CAREERS 360

PRACTICE Series

RBSE Class 12

Physics

Previous Year Questions with Detailed Solution

RBSE Class 12 Physics Question with Solution - 2024

SECTION-A

1) The electric flux on a Gaussian spherical surface of radius 15 cm , drawn with a point charge as the centre, is ' ϕ '. If the radius of this surface is tripled then the electric flux passing through the surface will be -
A) Zero
B) Infinity
C) 3ϕ
D) ϕ

Solution:

The correct answer is D) ϕ

According to Gauss's law, the electric flux through a closed surface depends only on the charge enclosed, not on the size of the surface. Since the charge enclosed remains the same, the electric flux remains ϕ , regardless of the radius of the surface.

2) The value of dielectric strength for air is -
A) $3 \times 10^6 \mathrm{~V/m}$
B) $3 \times 10^8 \mathrm{~V/m}$
C) Zero
D) Infinity

Solution:

The correct answer is A) $3 \times 10^6 \mathrm{~V/m}$
Dielectric strength for air is approximately $3 \times 10^6 \mathrm{~V/m}$
, which is the maximum electric field that air can withstand without breaking down and becoming conductive.

3) The SI unit of resistivity is -
A) Ω/m
B) Ω
C) Om
D) $\Omega\mathrm{m}^2$

Solution:

The correct answer is A Ω/m

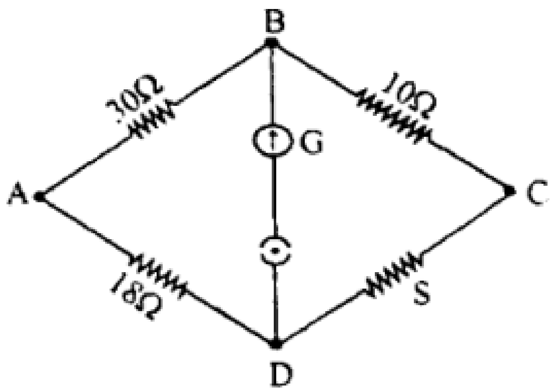
The SI unit of resistivity is ohm-meter $(\Omega\mathrm{m})$, which is derived from the formula:

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

where:
- R is the resistance,
- A is the cross-sectional area,
- L is the length of the material.

Resistivity quantifies the material's opposition to the flow of electric current.

4) In the given figure, if the Wheatstone bridge is in balanced condition, then the value of resistance 'S' will be



A) 12Ω
B) 9Ω
C) 3.0Ω
D) 6Ω

Solution:

In the given Wheatstone bridge configuration, we apply the balanced bridge condition:

$\frac{P}{Q} = \frac{R}{S}$
From the diagram:
- $P = 30\Omega$
- $Q = 18\Omega$
- $R = 10\Omega$

Now, using the balanced bridge formula:

$\frac{30}{18} = \frac{10}{S}$
Solving for S :

$S = \frac{10 \times 18}{30} = 6\Omega$
Thus, the correct answer is D) 6Ω

5) When a charged particle moves in a uniform magnetic field in a direction perpendicular to the field, then the path of the particle will be -
A) Parabolic

B) Circular
C) Straight line
D) Helical

Solution:

The correct answer is B) Circular.

When a charged particle moves in a direction perpendicular to a uniform magnetic field, it experiences a magnetic force that acts as a centripetal force, causing it to move in a circular path.

6) The device is based on the principle of mutual induction is -
A) ac generator
B) galvanometer
C) voltmeter
D) transformer

Solution:

The correct answer is D) transformer.

A transformer works on the principle of mutual induction, where a changing current in one coil induces an electromotive force (EMF) in another nearby coil.

7) The formula for displacement current (I_d) is -
A) $\mu_0 \frac{d\phi_\varepsilon}{dt}$
B) $\mu_0 \in_0 \frac{d\phi_E}{dt}$
C) $\epsilon_0 \frac{d\phi_E}{dt}$
D) $\frac{1}{\epsilon_0} \frac{d\phi_E}{dt}$

Solution:

The correct answer is C) $\epsilon_0 \frac{d\phi_E}{dt}$
The displacement current I_d is given by the formula:

$$I_d = \epsilon_0 \frac{d\phi_E}{dt}$$

where ϵ_0 is the permittivity of free space, and $\frac{d\phi_E}{dt}$ is the rate of change of the electric flux.

8) If the magnification of a optical instrument is negative, then the image will always be formed -
A) Real and inverted
B) Virtual and erect
C) Real and erect
D) Virtual and inverted

Solution:

The correct answer is A) Real and inverted.
If the magnification of an optical instrument is negative, it indicates that the image formed is real and inverted. This typically happens in devices like a convex lens or a concave mirror when the object is placed beyond the focal point.

9) If the magnification of objective and eyepiece in a compound microscope is ' m_0' ' and ' m_e ' respectively, then the total magnifying power (m) of the microscope will be -
A) $m_o + m_e$
B) $m_o - m_0$
C) $m_o \cdot m_e$
D) $\frac{m_o}{m_e}$

Solution:

The correct answer is C) $m_o \cdot m_e$.
In a compound microscope, the total magnifying power m is the product of the magnification of the objective lens m_o and the magnification of the eyepiece m_e. Therefore, the total magnification is given by:

$$m = m_o \cdot m_e$$

10) Natural light from the sun is -
A) polarised
B) unpolarised
C) partially polarised
D) linear polarised

Solution:

The correct answer is B) unpolarised.

Natural light from the sun is unpolarised, meaning that the light waves vibrate in all possible directions perpendicular to the direction of propagation.

11) The maximum kinetic energy of a photo electron emitted from a metal is 1.8 eV . The value of stopping potential (cut-off voltage) will be -
A) 3.6 V
B) 2.0 V
C) 1.8 V
D) 0.9 V

Solution:

The correct answer is C) 1.8 V .

The stopping potential V_s is related to the maximum kinetic energy $K_{\max}$ of the photoelectron by the equation:

$$K_{\max} = e \cdot V_s$$

where e is the charge of an electron (in eV , this value is 1 eV per volt).

Since the maximum kinetic energy is given as 1.8 eV , the stopping potential is:

$$V_s = \frac{K_{\max}}{e} = 1.8 \mathrm{~V}$$

Thus, the stopping potential is 1.8 V .

12) The momentum (p) of photon is -

A) $\frac{h}{\lambda}$

B) $\frac{\lambda}{h}$

C) $\frac{h C}{\lambda}$

D) $h \lambda$

Solution:

The correct answer is A) $\frac{h}{\lambda}$.

The momentum p of a photon is related to its wavelength λ by the equation:

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

where h is Planck's constant and λ is the wavelength of the photon.

13) The value of scattering angle of alpha particle for maximum value of impact parameter is -

A) 90°

B) 60°

C) 45°

D) 0°

Solution:

The correct answer is D) 0°.

The scattering angle of an alpha particle is 0° when the impact parameter is at its maximum value. This is because a larger impact parameter corresponds to the alpha particle passing farther from the nucleus, resulting in no deflection or scattering, and thus the scattering angle is zero.

14) The value of excitation energy required to bring an electron to the first excited state in hydrogen atom is -

A) 13.6 eV

B) 10.2 eV

C) 3.4 eV

D) -3.4 eV

Solution:

The correct answer is B) 10.2 eV .

The excitation energy required to bring an electron from the ground state ($n=1$) to the first excited state $(\mathrm{n}=2)$ in a hydrogen atom is 10.2 eV . This corresponds to the energy difference between the two levels:

$E=13.6 \mathrm{eV}\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$
For $n_1=1$ and $n_2=2$, the energy difference is 10.2 eV .

15) Those atoms which have the same atomic number but different mass number are called -
A) isobars
C) isotopes
B) isotones
D) isomers

Solution:

The correct answer is $\mathbf{B}$) isotopes.

Isotopes are atoms that have the same atomic number (same number of protons) but different mass numbers (different number of neutrons).

16) Example of inorganic semiconductor is -
A) Ge
C) anthracene
B) CdS
D) polyaniline

Solution:

The correct answer is B) CdS.

Cadmium Sulfide (CdS) is an example of an inorganic semiconductor. It is commonly used in optoelectronic devices such as photodetectors and solar cells.

The field lines of a single positive charge are radially

2. Fill in the blanks...

i) The field lines of a single positive charge are radially.......

Solution:

The field lines of a single positive charge are radially **outward.**
Electric field lines emanate outward from a positive charge, indicating the direction a positive test charge would be pushed if placed in the field. These lines radiate away from the charge in all directions.

ii) The magnitude of drift velocity of electron per unit electric field is called -

Solution:

The magnitude of drift velocity of an electron per unit electric field is called **mobility**. Mathematically, mobility μ is given by:

$\mu = \frac{v_d}{E}$

where v_d is the drift velocity, and E is the electric field. Mobility represents how easily electrons move through a conductor when subjected to an electric field.

iii) To convert a galvanometer into a voltmeter a resistance of   value is connected in series to it.

Solution:

To convert a galvanometer into a voltmeter, a resistance of **high** value is connected in series with it.

This high resistance limits the current through the galvanometer, allowing it to measure the potential difference (voltage) across a circuit without significantly altering the current in the circuit. The value of the resistance is chosen based on the desired range of the voltmeter.

iv) The resultant magnetic moment produced per unit volume of a substance is called   .

Solution:

The resultant magnetic moment produced per unit volume of a substance is called magnetization.

Magnetization (M) represents the density of magnetic moments in a material and is measured in amperes per meter (A/m). It quantifies how strongly a material is magnetized in response to an external magnetic field.

v) The mean value of alternating current in a complete cycle is...

Solution:

The mean value of alternating current (AC) in a complete cycle is zero.

This is because alternating current changes direction periodically, so the positive and negative halves of the cycle cancel each other out, resulting in an average value of zero over a full cycle. However, for practical purposes, the root mean square (RMS) value is used to represent the effective value of AC.

vi) The radius of curvature of a concave mirror is 24 cm . The value of its focal length will be   cm .

Solution:

The focal length f of a concave mirror is related to its radius of curvature R by the formula:

$f = \frac{R}{2}$

vii)Given that the radius of curvature $R = 24 \mathrm{~cm}$, the focal length will be:

$f = \frac{24}{2} = 12 \mathrm{~cm}$

So, the focal length of the concave mirror is 12 cm .

viii) The formula for the de Broglie wavelength associated with an electron accelerated by a potential ' V ' is $\lambda =$ nm .

Solution:

The de Broglie wavelength λ associated with an electron accelerated by a potential V is given by the formula:

$$\lambda = \frac{h}{\sqrt{2meV}}$$

where:
- h is Planck's constant,
- m is the mass of the electron,
- e is the charge of the electron,
- V is the accelerating potential.

For practical purposes, this formula can be simplified to:

$$\lambda = \frac{12.27}{\sqrt{V}} \text{ nm}$$

where V is the potential in volts, and λ is in nanometers (nm).

ix) If the radius of first orbit of hydrogen atom is 0.5×10^{-10} m, then the radius of its second orbit will be m .

Solution:

The radius of the n-th orbit in a hydrogen atom is given by the formula:

$$r_n = n^2 \cdot r_1$$

where:
- r_n is the radius of the n-th orbit,
- r_1 is the radius of the first orbit,
- n is the orbit number.

Given that the radius of the first orbit $r_1 = 0.5 \times 10^{-10}$ m, for the second orbit ($n = 2$):

$$r_2 = 2^2 \cdot r_1 = 4 \cdot \left(0.5 \times 10^{-10}\right) = 2 \times 10^{-10} \text{ m}$$

So, the radius of the second orbit is 2×10^{-10} m.

x) .....types of extrinsic semiconductors are found.

Solution:

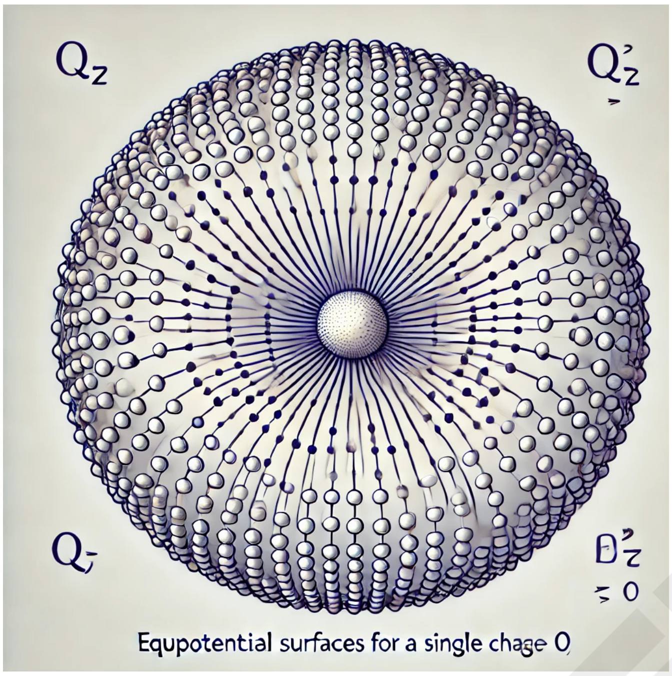
Two types of extrinsic semiconductors are found:
1. n-type semiconductor: Formed by doping a pure semiconductor (such as silicon) with a pentavalent impurity (such as phosphorus), which adds extra electrons as charge carriers.
2. p-type semiconductor: Formed by doping a pure semiconductor with a trivalent impurity (such as boron), which creates holes as charge carriers.

These impurities alter the electrical properties of the semiconductor, making it extrinsic.

3. Give the answer in one line

i) Draw an equipotential surface for a positive charge $(q > 0)$.

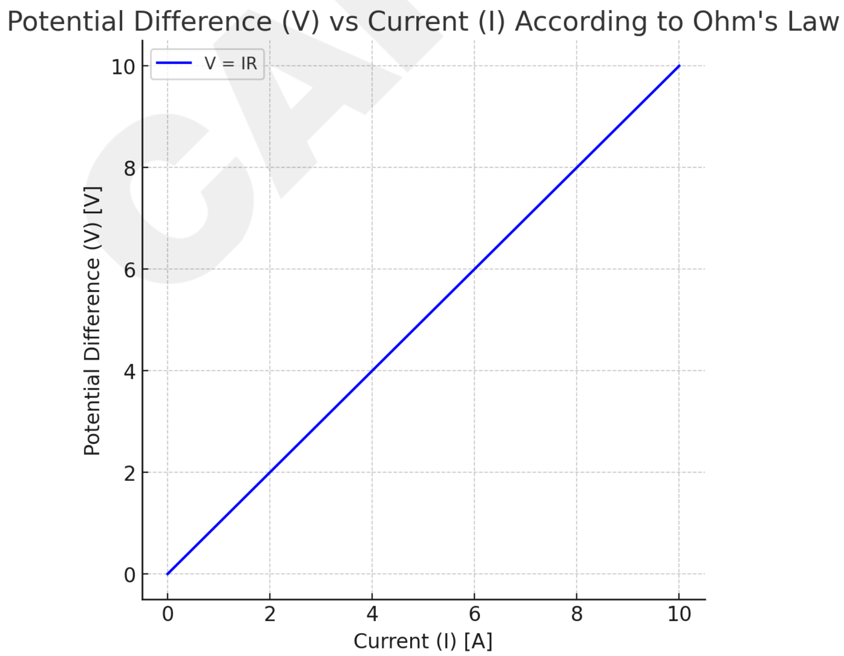
Here is the equipotential surface for a positive charge, represented by concentric spherical surfaces around the charge.



ii) Draw a graph between potential difference (V) and current (I) according to Ohm's law.

Solution:

Here is the graph representing the relationship between potential difference (V) and current (I) according to Ohm's Law. The graph shows a linear relationship, where $V = IR$. [-]



3) What is a paramagnetic substance?

Solution:

A paramagnetic substance is a material that becomes magnetized in the presence of an external magnetic field but loses its magnetism once the field is removed. These substances have unpaired electrons, which align with the magnetic field, causing a weak attraction. However, the magnetic effect is not permanent and disappears when the external field is turned off.

Examples of paramagnetic substances include aluminium, platinum, and oxygen.

4) Why self-inductance is called electrical inertia?

Solution:

Self-inductance is called electrical inertia because it opposes any change in the current flowing through a circuit, similar to how inertia in mechanics resists changes in motion. When the current in a circuit changes, the self-inductance generates an opposing electromotive force (EMF), which tries to maintain the original current. This behaviour is analogous to how inertia resists changes in the velocity of an object. Hence, self-inductance is often referred to as electrical inertia.

5) Define Coherent source.

Solution:

A coherent source refers to two or more light sources that emit waves with a constant phase difference and the same frequency. These sources produce waves that maintain a fixed relationship over time, allowing for constructive and destructive interference patterns to occur. Coherent sources are essential for phenomena like interference and diffraction in optics. An example of coherent sources is two beams of light derived from the same laser.

6) Write the definition of the threshold frequency of a substance.

Solution:

The threshold frequency of a substance is the minimum frequency of incident light required to eject electrons from the surface of the substance in the photoelectric effect. If the frequency of the incoming light is below the threshold frequency, no electrons will be emitted, regardless of the intensity of the light.

7) What is ionization energy?

Solution:

Ionization energy is the amount of energy required to remove an electron from a neutral atom or molecule in its gaseous state, converting it into a positively charged ion. It is typically measured in electron volts (eV) or kilojoules per mole $(\mathrm{kJ} / \mathrm{mol})$. The first ionization energy refers to the energy needed to remove the first electron, while higher ionization energies are needed for subsequent electrons. Ionization energy is a key factor in determining the chemical reactivity of an element.

8) Write Einstein's mass-energy equivalent relation.

Solution:

Einstein's mass-energy equivalence relation is expressed by the famous equation:

$E = mc^2$
Where:
* E is the energy,
* m is the mass,
* c is the speed of light in a vacuum (approximately $3 \times 10^8 \mathrm{~m/s}$).

This equation shows that mass can be converted into energy and vice versa, demonstrating the equivalence between mass and energy.

SECTION-B

4) Three capacitors of capacitance $6 \mu \mathrm{~F}$ are connected in parallel. Calculate the value of their equivalent capacitance.

Solution:

When capacitors are connected in parallel, the equivalent capacitance C_{eq} is the sum of the individual capacitances.

Given that each capacitor has a capacitance of $6 \mu \mathrm{~F}$, and there are three capacitors, the equivalent capacitance is:

$C_{\text{eq}} = C_1 + C_2 + C_3 = 6 \mu \mathrm{~F} + 6 \mu \mathrm{~F} + 6 \mu \mathrm{~F} = 18 \mu \mathrm{~F}$
Thus, the equivalent capacitance is $18 \mu \mathrm{~F}$.

5) Define:
i) Electromotive force and
ii) Internal resistance of a cell

Solution:

i) Electromotive force (EMF):

Electromotive force is the maximum potential difference between the terminals of a cell or battery when no current is flowing. It represents the energy provided by the cell per unit charge to move the charge around the circuit. EMF is measured in volts (V) and is often denoted by $\mathcal{E}$.

ii) Internal resistance of a cell:

Internal resistance is the inherent resistance within a cell or battery that opposes the flow of current. It is caused by the materials inside the cell through which the charge must pass. As current flows, this resistance causes a voltage drop within the cell, reducing the terminal voltage compared to the EMF.

Internal resistance is denoted by r and is measured in ohms (Ω).

6) Write any two properties of magnetic field lines.

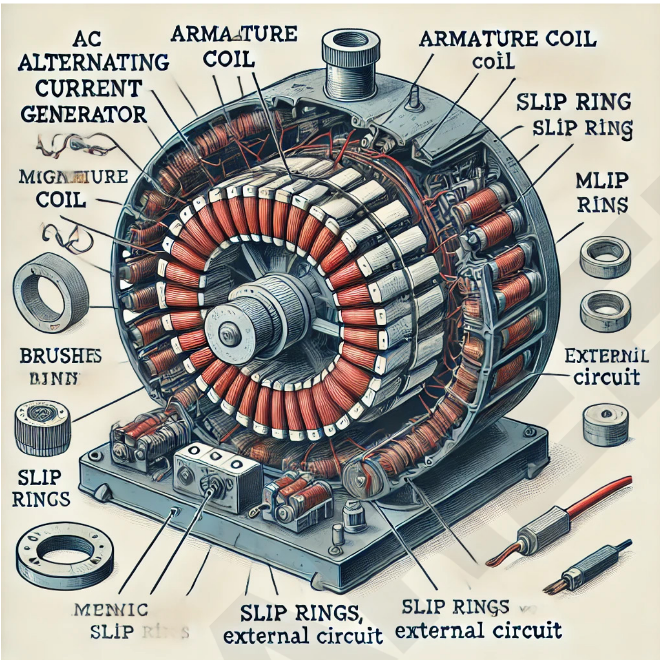
Solution:

Two properties of magnetic field lines are:
1. Magnetic field lines never intersect: If they were to intersect, it would imply that at the point of intersection, the magnetic field has two different directions, which is impossible.
2. Magnetic field lines form closed loops: They originate from the north pole of a magnet and terminate at the south pole outside the magnet, while inside the magnet, they move from the south pole to the north pole, forming continuous closed loops.

7) Draw a clear and labeled diagram of an alternating current generator.

Solution:

Here is the labeled diagram of an alternating current (AC) generator, displaying its key components.



8) A 5 m long straight horizontal conducting wire situated in the east to west direction is falling with a speed of $2 \mathrm{~m/s}$ perpendicular to the horizontal component of the earth magnetic field of $0.3 \times 10^{-1} \mathrm{~T}$. Find the instantaneous value of the emf induced between the ends of the wire.

Solution:

To calculate the induced electromotive force (EMF) in the wire, we use the formula for motional EMF:

$$\mathcal{E} = B \cdot v \cdot L$$

where:
- $B = 0.3 \times 10^{-1} \mathrm{~T}$ (the horizontal component of Earth's magnetic field),
- $v = 2 \mathrm{~m/s}$ (the speed at which the wire is falling),
- $L = 5 \mathrm{~m}$ (the length of the wire).

Substitute the values into the formula:

$$\mathcal{E}=\left(0.3\times 10^{-1}\right)\cdot 2\cdot 5$$
$$\mathcal{E}=0.03\cdot 2\cdot 5=0.3\ \mathrm{V}$$

Thus, the instantaneous value of the induced EMF between the ends of the wire is 0.3 V .

9) Write the names of any three waves (radiations) produced in the electromagnetic spectrum.

Solution:

Three types of waves (radiations) produced in the electromagnetic spectrum are:
1. Radio waves
2. X-rays
3. Infrared waves

10) The magnifying power of a small telescope is 9 and the length of the tube is 100 cm . Find the focal lengths of the objective and eyepiece of the telescope.

Solution:

The magnifying power (M) of a telescope is given by the formula:

$$M=\frac{f_o}{f_e}$$

where:
- f_o is the focal length of the objective lens,
- f_e is the focal length of the eyepiece lens.

Also, the length of the telescope tube (L) is the sum of the focal lengths of the objective and the eyepiece: □

$$L=f_o+f_e$$

Given:
- $M=9$,
- $L=100$ cm.

Now, using the magnifying power equation:

$$M=\frac{f_o}{f_e}=9\Longrightarrow f_o=9f_e$$

Substitute this into the equation for the length of the telescope:

$$L=f_o+f_e=9f_e+f_e=10f_e$$

Now solve for f_e :

$$f_e=\frac{L}{10}=\frac{100}{10}=10\ \mathrm{cm}$$

Now, substitute the value of f_e back into the equation $f_o=9f_e$:

$$f_o=9\times 10=90\ \mathrm{cm}$$

Thus, the focal length of the objective lens is 90 cm , and the focal length of the eyepiece is 10 cm .

11) Derive Snell's law for refraction of light by Huygen's wave theory.

Solution:

Snell's law can be derived using Huygens' principle, which explains how wavefronts propagate through different media. When a light wave passes from one medium to another, it bends, and this bending is described by Snell's law. Let's derive it step by step using Huygens' wave theory.

Step 1: Huygens' Principle
Huygens' principle states that every point on a wavefront acts as a source of secondary spherical wavelets, which spread out in all directions at the speed characteristic of the medium. The new wavefront at any later time is the tangential surface to these secondary wavelets.

Step 2: Setup for Refraction
Consider a wavefront approaching the boundary between two media, with different refractive indices n_1 and n_2 (where $n_1 < n_2$). Assume:
- c_1 is the speed of light in medium 1,
- c_2 is the speed of light in medium 2,
- i is the angle of incidence, and
- r is the angle of refraction.

Let an incident wavefront strike the boundary at an angle i to the normal. The wavefront travels from point A to point B in medium 1 during the time it takes for the wavefront at point A to travel to point C in medium 2.

Step 3: Time Taken for the Wavefront
- The distance traveled by the wavefront in medium 1 during time t is $AB = c_1 t$.
- The distance traveled by the wavefront in medium 2 during the same time t is $AC = c_2 t$.

Step 4: Relationship Between Wavefronts and Angles
From the geometry of the situation, we have:
- $AB = c_1 t = AB \sin i$,
- $AC = c_2 t = AC \sin r$.

Step 5: Ratio of Distances
Now, taking the ratio of the two distances:

$\frac{AB}{AC} = \frac{c_1}{c_2}$
Since $\sin i = \frac{AB}{BC}$ and $\sin r = \frac{AC}{BC}$, we get:

$\frac{\sin i}{\sin r} = \frac{c_1}{c_2}$

Step 6: Refractive Indices and Snell's Law
The speed of light in a medium is related to the refractive index by $c = \frac{c}{n}$. Thus, we can substitute the speed ratio as:

$\frac{c_1}{c_2} = \frac{n_2}{n_1}$
Substituting this into the previous equation, we get:

$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$
Rearranging, we arrive at Snell's law:

$n_1 \sin i = n_2 \sin r$
Conclusion
Using Huygens' wave theory, we derived Snell's law, which describes how light bends when passing between two media of different refractive indices.

12) Define the following:
a) Interference of light
b) Polarisation of light

Solution:

a) Interference of Light:

Interference of light is a phenomenon where two or more light waves superpose to form a resultant wave of greater, lesser, or the same amplitude. This occurs when coherent light waves from two sources meet, producing regions of constructive interference (where the waves amplify each other) and destructive interference (where the waves cancel each other). An example of this is the bright and dark fringes observed in the double-slit experiment.
b) Polarization of Light:

Polarization of light refers to the process by which the oscillations of light waves are restricted to a particular direction. In an unpolarized light wave, the electric field vectors vibrate in multiple directions perpendicular to the direction of wave propagation. Polarized light has its electric field vectors oscillating in a single plane. Polarization can be achieved by passing light through a polarizing filter, reflection, or scattering.

13) A 20 Watt bulb emits 5×10^9 photons per second. Find the energy of each photon.

Solution:

The power emitted by the bulb is 20 Watts, and the number of photons emitted per second is 5×10^9. We need to find the energy of each photon.

Step 1: Use the relation between power and energy
Power is the energy emitted per second:

$P = \frac{E_{\text{total}}}{t}$
Where:
- P is the power (20 W),
- E_{total} is the total energy emitted per second (in joules),
- t is the time in seconds (which is 1 second in this case).

So, the total energy emitted per second is:

$E_{\text{total}} = P \times t = 20 \text{ J}$
Step 2: Calculate the energy of each photon

The total energy is distributed among the photons. If N is the number of photons emitted per second, the energy of each photon E_{photon} is:

$$E_{\text{photon}} = \frac{E_{\text{total}}}{N}$$

Substituting the given values:

$$E_{\text{photon}} = \frac{20}{5 \times 10^9} = 4 \times 10^{-9}\ \mathrm{J}$$

Thus, the energy of each photon is $4 \times 10^{-9}\ \mathrm{J}$.

14) Explain Bohr's second postulate of quantisation by de Broglie hypothesis.

Solution:

Bohr's Second Postulate of Quantization:
Bohr's second postulate states that an electron in an atom revolves around the nucleus in certain stable orbits without radiating energy, and the angular momentum of the electron in these orbits is quantized. The angular momentum L is given by:

$$L = n\frac{h}{2\pi}$$

where:
- n is a positive integer (the quantum number),
- h is Planck's constant.

This postulate implies that only specific, discrete orbits are allowed for the electron, and the electron cannot exist in between these orbits.

Explanation by de Broglie Hypothesis:
The de Broglie hypothesis suggests that particles, including electrons, have a wave nature, and their wavelength λ is related to their momentum p by the equation:

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

For an electron in a circular orbit, the circumference of the orbit must be an integer multiple of the electron's de Broglie wavelength for constructive interference to occur. This means:

$$2\pi r = n\lambda$$

Substituting $\lambda = \frac{h}{p} = \frac{h}{mv}$, where m is the mass and v is the velocity of the electron:

$$2\pi r = n\frac{h}{mv}$$

Rearranging this:

$$mvr = n\frac{h}{2\pi}$$

Thus, we arrive at Bohr's quantization condition:

$$mvr = n\frac{h}{2\pi}$$

This shows that the angular momentum mvr of the electron is quantized, confirming Bohr's second postulate using de Broglie's wave hypothesis. The allowed orbits correspond to those where the electron's wave is in phase with itself, leading to stable, quantized orbits.

15) Define -
a) nuclear fission
b) nuclear fusion

Solution:

a) Nuclear Fission:

Nuclear fission is the process in which a heavy atomic nucleus (such as uranium-235 or plutonium-239) splits into two or more smaller nuclei, along with the release of a large amount of energy. This process is usually accompanied by the emission of neutrons and gamma radiation. Fission is the principle behind nuclear reactors and atomic bombs.
b) Nuclear Fusion:

Nuclear fusion is the process in which two light atomic nuclei (such as isotopes of hydrogen, deuterium, and tritium) combine to form a heavier nucleus, releasing a tremendous amount of energy. Fusion is the process that powers the sun and other stars, and it holds potential for clean and virtually limitless energy if harnessed on Earth.

SECTION-B

16) Derive formula for the electric field due to electric dipole at any point on the equatorial plane. Draw necessary diagram.

Solution:

An electric dipole consists of two equal and opposite charges, $+q$ and $-q$, separated by a small distance $2a$. We aim to derive the formula for the electric field due to a dipole at any point on the equatorial plane, which is the plane perpendicular to the dipole axis and passes through the midpoint of the dipole.

Step-by-Step Derivation:
Step 1: Setup and Coordinates
Consider an electric dipole with charges $+q$ and $-q$ located at a distance a from the origin on the x -axis, forming a dipole along the x -axis.

Let P be a point on the equatorial plane of the dipole, at a distance r from the center of the dipole (midpoint O). The position vector of point P is perpendicular to the dipole axis (along the y -axis).

Step 2: Electric Field Due to the Charges
1. The electric field due to the positive charge $+q$ at point P is directed away from the charge and denoted as $\mathbf{E}_{+}$.
2. The electric field due to the negative charge $-q$ at point P is directed toward the charge and denoted as $\mathbf{E}_{-}$.

Both electric fields have the same magnitude but are in opposite directions along the x-axis due to symmetry. The net electric field will be the vector sum of the fields due to both charges.

Step 3: Magnitude of the Electric Field
The magnitude of the electric field at point P due to each charge is given by Coulomb's law:

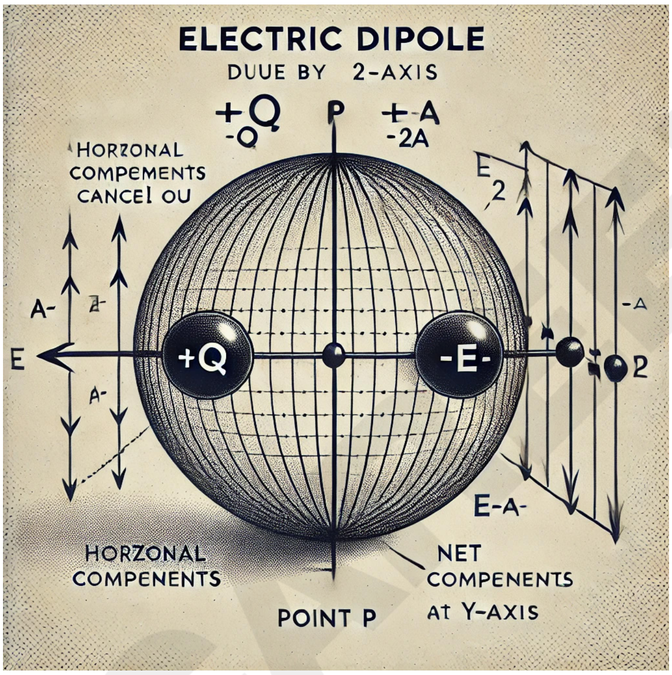
$$E=\frac{1}{4 \pi \varepsilon_0} \cdot \frac{q}{r^2+a^2}$$

where:
- q is the magnitude of each charge,
- r is the perpendicular distance from the center of the dipole to point P,
- a is half the separation between the charges.

Step 4: Vector Components of the Electric Field
The electric fields due to the charges $+q$ and -q can be resolved into horizontal (x-axis) and vertical (y-axis) components. The horizontal components cancel each other out because they are equal in magnitude and opposite in direction.

The vertical components add up, contributing to the net electric field along the negative y-axis.
The vertical component of each electric field is:

$$E \downarrow E \cdot \sin \theta$$



Here is the necessary diagram showing an electric dipole and the electric field components on the equatorial plane. The horizontal components of the electric fields cancel out, while the vertical components add up, giving the net electric field along the y-axis.

17) Derive expression of magnetic field at any point on the axis for a current carrying circular loop by Biot-Savart's law. Draw necessary diagram.

Solution:

To find the magnetic field at a point on the axis of a circular current loop using Biot-Savart's law, follow these steps:

Step 1: Biot-Savart's Law
Biot-Savart's law gives the magnetic field $d\mathbf{B}$ due to a small current element $d\mathbf{l}$ at a point in space:

$$d\mathbf{B} = \frac{\mu_0}{4\pi}\frac{Id\mathbf{l}\times\mathbf{r}}{r^3}$$

where:
- $d\mathbf{l}$ is the length element of the current-carrying wire,
- I is the current,
- $\mathbf{r}$ is the position vector from the current element to the point of observation,
- r is the distance between the current element and the observation point,
- μ_0 is the permeability of free space.

Step 2: Geometry of the Problem

Consider a circular loop of radius R, carrying a current I, centered at the origin. We need to calculate the magnetic field at a point P along the axis of the loop at a distance x from its center.
- Let P be on the axis of the loop, perpendicular to the plane of the loop.
- The magnetic field contributions from each current element $d\mathbf{l}$ will be symmetrically directed, resulting in only the z-components contributing to the net magnetic field, while the components in the plane of the loop will cancel each other out due to symmetry.

Step 3: Magnetic Field Due to a Small Current Element
The small magnetic field element due to a current element on the loop at point P is given by:

$$dB = \frac{\mu_0}{4\pi}\frac{Id\mathbf{l}\sin\theta}{r^2}$$

where:
- θ is the angle between the position vector $\mathbf{r}$ and the axis of the loop,
- r is the distance between the current element and the point P.

From geometry, $r = \sqrt{R^2 + x^2}$, and the angle θ is related to the position on the loop.
Step 4: Resolving the Components of the Magnetic Field

Only the z-component of the magnetic field contributes due to symmetry. The z-component of the magnetic field at point P is:

$$dB_z = dB \cdot \cos\theta$$

From geometry:

$$\cos\theta = \frac{x}{r} = \frac{x}{\sqrt{R^2+x^2}}$$

Substituting this into the expression for dB_z :

$$dB_z = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta\cdot\frac{x}{\sqrt{R^2+x^2}}}{r^2}$$

Since $\sin\theta = \frac{R}{r}$, this becomes:

$$dB_z = \frac{\mu_0}{4\pi}\frac{Id\mathbf{l}Rx}{(R^2+x^2)^{3/2}}$$

Step 5: Total Magnetic Field
To find the total magnetic field at point P, integrate dB_z over the entire loop. Since $d\mathbf{l}$ is the same for

the entire loop, the total magnetic field is:

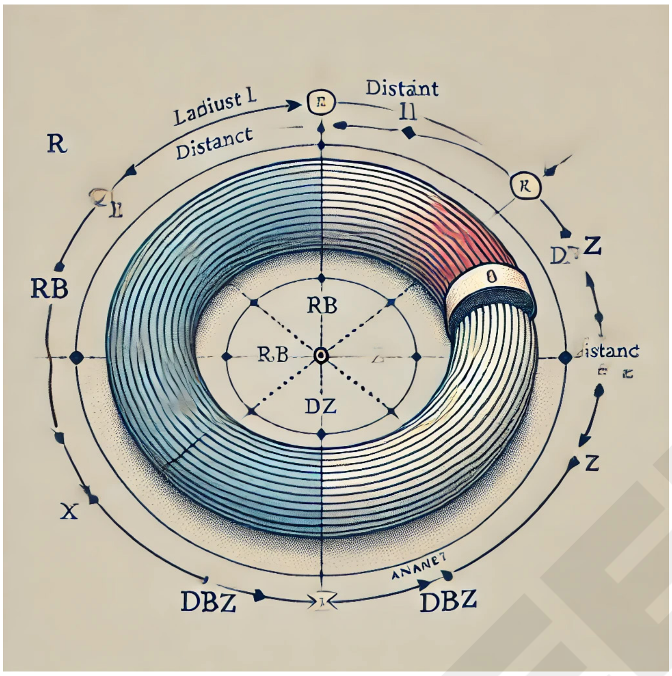
To find the total magnetic field at point P, integrate dB_z over the entire loop. Since $d\mathbf{l}$ is the same for the entire loop, the total magnetic field is:

$$B_z = \frac{\mu_0}{4\pi} \frac{IRx \cdot 2\pi R}{(R^2+x^2)^{3/2}}$$

Simplifying:

$$B_z = \frac{\mu_0 I R^2}{2(R^2+x^2)^{3/2}}$$

This is the expression for the magnetic field at a point on the axis of a current-carrying circular loop.



Here is the diagram illustrating the magnetic field at a point on the axis of a current-carrying circular loop. It shows the relevant components and geometry necessary for deriving the magnetic field using Biot-Savart's law.

18)

a) On the basis of energy band theory, write the difference between conductor, insulator and semiconductor.
b) Draw energy band diagram of n-types semiconductor.

b) Energy Band Diagram of n-type Semiconductor

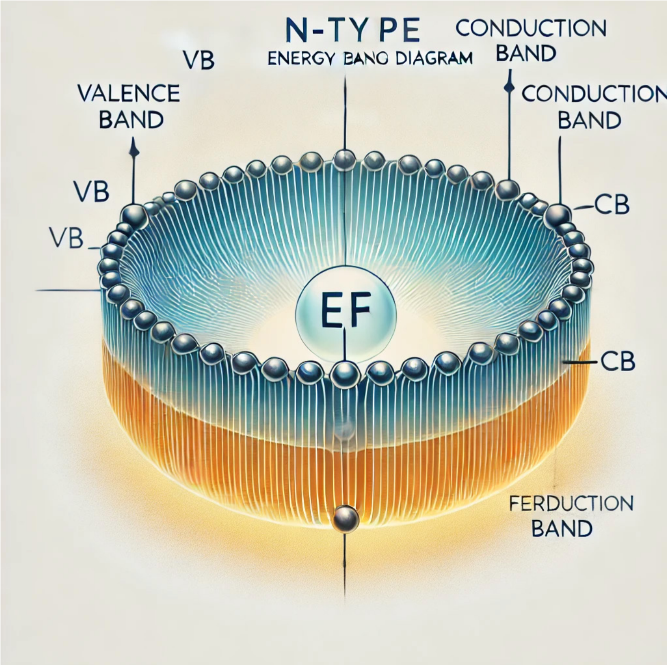
Solution:

Property	Conductor	Insulator	Semiconductor					

Energy Band Structure	Conduction band and valence band overlap or are very close to each other.	Large energy gap between conduction band and valence band.	Small energy gap between conduction band and valence band.
Band Gap	No significant band gap (almost zero or negligible).	Large band gap (typically greater than 5 eV).	Moderate band gap (typically around 1 eV).
Electrical Conductivity	Very high electrical conductivity as electrons can move freely.	Very low electrical conductivity (almost none).	Moderate conductivity; can be increased by doping.
Electron Availability	Electrons are readily available for conduction.	Electrons cannot jump from the valence band to the conduction band at room temperature.	Electrons can jump to the conduction band at moderate temperatures.
Example	Metals like copper (Cu), silver (Ag).	Materials like rubber, glass.	Silicon (Si), Germanium (Ge).

An n-type semiconductor is formed by doping a pure semiconductor with a pentavalent impurity (like phosphorus). This adds extra electrons as majority charge carriers, leading to the following energy band structure:
- Conduction Band (CB): The energy level where the extra electrons (donated by the dopant) reside. These electrons are ready to move to the conduction band, making conduction easier.
- Valence Band (VB): The energy level where the valence electrons reside.
- Fermi Level $\left(E_F\right)$: In an n-type semiconductor, the Fermi level lies closer to the conduction band because of the abundance of electrons.

Now, let's visualize the energy band diagram of an n-type semiconductor.



SECTION-D

19)

a) Prove that the peak value (I_m) of an alternating current is $\sqrt{2}$ times of its root mean square (rms) value.
b) If alternating current $I=4\sin\omega t$ and voltage $V=200\sin\left(\omega t+\frac{\pi}{3}\right)$, then calculate the average power dissipated in the circuit.

Solution:

a) Proving that the peak value I_m of an alternating current is $\sqrt{2}$ times its RMS value:

The relationship between the peak value I_m and the root mean square (RMS) value I_{rms} of an alternating current is given by:

$$I_{rms}=\frac{I_m}{\sqrt{2}}$$

Let's derive this:
1. The instantaneous value of an alternating current can be written as:

$$I(t)=I_m\sin(\omega t)$$

2. The RMS value of the alternating current is the square root of the mean of the squares of the instantaneous current values over a complete cycle:

$$I_{rms}=\sqrt{\frac{1}{T}\int_0^T I^2(t)dt}$$

Where T is the time period of the alternating current.
3. Substitute $I(t)=I_m\sin(\omega t)$:

$$I_{rms}=\sqrt{\frac{1}{T}\int_0^T I_m^2\sin^2(\omega t)dt}$$

4. Since I_m^2 is constant, it comes out of the integral:

$$I_{rms} = I_m \sqrt{\frac{1}{T} \int_0^T \sin^2(\omega t) dt}$$

5. The average value of $\sin^2(\omega t)$ over a complete cycle is $\frac{1}{2}$:

$$\frac{1}{T} \int_0^T \sin^2(\omega t) dt = \frac{1}{2}$$

6. Substituting this back:

$$I_{rms} = I_m \sqrt{\frac{1}{2}} = \frac{I_m}{\sqrt{2}}$$

Thus, the peak value I_m is:

$$I_m = \sqrt{2} \cdot I_{rms}$$

For voltage $V = 200 \sin\left(\omega t + \frac{\pi}{3}\right)$, the peak value is $V_m = 200$, so:

$$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{200}{\sqrt{2}} = 100\sqrt{2} \text{ V}$$

2. Phase difference ϕ :

The phase difference between the voltage and current is $\frac{\pi}{3}$.

3. Average Power:

Substitute the values into the power formula:

$$P_{avg} = V_{rms} \cdot I_{rms} \cdot \cos \phi$$
$$P_{avg} = (100\sqrt{2}) \cdot (2\sqrt{2}) \cdot \cos\left(\frac{\pi}{3}\right)$$
$$P_{avg} = 200 \cdot \frac{1}{2}$$
$$P_{avg} = 100 \text{ W}$$

Thus, the average power dissipated in the circuit is 100 W .

20) Define total internal reflection. Establish relation between u, v and f tor a spnerical mirror. Draw necessary ray diagram.

Solution:

Total Internal Reflection occurs when a light ray traveling from a denser medium to a rarer medium strikes the boundary at an angle greater than the critical angle, causing the light to reflect back entirely into the denser medium rather than refract into the rarer medium. For total internal reflection to occur, two conditions must be met:

1. The light must travel from a medium with a higher refractive index to one with a lower refractive index.
2. The angle of incidence must be greater than the critical angle for the given pair of media.

Relation Between u, v, and f for a Spherical Mirror (Mirror Formula):
To derive the relation between the object distance (u), the image distance (v), and the focal length (f) for a spherical mirror (either concave or convex), we use the mirror formula:

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

Where:
- f is the focal length of the mirror,
- v is the image distance from the mirror,
- u is the object distance from the mirror.

Derivation:
Consider a concave mirror for derivation (the formula is valid for convex mirrors as well with appropriate sign conventions):
1. Let an object be placed at a distance u from the mirror, and its image is formed at a distance v

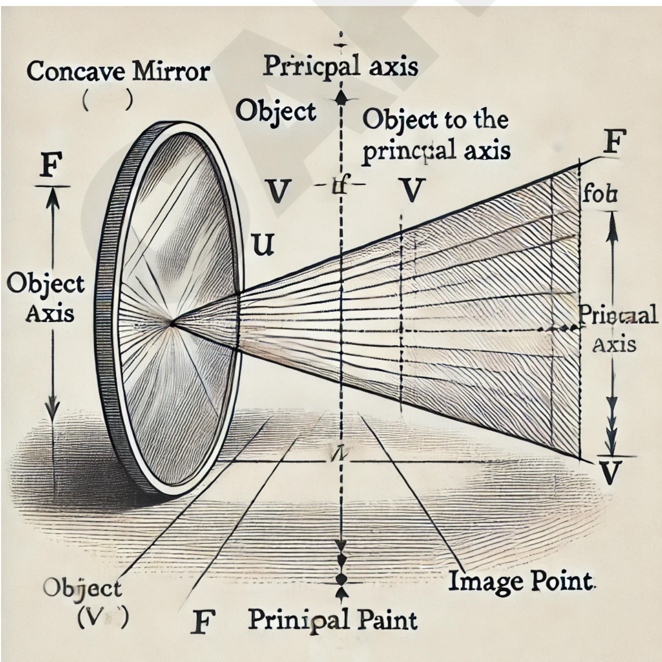
2. The focal length f is related to the curvature of the mirror and the image/object distances.

Using the geometry of reflection and similar triangles, we can derive the relationship:
From the diagram (which we will draw next):
- Using the sign conventions and the principle of similar triangles, we arrive at the mirror formula:

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

Ray Diagram:
The necessary ray diagram for the derivation of the mirror formula shows the path of light rays for a concave mirror. Here, we will consider:
1. A ray parallel to the principal axis reflects through the focal point.
2. A ray passing through the focal point reflects parallel to the principal axis.
3. The intersection of these rays gives the position of the image.

Let's now visualize the ray diagram.



Here is the ray diagram showing a concave mirror, with the object distance (u), image distance (v), and focal length (f) labeled. The diagram also illustrates the path of two rays: one parallel to the principal axis reflecting through the focal point, and another passing through the focal point reflecting parallel to the principal axis.

RBSE Class 12 Physics Question with Solution - 2023

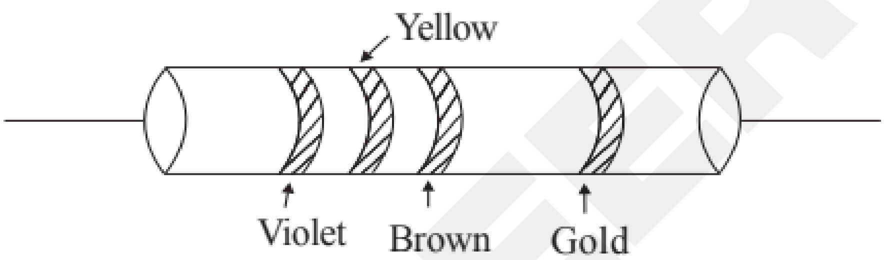
SECTION-A

1) The SI value of permittivity of free space or vacuum is-
A) $9 \times 10^{9} \mathrm{Nm}^{2} \mathrm{C}^{-2}$
B) $9 \times 10^{-9} \mathrm{Nm}^{2} \mathrm{C}^{-2}$
C) $8.854 \times 10^{-12} \mathrm{C}^{2} \mathrm{~N}^{-1} \mathrm{~m}^{-2}$
D) $8.854 \times 10^{+12} \mathrm{C}^{2} \mathrm{~N}^{-1} \mathrm{~m}^{-2}$

Solution:

The SI value of the permittivity of free space (vacuum) is approximately $8.854 \times 10^{-12} \mathrm{C}^{2} \mathrm{~N}^{-1} \mathrm{~m}^{-2}$, so the correct answer is C .

2) Tolerance (\%) for colour coded resistor in the following figure will be:



A) 10%
B) 5%
C) 20%
D) 15%

Solution:

In the given figure, the last band is gold, which corresponds to a tolerance of 5\%.

So, the correct answer is B) 5%.

3) Curie temperature of iron is
A) 1043 K
B) 1143 K
C) 893 K
D) 317 K

Solution:

The Curie temperature of iron is 1043 K , so the correct answer is A) 1043 K .

4) Frequency of electric current of alternating current $I=200 \sin \left(60 \pi t+\frac{\pi}{6}\right)$ will be

A) 120 Hz

B) 60 Hz

C) 90 Hz

D) 30 Hz

Solution:

The given equation for the alternating current is:

$I=200 \sin \left(60 \pi t+\frac{\pi}{6}\right)$

The general form of the equation for alternating current is:

$I=I_0 \sin (2 \pi f t+\phi)$

From the given equation, we can see that the angular frequency $\omega=60 \pi$. The relationship between angular frequency and frequency is:

$\omega=2 \pi f$

So, solving for f :

$$60 \pi=2 \pi f$$
$$f=\frac{60 \pi}{2 \pi}=30 \mathrm{~Hz}$$

Thus, the frequency of the alternating current is 30 Hz , and the correct answer is D) 30 Hz .

5) Communication frequency band range for FM broadcast is-

A) $530-1710 \mathrm{MHz}$

B) $540-890 \mathrm{MHz}$

C) $88-108 \mathrm{MHz}$

D) $54-85 \mathrm{MHz}$

Solution:

The communication frequency band range for FM (Frequency Modulation) broadcast is 88-108 MHz , so the correct answer is C) $88-108 \mathrm{MHz}$.

6) What will be the focal length of a convex lens whose power is +2.5 D ?

A) 50 cm

B) 25 cm

C) 250 cm

D) 40 cm

Solution:

The focal length f of a lens is related to its power P by the formula:

$P=\frac{1}{f}$

where P is in diopters (D) and f is in meters.

Given the power $P=+2.5 \mathrm{D}$, we can calculate the focal length:

$f=\frac{1}{P}=\frac{1}{2.5}=0.4 \mathrm{~m}=40 \mathrm{~cm}$
So, the focal length of the convex lens is $\mathbf{40 ~cm}$, and the correct answer is D) $\mathbf{40 ~cm}$.

7) The path difference equivalent to 4π phase difference is-
A) 8λ
B) 2λ
C) 6λ
D) 4λ

Solution:

The relationship between phase difference $\Delta \phi$ and path difference Δx is given by the formula:

$\Delta \phi=\frac{2 \pi}{\lambda} \Delta x$
Here, the phase difference is 4π. Let's substitute this into the equation:

$4 \pi=\frac{2 \pi}{\lambda} \Delta x$
Now solve for Δx :

$\Delta x=\frac{4 \pi \lambda}{2 \pi}=2 \lambda$
So, the path difference equivalent to a 4π phase difference is 2λ, and the correct answer is B) 2λ.

8) De-Broglie wavelength associated with an electron, accelerated through a potential difference of 100 volt is-
A) 12.27 nm
B) 1.227 nm
C) 0.1227 nm
D) 122.7 nm

Solution:

The de Broglie wavelength λ associated with an electron accelerated through a potential difference V can be calculated using the formula:

$\lambda=\frac{h}{\sqrt{2 m e V}}$

where:
- h is Planck's constant

- m is the mass of the electron $\left(9.109 \times 10^{-31} \mathrm{~kg}\right)$,
- e is the charge of the electron $\left(1.602 \times 10^{-19} \mathrm{C}\right)$,
- V is the accelerating potential (in volts).

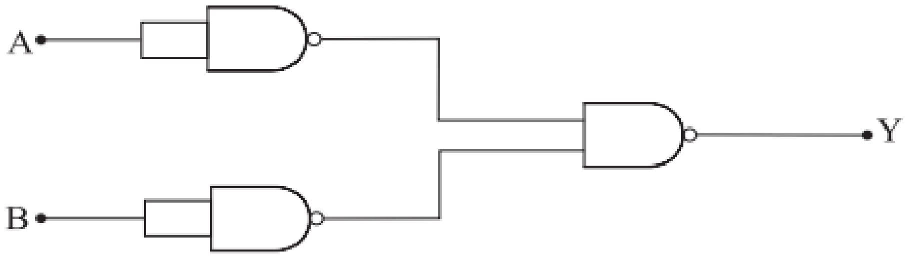
However, a simplified version of the formula for electrons in terms of the potential difference V is:

$\lambda=\frac{12.27}{\sqrt{V}} \mathrm{~nm}$
For $V=100 \mathrm{~V}$:

$\lambda=\frac{12.27}{\sqrt{100}}=\frac{12.27}{10}=1.227 \mathrm{~nm}$

Thus, the de Broglie wavelength is $1.227 \mathrm{nn} \downarrow$. Id the correct answer is B) 1.227 nm .

9) The output (Y) of the logic circuit shown in the figure will be



A) $\mathrm{Y}=\mathrm{A}+\mathrm{B}$
B) $\mathrm{Y}=\overline{\mathrm{A}+\mathrm{B}}$
C) $\mathrm{Y}=\mathrm{A} \cdot \mathrm{B}$
D) $\mathrm{Y}=\overline{\mathrm{A} \cdot \mathrm{B}}$

Solution:

The logic circuit in the image consists of two NOR gates, followed by an AND gate. Here's how the circuit operates:
1. Inputs A and B go into two NOR gates separately:
- A NOR gate outputs the negation of the OR of its inputs. For a single input, it behaves as a NOT gate. So, the output of the first NOR gate (with input A) will be $\bar{A}$, and the output of the second NOR gate (with input B) will be $\bar{B}$.
2. These outputs, $\bar{A}$ and $\bar{B}$, are then fed into an AND gate.
- The AND gate outputs the product of its inputs, so the final output will be $\bar{A} \cdot \bar{B}$, which can be written as $\bar{A} \cdot \bar{B}=\overline{A+B}$ (by De Morgan's law).

Thus, the output Y is:

$Y=\overline{A+B}$

The correct answer is B) $\overline{A+B}$.

2.Fill in the blanks

i) A uniformly charged thin spherical shell has an electric field at all points inside it.

Solution:

For a uniformly charged thin spherical shell, according to Gauss's law, the electric field inside the shell is zero at all points. This happens because the charge is distributed on the outer surface of the shell, and the net flux through any Gaussian surface inside the shell is zero.

So, the electric field inside a uniformly charged spherical shell is zero.

ii) On increasing the temperature, the resistivity of semiconductors is.....

Solution:

On increasing the temperature, the resistivity of semiconductors decreases. This happens because, in semiconductors, higher temperatures provide energy to more electrons, allowing them to jump into the conduction band and contribute to electrical conduction. As a result, the number of charge carriers increases, leading to a decrease in resistivity.

iii) The force between two parallel-carrying conductors is.....

Solution:

The force between two parallel current-carrying conductors is attractive if the currents are in the same direction, and repulsive if the currents are in opposite directions.

iv) Select two paramagnetic material from the following:

Sodium (Na), Bismuth (Bi), Copper (Cu), Aluminum (Al), Lead (Pb)

Solution:

The electromagnetic waves produced by a vacuum tube magnetron are microwaves.

These are used in various applications, including microwave ovens, radar systems, and communication devices.

The two paramagnetic materials from the given list are:
1. Sodium (Na)
2. Aluminum (Al)

v) Write the name of electromagneticwave produced by vacuum tube magnetron.

Solution:

These materials exhibit weak paramagnetism, meaning they are attracted to external magnetic fields due to unpaired electrons in their atomic structure.

The other materials like Bismuth (Bi), Copper (Cu), and Lead (Pb) are either diamagnetic or exhibit very weak magnetic properties.

vi) The radius of curvature of a concave mirror is 28 cm , its focal length will be?

Solution:

The focal length f of a concave mirror is related to the radius of curvature R by the following formula:

$f=\frac{R}{2}$

Given that the radius of curvature R is 28 cm , the focal length f will be:

$f=\frac{28}{2}=14 \mathrm{~cm}$

So, the focal length of the concave mirror is 14 cm .

vii) Write the formula which shows the relation between fresnel distance wavelength of light and size of aperture.

Solution:

The relation between the Fresnel distance Z_f, the wavelength of light λ, and the size of the aperture a is given by the following formula:

$Z_f = \frac{a^2}{\lambda}$
Where: □
- Z_f is the Fresnel distance,
- a is the size (typically diameter) of the aperture,
- λ is the wavelength of light.

This formula helps in determining the distance beyond which the diffraction effects become significant.

viii) Write name of majority charge carriers and minority charge carries in p-type semiconductor.

Solution:

In a p-type semiconductor:
- Majority charge carriers: Holes (positive charge carriers)
- Minority charge carriers: Electrons (negative charge carriers)

In p-type semiconductors, holes are created by the addition of acceptor impurities, which outnumber the thermally generated electrons. Hence, holes dominate as the majority carriers, while electrons are present in smaller quantities as the minority carriers.

SECTION-B

4) Calculate the electric potential at a point due to a charge of $2 \times 10^{-9} \mathrm{C}$ located 9×10^{-4} m away from it.

Solution:

The formula to calculate the electric potential V at a point due to a point charge q located at a distance r is given by:

$V = \frac{kq}{r}$
Where:
- k is Coulomb's constant, $k = 9 \times 10^9 \mathrm{Nm}^2/\mathrm{C}^2$,
- q is the charge,
- r is the distance from the charge to the point where the potential is being calculated.

Given:
- $q = 2 \times 10^{-9} \mathrm{C}$,
- $r = 9 \times 10^{-4}$ m,

Now substitute the values into the formula:

$V=\frac{9\times10^9\times2\times10^{-9}}{9\times10^{-4}}$
Simplify the expression:

$V=\frac{18\times10^0}{9\times^{-4}}=2\times10^4\ \mathrm{V}$
5) Find the expression for electric potential energy of a system of three point charges.

Solution:

The electric potential energy U of a system of three point charges q_1, q_2, and q_3 separated by distances r_{12}, r_{13}, and r_{23} is given by:

$U=\frac{1}{4\pi\varepsilon_0}\left(\frac{q_1q_2}{r_{12}}+\frac{q_1q_3}{r_{13}}+\frac{q_2q_3}{r_{23}}\right)$
Here, ε_0 is the permittivity of free space, and the terms represent the potential energy contributions from each pair of charges.

6) Current in a circuit falls from 5.0 A to 1.0 A in 0.1 s . If an average e.m.f. of 200 V induced. Give an estimate of the self inductance of the circuit.

Solution:

The self-inductance L of a circuit can be estimated using the formula for the induced electromotive force (emf) due to a change in current in a coil:

$\mathrm{emf}=-L\frac{\Delta I}{\Delta t}$
Where:
- $\mathrm{emf}=200\ \mathrm{V}$,
- $\Delta I=I_{\text{final}}-I_{\text{initial}}=1.0\ \mathrm{A}-5.0\ \mathrm{A}=-4.0\ \mathrm{A}$,
- $\Delta t=0.1\ \mathrm{s}$.

Now, solve for L :

$$200=L\left(\frac{-4.0}{0.1}\right)$$
$$200=L\times(-40)$$
$$L=\frac{200}{40}=5\mathrm{H}$$
7) Write statement for electromagnetic induction
i) Faraday's law
ii) Lenz's law

Solution:

Here are the statements for the laws related to electromagnetic induction:
i) Faraday's Law of Electromagnetic Induction: Faraday's law states that the induced electromotive force (emf) in any closed circuit is directly proportional to the rate of change of the magnetic flux through the circuit. Mathematically, it can be expressed as:

$\mathrm{emf}=-\frac{d\Phi_B}{dt}$

where Φ_B is the magnetic flux.
ii) Lenz's Law: Lenz's law states that the direction of the induced emf and the induced current in a circuit is such that it opposes the change in magnetic flux that produced it. This is reflected in the negative sign in Faraday's law and ensures the conservation of energy.
8) Find out value of power factor for following circuit
i) Purely capacitive circuit
ii) Series LCR resonance circuit
Solution:

Here are the values of the power factor for the given circuits:
i) Purely Capacitive Circuit: In a purely capacitive circuit, the voltage and current are 90 degrees out of phase. The power factor pf is given by:

$$\text{Power Factor (pf)} = \cos(\theta) = \cos\left(90^{\circ}\right) = 0$$

So, the power factor for a purely capacitive circuit is 0 .
ii) Series LCR Resonance Circuit: At resonance in a series LCR circuit, the inductive reactance and capacitive reactance cancel each other out, and the circuit behaves like a purely resistive circuit. The phase difference between current and voltage is 0 degrees, so the power factor pf is:

$$\text{Power Factor (pf)} = \cos\left(0^{\circ}\right) = 1$$

So, the power factor for a series LCR circuit at resonance is 1.
9) Describe any three energy losses in transformers. How these can be minimized explain?
Solution:

Three energy losses in transformers are:
1. Copper Loss: Occurs due to the resistance in the windings, causing heat generation. It can be minimized by using thicker wires or materials with lower resistance.
2. Iron Loss (Core Loss): Includes hysteresis and eddy current losses in the core due to alternating magnetic fields. It can be reduced by using high-quality, laminated steel cores with low hysteresis materials.
3. Leakage Flux Loss: Caused by magnetic flux that does not link the primary and secondary windings. It can be minimized by better core design and ensuring tighter coupling between

10) Define the following in photoelectric effect phenomenon
i) work function
ii) stopping potential
Solution:

i) Work Function: The work function (ϕ) is the minimum energy required to eject an electron from the surface of a material when light is incident on it. It is a property of the material and is usually measured in electron volts (eV). Only photons with energy greater than or equal to the work function can release electrons from the material.
ii) Stopping Potential: The stopping potential (V_s) is the minimum negative potential applied to the collector electrode to stop the most energetic photoelectrons from reaching it. It provides a measure of the maximum kinetic energy of the ejected electrons, which is related to the energy of the incident photons.
11) If the work function of caesium metal is 2.14 eV then find its threshold frequency in Hz .
Solution:

The threshold frequency (f_{th}) is related to the work function (ϕ) by the equation:

$\phi = h f_{\text{th}}$
Where:
- ϕ is the work function,
- h is Planck's constant ($h = 6.626 \times 10^{-34} \text{Js}$),
- f_{th} is the threshold frequency.

Given:
- Work function $\phi = 2.14 \text{eV}$,
- Convert work function to joules: $1 \text{eV} = 1.602 \times 10^{-19}$ J,

So, $\phi = 2.14 \times 1.602 \times 10^{-19}$ J $= 3.427 \times 10^{-19}$ J.

Now, using the equation:

$f_{\text{th}} = \frac{\phi}{h} = \frac{3.427 \times 10^{-19}}{6.626 \times 10^{-34}}$ Hz
Calculating:

$f_{\text{th}} = 517 \times 10^{14}$ Hz
12) The total energy of the electron in the ground state of Hydrogen atom is -13.6 eV . Find the kinetic energy and potential energy of electron in this state.

Solution:

For an electron in the ground state of a hydrogen atom, the total energy (E) is related to the kinetic energy (K) and potential energy (U) as follows:
1. Total Energy:

$E = K + U$
For the ground state of hydrogen, $E = -13.6 \text{eV}$.
2. Kinetic Energy: In a hydrogen atom, the kinetic energy of the electron is equal to the negative of the total energy:

$K = -E = 13.6 \text{eV}$

3. Potential Energy: The potential energy is twice the total energy but with a negative sign:

$U = 2E = 2 \times (-13.6) \text{eV} = -27.2 \text{eV}$
Thus:
- Kinetic energy $K = 13.6 \text{eV}$,
- Potential energy $U = -27.2 \text{eV}$.

13)

i) Write two drawbacks of Rutherford's atomic model.
ii) Name the series of the hydrogen spectrum whose lines fall in the visible region.

Solution:

i) Two Drawbacks of Rutherford's Atomic Model:
1. Instability of Electrons: According to classical electromagnetism, a charged particle like an electron moving in a circular orbit should continuously emit radiation, lose energy, and spiral into the nucleus, leading to the collapse of the atom. This instability was not observed in real atoms, but Rutherford's model couldn't explain why.
2. Lack of Explanation for Atomic Spectra: Rutherford's model couldn't explain the discrete spectral lines observed in atomic emission or absorption spectra. It failed to describe why atoms emit light only at specific frequencies, which was later explained by the quantum mechanical model.
ii) Series of the Hydrogen Spectrum in the Visible Region: The Balmer series is the series of spectral lines in the hydrogen spectrum that falls in the visible region.

14) Write the law of radioactive decay. The decay constant of a radioactive substance is 0.693 per minute. Calculate its half-life time in minute.

Solution:

Law of Radioactive Decay:
The law of radioactive decay states that the rate of decay of a radioactive substance at any instant is directly proportional to the number of undecayed nuclei present at that instant. Mathematically, it is expressed as:

$\frac{dN}{dt} = -\lambda N$
Where:
- N is the number of undecayed nuclei,
- λ is the decay constant,
- $\frac{dN}{dt}$ is the rate of decay.

The solution to this equation gives the exponential decay of the substance over time:

$N(t) = N_0 e^{-\lambda t}$

Half-Life Calculation:
The half-life $T_{1/2}$ is related to the decay constant λ by the following formula:

$T_{1/2} = \frac{\ln(2)}{\lambda}$
Given that the decay constant $\lambda = 0.693$ per minute, and $\ln(2) \approx 0.693$, we can calculate the half-life:

$T_{1/2} = \frac{0.693}{0.693} = 1 \text{ minute}$
So, the half-life of the substance is 1 minute.

15) Define the following.
i) nuclear fusion
ii) nuclear fission
iii) mass defect

Solution:

Here are the definitions of the given terms:
i) Nuclear Fusion:

Nuclear fusion is the process in which two light atomic nuclei combine to form a heavier nucleus, releasing a significant amount of energy. This process powers the sun and other stars. For example, in the sun, hydrogen nuclei fuse to form helium, releasing energy.
ii) Nuclear Fission:

Nuclear fission is the process in which a heavy atomic nucleus splits into two or more lighter nuclei, accompanied by the release of a large amount of energy. This process is used in nuclear reactors and atomic bombs. For example, the fission of uranium-235 produces lighter elements, free neutrons, and energy.
iii) Mass Defect:

Mass defect is the difference between the total mass of the individual nucleons (protons and neutrons) in an atomic nucleus and the actual mass of the nucleus. This "missing" mass is converted into binding energy, which holds the nucleus together, according to Einstein's equation $E = mc^2$.

SECTION-C

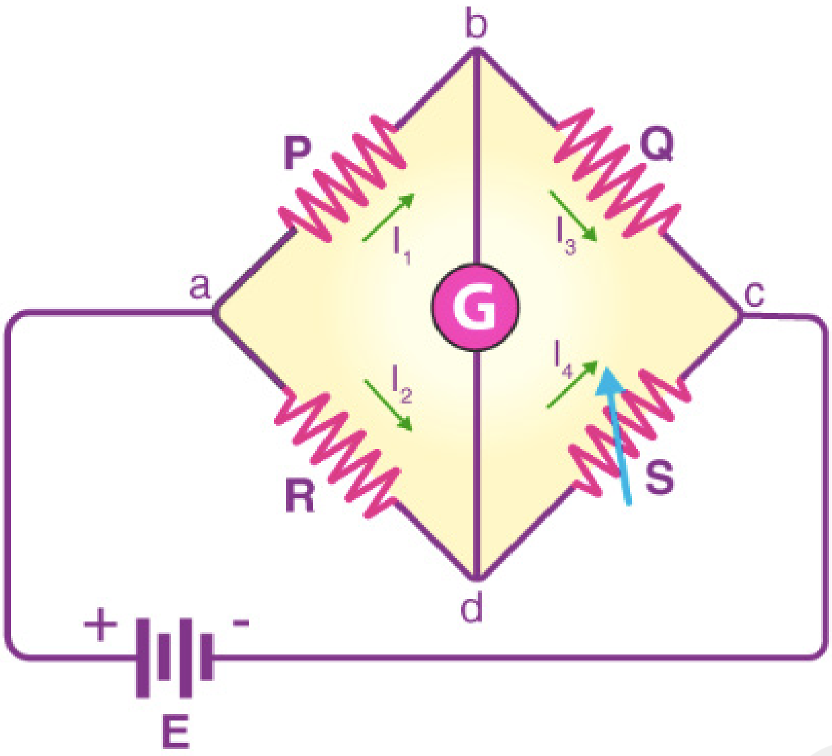
16) Drawing a labelled circuit diagram of Wheatstone bridge, derive condition for zero deflection in the bridge.

Solution:

Wheatstone Bridge:
The Wheatstone bridge is an electrical circuit used to measure an unknown resistance by balancing two legs of a bridge circuit. It consists of four resistors, a galvanometer, and a battery or power source.

Labelled Circuit Diagram of Wheatstone Bridge:
Below is a description of the labelled components:
1. R1 and R2: Two known resistances in one leg of the bridge.
2. R3 and Rx : In the other leg, $R3$ is a known resistance, and Rx is the unknown resistance to be measured.
3. G: A galvanometer connected between points B and D to measure the current.
4. Battery: A source of voltage is connected between points A and C.

Wheatstone Bridge Circuit Diagram:



Derivation of Condition for Zero Deflection:

The diagram you provided shows a Wheatstone bridge, a well-known electrical circuit used to measure an unknown resistance. To derive the condition for zero deflection (null point) in the galvanometer, let's follow the standard approach for Wheatstone Bridge.

Wheatstone Bridge Circuit Explanation:
The circuit has four resistors arranged in a diamond shape:
- Resistor P between points a and b,
- Resistor Q between points b and c,
- Resistor R between points a and d,
- Resistor S between points d and c,
- A galvanometer G connected between points b and d,
- A battery connected between points a and c to provide potential difference E.

Currents in the Circuit:
- Let the current entering the circuit from the battery be I.
- The current is split between the two branches:
- Current I_1 flows through P from a^{tn} b,
- Current I_2 flows through R from a to d.

- At point b, the current splits again:
- I_3 flows through Q from b to c,
- I_4 flows through S from d to c.

For zero deflection in the galvanometer, the potential difference between points b and d must be zero, meaning there is no current through the galvanometer.

Derivation of the Condition for Zero Deflection:
1. Apply Kirchhoff's Voltage Law (KVL): For the branch containing resistors P and Q :

$I_1P = I_3Q$
For the branch containing resistors R and S :

$I_2R = I_4S$

2. Conservation of Current at Nodes: At node a, the current splits, so:

$I = I_1 + I_2$
At node c, the currents recombine:

$I = I_3 + I_4$

3. Condition for Zero Deflection: For the potential difference between b and d to be zero, the ratio of resistances in one branch must equal the ratio of resistances in the other branch. This gives the condition for balance (zero deflection):

$\frac{P}{Q} = \frac{R}{S}$
Conclusion:
The condition for zero deflection in the Wheatstone bridge is:

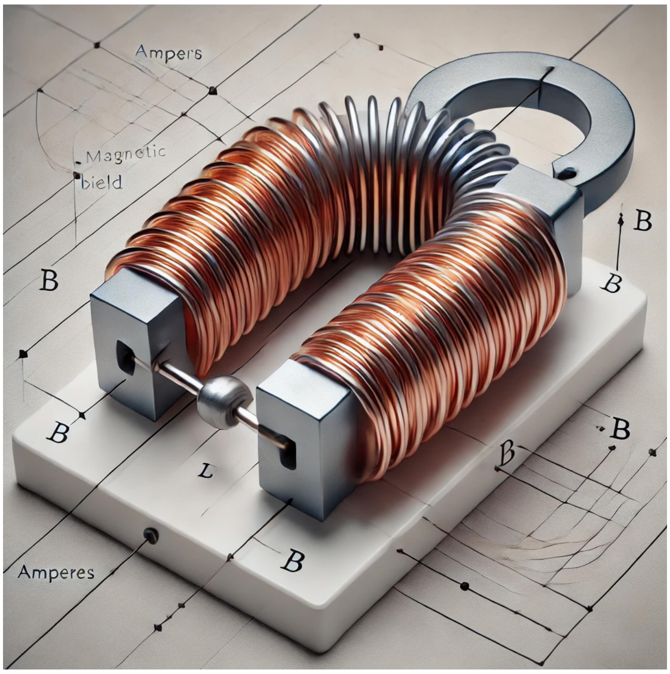
$\frac{P}{Q} = \frac{R}{S}$
When this condition is met, the bridge is said to be balanced, and no current flows through the galvanometer. This relationship is crucial for determining unknown resistances in the bridge circuit.

17) Obtain an expression for magnetic field on the axis of current carrying very long solenoid by Ampere's circuital law. Draw necessary diagram.

Solution:

Diagram:
Below is a simple description of a solenoid and the necessary Ampere's loop:
- A long solenoid consists of several closely wound turns of wire, carrying a current I.
- The magnetic field inside the solenoid is directed along its axis and is uniform for a long solenoid.
- The Ampere's loop is chosen as a rectangle that encloses a portion of the solenoid's length.

Diagram:



Steps to Derive the Magnetic Field Expression Using Ampere's Circuital Law:
1. Ampere's Circuital Law: Ampere's Circuital Law states that:

$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enc}}$
Where:
- $\vec{B}$ is the magnetic field,
- $d\vec{l}$ is the infinitesimal length element,
- μ_0 is the permeability of free space,
- I_{enc} is the current enclosed by the loop.
2. Choose an Ampere's Loop: We take a rectangular loop inside the solenoid along its axis to apply Ampere's law. The loop runs:
- Parallel to the solenoid axis inside the solenoid (length l).
- Partially outside the solenoid, where the magnetic field is nearly zero (because a long solenoid produces a negligible field outside).
3. Apply Ampere's Law: For the chosen loop:
- Inside the solenoid: The magnetic $f' \downarrow -y$ is uniform and directed along the axis.
- Outside the solenoid: The magnetic field is negligible.

So, the integral inside the solenoid simplifies to:

$\oint \vec{B} \cdot d\vec{l} = B \cdot l$
Where l is the length of the loop inside the solenoid.
4. Current Enclosed by the Loop: If n is the number of turns per unit length of the solenoid, then the total current enclosed by the loop is the current through each turn multiplied by the number of turns enclosed by the loop:

$I_{\text{enc}} = n \cdot I \cdot l$
Where I is the current through each turn of the solenoid.
5. Substitute into Ampere's Law: Using Ampere's Law, we get:

$B \cdot l = \mu_0 \cdot (n \cdot I \cdot l)$

6. Solve for the Magnetic Field: Simplifying the above equation, the magnetic field inside the solenoid is:

$B = \mu_0 n I$

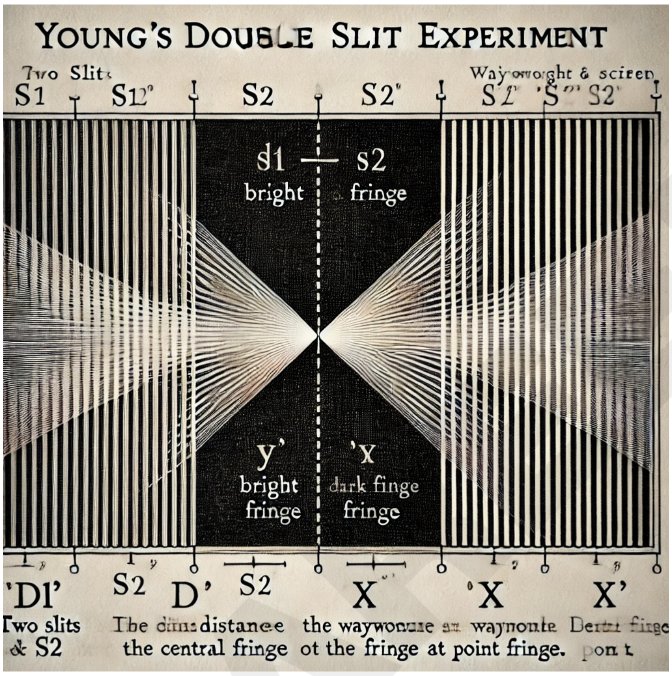
18) To produce interference fringe pattern, draw a necessary diagram of young's double slit experiment. Derive an expression of fringe width for bright fringes.

Solution:

Young's Double Slit Experiment

In Young's double slit experiment, light passing through two closely spaced slits produces an interference pattern of bright and dark fringes on a screen.

Diagram:



here

d : The distance between the two slits S_1 and S_2.
D : The distance between the slits and the screen where the interference pattern is observed.
λ : The wavelength of the light used in the experiment.
x : The distance from the central bright fringe (O) to a particular bright or dark fringe in the interference pattern.

Derivation of Fringe Width:
1. Path Difference: The condition for constructive interference (bright fringe) is that the path difference between the two waves from slits S_1 and S_2 should be an integral multiple of the wavelength λ. For the n-th bright fringe:

Δ path $= n\lambda$

For small angles θ, where θ is the angle between the central fringe and the nth bright fringe:

$\Delta \text{path} = d \sin \theta$

Equating the two expressions for the path difference:

$d \sin \theta = n\lambda$

2. Small Angle Approximation: For small angles, $\sin \theta \approx \tan \theta$, and $\tan \theta = \frac{x_n}{D}$, where x_n is the distance of the n-th bright fringe from the central bright fringe and D is the distance between the slits and the screen. Thus, we can write:

$d \frac{x_n}{D} = n\lambda$

Solving for x_n :

$x_n = \frac{n\lambda D}{d}$

This is the position of the n-th bright fringe.

3. Fringe Width: The fringe width β is the distance between two successive bright fringes. The fringe width is the distance between the $(n+1)$-th and n-th bright fringes:

$\beta = x_{n+1} - x_n = \frac{(n+1)\lambda D}{d} - \frac{n\lambda D}{d}$

Simplifying:

$\beta = \frac{\lambda D}{d}$

Final Expression for Fringe Width:

The fringe width β for bright fringes in Young's double slit experiment is:

$\beta = \frac{\lambda D}{d}$

Where:

- λ is the wavelength of the light,
- D is the distance between the slits and the screen,
- d is the distance between the two slits. $\downarrow$

SECTION-D

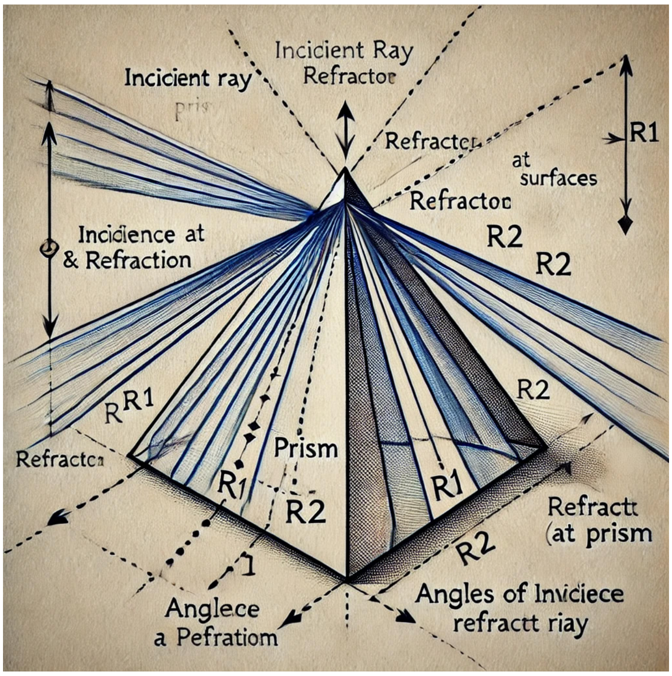
19) Draw a ray diagram of light passing throught a triangular glass prism. If prism angle is A then deduce the relation $\mu = \frac{\sin\left(\frac{\mathrm{A}+\delta m}{2}\right)}{\sin\left(\frac{\mathrm{A}}{2}\right)}$ (where $\mu =$ refractive index of substance of prism and $\delta \mathrm{m} =$ minimum deviation)

Solution:

Ray Diagram of Light Passing Through a Triangular Glass Prism:

In a triangular prism, light is refracted as it enters and exits the prism, resulting in a deviation from its original path.

Here is the labelled ray diagram:



Labelled Points:
- A: Prism angle.
- $\mathbf{r}_1, \mathbf{r}_2$: Angles of refraction inside the prism.
- $\mathbf{i}_1, \mathbf{i}_2$: Angles of incidence and emergence.
- δ : Deviation angle of the light ray.
- D: Path of light showing incident, refracted, and emerging rays.

To Derive the Relation for Minimum Deviation:

Step 1: Refraction at the First Surface of the Prism
When light enters the prism at an angle i_1, it is refracted inside the prism at an angle r_1, according to Snell's Law:

$$n = \frac{\sin(i_1)}{\sin(r_1)}$$

Step 2: Refraction at the Second Surface of the Prism
At the second surface, light emerges from the prism at an angle i_2 and has an internal angle of refraction r_2. Again, by Snell's law:

$$n = \frac{\sin(i_2)}{\sin(r_2)}$$

Step 3: Geometry of the Prism
The sum of the internal angles inside the prism is related to the prism angle A. From the triangle formed by the internal angles, we have the relation:

$$r_1 + r_2 = A$$

Step 4: Minimum Deviation Condition
The total deviation δ of the light ray is the angle between the direction of the incident and emergent rays. The deviation δ is given by:

$\delta = (i_1 - r_1) + (i_2 - r_2)$
At the condition of minimum deviation, $i_1 = i_2 = i$ and $r_1 = r_2$. This simplifies the equation to:

$\delta_m = 2i - A$
Thus:

$i = \frac{A+\delta_m}{2}$

Step 5: Deriving the Refractive Index Expression
Using Snell's law at the first surface for minimum deviation, we substitute the values:

$n = \frac{\sin(i)}{\sin(r)}$
Since $i = \frac{A+\delta_m}{2}$ and $r = \frac{A}{2}$, the refractive index of the prism material n becomes:

$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$
Final Expression:

$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$
Where: ☐
- A is the angle of the prism,
- δ_m is the minimum deviation,
- μ is the refractive index of the prism material.

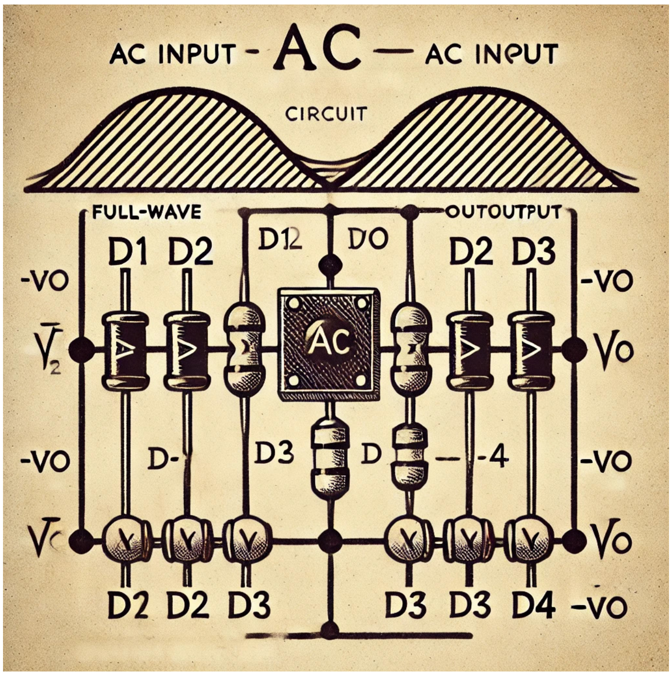
20) What is rectification? Draw the circuit diagram of full wave rectifier and explain its working. Show the input ac voltage and output voltage waveforms from the rectifier circuit.

Solution:

Rectification:
Rectification is the process of converting an alternating current (AC) into a unidirectional (DC) current. This is typically done using diodes, which allow current to pass only in one direction. The most common types of rectifiers are half-wave rectifiers and full-wave rectifiers. A full-wave rectifier uses both the positive and negative halves of the AC waveform to produce a more consistent DC output.

Full-Wave Rectifier Circuit Diagram:
A full-wave rectifier can be built using either a center-tap transformer or a bridge rectifier configuration. Here, we will describe the bridge rectifier setup, which uses four diodes to rectify both halves of the AC waveform.

Circuit Diagram of Full-Wave Rectifier (Bridge Rectifier):



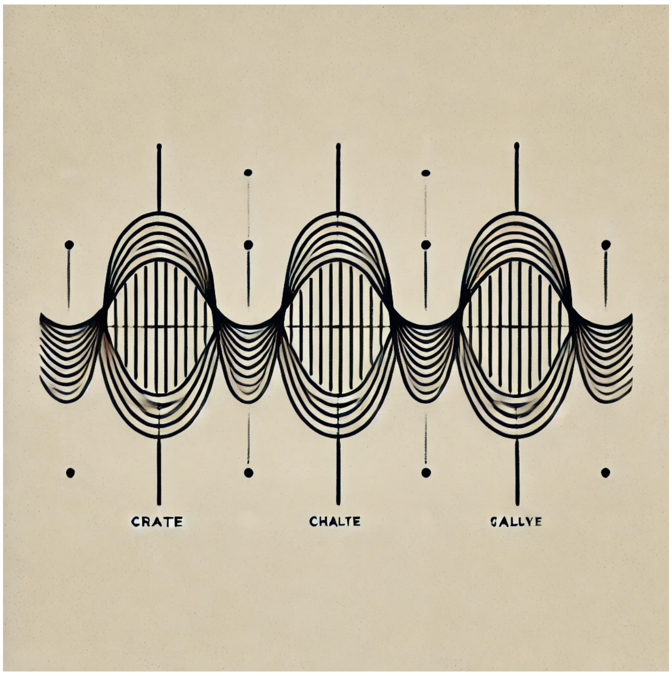
Components:
- D1, D2, D3, D4: Diodes arranged in a bridge configuration.
- AC Input: Alternating current supply.
- Load Resistor: The output DC voltage is measured across this resistor.

Working of Full-Wave Bridge Rectifier:
1. Positive Half-Cycle: During the positive half of the AC input, diodes D1 and D2 become forward-biased, allowing current to flow through the load resistor in the same direction (from top to bottom). At the same time, diodes D3 and D4 are reverse-biased, preventing current flow.
- Current flows from the positive terminal of the AC source, through D1, then through the load resistor, and finally through D2 to the negative terminal of the AC source.
2. Negative Half-Cycle: During the negative half of the AC input, diodes D3 and D4 become forward-biased, allowing current to flow through the load resistor in the same direction as in the positive half-cycle. Diodes D1 and D2 are reverse-biased during this cycle.
- Current flows from the negative terminal of the AC source, through D3, then through the load resistor, and finally through D4 to the positive terminal of the AC source.

This ensures that the current through the load resistor is always in the same direction, resulting in a unidirectional (DC) output.

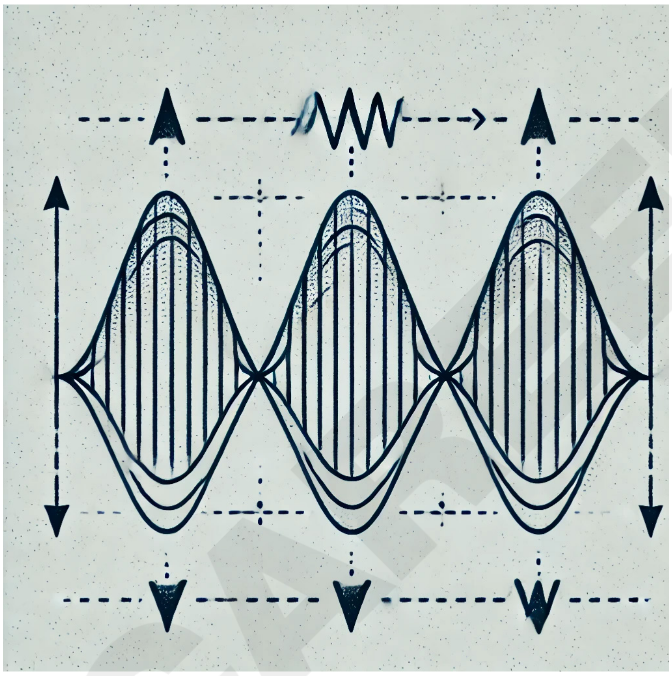
Input AC Voltage and Output Voltage Waveforms:

Input AC Voltage:



(Time →)

Output DC Voltage (after rectification):



(Time →)

Key Points:
- Input AC Voltage: Alternating current waveform with both positive and negative halves.
- Output DC Voltage: Pulsating DC voltage with all positive cycles, where the negative part of the AC waveform is inverted to the positive side.

Advantages of Full-Wave Rectifier:
- Utilizes both halves of the AC waveform, providing a more efficient conversion to DC.
- Higher average output voltage and current compared to a half-wave rectifier.

RBSE Class 12 Physics Question with Solution - 2022

SECTION-A

1) The SI unit of electric flux is -
(A) $\mathrm{NC}^{-1}\,\mathrm{m}^{2}$
(B) $\mathrm{NC}^{-1}\,\mathrm{m}^{-2}$
(C) $\mathrm{N}^{-1}\mathrm{C}^{-1}\,\mathrm{m}^{-2}$
(D) $\mathrm{N}^{-1}\mathrm{C}^{1}\,\mathrm{m}^{2}$

Solution:

The SI unit of electric flux is:
(A) $\mathrm{NC}^{-1}\,\mathrm{m}^{2}$

Explanation: Electric flux is given by the formula $\Phi_E = \mathbf{E} \cdot A$, where $\mathbf{E}$ is the electric field (with SI units of NC^{-1}) and A is the area (with SI units of m^2). Therefore, the SI unit of electric flux is $\mathrm{NC}^{-1}\,\mathrm{m}^{2}$

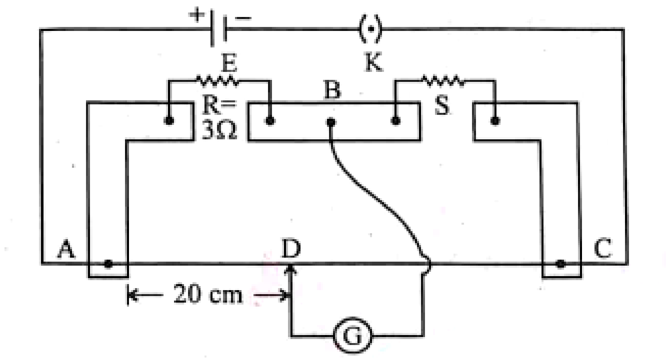
2) The dependence of electric potential (V) on distance (r) inside a uniformly charged spherical shell is -
(A) $\mathrm{V} \propto \mathrm{r}$
(B) $\mathrm{V} =$ constant
(C) $\mathrm{V} \propto \frac{1}{\mathrm{r}}$
(D) $\mathrm{V} \propto \frac{1}{\mathrm{r}^2}$

Solution:

The dependence of electric potential (V) on distance (r) inside a uniformly charged spherical shell is:
(B) $\mathrm{V} =$ constant

Explanation: Inside a uniformly charged spherical shell, the electric field is zero due to the symmetry of the shell (Gauss's law). As a result, the electric potential V remains constant throughout the interior of the shell. Therefore, the correct option is V is constant.

3) In meter bridge experiment, the balance point is found to be at 20 cm distance from end A when $R = 3\Omega$ resistor applied between A and B, then the value of unknown resistance S will be -



(A) 3Ω

(B) 6Ω

(C) 12Ω

(D) 10Ω

Solution:

From the information provided and based on the image of the meter bridge experiment, the formula we use to find the unknown resistance S is:

$\frac{R}{S}=\frac{l_1}{l_2}$
Where:
- $R=3\Omega$ (known resistance),
- $l_1=20 \mathrm{~cm}$ (distance from end A to the balance point),
- $l_2=100 \mathrm{~cm}-20 \mathrm{~cm}=80 \mathrm{~cm}$ (remaining length).

Now, substitute these values into the formula:

$\frac{3}{S}=\frac{20}{80}$
Simplify the ratio:

$\frac{3}{S}=\frac{1}{4}$
Solving for S :

$S=3 \times 4=12\Omega$
Thus, the value of the unknown resistance $S \underset{\text{is}}{\downarrow}$:

(C) 12Ω.
4) The correct relationship between the permittivity of free space (ϵ_0), the permeability of free space (μ_0) and the velocity of light in vacuum (c) is -
(A) $\mu_0 \in_0= c^2$
(B) $\frac{1}{\mu_0\epsilon_0}=c^2$
(C) $\sqrt{\mu_0\epsilon_0}=c^2$
(D) $\frac{1}{\sqrt{\mu_0\epsilon_0}}=c^2$

Solution:

The correct relationship between the permittivity of free space ϵ_0, the permeability of free space μ_0, and the velocity of light in vacuum c is:

$\frac{1}{\sqrt{\mu_0 \epsilon_0}}=c$
Thus, the correct option is:
(D) $\frac{1}{\sqrt{\mu_0 \epsilon_0}}=c$.

5) A moving charge can produce -
(A) Only electric field
(B) Only magnetic field
(C) Both electric \& magnetic field
(D) None of these

Solution:

A moving charge can produce:
(C) Both electric \& magnetic field

Explanation: A moving charge creates an electric field due to its charge and a magnetic field due to its motion. Therefore, a moving charge produces both electric and magnetic fields.

6) Eddy currents are used in -
(A) Magnetic braking in trains (B) Induction furnace
(C) Electromagnetic dalmping
(D) All of the above

Solution:

(D) All of the above

Explanation:
- Magnetic braking in trains: Eddy currents are generated in the metallic wheels or rails when exposed to magnetic fields, creating a resistive force that slows down the train.
- Induction furnace: Eddy currents are used to heat metals in induction furnaces, as they generate heat when flowing through conductive materials.
- Electromagnetic damping: Eddy currents are employed in devices like galvanometers to slow down the motion of the pointer, providing damping effects.

Thus, all the options listed utilize eddy currents.

7) If refractive index of denser medium 1 with respect to rarer medium 2 is n_{12} and critical angle for this pair of media is i_c, then correct relation between n_{12} and i_c is
(A) $n_{12}=\sin i_c$
(B) $\mathrm{n}_{12}=\tan \mathrm{i}_{\mathrm{c}}$
(C) $\mathrm{n}_{12}=\frac{1}{\tan \mathrm{i}_{\mathrm{c}}}$
(D) $\mathrm{n}_{12}=\frac{1}{\sin \mathrm{i}_{\mathrm{c}}}$

Solution:

The correct relation between the refractive index n_{12} of the denser medium with respect to the rarer medium and the critical angle i_c is:

Thus, the correct option is:
(D) $n_{12} = \frac{1}{\sin i_c}$.

7) If refractive index of denser medium 1 with respect to rarer medium 2 is n_{12} and critical angle for this pair of media is i_c, then correct relation between n_{12} and i_c is
(A) $n_{12} = \sin i_c$
(B) $\mathrm{n}_{12} = \tan \mathrm{i}_\mathrm{c}$
(C) $\mathrm{n}_{12} = \frac{1}{\tan \mathrm{i}_\mathrm{c}}$
(D) $\mathrm{n}_{12} = \frac{1}{\sin \mathrm{i}_\mathrm{c}}$

Solution:

The correct relation between the refractive index n_{12} of the denser medium with respect to the rarer medium and the critical angle i_c is given by:

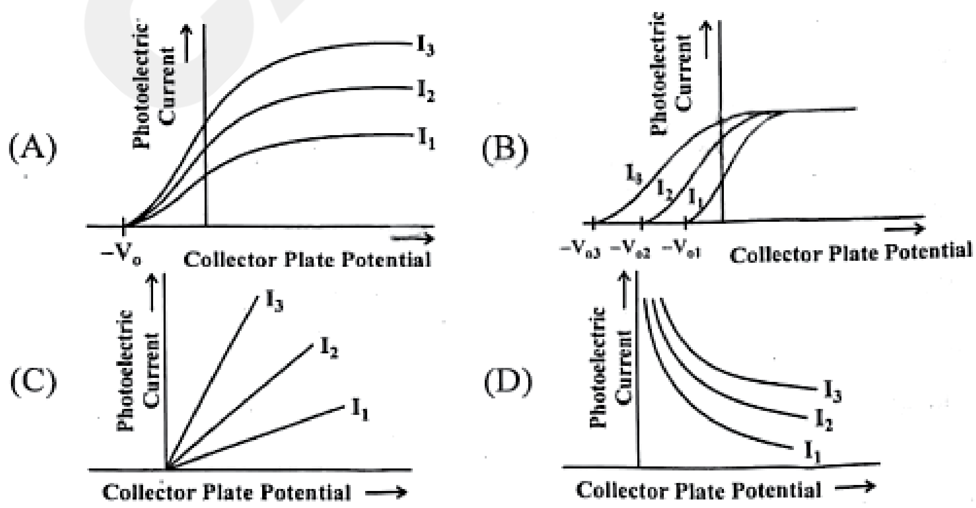
$$n_{12} = \frac{1}{\sin i_c}$$

This formula is derived from Snell's law at the critical angle, where the angle of refraction in the rarer medium is 90°. The critical angle i_c is the angle of incidence in the denser medium for which the refracted ray grazes along the boundary, making the angle of refraction exactly 90°.

Thus, the correct option is:

$$n_{12} = \frac{1}{\sin i_c}$$

8) In an experimental study of photoelectric effect, the correct graph between collector plate potential and photoelectric current for different intensities of incident radiation is



Solution:

- The graph shows that as the collector plate potential increases, the photoelectric current also increases until it reaches a saturation level.
- For higher intensities (denoted as I_3, I_2, I_1), the saturation current is higher, which aligns with the fact that higher intensity radiation ejects more electrons, leading to a greater photoelectric current.
- The stopping potential V_0 (negative potential) is the same for all intensities, as it depends on the frequency of the incident light and not on the intensity.

Thus, option (A) is the correct graph.

9) Who first experimentally verified the wave nature of the electron?

(A) Wilhelm Hallwachs and Philipp Lenard

(B) C.J. Davission and L.H. Germer

(C) Albert Einstein

(D) A.H. Compton
Solution:

(B) C.J. Davisson and L.H. Germer

2 i) The name of machine that accelerates charged particles or ions to high energies is

Solution:

The name of the machine that accelerates charged particles or ions to high energies is:

Particle accelerator

Examples of particle accelerators include the cyclotron, linear accelerator (linac), and synchrotron. These machines are used in various fields such as physics research, medicine, and industry.

The ratio of flux linkage $(\mathrm{N}\phi)$ associated with a coil having N turns to the current (I) flowing through it $\left(\frac{\mathrm{N}\phi}{\mathrm{I}}\right)$ is .

Solution:

The ratio of flux linkage $\left(\frac{N\phi}{I}\right)$ is called inductance and is denoted by the symbol L.
Therefore, the correct relation is:

$$L = \frac{N\phi}{I}$$

The unit of inductance is henry (H).

iii) If equal. of two particles are equal, then their de Broglie wavelength will be

Solution:

If the momenta of two particles are equal, then their de Broglie wavelengths will also be equal. The de Broglie wavelength λ is given by the formula:

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

where:
- λ is the de Broglie wavelength,
- h is Planck's constant, and
- p is the momentum of the particle.

If the momenta of two particles are equal ($p_1 = p_2$), then their de Broglie wavelengths will also be equal, since the wavelength is inversely proportional to the momentum. Therefore:

$$\lambda_1 = \lambda_2$$

iv) The are majority charge carriers and in p-type semiconductor. are minority charge carriers

Solution:

The holes are majority charge carriers in a p-type semiconductor, and electrons are the minority charge carriers.

Explanation:
- In a p-type semiconductor, the doping introduces more "holes" (absence of electrons), making them the majority charge carriers.
- Electrons, though present in smaller quantities, are the minority charge carriers in this type of semiconductor.

3 i) In Milikan's experiment, the charge found on a charged droplet was $-6.4 \times 10^{-19}\mathrm{C}$, then write the number of electrons in that charged droplet.

Solution:

To find the number of electrons in the charged droplet, we can use the following relation:

$$q = n \times e$$

Where:
- q is the total charge on the droplet, which is $-6.4 \times 10^{-19}\,\mathrm{C}$,
- e is the charge of a single electron, which is $1.6 \times 10^{-19}\,\mathrm{C}$,
- n is the number of electrons.

Rearranging the equation to solve for n :

$$n=\frac{q}{e}$$

Substitute the given values:

$$n=\frac{6.4\times10^{-19}}{1.6\times10^{-19}}=4$$

Thus, the number of electrons in the charged droplet is 4.

ii) Write the value of electric potential at a distance r from the mid dipole on the axis of the electric dipole of dipole moment p .

Solution:

The electric potential V at a distance r from the midpoint of an electric dipole, on the axis of the dipole (the line joining the two charges), is given by the formula:

$$V=\frac{1}{4\pi\epsilon_0}\cdot\frac{p}{r^2}$$

Where:
- V is the electric potential,
- ϵ_0 is the permittivity of free space,
- p is the dipole moment (defined as $p=q\times d$, where q is the charge and d is the distance between the charges),
- r is the distance from the midpoint of the dipole to the point where the potential is being measured.

This expression is valid for distances much larger than the separation between the charges of the dipole, i.e., $r\gg d$.

iii) Write dependence of resistivity with temperature for semiconductors.

Solution:

The resistivity of semiconductors decreases with an increase in temperature. This behavior is opposite to that of metals.

For semiconductors, the dependence of resistivity (ρ) on temperature (T) is given by the relation:

$$\rho(T)\propto e^{\frac{E_g}{2kT}}$$

Where:
- $\rho(T)$ is the resistivity at temperature T,
- E_g is the energy band gap of the semiconductor,

- k is Boltzmann's constant,
- T is the absolute temperature.

Explanation:
- In semiconductors, as the temperature increases, more electrons gain enough energy to jump from the valence band to the conduction band, increasing the number of charge carriers (electrons and holes).
- This increase in charge carriers causes the resistivity to decrease, making the material more conductive at higher temperatures.

Therefore, the resistivity of semiconductors has an inverse relationship with temperature.

iv) If two cells of e.m.f. $\varepsilon_1, \varepsilon_2$ and internal resistance r_1, r_2 are connected in parallel combination, then write the equivalent e.m.f. of this combination.

Solution:

When two cells with electromotive forces (e.m.f.) ε_1 and ε_2, and internal resistances r_1 and r_2, are connected in parallel, the equivalent e.m.f. ε_{eq} of the combination is given by the formula:

$$\varepsilon_{\text{eq}} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$$

This formula accounts for both the e.m.f. and internal resistance of each cell. The cells share the total current based on their internal resistances, and this is reflected in the equivalent e.m.f. 0.5

(v) How can a galvanometer be converted into a voltmeter?}

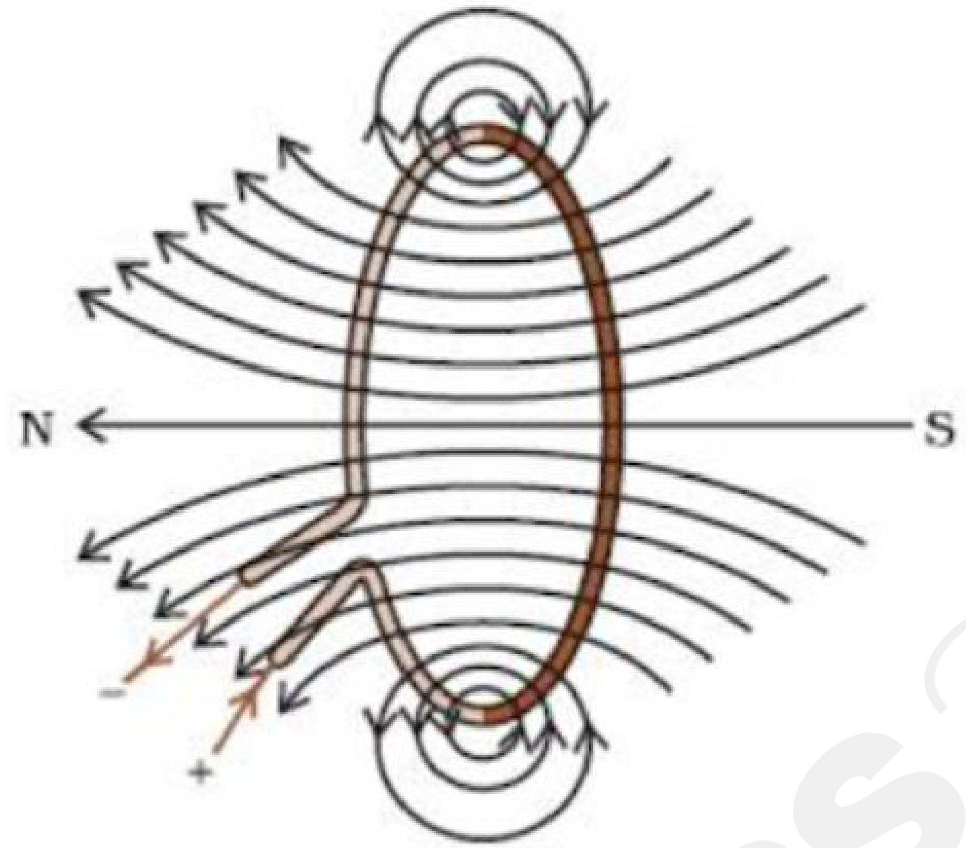
Solution:

A galvanometer can be converted into a voltmeter by connecting a high resistance in series with it. This allows the device to measure higher potential differences without allowing excessive current to pass through the galvanometer. The value of the resistance is chosen such that the total resistance of the voltmeter gives a full-scale deflection for the desired maximum voltage. This way, the galvanometer can measure voltage instead of current.

vi) Draw a diagram of the magnetic field lines due to a current carrying circular loop.

Solution:

Here is the diagram showing the magnetic field lines due to a current-carrying circular loop. The field lines form concentric circles around the loop and pass through the center, representing the magnetic field generated by the current.



vii) Write Faraday's law of electromagnetic induction.

Solution:

Faraday's Law of Electromagnetic Induction states:

The induced electromotive force (emf) in a closed circuit is directly proportional to the rate of change of magnetic flux through the circuit.

Mathematically, it is expressed as:

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

Where:
- ε is the induced emf,
- Φ_B is the magnetic flux through the circuit,
- $\frac{d\Phi_B}{dt}$ represents the rate of change of magnetic flux,
- The negative sign indicates the direction of the induced emf as per Lenz's Law, which opposes the change in magnetic flux.

viii) Draw a graph between angle of incidence (i) and angle of deviation (δ) for a triangular prism.

Solution:

Here is the graph showing the relationship between the angle of incidence (i) and the angle of deviation (δ) for a triangular prism. The curve illustrates how the angle of deviation initially decreases, reaches a minimum, and then increases as the angle of incidence continues to rise.

SECTION-B

4. Derive the capacitance formula for a parallel plate capacitor if the area of each conducting plate is A and d is the separation between them.}

Solution:} The capacitance C of a capacitor is defined as the charge Q stored per unit potential difference V across its plates:

Step 1: Electric Field and Voltage

The electric field E between the two plates of a parallel plate capacitor is uniform and is given by:

$$E = \frac{V}{d}$$

where:
- V is the potential difference between the plates,
- d is the separation between the plates.

Step 2: Surface Charge Density}

The surface charge density σ on the plates is the charge per unit area:

$$\sigma = \frac{Q}{A}$$

where A is the area of each plate.

Step 3: Electric Field and Charge Density}

The electric field E is related to the surface charge density σ by:

$$E = \frac{\sigma}{\varepsilon_0}$$

where ε_0 is the permittivity of free space.

Step 4: Substitute and Solve for V}

Substitute $\sigma = \frac{Q}{A}$ into the expression for E:

$$E = \frac{Q}{A\varepsilon_0}$$

Now, substitute $E = \frac{V}{d}$ from earlier:

$$\frac{V}{d} = \frac{Q}{A\varepsilon_0}$$

Rearrange to solve for V:

$$V = \frac{Qd}{A\varepsilon_0}$$

Step 5: Capacitance Formula}

Now, using the definition of capacitance $C = \frac{Q}{V}$:

$$C = \frac{Q}{\frac{Qd}{A\varepsilon_0}} = \frac{A\varepsilon_0}{d}$$

Thus, the capacitance of a parallel plate capacitor is:

$$C = \frac{A\varepsilon_0}{d}$$

where:
- A is the area of the plates,
- d is the separation between the plates,
- ε_0 is the permittivity of free space.

0.5cm

5. If C_1, C_2, C_3, C_4, C_5 are five capacitors connected in an electrical circuit as shown in the figure, calculate the equivalent capacitance of this mesh (network) between points A and B.}

Solution:

Given the network of capacitors:
- $C_1 = 40\,\mu\text{F}$
- $C_2 = 40\,\mu\text{F}$
- $C_3 = 20\,\mu\text{F}$
- $C_4 = 20\,\mu\text{F}$
- $C_5 = 40\,\mu\text{F}$

Step 1: Capacitors C_3 and C_4 are in Parallel}

For capacitors in parallel, the equivalent capacitance is the sum of the individual capacitances:

$$C_{34} = C_3 + C_4 = 20\,\mu\text{F} + 20\,\mu\text{F} = 40\,\mu\text{F}$$

Step 2: Capacitors C_1, C_2, C_{34}, and C_5 are in Series}

For capacitors in series, the reciprocal of the equivalent capacitance is the sum of the reciprocals of the individual capacitances:

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_{34}} + \frac{1}{C_5}$$

Substitute the values:

$$\frac{1}{C_{\text{eq}}} = \frac{1}{40\,\mu\text{F}} + \frac{1}{40\,\mu\text{F}} + \frac{1}{40\,\mu\text{F}} + \frac{1}{40\,\mu\text{F}}$$

This simplifies to:

$$\frac{1}{C_{\text{eq}}} = \frac{4}{40\,\mu\text{F}} = \frac{1}{10\,\mu\text{F}}$$

Step 3: Equivalent Capacitance}

Taking the reciprocal, we get the equivalent capacitance:

$$C_{\text{eq}} = 10\,\mu\text{F}$$

Thus, the equivalent capacitance of the network is:

$$C_{\text{eq}} = 10\,\mu\text{F}$$

0.5cm

6. Carbon resistors are widely used in electronic circuits. Why? Write any two reasons.

Solution: Carbon resistors are widely used in electronic circuits due to the following reasons:

1. Cost-effectiveness: Carbon resistors are inexpensive to produce, making them an affordable choice for mass production in electronic devices.
2. Wide resistance range: They offer a broad range of resistance values, allowing for versatility in various electronic applications. Additionally, they are compact and suitable for small electronic components.

0.5cm

7. If 12 resistors each of resistance $12\,\Omega$ are connected in a cubical network, determine the equivalent resistance of this network across the diagonally opposite corners of the cube.

Solution:

To find the equivalent resistance across the diagonally opposite corners of a cubical network consisting of 12 resistors, each of resistance $12\,\Omega$, we can use the symmetry of the cube to simplify the problem.

Step-by-Step Process:}

1. Cube Structure:} Each edge of the cube has a resistor of $12\,\Omega$. The cube has 8 corners, with resistors connecting these corners.
2. Symmetry Consideration:} Due to the symmetry of the cube, the potential at some points will be the same. This allows us to treat certain resistors as being in parallel and others in series.
3. Using Symmetry:} The resistors connected between the points on opposite corners can be combined using a symmetry approach, and we can reduce the problem to a simpler network of resistors.

The equivalent resistance across the diagonally opposite corners of the cube in this type of symmetrical arrangement is a well-known result:

$$R_{\text{eq}} = \frac{5}{6} \times R$$

where R is the resistance of each edge (in this case $R = 12\,\Omega$).

4. Substitute the value:}

$$R_{\text{eq}} = \frac{5}{6} \times 12\,\Omega = 10\,\Omega$$

Thus, the equivalent resistance of the cubical network across the diagonally opposite corners is $10\,\Omega$.

8. If the focal length of a concave mirror is f and radius of curvature is R, then prove that radius of curvature is twice the focal length.

Solution:

To prove that the radius of curvature (R) is twice the focal length (f) for a concave mirror, we use the mirror formula and the geometric relationship between these quantities.

Step-by-Step Proof:

Mirror Formula: The mirror formula relates the object distance (u), the image distance (v), and the focal length (f) of a mirror. It is given by:

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

2. Definition of Radius of Curvature:} The radius of curvature R is the distance between the center of curvature and the mirror. By definition, the center of curvature is the point on the principal axis such that any light ray passing through it is reflected back along the same path.

3. Relation Between Focal Length and Radius of Curvature:} For a concave mirror, the focal length f is half of the radius of curvature R. This can be derived from the fact that the focal point is halfway between the mirror's surface and its center of curvature.

$$f = \frac{R}{2}$$

4. Rearrange the Equation:} To express the radius of curvature in terms of the focal length, multiply both sides of the equation by 2:

$$R = 2f$$

Conclusion:

Thus, the radius of curvature R is twice the focal length f for a concave mirror.

9) If a concave lens of 25 cm focal length is placed in contact with a convex lens of 20 cm focal length, then calculate the power of the combined lens formed by this combination.

Solution:

To calculate the power of the combined lens formed by a concave lens and a convex lens placed in contact, we use the following formula for the total power of a lens combination:

$$P_{\text{total}} = P_1 + P_2$$

Where:
- P_1 is the power of the concave lens,
- P_2 is the power of the convex lens,
- P_{total} is the total power of the combination.

Step 1: Calculate the power of each lens}

The power P of a lens is related to its focal length f (in meters) by the formula:

$$P = \frac{1}{f}$$

- For the concave lens (focal length $f_1 = -25\,\text{cm} = -0.25\,\text{m}$):

$$P_1 = \frac{1}{-0.25} = -4\,\text{D}$$

10.By writing Einstein's photoelectric equation, explain any two observations related to photoelectric effect.

Solution:

Einstein's Photoelectric Equation:
Einstein explained the photoelectric effect using the concept of quantized energy in light. The equation is given as:

$$E_k = h\nu - \phi$$

Where:
- E_k is the kinetic energy of the emitted photoelectrons,
- h is Planck's constant,
- ν is the frequency of the incident light,
- ϕ is the work function (the minimum energy required to remove an electron from the metal surface).

Two Observations Explained:
1. Threshold Frequency: The photoelectric effect occurs only when the frequency of the incident light is above a certain threshold frequency, ν_0. This threshold frequency is the minimum frequency of light required to eject electrons from the metal surface. Below this frequency, no electrons are emitted, no matter how intense the light is.

Explanation: According to Einstein's equation, the energy of the incident photon $h\nu$ must be greater than or equal to the work function ϕ of the material for electrons to be emitted. If $\nu < \nu_0$, there is not enough energy to overcome the work function, and thus no photoelectrons are emitted.
2. Effect of Intensity: The number of photoelectrons emitted is proportional to the intensity of the incident light, but the kinetic energy of the emitted photoelectrons depends only on the frequency of the light, not its intensity.

Explanation: The intensity of light corresponds to the number of photons incident per unit area. A higher intensity means more photons, leading to the emission of more photoelectrons. However, the energy of each photoelectron depends only on the frequency of the light (as seen from $E_k = h\nu - \phi$), meaning that increasing intensity does not change the kinetic energy of the photoelectrons, only the number of electrons emitted.

(11) Calculate the de Broglie wavelength associated with an electron, accelerated through a potential difference of 100 V.}

Solution:} To calculate the de Broglie wavelength associated with an electron accelerated through a potential difference, we use the following formula:

$$\lambda = \frac{h}{\sqrt{2meV}}$$

Where:
- λ is the de Broglie wavelength,
- h is Planck's constant $\left(6.626 \times 10^{-34}\, \mathrm{Js}\right)$,
- m is the mass of the electron $\left(9.11 \times 10^{-31}\, \mathrm{kg}\right)$,
- e is the charge of the electron $\left(1.6 \times 10^{-19}\, \mathrm{C}\right)$,
- V is the accelerating potential difference.

Given that $V = 100\, \mathrm{V}$, we can now substitute the known values into the equation:

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19} \times 100}}$$

Let's calculate the value step by step:

1. Calculate the denominator:

$$2\mathrm{meV} = 2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19} \times 100 = 2.92 \times 10^{-26}$$

2. Take the square root:

$$\sqrt{2.92 \times 10^{-26}} = 1.71 \times 10^{-13}$$

3. Now calculate the wavelength:

$$\lambda = \frac{6.626 \times 10^{-34}}{1.71 \times 10^{-13}} = 3.87 \times 10^{-11}\, \mathrm{m}$$

Thus, the de Broglie wavelength associated with the electron is approximately:

$$\lambda \approx 3.87 \times 10^{-11}\, \mathrm{m \text{ or } 0.0387\, nm}$$

(12) What is meant by the half-life of a radioactive nucleus? Write the relation between half-life and mean life of a radioactive nucleus.}

Solution:}

Half-life of a Radioactive Nucleus:} The half-life of a radioactive nucleus is the time required for half of the radioactive nuclei present in a sample to decay. It is the time at which the number of undecayed nuclei reduces to 50% of the original quantity. After each half-life, the number of remaining radioactive nuclei continues to halve.

Relation Between Half-life ($T_{1/2}$) and Mean Life (τ):} The mean life (τ) of a radioactive nucleus is the average lifetime of a nucleus before it decays. The relation between half-life and mean life is given by the following formula:

$$T_{1/2} = \tau \ln(2)$$

Where:
- $T_{1/2}$ is the half-life,
- τ is the mean life,
- $\ln(2) \approx 0.693$

(13) Write any three features of the nuclear force.}

Solution:} Here are three key features of nuclear force:

1. Short Range:} Nuclear forces are extremely short-ranged, meaning they are effective only over distances of about 10^{-15} meters (1 femtometer), which is roughly the size of a nucleus. Beyond this range, the nuclear force rapidly diminishes and becomes negligible.

2. Strong and Attractive:} Nuclear forces are among the strongest forces in nature, much stronger than electromagnetic and gravitational forces. They are primarily attractive, which allows protons and neutrons (nucleons) to remain bound together inside the nucleus despite the repulsive electromagnetic force between protons.

3. Charge Independence:} Nuclear forces act equally between all nucleons (protons and neutrons), regardless of their charge. This means the force between two protons, two neutrons, or a proton and a neutron is the same, as long as the distance between them is the same.

(14) Write the working of a voltage regulator made by using a Zener diode.}

Solution:}

Working of a Voltage Regulator Using a Zener Diode:}

A Zener diode is commonly used in voltage regulator circuits to maintain a constant output voltage across a load, even if the input voltage or load current fluctuates. The Zener diode operates in the reverse breakdown region, where it allows current to flow to regulate the voltage.

Working Principle:}

1. Reverse Breakdown Region:} The Zener diode is connected in reverse bias across the output load. When the input voltage exceeds the Zener breakdown voltage (V_Z), the diode goes into the breakdown region and starts conducting, allowing current to pass through it without damaging the diode.

2. Constant Voltage Output:} In the breakdown region, the voltage across the Zener diode remains nearly constant at the Zener voltage V_Z, irrespective of changes in the input voltage or load current. The excess input voltage is dropped across a series resistor, which limits the current through the Zener diode.

3. Current Limiting Resistor:} A series resistor R is placed in the circuit to limit the current flowing through the Zener diode and prevent it from exceeding its maximum rated current. This resistor ensures that the voltage drop across the Zener diode remains at the regulated value V_Z.

Circuit Operation:}
- If the input voltage increases, the Zener diode draws more current, but the voltage across the load stays constant at V_Z.
- If the input voltage decreases, the current through the Zener diode decreases, but as long as the input voltage is higher than V_Z, the voltage across the load remains stable.

Thus, the Zener diode maintains a constant output voltage, acting as a reliable voltage regulator.