MPBSE Class 12th Physics - 2023 Question Paper with Solutions

Time Allowed :3 Hour	**Maximum Marks :**70	**Total Questions :**19

General Instructions

Read the following instructions very carefully and strictly follow them:

1. Attempt all questions.
2. Read the instructions carefully.
3. Marks alloted to each question are indicated against it.

1. (i) S.I. unit of current density is -

(1) Coulomb / meter
(2) Ampere / meter^2
(3) Coulomb / meter^2
(4) Ampere / meter

Correct Answer: (2) Ampere / meter^2

Solution:
Current density is defined as the amount of electric current flowing per unit area. The correct unit of current density is **Ampere per square meter** (Ampere / meter^2).

Quick Tip

The unit of current density is derived from the formula $J = \frac{I}{A}$, where I is the current in amperes and A is the area in square meters.

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1. (ii) The phase difference between flowing current and applied voltage in alternating circuit containing pure capacitor is -
(1) 0
(2) 1
(3) $\frac{\pi}{2}$
(4) $-\frac{\pi}{2}$

Correct Answer: (3) $\frac{\pi}{2}$

Solution:
In an alternating circuit with a pure capacitor, the current leads the voltage by $\frac{\pi}{2}$. Hence, the phase difference is $\frac{\pi}{2}$.

Quick Tip

In a purely capacitive circuit, current leads voltage by $\frac{\pi}{2}$.

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1. (iii) Bhabha Atomic Research Centre is situated in -
(1) New Delhi
(2) Mumbai
(3) Kolkata
(4) Bangalore

Correct Answer: (2) Mumbai

Solution:
Bhabha Atomic Research Centre (BARC) is located in Mumbai, India. It is the premier nuclear research facility in India.

Quick Tip

BARC is one of India's most prominent research institutes for atomic energy.

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1. (iv) Forbidden energy gap for Germanium semiconductor is -
(1) 1.1 eV
(2) 1.9 eV
(3) 0.72 eV
(4) 0.75 eV

Correct Answer: (3) 0.72 eV

Solution:
The forbidden energy gap for Germanium (Ge) semiconductor is 0.72 eV, which is smaller than that of Silicon.

Quick Tip

Germanium has a smaller band gap compared to Silicon, which makes it more sensitive to temperature.

1. (v) Which device is used as a rectifier?
(1) Junction diode
(2) Transformer
(3) Zener diode
(4) Photo diode

Correct Answer: (1) Junction diode

Solution:
A junction diode is used as a rectifier, as it allows current to flow in only one direction, effectively converting AC to DC.

Quick Tip

A junction diode is widely used for rectification in power supplies.

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1. (vi) The focal length of eye piece in telescope ________ the focal length of the objective.
(1) is less than
(2) is more than
(3) is equal
(4) none of these

Correct Answer: (1) is less than

Solution:
In a telescope, the focal length of the eyepiece is always less than the focal length of the objective lens. This is essential for forming an image at a comfortable viewing distance.

Quick Tip

The objective lens has a longer focal length to gather light, while the eyepiece has a shorter focal length for magnification.

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2. (i) The ohmic resistance of an ideal inductance is ________.
(1) Zero
(2) Infinite
(3) 1 ohm
(4) None of these

Correct Answer: (2) Infinite

Solution:
An ideal inductance has no resistance. However, any real inductor will have a small resistance. Since an ideal inductance is assumed to have no resistance, the correct answer is Infinite (because it is an ideal case).

> **Quick Tip**
>
> An ideal inductor is a perfect energy storage device with zero resistance. Its only property is inductance.

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2. (ii) The frequency of a Direct Current is ________.
(1) Zero
(2) 50 Hz
(3) 60 Hz
(4) 100 Hz

Correct Answer: (1) Zero

Solution:
Direct current (DC) is a constant current, which has no frequency. Thus, the frequency of a direct current is zero.

> **Quick Tip**
>
> Direct current (DC) has a constant value and does not vary with time, so its frequency is zero.

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2. (iii) Electromagnetic wave of highest frequency is ________.
(1) Gamma rays
(2) X-rays
(3) Ultraviolet
(4) Radio waves

Correct Answer: (1) Gamma rays

Solution:
Gamma rays have the highest frequency among all electromagnetic waves. They have a frequency greater than 10^{19} Hz.

> **Quick Tip**
>
> Gamma rays have the highest frequency and the shortest wavelength in the electromagnetic spectrum.

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2. (iv) The frequency of the light wave is order of ______.
(1) 10^3 Hz
(2) 10^{14} Hz
(3) 10^{10} Hz
(4) 10^8 Hz

Correct Answer: (2) 10^{14} Hz

Solution:
The frequency of visible light lies in the range of 10^{14} Hz. This corresponds to wavelengths in the range of 400-700 nm.

> **Quick Tip**
>
> Light waves have frequencies in the range of 10^{14} Hz, which is much higher than those of sound waves or other mechanical waves.

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2. (v) The velocity of light ______ when it goes to rare medium to denser.
(1) Increases
(2) Decreases
(3) Remains the same
(4) None of these

Correct Answer: (2) Decreases

Solution:
When light passes from a rarer medium (like air) to a denser medium (like water or glass), its speed decreases. This is due to the change in refractive index.

> **Quick Tip**
>
> The speed of light decreases when it enters a denser medium due to the higher refractive index.

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2. (vi) Magnetic field is a ________ quantity.
(1) Scalar
(2) Vector
(3) Neither scalar nor vector
(4) Both scalar and vector

Correct Answer: (2) Vector

Solution:
Magnetic field is a vector quantity because it has both magnitude and direction. The direction of the magnetic field is given by the direction of the force on a moving charge.

> **Quick Tip**
> Magnetic field is a vector quantity and is represented by field lines indicating both direction and strength.

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2. (vii) The ________ of the galvanometer is reduced by the use of shunt.
(1) Resistance
(2) Current
(3) Voltage
(4) Sensitivity

Correct Answer: (4) Sensitivity

Solution:
The sensitivity of a galvanometer is reduced by the use of a shunt resistor, as it divides the current between the galvanometer and the shunt.

> **Quick Tip**
> A shunt reduces the current through the galvanometer, thereby reducing its sensitivity to small currents.

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3. Write True or False:
(i) Infrared radiation is invented by scientist Retar.
(1) True
(2) False

Correct Answer: (2) False

Solution:
Infrared radiation was discovered by William Herschel in 1800, not by scientist Retar.

> **Quick Tip**
>
> Infrared radiation was first discovered by William Herschel while studying the properties of light in the 19th century.

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3. (ii) In an intrinsic semiconductor the number of free electrons is equal to the number of holes.
(1) True
(2) False

Correct Answer: (1) True

Solution:
In an intrinsic semiconductor, the number of free electrons is indeed equal to the number of holes. This is because every free electron that leaves a bond creates a hole.

> **Quick Tip**
>
> In intrinsic semiconductors, the electron and hole concentration is equal at thermal equilibrium.

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3. (iii) Voltmeter is more superior to potentiometer.
(1) True
(2) False

Correct Answer: (2) False

Solution:
A potentiometer is more accurate than a voltmeter because it does not draw current from the circuit, whereas a voltmeter does.

> **Quick Tip**
>
> A potentiometer can give more precise measurements of potential difference as it does not alter the circuit conditions.

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3. (iv) De-broglie waves are an electromagnetic wave.
(1) True
(2) False

Correct Answer: (2) False

Solution:
De Broglie waves refer to the wave-like behavior of particles, and they are not electromagnetic waves. These waves are related to matter, unlike electromagnetic waves, which are related to electric and magnetic fields.

> Quick Tip
>
> De Broglie waves are associated with particles, and their wavelength is given by $\lambda = \frac{h}{p}$, where p is momentum and h is Planck's constant.

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3. (v) Atom is a positive particle.
(1) True
(2) False

Correct Answer: (2) False

Solution:
An atom is electrically neutral overall. It consists of positively charged protons in the nucleus, negatively charged electrons surrounding the nucleus, and neutral neutrons.

> Quick Tip
>
> An atom is neutral as the positive charge of protons is exactly balanced by the negative charge of electrons.

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3. (vi) The average power supplied to an inductor over one complete cycle is zero.
(1) True
(2) False

Correct Answer: (1) True

Solution:
In an inductor, the energy supplied over one complete cycle is stored during one half of the

cycle and returned during the other half. Hence, the net power supplied over one complete cycle is zero.

Quick Tip

For purely inductive circuits, the average power over one cycle is zero as energy is alternately stored and released.

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3. (vii) Working of microwave oven is based on Radio wave.
(1) True
(2) False

Correct Answer: (2) False

Solution:
The working of a microwave oven is based on microwaves, which are a form of electromagnetic waves. These waves are different from radio waves, having higher frequency and shorter wavelengths.

Quick Tip

Microwave ovens use electromagnetic waves with frequencies between 300 MHz to 300 GHz, much higher than radio waves.

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4. Write answer of each question in one sentence:
(i) What is threshold frequency?
Correct Answer: The minimum frequency needed for a material to emit photoelectrons when exposed to light.

Solution:
Threshold frequency is the minimum frequency of incident light required to emit photoelectrons from a material's surface in the photoelectric effect.

Quick Tip

The threshold frequency corresponds to the work function of the material, which is the minimum energy required to release electrons.

(ii) What is diffraction?
Correct Answer: The bending of light waves around obstacles.

Solution:
Diffraction is the phenomenon where light or any other wave bends around obstacles or spreads as it passes through narrow openings.

Quick Tip

Diffraction occurs more prominently when the size of the obstacle or aperture is comparable to the wavelength of the wave.

(iii) What is the unit of power of lens?
Correct Answer: Diopter

Solution:
The power of a lens is measured in diopters (D), which is the reciprocal of the focal length (in meters).

Quick Tip

The power of a lens is given by $P = \frac{1}{f}$, where f is the focal length in meters.

(iv) What is direction of magnetic dipole moment of a magnet?
Correct Answer: From north pole to south pole.

Solution:
The magnetic dipole moment of a magnet is directed from its south pole to its north pole.

Quick Tip

The magnetic dipole moment is a vector quantity that points from the south pole to the north pole of a magnet.

(v) How Galvanometer is changed in a voltmeter?
Correct Answer: By adding a resistance in series.

Solution:
A galvanometer is converted into a voltmeter by adding a large resistance (called a series resistor) in series with it.

> Quick Tip
>
> The series resistance limits the current passing through the galvanometer, allowing it to measure higher voltages without damaging the meter.

(vi) What is the affect of temperature on drift velocity?
Correct Answer: Decreases drift velocity.

Solution:
As temperature increases, the drift velocity of electrons decreases because the increase in thermal motion of atoms causes more collisions with free electrons.

> Quick Tip
>
> At higher temperatures, the resistance of a conductor increases, which leads to a decrease in the drift velocity of electrons.

(vii) Give relations between energy and frequency of a radiation.
Correct Answer: $E = h\nu$

Solution:
The energy of a photon is related to its frequency by the equation $E = h\nu$, where E is energy, h is Planck's constant, and ν is frequency.

> Quick Tip
>
> The equation $E = h\nu$ shows that energy and frequency are directly proportional for a photon.

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5. What is Photoelectric effect? Write Einstein's photoelectric equation.
OR
What is de-broglie matter wave? Write de-broglie wave relation.
Solution:

a. Photoelectric Effect:
The photoelectric effect is the phenomenon in which electrons are ejected from the surface of a material (typically metal) when it is exposed to light of certain frequency. This phenomenon provided experimental evidence for the particle nature of light.
Einstein's Photoelectric Equation: The energy E of a photon is given by the equation:

$$E = h\nu$$

where h is Planck's constant and ν is the frequency of the incident light. The energy required to release an electron from the material's surface is the work function ϕ. Thus, the photoelectric equation is given by:

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

where E_k is the kinetic energy of the emitted electron.

b. de-Broglie Matter Waves:
de-Broglie proposed that particles, such as electrons, exhibit wave-like properties. The wavelength λ associated with a moving particle is given by the de-Broglie relation:

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

where h is Planck's constant and p is the momentum of the particle, given by $p = mv$, where m is the mass and v is the velocity of the particle.

Quick Tip

The photoelectric effect and de-Broglie waves both demonstrate the dual nature of matter and light, supporting the concept that particles and waves are interconnected.

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6. Write any two Postulates of Bohr's model.
OR
Who discovered the nucleus model of atom? Draw its diagram.
Solution:

a. Postulates of Bohr's Model:
Niels Bohr proposed a model for the atom in 1913, which explained the structure of the hydrogen atom. The two key postulates of Bohr's model are:

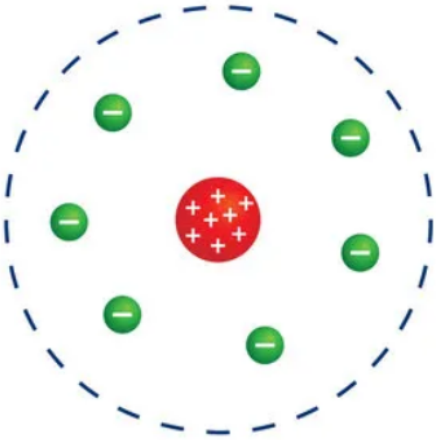
1. Electrons revolve in certain stable orbits around the nucleus without radiating energy. These orbits are called *stationary orbits*. This postulate was based on the fact that atoms do not emit energy continuously but only when electrons jump between orbits.

2. The energy of an electron in a stationary orbit is quantized and given by $E = -\frac{Ke^2}{2r}$, where r is the radius of the orbit, and K and e are constants. This postulate explains that only certain orbits with discrete energy levels are allowed.

b. Discovery of Nucleus Model of Atom:
The nucleus model of the atom was discovered by Ernest Rutherford in 1911. In his famous gold foil experiment, he demonstrated that the atom consists of a small, dense, positively charged nucleus at its center, with electrons orbiting around it.

Rutherford's Experiment:
In the experiment, alpha particles were directed at a thin sheet of gold foil. Most of the particles passed through, but a small fraction were deflected at large angles, indicating the presence of a dense center, which was identified as the nucleus. This was a pivotal moment in atomic theory, as it replaced the earlier plum pudding model of the atom.

Diagram of Rutherford's Nuclear Model:



> **Quick Tip**
>
> Rutherford's discovery of the atomic nucleus led to the development of modern atomic models, which were further refined by Bohr's postulates and quantum mechanics.

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7. What is isotopes? Write any two isotopes of hydrogen atom.
OR
What is Isobar? Give example.
Solution:

a. Isotopes:
Isotopes are atoms of the same element that have the same number of protons (atomic number) but different numbers of neutrons (mass number). This results in different atomic masses for the isotopes of the same element.

Example of Isotopes of Hydrogen: The three isotopes of hydrogen are:

1. *Protium* (^1_1H): This is the most common isotope of hydrogen, with one proton and no neutrons.
2. *Deuterium* (^2_1H): This isotope has one proton and one neutron. It is used in nuclear fusion reactions.
3. *Tritium* (^3_1H): This isotope has one proton and two neutrons. It is radioactive and used in nuclear reactors.

b. Isobars:
Isobars are atoms of different elements that have the same mass number but different atomic numbers. In other words, they have the same total number of protons and neutrons, but the protons are distributed between different elements.

Example of Isobars: An example of isobars is:

1. ^4_2He (Helium) and ^4_3Li (Lithium): Both have a mass number of 4 but different atomic numbers (2 for helium and 3 for lithium).

> Quick Tip
>
> Isotopes differ in the number of neutrons, while isobars differ in the number of protons.

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8. What is a fundamental charge? Write its value.
OR
Where will an electron move in an electric field, either high potential side or low potential side? And why?
Solution:

a. Fundamental Charge:
The fundamental charge is the smallest unit of electric charge that is carried by a single electron or proton. This charge is denoted by e. It is the basic unit of charge in the system of SI units. The value of the fundamental charge is:

$$e = 1.6 \times 10^{-19}\,\text{Coulombs}.$$

This is the charge on an electron, which is negative, and the same magnitude is carried by a proton but with a positive sign.

b. Movement of Electron in an Electric Field:
In an electric field, an electron will move towards the low potential side. This is because electrons carry a negative charge, and in an electric field, the direction of force on a negative charge is opposite to the direction of the field.
Hence, an electron moves from a region of higher potential to a region of lower potential, which is in line with the direction opposite to the electric field vector.

Quick Tip

Electrons move opposite to the direction of the electric field because they are negatively charged. The electric field pushes positive charges toward lower potential and negative charges (electrons) toward higher potential.

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9. What is an electric cell? Give an example.
OR
Write Ohm's law and also draw the graph between voltage and current.
Solution:

a. Electric Cell:
An electric cell is a device that converts chemical energy into electrical energy. It has two electrodes, namely the anode and cathode, and an electrolyte. When the cell is connected to an external circuit, it provides a potential difference (voltage) that drives electric current through the circuit.

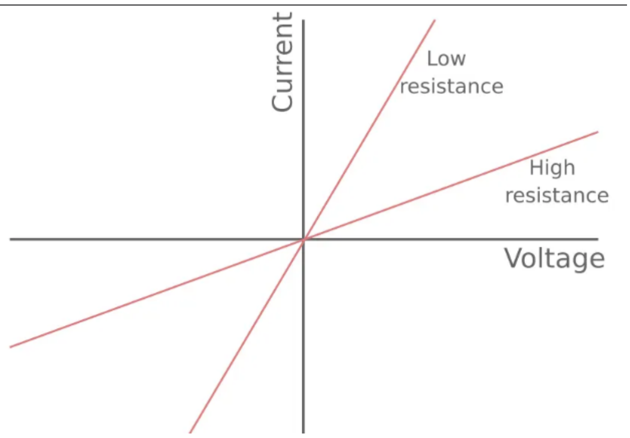
Example of Electric Cell: One common example of an electric cell is the Dry Cell used in batteries for various electronic devices. The Leclanché cell is another example of a simple electric cell used in torches.

b. Ohm's Law:
Ohm's law states that the current passing through a conductor is directly proportional to the voltage applied across it, provided the temperature and material remain constant. The law is mathematically expressed as:

$$V = I \cdot R$$

where: - V is the potential difference (voltage) in volts, - I is the current in amperes, - R is the resistance of the conductor in ohms (Ω).

Graph between Voltage and Current:
The graph between voltage (V) and current (I) for an Ohmic conductor is a straight line, indicating that the current increases linearly with an increase in voltage. The slope of this line represents the resistance of the conductor.



Quick Tip

Ohm's law applies to materials that obey the linear relationship between voltage and current, i.e., Ohmic materials.

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10. Write Bio-Savart expansion in vector form.
OR
Why there is no end point of magnetic field lines?
Solution:

a. Bio-Savart Law (Vector Form):
The Bio-Savart law gives the magnetic field $\vec{B}$ at a point in space due to a small current element. In vector form, it is expressed as:

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{I\, d\vec{l} \times \hat{r}}{r^2}$$

Where: - μ_0 is the permeability of free space, - I is the current flowing through the wire, - $d\vec{l}$ is the infinitesimal vector element of the wire in the direction of the current, - $\hat{r}$ is the unit vector pointing from the current element to the point where the magnetic field is being calculated, - r is the distance between the current element and the point of observation.
This law is used to calculate the magnetic field produced by a current-carrying conductor.

b. Why there is no end point of magnetic field lines?
Magnetic field lines do not have an end point because the magnetic field produced by a magnetic dipole or a current-carrying conductor forms a closed loop. This means that the lines start from the north pole (or current source) and loop around to the south pole (or return to the conductor), but they do not terminate in empty space. They always form continuous, closed loops.

Quick Tip

Magnetic field lines are closed loops; they never terminate in space. This is in contrast to electric field lines, which originate from positive charges and terminate at negative charges.

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11. A light bulb is rated at 200 W for a 220 V supply. Find the resistance of the bulb.
OR
A light bulb is rated at 200 W for a 220 V supply. Find the rms current through the bulb.
Solution:

Finding the Resistance of the Bulb:
We know that the power P consumed by the bulb is given by the formula:

$$P = \frac{V^2}{R}$$

where: - $P = 200\,\text{W}$ is the power, - $V = 220\,\text{V}$ is the voltage, - R is the resistance.
Rearranging the equation to solve for R:

$$R = \frac{V^2}{P}$$

Substitute the given values:

$$R = \frac{(220)^2}{200} = \frac{48400}{200} = 242\,\Omega$$

Thus, the resistance of the bulb is $242\,\Omega$.

Finding the rms Current Through the Bulb:
The rms (root mean square) current I_{rms} is related to the power P and voltage V by the formula:

$$P = I_{\text{rms}}^2 R$$

Rearranging the equation to solve for I_{rms}:

$$I_{\text{rms}} = \sqrt{\frac{P}{R}}$$

Substitute the known values:

$$I_{\text{rms}} = \sqrt{\frac{200}{242}} \approx \sqrt{0.826} \approx 0.91\,\text{A}$$

Thus, the rms current through the bulb is approximately $0.91\,\text{A}$.

Quick Tip

To find the rms current, use the relation $I_{\text{rms}} = \sqrt{\frac{P}{R}}$, where P is power and R is resistance.

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12. What is Conjugate focus?
OR
Write any two differences between refractive telescope and reflective telescope.
Solution:

a. Conjugate Focus:
In optical systems, two points are called conjugate foci if each point serves as the image of the other when light from one point passes through the optical system. These points are related by the lens equation, and they help in understanding how the image is formed in various optical instruments, such as telescopes and microscopes.

In the case of a simple lens or mirror, the object and image are conjugates of each other. The object at one focus of the lens or mirror produces an image at the other focus. This relationship is essential in understanding the behavior of light as it passes through optical devices, ensuring that the image formed is clear and well-defined.
For example, in a telescope, the object located at one focus (such as a distant star) will produce an image at the other focus (where the eyepiece is placed). This property is fundamental in optical systems because it ensures accurate image formation. The conjugate foci are particularly important when designing systems like microscopes and telescopes, where precision is crucial.

b. Differences Between Refractive and Reflective Telescopes:

There are several key differences between refractive and reflective telescopes. Below are the most notable:
1. Optical Principle: - Refractive Telescope: A refractive telescope uses lenses to focus light and form an image. The main lens (called the objective lens) gathers light and bends it (refracts it) to bring it to a focus. The eyepiece lens then magnifies the image. - Reflective Telescope: A reflective telescope uses mirrors to focus light. The primary mirror gathers light and reflects it to a focus, and a secondary mirror (or eyepiece) is used to magnify the image. Reflecting telescopes do not suffer from some of the limitations of refracting telescopes.
2. Chromatic Aberration: - Refractive Telescope: One major issue with refractive telescopes is chromatic aberration. This occurs because different wavelengths (colors) of light are bent by different amounts as they pass through the lens. As a result, the light of different colors does not focus at the same point, causing color fringes or blurring at the edges of the image. This is especially noticeable for lenses with a large aperture. - Reflective Telescope: Reflective telescopes do not suffer from chromatic aberration because mirrors reflect all wavelengths of light equally. This means that all colors of light are focused at the same point, producing a clearer and sharper image.
3. Size and Weight: - Refractive Telescope: Refractive telescopes can be quite heavy, especially if they have large lenses. Lenses of large diameter are difficult and expensive to make, and their weight can make the telescope difficult to handle and set up. - Reflective Telescope: Reflective telescopes, on the other hand, can use larger mirrors without increasing the weight as dramatically as refractive telescopes. This makes them easier to handle and more efficient for building larger telescopes.
4. Cost and Practicality: - Refractive Telescope: Building a large, high-quality refracting telescope is expensive due to the complexity of manufacturing large, perfect lenses. Additionally, lenses are more difficult to support without causing distortion. - Reflective Telescope: Reflecting telescopes are more affordable to build, and large mirrors can be supported more easily without introducing distortions. This has made reflective telescopes the preferred choice for modern observatories.

Quick Tip

Reflective telescopes are commonly used in large observatories today because they avoid the problems associated with chromatic aberration and can be built with larger mirrors more easily. Additionally, the cost of constructing large refracting telescopes is high, making reflective designs more practical.

13. Compare the resistance of 100 watt and 400 watt of two bulbs if their voltage is same.
OR
What will be the resistance of a wire if their length changes to half of their original length and cross-sectional area changes two times of original?
Solution:

a. Resistance of 100 watt and 400 watt Bulbs:
The power P consumed by an electrical device is related to the voltage V and resistance R by the formula:

$$P = \frac{V^2}{R}$$

Rearranging the equation to solve for R:

$$R = \frac{V^2}{P}$$

Since both bulbs have the same voltage, we can compare their resistances using their respective power ratings.
For the 100 watt bulb:

$$R_1 = \frac{V^2}{100}$$

For the 400 watt bulb:

$$R_2 = \frac{V^2}{400}$$

Thus, the resistance of the 100 watt bulb is four times the resistance of the 400 watt bulb. Therefore:

$$R_1 = 4 \times R_2$$

So, the resistance of the 100-watt bulb is four times greater than the resistance of the 400-watt bulb.

b. Resistance Change with Length and Area:
The resistance of a wire is given by the formula:

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

where: - ρ is the resistivity of the material, - L is the length of the wire, - A is the cross-sectional area of the wire.
When the length of the wire is halved and the area is doubled, we can substitute these changes into the formula.
New length = $\frac{L}{2}$ New area = $2A$
The new resistance R_{new} will be:

$$R_{\text{new}} = \rho \frac{\frac{L}{2}}{2A} = \frac{1}{4} \times R$$

Thus, the new resistance will be one-fourth of the original resistance.

Quick Tip

The resistance of a wire is inversely proportional to its cross-sectional area and directly proportional to its length.

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14. The radii of curvatures of the focus of a double convex lens are 10 cm and 15 cm and its focal length is 12 cm. What is the refractive index of glass? (Refractive index of air = 1)
OR
A convex lens has 20 cm focal length in air. What is focal length in water? (Refractive index of air-water = 1.33, refractive index for air-glass = 1.5)
Solution:

a. Refractive Index of Glass:
We can use the lens maker's formula to calculate the refractive index of glass. The lens maker's formula is:

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

Where: - f is the focal length of the lens, - n is the refractive index of the lens material (glass in this case), - R_1 and R_2 are the radii of curvature of the two surfaces of the lens.
From the problem, we are given: - $R_1 = 10\,\text{cm}$, - $R_2 = -15\,\text{cm}$ (since the second radius is on the opposite side of the first), - $f = 12\,\text{cm}$, - Refractive index of air is 1.
Substitute the given values into the lens maker's formula:

$$\frac{1}{12} = (n-1)\left(\frac{1}{10} - \frac{1}{-15}\right)$$
$$\frac{1}{12} = (n-1)\left(\frac{1}{10} + \frac{1}{15}\right)$$
$$\frac{1}{12} = (n-1)\left(\frac{5}{30} + \frac{2}{30}\right)$$
$$\frac{1}{12} = (n-1) \times \frac{7}{30}$$
$$(n-1) = \frac{30}{12 \times 7} = \frac{30}{84} = \frac{5}{14}$$
$$n = 1 + \frac{5}{14} = \frac{19}{14}$$
$$n = 1.357$$

Thus, the refractive index of glass is approximately 1.357.

b. Focal Length in Water:
The focal length of a lens in a medium other than air is related to its focal length in air by the following formula:

$$\frac{f_{\text{medium}}}{f_{\text{air}}} = \frac{n_{\text{air}}}{n_{\text{medium}}}$$

For this problem: - $f_{\text{air}} = 20\,\text{cm}$, - The refractive index of air is $n_{\text{air}} = 1$, - The refractive index of water is $n_{\text{water}} = 1.33$.
We can rearrange the equation to find the focal length in water:

$$f_{\text{water}} = f_{\text{air}} \times \frac{n_{\text{air}}}{n_{\text{water}}}$$

Substitute the given values:

$$f_{\text{water}} = 20 \times \frac{1}{1.33} \approx 15.04\,\text{cm}$$

Thus, the focal length of the lens in water is approximately $15.04\,\text{cm}$.

Quick Tip

The focal length of a lens decreases when it is placed in a medium with a higher refractive index compared to air.

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15. Derive an expression for Coulomb's law of electrostatics by Gauss's law.
OR
What is capacity of a conductor? Write the factors affecting the capacity of a conductor.
Solution:

a. Deriving Coulomb's Law from Gauss's Law:
Gauss's law states that the electric flux Φ_E through a closed surface is proportional to the charge enclosed by that surface. Mathematically, it is expressed as:

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\epsilon_0}$$

Where: - $\vec{E}$ is the electric field, - $d\vec{A}$ is the differential area element on the closed surface, - Q_{enc} is the charge enclosed within the surface, - ϵ_0 is the permittivity of free space.
For a point charge Q, we use a spherical Gaussian surface of radius r centered at the point charge. The electric field $\vec{E}$ is radially symmetric and has the same magnitude at every point on the surface. The surface area of a sphere is $4\pi r^2$, so the electric flux is:

$$\Phi_E = E \times 4\pi r^2$$

Using Gauss's law:

$$E \times 4\pi r^2 = \frac{Q}{\epsilon_0}$$

Solving for the electric field E:

$$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$$

This is Coulomb's law, which states that the electric field due to a point charge is inversely proportional to the square of the distance from the charge and directly proportional to the magnitude of the charge.

b. Capacity of a Conductor:
The capacity of a conductor refers to the amount of charge a conductor can hold at a particular potential. It is also known as the electrostatic capacitance of the conductor. The unit of capacitance is the farad (F), and it is defined as the amount of charge per unit potential:

$$C = \frac{Q}{V}$$

Where: - C is the capacitance, - Q is the charge stored on the conductor, - V is the potential of the conductor.

Factors Affecting the Capacity of a Conductor: The following factors affect the capacitance of a conductor:
1. Size of the Conductor: The larger the size of the conductor (particularly the surface area), the higher the capacitance, as it can store more charge at the same potential.
2. Distance Between Conductors: The closer the conductors are to each other, the higher the capacitance, because the electric field between the conductors is stronger.
3. Dielectric Material: The material between the conductors affects the capacitance. A dielectric material with a higher relative permittivity increases the capacitance by reducing the electric field between the conductors, allowing more charge to be stored.
4. Shape of the Conductor: The shape of the conductor can also affect the capacitance. For example, the capacitance of a parallel plate capacitor depends on the area of the plates and the distance between them.

> Quick Tip
>
> The capacitance increases when the surface area of the conductor is larger or when the distance between conductors is smaller. A dielectric material between the conductors increases the capacitance.

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16. Write any three differences between electromotive force and potential difference.
OR
Write any three differences between Resistance and Specific Resistance.
Solution:

a. Differences Between Electromotive Force (emf) and Potential Difference (pd):

1. Definition: - Electromotive Force (emf): emf is the energy supplied by a source (such as a battery or generator) per unit charge to move charges through a circuit. It is responsible for driving the current in the circuit. - Potential Difference (pd): pd is the difference in electric potential between two points in a circuit. It represents the energy required to move a unit charge between two points in the circuit.

2. Cause: - Electromotive Force (emf): It is caused by an energy source like a battery or generator, where chemical, mechanical, or thermal energy is converted into electrical energy. - Potential Difference (pd): pd is caused by the resistance in the circuit and represents the work done by the electric field to move charges.
3. Measurement: - Electromotive Force (emf): emf is measured in volts (V), and it is the work done per unit charge to move the charge through the complete circuit (when no current is flowing). - Potential Difference (pd): pd is also measured in volts (V), and it is the work done per unit charge between two points in a closed circuit (when current is flowing).

b. Differences Between Resistance and Specific Resistance:

1. Definition: - Resistance (R): Resistance is the opposition that a material offers to the flow of electric current. It depends on the material, shape, and size of the conductor. - Specific Resistance (Resistivity, ρ): Specific resistance, or resistivity, is a property of the material that quantifies its intrinsic resistance to electric current. It is independent of the size and shape of the conductor.
2. Formula: - Resistance (R): The formula for resistance is given by $R = \rho\frac{L}{A}$, where L is the length of the conductor, A is the cross-sectional area, and ρ is the specific resistance (resistivity). - Specific Resistance (Resistivity, ρ): Resistivity is represented by $\rho = R\frac{A}{L}$, where R is the resistance, A is the area, and L is the length of the conductor.
3. Units: - Resistance (R): The unit of resistance is ohms (Ω). - Specific Resistance (Resistivity, ρ): The unit of specific resistance is ohm-meter ($\Omega\,\mathrm{m}$).

Quick Tip

The resistance depends on the material's resistivity, the length of the conductor, and the cross-sectional area. Resistivity is an intrinsic property of materials and is independent of size and shape.

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17. Write the differences between intrinsic semiconductor and extrinsic semiconductor.
OR
What is P-N junction diode? Describe its use as a full wave rectifier with diagram.
Solution:

a. Differences Between Intrinsic and Extrinsic Semiconductor:

1. Definition:
- Intrinsic Semiconductor: An intrinsic semiconductor is a pure semiconductor in which the number of electrons is equal to the number of holes. It does not have any impurities added to it and has relatively low conductivity. Silicon and germanium in their pure forms are examples.
- Extrinsic Semiconductor: An extrinsic semiconductor is a semiconductor that has been doped with impurities to alter its electrical properties. It has either extra electrons (n-type) or extra holes (p-type) and has higher conductivity than intrinsic semiconductors.

2. Conductivity:
- Intrinsic Semiconductor: The conductivity of intrinsic semiconductors is low because they have very few charge carriers.
- Extrinsic Semiconductor: The conductivity of extrinsic semiconductors is higher than intrinsic semiconductors due to the addition of impurities, which provide free charge carriers (electrons or holes).

3. Doping:
- Intrinsic Semiconductor: Intrinsic semiconductors are pure materials and are not doped with any foreign elements.
- Extrinsic Semiconductor: Extrinsic semiconductors are doped with foreign elements to increase the number of free charge carriers. Doping can create n-type or p-type semiconductors.

4. Charge Carriers:
- Intrinsic Semiconductor: In intrinsic semiconductors, the charge carriers (electrons and holes) are generated purely by thermal excitation.
- Extrinsic Semiconductor: In extrinsic semiconductors, the charge carriers (electrons in n-type and holes in p-type) are supplied by the dopant atoms.

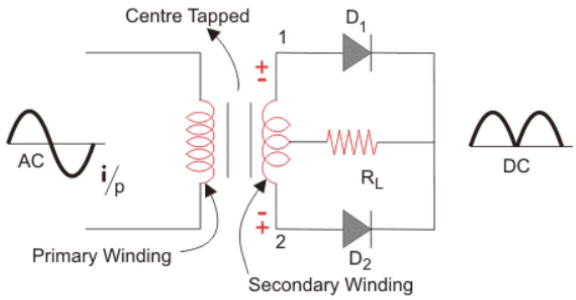
b. P-N Junction Diode and its Use as a Full-Wave Rectifier:

A P-N junction diode is a semiconductor device formed by joining a p-type material (which has an excess of holes) and an n-type material (which has an excess of electrons). The junction between these two materials is called the P-N junction. The P-N junction diode allows current to flow in one direction (forward bias) and blocks current in the opposite direction (reverse bias), making it useful in rectification.

Working as a Full-Wave Rectifier:
A full-wave rectifier uses both halves of the input AC signal, making it more efficient than a half-wave rectifier. It typically uses two diodes in a bridge configuration to convert the AC signal into a pulsating DC signal.

Working Principle:
1. In the positive half cycle of the input AC signal, current flows through the P-N junction diodes in the direction that allows the current to pass through the load resistor. This results in a positive voltage across the load.
2. In the negative half cycle of the AC input, the diodes conduct in the opposite direction, but due to the arrangement, current still flows through the load resistor, maintaining the same direction of current. This results in a continuous DC output.

The diagram below shows a simple full-wave rectifier circuit with a P-N junction diode:



Quick Tip

In a full-wave rectifier, both positive and negative cycles of the input AC are utilized, making it more efficient in converting AC to DC compared to a half-wave rectifier.

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18. Derive an expression for the refractive index of a glass prism.
OR
Derive the lens maker formula for thin lenses.
Solution:

a. Expression for the Refractive Index of a Glass Prism:
The refractive index μ of a glass prism can be derived using the angle of deviation δ and the prism angle A.

The formula for the refractive index μ of the prism is given as:

$$\mu = \frac{\sin\left(\frac{A+\delta}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Where:
- A is the angle of the prism,
- δ is the angle of deviation for a ray passing through the prism.

This formula relates the refractive index of the prism material to the angle of the prism and the deviation of the light passing through it.

The derivation of this formula involves considering the geometry of the light passing through the prism, including the angle of incidence, refraction, and the relationship between these angles for different media.

b. Lens Maker Formula for Thin Lenses:
The lens maker's formula gives the relationship between the focal length f of a lens and the radii of curvature R_1 and R_2 of the lens surfaces. The formula is given as:

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

Where:
- f is the focal length of the lens,
- μ is the refractive index of the lens material relative to the surrounding medium,
- R_1 is the radius of curvature of the first surface of the lens,
- R_2 is the radius of curvature of the second surface of the lens.

This formula is used to calculate the focal length of a lens based on its curvature and the refractive index of the material from which it is made.

The derivation of the lens maker's formula involves using the refraction laws at each surface of the lens and applying them to the overall geometry of the lens.

Quick Tip

For a convex lens, the radii of curvature R_1 and R_2 are positive, and for a concave lens, R_1 is negative and R_2 is positive.

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19. What is Self Inductance? Derive an expression for the self-inductance of a solenoid. Also write the factor affecting it.
OR
What is a Transformer? Describe its principle and different types of energy losses in it.
Solution:

a. Self Inductance and Expression for the Self-Inductance of a Solenoid:
Self-inductance is the property of a coil or solenoid that opposes the change in the current flowing through it. When the current in the coil changes, it induces an electromotive force (emf) that opposes the change in current, according to Lenz's Law. The self-inductance of a coil or solenoid depends on the geometry of the coil and the material within it.

The self-inductance L of a solenoid is given by the formula:

$$L = \frac{\mu_0 N^2 A}{l}$$

Where:
- μ_0 is the permeability of free space ($4\pi \times 10^{-7}$ H/m),
- N is the number of turns of the solenoid,
- A is the cross-sectional area of the solenoid,
- l is the length of the solenoid.

This expression shows that the self-inductance is directly proportional to the number of turns squared and the cross-sectional area, and inversely proportional to the length of the solenoid.

Factors Affecting Self-Inductance:
The self-inductance of a solenoid depends on the following factors:
1. Number of Turns (N): Increasing the number of turns increases the self-inductance, as more loops of wire generate a greater magnetic field.
2. Area of Cross-Section (A): The larger the cross-sectional area of the solenoid, the greater the self-inductance, because a larger area allows a stronger magnetic field.
3. Length of the Solenoid (l): The self-inductance is inversely proportional to the length of the solenoid. A longer solenoid will have a lower self-inductance.
4. Permeability of the Core Material (μ): The presence of a magnetic material as the core increases the inductance. The permeability of the core material (μ) influences how much magnetic flux is generated for a given current.

b. Transformer and Energy Losses:
A transformer is an electrical device used to change the voltage level in an alternating current (AC) circuit. It works on the principle of electromagnetic induction and operates based on Faraday's law of induction. A transformer consists of two coils, the primary coil and the secondary coil, wound around a common core.

Principle:
When an alternating current flows through the primary coil, it generates a changing magnetic flux. This changing magnetic flux induces a voltage (emf) in the secondary coil due to electromagnetic induction. The voltage induced in the secondary coil depends on the ratio of the number of turns in the primary and secondary coils:

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

Where:
- V_1 and V_2 are the voltages in the primary and secondary coils, respectively,
- N_1 and N_2 are the number of turns in the primary and secondary coils, respectively.

This equation shows that the voltage in the secondary coil is proportional to the voltage in the primary coil by the ratio of the number of turns.

Types of Energy Losses in a Transformer:
1. Copper Losses: These losses occur due to the resistance of the wires (primary and secondary coils) through which the current flows. The power lost is given by I^2R, where I is the current and R is the resistance of the wire.
2. Core Losses (Hysteresis and Eddy Current Losses): These losses occur in the core of the transformer due to the alternating magnetic field. Hysteresis loss arises from the continuous reversal of magnetization in the core material. Eddy current loss occurs when circulating currents are induced in the core material, causing energy dissipation.
3. Stray Losses: These losses occur due to leakage flux, which does not contribute to energy transfer between the coils. Stray flux can also cause additional heating of the transformer.

Quick Tip

To improve transformer efficiency, minimize copper and core losses. This can be done by using high-quality materials for the wire and core and designing the transformer to reduce losses caused by leakage flux.
