PHYSICS – 10

Chapter 18

ELECTROMAGNETIC INDUCTION AND ELECTROMAGNETIC (E.M.) WAVES

Key Concepts

- 1. Electromagnetic Induction
- 2. A.C. Generator
- 3. Transformer
- 4. Deflection of electron beam in electric and magnetic fields
- 5. Waveform on Oscilloscope
- 6. Scattering of light in the atmosphere
- 7. Particle nature of light

Q.1 What is an electromagnetic induction? Explain experiment to describe electromagnetic induction. How an e.m.f. is induced in a conductor placed in magnetic field? What are different ways to increase current?

Electromagnetic Induction

Definition: 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.

Experiment

- Take a coil of conducting wire, labelled C, and connect it to a galvanometer G.
- 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.
- Now, move the magnet towards the coil. The galvanometer needle deflects in one direction, meaning that current is being produced.
- Move the magnet away from the coil. This time, the galvanometer needle deflects in the opposite direction, showing the current has reversed.

Different Ways to Produce Induced e.m.f

- 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.
- 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.
- 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 the same:

$$I \times R = constant$$

This constant value is the induced e.m.f. When the circuit is complete, this induced e.m.f. causes a current to flow.

Ways to Increase Current

The 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.2 Define magnetic flux and its units.

Magnetic Flux

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

Mathematically, the magnetic flux (φ) is given by:

$$\varphi = B\,A\cos\theta \quad \text{...........} \ (18.1)$$

- 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).

Weber

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

$$1\ Wb = T\ m^{-1}$$

Factors

- The magnetic flux is maximum when the angle between B and A is 0°.
- However, when the angle between B and A is 90°, flux will be zero.

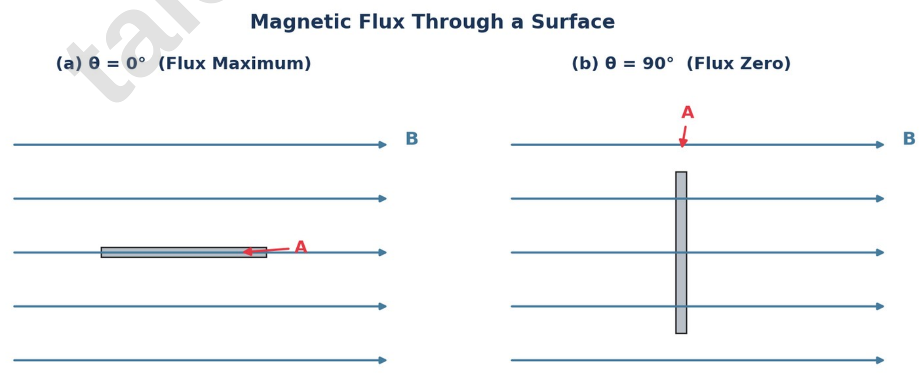

Fig 18.3: Magnetic flux through a surface (a) Maximum (b) Zero

Q.3 State and explain Faraday's law of electromagnetic induction.

Faraday's Law of Electromagnetic Induction

Statement: The change in magnetic flux through a coil induces an emf in the circuit. The magnitude of induced e.m.f. is directly proportional to the rate of change of magnetic flux.

Mathematically, it is expressed as:

$$\varepsilon = -N\, \Delta\varphi/\Delta t \quad \text{............ (18.2)}$$

- ε = induced e.m.f. (in volts, V)
- N = number of turns in the coil
- $\Delta\varphi/\Delta t$ = rate of change of magnetic flux

Negative sign indicates that the induced e.m.f. opposes the change of magnetic flux that produce it.

Q.4 State and explain Lenz's law.

Magnitude and Direction of Induced e.m.f (Lenz's Law)

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

Explanation

- Lenz's Law is a fundamental principle in electromagnetism that describes the direction of the induced current resulting from a changing magnetic flux.
- 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. 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.
- Conversely, if the magnet is pulled away, the induced current will create a field that attracts the magnet, again opposing the movement.

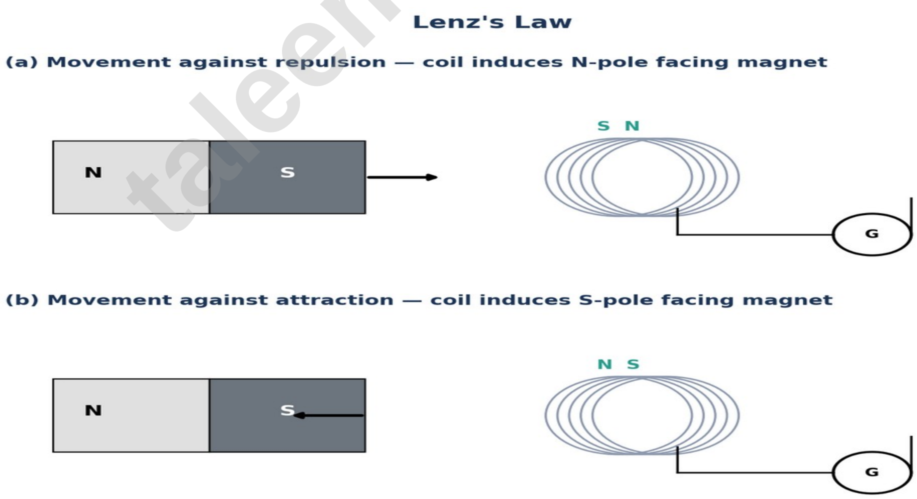

Fig 18.4: Lenz's law — movement against repulsion and attraction

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

No, current will be induced as the magnet stops its motion.

Do You Know? — How can moving a magnet through a coil generate electricity, and where is this principle applied?

Simply moving a magnet through a coil changes the magnetic field through the coil, which induces an electromotive force (e.m.f.) and generates an electric current. This principle of electromagnetic induction is used in devices like wind turbines and bicycle dynamos to produce electricity from mechanical motion.

Brain Teaser — If we stop moving a magnet near a coil, what happens to the induced current?

The induced current stops. An induced current is only produced when there is a change in the magnetic field (or magnetic flux) through the coil. When the magnet stops moving, the magnetic field through the coil is no longer changing, so the induced electromotive force (e.m.f.) becomes zero, and the current stops.

Q.5 Describe construction, principle and working of an A.C. generator.

A.C. Generator

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

1. Principle

It works on the principle of electromagnetic induction.

2. Construction

- The most basic type includes a rectangular coil placed between the poles of a permanent magnet.
- The coil is connected to two slip rings, which rotate along with the coil, while carbon brushes remain fixed and maintain contact with the slip rings to transfer the generated current.

3. Working

- 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.
- 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).
- For 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 mains electricity in many countries like Pakistan).
- 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.

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

4. Explanation of Graphical Representation

- The graph 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.
- 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 π/2, the e.m.f. is positive maximum.
- At 3π/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 over time.

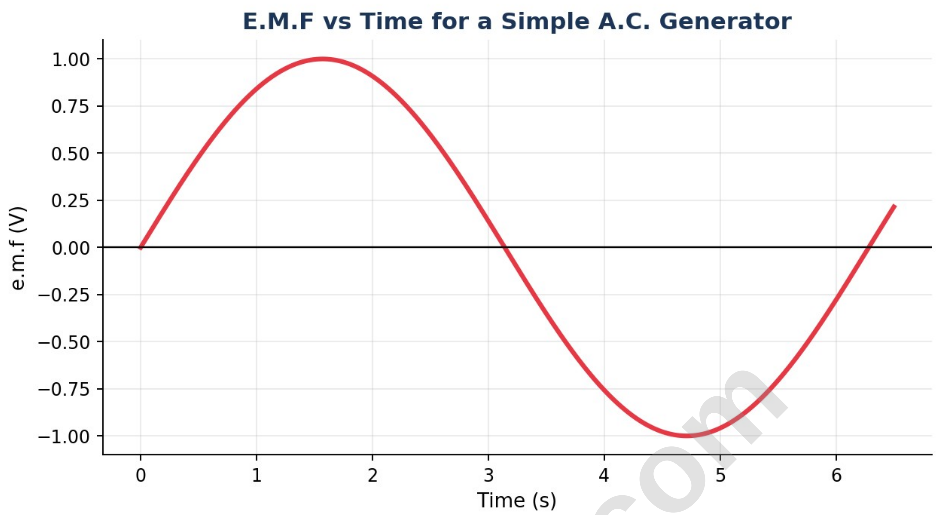

Fig 18.6: Graph of e.m.f. against time for simple A.C generator

Do You Know? — How does the speed of changing a magnetic field affect the electricity produced in a coil?

The faster you change the magnetic field in a coil (for example, by moving a magnet faster or rotating a coil more quickly), the greater the induced e.m.f. and current. This is why fast-rotating generators are used to produce stronger electric currents.

Q.6 What is a transformer? Give its principle, construction, types and operation in detail.

Transformer

Definition: A transformer is a device used to increase or decrease the voltage in an alternating current (A.C) circuit. It works without any electrical connection between its input and output coils.

1. Construction

- Figure 18.7 shows a simple transformer.
- It has two coils of wire: the primary coil with Np turns and the secondary coil with Ns turns.
- Both coils are wound on a soft iron core, which helps carry the magnetic field from one coil to the other.

2. Working

- When an alternating voltage is applied Vp to the primary coil, it causes an alternating current Ip 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 Vs. This causes an alternating current Is 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.

Do You Know? — Why does the voltage in an A.C. generator reverse direction, and what is the role of slip rings?

In an A.C. generator, the voltage reverses direction with every half-turn of the coil because the coil's motion relative to the magnetic field reverses, which is why it produces alternating current. Slip rings help maintain continuous electrical contact with the rotating coil while allowing the current to alternate naturally without interruption.

3. Types of Transformer

- In figure 18.8 (a), the secondary coil has more turns than the primary, making it a step-up transformer. This increases the voltage from the input to the output.
- In Fig. 18.8 (b), the secondary coil has fewer turns, indicating a step-down transformer that reduces the voltage.

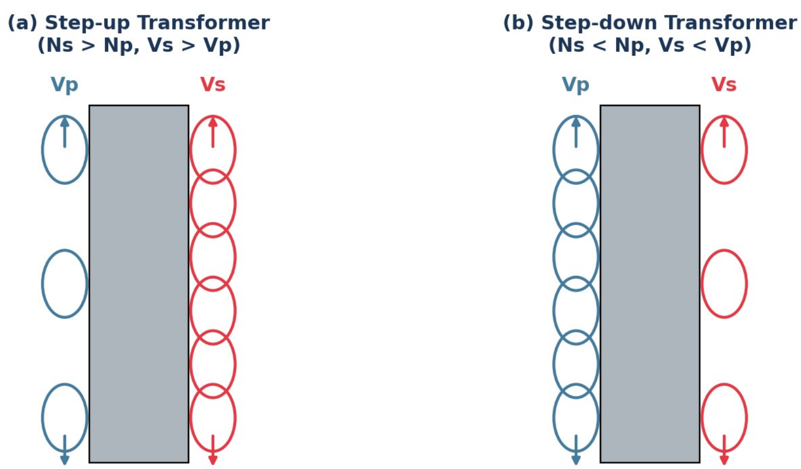

Fig 18.8: (a) Step-up and (b) Step-down transformers

4. Step-up and Step-down Transformers

- When the secondary coil has more turns than the primary coil, the transformer increases the output voltage, it is called a step-up transformer.
- Conversely, when the secondary coil has fewer turns than the primary, the output voltage is reduced, and it is known as a step-down transformer.

5. Formula or Equation

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

$$V_s / V_p = N_s / N_p \quad \ldots\ldots\ldots\ldots (18.2)$$

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

- 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.

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

Do You Know? — Why do transformers often produce a buzzing sound?

The buzzing sound in transformers is due to the iron core vibrating. This vibration is caused by the rapidly changing (alternating) magnetic field inside the core, typically at 50 or 60 Hz, and not by electricity flowing directly.

Q.7 Explain deflection of an electron beam in electric and magnetic fields.

Deflection of Electron Beam in Electric and Magnetic Fields

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

1. 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.

2. Deflection by Magnetic 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.
- To determine the direction of force and thus the deflection of the electron beam, the Fleming's left-hand rule can be used.

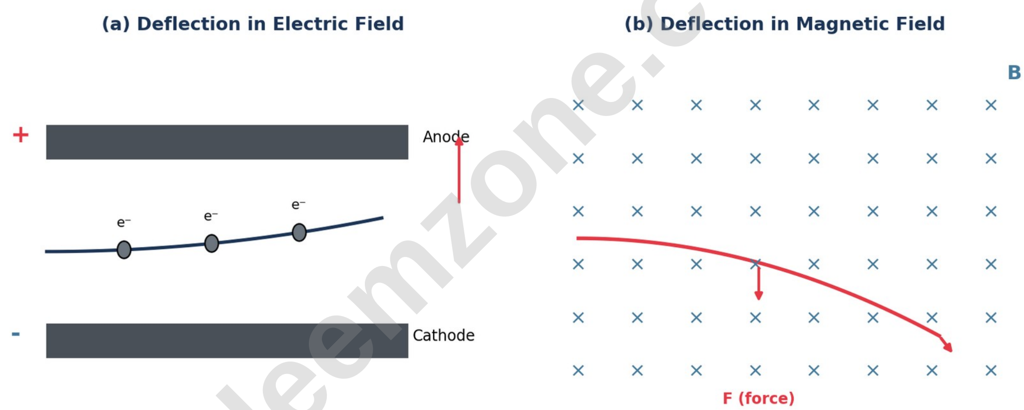

Fig 18.9 & 18.10: Deflection of electron beam in electric field and uniform magnetic field

Do You Know? — Which travels faster, radio waves or gamma rays? Why?

Both travel at the same speed. All electromagnetic waves, including radio waves and gamma rays, travel at the speed of light in a vacuum, which is 3.0×10^8 ms^{-1}. The speed is a constant property of electromagnetic waves, regardless of their type or wavelength.

Q.8 What is a C.R.O? Explain its construction and working. State its uses also.

C.R.O

Definition: A Cathode Ray Oscilloscope (C.R.O) is a widely used electronic instrument designed to display, observe, and measure how electrical signals change with time.

1. Construction

The main component of the C.R.O is a cathode ray tube (C.R.T), which includes an electron gun, deflecting system, and a fluorescent screen.

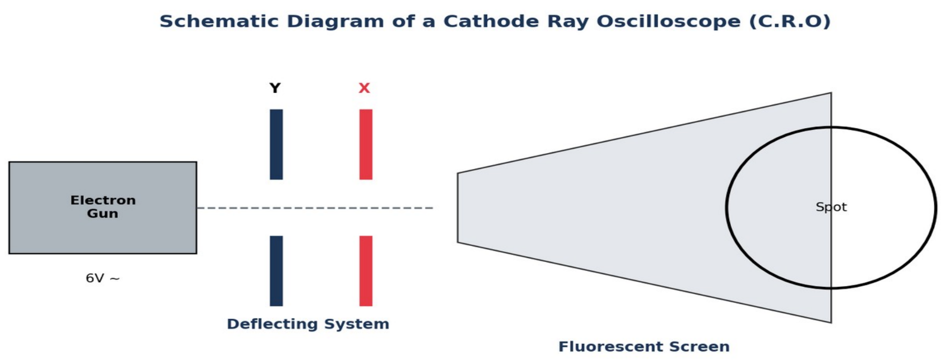

Fig 18.11: Schematic diagram of CRO

- 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.

2. Brighteners Control

- 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.
- 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).
- The fluorescent screen is coated with a material that glows when the electron beam strikes it.

3. Working

- 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 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 quickly return to the left. This motion creates a time axis on the screen, enabling the CRO to display how the signal changes over time.
- 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 saw-tooth 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.

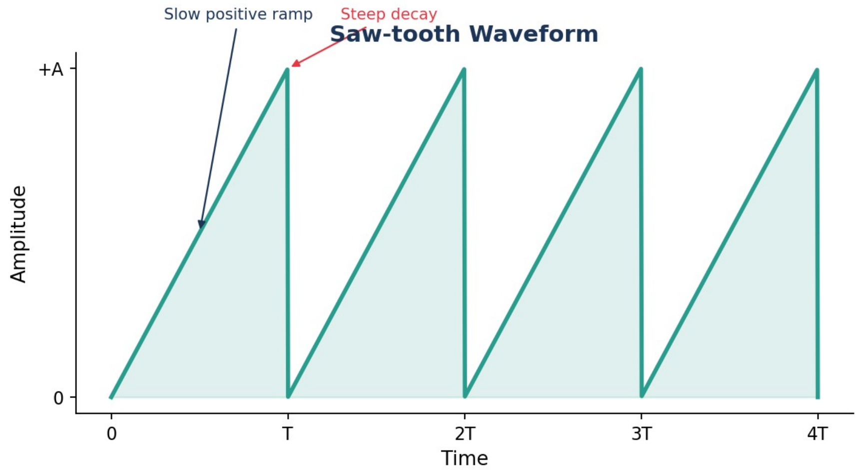

Fig 18.12: Schematic diagram of a saw-tooth wave

4. Uses

- 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.
- 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.

Q.9 Explain scattering of light in atmosphere. (OR) Why does sun appear blue during the day but red at sunset?

Scattering of Light in the Atmosphere

- 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. During daytime, this scattered blue light reaches us from all directions, making the sky appear blue.

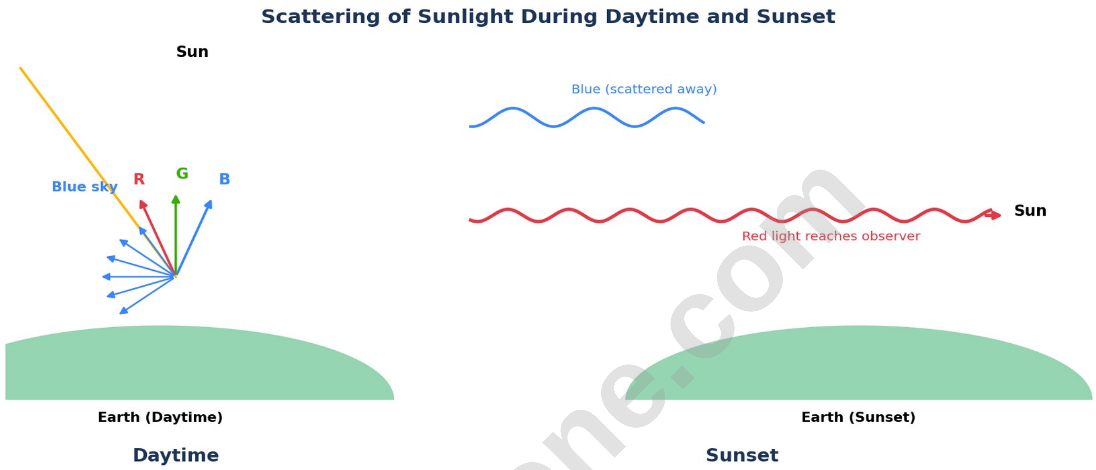

Fig 18.13: Scattering of sunlight during daytime and sunset

- 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 wavelengths 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.

Tidbit: 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.

Do You Know? — Why does the sky appear blue during the day but red at sunset?

During the day, sunlight passes through a shorter path in the atmosphere. Shorter wavelength blue light scatters more easily off air molecules, reaching our eyes from all directions and making the sky appear blue. At sunset, sunlight travels through a much longer path in the atmosphere. Most of the blue light is scattered away before reaching us, leaving the longer wavelengths (red and orange) to dominate the sky near the horizon, giving it a reddish hue.

Q.10 Explain particle nature of light.

Particle Nature of Light

- Light is commonly known to behave as a wave, but it also has a particle-like nature.
- According to modern physics, light can be viewed as a stream 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.

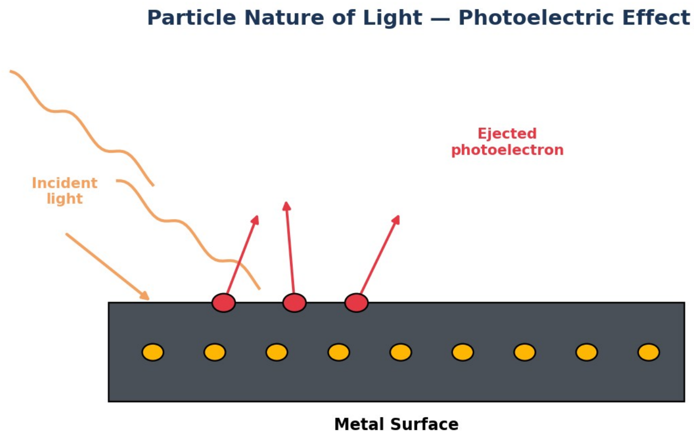

Fig 18.14: Particle nature of light — photoelectric effect

- One important piece of evidence for the particle nature of light is the photoelectric effect. 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.
- Another example is radiation pressure — light can exert a tiny force when it hits an object. Though the force is very small, it has real-world applications. For instance, solar sails on some spacecrafts 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.

Formula Sheet

#	Formula	Description
1	$\varphi = BA \cos \theta$	Magnetic flux
2	$\varepsilon = -N\, \Delta\varphi/\Delta t$	Faraday's Law
3	$V_s/V_p = N_s/N_p$	Transformer equation
4	$P = I^2R,\ \ P = VI$	Electric power

Solved Examples

Example 18.1: A coil with 25 turns experiences an induced emf of 2.5 V for 0.20 s. Assuming the emf is constant during this interval, calculate the total change in magnetic flux (Δφ) through the coil.

Solution — Given: Number of turns N = 25; Induced emf ε = 2.5 V; Time interval Δt = 0.20 s. To find: Change in flux Δφ = ?

$$\text{Using the formula: } \varepsilon = N \times \Delta\varphi/\Delta t \implies \varepsilon = (N \times \Delta\varphi)/\Delta t$$

Rearranging to solve for Δφ:

$$\Delta\varphi = (emf \times \Delta t) / N = (2.5\ V \times 0.20\ s) / 25 = 0.5/25 = 0.02\ Wb$$

Example 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: Voltage V = 20,000 V; Current I = 5 A; Resistance R = 10 Ω. To find: Power loss P = ?

$$\text{Power loss } P = I^2R = (5)^2 \times 10 = 25 \times 10 = 250\ W$$

The power loss in the cables is 250 W.

Multiple Choice Questions Exercise

#	Question	Options
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
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
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
4	Light can be considered as massless particles called:	(a) electrons (b) protons (c) photons (d) neutrons
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

Answer Key: 1-c, 2-a, 3-b, 4-c, 5-b

SLO Based Additional MCQs + Past Papers MCQs of Punjab Boards

#	Question	Options
1	Electromagnetic induction is the process of producing an electric current by:	(a) a stationary magnet near a coil (b) a changing magnetic field (c) a constant electric field (d) heating a conductor
2	According to Faraday's Law, the magnitude of the induced e.m.f. is directly proportional to the:	(a) strength of the magnet (b) number of turns in the coil (c) rate of change of magnetic flux (d) area of the coil only
3	The unit of magnetic flux is the:	(a) Tesla (T) (b) Weber (Wb) (c) Henry (H) (d) Joule (J)
4	Magnetic flux through a coil is zero when the angle between the magnetic field and the normal to the coil is:	(a) 0° (b) 45° (c) 90° (d) 180°
5	Lenz's Law states that the direction of the induced current is such that it:	(a) aids the change producing it (b) opposes the change producing it (c) is always clockwise (d) is always counter-clockwise
6	The negative sign in Faraday's Law formula ($\varepsilon = -N \Delta\varphi/\Delta t$) signifies:	(a) the induced e.m.f. is always negative (b) the induced e.m.f. opposes the change in flux (c) the number of turns is negative (d) the rate of change is decreasing

#	Question	Options
7	In an A.C. generator, the induced e.m.f. is maximum when the coil is:	(a) vertical (b) horizontal (c) at a 45° angle (d) parallel to the field
8	The frequency of the A.C. produced is 50 Hz. This means the coil rotates:	(a) 50 times per second (b) 100 times per second (c) once every 50 seconds (d) 25 times per second
9	A transformer works on the principle of:	(a) electrostatic induction (b) electromagnetic induction (c) chemical effect of current (d) heating effect of current
10	For a step-up transformer:	(a) Ns > Np and Vs > Vp (b) Ns < Np and Vs < Vp (c) Ns = Np and Vs = Vp (d) Ns > Np and Vs < Vp
11	The turns ratio equation for a transformer is:	(a) Vp/Vs = Np/Ns (b) Vp/Vs = Ns/Np (c) Vs/Vp = Np/Ns (d) Vs/Vp = Ns/Np
12	In an electric field, a beam of electrons (cathode rays) is deflected towards the:	(a) negative electrode (b) positive electrode (c) north pole (d) south pole
13	The force on a moving electron in a magnetic field can be determined using:	(a) Fleming's right-hand rule (b) Fleming's left-hand rule (c) Right-hand grip rule (d) Ohm's law
14	The part of a CRO that emits electrons is called the:	(a) fluorescent screen (b) deflecting plates (c) electron gun (d) time base
15	The saw-tooth waveform applied to the X-plates of a CRO is used to:	(a) deflect the beam vertically (b) create a time axis for horizontal sweep (c) increase the brightness (d) measure frequency directly
16	During sunset, the sky appears red because:	(a) blue light is scattered away over the longer path (b) red light is absorbed (c) the sun emits only red light (d) light is reflected by the ocean
17	Massless particles of light that carry energy and momentum are called:	(a) electrons (b) protons (c) photons (d) neutrons
18	An example demonstrating the particle nature of light is:	(a) reflection in a mirror (b) the photoelectric effect (c) refraction through a prism (d) dispersion forming a rainbow
19	The speed of all electromagnetic waves in a vacuum is:	(a) 3.0×10^5 m/s (b) 3.0×10^8 m/s (c) 3.0×10^{10} m/s (d) 3.0×10^3 m/s

Answer Key: 1-b, 2-c, 3-b, 4-c, 5-b, 6-b, 7-b, 8-a, 9-b, 10-a, 11-d, 12-b, 13-b, 14-c, 15-b, 16-a, 17-c, 18-b, 19-b

Exercise Short Questions

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

According to Lenz's law, the direction of induced current is always such that it opposes the cause which produces it. The induced current generates its own magnetic field that counteracts the change in the original magnetic flux. For example, when a magnet is pushed toward a coil, the coil's induced current produces a magnetic field that repels the magnet. When the magnet is pulled away, the induced current creates a field that attracts the magnet, opposing the movement.

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

Slip rings are used to maintain continuous electrical contact with the rotating coil. They allow current to reverse direction naturally every half rotation. This results in alternating current in the external circuit. Without slip rings, continuous A.C would not be produced.

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

The induced e.m.f. is zero in an A.C generator when the coil is in the vertical position. At this position, the coil moves along the field lines and does not cut any magnetic field lines. Therefore, no change in magnetic flux occurs, resulting in zero induced e.m.f.

18.4 Why is the sky red at sunset?

During sunset, sunlight travels through a longer path in the atmosphere to reach the observer. Most of the blue light is scattered away before reaching the observer. Red and orange wavelengths scatter less and reach the eyes. Therefore, the sky appears red near sunset.

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

Transformer: A transformer is a device used to increase or decrease A.C voltage. Working Principle: It works on the principle of mutual induction. A changing current in the primary coil produces a changing magnetic field. This magnetic field passes through the secondary coil and induces an e.m.f. in the secondary coil.

SLO Based Additional Short Questions + Past Papers Short Questions of Punjab Boards

Q.1 Define electromagnetic induction.

Electromagnetic induction is the phenomenon of producing an induced e.m.f. in a conductor. It occurs when the magnetic flux linked with the conductor changes. This change may be due to relative motion between magnet and conductors. As a result, an induced current flows in the circuit. The process of generating an induced current in a circuit by changing the number of magnetic lines of force passing through it.

Q.2 What happens when a magnet is kept stationary inside a coil?

When the magnet is stationary inside the coil, no current is induced. This is because there is no change in magnetic flux. The galvanometer shows no deflection. Induced e.m.f. exists only when flux changes.

Q.3 How does the speed of a moving magnet affect induced current?

When the magnet is moved faster, induced current increases. Fast motion causes a rapid change in magnetic flux. According to Faraday's law, induced e.m.f. depends on rate of change of flux. Hence, higher speed produces larger current.

Q.4 Define magnetic flux and state its unit.

Magnetic flux is the total number of magnetic field lines passing through a surface area. It depends on magnetic field strength, area, and orientation. Its unit is weber (Wb).

Q.5 State Faraday's law of electromagnetic induction.

Faraday's law states that induced e.m.f. is produced in a circuit. It is directly proportional to the rate of change of magnetic flux. Greater flux change produces greater induced e.m.f. This law explains the principle of generators. Mathematically: $\varepsilon = -N \times d\varphi/dt$

Q.6 Why is Lenz's law important in electromagnetic induction?

Lenz's law determines the direction of induced current. It states that induced current opposes the change producing it. This opposition maintains conservation of energy. Thus, it prevents energy creation without work.

Q.7 What happens according to Lenz's law when a magnet is pushed into a coil?

When a magnet is pushed into a coil, induced current flows. The current produces a magnetic field opposing the magnet's motion. This opposition resists the entry of the magnet. Thus, Lenz's law is satisfied.

Q.8 Define an A.C generator.

An A.C generator is a device that converts mechanical energy into electrical energy. It produces alternating current using electromagnetic induction. The direction of current changes periodically. It is commonly used in power stations and home supply.

Q.9 When is induced e.m.f. maximum in an A.C generator?

Induced e.m.f. is maximum when the coil is parallel to the magnetic field. At this position, the rate of change of magnetic flux is greatest. Maximum field lines are cut by the rotating coil. Hence, e.m.f. attains its peak value.

Q.10 Define a transformer.

Transformer: A transformer is a device used to increase or decrease A.C voltage. It works on the principle of electromagnetic induction. Energy is transferred through a magnetic field. It cannot operate on direct current.

Q.11 Why does a transformer not work on D.C?

A transformer requires a changing magnetic field. D.C produces a constant magnetic field. No change in flux means no induced e.m.f. Therefore, transformers cannot work on D.C.

Q.12 What is the function of deflecting plates in a CRO?

Deflecting plates control the movement of the electron beam. Y-plates produce vertical deflection of the beam. X-plates provide horizontal movement. Together, they help display waveforms on the screen.

Q.13 Why does blue light scatter more than red light?

Blue light has a shorter wavelength. Shorter wavelengths scatter more easily in the atmosphere. Air molecules scatter blue light strongly. This causes the sky to appear blue.

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?

A larger e.m.f. is induced when the magnet is moved faster. Reason: When a magnet moves quickly, the magnetic flux through the coil changes more rapidly. According to Faraday's law, $\varepsilon = -N\, \Delta\varphi/\Delta t$. Hence induced e.m.f. is proportional to this rate. Hence, higher speed produces a larger induced current.

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

Reason: Iron is a ferromagnetic material that has high magnetic permeability, allowing magnetic field lines to pass through it easily and with minimal loss. Wood and plastic are non-magnetic materials that do not support magnetic field propagation effectively. Without an effective iron core, most of the magnetic field would leak away, making the transformer inefficient.

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

Ans. Photons carry momentum even though they have no rest mass. When photons from sunlight hit a reflective solar sail, they transfer momentum to it. Reason: According to the particle nature of light, light consists of massless particles called photons that carry both energy and momentum. When these photons strike and reflect off a solar sail, they impart momentum to it. Though the force is very small, accumulated momentum from billions of photons gradually pushes the spacecraft forward, allowing it to accelerate through space without using fuel.

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

Ans. A transformer works only with A.C. Reason: A.C produces a continuously changing magnetic field. This changing field induces e.m.f. in the secondary coil. Direct current produces a constant magnetic field that does not change with time. As a result, no e.m.f. induces which makes the transformer non-functional.

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.

See Q.#4 of theory.

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

See Q.#6 of theory.

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

See Q.#9 of theory.

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

See Q.#8 of theory.

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.

See Q.#7 of theory.

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: Number of turns N = 50; Initial magnetic flux $\varphi 1$ = 0.3 Wb; Final magnetic flux $\varphi 2$ = 0.8 Wb; Time interval t = 0.4 s. To find: Average induced e.m.f. = ε

$$\text{Change in flux: } \Delta\varphi = \varphi 2 - \varphi 1 = 0.8 - 0.3 = 0.5\ Wb$$

$$\varepsilon = -N\ \Delta\varphi/t = -50 \times 0.5/0.4 = -50 \times 1.25 = -62.5\ V$$

Result: -62.5 V (The average induced e.m.f. is -62.5 V)

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: Radius of loop r = 0.2 m; Resistance R = 5 Ω; Initial magnetic field B1 = 0.5 T; Final magnetic field B2 = 0 T; Time interval t = 0.1 s; Number of turns N = 1 (single loop).

(a) Induced emf:

$$\text{Area of loop: } A = \pi r^2 = 3.14 \times (0.2)^2 = 0.125\ m^2$$

$$\text{Initial flux: } \varphi 1 = B1A = 0.5 \times 0.1256 = 0.0628\ Wb; \quad \text{Final flux: } \varphi 2 = B2A = 0.5 \times 0.1256 = 0\ Wb$$

$$\text{Change in flux: } \Delta\varphi = 0.0628 - 0 = 0.0628\ Wb$$

$$\varepsilon = -1 \times 0.0628/0.1 = -0.628\ V \approx 0.63\ V\ (\text{magnitude})$$

(b) Induced current:

$$I = \varepsilon/R = 0.63/5 = 0.126\ A$$

Direction: Field points into page (×) and decreases, so induced current produces field into page (×) to oppose decrease. By right-hand rule, current flows clockwise.

Result: (a) 0.63 V (b) 0.126 A, clockwise

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: Np = 500; Ns = 100; Vp = 220 V. To find: (a) Vs (b) Type of transformer.

$$Vs/Vp = Ns/Np \implies Vs = Vp \times Ns/Np = 220 \times 100/500 = 220 \times 0.2 = 44\ V$$

Since Ns < Np and Vs < Vp, it is a step-down transformer.

Result: (a) 44 V (b) Step-down transformer

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: Turns ratio Np : Ns = 2 : 100, i.e., Np = 2, Ns = 100; Primary voltage Vp = 25 V. To find: Vs = ?

$$Vs = Vp \times Ns/Np = 25 \times 100/2 = 25 \times 50 = 1250\ V$$

Result: 1250 V

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: Turns ratio $N_p : N_s = 100 : 5$, i.e., $N_p = 100$, $N_s = 5$; Primary voltage $V_p = 190$ V. To find: Secondary voltage $V_s = ?$

$$V_s = V_p \times N_s/N_p = 190 \times 5/100 = 190 \times 0.05 = 9.5\ V$$

Result: 9.5 V (The secondary voltage is 9.5 V)

Important Questions of Board Examination

- (i) (a) What is a transformer? Explain the construction and working of a transformer.
- (ii) Describe magnetic field of a solenoid.
- (iii) Explain the deflection of electrons by electric field and magnetic field.
- (iv) What is a C.R.O? Explain the working of different parts of C.R.O.

Important Short Questions of Board Examination

- (i) Define electromagnetic induction.
- (ii) Define magnetic flux and its SI units.
- (iii) State faraday's law. Write its mathematical form.
- (iv) State Lenz's law.
- (v) Why A.C cannot work with D.C?
- (vi) Different between step down and step up transformer.
- (vii) Define photon.
- (viii) What is function of grid of a C.R.O?
- (ix) Why does sky appear blue during day and red at sunset?
- (x) State two uses of a C.R.O.