2013

Set: I

Set: I

Question: 1

Answer all questions briefly and to the point. [1]

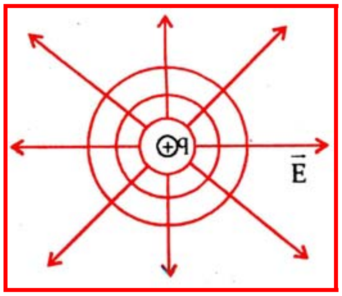
What are permanent magnets? Give one example.

Answer:
Permanent magnets are those magnets which have high retentivity and coercitivity. The magnetization of permanent magnet is not easily destroyed even if it is handled roughly or exposed in stay reverse magnetic field. For example: Steel.

Question: 2

What is the geometrical shape of equipotential surfaces due to a single isolated charge? [1]

Answer:



For an isolated charge the equipotential surfaces are concentric spherical shells and the distance between the shells increases with the decrease in electric field.

Question: 3

Which of the following waves can be polarized (i) Heat waves (ii) Sound waves? [1]

Answer:
Heat waves can be polarized because heat waves are transverse whereas sound waves cannot be polarized because sound waves are longitudinal waves.
Transverse waves can oscillate in the direction perpendicular to the direction of its propagation but longitudinal waves like sound waves oscillate only along the direction of it propagation. So, longitudinal waves cannot be polarized.

Question: 4

A capacitor has been charged by a DC source. What are the magnitudes of conduction and displacement currents, when it is fully charged? [1]

Answer:

Electric flux through plates of capacitor, $\phi = \frac{q}{\varepsilon_0}$

Here q $\rightarrow$ constant, the capacitor is fully charged.

Displacement current, $I_D = \varepsilon_0 \frac{d\phi E}{dt} = \varepsilon_0 \frac{d\left(\frac{q}{\varepsilon_0}\right)}{dt} = 0$

Conduction current, I = C

$\frac{dv}{dt} = 0$ as voltage becomes constant, when the capacitor becomes fully charged.

Question: 5

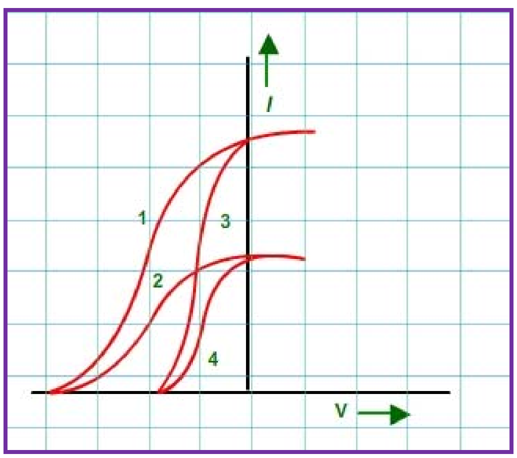
Write the relationship between angle of incidence 'i', angle of prism 'A' and angle of minimum deviation for a triangular prism. [1]

Answer:

The relation between the angle of incidence I, angle of prism A and the angle of minimum deviation Δm for a triangular prism is given as in given by $i = \frac{A + \Delta_m}{2}$

Question: 6

The given graph shows the variation of photo electric current (I) versus applied voltage (V) for two different photosensitive materials and for two different intensities of the incident radiation. Identify the pairs of curves that correspond to different materials but same intensity of incident radiation. [1]



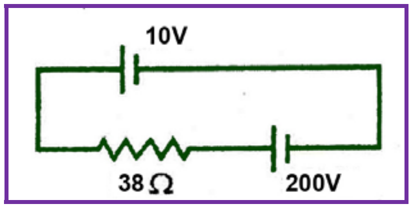
Answer:

Curves 1 and 2 correspond to similar materials while curves 3 and 4 represent different materials, since the value of stopping potential for the pair of curves 1 and 2 and 3 and 4 are the same. For given frequency of the incident radiation the stopping potential is independent of its intensity.

So, the pair of curves 1 and 3 and 2 and 4 correspond to different materials but same intensity of incident radiation.

Question: 7

A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω as shown in the figure. Find the value of the current circuit. [1]



Answer:

Since, the positive terminal of the batteries are connected together, so the equivalent emf of the batteries is given by ε = 200 – 100 = 190v.

Hence, the current in the circuit is given by I = $\frac{\varepsilon}{R}$.

$$I = \frac{190}{38} = 5A$$

Question: 8

The emf of a cell is always greater than its terminal voltage. Why? Give reason. [1]

Answer:

The emf of a cell is greater than its terminal voltage because there is some potential drop across the cell due to its small internal resistance.

Question: 9

a. Write the necessary conditions for the phenomenon of total internal reflection to occur.

Answer:

Necessary conditions for total internal reflection to occur are:

i. The incident ray on the interface should travel in optically denser medium.

ii. The angle of incidence should be greater than the critical angle for the given pair of optical media.

b. Write the relation between the refractive index and critical angle for a given pair of optical media. [2]

Answer:

$_a\mu_b = \frac{1}{\sin c}$, where a and b are the rate and denser media respectively, C is the critical angle for the given pair of optical media.

Question: 10

State Lenz's law. A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an emf induced at its ends? Justify your answer. [2]

Answer:

Lenz's Law states that the polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produces it.

Yes, emf will be induced in the rod as there is change in magnetic flux.

When a metallic rod held horizontally along East –West direction, is allowed to fall freely under gravity i.e fall from north to south, the intensity of magnetic lines of earth's magnetic field changes through it i.e the magnetic flux changes and hence the induced emf in it.

Question: 11

A convex lens of focal length 25 cm placed coaxially in contact with a concave lens of focal length 20 cm. Determine the power of the combination. Will the system be converging or diverging in nature? [2]

Answer:

We have focal Length of Convex Lens,

f_1 = +25 cm = +0.25 m and focal length of concave lens, f_2 = -20cm = -0.20 m.

Equivalent focal length, $F = \frac{1}{f_1} + \frac{1}{f_2}$

$= \frac{1}{25} + \frac{1}{-20}$

$= \frac{-1}{100}$

$\therefore$ F = -100 cm

Power of Convex Lens, $P_1 = \frac{1}{f_1} = \frac{1}{0.25}$

Power of Concave Lens, $P_2 = \frac{1}{f_2} = \frac{1}{-0.20}$

Power of the combination,

$P = P_1 + P_2 = \frac{1}{0.25} + \frac{1}{-0.20}$

$= \frac{100}{25} - \frac{100}{20}$

$= \frac{400-500}{100}$

$= \frac{-100}{100}$

= -ID.

As the focal length is in negative, the system will be diverging in nature.

Question: 12

An ammeter of resistance 0.80 Ω can measure current upto 1.0 A.

a. What must be the value of shunt resistance to enable the ammeter to measure current 5.0A?
b. What is the combined resistance of the ammeter and the shunt? [2]

Answer:

We have, resistance of ammeter, R_A = 0.80 ohm and maximum current across ammeter, IA = 1.0A.

So, voltage across ammeter,

V = IR

= 1.0 x 0.80

= 0.8V.

Let the value of shunt be x.

i. Resistance of ammeter, with shunt,

$$R = \frac{R_A x}{R_A + x}$$

$$= \frac{0.8x}{0.8 + x}$$

Current through ammeter, I = 5A

$$\therefore \left(\frac{0.8x}{0.8+x}\right) \text{ x } 5 = 0.8 \Rightarrow 0.8x \text{ x } 5 = 0.8\ (0.8 + x)$$

4x = 0.64 + 0.8x

$$x = \frac{0.64}{3.2}$$

= 0.2

Thus, the shunt resistance is 0.2 ohm.

ii. Combined resistance of the ammeter and the shunt,

$$R = \frac{0.8x}{0.8 + x}$$

$$= \frac{0.8 \text{ x } 0.2}{0.8 + 0.2}$$

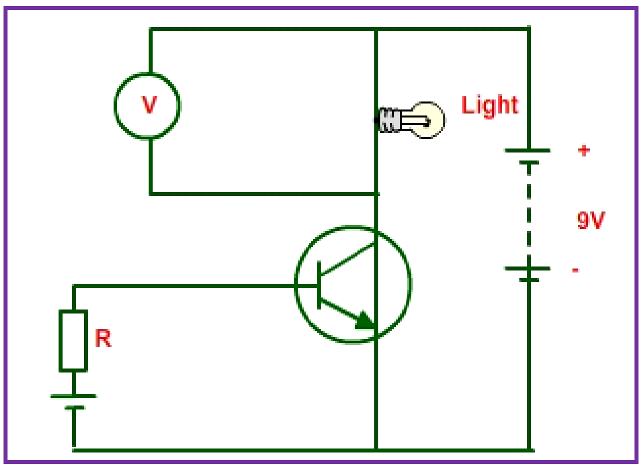
$$= \frac{0.16}{1}$$

Question: 13

In the given circuit diagram, a voltmeter 'V' is connected across a lamp 'L'. How would

a. The brightness of the lamp and

b. Voltmeter reading 'V' be affected, if the value of resistance 'R' is decreased? Justify your answer. [2]



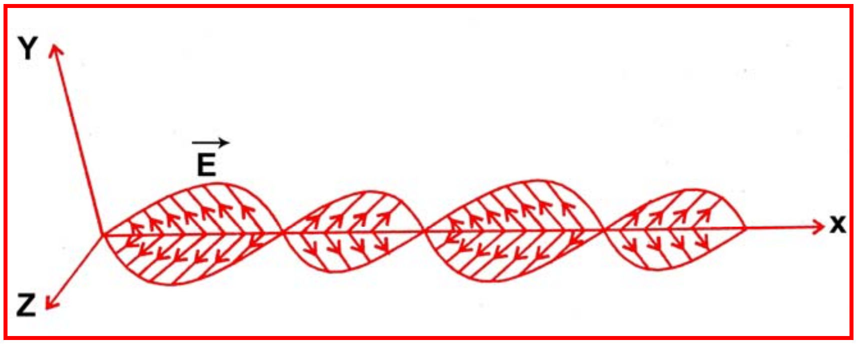
Answer:

The given figure is Common Emitter (CE) configuration of an npn transistor. The input circuit is forward biased and collector circuit is reverse biased. As the base resistance R decreases, the input circuit will become more forward biased thus decreasing the base current (I_B) and increasing the emitter current (I_E). This will increase the collector current (I_C) as $I_E = I_B + I_C$. When IC increases which flows through the lamp, the voltage across the bulb will also increase thus making the lamp brighter and as the voltage is connected in parallel with the lamp, the reading in the voltmeter will also increase.

Question: 14

a. An em wave is travelling in a medium with a velocity $\vec{v} = v\hat{i}$. Draw a sketch showing the propagation of the em wave, indicating the direction of the oscillating electric and magnetic fields.

Answer:



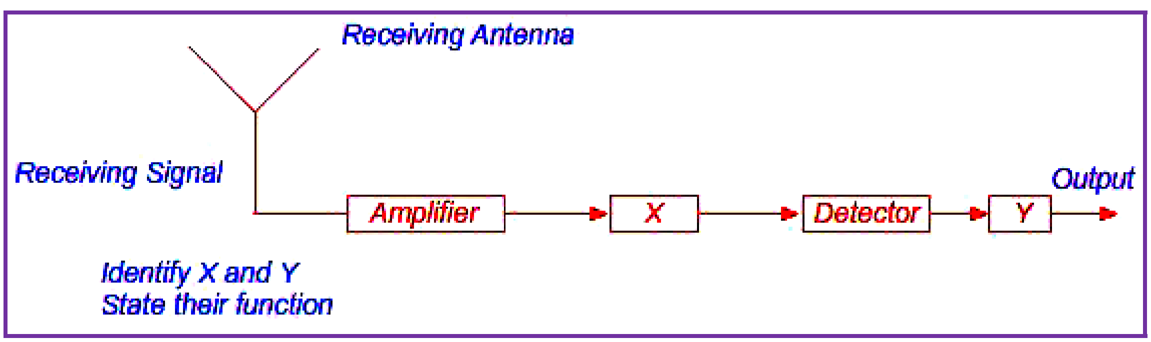
Given that velocity, $V = v\hat{i}$ and electric filed, E along X-axis and magnetic field, B along Z-axis.

b. How are the magnitudes of the electric and magnetic fields related to the velocity of the em wave? [2]

Answer:

Speed of EM wave can be given as the ratio of magnitude of electric field (ε_0) to the magnitude of magnetic field (B_0). $C = \frac{\varepsilon_0}{B_0}$

Question: 15



Block Diagram of a receiver is shown in the figure :

a. Identify 'X' and 'Y'.
b. Write their functions. [2]

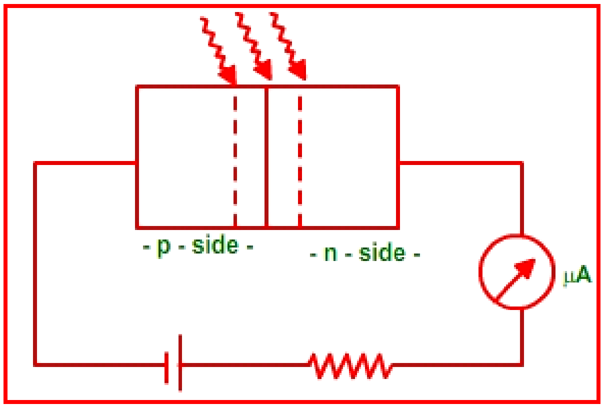
Answer:
From the given block diagram of Demodulation of a typical receiver, we can conclude the following;

a. X represents Intermediate Frequency (IF) stage while Y represents an Amplifier.
b. At IF stage, the carrier frequency is changed to a lower frequency and in this process, the modulated signal is detected. While the function of amplifier is to amplify the detected signal which may not be strong enough to be made use of and hence is required.

Question: 16

Explain, with the help of a circuit diagram the working of a photo –diode. Write briefly how it is used to detect the optical signals.

Answer:



See topics on 'Photo diode (photo cell)'.

OR

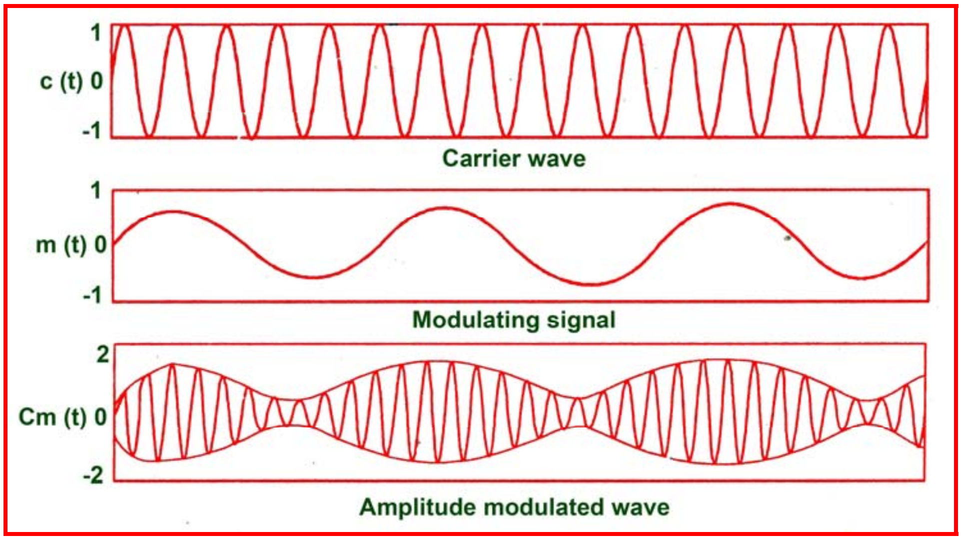
Mention the important considerations required while fabricating a p-n junction diode to be used as a Light Emitting Diode (LED). What should be the order of band gap of an LED if it is required to emit light in the visible range? [2]

Answer:
1. The reverse breakdown voltages of LEDs are very low, typically around 5V. so care should be taken while fabricating a pn-junction diode so that the high reverse voltages do not appear across them.
2. There is very little resistance to limit the current in LED. Therefore, a resistor must be used in series with the LED to avoid any damage to it.
3. The semiconductor used for fabrication of visible LEDs must at least have a band gap of 1.8 eV.

Question: 17

Write three important factors which justify the need of modulating a message signal. Show diagrammatically how an amplitude wave is obtained when a modulating signal is superimposed on a carrier wave. [2]

Answer:



Three important factors which justify the need of modulating a message signal:

i. Size of antenna or aerial – For communication within the effective length of the antennas, the transmitting frequencies should be high, so modulation is required.
ii. Effective power which is radiated by antenna – Since the power radiated from a linear antenna is inversely proportional to the square to the transmitting wavelength. As high powers are needed for good transmission so, higher frequency is required which can be achieved by modulation.
iii. The interference of signals from different transmitters – To avoid the interference of the signals there is need of high frequency which can be achieved by the modulation.

Question: 18

A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is 360 μC. When potential across the capacitor is reduced by 120 V, Charge stored in it becomes 120 μC.

a. The potential V and the unknown capacitance C.

Answer:

Initial voltage V_1 = V volts and charge stored,

$Q_1 = 360\mu C$

$Q_1 = CV_1$ ….(i)

Changed potential $V_2 = V - 120$

$Q_2 = 120\ \mu C$

$Q_2 = CV_2$ ….(ii)

By dividing (ii) from (i) we get,

$$\frac{Q_1}{Q_2} = \frac{CV_1}{CV_2} \Rightarrow \frac{360}{12} = \frac{V}{V-120}$$

V = 180 volts.

$$C = \frac{Q_1}{V_1} = \frac{360 \text{ x } 10^{-6}}{180}$$

= 2 x 10-6 F = 2μF

b. What will be the charge stored in capacitor, if the voltage applied had increased by 120 V?

Answer:

If the voltage applied had increased by 120V, then V3 = 180 + 120 = 300 V

Hence, charge stored in the capacitor,

$Q_3 = CV_3$

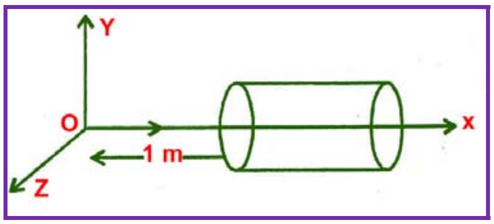
= 2 x 10-6 x 300 μC

= 600

OR

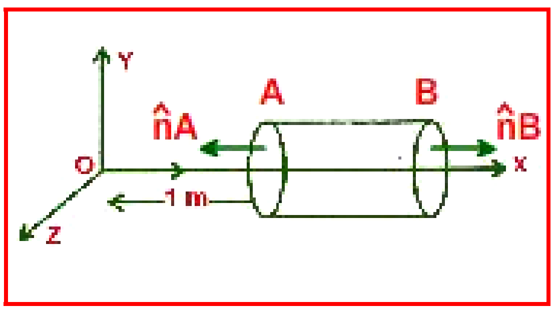
A hollow cylindrical box of length 1 m and the area of cross – section $25cm^2$ is placed in a three dimensional coordinate system as shown in the figure . The electric field in the region is given by $\vec{E} = 50x\hat{i}$, where E is in NC^{-1} and x is in meters. Find

i. Net flux through the cylinder.
ii. Charge enclosed by the cylinder. [2]



Answer:

i. Given, $\vec{E} = 50\ \chi\hat{i}$ and $\Delta s = 25cm^2 = 25 \times 10^{-4}$ m2



As the electric field I sonly along the x-axis, so flux will pass only through the cross-section of cylinder.

Magnitude of electric field at cross-section A,

$E_A = 50 \times 1 = 50NC^{-1}$

Magnitude of electric field at cross section B,

$E_B = 50\ X\ 2 = 100\ NC^{-1}$

The corresponding electric fluxes are :

$\phi_A = \vec{E}.\vec{\Delta}s = 50\ X\ 25\ X\ 10^{-4}\ X\cos 180^0$

$\phi_A = \vec{E}.\vec{\Delta}s = -0.125Nm^2 / C$

$\phi_B = \vec{E}.\vec{\Delta}s = 100\ X\ 25\ X\ 10^{-4}\ X\ \cos 0^0$

$\phi_B = \vec{E}.\vec{\Delta}s = 0.25Nm^2 / C$

So , The net flux through the cylinder ,

$\phi = \phi_A + \phi_B$

$= -0.125 + 0.25$

$= 0.125\ Nm^2/C$

Answer:

ii. Using Gauss's Law :

$$\oint \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0} \Rightarrow 0.125$$

$$= \frac{q}{8.85 \text{ X } 10^{-12}}$$

$q = 8.85 \text{ X } 0.125 \text{ X } 10^{-12}$

$= 1.1 \text{ X } 10^{-12}$ C

Question: 19

a. In a typical unclear reaction, e.g $^2_1H + ^2_1H \rightarrow ^3_2He + n + 3.27 MeV$, although number of nucleons is conserved, yet energy is released. How? Explain.

Answer:

In a nuclear reaction, the sum of the masses of the target nucleus $\left(^2_1H\right)$, and the bombarding particle $\left(^2_1H\right)$ may be greater or less than the sum of the masses of the product nucleus $\left(^3_1He\right)$ and the outgoing particle $\left(^1_0n\right)$. So from the Law of conservation of mass energy (3.27 MeV) is evolved or involved in a nuclear reaction. This energy is called Q-value of the nuclear reaction.

b. Show that nuclear density in a given nucleus is independent of mass number A. [3]

Answer:

Density of the nucleus

$= \frac{\text{mass of nucleus}}{\text{volume of nucleus}}$

Mass of the nucleus

= A amu

$= A \times 1.66 \times 10^{-27}$ kg

Volume of the nucleus

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

$= \frac{4}{3}\pi (R_0 A^{\frac{1}{3}})^3$

$= \frac{4}{3}\pi R_0^3 A$

Thus, density

$$\frac{A \times 1.66 \times 10^{-27}}{\left(\frac{4}{3}\pi R_0^3\right)A}$$

$$\frac{1.66 \times 10^{-27}}{\left(\frac{4}{3}\pi R_0^3\right)}$$

Question: 20

a. Why photoelectric effect cannot be explained on the basis of wave nature of light? Give reasons.'

Answer:

Wave nature of radiation cannot explain the following:

i. The instantaneous ejection of photoelectrons.
ii. The existence of threshold frequency for a metal surface.
iii. The fact that kinetic energy of the emitted electrons is independent of the intensity of light and depends upon the frequency.

Thus, the photoelectric effect cannot be explained on the basis of wave nature of light.

b. Write the basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based. [3]

Answer:

Photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based on particle nature of light. Its basic features are:

i. In interaction with matter, radiation behaves as if it is made up of particles called photons.
ii. Each photon has energy E = hv and momentum $p = \frac{hv}{c}$ and speed C, the speed of light.
iii. All photons of light of a particular frequency v, or wavelength λ have the same energy $E = hv = \frac{hv}{\lambda}$ and momentum $p = \frac{hv}{c} = \frac{hv}{\lambda}$ whatever the intensity of radiation may be.
iv. By increasing the intensity of light of given wavelength, there is only an increase in the number of photons per second crossing a given area, with each photon per second crossing a given area, with each photon having the same energy. Thus, photon energy is independent of intensity of radiation.
v. Photons are electrically neutral and are not deflected by electric and magnetic fields.

Question: 21

A metallic rod of length 'l' is rotated with a frequency v with one end hinged at the centre and the other end at the circumference of a circular metallic through the centre and perpendicular the plane of the ring . A constant uniform magnetic field B parallel the axis is present everywhere. Using Lorentz force, explain how emf is induced between the centre and the metallic ring and hence obtain the expression for it . [3]

Answer:

Suppose the length of the rod is greater than the radius of the circle and rod rotates anticlockwise and suppose the direction of electrons in the rod at any instant be along +y – direction. Suppose the direction of the magnetic field is along +z – direction.

Then, using Lorentz Law, we get the following:

$\vec{F} = -e\left(\vec{v} \times \vec{B}\right)$

$\vec{F} = -e\left(v\hat{j} \times B\hat{k}\right)$

$\vec{F} = -evB\hat{i}$

Thus, the direction of force on the electron is along –x- axis.
Thus, the electrons will move towards the centre i.e the fixed end of the rod. This movement of electrons will result in current and hence it will produce emf in the rod between the fixed end and the point touching the ring. Let θ be the angle between the rod and radius r of the circle at any time t. then, area swept by the rod inside the circle $= \frac{1}{2}\pi r^2 v$

Induced emf = $B \times \frac{d}{dt}\left(\frac{1}{2}\pi r^2 \theta\right)$

$= \frac{1}{2}\pi r^2 B\, dt \frac{d\theta}{dt} = \frac{1}{2}\pi r^2 B\omega$

$= \frac{1}{2}\pi r^2 B(2\pi v) = \pi^2 r^3 Bv$

Question: 22

Output characteristics of an n-p-n transistor in CE configuration is shown in the figure. Determine:

i. Dynamic output resistance

***Answer*:**

Dynamic output resistance is given as:

$R_0 = \left(\frac{\Delta V_{CE}}{\Delta I_c}\right) I_{b\,constant}$

$= \frac{12-8}{(3.6-3.4) \times 10^{-3}}$

$= \frac{4}{0.2 \times 10^{-3}} = 20k\Omega$

ii. DC current gain and

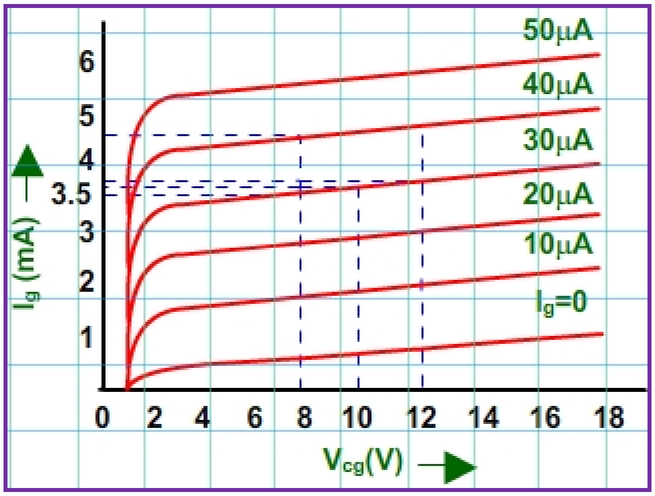
***Answer*:**

dc current gain,

$\beta d.c. = \frac{I_C}{I_B} = \frac{3.5mA}{30\mu A}$

$= \frac{3.5 \times 10^{-3}}{30 \times 10^{-6}} = \frac{350}{3} = 116.67$

iii. ac current gain at gain at an operating point $V_{CE} = 10\,V$, When $I_N = 30\mu A$. [3]



Answer:
a.c current gain, βa.c.

$$= \frac{\Delta I_C}{\Delta I_B} = \frac{(4.7 - 3.5)\text{mA}}{(40 - 30)\mu\text{A}}$$

$$= \frac{1.2 \times 10^{-3}}{10 \times 10^{-6}} = 120$$

Question: 23

Using Bohr's postulates, obtain the expression for the total energy of electron in the stationary states of the hydrogen atom. Hence draw the energy level diagram showing how the line spectra corresponding to Balmer series occur due to transition between energy levels. [3]

Answer:
See topics on 'Bohr's theory'.

Question: 24 [3]

a. In what way is diffraction from each slit related to the interference pattern in a double slit experiment?

Answer:
If the width of each slit is comparable to the wavelength of light used, the interference pattern thus obtained in the double-slit experiment is modified by diffraction from each of two slits.

b. Two wavelengths of sodium light 590nm and 596nm are used, in turn, to study the detraction taking place at a single slit of aperture 2 x 10^{-4} m. The distance between the slit and the screen is 1.5m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases.

Answer:
Given that: Wavelength of the light beam,
λ_1 = 590nm = 5.9 x 10-7 m
Wavelength of another light beam,
λ_1 = 596nm = 5.96 x 10^{-7} m

Distance of the slits from the screen = D = 1.5 m
Distance between the two slits = a = 2 x 10-4 m
For the first secondary maxima,

$\sin\theta = \frac{3\lambda_1}{2a} = \frac{x_1}{D}$

Question: 25

In a series LCR circuit connected to an ac source of variable frequency and voltage $v = v_m \sin \omega t$, draw a plot showing the variation of current (I) with angular frequency (ω) for two different values of resistance R_1 and R_2 ($R_1 > R_2$). Write the condition under which the phenomenon of resonance occurs. For which value of the resistance out of the two curves, a sharper resonance is produced? Define Q-factor of the circuit and give its significance. [3]

Answer:

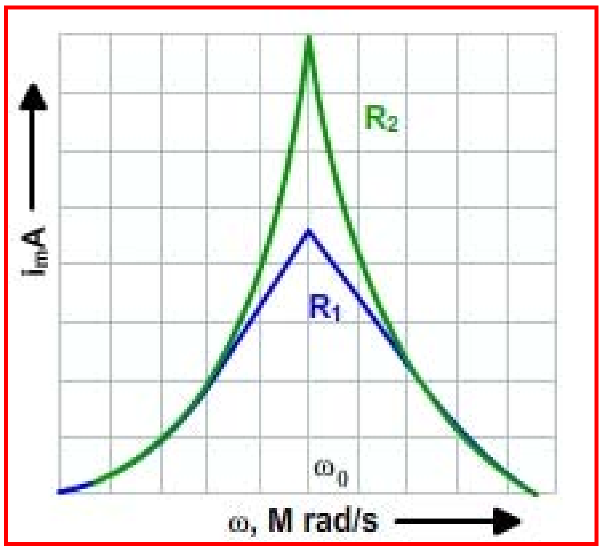


Figure shows the variation of i_m with ω in a LCK series circuit for two values of Resistance R_1 and R_2 ($R_1 > R_2$).

The condition for resonance in the LCR circuit is, $\omega_0 = \frac{1}{\sqrt{LC}}$

We see that the current amplitude is maximum at the resonant frequency ω. Since $i_m = \frac{V_m}{R}$ at resonance, the current amplitude for case R2, is sharper to that for case R1.
Quality factor or simply the Q-factor of a resonant LCR circuit is defined as the ratio of voltage drop across the capacitor to that of the applied voltage.
It is given by

$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

The Q factor determines the sharpness of the resonance curve and if the resonance is less sharp, not only is the maximum current less, the circuit is close to the resonance for a larger range Δw of frequencies and the tuning of the circuit will not be good. So, Less sharp the resonance, Less is the selectivity of the circuit while higher is the Q, sharper is the resonance curve and lesser will be the loss in energy of the circuit.

Question: 26

While travelling back to his residence in the car, Dr. Pathak was caught up in the thunderstorm to stop. Suddenly he noticed a child walking alone on the road. He asked the boy to come inside the car inside the car till the boy to come inside the car till the thunder stopped. Dr. Pathak dropped the boy at his residence. The boy insisted that Dr. Pathak should meet his parents. The parents expressed their gratitude to Dr. Pathak for his concern for safety of the child.
Answer the following questions based on the above information:

a. Why is it safer to sit inside a car during a thunderstorm?

Answer:
It is safer to be inside a car during thunder-storm because the car acts like a Faraday cage. The metal in the car will shield you from any external electric field and thus prevent the lighting from travelling within the car.

b. Which two values are displayed by Dr. Pathak in his actions?

Answer:
Awareness and Humanity

c. Which values are reflected in parents' response to Dr. Pathak?

Answer:
Gratitude and obliged

d. Give an example of a similar action on your part in the past from everyday life. [3]

Answer:
I once came across to a situation where a puppy was struck in the middle of a buzy road during rain and was not able to cross due to heavy flow, so I quickly rushed and helped him.

Question: 27

a. Draw a ray diagram showing the image formation by a compound the image formation by a compound microscope. Hence obtain expression for total magnification when the image is formed at infinity.
b. Distinguish between myopia and hypermetropia. Show diagrammatically how these defects can be corrected. [3]

Answer:
See topics on 'compound microscope'.

OR

a. State Huygen's principle. Using this principle draw a diagram to show how a plane wave front incident at the interface of the two media gets refracted when it propagates from a rarer to denser medium. Hence verify Snell's law of refraction.
b. When monochromatic light travels from a rarer to a denser medium, explain the following giving reasons –
    i. Is the frequency of reflected and refracted light same as the frequency of incident light.
    ii. Does the decrease in speed imply a reduction in the energy carried by light wave?

Answer:
See topics on 'Huygen's principle'.

Question: 28 [5]

a. State the working principle of a potentiometer. With the help of the circuit diagram, explain how a potentiometer is used to compare the emf's of two primary cells. Obtain the required expression used for comparing the emfs.

Answer:
See topics on 'EMF of two cells'.

b. Write two possible causes for one sided deflection in a potentiometer experiment.

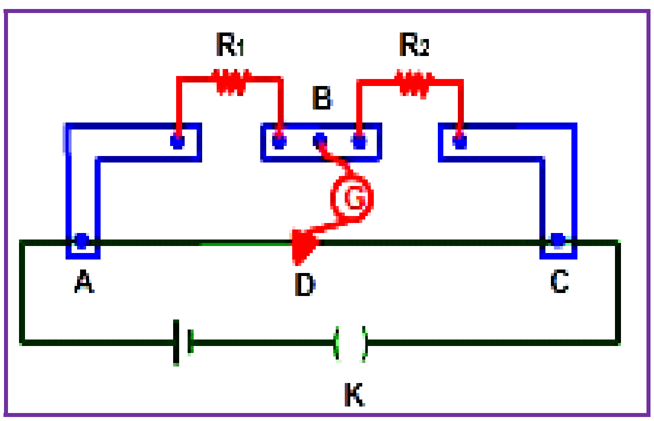
Answer:
i. the emf of the cell

OR

a. State Kirchhoff's rules for an electric network. Using Kirchhoff's rules, obtain the balance condition in terms of the resistances of four arms of Wheatstone bridge.

Answer:
See topics on 'Kirchhoff's laws'.

b. In the meter bridge experiment set up, shown in the figure, the null point 'D' is obtained at a distance of 40cm from end A of the meter bridge wire. If a resistance of 10Ω is connected in series with R_1, null point is obtained at AD = 60cm. calculate the values of R_1 and R_2.



Answer:
Considering both the situations and writing them in the form of equations.
Let R be the resistance per unit of length of the potential meter wire.

$$\frac{R_1}{R_2} = \frac{R' x 40}{R'(100-40)}$$

$$= \frac{40}{60} = \frac{2}{3}$$

$$\frac{R_1+10}{R_2} = \frac{R' x 60}{R'(100-60)}$$

$$= \frac{60}{40} = \frac{3}{2}$$

$\frac{R_1}{R_2} = \frac{2}{3}$ .....(i)

$\frac{R_1 + 10}{R_2} = \frac{3}{2}$ .....(ii)

Putting the value of R_1, from equation (i) subtracting in equation (ii)

$\frac{2}{3} + \frac{10}{R_2} = \frac{3}{2}$

R2 = 12Ω

Recalling equation (i) again

$\frac{R_1}{l^2} = \frac{2}{3}$

$R_1 = 8\Omega$

Question: 29 [5]

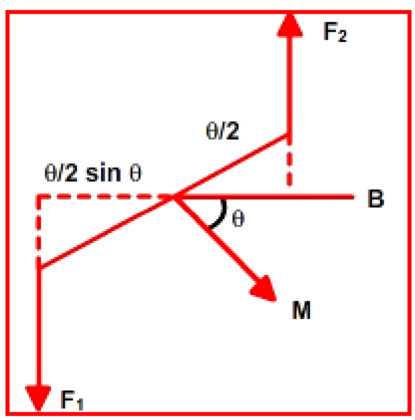
a. Derive the expression for the torque on a rectangular current carrying loop suspended in a uniform magnetic field.

Answer:

See topics on 'Torque'.

b. A proton and a deuteron having equal momenta enter in a region of uniform magnetic field at right angle to the direction of the field. Depict their trajectories in the field.

Answer:



We know, Lorentz force

$F = Bqv \sin\theta$

Where θ = angle b/w velocity of particle and magnetic field

$\theta = 90^0$

So, Lorentz force F = Bqv.

Thus, the particles will move in circular path.

$Bqv = \frac{mv^2}{r}$

$r = \frac{mv}{Bq}$

Let m_p = Mass of proton

M_d = Mass of dentron

V_p = Velocity of proton

V_d = Velocity of dentron
The charge of proton and dentron are equal.
Given that MpVp = MdVd

$$r_p = \frac{m_p V_p}{Bq} \quad \text{....(i)}$$

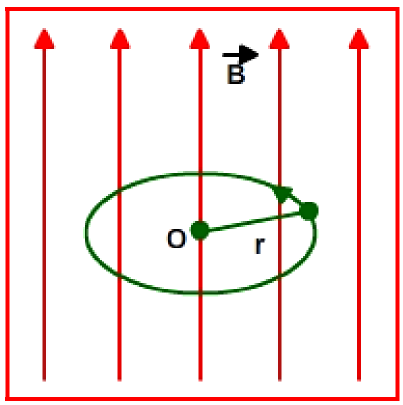
$$r_d = \frac{m_d v_d}{Bq} \quad \text{...(ii)}$$

As (i) and (ii) are equal, So $r_p = r_d = r$.
Thus, the trajectory of both the particles will be same.

OR

a. A small compass needle of magnetic moment 'm' is free to turn about an axis perpendicular to the direction of uniform magnetic field 'B'. the moment of inertia of the needle about the axis is 'I'. the needle is then released. Prove that it executes simple harmonic motion. Hence deduce the expression for its time period.

Answer:



The torque on the needle is τ = m x B
In magnitude
$\tau = mB \sin\theta$
Here τ is restoring torque and θ is the angle between m and B.

Therefore, in equilibrium $I\frac{d^2\theta}{dt^2} = -mB\sin\theta$

Negative sing with mB sin θ implies that restoring torque is in opposition to deflecting torque.

For small values of θ in radians, we approximate $\sin\theta = \theta$ and get $I\frac{d^2\theta}{dt^2} = -mB\sin\theta$

Or $\frac{d^2\theta}{dt^2} = \frac{-mB}{I}\theta$

This represents a simple harmonic motion.

The square of the angular frequency is $\omega^2 = \frac{mB}{\tau}$ and the time period is $T = 2\pi\sqrt{\frac{I}{mB}}$

b. A compass needle, free to turn in a vertical plane orients itself with its axis vertical at a certain place on the earth. Find out the values of (i) horizontal component of earth's magnetic field and (ii) angle of dip at the place.

Answer:

i. As Horizontal component of earth's magnetic field, BH = B cos δ

Putting $\delta = 90^0$

$\therefore$ BH = O

ii. for a compass needle align vertical at a certain place, angle of dip

$\delta = 90^0$