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**2010**

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Set: I

Question: 1 – 30

ii - xviii

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**Set: I**

**Question: 1**

Answer all questions briefly and to the point.

[1]

In which orientation, a dipole placed in a uniform electric field is in

- a. Stable
- b. Unstable equilibrium

**Answer:**

A dipole placed in a uniform electric field is in,

- a. Stable equilibrium when the electric field is directed along the direction of the dipole i.e. when  $\vec{E}$  is parallel to  $\vec{p}$ .
- b. Unstable equilibrium when the electric field is directed at an angle of 180 degrees with the direction of the dipole i.e. when  $\vec{E}$  is anti-parallel to

**Question: 2**

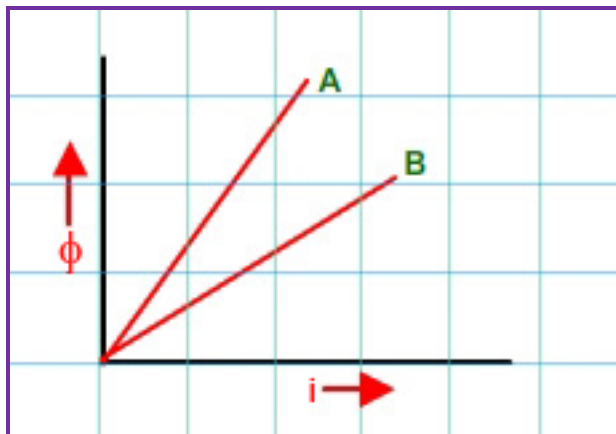
Which part of electromagnetic spectrum has largest penetrating power?

[1]

**Answer:**

Gamma rays

**Question: 3**



A plot of magnetic flux ( $\Phi$ ) versus current ( $i$ ) is shown in the figure for two inductors A and B. Which of the two has larger value of self-inductance? [1]

**Answer:**

Since flux is given as,  $\Phi = L \cdot \frac{i}{N}$

Larger is the slope of the graph between  $\Phi$  vs.  $i$ , more will be the value of self inductance  $L$  of the coil.

In the given graphs, slope of A > slope of B.

Hence,



- A will represent coil of higher L
- B will represent coil of lower L.

**Question: 4**

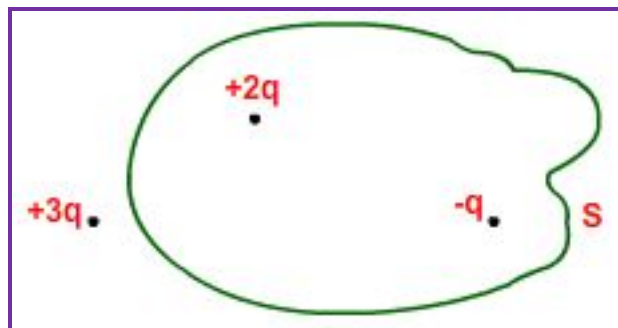


Figure shows three point charges,  $+2q$ ,  $-q$  and  $+3q$ . Two Charges  $+2q$  and  $-q$  are enclosed within a surface 'S'. What is the electric flux due to this configuration through the surface 'S'?

[1]

**Answer:**

The net electric flux through the surface 'S' is,  $\frac{q}{\epsilon_0}$  where  $\epsilon_0$  is the permittivity of free space.

**Question: 5**

A glass lens of refractive index 1.45 disappears when immersed in a liquid. What is the value of refractive index of the liquid?

[1]

**Answer:**

The refractive index of the liquid is 1.45.

**Question: 6**

What is the ratio of the orbits corresponding to first excited state and ground state in a hydrogen atom?

[1]

**Answer:**

Radius of the  $n$ th orbit is given as,

$$r_n = \left( \frac{n^2}{m} \right) \cdot \left( \frac{h}{2\pi} \right)^2 \cdot \frac{4\pi\epsilon_0}{e^2}$$

For the ground state,  $n=1$

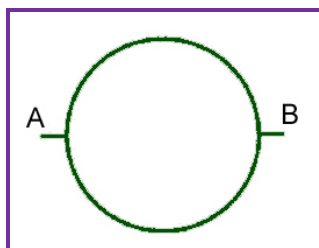
For excited state,  $n=2$

So the ratio between radii of the first orbital & the ground state radii is 4.



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**Question: 7**



A wire of resistance  $8R$  is bent in the form of a circle. What is the effective resistance between the ends of a diameter  $AB$ ? [1]

**Answer:**

The effective resistance between the ends of diameter  $AB$  is  $\frac{1}{\frac{1}{4R} + \frac{1}{4R}} = \frac{1}{\frac{1}{2R}} = 2R$

**Question: 8**

State the conditions for the phenomenon of total internal reflection to occur. [1]

**Answer:**

Conditions for total internal reflection:

1. Light should travel from an optically denser medium to a rarer medium at the interface.
2. Angle of incidence in the denser medium should exceed the critical angle

**Question: 9**

Explain the function of a repeater in a communication system. [2]

**Answer:**

A repeater is used for extending the range of a communication system. It consists of a receiver and a transmitter. The receiver of a repeater collects the signal from the transmitter of another repeater and after amplifying it retransmits the signal. Sometimes, it also changes the carrier frequency of the pickup signal before transmitting it to the receiver.

**Question: 10**

a. Write two characteristics of a material used for making permanent magnets. [2]

**Answer:**

Two characteristics of materials used for making permanent magnets:

- i. high retentivity so that the magnet is strong and
- ii. high coercivity so that the magnetisation is not erased by stray magnetic fields, temperature fluctuations or minor mechanical damage.

b. Why is core of an electromagnet made of ferromagnetic materials?

**Answer:**

Core of electromagnets are made of ferromagnetic materials because they have high permeability and low retentivity. That is to ensure that heating losses are minimum as they will have narrow Hysteresis curve.

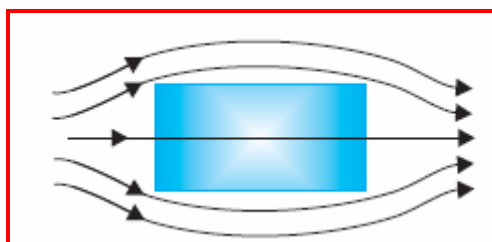


OR

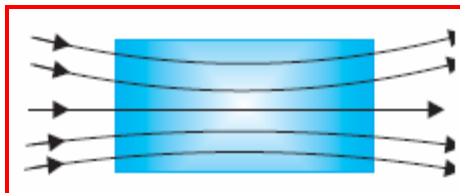
Draw magnetic field lines when a (i) diamagnetic, (ii) paramagnetic substance is placed in an external magnetic field. Which magnetic property distinguishes this behavior of the field lines due to the two substances? [2]

**Answer:**

Magnetic field lines when a diamagnetic material is placed in external magnetic field:



Magnetic field lines when a paramagnetic material is placed in external magnetic field:



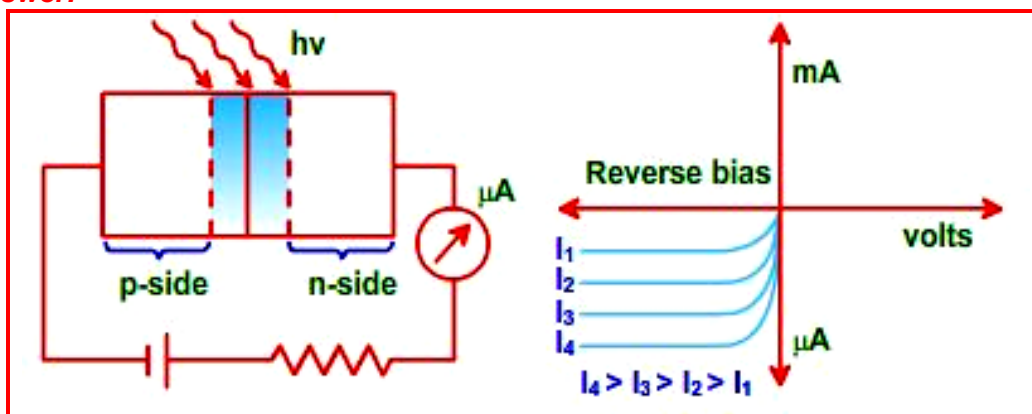
Property that is responsible for the above behavior is magnetic dipole moment.

- Diamagnetic material has zero magnetic moment
- Paramagnetic material has non zero magnetic moment

**Question: 11**

Draw the circuit diagram of an illuminated photodiode in reverse bias. How is photodiode used to measure light intensity? [2]

**Answer:**

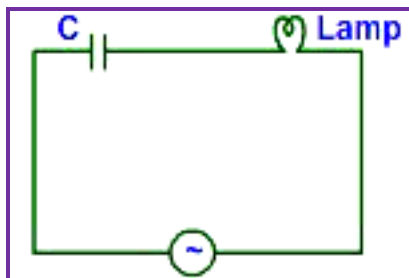


The magnitude of the photocurrent depends on the intensity of incident light as the photocurrent is proportional to incident light intensity. A change in the photocurrent with indicate a change in



the light intensity, if a reverse bias is applied. Thus photodiode can be used as a photodetector to detect optical signals.

**Question: 12**



An electric lamp having coil of negligible inductance connected in series with a Capacitor and an AC source is glowing with certain brightness. How does the brightness of the lamp change on reducing the (i) capacitance, and (ii) the frequency? Justify your answer. [2]

**Answer:**

(a) By reducing the capacitance, the capacitive reactance  $\left(X_c = \frac{1}{C\omega}\right)$  increase. So the bulb brightness will decrease.

(b) By reducing the frequency, the capacitive reactance will again increase. So the bulb brightness will again decrease.

**Question: 13**

Arrange the following electromagnetic radiations in ascending order of their frequencies:

- i. Microwave
- ii. Radio wave
- iii. X- rays
- iv. Gamma rays

Write two uses of any one of these.

[2]

**Answer:**

Ascending order of the em waves (in terms of frequencies)

Radio waves < Microwaves < X rays < Gamma rays

*Two uses of any one:*

**Radio waves**

Radio and television communication systems; Cellular phones use radio waves to transmit voice communication

**Microwaves**

In microwave ovens; in radar systems of aircraft navigation

**X rays**

As diagnostic tool in medicine; For cancer treatment



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### Gamma rays

In medicine for cancer treatment; Solid state physics

#### Question: 14

The radii of curvature of the faces of a double convex lens are 10 cm and 15 cm. If focal length of the lens is 12 cm, find the refractive index of the material of the lens. [2]

#### Answer:

Using the lens maker's formula:

$$\frac{1}{f} = (n-1) \cdot \left( \frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{1}{12} = (n-1) \cdot \left( \frac{1}{10} - \frac{1}{15} \right)$$

Here for convex lens,  $R_1 = 10$  cm,  $R_2 = -15$  cm

Solving the above equation we get,  
Refractive index of the material of the lens:  $n = 1.5$

#### Question: 15

An electron is accelerated through a potential difference of 100 volts. What is the De-Broglie wavelength associated with it? To which part of the electromagnetic spectrum does this value of wavelength correspond? [2]

#### Answer:

$$\text{de-Broglie wavelength: } \lambda = \frac{h}{\sqrt{2meV}}$$

Where,  $m \rightarrow$  Mass of electron:  $9.1 \times 10^{-31}$  kg

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 64}}$$

$$= \frac{6.626 \times 10^{-34}}{\sqrt{1863.63 \times 10^{-50}}}$$

$$= \frac{6.626 \times 10^{-34}}{\sqrt{1063.86 \times 10^{-25}}}$$

$$= \frac{6.626}{43.17} \times 10^{-9}$$

$$= 0.15 \times 10^{-9} \text{ m}$$

$$= 1.5 \times 10^{-10} \text{ m}$$

#### Question: 16

A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy of nucleons in Y and Z is 8.5 MeV per nucleon. Calculate the energy Q released per fission in MeV. [2]



**Answer:**

Total energy of nucleus (X):  $240 \times 7.6 = 1824 \text{ MeV}$

Total energy of nucleus (Y):  $11 \times 8.5 = 935 \text{ MeV}$

Total energy of nucleus (Z):  $130 \times 8.5 = 1105 \text{ MeV}$

Therefore, energy released from fusion (Q):  $935 + 1105 = 1824 = 216 \text{ MeV}$

**Question: 17**

The bluish color predominates in clear sky. Violet color is seen at the bottom of the spectrum when white light is dispersed by a prism. State reasons to explain these observations. [2]

**Answer:**

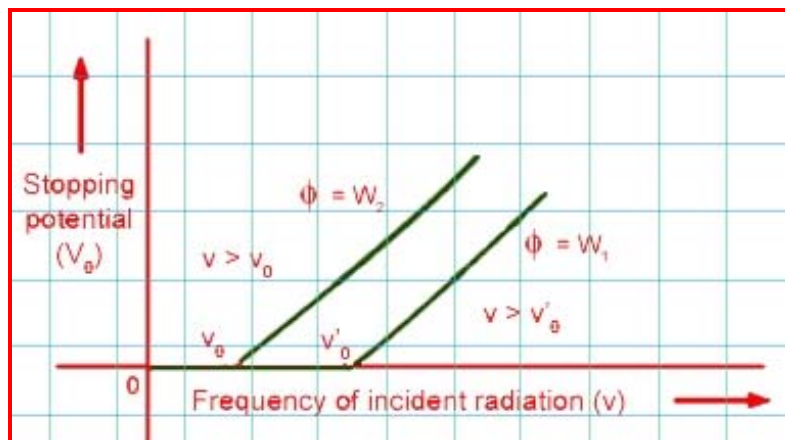
- As sunlight travels through the earth's atmosphere, it gets scattered by the atmospheric particles. Light of shorter wavelengths is scattered much more than light of longer wavelengths.

The amount of scattering is inversely proportional to the fourth power of the wavelength. This is known as Rayleigh scattering). Hence, the bluish colour predominates in a clear sky, since blue has a shorter wavelength than red and is scattered much more strongly.

- Violet color undergoes maximum bending as it has the minimum wavelength and maximum refractive index with respect to the glass medium.

**Question: 18**

Plot a graph showing the variation of stopping potential with the frequency of Incident radiation for two different photosensitive materials having work functions  $W_1$  and  $W_2$  ( $W_1 > W_2$ ). On what factors does the (i) slope and (ii) intercept of the lines depend? [2]

**Answer:**

- The slope of the graph is constant and equals to  $\left(\frac{h}{e}\right)$ . Therefore, the slope does not depend on any factor.
- The intercept of the lines depends on the work function ' $\phi$ ' of the metals.





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**Question: 19**

A parallel plate capacitor is charged by a battery. After sometime the battery is disconnected and a dielectric slab with its thickness equal to the plate separation is inserted between the plates.

How will (i) the capacitance of the capacitor, (ii) potential difference between the plates and (iii) the energy stored in the capacitor be affected? Justify your answer in each case. [3]

**Answer:**

- i. Capacitance of the capacitor increases by a factor  $K$ , i.e., it becomes  $KC$ .
- ii. Net electric field will get reduced. As potential difference  $V = -Ed$ , as  $E$  is reduced, potential difference between the capacitor plates also reduces.
- iii. Energy of the capacitor:

As the charge  $Q$  is fixed on plates,

Energy stored in the capacitor

$$U = \frac{Q^2}{2C} \rightarrow \frac{1}{K} \times (\text{Energy without dielectric})$$

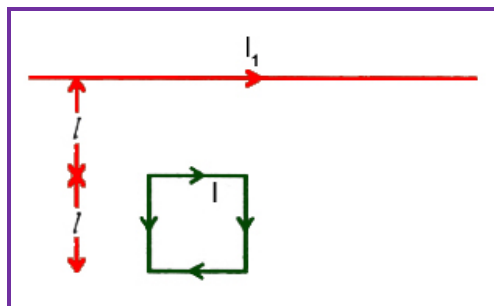
$$U \propto \frac{1}{K}, \text{ it goes down}$$

**Question: 20**

Write the principle of working of a potentiometer. Describe briefly, with the help of a circuit diagram, how a potentiometer is used to determine the internal resistance of a given cell. [3]

**Answer:**

See topics on 'potentiometer'.

**Question: 21**

Write the expression for the magnetic moment ( $\vec{m}$ ) due to a planar loop of side ' $l$ ' carrying a steady current  $I$  in vector form.

In the given figure this loop is placed in a horizontal plane near a long straight conductor carrying a steady current  $I_1$  at a distance  $l$  as shown. Give reasons to expression for this force acting on the loop. [3]



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**Answer:**

The expression for the magnetic moment (**m**) due to a planar square loop of side  $l$  carrying a steady current  $I$  in a vector form is given as  $\mathbf{m} = I\mathbf{A}$

Therefore,  $m = I(l^2)$  where,  $\mathbf{n}$  is the unit vector along the normal to the surface of the loop.

The attractive force per unit length on the loop is  $I \times B$ . The repulsive force per unit length on the loop is  $I \times B$ . Since the attractive force is greater than the repulsive force, a net force acts on the loop. The torque on the loop is given as

$$\begin{aligned}\tau &= \mathbf{m} \times \mathbf{B} \\ &= mB \sin \theta \\ &= IAB \sin \theta \\ \theta &= 0^\circ \quad (\because \text{Area vector is parallel to the magnetic field})\end{aligned}$$

$$\begin{aligned}T &= IAB \sin 0^\circ \\ \tau &= 0\end{aligned}$$

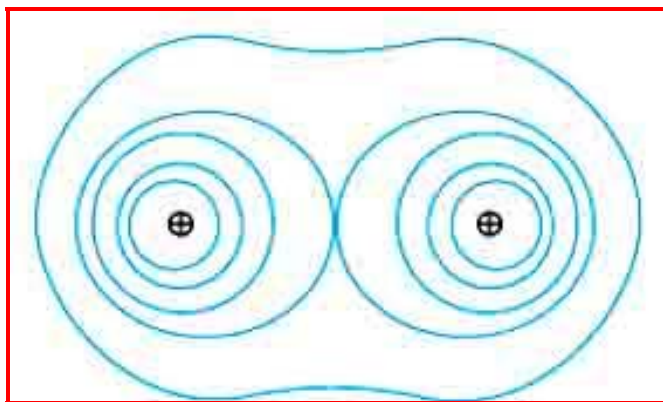
The torque acting on the loop is zero

**Question: 22**

- Depict the equipotential surfaces for a system of two identical positive point charges placed a distance  $d$  apart. (\*\*) [3]
- Deduce the expression for the potential energy of a system of two point charges  $q_1$  and  $q_2$  brought from infinity to the points  $\vec{r}_1$  and  $\vec{r}_2$  respectively in the presence of external electric field  $\vec{E}$ . [3]

**Answer:**

- An equipotential surface is a surface with a constant value of potential at all points on the surface.



Equipotential surfaces for two identical positive charges.

- First, we calculate the work done in bringing the charge  $q_1$  from infinity to  $r_1$ .

Work done in this step is  $q_1 V(r_1)$ .

Next, we consider the work done in bringing  $q_2$  to  $r_2$ . In this step, work is done not only against the



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External field  $E$  but also against the field due to  $q_1$ .

Work done on  $q_2$  against the external field:  $q_2 V(r_2)$

Work done on  $q_2$  against the field due to  $q_1$ :  $\frac{q_1 q_2}{4\pi\epsilon_0 r_{12}}$

Where,  $r_{12}$  is the distance between  $q_1$  and  $q_2$ .

By the superposition principle for fields, we add up the work done on  $q_2$  against the two fields ( $E$  and that due to  $q_1$ ):

Work done in bringing  $q_2$  to  $r_2$ :  $\frac{q_1 q_2}{4\pi\epsilon_0 r_{12}}$

Thus, potential energy of the system:  
= the total work done in assembling the configuration

$$= q_1 V(r_1) + q_2 V(r_2) + \frac{q_1 q_2}{4\pi\epsilon_0 r_{12}}$$

**Question: 23**

What is an unpolarized light? Explain with the help of suitable ray diagram how an unpolarized light can be polarized by reflection from a transparent medium. Write the expression for Brewster angle in terms of the refractive index of denser medium. [3]

**Answer:**

*Unpolarized light*

An unpolarized light is one in which the vibration of electric field vector is not restricted in one particular plane. When an unpolarized light falls on the surface, the reflected light is such that the vibration of its electric field vector is confined to one particular plane.

The direction of this plane is parallel to the surface of reflection. A component of electric field vector is absent from the refracted light. Therefore, the refracted light is partially polarised. Also study the readings on electric potential and potential difference

**Question: 24**

[3]

- a. Define 'activity' of radioactive material and its S.I. unit.

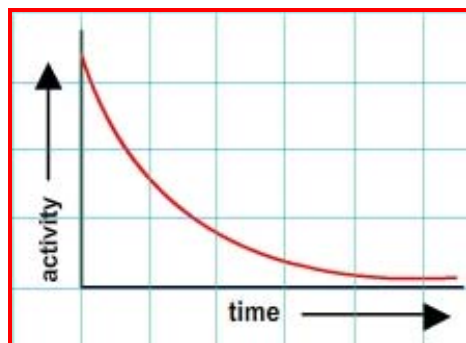
**Answer:**

The activity of a radioactive material is defined as the decay rate of a sample containing one or more radio nuclides. The SI unit of radioactivity is Becquerel (B).

- b. Plot a graph showing variation of activity of a given radioactive sample with time.

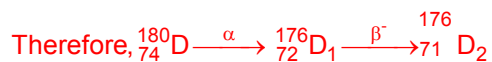
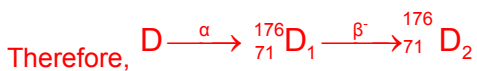
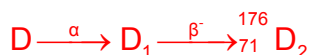


**Answer:**



- c. The sequence of stepwise decay of a radioactive nucleus is,  $D \xrightarrow{\alpha} D_1 \xrightarrow{\beta^-} D_2$ . If the atomic number and mass number of  $D_2$  are 71 and 176 respectively, what are their corresponding values for D?

**Answer:**



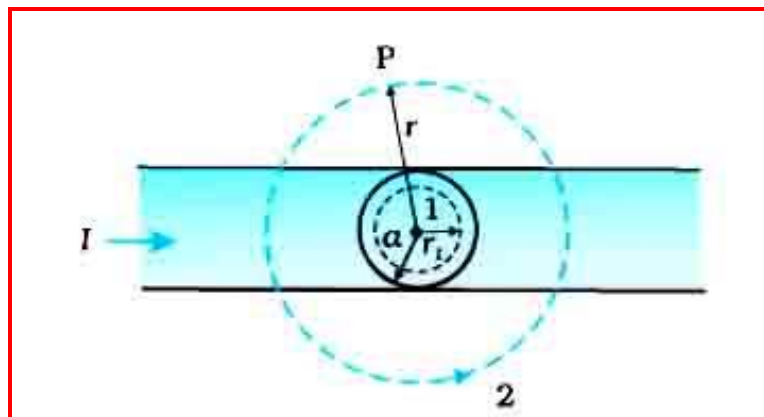
So, the corresponding values of atomic number and mass number for D are 74 and 180.

**Question: 25**

A long straight wire of a circular cross-section of radius 'a' carries a steady current 'I'. The current is uniformly distributed across the cross-section. Apply Ampere's circuital law to calculate the magnetic field at a point 'r' in the region for (i)  $r < a$  and (ii)  $r > a$ . [3]

**Answer:**

i.



Consider the case  $r < a$ . The Amperian loop is a circle labelled 1. For this loop, taking the radius of the circle to be  $r$ ,

$$L = 2\pi r$$

Now the current enclosed  $I_e$  is not  $I$ , but is less than this value. Since the current distribution is uniform, the current enclosed is,

$$I_e = I \left( \frac{\pi r^2}{\pi a^2} \right) = \frac{I r^2}{a^2}$$

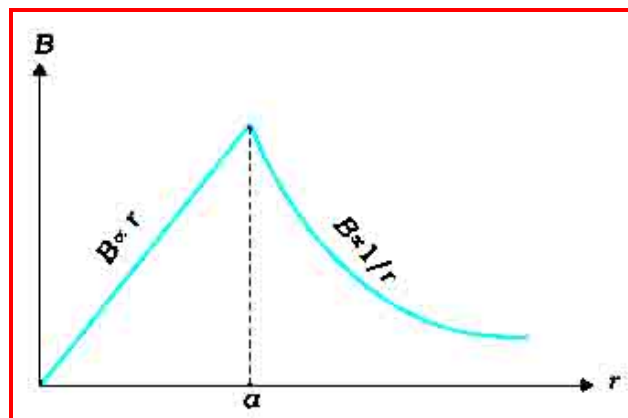
Using Ampere's law:

$$B(2\pi r) = \mu_0 \frac{I r^2}{a^2}$$

$$B = \left( \frac{\mu_0 I}{2\pi a^2} \right) r$$

$$B \propto r \quad (r < a)$$

ii.



Consider the case  $r > a$ . The Amperian loop, labelled 2, is a circle concentric with the cross-section. For this loop,

$$L = 2\pi r$$

$I_e$  = Current enclosed by the loop  $I$

The result is the familiar expression for a long straight wire

$$B(2\pi r) = \mu_0 I$$

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

$$B \propto \frac{1}{r} \quad (r > a)$$

OR



State the underlying principle of working of a moving coil galvanometer. Write two reasons why a galvanometer cannot be used as such to measure current in a given circuit. Name any two factors on which the current sensitivity of a galvanometer depends. [3]

**Answer:**

See topics on moving coil galvanometer

**Question: 26**

What is space wave propagation? Give two examples of communication system which use space wave mode. A TV tower is 80 m tall. Calculate the maximum distance up to which the signal transmitted from the tower can be received. [3]

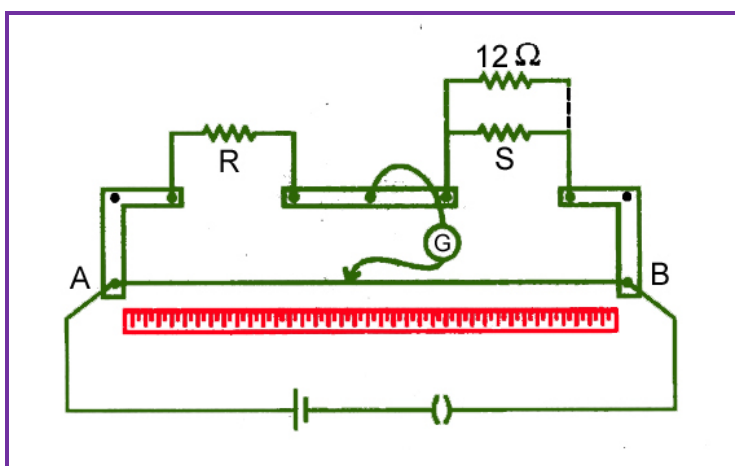
**Answer:**

See topics on space waves

The maximum distance up to which signals can be received:

$$\begin{aligned} x &= \sqrt{2R_E h_T} \\ &= \sqrt{2 \times 6400000 \times 80} \\ &= 32000 \text{ m} \\ &= 32 \text{ km} \end{aligned}$$

**Question: 27**



In a meter bridge, the null point is found at a distance of 40cm from A. If a resistance of  $12 \Omega$  is connected in parallel with S, the null point occurs at 50.0 cm. from A. then determine the values of R and S. [3]

**Answer:**

Initially, when x is not connected

$$\frac{R}{S} = \frac{l_1}{100 - l_1} \quad \text{Condition for balance (i)}$$

$$\frac{1}{R_{eq}} = \frac{1}{X} + \frac{1}{S}$$



$$R_{eq} = \frac{SX}{X+S}$$

$$\frac{R}{R_{eq}} = \frac{I_2}{100 - I_2}$$

$$\frac{R(X+S)}{SX} = \frac{I_2}{100 - I_2} \quad (ii)$$

On dividing (i) by (ii), we obtain

$$\frac{R}{R(X+S)} \cdot \frac{SX}{X} = \frac{I_2 \cdot (100 - I_2)}{I_2 \cdot (100 - I_2)}$$

$$\frac{X}{X+S} = \frac{I_2(100 - I_2)}{I_2(100 - I_2)}$$

$$XI_2(100 - I_2) = XI_1(100 - I_2) + SI_1(100 - I_2)$$

$$X = \frac{SI_1(100 - I_2)}{I_2(100 - I_1) - I_1(100 - I_2)}$$

This is the expression for X in terms of S,  $I_1$  and  $I_2$ .

**Question: 28**

[5]

Describe briefly, with the help of a labeled diagram, the basic elements of an A.C generator. State its underlying principle. Show diagrammatically how an alternating emf is generated by a loop of wire rotating in a magnetic field. Write the expression for the instantaneous value of the emf induced in the rotating loop.

**Answer:**

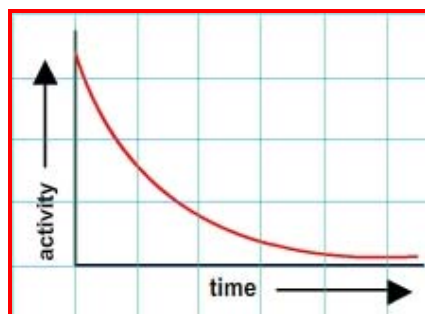
See topics on 'AC generator'.

OR

A series LCR circuit is connected to an AC source having voltage  $v = v_m \sin \omega t$ . Derive the expression for the instantaneous current I and its phase relationship to the applied voltage. Obtain the condition for resonance to occur. Define 'power factor'. State the conditions under which it is (i) maximum and (ii) minimum.

**Answer:**

Power factor =  $\cos \phi$



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Where,  $\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + (X_C - X_L)^2}}$

- i. Conditions for maximum power factor (i.e.,  $\cos\phi = 1$ ):  $X_C = X_L$  or  $R = 0$
- ii. Conditions for minimum power factor: Where circuit is purely inductive, or capacitive

**Question: 29**

[5]

- a. State Huygens's Principle. Show, with the help of a suitable diagram, how this principle is used to obtain the diffraction pattern by a single slit.

**Answer:**

See topics on 'Huygens's Principle'.

- b. Draw a plot of intensity distribution and explain clearly why the secondary maxima become weaker with increasing order (n) of the secondary maxima.

**Answer:**

See topics on diffraction by single slit

OR

Draw a ray diagram to show the working of a compound microscope. Deduce an expression for the total magnification when the final image is formed at the near point.

In a compound microscope, an object is placed at a distance of 1.5 cm from the objective of focal length 1.25 cm. If the eye piece has a focal length of 5cm and the final image is formed at the near point, estimate the magnifying power of the microscope.

**Answer:**

See topics on compound microscope

Numerical:

Given,  
 $f_o = 1.25$  cm.  
 $u = 1.5$  cm.  
 $f_e = 5$  cm.

We know,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Therefore,

$$\begin{aligned} \frac{1}{v} &= \frac{1}{f} + \frac{1}{u} \\ &= \frac{1}{1.25} + \frac{1}{1.5} \end{aligned}$$

Then,  $v = 1.46$

We can write,

$$\begin{aligned} L &= f_o + f_e + (v - f_o) \\ &= 1.25 + 5 + (1.46 - 1.25) \end{aligned}$$





$$= 6.46$$

As the final image is formed at a near point we can take  
 $D = 25 \text{ cm}$ .

Therefore,

$$m_e = 1 + \frac{D}{f_e}$$

$$= 1 + \frac{25}{5}$$

$$= 1 + 5$$

$$= 6$$

$$m_o = \frac{L}{f_o}$$

$$= \frac{6.46}{1.25}$$

$$= 5.17$$

Thus magnification of the microscope is given by,

$$m = m_o \times m_e$$

$$= 5.17 \times 6$$

$$= 31.04$$

**Question: 30**

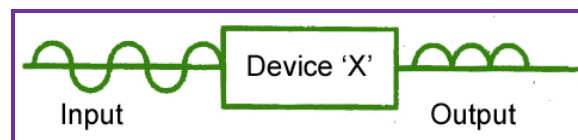
[5]

- a. Explain the formation of depletion layer and potential barrier in a p-n junction.

**Answer:**

See topics on 'I-V characteristics in Forward and Reverse Bias'.

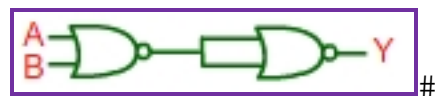
- b. In the figure given below the input waveform is converted into the output waveform by a device 'X'. Name the device and draw its circuit diagram.



**Answer:**

See topics on full wave

- c. Identify the logic gate represented by the circuit as shown as write its truth table.



**Answer:**

See topics on AND gate

OR



- 
- a. With the help of the circuit diagram explain the working principle of a transistor amplifier as an oscillator. [5]

**Answer:**

See topics on 'transistors'.

- b. Distinguish between a conductor, a semiconductor and an insulator on the basis of energy band diagrams.

**Answer:**

See topics on 'conductors and insulators'.

(\*\*) Currently out of syllabus. Answer can be provided up on request.

