CBSE Board
Class XII Physics – Set 1
Board Paper - 2011

Time: 3 hours **[Total Marks: 70]**

General instructions:

1. All questions are compulsory.

2. There are 30 questions in total. Questions 1 to 8 are very short answer type questions and carry one mark each.

3. Questions 9 to 18 carry two marks each, questions 19 to 27 carry three marks each and questions 28 to 30 carry five marks each.

4. There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all three questions of five marks each. You have to attempt only one of the given choices in such questions.

5. Use of calculators in not permitted. However, you may use log tables if necessary.

6. You may use the following values of physical constants wherever necessary.

$c = 3 \times 10^8\ ms^{-1}$

$h = 6.626 \times 10^{-34}$ Js

$e = 1.602 \times 10^{-19}$ C

$\mu_o = 4\pi \times 10^{-7} TmA^{-1}$

$\frac{1}{4\pi\varepsilon_o} = 9 \times 10^{-9} Nm^2C^{-2}$

Mass of electron $m_e = 9.1 \times 10^{-31}$ kg

Mass of neutron $m_n \cong 1.675 \times 10^{-27}$ kg

Boltzmann's constant $k = 1.381 \times 10^{-23}\ J\ K^{-1}$

Avogadro's number $N_A = 6.022 \times 10^{23}\ mol^{-1}$

Radius of earth = 6400 km

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1. A point charge Q is place at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero, if Q is (i) positive (ii) negative?

2. A plane electromagnetic wave travels in vacuum along z-direction. What can you say about the direction of electric and magnetic field vectors?

3. A resistance R is connected across a cell of emf ε and internal resistance r. A potentiometer now measures the potential difference between the terminals of the cell as V. Write the expression for 'r' in terms of ε, V and R.

4. The permeability of a magnetic material is 0.9983. Name the type of magnetic materials it represents.

5. Show graphically, the variation of the de-Broglie wavelength (λ) with the potential (V) through which an electron is acceleration from rest.

6. In a transistor, doping level in base is increased slightly. How will it affect (i) collector current and (ii) base current?

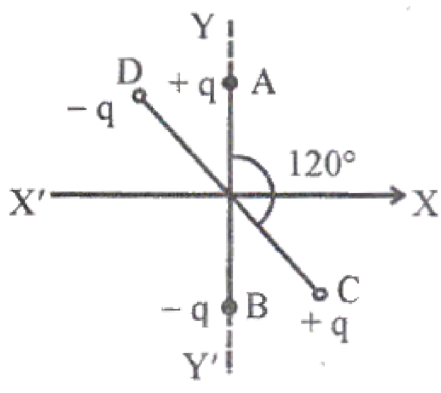
7. Define the term 'wattles current'.

8. When monochromatic light travels from one medium to another its wavelength changes but frequency remains the same. Explain.

9. Two uniformly large parallel thin plates having charge densities $+\sigma$ and $-\sigma$ are kept in the X-Z plane at a distance'd' apart. Sketch an equipotential surface due to electric field between the plates. If a particle of mass m and charge '-q' remains stationary between the plates, what is the magnitude and direction of the field?

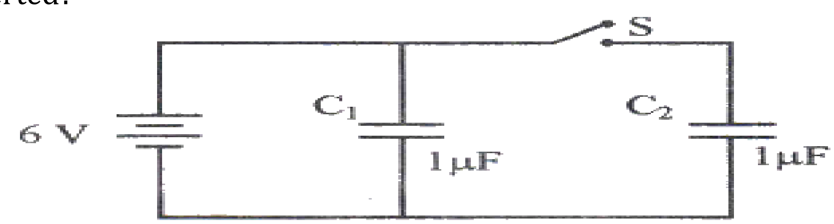
OR

Two small identical electrical diploes AB and CD, each of dipole moment 'p' are kept an angle of 120° as shown in the figure. What is the resultant dipole moment of this combination? If this system is subjected to electric field $\vec{E}$ directed along +X direction, what will be the magnitude and direction of the torque acting on this?



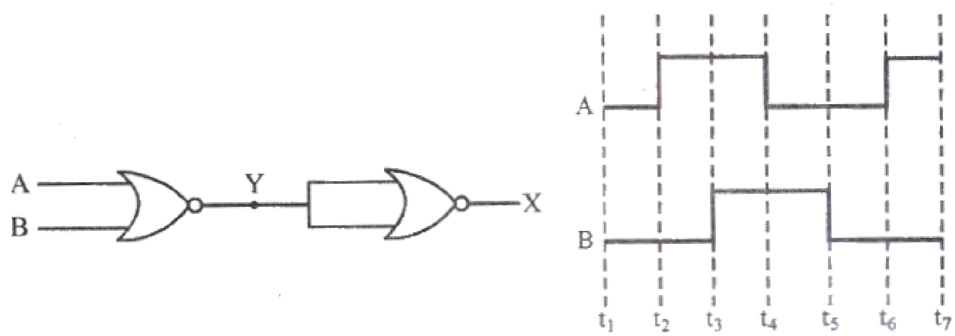
10. A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its north tip down in 60° with the horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.4 G. Determine the magnitude of the earth's magnetic field at the place.

11. Figure shows to identical capacitors, C_1 and C_2, each of 1 μF capacitance connected to a battery of 6V. Initially switch 'S' is closed. After sometimes 'S' is left open and dielectric slabs of dielectric constant K = 3 are inserted to fill completely the space between the plates of the two capacitors. How will the (i) charge and (ii) potential difference between the plates of the capacitors be affected after the slabs are inserted?



12. Two convex lenses of same focal length but of aperture A_1 and A_2 <$A_2 < A_1$) are used as the objective lenses in two astronomical telescopes having identical eyepieces. What is the ratio of their resolving power? Which telescope will you prefer and why? Give reason.

13. Draw the output waveform at X, using the given inputs A and B for the logic circuit shown below. Also, identify the logic operation performed by this circuit.



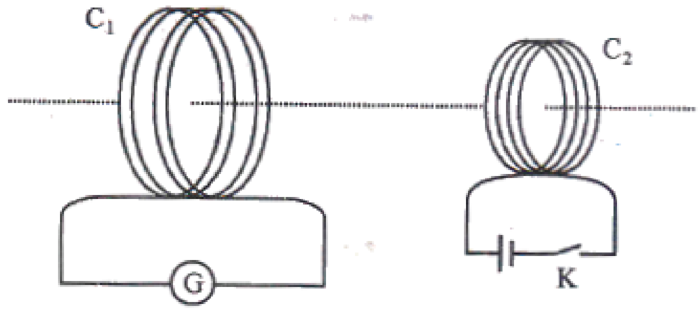
14. Name the semiconductor device that can be used to regulate an unregulated dc power supply. With the help of I-V characteristic of this device, explain its working principle.

15. How are infrared waves produced? Why are these referred to as 'heat waves'? Write their one important use.

16. Draw the transfer characteristic curve of a base biased transistor in CE configuration. Explain clearly how the active region of the V_o versus V_i curve in a transistor is used as an amplifier.

17. (i) Define modulation index.
(ii) Why is the amplitude of modulating signal kept less than the amplitude of carrier wave?

18. A current is in induced in coil C_1 due to the motion of current carrying coil C_2.
(a) Write any two ways by which a large deflection can be obtained in the galvanometer G, (b) Suggest an alternative device to demonstrate the induced current in place of a galvanometer.



19. Define the terms (i) drift velocity, (ii) relaxation time.
A conductor of length L is connected to a de source of emf ε. If this conductor is replaced by another conductor of same material and same area of cross-section but of length 3L, how will the drift velocity change?

20. Using Gauss's law to obtain the expression for the electric field due to a uniformly charged thin spherical shell of radius R at a point outside the shell. Draw a graph showing the variation of electric field with r, for r > R and r < R.

21. An electron and a photon each have a wavelength 1.00 nm. Find
(i) Their momenta.
(ii) The energy of the photon and
(iii) The kinetic energy of electron.

22. Draw a schematic diagram showing the (i) ground wave (ii) sky wave and (iii) space wave propagation modes for em waves.
Write the frequency range for each of the following:
(i) Standard AM broadcast
(ii) Television
(iii) Satellite communication

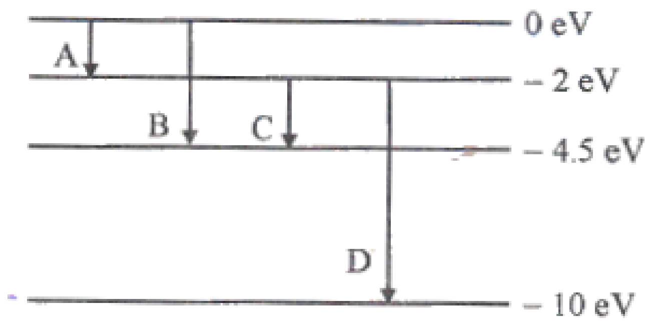
23. Describe Young's double slit experiment to produce interference pattern due to a monochromatic source of light. Deduce the expression for the fringe width.

OR

Use Huygen's principle to verify the laws of refraction.

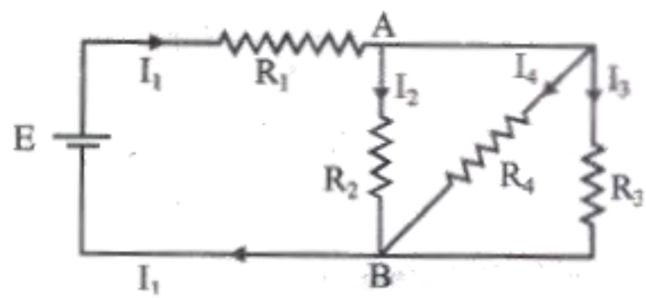
24. (a) Describe briefly, with the help of suitable diagram, how the transverse nature of light can be demonstrated by the pheomenona of polarization.
(b) When unpolarized light passes from air to a transparent medium, under what condition does the reflected light get polarized?

25. The energy levels of a hypothetical atom are shown below. Which of the shown transitions will result in the emission of a photon of wavelength 275 nm?
Which of these transitions correspond to emission of radiation of (i) maximum and (ii) minimum wavelength?



26. State the law of radioactive decay.
Plot a graph showing the number (N) of undecayed nuclei as a function of time (t) for a given radioactive sample having half life $T_{1/2}$.
Depict in the plot the number of undecayed nuclei at (i) $t = 3\ T_{1/2}$ and (ii) $t = 5\ T_{1/2}$.

27. In the circuit shown, $R_1 = 4\,\Omega$, $R_2 = R_3 = 15\,\Omega$, $R_4 = 30\,\Omega$ and E = 10 V. Calculate the equivalent resistance of the circuit and the current in each resistor.



28. State Biot-Savart law, giving the mathematical expression for it.
Use this law to derive the expression for the magnetic field due to a circular coil carrying current at a point along its axis.
How does a circular loop carrying current behave as a magnet?

OR

With the help of a labelled diagram, state the underlying principle of a cyclotron. Explain clearly how it works to accelerate the charged particles.
Show that cyclotron frequency is independent of energy of the particle. Is there an upper limit on the energy acquired by the particle? Give reason.

29. (a) Draw a ray diagram to show refraction of a ray of monochromatic light passing through a glass prism.
Deduce the expression for the refractive index of glass in terms of angle of prism and angle of minimum deviation.
(b) Explain briefly how the phenomenon of total internal reflection is used in fibre optics.

OR

(a) Obtain lens makers formula using the expression

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

Here the ray of light propagating from a rarer medium of refractive index (n_1) to a donser medium of refractive index (n_2) is incident on the convex side of spherical refracting radius of curvature R.

30. (i) With the help of a labelled diagram, describe briefly the underlying principle and working of a step up transformer.

(ii) Write any two sources of energy loss in a transformer.

(iii) A step up transformer converts a low input voltage into a high output voltage. Does it violate law of conservation of energy? Explain.

OR

Derive an expression for the impedance of a series LCR circuit connected to an AC supply of variable frequency.

Plot a graph showing variation of current with the frequency of the applied voltage.

Explain briefly how the phenomenon of resonance in the circuit can be used in the tuning mechanism of a radio or a TV set.

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Board Paper – 2011 (Solution)

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1. Potential at a point: V = kq/r

For any Q,

$$V_A - V_B = kQ\left[\frac{1}{r_A} - \frac{1}{r_B}\right]$$

Where $r_A < r_B$

So $1/r_A > 1/r_B$

So $\left[\frac{1}{r_A} - \frac{1}{r_B}\right] > 0$

If Q at O is positive, V_A-V_B will be positive

If Q at O is negative, V_A-V_B will be negative.

2. The electromagnetic wave travels in a vacuum along the z-direction. The electric field (*E*) and the magnetic field (B) are in the *x*-*y* plane. They are mutually perpendicular.

3. As emf ε =I (r+R)

& pd =V = IR

Taking the ratio,

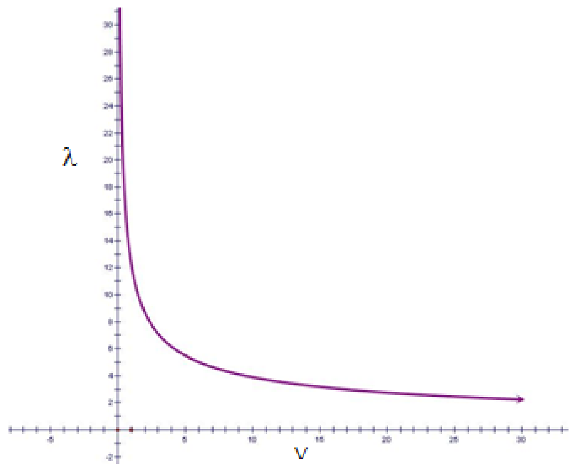
$\varepsilon/V = (r+R)/R$

$\varepsilon = V(1+r/R)$

r = R(E/V - 1)

4. It represents a diamagnetic substance since its permeability (0.9983) is less than 1.

5.



6. If the doping level in the base of a transistor is increased:

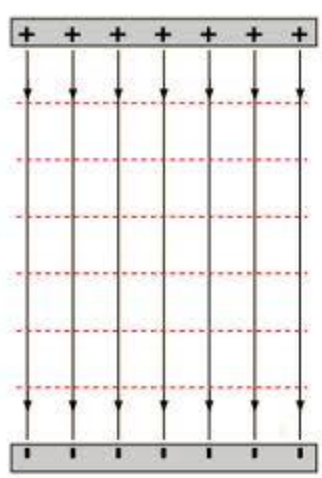
(i) Collector current will decrease.

(ii) Increased base doping lowers its resistance hence its base current should increase.

7. An AC circuit containing only Capacitor or inductor will have zero power dissipation even though the current is flowing through it. Such current is called wattless current.

8. Refraction occurs when the energy of an incoming light wave matches the natural vibration frequency of the electrons in a material. The light wave penetrates deeply into the material, and causes small vibrations in the electrons. The electrons pass these vibrations on to the atoms in the material, and they send out light waves of the same frequency as the incoming wave.

9.



Here the red dotted lines represent the parallel equipotential surfaces along X-Z plane.

If a charge q has to be held stationary between the two plates, it will have to be balanced by two forces.

Gravitational force: mg, downwards

Electrostatic force= 2qE, acting upwards.

This implies, that in X-Z plane, the upper plate is + charged plate & lower plate is – charged plate.

So, E field lines have to be directed along –y axis.

OR

Resultant dipole moment,

$$\vec{p}_{res} = \vec{p}_1 + \vec{p}_2$$
$$p_{res} = \sqrt{p_1^2 + p_2^2 + 2p_1p_2\cos 120}$$
$$p_{res} = p$$

Direction of resultant dipole moment:

$$\tan\theta = \frac{p\sin 120}{p + p\cos 120}$$
$$\tan\theta = \sqrt{3}$$
$$\theta = 60$$

That is, 30 degrees with +x axis.

Given applied E is along +x axis,

So torque on resultant dipole will be

$$\tau = pE\sin 30 = pE/2$$

Direction will be along -z axis.

10. Horizontal component of earth's magnetic field, B_H =0.4 G

Angle made by the needle with the horizontal plane = Angle of dip = $\delta = 60^{\circ}$.

Earth's magnetic field strength = B

We can relate B and B_H as:

$$B_H = B\cos\theta$$
$$\therefore B = \frac{B_H}{\cos\delta} = \frac{0.4}{0.5} = 0.8G$$

Hence, the strength of earth's magnetic field at the given location is 0.8G.

11. In C_2:

Charge $Q_D = C_D V_D$ will not change.

Where C_D = K C= increases K times

$V_D = V/K$ = decreases K times

In C_1:

Charge $Q_D = C_D V$

Potential V remains the same as 6V

Charge Q_D =KCV= KQ, increases K times.

12. Resolving power = $\frac{a}{1.22\lambda}$

$$\Rightarrow \frac{(R.P.)_1}{(R.P.)_2} = \frac{A_1}{A_2}$$

The telescope with the objective of aperture A1 should be preferred for viewing as this would:

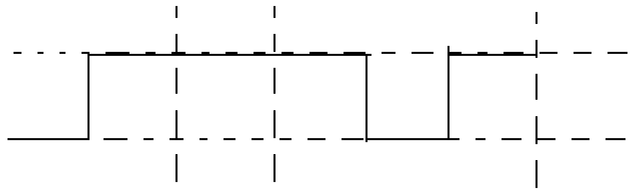
(i) Give a better resolution

(ii) Have a higher light gathering power of telescope.

13. The truth table will be

A	B	Y	X
0	0	1	0
1	0	0	1
1	1	0	1
0	1	0	1
0	0	1	0
1	0	0	1

The output waveform will be



14. Zener diode is used for regulating the unregulated voltage supply.

In Zener diode, both p and n sides are heavily doped. Due to high dopant density, the depletion junction width is small and the junction field is high. Under large reverse bias, the high junction field may strip an electron from the valence band which can tunnel to the n side quantum mechanically through the thin depletion layer.

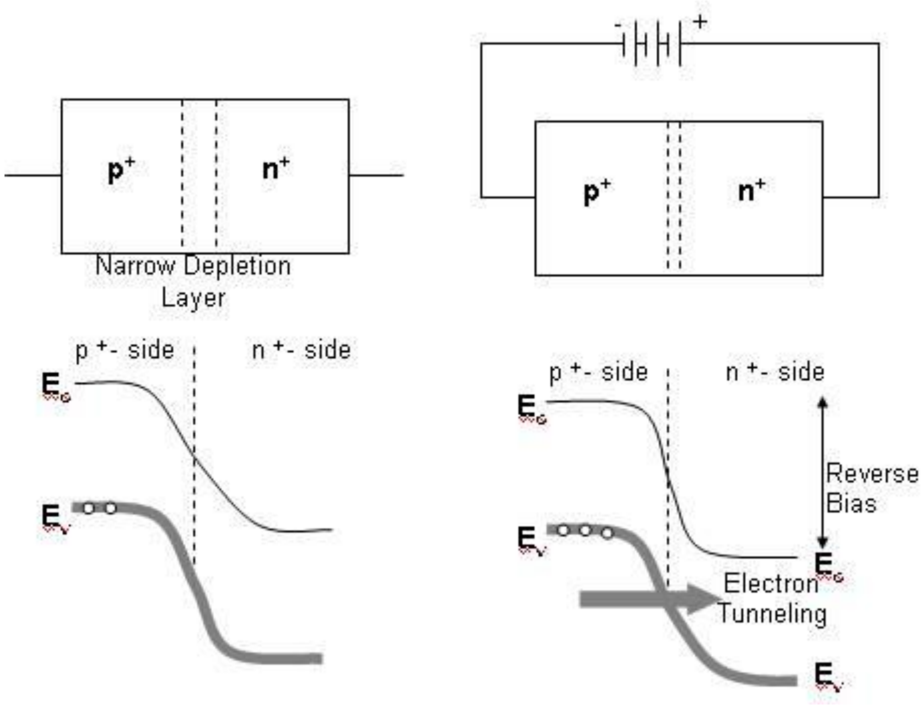


Fig (a) Unbiased p^+-n^+ junctions Fig (b) Reverse biased p^+-n^+ junctions of Zener diode

This takes place after a certain critical voltage is crossed, and is called 'internal field emission', which gives rise to a high reverse or 'breakdown' current. Such a breakdown is called 'Zener breakdown'.

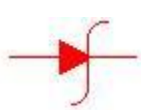
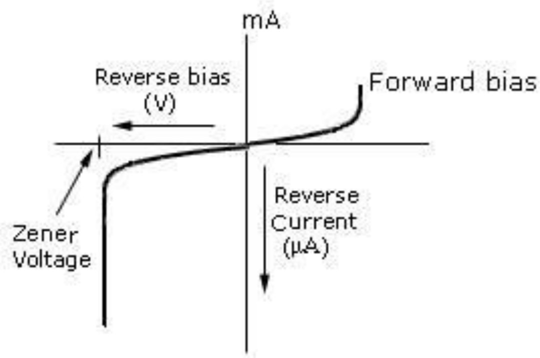


Fig (a) Symbol of Zener diode



Fig(b) V-I characteristics of a Zener diode.

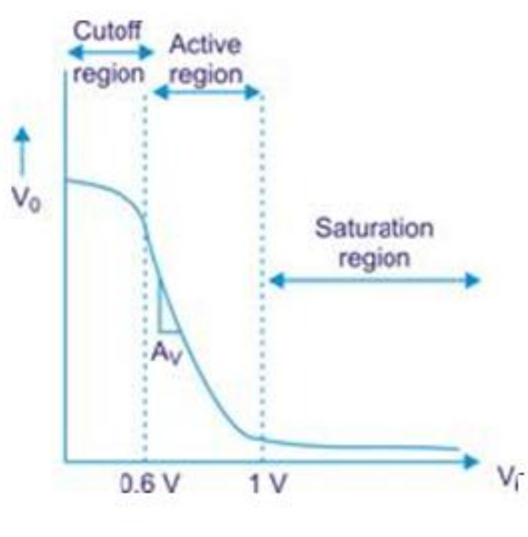
After breakdown, a large current can be produced by an almost insignificant change in the reverse bias voltage. So, for widely different currents, the voltage across the Zener-diode stays constant. This leads it to be used in voltage regulation of DC voltages.

15. Infra red waves are produced by hot bodies or due to vibrations of atoms and molecules.

They are called heat waves because they cause heating effect or increase the temperature.

Use: Infra red lamps; play important role in maintaining warmth through greenhouse effect.

16.



If we plot V_o Vs V_i , we get a graph as shown in figure; this characteristic curve is also called **transfer characteristic curve** of a base biased transistor in CE configuration.

The curve shows that there are three non-linear regions:

(i) between cut-off stage and active stage

(ii) between active stage and saturation stage;

For using the transistor as an amplifier we will use the active region of the Vo versus V_i curve. The slope of the linear part of the curve represents the rate of change of the output with the input. It is negative because the output is $V_{CC} - I_C R_C$ and not $I_C R_C$. That is why as input voltage of the CE amplifier increases its output voltage decreases and the output is said to be out of phase with the input. If we consider ΔVo and ΔV_i as small changes in the output and input voltages then $\Delta Vo / \Delta V_i$ is called the small signal voltage gain A_V of the amplifier.

If the V_{BB} voltage has a fixed value corresponding to the mid point of the active region, the circuit will behave as a CE amplifier with voltage gain $\Delta Vo / \Delta Vi$. We can express the voltage gain A_V in terms of the resistors in the circuit and the current gain of the transistor as follows.

We have, $Vo = V_{Cc} - I_C R_C$

Therefore, $\Delta Vo = 0 - R_C \Delta I_C$

Similarly, from $Vi = I_B R_B + V_{BE}$

$\Delta Vi = R_B \Delta I_B + \Delta V_{BE}$

But ΔVBE is negligibly small in comparison to $\Delta IBRB$ in this circuit.

So, the *voltage gain* of this *CE amplifier* is given by

$AV = - R_C \Delta I_C / R_B \Delta I_B$

$= - \beta ac(R_C / R_B)$ (14.14)

where βac is equal to $\Delta IC / \Delta IB$.

Thus the linear portion of the active region of the transistor can be exploited for the use in amplifiers.

17. Modulation index is the ratio of amplitude of modulating signal and amplitude of carrier wave.

$$\mu = \frac{A_m}{A_c}$$

$\mu = \frac{A_m}{A_c} < 1$ Modulation index is kept less than 1, that is $A_m < A_c$, in order to avoid distortion.

18.(a) Two ways by which a large deflection can be obtained in the galvanometer are :

(i) By increasing the relative motion between the coils.

(ii) By inserting an iron rod into the coils along their axes.

(b) An LED.

19. The average velocity of electrons, independent of time, although accelarated through a conductor is called drift velocity.

The average time interval between successive collisions is called relaxation time.

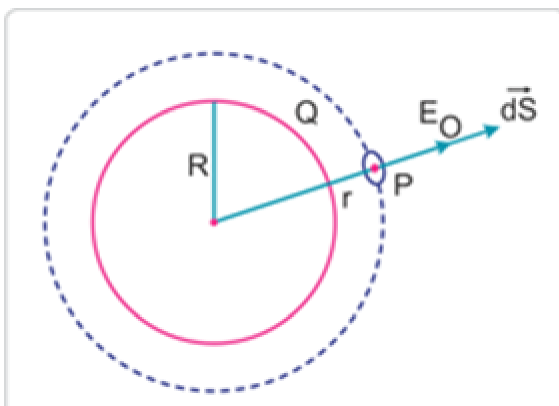
Drift velocity

$$v_d = \frac{e\tau E}{m} = \frac{e\tau V}{mL}$$

Where V is the potential difference applied across the length of the conductor.

Keeping V constant,if Length L of the conductor is made 3 times, the drift velocity will become $1/3^{rd}$.

20.



Consider a spherical Gaussian surface of radius r (>R), concentric with given shell. If $\vec{E}$ is electric field outside the shell, then by symmetry, electric field strength has same magnitude $\vec{E}_o$ on the Gaussian surface and is directed radially outward. Also the directions of normal at each point is radially outward, so angle between $\vec{E}_o$ and $d\vec{s}$ is zero at each point. Hence, electric flux through Gaussian surface =

$$= \phi_s \overrightarrow{E_o}.d\vec{s}$$
$$= \phi E_o dS \cos 0^o = E_o.4\pi r^2$$

Now, Gaussian surface is outside the given charged shell, so charge enclosed by the Gaussian surface is Q.

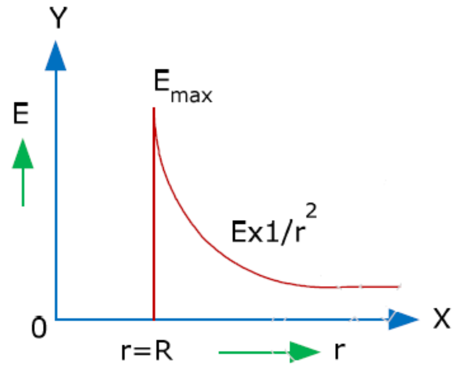
Hence, by Gauss's theorem

$$\oint_s \vec{E_o}.d\vec{s} = \frac{1}{\varepsilon_o} \times charge-enclosed$$

$$\Rightarrow E_o.4\pi r^2 = \frac{1}{\varepsilon_o} \times Q$$

$$\Rightarrow E_o = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}$$

Thus, electric field outside a charged thin spherical shell is same as if the whole charge Q is concentrated at the centre. Graphically,



For r < R, there is no strength of electric field inside a charged spherical shell.

For r > R, electric field outside a charged thin spherical shell is same as if the whole charge Q is concentrated at the centre.

21. Wavelength of an electron λ and a photon λ_p , $\lambda_e = \lambda_p = \lambda = 1\text{nm}$

$= 1 \times 10^{-9}$ m

Planck's constant, $h = 6.63 \times 10^{-34}$ Js

(a) The momentum of an elementary particle is given by de Broglie relation:

$$\lambda = \frac{h}{p}$$

$$p = \frac{h}{\lambda}$$

It is clear that momentum depends only on the wavelength of the particle. Since the wavelengths of an electron and a photon are equal, both have an equal momentum.

$$\therefore p = \frac{6.63 \times 10^{-34}}{1 \times 10^{-9}} = 6.63 \times 10^{-25} \text{kg ms}^{-1}$$

(b) The energy of a photon is given by the relation:

$$E = \frac{hc}{\lambda}$$

Where,

Speed of light, $c = 3 \times 10^{8}$ m/s

$$\therefore E = \frac{6.63\times10^{-34}\times3\times10^{8}}{1\times10^{-9}\times1.6\times10^{-19}}$$
$$= 1243.1\text{eV} = 1.243\text{keV}$$

Therefore, the energy of the photon is 1.243 keV.

(c) The kinetic energy (K) of an electron having momentum p,is given by the relation:

$$K = \frac{1}{2}\frac{p^2}{m}$$

Where,

m = Mass of the electron = 9.1×10^{-31} kg

$p = 6.63 \times 10^{-25}$ kg m s^{-1}

$$\therefore K = \frac{1}{2}\times\frac{{6.63\times10^{-25}}^{\,2}}{9.1\times10^{-31}} - 2.415\times10^{-19}\,\text{J}$$

$$= \frac{2.415\times10^{-19}}{1.6\times10^{-19}} = 1.51\text{eV}$$

Hence, the kinetic energy of the electron is 1.51 eV.

22. Diagram showing the (i) ground wave (ii) sky wave and (iii) space wave propagation modes for em waves:

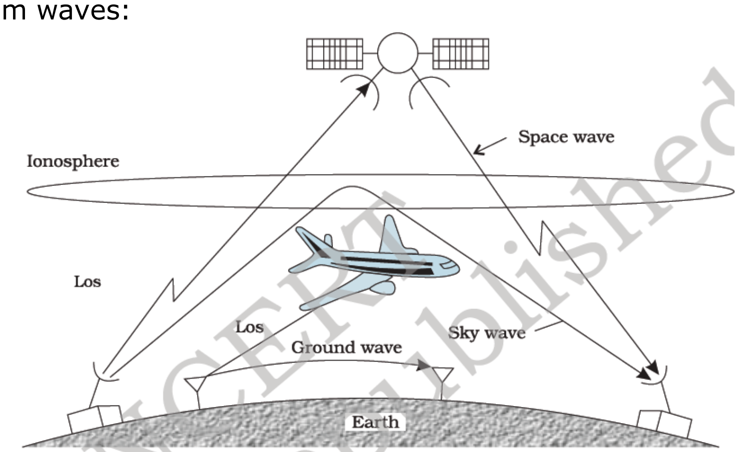


FIGURE 15.6 Various propagation modes for em waves.

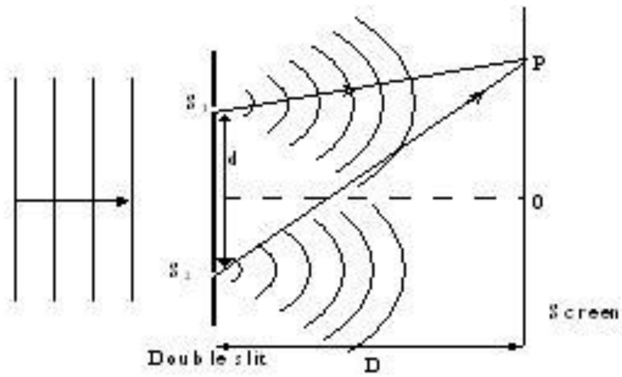
Frequency range:
(i) Standard AM broadcast: 540-1600 kHz
(ii) Television: 54-72 MHz
76-88 MHz: VHF (very high frequencies)
174-216 MHz
420-890 MHz: UHF (ultra high frequencies)

(iii) Satellite communication: 5.925-6.425 GHz (uplink)

3.7 – 4.2 GHz (downlink)

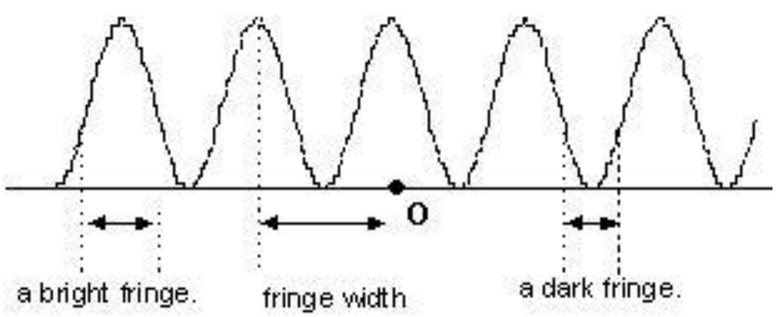
23.Young double slit experiment:

A train of plane light waves is incident on a barrier containing two narrow slits separated by a distance'd'. The widths of the slits are small compared with wavelength of the light used, so that interference occurs in the region where the light from S_1 overlaps that from S_2.



A series of alternately bright and dark bands can be observed on a screen placed in this region of overlap.

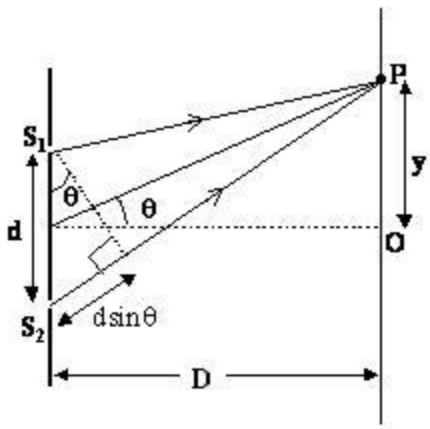
The variation in light intensity along the screen near the centre O shown in the figure



Now consider a point P on the screen. The phase difference between the waves at P is θ, where

$$\theta = 2\pi / \lambda \Delta P_o$$

(where ΔP_o is optical path difference, $\Delta P_o = \Delta P_g$; ΔP_g being the geometrical path difference.)



$= 2\pi/\lambda$ [$S_2P - S_1P$] (here $\lambda = 1$ in air)

As As, D >> d,

$S_2P - S_1P \approx \lambda$ d sin θ

sin θ λ $\approx$ tan θ (= y/D).

[for very small θ]

Thus, $\theta = 2\pi/\lambda$ (dy/D)

For constructive interference,

$\theta = 2n\lambda$ (n = 0, 1, 2...)

$\Rightarrow$ $2\pi/\lambda$ (dy/D) = 2nπ $\Rightarrow$ $y = n\,\lambda D/d$

Similarly for destructive interference,

$y = (2n - 1)\,\lambda D/2d$ (n = 1, 2 ...)

Fringe Width W

It is the separation of two consecutive maxima or two consecutive minima.

Near the centre O [where θ is very small],

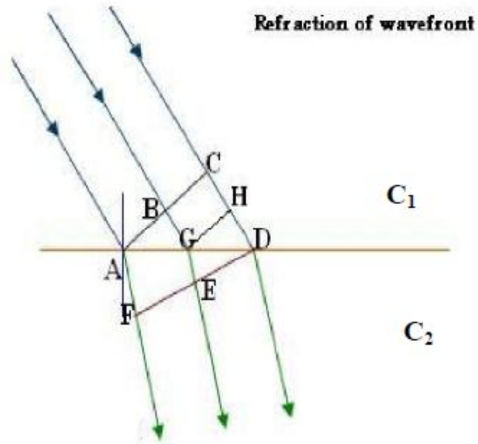
$W = y_{n+1} - y_n$ [y_n gives the position of nth maxima on screen]

$= \lambda D/d$

OR

Laws of refraction: Proof using Huygen's principle

If **AC** is the incident wavefront and **FD** is refracted wavefront then we can show that refraction of wavefront obeys Snell's law.



Let the time taken by to reach from C to D be **t** and now in same time Point **A** would be at **F** hence we can write,

CD = c1 t and AF = c2 t

Also the angle **CAD** = angle **i**

[Angle of incidence for wavefront]

Similarly, angle **ADF** = angle **r**

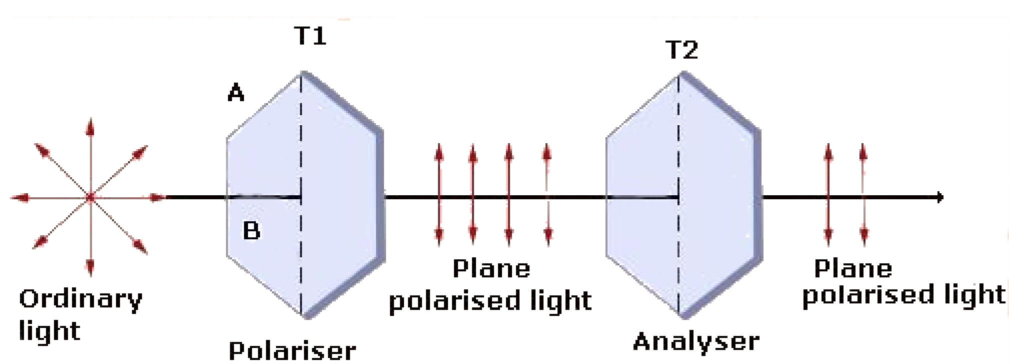
Now, sin i = sin∠CAD= CD/AC=c_1 *t/AC*

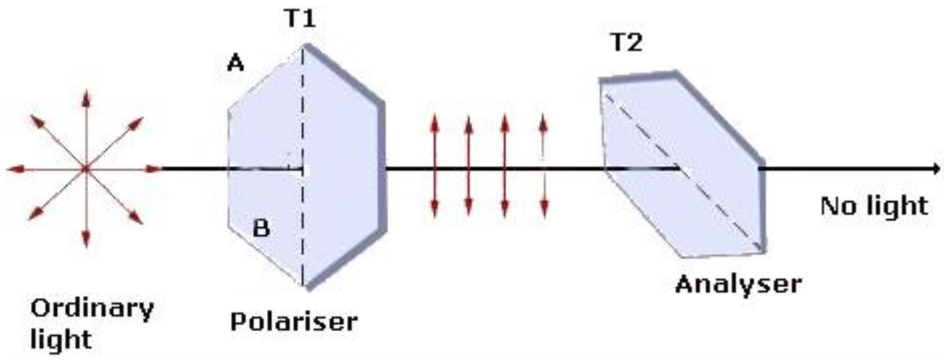
And, sin r = sin ∠FDA= AF/FD= c_2 t/FD

We get the ratio sin i/sin r = $c_1/c_2 = {}_1\mu^2$

This verifies the law of refraction or Snell's law.

24.(a) Experiment to prove transverse nature of light waves:





i.e., T_2 analyses if the light waves are polarized or not.

(b) When unpolarised light is passed through a tourmaline crystal cut with its face parallel to its axis AB, only those vibrations of light pass through which are parallel to AB and all others are absorbed. The light intensity, therefore, is reduced. The emergent light from the first crystal is a plane-polarized light. This can be checked by using a second crystal. When this second crystal is rotated, a change in intensity is noted, the light is said to be plane polarized. When the axis of the second crystal is perpendicular to the axis of the first crystal, no light is passed. The light coming out of the crystal T_1 is said to be polarized i.e., the vibrations of light (electric vector) is restricted in a particular direction. This phenomenon is called polarization. The first crystal acts as a polarizer and the second crystal acts as an analyzer.

i.e., T_2 analyses if the light waves are polarized or not.

Wavelength associated: $\lambda = \frac{hc}{E} = \frac{6.62x10^{-34}x3x10^{8}}{Ex1.6x10^{-19}} = \frac{12.3}{E}x10^{-7}$

25.For A:

Energy change: E_1-E_2 = 0 – (-2) = 2 eV

So wavelength of the radiation emitted is:

$\lambda_A = \frac{12.3}{2}x10^{-7} = 618nm$

$\lambda_B = \frac{12.3}{4.5}x10^{-7} = 275nm$ (wavelength emitted is 256 nm, i.e, radiation B)

$\lambda_C = \frac{12.3}{2.5}x10^{-7} = 500nm$

$\lambda_D = \frac{12.3}{8}x10^{-7} = 153nm$

Maximum wavelength: emission A

Minimum wavelength: emission D

26. According to radioactive decay law the rate of disintegration of a radioactive substance at an instant is directly proportional to the number of nuclei in the Radioactive substance at that time i.e.

$N = N_o e^{-\lambda t}$, Where symbols have their usual meanings.

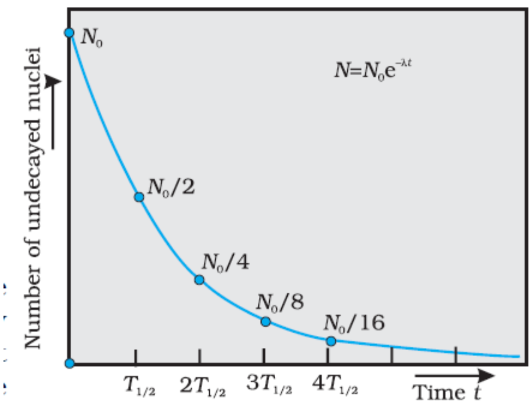


FIGURE 13.3 Exponential decay of a radioactive species. After a lapse of $T_{1/2}$, population of the given species drops by a factor of 2.

<u>**From graph:**</u>

No. of un-decayed nuclei at t = $3T_{1/2}$ is $N_o/8$

No. of un-decayed nuclei at t = $5T_{1/2}$ is $N_o/32$

27. R3, R4, R2 : parallel

Upon calculation comes out to be

$R_p = 6\Omega$

R_1 and R_p are in series.

$R_{eq} = 6 + 4 = 10\Omega$

Using Kirchoff's rules we get following equations,

$E - I_1R_1 - I_2R_2 = 0$

$-R_4I_4 + I_2R_2 = 0$

$-I_3R_3 + I_4R_4 = 0$

$E - I_1R_1 - I_3R_3 = 0$

$-I_3R_3 + I_2R_2 = 0$

$I_1 = I_2 + I_3 + I_4$

Solving the above equations we get

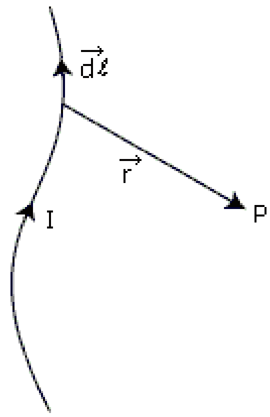
I1=1A

I2=10/25 A

I3= 10/25 A

I4 =5/25 A

28. For any general shape of the wire, magnetic field due to current carrying wire is given by Biot Savart Law:



$$\vec{B}(P) = \frac{\mu_0 I}{4\pi}\int \frac{\vec{d\ell}\times\vec{r}}{r^3}$$

Where $\vec{d\ell}$ is a vector tangent to the current wire equal to $dy\,\hat{j}$ for a straight wire along y-axis.

Consider a circular loop of radius r carrying a current I.

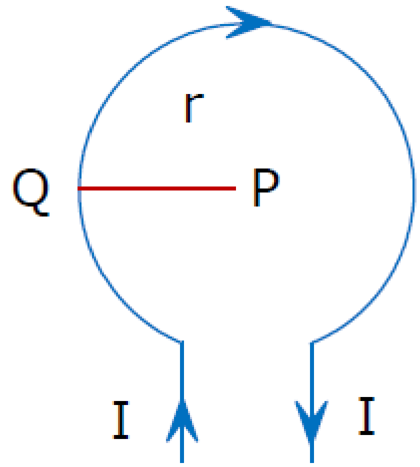
Since

$$dl \perp \vec{r}$$
$$\Rightarrow \theta = 90^o$$

Applying Biot Savart law;

$$dB = \frac{\mu_o}{4\pi}\frac{Idl\sin 90^o}{r^2}$$

For entire closed circular loop;



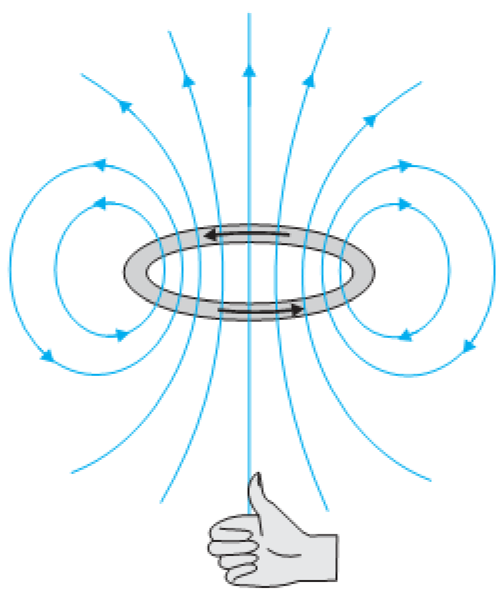
$$dB = \int_{0}^{2\pi r} \frac{\mu_o}{4\pi} \frac{Idl \sin 90^o}{r^2}$$

$$B = \frac{\mu_o}{4\pi} \frac{I}{r^2} \int_{0}^{2\pi r} dl = \frac{\mu_o}{4\pi} \left(\frac{2\pi I}{r} \right)$$

For n turns of a coil; $B = \frac{\mu_o}{4\pi} \frac{2\pi nI}{r}$

The magnetic field lines due to a circular wire form closed loops.

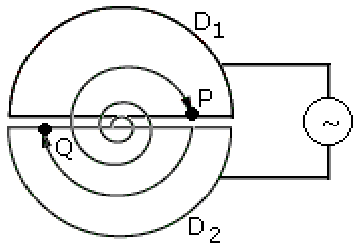
The direction of the magentic field is given by right hand thumb rule.



The current carrying loop produces a magnetic field around it, whose magnetic moment is given as I x A(here, I is the current through the loop and A is the area of cross-section; hence it behaves like a magnet.

OR

The principle behind the working of a cyclotron is that in a uniform magnetic field, charged particle executes uniform circular motion with a frequency that is independent of its radius (which depends on the energy of the particle)



A cyclotron has a uniform magnetic field spread over a circular region split in two halves by two semi-circular D's, D_1 and D_2.

Let us assume for definiteness that the particle has positive charge. Then, as it comes around in D_1 clockwise to point P, D_1 and D_2 are so connected to an alternating voltage that at this point, D_1 is at a higher potential than D_2. This accelerates the particles, so that it gains kinetic energy by $\Delta T = q(V_1 - V_1)$ where V_1 and V_2 are potentials of D_1 and D_2 respectively.

This increases the radius of circular motion since $r=\left(\frac{mV}{qB}\right)$ and is proportional to square root of kinetic energy.

Since frequency of circular motion, given by $fc=\left(\frac{qB}{2\pi m}\right)$ is independent of r, the frequency of alternating voltage is made twice f_c, so that when the particle reaches point Q, V_2 and V_1 flip and D_2 is at higher potential than D_1, so that particle is accelerated again. This goes on till the kinetic energy is high enough and consequently the radius is large enough so that the particle is ejected out tangentially from the magnetic field with high energy.

Frequency

$f_c = \left(\frac{qB}{2\pi m}\right)$ is independent of the energy or the speed of the charged particle.

Upper limit is releativistic speeds. The cyclotron is limited by relativistic effects due to which the mass of the accelerating particle increases with energy and so f_c changes after each cycle.

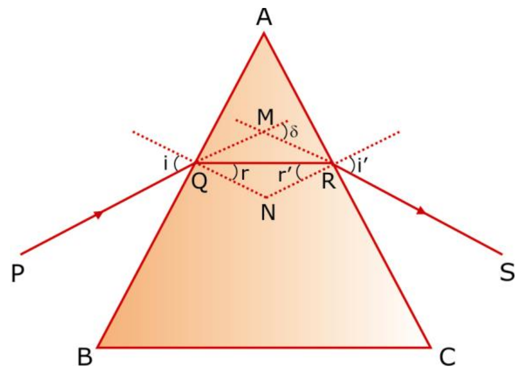
Also, for light charged particles, f_c is enormously high and difficult to maintain.
Also, it is not easy to maintain uniformity of the magnetic field.
To add to that, a charged particle in circular motion (even if it is uniform) is accelerating and all accelerated charges radiate electromagnetic energy, thereby losing energy.

29.(a) i: angle of incidence

r & r′: angles of refractions

δ : angle of deviation

Consider light passing through a prism ABC as shown



As shown, the angles of incidence and refraction at the first face AB are i and r, while the angle of incidence (from glass to air) at the second face AC is r′ and the angle of emergence i′. The angle between the emergent ray RS and incident ray direction PQ is called the angle of deviation, δ .

In the quadrilateral AQNR, two of the angles (at the vertices Q and R) are right angles. Therefore, the sum of the other angles of the quadrilateral is 180°.

$\angle A + \angle QNR = \angle 180^\circ$

From triangle QNR,

$r + r' + \angle QNR = 180^\circ$

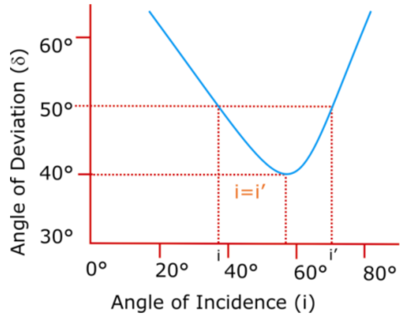
Comparing, we get

$r + r' = A$

The total deviation is the sum of deviations at the two faces:

$\delta = (i - r) + (i' - r')$
$\Rightarrow \delta = i + i' - A$

A plot between angle of deviation and the angle of incidence is seen to be as follows



It is seen that in general, any given value of δ corresponds to two values i and i'. Physically, this is due to the fact that the path of the ray can be traced back, resulting in the same angle of deviation.

At the minimum deviation, $\delta = D_m$,

$i = i'$ which implies that r = r'.

Then, we get from (0.36)

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

Similarly, equation gives

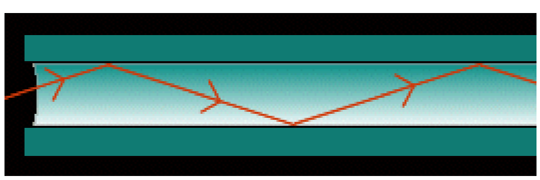
$$D_m = 2i - A$$
$$\Rightarrow i = \frac{A + D_m}{2}$$

The refractive index of the prism with respect to the medium outside is

$$n_{21} = \frac{n_2}{n_1} = \frac{\sin[(A + D_m)/2]}{\sin[A/2]}$$

Angles A and D_m can be measured experimentally with good precision.
So, equation provides a good way of measuring refractive index of a prism.

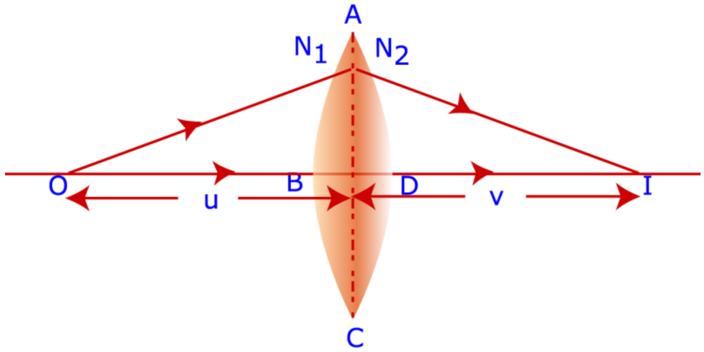
(b) Total Internal Reflection has many practical uses, one of which is in optical fibers. An optical fiber has two layers: a core made of a material of with a high refractive index, and a second, outer layer with lower refractive index. The light waves transmitted by an optical fiber are reflected off of the boundary between these two substances, as shown in the diagram of a cross-section of a fiber below.

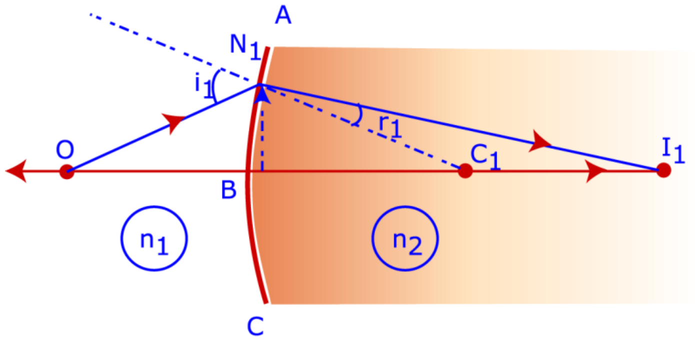


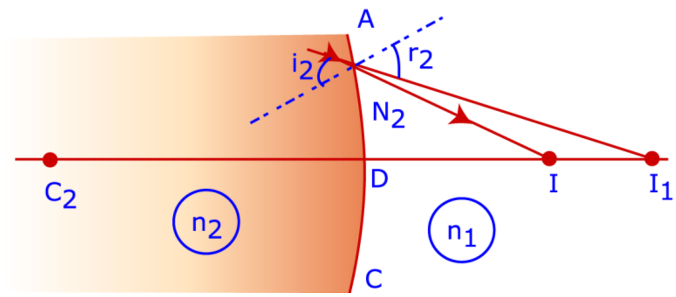
The smaller the refractive index of the cladding is compared to the refractive index of the core, the smaller the critical angle is, allowing T.I.R. to take place in more conditions (as it can be more often exceeded).

OR

(a). The image formation by a double convex lens can be visualized as a two step process, the first being formation of image I_1 of the object O by the first refracting surface, which acts as a virtual source for image I formed by the second surface.







Applying equation $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ to the first interface ABC and the second interface ADC, we get

$$\frac{n_1}{OB} + \frac{n_2}{BI_1} = \frac{n_2 - n_1}{BC_1}$$

and

$$\frac{n_1}{DI} - \frac{n_2}{DI_1} = \frac{n_2 - n_1}{DC_2}$$

For a thin lens, $BI_1 = DI_1$.

Then, adding the equations above,

$$\frac{n_1}{OB} + \frac{n_1}{DI} = (n_2 - n_1)\left[\frac{1}{BC_1} + \frac{1}{DC_2}\right]$$

If the object is at infinity, $OB = \infty$ and I is at the focus of the lense, so that DI = f, the focal length of the lens.

Then, we get from

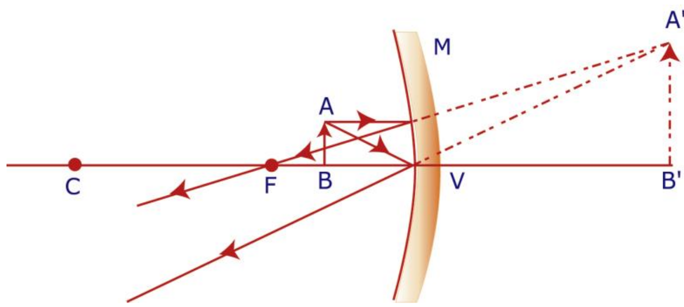
$$\frac{n_1}{f} = (n_2 - n_1)\left[\frac{1}{BC_1} + \frac{1}{DC_2}\right]$$

Since $BC_1 = R_1,\ DC_2 = -R_2$, this gives us

$$\frac{1}{f} = (n_{21} - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

which is known as the 'Lens maker's formula'.

(b)



The magnification (m) of a mirror is the ratio of the size of the image (h') to the size of the object (h)

$$m = \frac{h'}{h}$$

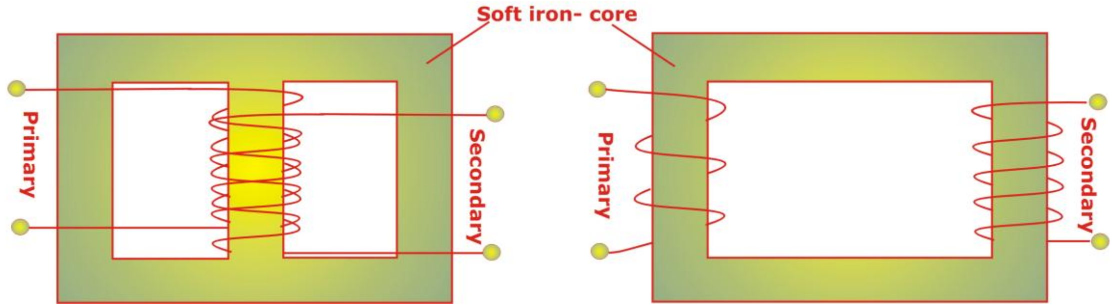
The size of the object is always taken to be positive, and h' is negative if the image is inverted, and positive if the image is erect.

In the figure, since triangles A'B'V and ABV are similar, we have,

$$\frac{A'B'}{AB} = \frac{B'V}{BV}$$
$$\Rightarrow \frac{h'}{h} = \frac{v}{-u}$$
$$\Rightarrow m = \frac{h'}{h} = -\frac{v}{u}$$

30.(i)Principle underlying tehw orking of transformer: The principle is Mutual Inductance. When a changing source of voltage is introduced across a coil (which is physically coupled to another coil), the changing current through it induces an EMF across the second coil.

A transformer consists of two sets of coils, insulated from each other. They are wound on a soft-iron core, either one on top of the other, or on separate limbs of the core.



One of the coils is called the *primary coil*, and has N_p turns. The other coil, the *secondary coil*, has N_p turns. The relative numbers depend on whether the voltage needs to be stepped up or stepped down.

By definition, the voltage to be *transformed* is introduced across the *primary* coil. When the alternating voltage is applied across the primary, the resulting alternating current through it produces a changing magnetic field, whose flux through the secondary coil changes.

From Faraday's law, this changing flux induces an EMF across the secondary, whose magnitude depends on the amount of coupling of the two coils, numerically measured as mutual inductance. The more this coupling or association of the two coils, the more is mutual inductance, and therefore the induced EMF.

If Φ is the flux through each turn of the core, then through *N* turns around the core, the total flux is $N\Phi$.

So, the EMF induced in the secondary coil is $E_S = -N_S \frac{d\Phi}{dt}$

Similarly, there will also be an EMF induced in the *primary* coil itself, due to self inductance, given by

$$E_P = -N_P \frac{d\Phi}{dt}$$

If the voltage applied across the primary is V_P, then if its resistance is *R*, the current through it will be $I_P = \frac{V_P - E_P}{R}$.

However, assuming negligible resistance, since we cannot have an infinite current through the coil, then

$$E_P \simeq V_P$$

If the secondary is an open circuit, no current is drawn from it then, voltage across it will be

$$V_S = E_S = -N_S \frac{d\Phi}{dt}$$

From equations, it is clear that

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

If the transformer is 100% efficient, that is, all the input power is transferred to the secondary without any leakage or losses, then

$$I_P V_P = I_S V_S$$

This implies that

$$\frac{I_P}{I_S} = \frac{V_s}{V_P} = \frac{N_S}{N_P}$$

It is clear from that if $N_S > N_P$, the voltage will be stepped up, and if $N_S < N_P$ it will be stepped down.

However, in a step down transformer, there will be a greater current in the secondary as compared to the primary and vice-versa.

(ii)The possible sources of power losses in practical transformers can be
(1) Flux Leakage: Not all flux of the primary can be associated with the secondary. There is always some flux which due to lack of absolute coupling, can leak. To avoid this, the coils are wound over each other again and again.

(2) Resistance of windings: The transformer coil wires cannot have absolutely zero resistance, so some Joule loss is inevitable.

(3) Core eddy currents: Since the core is a very good conductor itself, currents are induced in it due to changing magnetic fields, called eddy currents. These also result in losses.

(4) Hysteresis: Some part of energy is frozen into the core permanently in the form of a residual magnetic field due to its ferromagnetic character.

(iii) No, it doesnot violate the energy conservation. When low voltage is converted to high volatge , the current is lowered, thereby conserving the total energy dissipated across the primary & secondary coil.

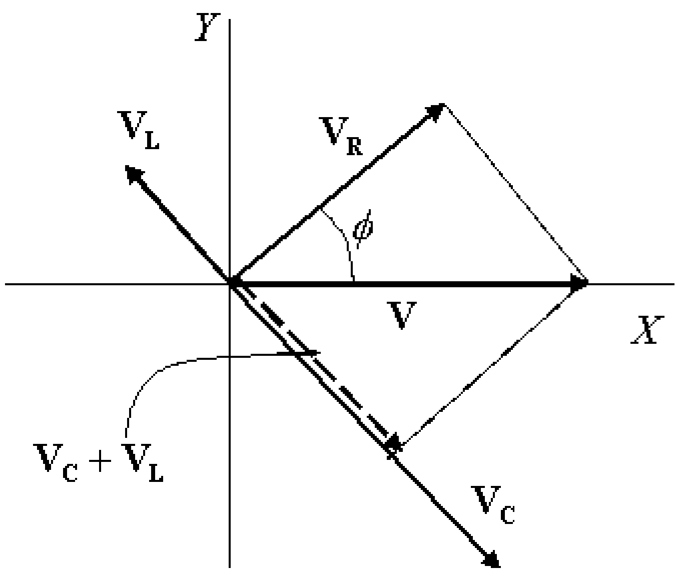
OR

In the phasor diagram, since at $t = 0$, the external source of EMF is $V = V_0$ (peak value), which is the *x* component of the phasor $\mathbf{V}$, this vector will be along the *X* axis. The current phasor $\mathbf{I}$ will be at an angle ϕ relative to this.

So, since $\mathbf{V_R} = R\mathbf{I}$, it will be parallel to this current phasor, at angle ϕ relative to $\mathbf{V}$.

Similarly, looking at equations(0.32), it is evident that $\mathbf{V_L}$ will make an angle $+\frac{\pi}{2}$ and $\mathbf{V_C}$ will make angle $-\frac{\pi}{2}$ relative to $\mathbf{V_R}$.

This also implies that $\mathbf{V_L}$ and $\mathbf{V_C}$ will lie in *opposite* directions, as the following figure shows.



It is obvious from the figure that the vector $\mathbf{V_R}$ is perpendicular to the vector $\mathbf{V_C} + \mathbf{V_L}$, and *also*, of course, $\mathbf{V} = \mathbf{V_R} + (\mathbf{V_L} + \mathbf{V_C})$

Taking the dot product

$\mathbf{V} \bullet \mathbf{V}$ gives

$$
\begin{aligned}
V_0^{\,2} &= \left(V_R\right)_0^{\,2} + (\mathbf{V_C} + \mathbf{V_L}) \bullet (\mathbf{V_C} + \mathbf{V_L}) \\
&= \left(V_R\right)_0^{\,2} + [\left(V_L\right)_0 - \left(V_C\right)_0]^2 \\
&= [R^2 + (X_C - X_L)^2] I_0^{\,2}
\end{aligned}
$$

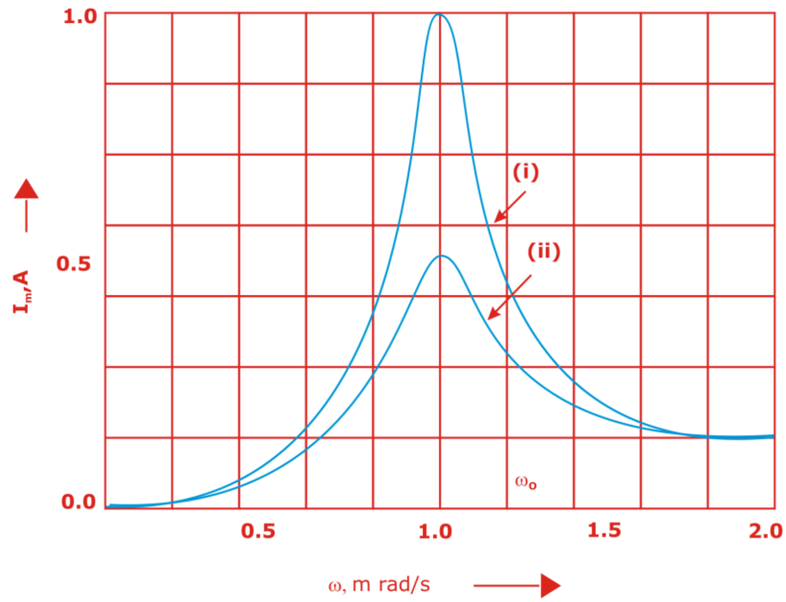
From this, we immediately get

$$I_0 = \frac{V_0}{Z}; \;\; Z = \sqrt{R^2 + (X_C - X_L)^2}$$

The factor *Z* is the analog of resistance in a purely resistive circuit, and is called *Impedance*.

The phase is immediately found from the simple phasor picture $\tan\phi = \frac{X_C - X_L}{R}$

(ii)The current as a function of source frequency is plotted below:



(iii)Whenever one needs a selection mechanism to select a particular frequency out of a range of frequencies, such resonating circuits are useful.

For instance, the tuner in a radio is precisely such a circuit, whose *L* and *C* can be varied. Varying these components varies the resonant frequency. As soon as the resonant frequency matches a particular external signal (radio signal) frequency, there is a sharp response, and the device picks up that signal.