the circuit and is equal to 1.

Or

Principle: A transformer works on the principle of electromagnetic induction.

Construction: A transformer consists of two sets of windings – primary and secondary coils, which are wound on a common iron core. In step-up transformer, the number of turns in the secondary coil is greater than in the primary coil.



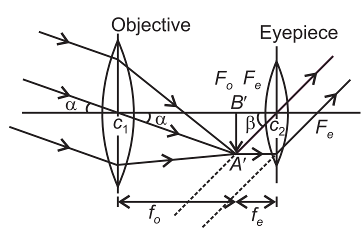
Working:

- When an alternating current is applied to the primary coil, it generates a varying magnetic field around the coil
- This varying magnetic field is concentrated by the iron core and links with the secondary coil, inducing an alternating voltage in it.
- Since the secondary coil has more turns than the primary, the voltage induced in the secondary coil is higher thus 'stepping up' the voltage.
- The voltage transformation follows the equation:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

Where V_S and V_P are the secondary and primary voltages, and N_S and N_P are the number of turns in the secondary and primary coils, respectively.

33. (*a*)



Refracting telescope

Magnifying power: The magnifying power of a telescope is measured by the ratio of angle (β) subtended by final image on the eye to the angle (α) subtended by object on the eye.

(*b*) (*i*) The lens with the smallest power or largest focal length should be used as the objective, i.e. lens with power 0.5 D.

The lens with the largest power or smallest focal length should be used as the eyepiece, i.e. lens with power 10 D.

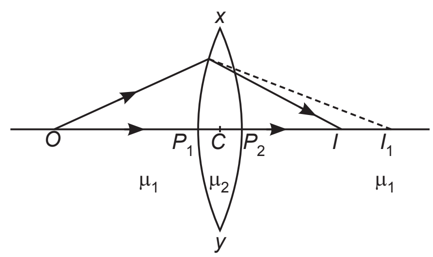
(*ii*) the aperture is preferred to be large so that the telescope can collect as much as light coming from the distant object as possible.

Or

Lens Maker's Formula: Consider a thin convex lens made of a material of absolute refractive index μ_2 placed in a rarer medium of absolute refractive index μ_1. Let μ be the refractive index of the material of the lens with respect to the medium surrounding it.

So $$\mu = \frac{\mu_2}{\mu_1}$$

Let us first consider the refraction of light from the object O at surface XP_1Y of the lens of radius of curvature R_1. Let I_1 be the real image formed due to refraction at surface XP_1Y assuming that the material of the lens extends beyond I_1 then



$$\frac{\mu_2}{v_1} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} \quad \ldots(i)$$

Here $v_1 = P_1I_1 = CI_1$ and $u = -OP_1 = -OC$

$$\therefore \quad \frac{\mu_2}{CI_1} + \frac{\mu_1}{OC} = \frac{\mu_2 - \mu_1}{R_1} \quad \ldots(ii)$$

Let us now consider the refraction at surface XP_2Y of the lens of radius of curvature R_2. For this surface I_1 acts as the virtual object. Therefore, the final image (real) of the object O is formed at I as shown in the diagram above.

For refraction at surface, XP_2Y, we have

$$\frac{\mu_1}{v} - \frac{\mu_2}{v_1} = \frac{\mu_1 - \mu_2}{R_2} \quad \ldots(iii)$$

Here $v = P_2I = CI$ and $v_1 = P_2I_1 = CI_1$

Therefore, equation (*iii*) can be rewritten as

$$\frac{\mu_1}{CI} - \frac{\mu_2}{CI_1} = \frac{\mu_1 - \mu_2}{R_2} \quad \ldots(iv)$$

From equations (*ii*) and (*iv*), on adding, we get

$$\frac{\mu_1}{CI} - \frac{\mu_2}{CI_1} + \frac{\mu_2}{CI_1} + \frac{\mu_1}{OC} = (\mu_2 - \mu_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

or $$\mu_1\left[\frac{1}{CI} + \frac{1}{OC}\right] = (\mu_2 - \mu_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

or $$\frac{1}{CI} + \frac{1}{OC} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

As $CI = v$ and $OC = -u$ and $\frac{\mu_2}{\mu_1} = \mu$

$$\therefore \quad \frac{1}{v} - \frac{1}{u} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

Following assumptions are considered:

(*i*) The lens is considered to be thin.

(*ii*) The rays are considered paraxial.

(*iii*) Aperture effects are considered neglible.

(*iv*) The surfaces of the lens are assumed to be perfectly spherical with radii of curvature R_1 and R_2.