Answers to RSPL/2

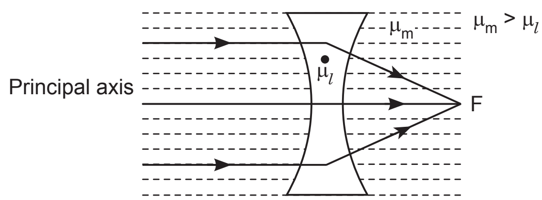
SECTION – A

1. Negative. $\vec{E}$ acts in the direction of decreasing potential.

2. (*a*) A is a better conductor.

(*b*) Slope = Conductance = $\frac{1}{\text{Resistance}}$.

3. The lens will behave as converging lens.



4. Pure semiconductors have very low conductivity. It is also temperature dependent. Doping improves the conductivity to a desired level and reduces temperature dependence.

5. (*i*) It fails to explain the stability of the atom because the accelerated motion of electrons will result in release of energy making them follow spiral path.

(*ii*) It fails to explain the characteristic line spectra of different atoms.

SECTION – B

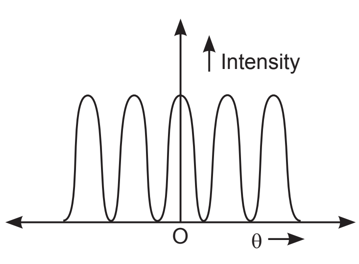
6. (*a*) Given $V = 56$ volts; $p = ?$

We have momentum $p = \sqrt{2\,m\,K} = \sqrt{2\,meV} = \sqrt{2 \times (9.11 \times 10^{-31})\,(1.6 \times 10^{-19})\,(56)}$

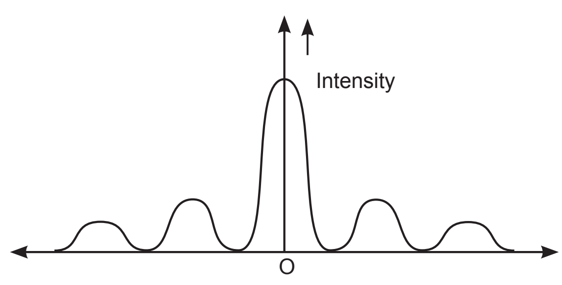
$= 4.04 \times 10^{-24}$ kg ms^{-1}

(*b*) de Broglie wavelength $\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{4.04 \times 10^{-24}} = 1.64 \times 10^{-10}$ m = 1.64 Å

7.



Intensity distribution due to superposition of light from two slits.
Phenomenon: Interference.



Intensity distribution due to light from a single slit.
Phenomenon: Diffraction

8. The force F on a moving charge in a magnetic field;

$$F \propto q; \text{ the magnitude of the charge}$$
$$\propto v; \text{ the speed of the charged particle}$$
$$\propto B; \text{ the intensity of the magnetic field}$$
$$\propto \sin\theta; \theta \text{ is the angle between } \vec{v} \text{ and } \vec{B}$$

Combining, we get $F = qvB \sin\theta$ [Constant = 1 in SI units]

$$B = \frac{F}{qv\sin\theta}$$

SI unit of B is tesla $1\text{ T} = \frac{1\text{ N}}{1\text{ C} . 1\text{ m/s}}$ (sin 90 = 1)

Hence one tesla is the intensity of the magnetic field which exerts a force of 1 N on a 1 C charge moving at 1 m/s perpendicular to the field direction.

In vector form; $\vec{F} = q(\vec{v} \times \vec{B})$

The direction of the force is given by right hand rule applied to $(\vec{v} \times \vec{B})$.

9. Originally; length = L; Area = A

Resistance $R = \rho\frac{L}{A}$

$$I = \frac{V}{R} = \frac{VA}{\rho L} \quad ...(i)$$

The volume of material is the same when the wire is pulled to length L' and area A'.

$\therefore$ $A'L' = AL \Rightarrow A' . 2L = AL$ $(\therefore\ L' = 2L)$

$\therefore$ $A' = \frac{A}{2}$

New resistance $R' = \rho\frac{L'}{A'} = \rho . \frac{2L}{A/2} = \frac{4\rho L}{A}.$

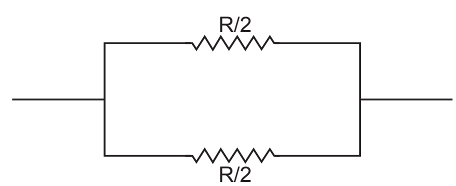
For current I; $V' = IR' = \frac{VA}{\rho L} \times \frac{4\rho L}{A} = 4V$

OR

Originally, resistance of the wire is

$$R = \frac{\rho L}{A} \quad ...(i)$$

For each of the two parts of equal length; $L' = \frac{L}{2}$



$\therefore$ Resistance $R' = \frac{\rho L/2}{A} = \frac{1}{2}\frac{\rho L}{A} = \frac{1}{2}R$

Net resistance R'' of the combination

$$R'' = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{\frac{1}{2}R \times \frac{1}{2}R}{\frac{1}{2}R + \frac{1}{2}R} = \frac{1}{4}R$$

10. We have $q_1 = q_2 = 10\ \mu C = 10^{-5}$ C

For charges placed 1 m apart; electrostatic potential energy

$$U_i = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} = \frac{9 \times 10^9 \times 10 \times 10^{-6}\, 10 \times 10^{-6}}{1}$$
$$= 9 \times 10^{-1} = 0.9 \text{ J}$$

With distance reduced to 0.5 m; potential energy

$$U_f = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r'} = \frac{9\times10^9\times10^{-5}\times10^{-5}}{1/2} = 1.8 \text{ J}$$

$\therefore$ Work done = $U_f - U_i$ = 1.8 J – 0.9 J = 0.9 J

SECTION – C

11. Capacitance: It is defined as the charge required to raise the potential of the capacitor by one volt. Its SI unit is farad (F).

For parallel combination; we have $U_p = 0.25$ J

$$V = 100 \text{ volt}$$

$$\therefore \quad \frac{1}{2}(C_1 + C_2)V^2 = 0.25 \text{ J}$$

$$C_1 + C_2 = 2 \times 0.25 \times 10^{-4}$$

or $$C_1 + C_2 = 5 \times 10^{-5} \text{ F} \quad ...(i)$$

In series combination; $$U_S = 0.045 \text{ J}$$

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\Rightarrow \quad C_S = \frac{C_1 C_2}{C_1 + C_2}$$

$$\therefore \quad \frac{1}{2}\left(\frac{C_1 C_2}{C_1 + C_2}\right)(100)^2 = 0.045 \text{ J}$$

$$\frac{1}{2}\left(\frac{C_1 C_2}{5\times10^{-5}}\right)\times10^4 = 0.045$$

or $$C_1 C_2 = 4.5 \times 10^{-10} \text{ F} \quad ...(ii)$$

Also $$(C_1 - C_2)^2 = (C_1 + C_2)^2 - 4C_1C_2 = (5 \times 10^{-5})^2 - 4(4.5) \times 10^{-10}$$

$$= 7 \times 10^{-10} \text{ or } C_1 - C_2 = 2.65 \times 10^{-5} \text{ F} \quad ...(iii)$$

Using (*i*) and (*iii*); $$C_1 = 3.8 \times 10^{-5} \text{ F}$$

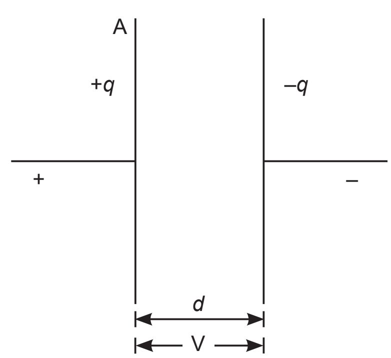
and $$C_2 = 1.2 \times 10^{-5} \text{ F}$$

In parallel combination; each of the two capacitors C_1 and C_2 will be charged to 100 V.

$$\therefore \quad q_1 = C_1V = 3.8 \times 10^{-3} \text{ C} = 3.8 \text{ mC}$$

and $$q_2 = C_2V = 1.2 \times 10^{-3} \text{ C} = 1.2 \text{ mC}$$

OR



Consider a parallel plate capacitor with plates of area '*A*' each held at a distance '*d*' apart.

The capacitance is given by $C = \frac{\varepsilon_0 A}{d}$.

Charging a capacitor requires transfer of electric charge from one plate to the other so as to raise the potential difference to *V* and the charge to '*q*'.

Let q' be some intermediate value of charge between O and 'q' and V' the corresponding potential.

Then $$V' = \frac{q'}{C}$$

If an additional charge dq' is transferred to the capacitor; the work done dW is given by

$$dW = V' \times dq' = \frac{1}{C} q' \, dq'$$

Work done to raise the charge from 0 to q is

$$W = \int dW = \frac{1}{C} \int_0^q q' \, dq'$$

$$= \frac{1}{C} \left| \frac{(q')^2}{2} \right|_0^q = \frac{q^2}{2C} = \frac{C^2V^2}{2C} = \frac{1}{2} CV^2$$

This work measures the energy stored in the capacitor.

$\therefore$ $$U = W = \frac{1}{2} CV^2 = \frac{q^2}{2C}.$$

$$\text{Energy density} = \frac{\text{Energy}}{\text{Volume of the capacitor}}$$

$$= \frac{1}{2} CV^2 \div Ad = \frac{1}{2} \frac{\varepsilon_0 A}{d} \times \frac{1}{Ad} \cdot V^2$$

$$= \frac{1}{2} \varepsilon_0 \left(\frac{V}{d}\right)^2 = \frac{1}{2} \varepsilon_0 E^2$$

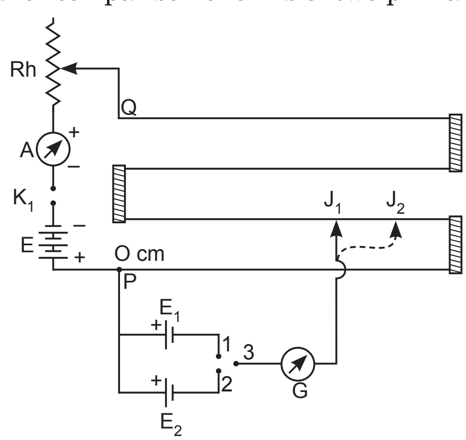
or $$u = \frac{U}{\text{Volume}} = \frac{1}{2} \varepsilon_0 E^2$$

S.I. unit of energy density is Joule/meter^3

12. **Principle of potentiometer:** For a wire of uniform area of cross-section carrying a steady current; the potential difference across any length of the conductor is directly proportional to the length, Mathematically $V \propto l$ or $V = kl$.

Circuit diagram for comparison of emf's of two primary cells

The circuit diagram used for comparison of emf's of two primary cells is as under:



Insert key K_1 and the key between terminals 1 and 3 of the two-way key to bring cell E_1 in the circuit. Adjust the position of the jockey to get the balancing length l_1 for zero deflection in the galvanometer.

We have $E_1 = kl_1$ ...(*i*)

Repeat with key between terminals 2 and 3 of the two-way key to get balancing length l_2 for the cell E_2.

We have $E_2 = kl_2$ ...(*ii*)

Dividing (*i*) by (*ii*) gives,

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

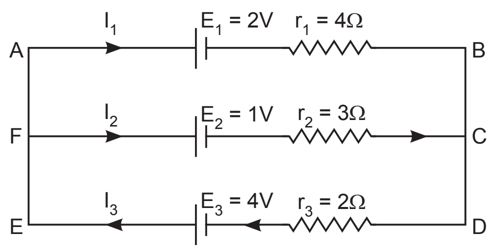
Possible causes for one sided deflection:

(*i*) The emf of the driver cell E may be smaller than E_1 or E_2.

(*ii*) The positive terminal of the cells may not be joined to common end of the potentiometer.

13. (*i*) Kirchhoff's junction rule: In an electric circuit, the algebraic sum of the currents meeting at any junction is zero.

(*ii*) Loop rule: In any closed loop in an electric circuit; the algebraic sum of the change in potential across various parts is zero.



In loop ABCFA; we have

$$-2 - 4I_1 + 3I_2 + 1 = 0$$

or $4I_1 - 3I_2 = -1$ ...(*i*)

In loop CDEFC;

$$-2I_3 + 4 - 1 - 3I_2 = 0$$

or $3I_2 + 2I_3 = 3$ ...(*ii*)

By junction rule at C; we get

$I_1 + I_2 = I_3$ ...(*iii*)

Using (*i*) in (*ii*); we get

$2\,I_1 + 5\,I_2 = 3$ ...(*iv*)

Solving (*i*) and (*iv*), we get

$$-13\,I_2 = -7 \quad \text{or} \quad I_2 = \frac{7}{13}\text{ A}$$

$\therefore$ From (*iv*); $2\,I_1 = 3 - \frac{35}{13} = \frac{4}{13}$ or $I_1 = \frac{2}{13}$ A

and From (*iii*) $I_3 = \frac{9}{13}$ A

14. Given energy stored in inductor = $U = \frac{1}{2} LI^2$ ...(*i*)

For a coil; Inductance $L = \mu_0 n^2 Al$ ...(*ii*)

Magnetic field intensity in the inductor = $B = \mu_0 nI$ ...(*iii*)

or $$I^2 = \frac{B^2}{\mu_0^2 n^2}$$

∴ From (*i*) $$U = \frac{1}{2}(\propto_0 n^2 Al)\frac{B^2}{\propto_0^2 n^2}$$

or $$U = \frac{B^2}{2\mu_0} . A . l$$

Energy density of the magnetic field = $u = \frac{\text{Energy}}{\text{Volume}}$

∴ $$u = \frac{U}{V} = \frac{1}{A . l} \cdot \frac{B^2}{2\mu_0} A . l = \frac{B^2}{2\mu_0}$$

15. We have total length of the transmission line = 2 × 16 = 32 km.

∴ Resistance per km = 0.5 Ω/km

Resistance of the line wire = 0.5 × 32 = 16Ω.

(*a*) Given; Power received: $P = 600 \text{ kW} = 6 \times 10^5 \text{ W}$

$V = 3000 \text{ V}$

∴ $$I = \frac{P}{V} = \frac{6 \times 10^5}{3000} = \frac{600}{3} = 200 \text{ A}$$

∴ Power loss in the line as heat = $I^2R = (200)^2 \times 16 = 640$ kW

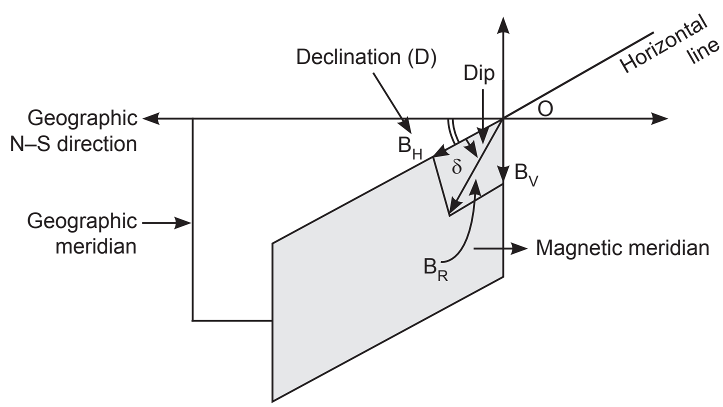
(*b*) Total power supply required from the plant = power required + power loss

= 600 kW + 640 kW = 1240 kW

(*c*) **Principle of transformer:** It works on the phenomenon of mutual induction i.e. whenever there is a change in magnetic flux linked with a coil, an induced emf is developed in the neighbouring coil.

The power loss can be reduced if the supply is made at a higher voltage; say 6000 V as compared to 3000 V.

16.



The three elements used to completely define earth's magnetic field at a place are:

Declination (D): It is the angle between the magnetic meridian and the geographic meridian at a place. It helps us find the true geographic meridian at a that place.

Inclination (Dip) δ: It is the angle subtended by the resultant intensity of earth's magnetic field with the horizontal at a place. Its value gives the direction of earth's magnetic field.

Horizontal component of earth's magnetic (B_H): It is the component of earth's magnetic field along horizontal at a place. Its value gives the net intensity B_R of the magnetic field at that place.

(*a*) Given $B_H = 4 \times 10^{-5}$ T = 0.4 G

$$\delta = 30°$$

$$\frac{B_V}{B_H} = \tan\delta$$

$\therefore$
$$B_V = B_H \tan\delta$$
$$= 4 \times 10^{-5} \times \tan 30$$
$$= 4 \times 10^{-5} \times \frac{1}{\sqrt{3}}$$
$$= 2.3 \times 10^{-5} \text{ T} = 0.23 \text{ G}$$

(*b*) Also $\frac{B_H}{B_R} = \cos\delta \Rightarrow B_R = B_H \sec\delta = \frac{0.4\text{ G} \times 2}{\sqrt{3}} = 0.46$ G

(*c*) $B_V = 0$ on magnetic equator.

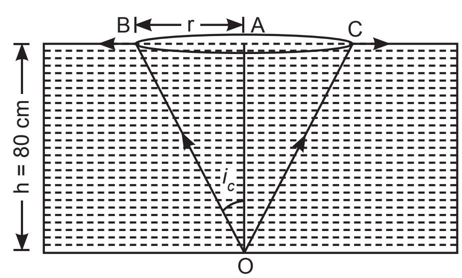
17. (*a*) Electromagnetic waves are associated both with time varying electric and magnetic fields.

An oscillating charge is an accelerated charge. It produces both electric and magnetic fields each varying with time. These time varying fields produce each other helping electromagnetic waves to sustain in space or a medium.

(*b*) (*i*) Microwaves (*ii*) Ultraviolet radiations

(*iii*) Infra red waves (*iv*) Gamma rays.

18. The path of light rays from the small source at 'O' to the water surface is as shown.



'h' denotes the depth of water in the tank. The light from 'O' can emerge out of a cone with height 'h' and a semi-vertical angle i_c; the critical angle of water.

We have $\frac{AB}{OA} = \tan i_c$ or $AB = r = h \tan i_c$

Also, $\mu = \frac{1}{\sin i_c} \Rightarrow \sin i_c = \frac{1}{\mu} = \frac{1}{4/3} = \frac{3}{4}$

$\therefore$ In the adjoining triangle; $\tan i_c = \frac{3}{\sqrt{7}}$

Hence $r = h \tan i_c = 80\left(\frac{3}{\sqrt{7}}\right)$ cm = 91 cm = 0.91 m

Area of water surface allowing light to emerge out

$$= \pi r^2 = 3.14 \times (0.91)^2 \text{ m}^2$$

$$= 2.6 \text{ m}^2.$$

The light cannot emerge out of the entire surface due to total internal reflection.

19. In order to observe a sustained interference pattern, the light from the sources should be coherent. Two independent light sources cannot be coherent. Hence the interference pattern can't be observed.

Suppose $I_1 = I_2 = I$

(*a*) At point *P*; $\phi = 0$

$\therefore$ The resultant intensity $I_p = 4I \cos^2 \frac{\phi}{2} = 4I \cos^2 \theta = 4I$

(*b*) At point *Q*; $\phi = \frac{\pi}{2}$

$$\therefore \quad I_Q = 4I \cos^2 \left(\frac{\phi}{2}\right)$$

$$= 4I \cos^2 \frac{\pi}{4} = 4I\left(\frac{1}{\sqrt{2}}\right)^2 = 2I$$

$$\therefore \quad \frac{I_P}{I_Q} = \frac{4I}{2I} = 2 : 1.$$

20. (*a*) Given $\lambda = 550$ nm $= 5.50 \times 10^{-7}$ cm

Energy per unit area per unit time = 1.388×10^3 W/m^2

Energy of each photon = $E = h\nu = h\frac{c}{\lambda}$

or $$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{5.5 \times 10^{-7}} = 3.6 \times 10^{-19} \text{ J}$$

If *n* is the number of photons incident on 1 sq. m per sec; then

$$n.E = 1.388 \times 10^3$$

or $$n = \frac{1.388 \times 10^3}{3.6 \times 10^{-19}} = \frac{13.88}{3.6} \times 10^{21}$$

$$\simeq 4 \times 10^{21} \text{ /m}^2\text{/s}.$$

(*b*) According to Einstein's equation:

K.E = $h\nu - h\nu_0 = \text{h}(\nu - \nu_0)$

For $\nu < \nu_0$; K.E of photoelectron will be negative which is impossible.

Hence, there exists a minimum frequency, called threshold frequency below which photoelectric emission is not possible.

21. The transmission and reception system shown has the following drawbacks:

(*i*)

$$\nu_{max} = 20000 \text{ Hz}$$

$$\lambda_{min} = \frac{c}{\nu_{max}} = \frac{3 \times 10^8}{20000} = 15000 \text{ m} = 15 \text{ km}$$

The minimum antenna length for transmission and reception is $\frac{\lambda}{4}$ i.e. $\frac{15}{4}$ km = 3.75 km. Such tall antenna is not feasible.

(*ii*) Power associated with a signal is inversely proportional to the square of the wavelength.

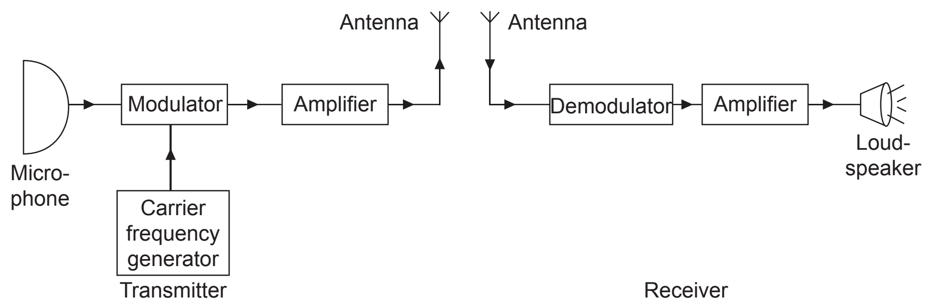
i.e. $$P \propto \frac{1}{\lambda^2}$$

As λ is very large; the signal is very weak (has low power) and hence cannot travel far. It does not have the effective intensity for long range transmission.

(*iii*) All audio signals from different stations will use the same frequency range of 20 Hz to 20000 Hz. This results in overlapping/mixing of signals at the receiving station.

The above drawbacks can be removed by using the following arrangement.

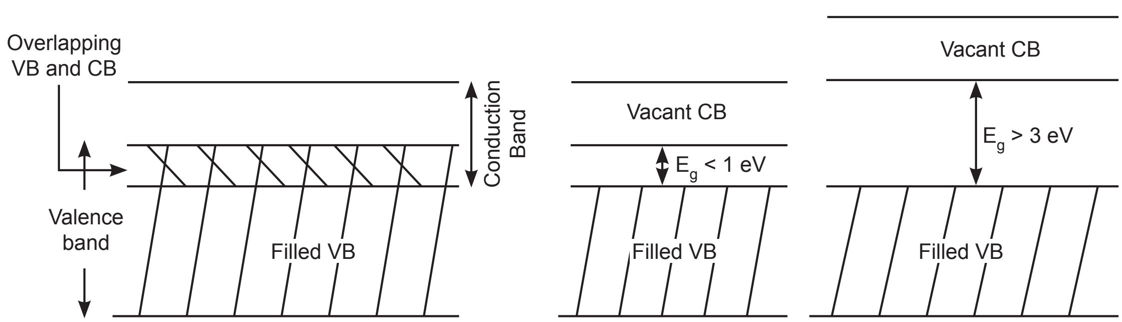
A schematic arrangement for transmitting a message signal (20 Hz to 20 kHz) is given below:



The audio signal from the microphone is superimposed on a suitable carrier frequency radio wave by a modulator.

The audio signal is recovered by a demodulator provided at the receiving end.

22. The energy band diagrams are as under.



(*i*) Metals **(*ii*) Semiconductors** **(*iii*) Insulators**

(*i*) In metals; the valence band and the conduction band overlap *OR*; the valence band is partially filled and hence the electrons in it can take part in conduction.

(*ii*) In insulators; the valence band is completely filled and the conduction hand is completely vacant. There is a wide gap between the V.B. and the C.B. The condition is not altered at 0 K or 300 K (room temperature).

(*iii*) In semiconductors, the valence band is completely filled and the conduction band is completely vacant at 0 K. The forbidden gap between the two is small. The electrons can jump to conduction band at room temperature.

SECTION – D

23. (*a*) The atom bombs used in Hiroshima and Nagasaki caused death of a very large number of people. This perturbed Einstein as the bombs were based on Einstein's theory.

(*b*) Love for humanity, desire that scientific knowledge should be used only for welfare of mankind.

(*c*) As $E = mc^2$; For $m = 1$ mg $= 10^{-6}$ kg

We have $E = 10^{-6} \times (3 \times 10^8)^2 = 9 \times 10^{10}$ J

(*d*) (*i*) Nuclear fission

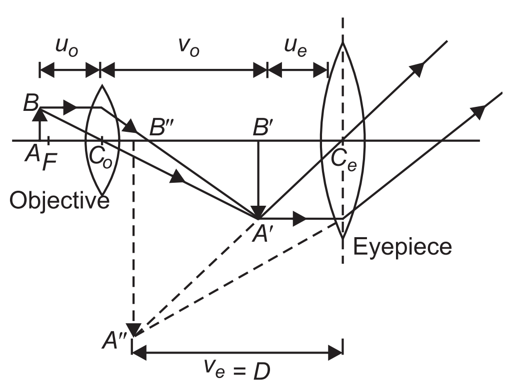
(*ii*) Nuclear fusion.

SECTION – E

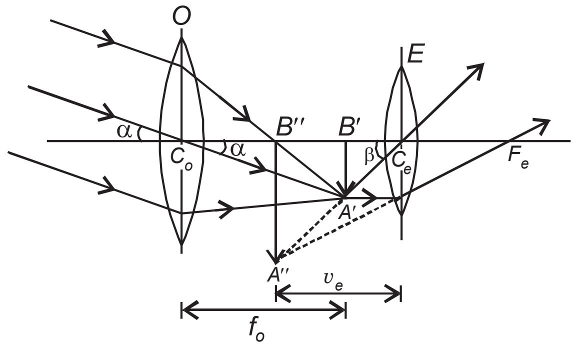
24. (*a*)

Compound Microscope	Astronomical Telescope
(*i*) The objective has a small aperture and short focal length.	(*i*) The objective has a large aperture and large focal length.
(*ii*) The eye-piece has a comparatively larger focal length (but not very large).	(*ii*) The eye-piece should have short focal length.
(*iii*) Both the objective and the eye-piece produce magnification.	(*iii*) The objective produces diminished image only while eye-piece produces magnification.

Ray Diagrams



Compound Microscope



Astronomical Telescope

(*b*) Given $f_0 = 1.25$ cm

$f_e = 5.0$ cm

Angular magnification $M = 30$

The eye-piece produces image at the distance of distinct vision i.e. 25 cm from the eye.

$\therefore \quad m_e = 1 + \frac{D}{f_e} = 1 + \frac{25}{5} = 6$

Also $\quad M = m_0 \times m_e$

or $\quad 30 = m_0 \times 6 \quad \Rightarrow \quad m_{\text{objective}} = 5$

The objective produces a real image. So object distance '*u*' is negative and image distance '*v*' is positive.

Suppose $\quad u = -x$ cm

Then $\quad \frac{v}{u} = 5 \quad \Rightarrow \quad v = 5|u| = +5x$ cm

Using lens equation $\quad \frac{1}{f} = \frac{1}{v} - \frac{1}{u};$

We get $\quad \frac{1}{5x} - \frac{1}{-x} = \frac{1}{1.25}$

or $\quad \frac{1}{5x} + \frac{1}{x} = \frac{1}{1.25} = \frac{1}{5/4} = \frac{4}{5}$

Multiply by $5x$, we get $1 + 5 = 4x$

$\therefore \quad x = \frac{6}{4} = 1.5$ cm

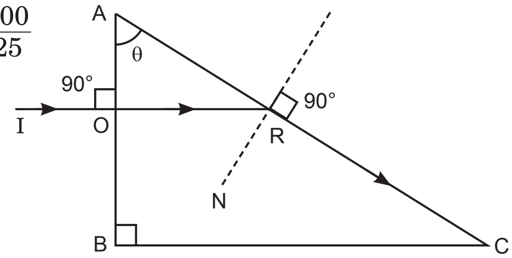
Hence the object should be placed 1.5 cm away from the objective.

OR

In the given figure; $\angle ARO = 90 - \theta$

$\therefore \quad \angle ORN = \theta \quad$ or $\quad \angle i = \theta.$ [on face AC]

Since light grazes along AC; $\angle i$ $(= \theta)$ is the critical angle



$\therefore$ For $\lambda = 4000$ Å; $\mu = \frac{1}{\sin i_c} = \frac{1}{\sin \theta} = \frac{1}{0.625} = \frac{1000}{625}$

or $\mu = \frac{8}{5} = 1.6$

$\therefore$ We have $1.6 = 1.2 + \frac{b}{(4 \times 10^{-7})^2}$

$b = 16 \times 10^{-14} \times 0.4$

$= 6.4 \times 10^{-14}$ m^2

Hence for $\lambda = 5000$ Å, we get

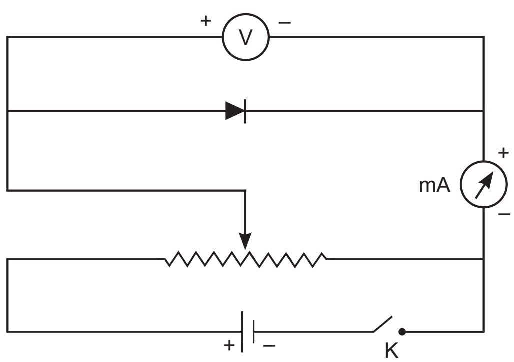
$\mu = 1.2 + \frac{b}{\lambda^2}$

$= 1.2 + \frac{6.4 \times 10^{-14}}{5000 \times 5000 \times 10^{-20}}$

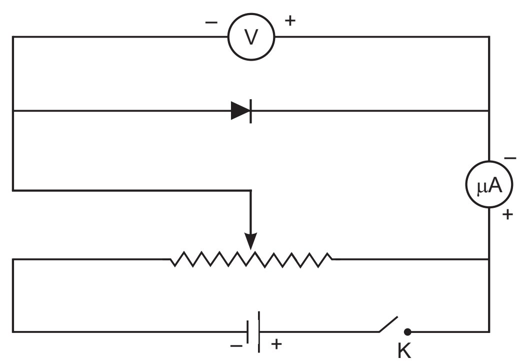
$= 1.2 + \frac{6.4}{25} = 1.2 + 0.256$

$= 1.456 \simeq 1.46.$

25. (*a*) The circuit diagrams for the study of *p*-*n* junction characteristics are as under:



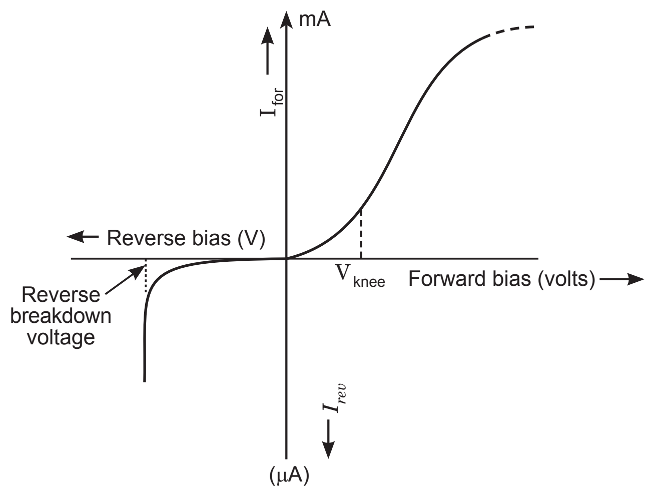
(*i*) Study of the characteristics of a forward biased *p-n* junction



(*ii*) Study of the characteristics of a reverse biased *p-n* junction

(*i*) **Forward bias:** For applied voltages below the barrier potential, the current is zero and increases very slowly above barrier potential. For applied voltages above knee potential, the current increases rapidly showing a large increase for small increase in forward potential. The current in forward bias is measured in *m*A.

(*ii*) **Reverse bias:** In reverse bias, the current flows due to minority charge carriers and is small. It is expressed in μA. The current increase very slowly for small voltage. At a certain reverse potential, called reverse breakdown voltage, the current shows a rapid increase as shown.



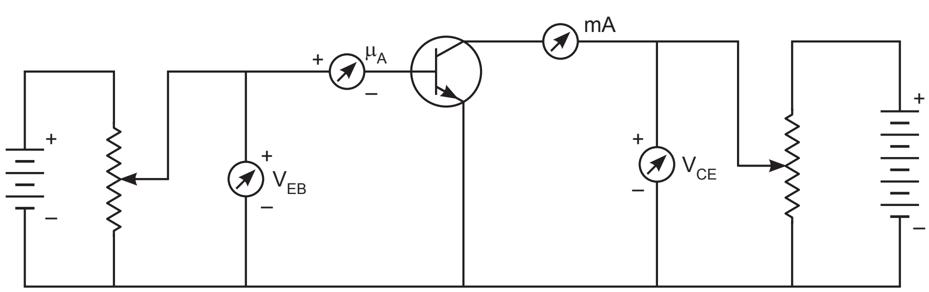
The Characteristic Curve

(*b*) **Photodiode:** It is fabricated photosensitive semiconducting material and converts light energy to electrical energy. It is always operated in reverse bias. The incident light on the junction breaks bonds resulting in increase in reverse leakage current.

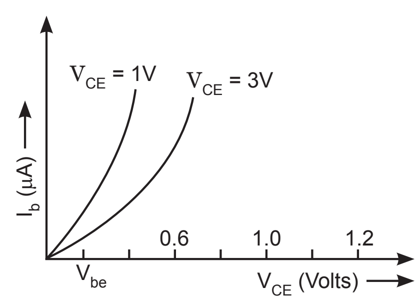
It is used in automation and for measuring intensity of light.

OR

(*a*) The circuit diagram for study of the input and output characteristics of *npn* transistor in common-emitter configuration is as under.



Input characteristics: It is a graph showing variation of base current with increasing emitter-base potential keeping collector emitter voltage constant. The graph resembles forward bias characteristics of *pn* junction. For different fixed values of V_{CE}, we get a family of input characteristic curves.



Input characteristics

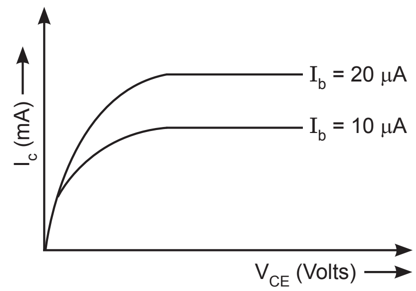
(*i*) The ratio of change in emitter-base potential to the corresponding change in base current is defined as the input resistance.

$$R_{\text{in}} = \frac{\Delta V_{EB}}{\Delta I_b}$$

It is low because the *BE* junction is forward biased.

Output characteristics: It is the study of change in collector current with change in collector-emitter potential (V_{CE}) for a fixed value of base current I_b.

For different fixed values of base current, we get a family of output characteristics curves.



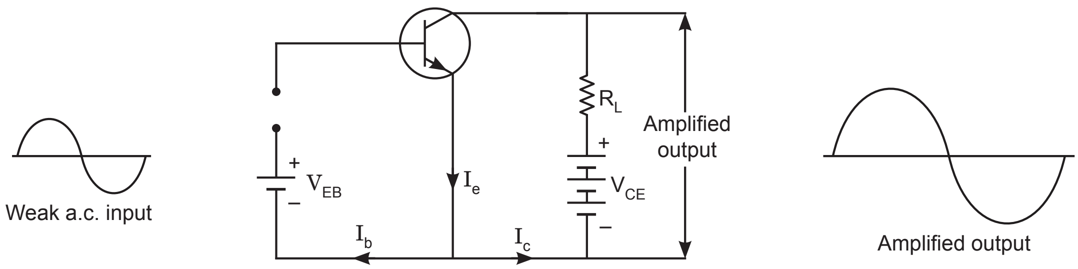
Output characteristics

(*ii*) The current amplification factor of a transistor is the ratio of change in collector current to corresponding change in base current at a fixed V_{CE}

$$\beta_{ac} = \frac{\text{Change in collector current}}{\text{Change in base current}} = \frac{\Delta I_c}{\Delta I_b}$$

It values varies between 15 to 50 depending on the design of the transistor.

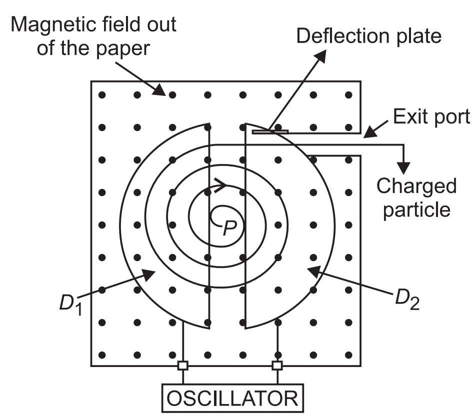
(*b*) The circuit diagram showing use of common emitter *npn* transistor is as under.



The weak varying signal to be amplified is superimposed on the emitter-base voltage. Small variations in input signal change the forward potential of emitter-base circuit resulting in a large increase in output potential.

The output is amplified but out of phase with the input as shown.

26. The arrangement used in a cyclotron is as under.



Principle: A charged particle can be accelerated by an oscillating electric field by making it follow circular path in a transverse magnetic field.

(*a*) The magnetic field applied makes the charged particles follow circular path. The oscillating electric field speeds up the charged particles.

(*b*) A magnetic field of intensity B is applied in a direction perpendicular to the plane in which the charged particle moves. If 'q' is the charge; m the mass and v the instantaneous speed; we have

Lorentz's magnetic force = Centripetal force

or $$qvB \sin \theta = \frac{mv^2}{r}$$

or $$r = \frac{mv}{qB} \qquad [\theta = 90°]$$

Period of revolution of the particle

$$T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$$

which is independent of both the speed of the particle as well as the radius of its circular path.

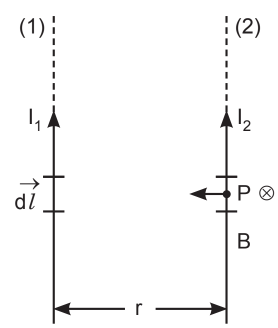
(*c*) **Resonance Condition:** The resonance condition in a cyclotron is

$$qB = 2\pi m\, \nu_{osc.}$$

So the energy has to be fed to the particle by the electric field at frequency $\nu_{osc.}$. The magnetic field intensity and the frequency of the oscillator are adjusted to satisfy the above equation. This resonance helps to keep the particle in step with the accelerating field.

OR

(*a*) Consider two long, straight, thin parallel metallic wires held at a distance 'r' apart in vacuum. Suppose the wires (1) and (2) carry currents I_1 and I_2 as shown.



The wires exert force on each other due to interaction of their magnetic fields. Take a point on conductor (2), magnetic field at P due to conductor (1) is $B = \frac{\mu_0 I_1}{2\pi r}$ into the paper; the force on a length 'l' of (2) due to field of conductor (1) is

$$F = I_2(\vec{l} \times \vec{B})$$

$$= BI_2 l \qquad (\text{As } \vec{l} \perp \vec{B})$$

∴ $$F = \left(\frac{\mu_0 I_1}{2\pi r}\right) I_2 l$$

or $$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}$$ which is the required expression.

Definition of Ampere: If $I_1 = I_2 = 1\text{A}$

$$r = 1 \text{ m};$$

Then $$\frac{F}{l} = \frac{\mu_0}{2\pi} = \frac{4\pi \times 10^{-7}}{2\pi} = 2 \times 10^{-7}\ \text{Nm}^{-1}$$

Hence one ampere is the current which when flowing through two long, straight conductors of negligible cross-section held 1 m apart in vacuum exerts a force of 2×10^{-7} newton per metre of the conductors.

(*b*) We have $q = e = 1.6 \times 10^{-19}$C

$B = 6.5\text{G} = 6.5 \times 10^{-4}$ T

$v = 4.8 \times 10^6$ m/s

$\theta = 90°$

$\therefore$ $F = q\,vB \sin\theta = qvB = evB$ [sin 90 = 1]

or $F = 1.6 \times 10^{-19} \times 4.8 \times 10^6 \times 6.5 \times 10^{-4}$ N

$\simeq 5.0 \times 10^{-16}$ N

The path followed by the electron will be circular.

Radius of the path $= r = \dfrac{mv}{qB}$

$$= \frac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}} = 4.2 \times 10^{-2} \text{ m}$$

$= 4.2$ cm