ISC Boards 2023

Physics

Question 1.

A. In questions (i) to (vii) given below, choose the correct alternative (a), (b), (c) or (d) for each of the questions.

(i) A hollow sphere of radius R has a point charge Q at its centre. Electric flux emanating from it is φ. If both the charge and the radius of the sphere be doubled, electric flux emanating from the sphere will:

a) Remain the same.
b) Become 2φ
c) Become 4φ
d) Become 8φ

Answer (b)

Gauss law states that, Electric flux,

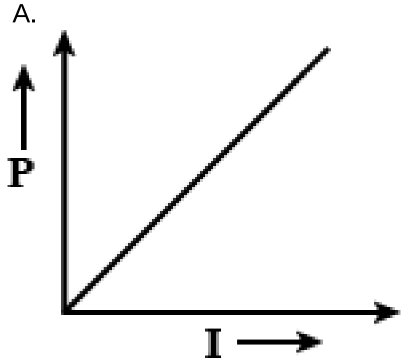
$\Delta\phi = \frac{q_{in}}{\epsilon_0}, \qquad q_{in} = charge\ enclosed$

$\Delta\phi_1 = \frac{Q}{\epsilon_0}, \Delta\phi_2 = \frac{2Q}{\epsilon_0}$

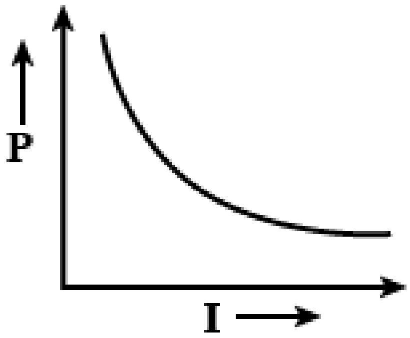
$\Delta\phi_2 = 2\Delta\phi_1$

(ii) An electric current (I) flowing through a metallic wire is gradually increased. The graph of heating power (P) developed in it versus the current (I) is:

A.



B.



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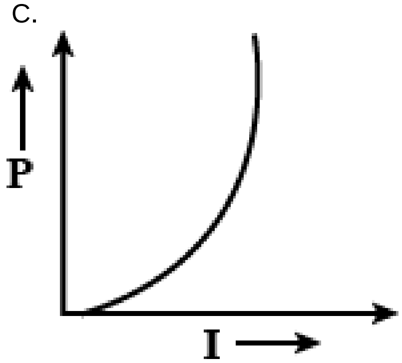
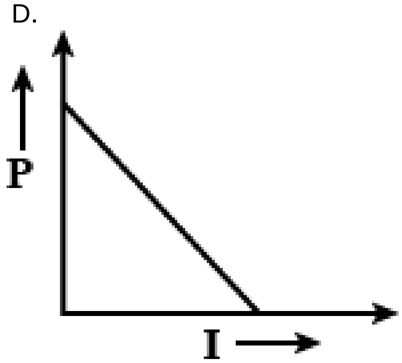
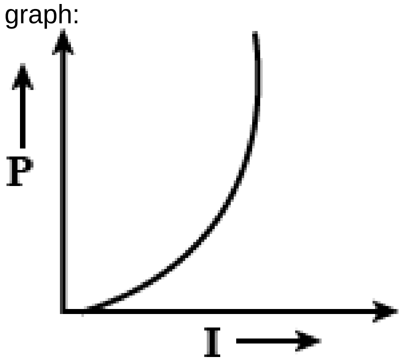


D.



Answer (c)

We know,
The heating power of metallic wire,
$P = I^2 R,\ \ R$ →Resistance of wire
If the current I is gradually increased, the heating power P will increase quadratically, as shown in the following graph:



(iii) A circular coil has radius ' r ', number of turns ' N ' and carries a current ' I '. Magnetic flux density ' B ' at its centre is:

(a) $B = \mu_0\ NI$
(b) $B = \mu_0\ NI/2\ r$
(c) $B = \frac{\mu_0 NI}{4\pi r}$
(d) $B = \mu_0 NI/4\ r$

Answer (b)

Magnetic field due to a circular loop of radius r carrying I current is given by:

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

Magnetic field due to a circular coil of radius r and N number of turns carrying I current is:

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

(iv) If an object is placed at a distance of 10 cm in front of a concave mirror of focal length 20 cm, the image formed will be:

(a) real and 20 cm in front of the mirror.
(b) real and 6.67 cm in front of the mirror.
(c) virtual and 20 cm behind the mirror
(d) virtual and 6.67 cm behind the mirror.

Answer (c)

the mirror formula is given as

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

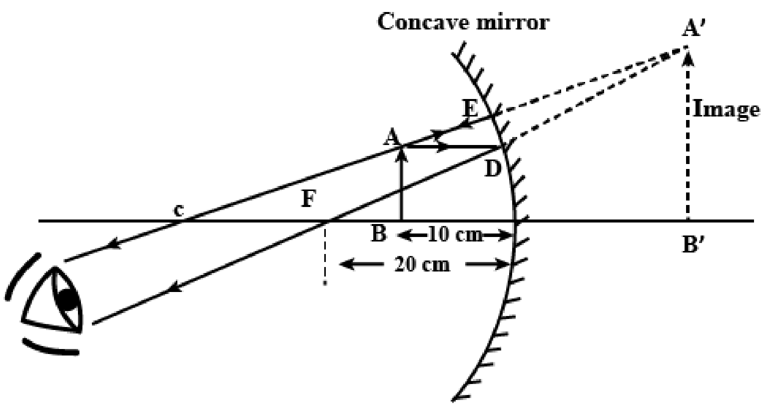
here
f= focal length =-20 cm
v= image distance
object distance, u=-10 cm
so, $\frac{1}{-20} = \frac{1}{v} + \frac{1}{-10}$

$$\frac{1}{v} = \frac{1}{-20} + \frac{1}{10}$$

$$\frac{1}{v} = \frac{-1+2}{20} = \frac{1}{20}$$

$$v = 20\ cm$$

The ray diagram below



(v) What type of wavefronts are associated with a source at infinity?

(a) Cylindrical wavefronts
(b) Plane wavefronts
(c) Spherical wavefronts
(d) All types of wavefronts

Answer (b)

A distant source is so far away that it is considered to be at infinity, the rays traveling from a distant light source are taken as planes moving in the direction of propagation of waves. And hence the wavefront is a plane wavefront.

(vi) Matter waves are:

(a) Waves associated with moving particles.
(b) Waves associated with stationary particles.
(c) Waves associated with any charged particles.
(d) Waves associated with electrons only.

Answer (a)

Matter waves: according to De-Brogile, a wave is associated with each moving particle which is called matter waves. This wave has wavelength,

$$\lambda = \frac{h}{mv} = \frac{h}{momentum}$$

(vii) With an increase in the temperature, electrical conductivity of a semiconductor:

(a) Decreases.
(b) Increases.
(c) Does not change.
(d) First increases and then decreases.

Answer (b)

The electrical conductivity of semiconductors increases with increasing temperature because, with increase in temperature, number of electrons from the valence bond can jump to the conduction band in semiconductors.

B. Answer the following questions briefly.

(i) What is meant by an equipotential surface?

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

(ii) In case of metals, what is the relation between current density (J), electrical conductivity (σ) and electric field intensity (E)?

Answer: Let I current flow through a conductor when applied potential difference V volt. Then, from ohm's law,

$$I = \frac{V}{R}$$

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

Therefore,

$$I = \frac{V}{\rho \frac{L}{A}}$$

$$\Rightarrow \frac{I}{A} = \frac{V}{\rho L}$$

but, $\frac{I}{A} = J, \frac{V}{L} = E$

Hence, $J = \sigma E$

$$\Rightarrow \sigma = \frac{J}{E}$$

(iii) What is meant by "Motional emf"?

Answer: Motional emf is the emf induced in a conducting rod when it moves in a region of magnetic field.

Motional emf is calculated by $\varepsilon = vBl$

where B is the magnetic field and l is the length of the rod and v is the velocity of rod perpendicular to the length of the rod.

Motional emf depends on

1. The magnitude of length of rod and
2. Velocity of rod and
3. Magnetic field.

(iv) What is meant by a microscope in normal use?

Answer: A microscope is a device that allows you to see items that are too small for the naked eye to see.

(v) In a single slit Fraunhofer diffraction experiment, how does the angular width of central maximum change when the slit width is increased?

Answer: In Fraunhofer diffraction, $b\ sin\theta = n\lambda$
where b is the width of slit, λ is the wavelength of light used.
Form central bright fringe, $n = 1$
$\Rightarrow b \sin\theta = \lambda$
Thus angular width of central bright width $= 2\sin\theta = \frac{2\lambda}{b}$
So, angular width of central bright fringe will decrease when the width of slit is increased.

(vi) Name the type of nuclear reaction that takes place in the core of the Sun.

Answer: Nuclear fusion reaction takes place in the Sun. The Sun's tremendous pressure and high temperature fuse hydrogen nuclei to form helium through various steps. Every second, millions of tons of hydrogen is converted into helium in the Sun's centre which releases an enormous amount of energy enough to lit and maintain a star for ages.

(vii) What type of semiconductor is obtained when a crystal of silicon is doped with a trivalent element?

Answer: When trivalent impurity is added to an intrinsic semiconductor, it forms a semiconductor having holes as majority carriers and electrons as minority carriers. So p-type semiconductor is formed.

Question 2.

(i) Calculate equivalent capacitance of the circuit shown in Figure 1 given below:

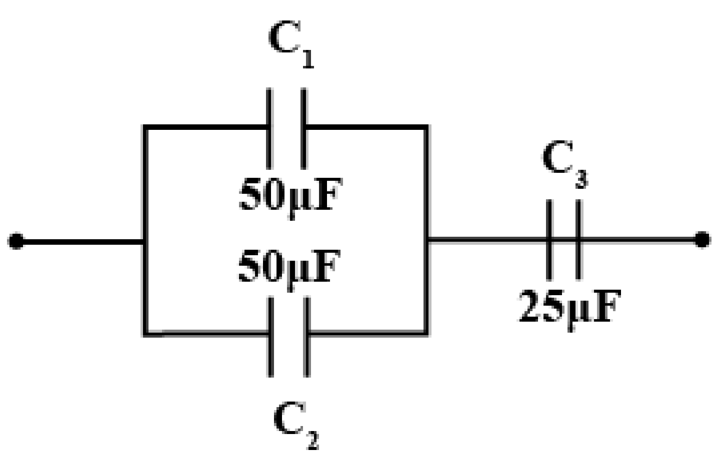


Figure 1

OR

(ii) Calculate electric potential at a point P which is at a distance of 9cm from a point charge of 50 μC.

Answer:

(i) $C_1 \& C_2$ are parallel
Equivalent capacitance of $C_1 \& C_2$ is $C_1 + C_2 = 100\ \mu F = C'(say). C' \& C_3$ are in series.
So, Equivalent capacitance,
$\frac{1}{C} = \frac{1}{C'} + \frac{1}{C_3} = \frac{1}{100} + \frac{1}{25} \Rightarrow C = 20\ \mu F$

OR

(ii) $r = 9cm = 9 \times 10^{-2} m$

$Q = 50\ \mu C = 50 \times 10^{-6} C$

$$V = \frac{kQ}{r} = \frac{9 \times 10^{9} \times 50 \times 10^{-6}}{9 \times 10^{-2}} = 5 \times 10^{6} V$$

Question 3.

(i) Write balancing condition of a Wheatstone bridge.

(ii) Current 'I' flowing through a metallic wire is related to drift speed V_d of free electrons as follows:

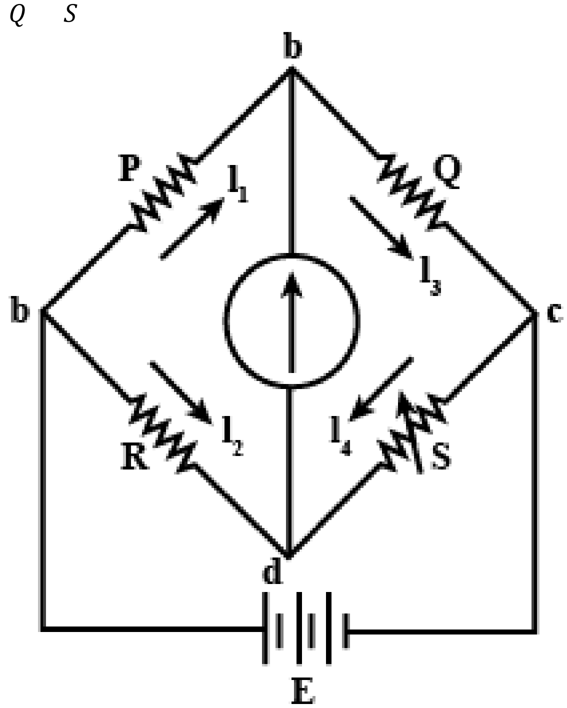
$I = nAeV_d$

State what symbol 'n' stands for.

Answer:

(i) When the Wheatstone bridge is balanced, then the ratio of the resistances of ratio arms are equal.

$$\frac{P}{Q} = \frac{R}{S}$$



Wheatstone Bridge

(ii) The relation between current and drift velocity is,

$I = ne\ Av_d$

where, n is the number of free electrons per unit volime, e is the charge of an electron,

A is the planar area located inside the conductor.

Question 4.

When an electric current is passed through a wire or a coil, a magnetic field is produced. Is the reverse phenomenon possible i.e., can a magnetic field produce an electric current?
Explain with the help of an appropriate example.

Answer:

We have now seen that if electrical current is flowing in a conductor, there is an associated magnetic field created around the wire. In a similar manner, if we move a wire inside a magnetic field there will be an electrical current that will be generated in the wire.

Current is produced in a conductor when it is moved through a magnetic field because the magnetic lines of force are applying a force on the free electrons in the conductor and causing them to move. This process of generating current in a conductor by placing the conductor in a changing magnetic field is called induction. The current is said to be induced in the conductor by the magnetic field.e.g., **AC generators** and **electrical transformers** work on the principle of electromagnetic induction.

Question 5.

(i) A long straight wire AB carries a current of $5A. P$ is a proton travelling with a velocity of $2 \times 10^6\ m/s$, parallel to the wire, $0.2\ m$ from it and in a direction opposite to the current, as shown in Figure 2 below. Calculate the force which magnetic field of the current carrying conductor AB exerts on the proton.

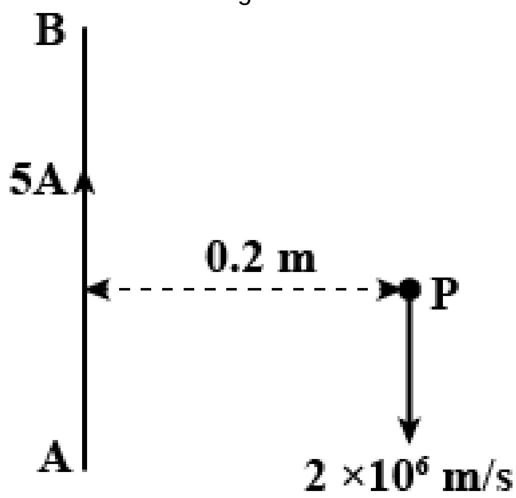


Figure 2

OR

(ii) A moving coil galvanometer of resistance 55Ω produces a full scale deflection for a current of $250\ mA$. How will you convert it into an ammeter having a range of $0 - 3A$?

Answer:

(i) The force on a charged particle moving in a magnetic field is given by the formula:
$F = qvBsin\ \theta$
where F is the force on the particle, q is its charge, v is its velocity, B is the magnetic field strength, and θ is the angle between the velocity and the magnetic field.
In this case, the proton is moving parallel to the wire and in the opposite direction to the current, so its velocity is perpendicular to the magnetic field. The magnetic field strength at a distance of $0.2\ m$ from the wire can be calculated using the formula:
$$B = \frac{\mu_0 I}{2\pi r}$$
where μ_0 is the permeability of free space, I is the current in the wire, and r is the distance from the wire.
Plugging in the values given:
$B = (4\pi \times 10^{-7} T\ m/a\ )\ (5A)/(2\pi \times 0.2\ m) = 1 \times 10^{-5} T$
The charge of a proton is $q = 1.602 \times 10^{-19} C,$ and its velocity is $v = 2 \times 10^6 m/s$. The angle between its velocity and the magnetic field is 90 degrees, so $\sin\theta = 1$. Plugging in the values:
$F = (1.602 \times 10^{-19} C)(2 \times 10^6 m/s)(1 \times 10^{-5} T)(1) = 3.204 \times 10^{-18} N$
The direction of the force can be found using the right-hand rule. If you point your right thumb in the direction of the particle's velocity (to the left in this case), and curl your fingers in the direction of the magnetic field (into the page in this case, since the current is coming out of the page), your palm will face downwards. This means the force on the proton is downwards.

OR

(ii) To convert the galvanometer into an ammeter of range 0 to 3 A, we need to add a shunt resistance in parallel to the galvanometer. The shunt resistance will divert most of the current, allowing only a fraction of the current to flow through the galvanometer, thereby extending its range.

The shunt resistance can be calculated using the formula:
$R_s = \frac{I_g R_g}{I - I_g}$
Where,
Rs = Shunt resistance
$I_{\max}$ = Maximum current range of ammeter (3 A in this case)
I_g= Full-scale deflection current of the galvanometer (250 mA in this case)
Rg= Resistance of the galvanometer (55 Ω in this case)
Substituting the given values, we get:

$$R_s = \frac{0.25 \times 55}{3 - 0.25} = \frac{13.75}{2.75} = 5\Omega$$

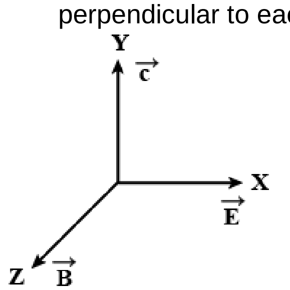
Therefore, we need to add a shunt resistance of 5 Ω in parallel to the galvanometer to convert it into an ammeter of range 0 to 3 A.

Question 6.

(i) State how vectors $\vec{E}, \vec{B}$ and $\vec{C}$ are oriented in an electromagnetic wave
(ii) Name the electromagnetic wave / radiation which is used to study crystal structure.

Answer

(i) According to Fleming's right hand rule, the vector $(\vec{E})$, the magnetic vector $(\vec{B})$, and the velocity $\vec{c}$ are mutually perpendicular to each other



(ii) X-ray is the electromagnetic radiations used for studying the crystal structure of solids.

Question 7.

Name any two phenomenon which takes place in the formation of a rainbow.

Answer

Rainbow formation reasons:
Dispersion of light:
A. A prism splits the ray of light into seven different colors. This splitting of light into many colors is called dispersion of light.
B. This shows us that the sunlight is constituted of several colors.
C. Sometimes in the rainbow, all the seven colors are not visible.

Total internal reflection:
A. It is the kind of phenomenon when a beam of light passing through a denser medium, is incident at the surface of a less dense medium.
B. In this case, the angle of incidence is always greater than the critical angle for both the medium, and the beam of light is reflected totally back into the denser medium.

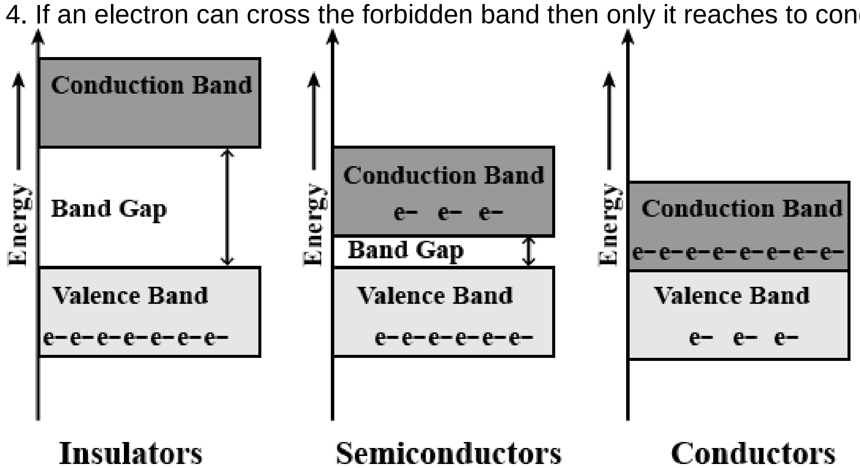
Refraction of light:
A. Refraction of light is constituted by a small change in the speed of light at the interface of two optical different mediums.
B. An example of refraction is: A pencil immersed in a glass of water appears tilted at the interface of water and air.

Question 8.

With reference to semiconductor physics, answer the following questions.
(i) What is meant by "Forbidden band" of energy levels?
(ii) In which material "Forbidden band" is absent?

Answer

(i)
1. The gap between the valence band and the conduction band is referred to as the forbidden gap.
2. The difference in energy levels between the conduction band and valence band is known as the forbidden energy gap.
3. No electron stays in the forbidden band.
4. If an electron can cross the forbidden band then only it reaches to conduction band from the valance band.



5. In the case of an insulator, the forbidden band is at the highest then comes the semiconductor, and at the end comes the conductor.
6. From the above point, we can say that it is easy for an electron of a conductor to jump over the forbidden band than the insulator.
7. The transport of electrons from the valence band to the conduction band is what causes current to flow through the materials.

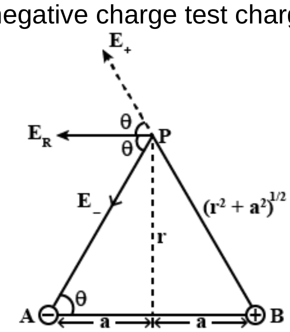
ii)
In a conductor, valence band and conduction band overlap each other as shown in figure. Therefore, there is no forbidden gap in a conductor

Question 9.

Show that intensity of electric field at a point in broadside position of an electric dipole is given by:
$E = \left(\frac{1}{4\,\pi\epsilon_0}\right)\frac{p}{(r^2 + l^2)^{3/2}}$
where the terms have their usual meaning.

Answer

The electric field at a point, P due to an electric dipole.Due to the positive charge, the positive test charge will experience repulsive force whereas due to negative charge test charge will experience the attraction. Hence,



$$|E_+| = \frac{1}{4\,\pi\,\epsilon_0} \frac{q}{r^2 + a^2}$$
$$|E_-| = \frac{1}{4\,\pi\,\epsilon_0} \frac{q}{r^2 + a^2}$$
$$E_R = E_+ cos\,\theta + E_- cos\,\theta$$
$$= \frac{1}{4\,\pi\,\epsilon_0} \frac{2q}{r^2 + a^2} \cdot\ cos\,\theta$$
$$= \frac{1}{4\,\pi\,\epsilon_0} \frac{p}{r^2 + a^2} \cdot \left(\frac{q}{(r^2 + a^2)^{\frac{1}{2}}} \right)$$
$$E_R = \frac{1}{4\,\pi\,\epsilon_0} \frac{2q \times a}{(r^2 + a^2)^{\frac{3}{2}}} = \frac{1}{4\,\pi\,\epsilon_0} \frac{p}{(r^2 + a^2)^{\frac{3}{2}}}$$

Question 10.

(i) Eight identical cells, each of emf 2 V and internal resistance 3 Ω , are connected in series to form a row. Six such rows are connected in parallel to form a battery. This battery is now connected to an external resistor R of resistance 6 Ω. Calculate:

(a) emf of the battery.
(b) internal resistance of the battery.
(c) current flowing through R.

Answer

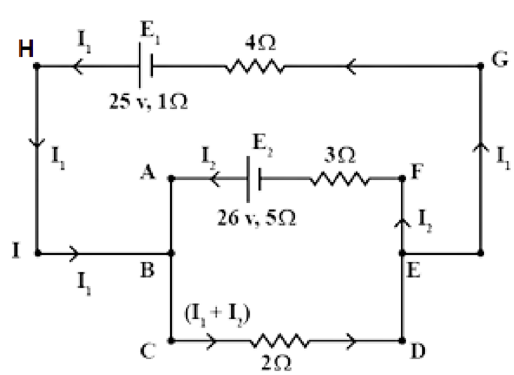
(a) The emf of each cell is 2V, so the emf of the battery consisting of six rows connected in parallel is:
E_battery = $6 \times 2V = 12V$

(b) The internal resistance of a single cell is 32 ohms. When six rows of cells are connected in parallel, the equivalent internal resistance of the battery is:
$$\frac{1}{R_{internal}} = \frac{1}{32} + \frac{1}{32} + \frac{1}{32} + \frac{1}{32} + \frac{1}{32} + \frac{1}{32} = \frac{6}{32}$$
$$R_{internal} = \frac{32}{6} = 5.33\ ohms$$

(c) To calculate the current flowing through R, we need to first calculate the total resistance of the circuit:
$$R_{total} = R + R_{internal}$$
$$R_{total} = 62 + 5.33 = 67.33\ ohms$$
Using Ohm's Law, the current flowing through R is:
$$I = \frac{E}{R_{total}}$$
$$I = \frac{12V}{67.33}\ ohms$$
$$I = 0.178\ A$$
Therefore, the current flowing through R is $0.178\ A$.

OR

(ii) In the circuit shown in Figure 3 below, E_1 and E_2 are batteries having emfs of 25 V and 26 V. They have an internal resistance of $1\ \Omega$ and $5\ \Omega$ respectively. Applying Kirchhoff's laws of electrical networks, calculate the currents I_1 and I_2 .



Answer

Considering loop ABCDEF in the same order and applying Kirchhoff's Voltage law

$$3I_2 + 2(I_1 + I_2) - (26 - 5I_2) = 0$$

$$2I_1 + 10I_2 = 26 \qquad \dots\dots\dots\dots(i)$$

Considering loop HICDGH in the same order and applying Kirchhoff's Voltage Law

$$4I_1 + 2(I_1 + I_2) - (25 - I_1) = 0$$

$$7I_1 + 2I_2 = 25 \qquad \dots\dots\dots(ii)$$

Solving (i) and (ii) we get

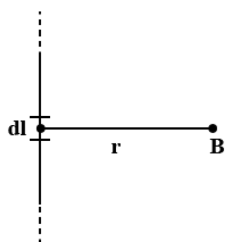
$$I_1 = 3\ A$$

Putting this in eq. (i) we get

$$I_2 = 2A$$

Question 11.

Using Ampere's circuital law, obtain an expression for magnetic flux density 'B' at a point near an infinitely long and straight conductor, carrying a current I.

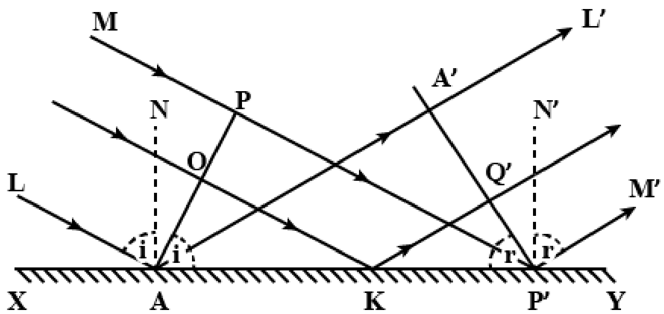


Answer

Let MN be a long straight wire carrying current and P a point at distance 'a'
from wire where magnetic field B has to be found
using Ampere's circuital law, let us consider a circle element dl at P
$\Rightarrow \oint \vec{B}.\vec{dl} = \mu_0 I$
B is constant everywhere on the loop
$\Rightarrow B \oint dl = \mu_0 I$
$\Rightarrow B \times 2\pi a = \mu_0 I$
$\Rightarrow B = \left(\frac{\mu_0}{4\pi}\right) \times \frac{2I}{a}$

Question 12.

Using Huygen's wave theory of light, show that the angle of incidence is equal to the angle of reflection. Draw a neat and labelled diagram.



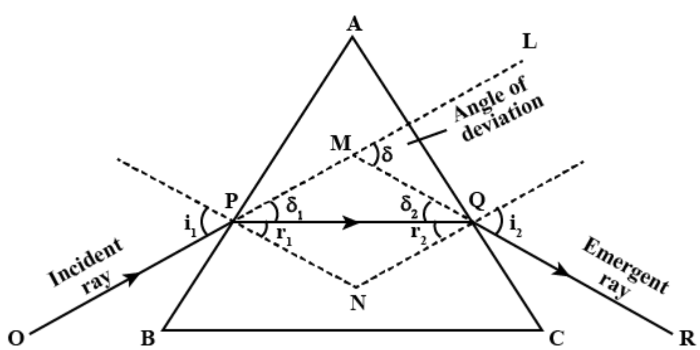
Answer

Consider any point Q on the incident wavelength PA.
When the disturbance from P on incident wavefront reaches point P^\prime, the disturbance from point Q reaches 'Q'
If c is the velocity of light, then the time taken by light to go from point Q to Q ' (via point K) is given by,
$t=\frac{QK}{c}+\frac{KQ'}{c}$ ... (i)
In right-angled $\Delta\ AQK$,
$\angle\ QAK=i$
$\therefore\ QK=AK\ sin\ i$
In right-angled $\Delta KQ'\ P'$
$\angle Q'\ P'K=r$
$\therefore\ \ KQ'=KP'\ sin\ r$
Substituting these values in equation (1),
$t=\frac{AKsin\ i}{c}+\frac{P'sin\ r}{c}$
$t=\frac{AKsin\ i+(AP'-AK)\sin r}{c}(\because\ KP'=AP'-AK)$
$t=\frac{AP'\ sin\ r+AK(sin\ i-sin\ r)}{c}$ ... (ii)
The rays from different points on incident wavefront will take the same time to reach the corresponding points on the reflected wavefront if 't' given by equation (ii) is independent of AK
$\therefore AK(sin\ i-sin\ r)=0$
$sin\ i-sin\ r=0$
$sin\ i=sin\ r$
$i=r$
i.e the angle of incidence is equal to the angle of reflection

Question 13.

(i) For any prism, obtain a relation between angle of the prism (A). angle of minimum deviation (δ_m) and refractive index of its material $(\mu\ or\ n)$.

Answer

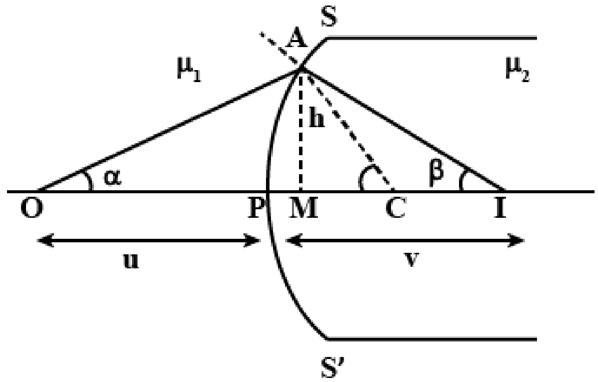


In the given diagram,
OP is the incidence ray, which is making the angle i_1 with normal, and QR is the angle of emergence, which is represented by i_2, A is the prism angle amd μ is the refractive index of the prism.
Now, We know that,
A =Prism angle, δ =Angle of deviation, i_1 = Angle of incidence, i_2 = Angle of emergent.
In the case of minimum deviation, $\angle\ r_1=\angle\ r_2=\angle r$
$A=\angle r_1\ +\angle\ r_2$
$SO, A=\angle\ r+\angle\ r=\angle\ 2r$
$\angle r=\frac{A}{2}$
Now, again
$A+\delta=i_1+i_2$ ($\because$ In the case of minimum deviation
$i_1=i_2=i\ and\ \delta=\delta_m$)

So, $A + \delta_m = i + i = 2i$
Now, $i = \frac{A+\delta_m}{2}$
Now, from snell's mule,
$\mu = \frac{sin\ i}{sin\ r}$
$\mu = \frac{sin\frac{A+\delta_m}{2}}{sin\frac{A}{2}}$

OR

(ii) Obtain an expression for refraction at a single convex spherical surface i.e., the relation between μ_1 (rarer medium), μ_2 (denser medium), object distance u. image distance v and the radius of curvature



Answer

In $\Delta\ COA$
$i = a + \gamma\ \ ...(i)$
$\gamma = r + \beta$
$r = \gamma - \beta$
Using Snell's law, we have
$\frac{sin\ i}{sin\ r} = \frac{\mu_2}{\mu_1}$
$\mu_1 sin\ i = \mu_2\ sin\ r$
Since aperture is small.
So, $\angle\ i$ and $\angle\ r$ will be small
$So,$
$\mu_1\ sin\ i = \mu_2\ sin\ r$
Since apertume is Small So $\angle\ i\ \ a \angle\ r$ will be Small.
$So\ \mu_1 i = \mu_2\ r$
$So\ \mu_1(a+\gamma) = \mu_2(\gamma+\beta)$
$\mu_2\ \beta + \mu_1\alpha = (\mu_2 - \mu_1)\gamma\ \ \ ...(i)$
$So,$
$\alpha = \frac{h}{-u}\ ; \beta\ tan\ \beta = \frac{h}{V}\ ;\ Y = tan\ Y = \frac{h}{R}$
Substituting the above values in eqn (i)
$\mu_2\frac{h}{v} + \mu_1\frac{h}{-u} = (\mu_2 - \mu_1)\frac{h}{R}$
$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2 - \mu_1)}{R}$

Question 14.

(i) What is the essential condition for obtaining a sustained interference?
(ii) In Young's double slit experiment, the distance of the 4th bright fringe from the centre of the interference pattern is 1.5mm. The distance between the slits and the screen is 1.5m and the wavelength of light used is 500nm. Calculate the distance between the two slits.

Answer

(i)

(1) The two sources of light must be coherent. In other words, they should emit continuous light waves of same wavelength or frequency, having either the same phase or a constant phase difference.
(2) The two sources must be very narrow as a broad source is equivalent to a large number of narrow sources lying side by side, which causes general illumination rather than interference pattern.
(3) The two sources should preferably be monochromatic.
(4) The coherent sources must be very close to each other.

(ii) In Young's double-slit experiment, the bright fringes are observed when the path difference between the waves from the two slits is an integer multiple of the wavelength. The distance between two consecutive bright fringes is given by: $d = \frac{\lambda L}{D}$

where λ is the wavelength of the light, L is the distance between the slits and the screen, D is the distance from the central maximum to the nth bright fringe, and d is the distance between the slits.

We are given $\lambda = 500nm, L = 1.5m, D = 1.5mm/1000 = 0.0015m$, and we need to find d.

$d = \lambda L/D = (500nm)(1.5m)/(0.0015m) = 500 \times 10^{-9} \times 1.5 / 0.0015\, m = 0.5\, mm$

Therefore, the distance between the two slits is 0.5mm.

Question 15.

Monochromatic light of wavelength 396nm is incident on the surface of a metal whose work function is 1.125eV. Calculate: (i) the energy of an incident photon in eV. (ii) the maximum kinetic energy of photoelectrons in eV.

Answer

We can use the following formulas to calculate the energy of a photon and the maximum kinetic energy of photoelectrons:
(i) Energy of a photon = Planck's constant × speed of light / wavelength
(ii) Maximum kinetic energy of photoelectrons = Energy of a photon - Work function
Given:
Wavelength of incident light = $396\, nm = 396 \times 10^{-9}\, m$
Work function of the metal = $1.125\, eV$

Energy of a photon = $\frac{(6.6262\times10^{-34} Js)\times(2.998\times10^{8} m/s)}{(396\times10^{-9} m)} = \frac{\frac{4.98\times10^{-19} J}{1.602\times10^{-19}} J}{eV} \approx 3.11 eV$

Therefore, the energy of an incident photon is approximately 3.11 eV

Maximum kinetic energy of photoelectrons = $3.11\, eV - 1.125\, eV = 1.985\, eV$

Therefore, the maximum kinetic energy of photoelectrons is approximately 1.985 eV.

Question 16.

Name any two essential parts of a nuclear reactor. State the function of any one of them.

Answer

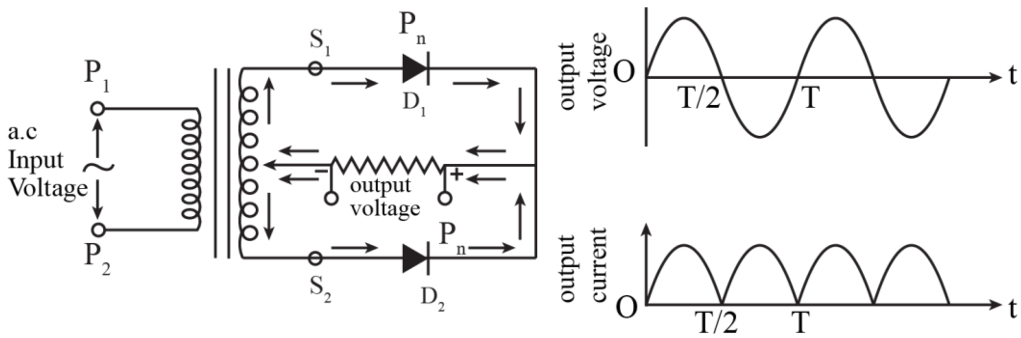
Two essential parts of a nuclear reactor are:

- Fuel: The fuel used in a nuclear reactor is typically enriched uranium or plutonium, in the form of rods or pellets. The fuel is responsible for producing heat through nuclear fission, which is used to generate electricity.
- Control rods: Control rods are made of a material such as cadmium or boron that absorbs neutrons. These rods can be moved in and out of the reactor core to regulate the rate of the nuclear reaction. By absorbing more or fewer neutrons, the control rods can slow down or speed up the reaction, allowing operators to control the amount of heat generated by the reactor.

Question 17.

Draw a labelled circuit diagram of a full wave rectifier. Show graphically how the output voltage varies with time

Answer



Question 18.

(i) A 60Ω resistor, a 1.0 H inductor and 4μF capacitor are connected in series to an ac supply generating an emf e = 300 sin (500t)V. calculate:

A. Impedance of the circuit.
B. Peak value of the current flowing through the circuit.
C. Phase difference between the current and the supply voltage.

Answer

(i)

Impedence $(Z) = \sqrt{R^2 + (X_L - X_C)^2}$, where R is the resistance, XL is the inductive reactance, and XC is the capacitive reactance.

Peak current (I) = $\frac{peak\ voltage\ (V)}{Impedance\ (Z)}$

Phase difference $(\varphi) = \arctan((X_L - X_C)\,/R)$

Given:

Resistance (R) = 602 Ω
Inductance (L) = 1.0 H
Capacitance (C) = 4μF = 4×10^{-6} F
AC voltage (e) = 300 sin(500t) V

a) Impedance of the circuit:

$X_L = 2\pi f L$
$= 2\pi(500\ Hz)(1.0H) = 3141.6\ \Omega$
$X_C = \frac{1}{2\pi fc} = \frac{1}{2\pi(500Hz)(4 \times 10^{-6}F)} = 7957.7\ \Omega$
$= \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{602^2 + (3141.6 - 7957.7)^2} \approx 8458\Omega$

Therefore, the impedance of the circuit is approximately 8458 Ω.

b) Peak value of the current flowing through the circuit: The peak voltage is 300 V, so the peak current is

$I = \frac{V}{Z} = \frac{300V}{8458\Omega} \approx 0.0355\ A$

Therefore, the peak value of the current flowing through the circuit is approximately 0.0355 A.

c) Phase difference between the current and the supply voltage:

$\boldsymbol{\varphi} = \arctan\frac{(X_L - X_C)}{R} = arctan\frac{3141.6 - 7957}{602} \approx 79.5^0$

Therefore, the phase difference between the current and the supply voltage is approximately -79.5°.

OR

ii.

a) An ac generator generates an emf which is given by $e = 311\sin(240\pi t)V$.
Calculate:
1. Frequency of the emf.
2. r.m.s value of the emf.

b) The primary coil of a transformer has 60 turns whereas its secondary coil has 3000 turns.
1. If a 220 V ac voltage is applied to the primary coil, how much emf is induced in the secondary coil?
2. If a current of 5A flows in the primary coil, how much current will flow in a load in the secondary coil? State the assumption you have made regarding the transformer, in this calculation.

Answer

(a) The equation for the emf generated by the ac generator is $e = 311\sin(240\pi t)V$.

1) The frequency of the emf is given by the formula:
$f = \frac{\omega}{2\pi}$
where ω is the angular frequency, which is equal to 240π radians per second.
Therefore, the frequency is:
$f = \frac{240\pi}{2\pi} = 120\ Hz$
So, the frequency of the emf is 120 Hz.

2) The r.m.s. value of the emf is given by the formula:
$E_{rms} = \frac{1}{\sqrt{2}} \times E_m$
where Em is the maximum value of the emf, which is equal to 311 V.
Therefore, the r.m.s. value is:

$E_{rms} = \frac{1}{\sqrt{2}} \times 311V = 220V$
So, the r.m.s. value of the emf is 220 V

(b) Given: The primary coil of a transformer has 60 turns, and the secondary coil has 3000 turns.
1) The transformer equation is:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

where V_p and V_s are the voltages in the primary and secondary coils, respectively, and Np and Ns are the number of turns in the primary and secondary coils, respectively.
If a 220V AC voltage is applied to the primary coil, then the voltage induced in the secondary coil is:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$\frac{220}{V_s} = \frac{60}{3000}\ V_s = 11V$$

Therefore, the emf induced in the secondary coil is 11V.

2) According to the transformer equation, the current in the secondary coil is:

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}$$

where I_p and I_s are the currents in the primary and secondary coils, respectively, and Np and Ns are the number of turns in the primary and secondary coils, respectively.
Assuming an ideal transformer, which means that there is no energy loss in the transformer, we can say that the power in the primary coil is equal to the power in the secondary coil. Thus, we can use the formula:
$I_p V_p = I_s V_s$

where I_p and V_p are the current and voltage in the primary coil, and I_s and V_s are the current and voltage in the secondary coil.
Substituting the values, we get:
$5A \times 220V = I_s \times 11V$
$I_s = 100A$
Therefore, the current flowing in the load in the secondary coil is $100\ A$.

Question 19.

i. (a) Name the series of lines of hydrogen spectrum which lies in the (1) ultraviolet region. (2) visible region.

(c) How much is the angular momentum of an electron when it is orbiting in the second Bohr orbit of a hydrogen atom?

(c) With reference to Nuclear Physics, answer the following questions.
(1) What is meant by "Isotopes"?
(2) Define 1u (where u stands for unified atomic mass unit).

Answer

(i)

(a)
(1) The series of lines of the hydrogen spectrum which lies in the ultraviolet region is the Lyman series.
(2) The series of lines of the hydrogen spectrum which lies in the visible region is the Balmer series.

(b)
The angular momentum of an electron is given as; $\frac{nh}{2\pi}$.
Therefore the angular momentum of an electron revolving in second orbit is $\frac{2h}{2\pi} = \frac{h}{\pi}$

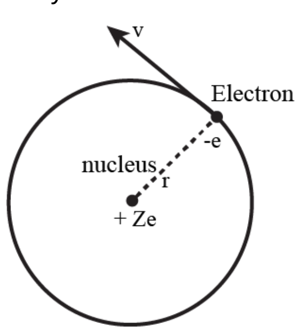
(c)
(1) Isotopes are atoms of the same element that have the same number of protons but different numbers of neutrons in their nucleus. This means that isotopes of an element have the same atomic number (Z) but different mass numbers (A), which is the sum of the number of protons and neutrons in the nucleus. Isotopes of an element have similar chemical properties due to having the same number of electrons, but their physical properties may differ due to differences in their atomic mass.
(2) The unified atomic mass unit (u) is a standard unit of mass used to express the mass of atomic and subatomic particles. One unified atomic mass unit is defined as one-twelfth of the mass of an atom of carbon-12. This means that the mass of one u is approximately equal to the mass of a proton or neutron. The u is often used to express the masses of particles such as atoms, nuclei, and subatomic particles like electrons and quarks.

OR

ii.
a) Using Bohr's theory of hydrogen atom, obtain an expression for the velocity of an electron in nth orbit of an atom.
b) What is meant by Binding Energy per nucleon of a nucleus? State its physical significance.

Answer

(a)
Let e, m and v be respectively the charge , mass and velocity of the electron and r is the radius of the orbit. The positive charge on the nucleus is Ze, where Z is the atomic number (in case of hydrogen atom Z = 1)
As the centripetal force is provided by the electrostatic force of attraction. We have



$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_o}\frac{(Ze)e}{r^2}$$

$$mv^2 = \frac{Ze^2}{4\pi\varepsilon_o r} \quad \text{........(i)}$$

From the first postulate, the angular momentum of the electron us

$$mvr = n\frac{h}{2\pi} \quad \text{........(ii)}$$

Where n(=1, 2, 2, 3, …..) is quantum number. Squaring eq. (ii) and dividing by eq (i) we get

$$r = n^2\frac{h^2\varepsilon_0}{\pi mZe^2}$$

$$Z = 1$$

Since $r = n^2\frac{h^2\varepsilon_0}{\pi me^2}$

(b) The binding energy per nucleon of a nucleus is the amount of energy required to separate the nucleons (protons and neutrons) of a nucleus into individual protons and neutrons, divided by the total number of nucleons in the nucleus. In other words, it is the average amount of energy required to remove one nucleon from the nucleus.

The physical significance of the binding energy per nucleon is that it gives an indication of the stability of a nucleus. Nuclei with high binding energy per nucleon are more stable than those with lower binding energy per nucleon. This is because the binding energy represents the amount of energy that is released when the nucleons come together to form the nucleus. As the number of nucleons increases, the binding energy per nucleon typically increases due to the strong nuclear force that holds the nucleons together.

Question 20.

Read the passage given below and answer the questions that follow.

There are two types of lenses: Converging lenses and Diverging lenses, depending on whether they converge or diverge an incident beam of light. They are also called convex or concave lenses. Lenses are usually made of glass. Convex lenses are more popular as they form a real image of an object. They are widely used in our daily life, for instance, in microscopes, telescopes, projectors, cameras, spectacles etc. Microscopes are used to view small and nearby objects whereas telescopes are used to see distant objects.

i. State any one factor on which focal length of a lens depends.
ii. Give an example where a convex lens behaves like a diverging lens.
iii. What type of lens is used in a camera?
iv. Write an expression for magnifying power of a compound microscope when its final image lies at the least distance of distinct vision (D).
v. State any one difference between a reflecting telescope and a refracting telescope.

Answer

i. One factor on which the focal length of a lens depends is its refractive index. The higher the refractive index, the shorter the focal length for a given curvature of the lens surfaces.

ii. A convex lens can behave like a diverging lens when it is immersed in a medium with a refractive index greater than that of the lens material. This can cause the light rays passing through the lens to bend away from the optical axis, resulting in a virtual image that is smaller than the object.

iii. A camera typically uses a converging lens, such as a double-convex or plano-convex lens, to focus light from the scene onto the image sensor or film. This allows the camera to form a clear and sharp image of the scene being photographed.

iv. The magnifying power (M) of a compound microscope when its final image lies at the least distance of distinct vision (D) is given by the formula: $M = \left(\frac{D}{f_1}\right) \times \left(1 + \frac{d}{f_2}\right)$, where f_1 is the focal length of the objective lens, f_2 is the focal length of the eyepiece lens, and d is the distance between the lenses.

v. One difference between a reflecting telescope and a refracting telescope is the way they use lenses and mirrors to focus light. Refracting telescopes use lenses to bend and focus light, while reflecting telescopes use mirrors to reflect and focus light. This can lead to differences in their designs, performance, and costs. Reflecting telescopes are often used for astronomical observations due to their larger apertures and shorter focal lengths, while refracting telescopes are more commonly used for terrestrial and amateur astronomy applications.