CHAPTER 18
Electromagnetic Induction and Electromagnetic (E.M.) Waves

Student's Learning Outcomes (SLOs)

After studying this chapter, student will be able to:

- describe an experiment to demonstrate electromagnetic induction.
- use the fact that the magnitude of an induced e.m.f. is affected by the rate of change of the magnetic field or the rate of cutting of magnetic field lines, and the number of turns in a coil, to solve simple electromagnetic problems.
- use the fact that the effect of the current produced by an induced e.m.f. is to oppose the change producing it (Lenz's law).
- describe how a.c. generators work (rotating coil or rotating magnet setup) and the use of slip rings and brushes where needed.
- sketch and interpret graphs of e.m.f. against time for simple A.C. generators (including relating the position of the generator coil to the peaks, troughs and zeros of the e.m.f.).
- explain the principle of operation of a simple iron-cored transformer.
- use the terms primary, secondary coils and step-up and step-down transformer.
- use the equation $V_p / V_s = N_p / N_s$ (where P and S refer to primary and secondary) to solve problems.
- describe the deflection of an electron beam by electric fields and magnetic fields, interpret wave forms on oscilloscopes.
- state that the speed of all electromagnetic waves in: vacuum is 3.0×10^8 ms^{-1}, air is approximately the same as in a vacuum.
- explain qualitatively, how scattering of light by molecules in the air give the sky its blue colour during the day and its shades of red during sunset (use of the terms Rayleigh and Mei scattering are not required).
- state that theoretically light can also be considered to be made of massless particles that carry energy and momentum called 'photons'.
  (Students should know as an example of this particle nature, light exerts pressure on objects (very slight) and this has been used by satellites that have 'solar sails' that accelerate with the help of force from light rays.)

Subjective Type Questions

Long Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

Introduction

Q.1: How electricity can be created without a battery in daily life?

Ans. When a magnet moves near a wire, it produces electricity, a fascinating process

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called electromagnetic induction. This simple idea powers huge machines like generators and even charges our phone wirelessly. But the story does not end there. These changing electric and magnetic fields can travel through space as electromagnetic (E.M) waves bringing us light, radio signals, Wi-Fi, and even microwaves that heat our food. From lighting up cities to connecting people across the world, electromagnetic induction and E.M waves are the hidden forces shaping our everyday lives.

18.1 Electromagnetic Induction

Q.2: What is electromagnetic induction? Explain it with diagram.

Ans. Electromagnetic induction:

Electromagnetic induction is the process by which a changing magnetic field produces an electric current in a conductor.

Explanation: This principle, first discovered by Michael Faraday and at the same time Joseph Henry in 1831, is fundamental to the operation of many devices such as generators, transformers, and inductors. To understand the phenomena of electromagnetic induction let us perform experiments.

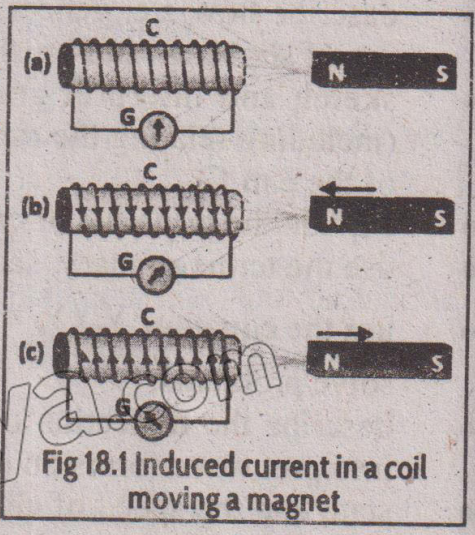


Fig 18.1 Induced current in a coil moving a magnet

Experiment: Take a coil of conducting wire, labelled C, and connect it to a galvanometer G, as shown in Fig. 18.1. First, keep the magnet still near the coil. We will notice that the galvanometer needle does not move, no electricity is produced because there is no change happening in the magnetic field. (Fig 18.1 a)

Now, move the magnet towards the coil. The galvanometer needle deflects in one direction, meaning that current is being produced (Fig. 18.1-b). Move the magnet away from the coil. This time, the galvanometer needle deflects in the opposite direction, showing the current has reversed (Fig.18.1-c).

Q.3: Explain different ways to produced induced E.M.F.

Ans. There are different ways to produce induced e.m.f. Imagine a straight wire of length (l) placed in the magnetic field of a permanent magnet as shown in Fig. 18.2.

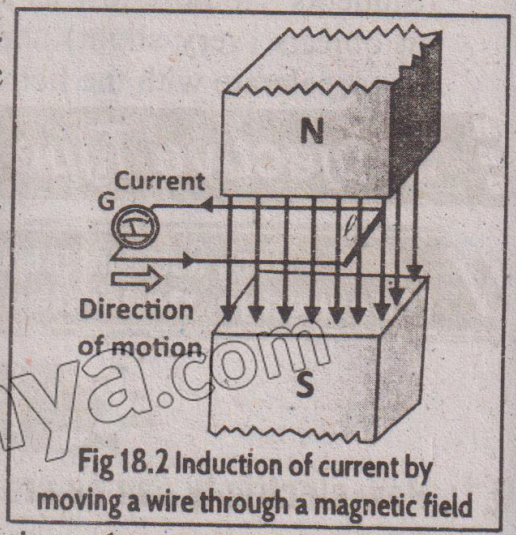


Fig 18.2 Induction of current by moving a wire through a magnetic field

This wire is connected to a sensitive galvanometer, forming a closed circuit or loop without using any battery. When the loop is still in the magnetic field, no current flows, and the galvanometer shows no deflection. But when the loop is moved from left to right, the wire cuts through the magnetic field lines, and current starts to flow through the loop. The galvanometer shows this current. When the motion stops, the current also stops. If the loop is moved in the opposite direction, the current also changes

direction, which is shown by the galvanometer deflecting in the opposite direction.

Conditions:

The amount of the induced current depends on how fast the wire is moved and the resistance in the loop. If we change the resistance of the loop by connecting different resistors and move the loop at the same speed each time, we notice that the product of the current I and resistance R always remains constant.

i.e; $\boxed{I \times R = \text{constant}}$

This constant value is the induced e.m.f. When the circuit is complete, this induced e.m.f. causes a current to flow. The induced current can be increased in the following ways:

(i) using a stronger magnetic field
(ii) moving the loop more quickly
(iii) using a coil with many turns instead of a single loop

We can also do the experiment in another way: instead of moving the loop through the magnetic field, we can keep the loop still and move the magnet. The result is the same in both cases. This shows that it is the relative motion between the loop and the magnet that creates the induced e.m.f. In simple terms, this movement changes the magnetic flux through the loop.

Q.4: State and explain magnetic flux.

Ans. Magnetic Flux:

Magnetic flux is the number of magnetic field lines passing through a certain area.

Formula:

The magnectic flux (ϕ) is given by

$$\phi = B A \cos\theta \quad .....(18.1)$$

B = Magnetic field strength

A = Area of the coil

θ = Angle between magnetic field and normal to the coil

Unit: The unit of magnetic flux is weber (Wb).

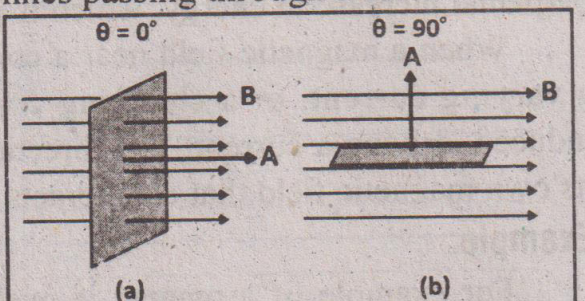


Fig 18.3: Magnetic flux through a surface (a) Maximum (b) Zero

Weber:

When a magnetic field of 1 tesla passes perpendicularly through an area of one square metre, the magnetic flux is equal to one weber.

Mathematically; 1 Wb = 1 T m^2.

Maximum magnetic flux: The magnetic flux is maximum when the angle between **B** and **A** is 0° (Fig. 18.3-a).

Minimum magnetic flux: However, when the angle between **B** and **A** is 90°, flux will be zero (Fig. 18.3-b).

Q.5: Explain Faraday's Law of Electromagnetic Induction.

Ans. Statement:

The average e.m.f induced in a conducting coil of N Loops is equal to the negative

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of the rate at which the magnetic flux is changing with time.

Formula: Mathematically, it is expressed as:

$$\varepsilon = -N\frac{\Delta\phi}{\Delta t} \quad \text{.....(18.2)}$$

Where:

ε = induced e.m.f. (in volts, V)

N = number of turns in the coil

$\frac{\Delta\phi}{\Delta t}$ = rate of change of magnetic flux

Negative sign indicates that the induced emf opposes the change of magnetic flux that produce it.

Q.6: Explain Lenz's Law, also describe magnitude and direction of induced e.m.f.

Ans. Lenz's Law is a fundamental principle in electromagnetism that describes the direction of the induced current resulting from a changing magnetic flux. It states that:

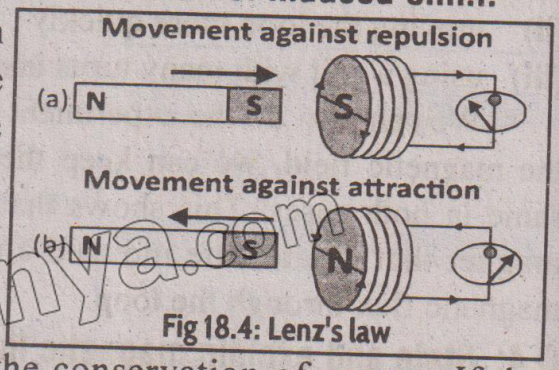


Fig 18.4: Lenz's law

Statement:

The direction of induced current is always such that it opposes the cause which produces it.

Explanation: This law is a direct consequence of the conservation of energy. If the induced current were to reinforce the change instead of opposing it, it would lead to a perpetual increase in energy, which is impossible.

When a magnetic field near a conductor changes whether due to a moving magnet, a varying current, or a changing coil orientation an electromotive force (e.m.f.) is induced, driving a current. The direction of this current is not arbitrary; it must generate its own magnetic field that counteracts the original change in flux.

Example:

For example, if a magnet is pushed toward a coil, the coil's induced current will produce a magnetic field that repels the magnet, resisting its motion (Fig. 18.4-a). Conversely, if the magnet is pulled away, the induced current will create a field that attracts the magnet, again opposing the movement (Fig.18.4-b).

18.2 A.C. Generator

Q.7: What is A.C. Generator? Explain how it is works?

Ans. A.C. Generator:

An alternating current (A.C) generator is a device that converts mechanical energy into electrical energy using electromagnetic induction.

Construction:

The most basic type includes a rectangular coil placed between the poles of a permanent magnet, as shown in Fig. 18.5(a). The coil is connected to two slip rings,

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which rotate along with the coil, while carbon brushes remain fixed and maintain contact with the sliprings to transfer the generated current.

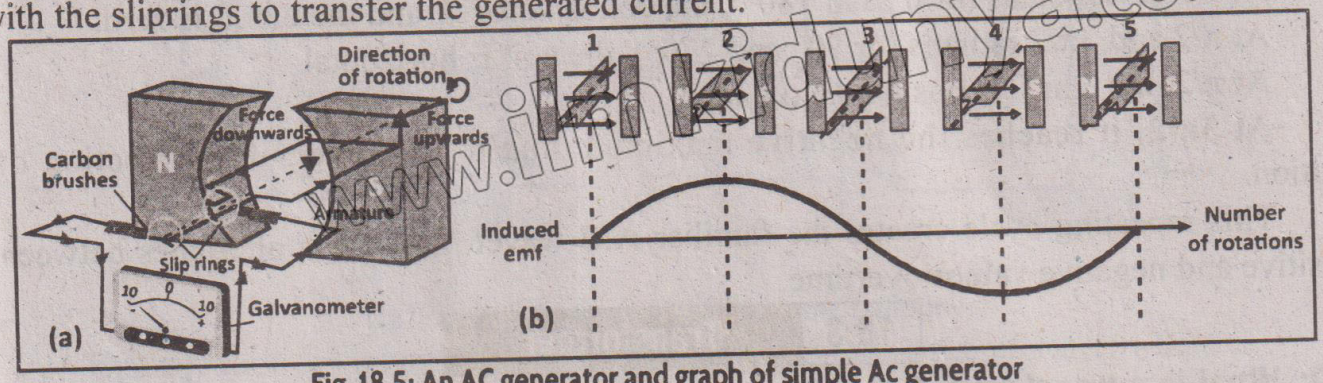


Fig. 18.5: An AC generator and graph of simple Ac generator

Explanation: As the coil rotates, it moves through the magnetic field, cutting the magnetic lines of force. This motion induces a voltage across the ends of the coil. The faster the coil rotates, the faster it cuts the magnetic field, resulting in a larger induced voltage. The induced voltage (e.m.f.) changes throughout the rotation, as shown in Fig. 18.5(b).

When the coil is vertical, it moves along the field lines, and no magnetic flux is cut. So, the induced voltage is zero. As the coil rotates and becomes horizontal, it cuts the magnetic field lines at the maximum rate, producing the maximum voltage. After a half-turn, the direction of the coil's movement through the field reverses, causing the polarity of the voltage to switch, resulting in an alternating voltage. This continuous change in direction creates an alternating current (A.C), which flows back and forth in the external circuit. The shape of the voltage graph is a sine wave, completing one full cycle in each full rotation of the coil. The number of such cycles per second is called the frequency, measured in hertz (Hz).

Example: if the coil rotates once per second, the frequency is 1 Hz, and if it rotates 50 times per second, the frequency is 50 Hz (which is the frequency of A.C mains in many countries like Pakistan).

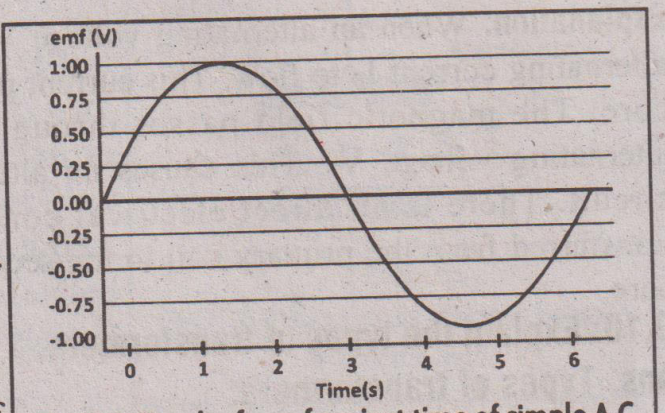


Fig 18.6: Graph of e.m.f against time of simple A.C generator

According to Faraday's law of electromagnetic induction, an e.m.f. is produced in a coil when there is a change in magnetic flux through it. The amount of e.m.f. generated depends on how fast the magnetic field is being cut by the coil.

Figure 18.6 shows how the e.m.f. varies with time during the rotation of a coil in a simple A.C generator. The graph clearly displays a sinusoidal pattern, which represents the alternating nature of the generated voltage.

Q.8: Explain the maximum value of e.m.f.

Ans. The e.m.f. reaches its maximum value when the coil is horizontal, as this is when it cuts the magnetic field lines at the highest rate. The e.m.f. becomes zero when the coil is vertical, since no magnetic flux is being cut at that position. As the coil continues to

rotate, the direction of the e.m.f. reverses every half-turn, producing alternating current.

- At 0 and π radians (or 0° and 180°), the coil is vertical, and the e.m.f. is zero.
- At $\pi/2$ and $3\pi/2$ radians (or 90° and 270°), the coil is horizontal.
- At $\pi/2$, the e.m.f. is positive maximum.
- At $3\pi/2$, it reaches the negative maximum due to the reversal in direction of motion.

This repeating cycle creates the familiar A.C waveform, which alternates between positive and negative values overtime.

18.3 Transformer

Q.9: What is a transformer? Explain the working of a transformer.

Ans. Transformer:

A transformer is a device used to increase or decrease the voltage in an alternating current (A.C) circuit.

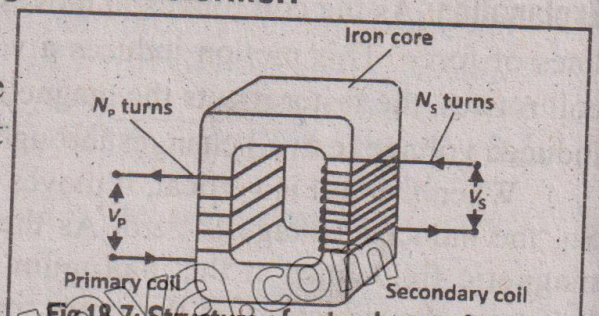


Fig 18.7: Structure of a simple transformer showing primary and secondary coils wound around an iron core

Principle:

It works without any electrical connection between its input and output coils.

Structure:

It has two coils of wire: the primary coil with N_p turns and the secondary coil with N_s turns. Both coils are wound on a soft iron core, which helps carry the magnetic field from one coil to the other.

Explanation: When an alternating voltage V_p is applied to the primary coil, it causes an alternating current I_p to flow. This current produces a changing magnetic field in the iron core. The magnetic field passes through the secondary coil, where it induces an alternating voltage V_s. This causes an alternating current I_s to flow in the secondary circuit. There is no direct electrical connection between the two coils. Energy is transferred from the primary coil to the secondary coil through the magnetic field in the core.

Q.10: Explain the types of transformers.

Ans. Types of transformers:

Transformers are used to either increase or decrease voltage in A.C circuits.

Step-up transformer: When the secondary coil has more turns than the primary coil, the transformer increases the output voltage, it is called a step-up transformer (Fig. 18.8-a).

Step-down transformer: When the secondary coil has fewer turns than the primary, the output voltage is reduced, and it is known as a step-down transformer (Fig. 18.8-b).

Equation:

This relationship between coil turns and voltages is described by the equation:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} \qquad \text{.....(18.3)}$$

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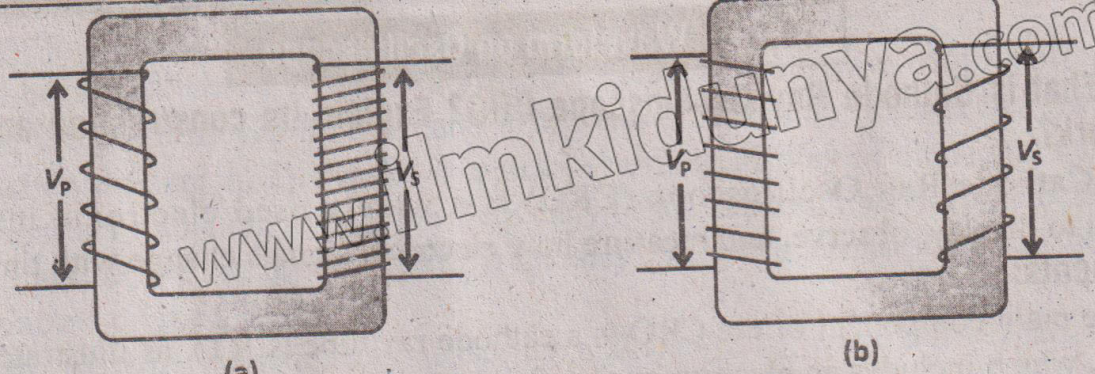


Fig 18.8: (a) Step-up and (b) Step-down tranformers

This equation is known as the turns-ratio equation for a transformer, where

V_p is the voltage across the primary coil

V_s is the voltage across the secondary coil

N_p is the number of turns in the primary coil

N_s is the number of turns in the secondary coil

This equation shows that the voltage ratio is directly proportional to the number of turns in the coils. For example, if the primary has 5 turns and the secondary has 10 turns, the output voltage will be twice the input

18.4 Deflection of Electron Beam in Electric and Magnetic Fields

Q.11: Explain the deflection of Electron Beam in Electric and Magnetic Fields.

Ans. The direction of electron beam or cathode rays can be changed by electric and magnetic field.

Deflection by Electric Field:

The cathode rays generated from an electron gun are negatively charged electrons moving with high speed. Each negatively charged electron in cathode ray beam is attracted by the positive electrode and is repelled by the negative electrode. Thus, we can say that cathode rays are deflected toward positive electrode in the presence of electric field, as shown in Fig. 18.9.

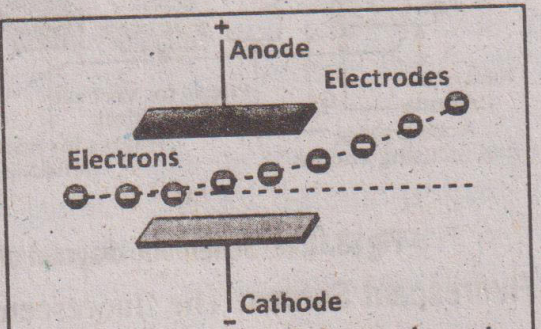


Fig 18.9: Deflection of electron beam in an electric field

Deflection by Electric Field:

A magnetic field exerts force on electrically charged particles that are in motion. Cathode rays generated from an electron gun are a stream of negatively charged electrons. Electrons, while passing through the magnetic field, are deflected as shown in Fig. 18.10. To determine the direction of force and thus the deflection of the electron beam, the Fleming's left-hand rule can be used.

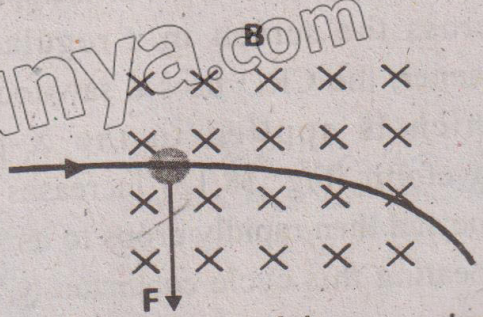


Fig 18.10: Deflection of electron passing through uniform manetic field

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Q.12: What is Cathode Ray Oscilloscope CRO? Explain its construction and how it work?

Ans. A Cathode Ray Oscilloscope (CRO) is a widely used electronic instrument designed to display, observe, and measure how electrical signals change with time.

Components:

The main component of the CRO is a cathode ray tube (CRT), as illustrated in Fig. 18.11(a), which includes an electron gun, deflecting system, and a fluorescent screen.

Electron Gun: The electron gun generates a focused beam of electrons. It contains a heated filament F that heats the cathode C, causing it to emit electrons. These electrons are then accelerated and focused by three anodes placed at high positive potential. A control grid G, kept at a negative potential, controls how many electrons reach the screen and thus adjust the brightness of the spot formed. Once accelerated, the electron beam enters the deflecting system.

Deflection system: The deflection system consists of two pairs of plates: the Y-plates, which control vertical movement (up and down) based on the input signal, and the X-plates, which control horizontal movement (left to right).

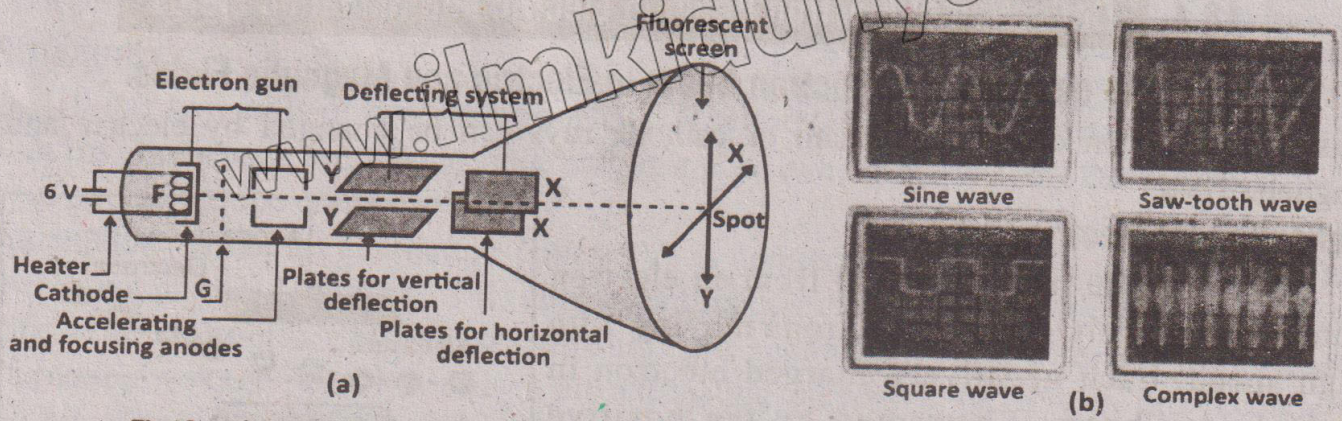


Fig 18.11: (a) Schematic diagram of CRO (b) Different waveforms displayed on a CRO screen

Fluorescent Screen: The fluorescent screen is coated with a material that glows when the electron beam strikes it. As the beam strikes different points on the screen, it leaves a visible trace, allowing the waveform of the signal to be seen. To move the spot horizontally across the screen in a regular time-based manner, the CRO uses a saw-tooth waveform, which is applied to the X-plates. This waveform (Fig. 18.12) increases steadily over time and then rapidly drops to its starting value, repeating this cycle continuously. This pattern of voltage, called a saw-tooth wave, causes the electron beam to sweep from left to right and then drops to zero. This motion creates a time axis on the screen, enabling the CRO

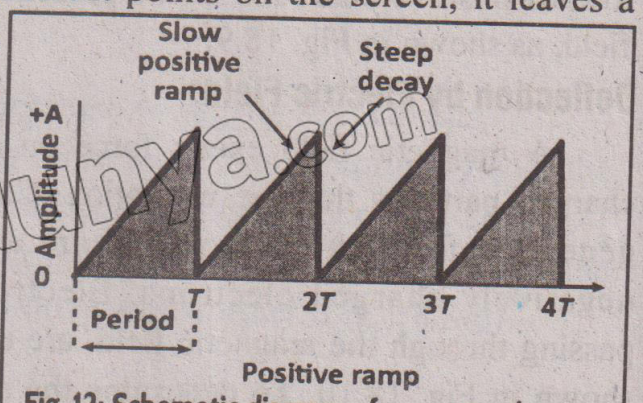


Fig. 12: Schematic diagram of a saw-tooth wave

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to display how the signal changes overtime.

When a sine wave is applied to the Y-plates and a saw-tooth voltage to the X-plates, the beam moves both up and down and side to side, tracing the waveform of the signal on the screen. The result is a clear, real-time display of the signal's shape. The display appears stable only when the frequency of the sawtooth wave (time base) is equal to or a multiple of the input signal's frequency. This synchronization can be adjusted using controls on the CRO.

CROs are extremely useful for measuring and analyzing electrical signals. They can show the waveform of a signal, measure its amplitude, determine its time period and frequency, and even allow comparison of two signals to measure their phase difference. For instance, if two waveforms are displayed together and one rises while the other falls, they may be out of phase by 180°, which can be easily observed on the screen.

Uses: A cathode ray oscilloscope is an essential tool in electronics, physics, and medical diagnostics. It uses electron beams, deflecting plates, and a fluorescent screen to visually represent electrical signals. The inclusion of a saw-tooth wave in its time base is important, as it ensures that the electron beam sweeps across the screen at a constant rate, making accurate and stable signal display possible.

18.6 Scattering of Light in the Atmosphere

Q.13:How does the scattering of sunlight cause the sky to appear blue during the day and red at sunset? Explain.

Ans. Principle:

We are ever wondered why the sky is blue during the day and turns reddish at sunset. This beautiful phenomenon is caused by scattering of sunlight in the Earth's atmosphere.

Explanation: Sunlight is made up of all the colours of the visible spectrum; red, orange, yellow, green, blue, indigo, and violet. As this light passes through the atmosphere, it interacts with tiny gas molecules. Blue light, having a shorter wavelength, scatters more easily than red or green light. As shown in Fig. 18.13, during daytime, this scattered blue light reaches us from all directions, making the sky appear blue.

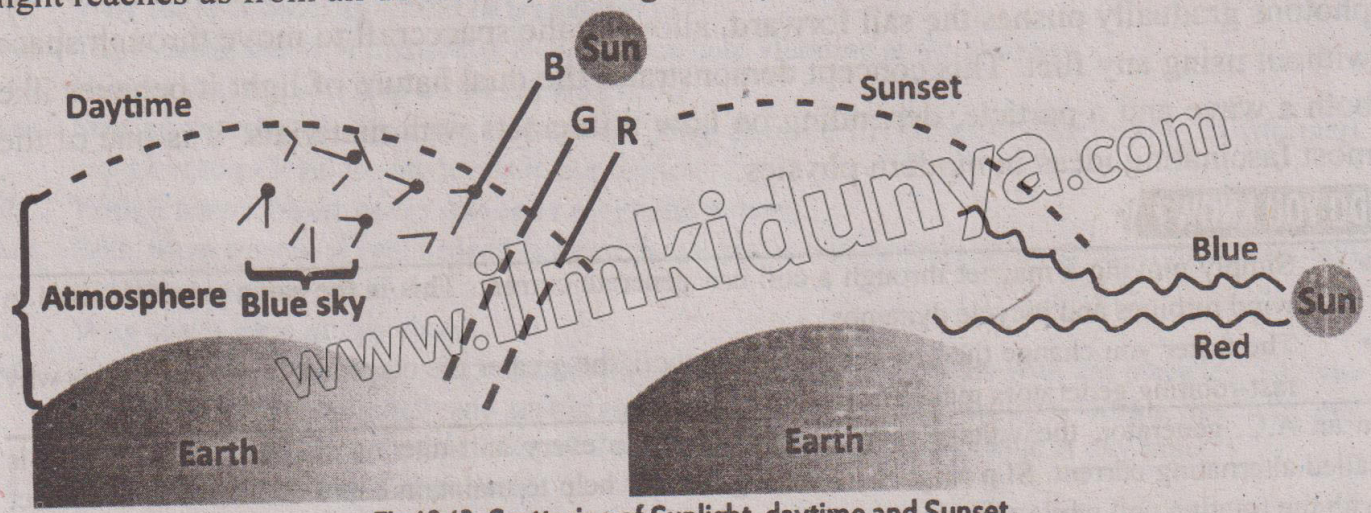


Fig 18.13: Scattering of Sunlight daytime and Sunset

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During sunrise or sunset, the sunlight has to pass through a longer path in the atmosphere. By the time the light reaches us, much of the blue light has already been scattered out of the path. What remains are the longer wave lengths like red and orange, which scatter less. These colours dominate the sky near the horizon, giving it the warm, reddish hues we often see in the evening.

Factors such as dust, pollution, and water droplets in the atmosphere can make the sunset even more dramatic by enhancing the scattering of certain colours, leading to deep reds and purples.

18.7 Particle Nature of Light

Q.14:Explain how light intract with matter in situation where wave theory falls short?

Ans. Particle nature of light:

Light is commonly known to behave as a wave, but it also has a particle-like natu[illegible].

Explanation:

According to modern physics, light can be viewed as a steam of massless particles known as photons. These photons carry energy and momentum, even though they have no rest mass. This idea helps explain how light interacts with matter in situations where wave theory falls short.

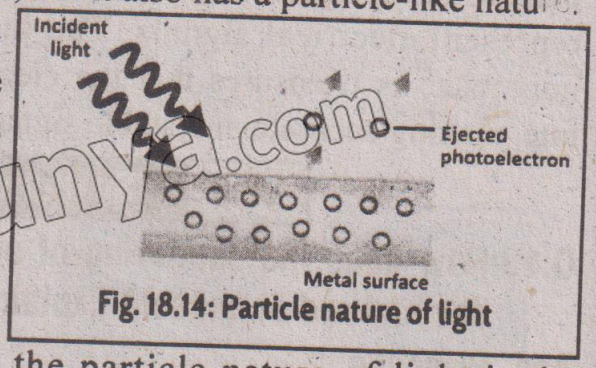


Fig. 18.14: Particle nature of light

Evidence: One important piece of evidence for the particle nature of light is the photoelectric effect, shown in Fig. 18.14. When light shines on a metal surface, it can transfer energy to electrons. If the energy is high enough, electrons are ejected from the surface, these are called photoelectrons. This effect proves that light energy comes in packets (photons), and not as a continuous wave.

Example: Another example is radiation pressure light can exert a tiny force when it hits an object. Thought the force is very small, it has real-world applications. For instance, solar sails on some spacescrafts are designed to reflect sunlight. The momentum of the photons gradually pushes the sail forward, allowing the spacecraft to move through space without using any fuel. This concept demonstrates the dual nature of light it behaves like both a wave and a particle, depending on how it interacts with materials. It is one of the most fascinating ideas in modern physics.

DO YOU KNOW?

- Simply moving a magnet through a coil can generate current. This is the same principle used in wind turbines and bicycle dynamos.
- The faster you change the magnetic field in a coil, the greater the current it produces, this is why fast-rotating generators make strong current.

In an A.C. generator, the voltage reverses direction with every half-turn of the coil that is why it is called alternating current. Slip rings in an A.C. generator help to maintain continuous electrical contact with the rotating coil while allowing current to alternate naturally.

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The buzzing sound in transformers is due to the iron core vibrating at 50 or 60 Hz. This vibration is caused by varying magnetic field and not by electricity directly.

Tidbits

The faster we move a magnet through a coil, the greater the voltage (e.m.f.) is induced.

A generator works by spinning a coil in a magnetic field, creating electricity powering cities.

Step-up transformers increase voltage for long-distance transmission, while step- down transformers reduce it to safe levels in our home.

The sky is not blue, it is violet. But our eyes perceive scattered violet + blue as blue. Sunsets are red because blue light gets scattered away over long distances.

Brain Teaser

1. If we stop moving a magnet near a coil, what happens to the induced current?

Ans. If we stop moving a magnet near a coil, then the induced current stops (i.e. drops to zero).

2. Which travels faster radiowaves or gamma rays? Why?

Ans. They travel at the same speed because they are both electromagnetic waves.

3. Why does the sky appear blue during the day but red at sunset?

Ans. The sky appears blue during the day due to rayleight scattering of blue light by atmospheric particles. At sunset, sunlight travels through more of the atmosphere, scattering away most of the blue light, leaving the longer wavelengths like red and orange to dominate.

4. How can electricity produce by magnet?

Ans. Simply moving magnet through a coil produce electricity.

5. Is speed of moving magnet affect current?

Ans. The faster you change the magnet through coil, stronger electricity produce.

6. If we stop moving a magnet near a coil, what happened to induced current?

Ans. When magnet stop moving through coil current will be zero.

7. How generator works simply and where this current used?

Ans. A generator work by spinning a coil in a magnetic field.
This electricity used in powering cities.

8. In A.C genrator why current is called A.C current.

Ans. The voltages reverses direction with every half turn of the coil that is why it is called alternating current.

9. What does slip ring do in A.C generator?

Ans. It helps in maintain continous electrical contact with rotating coil while allowing current to alternate naturally.

10. Why there is buzzing sound in transformer?

Ans. The buzzing sound in trnsformer is due to iron core vibrating at 50 or 60 Hz.

11. Uses of step up and step down transformer?

Ans. Step-up transformers increase voltage for long distance transmission. Step-down transformers reduce voltage level to safe levels in our homes.

12. Which travel faster radio waves or magnetic waves.

Ans. Both wave travels at same speed because radio waves and gamma rays are electromagnetic rays and travel at same speed.

13. Why sun is blue at day time?

Ans. The sky is not blue, As this light passes through atmosphere it interact with gas particles. So, blue light have short wavelength and scatter more easily then red or green light. during day time, this scattered blue light reached us from all direction that's why sky looks blue at day time.

14. Why does sky look red at sunset?

Ans. During sunrise or sunset, light passes through a longer path in which blue light has been scattered

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and what left is red or orange. These two colors dominate sky at horizon time giving warm reddish look at sunset.

Examples

18.1 A coil with 25 turns experiences an induced emf of 2.5 V for 0.20 s. Assuming the e.m.f. is constant during this interval, calculate the total change in magnetic flux ($\Delta\phi$) through the coil.

Solution:

Given that;

Numbers of turns N = 25

Induced emf ε = 2.5 V

Time interval Δt = 0.20 s

To find; Change in flux $\Delta\phi$ = ?

Using the formula: $$\varepsilon = \frac{(N \times \Delta\phi)}{\Delta t}$$

Rearranging to solve for $\Delta\phi$:

$$\Delta\phi = (\varepsilon \times \Delta t) / N$$

$$\Delta\phi = (2.5\ V \times 0.20\ s) / 25$$

$$\Delta\phi = 0.5\ Vs / 25$$

$$= 0.02\ Wb$$

18.2 Electricity is transmitted at a voltage of 20,000 V with a current of 5 A through power cables that have a resistance of 10 Ω. Calculate the power loss in the cables?

Solution:

Given that;

Voltage V = 20,000 V

Current I = 5 A

Resistance R = 10 Ω

To find;

Power loss P = ?

We know that;

Power loss $P = I^2 R$

Substituting the values

$$P = (5)^2 \times 10$$

$$P = 25 \times 10$$

$$P = 250\ W$$

The power loss in the cables is 250 W.

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Objective Type Questions

Additional MCQ's

Multiple Choice Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

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18.1 Electromagnetic Induction

1. **Electricity created without battery this phenomenona is known as:**
   (a) electrical induction (b) electromagnetic induction
   (c) both (a) and (b) (d) none
2. **Electromagnetic induction firstly discovered by:**
   (a) Michael Faraday (b) Joseph Hanry
   (c) both at same time (d) none of them
3. **In electromagnetic induction when magnet move toward the coil galvanometer needles moves:**
   (a) in one direction (b) still constant
   (c) in opposite direction (d) none
4. **The amount of induced current depends on:**
   (a) movement of wire and resistance (b) resistance
   (c) movement of wire (d) none
5. **In what condition induced e.m.f value constant.**
   (a) when circuit is complete (b) when resistance add in circuit
   (c) when wire move in circuit (d) both (b) and (c)
6. **The current can be increased in electromagnetic induction:**
   (a) remain wire constant (b) by adding loops in coil
   (c) using weaker magnet (d) none
7. **If we stop moving magnet near a coil:**
   (a) current will increase (b) curent will decrease
   (c) current become zero (d) remain cosntant

18.2 A.C. Generator

8. **A generator works by:**
   (a) spinning coil in a magnetic field (b) by voltage reverse
   (c) by adding galvanometer (d) none
9. **According to Farady's Law of electromangetic induction an e.m.f is produced in a coil when:**
   (a) magnetic flux remain consant (b) magnetic flux is changing
   (c) only when magnetic flux increasing (d) none

18.3 Transformer

10. A transformer is used to:

(a) increase voltage (b) decrease voltage
(c) increase or decrease voltages (d) none

11. When secondary coil has more turns this type transformer called:

(a) step-down transformer (b) step-up transformer
(c) simple transformer (d) none

18.4 Deflection of Electron Beam in Electric and Magnetic Fields

12. Electron passing through magnetic field always move.

(a) Prependicular to force (b) Parallel to force
(c) remains straight (d) move backwrd

13. To find direction of electron used:

(a) Michael Faraday's rule (b) Joseph Henry rule
(c) Fleming's left hard rule (d) none

18.5 Waveform on Oscilloscope

14. Which rays move faster:

(a) gamma rays (b) radio rays
(c) both at same speed (d) none of them

15. Which rays are electromagnetic rays.

(a) both gamma and radio rays (b) radio rays
(c) gamma rays (d) none

Answers

1.	(b)	2.	(c)	3.	(a)	4.	(a)	5.	(c)	6.	(b)	7.	(c)
8.	(a)	9.	(b)	10.	(c)	11.	(b)	12.	(a)	13.	(c)	14.	(c)
15.	(a)												

Additional Short Questions

Short Answer Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

18.1 Electromagnetic Induction

1. Is it possible electricity can be created without battery?

Ans. Yes, It is possible. When a magnet moves near a wire, it produces electricity.

2. Benefits of electromagnetic waves?

Ans. These waves bringing us light, radio signals, wifi and even microwaves that heat food.

From lighting up cities to connecting people across the world electro magnetic

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induction shaping our daily life.

3. The amount of e.m.f depend which factors?

Ans. It depends how fast the wire is moved and resistance in loop.

4. By adding resistors in loop with constant speed product of current remain same or changed?

Ans. If we change resistance by adding resistors with same speed product of current and resistance remains constant.

$$I \times R = \text{constant}$$

5. In Farady's law negative sign indicates what?

Ans. Negative sign indicate that induced e.m.f oppose the change of magnetic flux that produce it.

6. What happened when magnet pull toward a coil in electromagnetism?

Ans. When magnet pull toward a coil the coil induced's current will produce magnetic field that repel magnet resisting the motion.

7. What happened when pull away from coil in electromagnetism?

Ans. If the magnet is pulled away, the induced current will create a field that attracts the magnet again opposing movement.

18.2 A.C. Generator

8. Why fast moving generators make strong current?

Ans. Simply moving a magnet through a coil can generate electricity. The faster you change magnetic field in a coil, the greater and stronger electricity produce.

9. In AC generator, why current called alternating current?

Ans. Because the voltage reverses direction with very half turn of the coil that's why it is called alternating current.

10. Why in AC generators no current is produced when coil is vertical?

Ans. When coil is vertical it moves along field lines and no magnetic flux is cut. So. the induced voltage is zero.

11. At what position e.m.f reached at its maximum value?

Ans. The e.m.f reaches at its maximum value. When coil is horizontal as this is when it cut the magnetic field lines at highest rate.

18.3 Transformer

12. Why we heard buzzing sound in transformers?

Ans. The buzzing sound in transformers is due to iron core vibrating at 50 or 60 Hz. This vibration is caused by varying magnetic field not electricity.

13. How many types of transformer? Write their names.

Ans. There are two types of transformers

i. Step-up transformer.

ii. Step-down transformer.

14. Why transformers used?

Ans. Transformers are used to either increase or decrease voltage in A.C circuits.

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15. What is turns-ratio equation?

Ans. $\frac{V_S}{V_P} = \frac{N_S}{N_P}$

This equation shows turns-ratio equation in transformers.

This equation shows voltage ratio is directly proportional to the number of turns in coil.

18.4	Deflection of Electron Beam in Electric and Magnetic Fields
18.5	Waveform on Oscilloscope
18.6	Scattering of Light in the Atmosphere

16. Is it possible to change the direction of electron beam?

Ans. Yes, it is possible.

The direction of electron beam can be changed by electric and magnetic field.

17. Why CRO is used?

Ans. In electronic instrument CRO is used the display, observe and measure how electrical signals change with time.

18. What is saw-tooth wave?

Ans. In CRO, (Cathode Ray Oscilloscope) this is a type of periodic wave-form in which the voltage increase linearly with time and then suddenly drops back to zero, repeating this pattern continuously. This pattern show like saw-tooth.

19. Why sky is blue during day and turn red during night?

Ans. This is because of scattering of sunlight in Earth's atmosphere.

Exercise Questions (Solved)

A. Multiple Choice Questions

☆ **Tick (✓) the correct answer.**

18.1 What happens to the induced e.m.f. in a coil if the rate of change of the magnetic field increases?

(a) Decreases (b) Remains the same

(c) Increases (d) Becomes zero

18.2 In an A.C generator, slip rings are used to:

(a) reverse current direction periodically (b) convert A.C to D.C

(c) prevent induced current (d) increase magnetic flux

18.3 The sky appears blue during the day due to:

(a) reflection of light (b) scattering of shorter wavelengths

(c) absorption of blue light (d) refraction of light

18.4 Light can be considered as massless particles called:

(a) electrons (b) protons (c) photons (d) neutrons

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18.5 In a transformer, energy is transferred from the primary coil to the secondary coil through:

(a) direct electrical connection (b) a magnetic field in the iron core

(c) electrons flowing through the core (d) heat conduction

Answers

18.1 (c) **18.2** (a) **18.3** (b) **18.4** (c) **18.5** (b)

B. Short Answer Questions

18.1 What is the direction of induced current in Lenz's law?

Ans. According to Lenz's Law the direction of induced current is such that it opposes the change in magnetic flux that produces it.

18.2 Why are slip rings used in an A.C generator?

Ans. Slip rings are used to maintain continuous contact between the rotating coil and the external circuit in an A.C. generator.

18.3 When is induced e.m.f. zero in an A.C generator?

Ans. The induced e.m.f in an A.C. generator is zero when the plane of the coil is perpendicular to the magnetic field. At this instant, the rate of change of magnetic flux is zero, resulting in zero induced e.m.f.

18.4 Why is the sky red at sunset?

Ans. At sunset, sunlight travel a longer path through the atmosphere shorter wavelength blue are scattered away and red light reaches our eyes, making the sky appear red.

18.5 What is a transformer and on what principle does it work?

Ans. A transformer is a device used to increase or decrease the voltages in an alternating current.

Principle: It works on the principle of mutual induction.

C. Constructed Response Questions

18.1 If a magnet is moved quickly into a coil, a larger e.m.f. is induced. Why does speed affect the magnitude of the induced current?

Ans. By Faraday's Law induced e.m.f depends on rate of change of magnetic flux.

- Moving magnet faster, magnetic field through the coil changes more quickly.
- Faster change in flux larger induced e.m.f.
- Larger e.m.f larger induced current.

So, speed matters because it changes how fast the magnetic field lines are being cut.

18.2 Why is an iron core used in transformers instead of wood or plastic? Explain briefly.

Ans. Iron has high magnetic permeability. This strengthens the magnetic flux linking the primary and secondary coils.

Wood and plastic are non-magnetic, so they would not help transfer magnetic flux.

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18.3 How does the concept of photons help explain the working of solar sails in space?

Ans. Photons are packets of light energy the carry momentum. When sunlight falls on solar sails, photons strike and reflect from its surface.

During reflection, they transfer momentum to the sail, producing a small pressure. This continuous pressure pushes sail forward allowing spacecraft move through space without fuel.

18.4 Why can a transformer work only on alternating current and not on direct current?

Ans. A transformer work on changing magnetic flux.

AC continuously changes direction and magnetite. This changing field induces voltage in the secondary coil.

With DC, current is constant, no changes in flux, no induced e.m.f so transformer need AC not DC.

D. Comprehensive Questions

18.1 Describe how Lenz's Law supports the law of conservation of energy. Give one real-life example to support your explanation.

Ans. See Answer Q.6.

18.2 Compare step-up and step-down transformers. Include the difference in number of turns, voltage output, and where is each used.

Ans.

Step-up Transformer	Step-down Transformer
Definition: When secondary coil has more turns than the primary coil the transformer increase voltage it is called step-up transformer.	When secondary coil has fewer than primary coil the output voltage is reduced and it is known as step-down transformer.
Number of turns: In step-up transformer secondary coil has more turns.	In step-down transformer primary coil has more turns.
Voltage: In step-up transformer output voltage is increase.	In step-down transformer output voltage is reduced.
Uses: • In power transmission and distribution. • Renewable energy system. • Industrial equipment. • Audio equipment.	• HVAC system & Lighting. • Voltage regulation and safety. • Recitifier circuits

18.3 How does the scattering of sunlight cause the sky to appear blue during the day and red at sunset? Explain.

Ans. See Answer Q.13.

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18.4 What is an oscilloscope, and how does it help in analyzing electrical signals? Describe its main components.

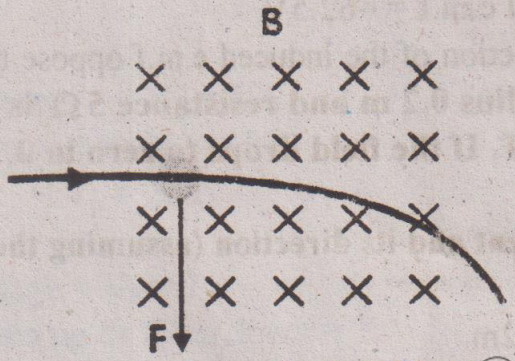
Ans. See Answer Q.12.

A cathode ray oscillscope adjusted using control on the CRO.

18.5 What is the shape of the path followed by an electron when it moves at right angles to a uniform magnetic field? Explain why.

Ans. Shape of Path: When an electron moves at right angles (perpendicular) to a uniform magnetic field it follows a circular path.

Diagram:



Explanation: When a charged partical such as an field with its velocity perpendicular to the direction of the field, it experience magnetic force known as "Lorentz force" the magnitude of the force is given by

$$F = qvB$$

where q = charge of electron
v = velocity of electron
B = magnitude of field strength

This magnetic force has some characteristics.

Direction of force: The magnetic force always act as perpendicular to the direction of motion of electrons therefore, it cannot change speed, it only change direction of electron.

Direction of motion: The direction of motion can be determined by "Fleming's left hand rule".

E. Numerical Problems

18.1 A coil consisting of 50 tightly wound turns experiences a change in magnetic flux from 0.3 Wb to 0.8 Wb over a time interval of 0.4 s. Determine the average induced electromotive force (e.m.f.) generated in the coil during this time.

Given that;

Number of turns, N = 50

Change in magnetic flux = $\Delta\phi = 0.8\text{Wb} - 0.03\text{Wb} = 0.5$ Wb

Time interval = $\Delta t = 0.4\text{s}$

To find;

induced e.m.f $\varepsilon = ?$

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Solution:

Apply Faraday's Law of electromagnetic induction:

$$\text{induced e.m.f } \varepsilon = -N\frac{\Delta\phi}{\Delta t}$$

Substitute the values:

$$\varepsilon = -50 \times \frac{0.5\text{Wb}}{0.4\text{s}}$$

$$\varepsilon = -62.5\text{V}$$

Thus, Average induced e.m.f = –62.5V

–ve sign shows the direction of the induced e.m.f oppose the change in magnetic flux.

18.2 A circular loop of radius 0.2 m and resistance 5 Ω is placed perpendicular to a magnetic field of 0.5 T. If the field drops to zero in 0.1 s, calculate:

(a) the induced emf

(b) the induced current and its direction (assuming the field points into the page)

Given that:

Radius of loop = r = 0.2m

Resistance = R = 5Ω

Magnetic field = B = 0.5T

Time interval = Δt = 0.1s

Loop is prependicular to field maximum flux

To find;

(a) induced emf, ε = ?

(b) induced current, I = ?

direction = ?

Solution:

Calculate the area of the loop:

Area of loop = $A = \pi r^2$

$$\Rightarrow A = 3.14(0.2\text{m})^2$$

$$A = 0.1257\text{m}^2$$

Calculate change in magnetic flux

$\Delta\phi = B \times A = (0.5\text{ T}) \times (0.1257\text{m}^2)$

$\Delta\phi = 0.06285$ Wb

(a) Calculate the induced emf using Faraday's Law:

$$\varepsilon = -\left(\frac{\Delta\phi}{\Delta T}\right)$$

$$\varepsilon = -\left(\frac{0.06285\text{Wb}}{0.1\text{s}}\right) = -0.6285\text{V}$$

$$\boxed{\varepsilon \approx -0.63\text{V}}$$ ***Ans.***

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(b) Calculate the induced current by using Ohm's law:

$$I = \frac{\varepsilon}{R} = \frac{0.63V}{5\Omega} = 0.126A$$

Direction of the induced current:

Since the field points into the page so the direction of induced current is clockwise.

(a) $\varepsilon \approx 0.63V$, (b) $= 0.126A$ (Clockwise direction)

18.3 A transformer has 500 primary turns and 100 secondary turns. If the primary voltage is 220 V, find: (a) secondary voltage (b) is this a step-up or step- down transformer?

Given that:

Number of primary turns $= N_p = 500$

Number of secondary turns $= N_s = 100$

Primary voltage $= V_p = 220V$

To find:

(a) Secondary voltage $= V_S = ?$

(b) Transformer step up or Step down = ?

Solution:

(a) Using the transformer equation:

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

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

$$V_s = 220 \times \frac{100}{500}$$

$$V_s = (220 \times 0.2)V$$

$$V_s = 44V \quad \textit{Ans.}$$

(b) Determine if it is a step-up or step-down transormer:

Since Vs < Vp (44V < 220V),

It is a step-down transformer.

(a) 44V

(b) Step-down ($V_s < V_p$)

18.4 A step-up transformer has a turns ratio of 2:100. If an alternating voltage of 25 V is applied to the primary coil, what will be the secondary voltage?

Given that;

Turns ratio, $N_p : N_s = 2:100$

Primary turn $= N_p = 2$

Secondaryt turns $= N_s = 100$

Primary voltage $= V_p = 25V$

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To find:

Secondary voltage = V_s = ?

Solution:

Using the transformer equation.

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

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

Substitue the values

$$= (25V) \times \frac{100}{2}$$

$$V_s = (25 \times 50)V$$

$$\boxed{V_s = 1250V}$$ ***Ans.***

18.5 A step-down transformer has a turns ratio of 100:5. If an A.C voltage of 190 V is applied to the primary coil, what is the voltage across the secondary coil?

Given that;

Turns ratio, $N_p:N_s = 100 : 5$

Primary turn $= N_p = 100$

Secondary turn $= N_s = 5$

Primary voltage $= V_p = 190V$

To find;

Secondary voltage = V_s = ?

Solution:

Using the transformer equation.

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

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

Substitue the values

$$V_s = (190V) \times \frac{5}{100}$$

$$V_s = (190 \times 0.05)\ V$$

$$\boxed{V_s = 9.5V}$$ ***Ans.***

Voltage across the secondary coil is 9.5V.

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