AL HUDA SCIENCE ACADEMY

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Solved Exercise & Numerical of Physics Class 10

Unit No. 10: Thermal Physics

A. Multiple Choice Questions

10.1 When the temperature of a rod of copper is increased, its length:

- (a) remains the same
- **(b) increases ✓**
- (c) decreases
- (d) becomes double

10.2 The amount by which unit length of a material increases when the temperature is raised to 1°C is called the coefficient of:

- (a) cubic expansion
- (b) volume expansion
- **(c) linear expansion ✓**
- (d) none of these

10.3 What does a liquid turn into once it is evaporated?

- (a) Gas
- (b) Water vapours
- (c) Air
- **(d) Both (a) and (b) ✓**

10.4 Which property determines how much heat a solid can absorb before its temperature changes significantly?

- (a) Density
- **(b) Specific heat capacity ✓**
- (c) Colour
- (d) Hardness

10.5 High-temperature superconductors typically involve which type of material?

- (a) Pure metals
- (b) Organic compounds
- **(c) Ceramics ✓**
- (d) Liquid crystals

B. Short Answer Questions

10.1 What factors influence the thermal expansion of solids?

Answer: Initial Length (L_o): Larger objects expand more. Change in Temperature (ΔT): Higher temperature increase leads to more expansion. Nature of Material (α): Different materials expand at different rates.

10.2 What is latent heat of fusion?

Answer: It is the amount of heat energy required to change a unit mass (1 kg) of a substance from solid state to liquid state at its melting point without any change in temperature.

10.3 How do different materials exhibit varying thermal expansion behaviours?

Answer: Materials expand differently based on their internal molecular structure and the strength of the bonds between their atoms. Materials with weaker intermolecular forces generally expand more for the same temperature rise.

10.4 How does evaporation contribute to cooling processes in everyday life?

Answer: During evaporation, the most energetic molecules escape from the surface of the liquid. This leaves behind molecules with lower average kinetic energy, resulting in a decrease in the temperature of the liquid and its surroundings (e.g., sweating cools the human body).

10.5 What is latent heat of vaporization, and how is it calculated?

Answer: It is the heat required to change unit mass of a liquid into gas at its boiling point without temperature change. It is calculated using the formula: $Q = m \times L_v$ where Q is heat, m is mass, and L_v is the latent heat of vaporization.

C. Constructed Response Questions

10.1 Why do bridges need expansion joints but glass jars with metal lids do not, even though both experience temperature changes? Discuss in terms of the nature of thermal expansion.

Answer: Bridges are massive structures whose large original lengths result in significant, hazardous expansions that require gaps to prevent buckling. In contrast, glass jars and lids have tiny dimensions, meaning their total physical expansion is minimal and manageable without joints.

10.2 If two liquids are heated under same conditions, but one of them heats up faster, what does this indicate about the specific heat capacity?

Answer: The liquid that heats up faster possesses a lower specific heat capacity. This is because a lower specific heat capacity requires less heat energy to register a given rise in temperature compared to the other liquid.

10.3 Why does a liquid evaporate faster when the air is dry?

Answer: Dry air contains a very low concentration of water vapor molecules, which reduces the rate at which vapor molecules return to the liquid. This net imbalance allows liquid molecules to escape into the air much more rapidly.

10.4 When a piece of ice melts, the temperature does not increase even though heat is supplied. Where does the energy go, and why is this important in phase change?

Answer: The supplied heat energy is used entirely to break the intermolecular crystalline bonds holding the ice molecules together. This process is essential for the phase change from solid to liquid without temperature change.

D. Comprehensive Questions

10.1 How does thermal expansion differ between solids, liquids, and gases? Provide examples to illustrate these differences.

Answer:

- **Solids:** Smallest expansion because of strong intermolecular forces (e.g., railway tracks).
- **Liquids:** Expand more than solids as their bonds are weaker (e.g., mercury in a thermometer).
- **Gases:** Expand the most because molecules are far apart with negligible forces (e.g., a heated balloon).

10.2 What are some practical consequences of thermal expansion in everyday life, such as in construction materials or household appliances?

Answer:

- **Bridges and Roads:** Concrete structures are built with metal expansion joints to give the blocks room to expand in summer heat, preventing the roadway from buckling and cracking.
- **Railway Tracks:** Small gaps are left between steel rails so they can expand safely under the hot sun without building up massive thermal stress that bends the tracks out of shape.
- **Thermostats and Electric Irons:** These appliances use a bimetallic strip made of two different metals; when heated, it bends due to unequal expansion rates, opening the circuit to prevent overheating.
- **Sagging Power Lines:** Overhead utility wires are hung with a deliberate slack so that when they contract and tighten in freezing winter temperatures, they do not snap under tension.

10.3 What is latent heat, and why is it important in phase transitions like melting and vaporization?

Answer:

- **Latent Heat:** This is the hidden energy absorbed or released by a substance during a phase change that goes entirely into rearranging molecules without altering the temperature.

- **Importance in Melting:** It provides the energy required to loosen the rigid bonds of a solid structure, allowing molecules to move freely as a liquid while keeping the temperature constant.
- **Importance in Vaporization:** It supplies the massive amount of energy needed to completely break all remaining intermolecular forces, freeing liquid molecules to separate entirely into a gas.

10.4 Why do solids, liquids, and gases expand when heated? Explain with examples.

Answer:

- **Solids:** Heating causes tightly packed atoms to vibrate more violently in their fixed positions, pushing slightly against their neighbors and expanding the material's overall size, like a metal jar lid loosening under hot water.
- **Liquids:** When heated, fluid molecules slide around and collide with greater kinetic energy, forcing them to occupy more volume than solids, which is how fluid rises inside a glass thermometer.
- **Gases:** Because gas molecules have virtually no bonds holding them together, heating makes them fly faster and collide with immense force, expanding their volume dramatically, as seen in a rising hot air balloon.

10.5 If we have an equal amount of water in a wide, shallow dish and a tall, narrow container kept at the same temperature, in which container will evaporation occur faster? Explain the reason scientifically.

Answer: Evaporation happens faster in the wide, shallow dish because it provides a much larger surface area exposed to the open air. This allows a greater number of high-energy surface molecules to simultaneously overcome intermolecular forces and escape as vapor, whereas the narrow container creates a bottleneck.

E. Numerical Problems

10.1 A metal rod of length 1 m expands by 0.02 m when heated from 20°C to 120°C. Calculate its coefficient of linear expansion.

Given: $L_0 = 1$ m, $\Delta L = 0.02$ m, $T_1 = 20°C$, $T_2 = 120°C$

$\Delta T = 120°C - 20°C = 100°C = 100$ K

Formula: $\alpha = \Delta L / (L_0 \times \Delta T)$

Solution: $\alpha = 0.02 / (1 \times 100) = 0.0002\ °C^{-1} = 2 \times 10^{-4}\ K^{-1}$

10.2 A container holds 1 litre of water at 20°C. What will be its volume at 80°C, assuming water's coefficient of volume expansion is 2.1×10^{-4} per °C?

Given: $V_0 = 1$ litre $= 1000\ cm^3$, $T_1 = 20°C$, $T_2 = 80°C$, $\Delta T = 60°C$, $\beta = 2.1 \times 10^{-4}\ °C^{-1}$

Formula: $V = V_0(1 + \beta\Delta T)$

Solution: $V = 1000 \times [1 + (2.1 \times 10^{-4} \times 60)]$
$V = 1000 \times [1 + 0.0126] = 1000 \times 1.0126 = 1012.6\ cm^3$

10.3 A steel rod initially measures 2 m at 20°C. If its coefficient of linear expansion is $1.2 \times 10^{-5}\ °C^{-1}$, what will be its length at 100°C?

Given: $L_0 = 2$ m, $T_1 = 20°C$, $T_2 = 100°C$, $\Delta T = 80°C$, $\alpha = 1.2 \times 10^{-5}\ °C^{-1}$

Formula: $L = L_0(1 + \alpha\Delta T)$

Solution: $L = 2 \times [1 + (1.2 \times 10^{-5} \times 80)]$
$L = 2 \times [1 + 0.00096] = 2 \times 1.00096 = 2.00192\ m \approx 2.002\ m$

10.4 A steel bridge expands by 5 cm on a hot summer day. If the bridge originally spanned 100 m, what is the temperature change?

Given: $\Delta L = 5\ cm = 0.05\ m$, $L_0 = 100\ m$, $\alpha = 1.2 \times 10^{-5}\ °C^{-1}$

Formula: $\Delta T = \Delta L / (L_0 \times \alpha)$

Solution: $\Delta T = 0.05 / (100 \times 1.2 \times 10^{-5}) = 0.05 / 0.0012 = 41.67°C$

10.5 How much heat is required to raise the temperature of a 2 kg iron bar from 20°C to 100°C, given that the specific heat capacity of iron is $450\ J\ kg^{-1}\ K^{-1}$?

Given: $m = 2\ kg$, $T_1 = 20°C$, $T_2 = 100°C$, $\Delta T = 80°C = 80\ K$, $c = 450\ J\ kg^{-1}\ K^{-1}$

Formula: $Q = mc\Delta T$

Solution: $Q = 2 \times 450 \times 80 = 900 \times 80 = 72000\ J = 72\ kJ$

10.6 How much heat is required to melt 500 g of ice at 0°C into water at 0°C? (Latent heat of fusion of ice = $3.36 \times 10^5\ J\ kg^{-1}$)

Given: $m = 500\ g = 0.5\ kg$, $Hf = 3.36 \times 10^5\ J\ kg^{-1}$

Formula: $Q = mHf$

Solution: $Q = 0.5 \times 3.36 \times 10^5 = 168000\ J = 168\ kJ$

10.7 Calculate the heat required to completely vaporize 1 kg of water at 100°C. (Latent heat of vaporization of water = $2.26 \times 10^6\ J\ kg^{-1}$)

Given: $m = 1$ kg, $H_v = 2.26 \times 10^6$ J kg^{-1}

Formula: $Q = mH_v$

Solution: $Q = 1 \times 2.26 \times 10^6 = 2260000$ J $= 2.26$ MJ

Unit No. 11: Heat Transfer

A. Multiple Choice Questions

11.1 Which method of heat transfer requires direct contact between particles?

- (a) Convection
- (b) Radiation
- **(c) Conduction ✓**
- (d) Evaporation

11.2 What causes convection currents in liquids and gases?

- (a) The continuous movement of particles in all directions
- **(b) The rising of warm regions and sinking of cooler regions ✓**
- (c) The conduction of heat through the medium
- (d) The reflection of heat waves

11.3 The natural phenomenon caused by convection currents is:

- (a) earthquakes
- **(b) land and sea breezes ✓**
- (c) magnetic fields
- (d) solar eclipses

11.4 How does heat transfer occur through radiation?

- Heat is transferred through electromagnetic waves without requiring a medium.

11.5 The surface which absorbs and emits the most radiation is:

- (a) smooth and shiny surfaces
- **(b) dark and rough surfaces ✓**
- (c) transparent and thin surfaces
- (d) polished and white surfaces

11.6 What is the role of the greenhouse effect in Earth's temperature regulation?

- (a) It allows all heat to escape into space
- (b) It blocks heat from entering the atmosphere
- **(c) It traps heat to maintain a stable temperature ✓**

- (d) It causes immediate cooling of Earth's surface

11.7 The Sun's heat reaches the Earth:

- (a) through conduction between air particles
- (b) through convection in space
- **(c) through radiation via electromagnetic waves ✓**
- (d) through reflection by the moon

B. Short Answer Questions

11.1 What are the three primary types of heat transfer?

Answer: The three primary types of heat transfer are conduction, convection, and radiation. Conduction occurs via direct contact, convection through fluid movement, and radiation through electromagnetic waves.

11.2 Why does heat travel faster in metals compared to non-metals?

Answer: Metals contain a high density of free electrons that move rapidly and transfer kinetic energy quickly. This process of electron diffusion allows heat to travel much faster than the slow atom-to-atom vibrations found in non-metals.

11.3 How does convection transfer heat in liquids and gases?

Answer: When a fluid is heated, it expands, becomes less dense, and rises upward. The cooler, denser fluid sinks to take its place, creating a continuous circulating loop known as convection current.

11.4 What natural phenomenon causes land and sea breezes?

Answer: Land and sea breezes are caused by the unequal heating and cooling of land and water surfaces by the Sun. This temperature difference creates localized pressure variations, driving convection currents of air between the land and the sea.

11.5 How do birds and gliders take advantage of convection currents?

Answer: Birds and gliders seek out upward-moving columns of warm air called thermals, which are caused by convection. By hitching a ride on these rising currents, they can glide effortlessly and maintain altitude without flapping wings or using engines.

11.6 What is radiation, and how does it transfer heat?

Answer: Radiation is the transfer of heat energy through thermal electromagnetic waves. Unlike conduction and convection, it does not require any material medium and can travel through the vacuum of empty space.

11.7 Why does a dull black surface emit and absorb more radiation than a shiny silver surface?

Answer: Dull black surfaces are excellent absorbers and emitters because their rough texture and dark color minimize reflection. Shiny silver surfaces reflect most incoming radiation, making them poor absorbers and poor emitters.

11.8 How does the greenhouse effect help regulate Earth's temperature?

Answer: Greenhouse gases in the atmosphere allow solar radiation to pass through but trap the infrared heat radiated back from Earth's surface. This trapped heat acts like an insulating blanket, keeping the planet warm enough to sustain life.

C. Constructed Response Questions

11.1 During the Leslie's Cube experiment, why does the dull black surface radiate more heat than the shiny silver one, even though they are at the same temperature?

Answer: The dull black surface radiates more heat because its surface texture and high emissivity make it a highly efficient thermal emitter. The shiny silver surface has low emissivity because it is structurally optimized to reflect radiation inward rather than emitting it outward.

11.2 How does the size (surface area) of a radiator affect the amount of heat it emits through radiation? Explain using a real-world example.

Answer: A larger surface area provides more space for thermal energy to escape, significantly increasing the total rate of heat radiation. For example, industrial car radiators are designed with numerous thin metal fins to maximize surface area and quickly cool the engine.

11.3 Why is convection not possible in solids, and how do convection currents in liquids and gases compensate for their poor thermal conductivity?

Answer: Convection is impossible in solids because their particles are tightly bound in fixed positions and cannot flow. In fluids, mass particle movement compensates for poor conductivity by physically carrying thermal energy from hot zones to cold zones.

11.4 How do birds like eagles and gliders manage to stay aloft without flapping their wings for hours? Explain the scientific principle involved.

Answer: They utilize the principle of thermal convection, where the sun heats the ground and creates rising columns of warm, low-density air. Eagles and gliders circle within these thermal updrafts, using the upward force of the air current to balance out the downward pull of gravity.

11.5 Why does a hot metal object placed in a cooler room eventually cool down? Explain using the concepts of radiation and thermal equilibrium.

Answer: The hot object emits thermal radiation into the room at a faster rate than it absorbs radiation from the cooler surroundings. This net loss of heat energy continues until the object and the room reach the same temperature, achieving a state of thermal equilibrium.

D. Comprehensive Questions

11.1 Describe how convection occurs in fluids. How do convection currents contribute to natural phenomena such as sea breezes and wind patterns?

Answer: Convection happens when a fluid is heated from below, causing it to expand, become less dense, and float upward, while cooler, denser fluid sinks to take its place and create a continuous circulating loop.

Sea Breezes: During the day, hot air rising over the quickly heated land creates a low-pressure area, pulling in the cooler, denser air from over the sea to form a refreshing coastal breeze.

Global Wind Patterns: Intensely heated air at the equator expands and rises into the upper atmosphere, flowing toward the poles where it cools, sinks, and rushes back along the Earth's surface to generate planetary wind belts.

11.2 How does radiation differ from conduction and convection in terms of heat transfer? Give examples of radiation in everyday life and explain how different surfaces affect radiation absorption and emission.

Answer:
Comparison: Unlike conduction and convection, which require physical matter to transfer heat via colliding or moving molecules, radiation transfers energy through electromagnetic waves and can travel through a vacuum.

Everyday Examples: Radiation is felt when sunlight travels through the vacuum of space to warm the Earth, or when sitting next to a campfire and instantly feeling the heat on your face.

Surface Effects: Dull, black surfaces are excellent absorbers and emitters that quickly soak up or radiate heat, while shiny, silver surfaces are highly reflective, making them poor absorbers and emitters.

11.3 Discuss the role of the greenhouse effect in regulating Earth's temperature. What are the potential consequences of an enhanced greenhouse effect due to human activities?

Answer:
Role in Regulating Temperature: The greenhouse effect acts as a natural thermal blanket, allowing short-wave solar radiation to pass through the atmosphere while trapping outgoing long-wave infrared heat, keeping our planet warm enough to sustain life.

Consequences of Enhancement: Human activities thicken this gas layer, trapping excess heat and driving dangerous consequences like:

- **Global Warming:** A steady, unnatural rise in the Earth's average global temperatures.
- **Melting Ice Caps and Glaciers:** Accelerated melting of polar ice reserves and glaciers.
- **Rising Sea Levels:** Thermal expansion of the oceans combined with glacial melt water causes sea levels to rise, threatening coastal cities with flooding.
- **Extreme Weather Events:** Increased intensity and frequency of severe droughts, heavy heat waves, hurricanes, and unpredictable rainfall patterns.

11.4 Compare the absorption and emission of heat by different surfaces. How does the colour and texture of a surface affect its ability to absorb and emit heat?

Answer:
Color Effects: Dark colors absorb almost all incoming radiant heat and emit their internal warmth quickly, while light colors reflect most radiation away, making them poor absorbers and poor emitters.

Texture Effects: Dull, rough textures trap heat waves in their microscopic ridges for high absorption and offer more surface area for high emission, whereas smooth, shiny surfaces act like mirrors that reflect heat away and resist emitting it.

11.5 Analyze how uneven heating of Earth's surface leads to the formation of convection currents and influences wind patterns.

Answer:
Formation of Convection Currents: Intense solar heating at the equator causes air to expand, lose density, and rise, while cold, dense polar air sinks and flows along the surface to replace it, creating a giant circulating loop.

Influence on Wind Patterns: This global air circulation combines with the Earth's rotation to deflect the straight paths of the moving air, dividing the atmosphere into steady, predictable planetary wind belts like the Trade Winds.

Unit No. 12: Waves

A. Multiple Choice Questions

12.1 The direction of vibration in a longitudinal wave is:

- (a) at right angles to the wave direction
- (b) in circular motion
- (c) opposite to the wave direction
- **(d) in the same direction as the wave travels ✓**

12.2 Which part of a transverse wave carry the lowest point?

- (a) Crest
- (b) Compression
- (c) Rarefaction
- **(d) Trough ✓**

12.3 Which of the following wave type requires a medium to travel?

- (a) X-rays
- (b) Light waves
- (c) Radiowaves
- **(d) Sound waves ✓**

12.4 The property of a wave which indicates how much energy it carries is:

- (a) crest
- **(b) amplitude ✓**
- (c) wavelength
- (d) speed

12.5 A wave front is:

- (a) the distance between two crests
- (b) a region of high pressure in a wave
- **(c) a line joining points that vibrate in phase ✓**
- (d) the outer edge of a wave medium

12.6 The wave phenomenon which occurs when waves change direction due to a change in speed is:

- (a) diffraction
- (b) reflection
- (c) absorption
- **(d) refraction ✓**

12.7 What happens to wave speed and wavelength when a tsunami approaches shallow water?

- (a) Speed increases, wavelength increases
- **(b) Speed decreases, wavelength shortens ✓**
- (c) Speed remains the same, wavelength shortens
- (d) Speed increases, wavelength stays constant

12.8 Which wave behaviour explains how sound is heard around a corner?

- (a) Reflection
- (b) Refraction
- (c) Interference
- **(d) Diffraction ✓**

B. Short Answer Questions

12.1 What do waves transfer from one place to another?

Answer: Waves transfer energy from one place to another through the oscillations or vibrations of particles or fields. Crucially, this energy transfer happens without transferring any matter along with the wave.

12.2 Name any two examples of mechanical waves.

Answer: Two common examples of mechanical waves are sound waves and water waves. Both of these wave types require a material medium (like air or water) to propagate.

12.3 Which type of wave can travel through vacuum?

Answer: Electromagnetic waves can travel through a vacuum. Unlike mechanical waves, they consist of oscillating electric and magnetic fields and do not require any physical medium to propagate.

12.4 What is the difference between transverse and longitudinal waves?

Answer: In transverse waves, particles of the medium vibrate perpendicular to the direction of wave travel (e.g., light waves). In longitudinal waves, particles vibrate parallel to the direction of wave travel (e.g., sound waves).

12.5 What is meant by wavelength?

Answer: Wavelength is the shortest distance between two consecutive points that are in the same phase of vibration. For example, it is the distance from one crest to the next consecutive crest in a transverse wave.

12.6 Write the definition of frequency.

Answer: Frequency is defined as the total number of complete waves or cycles passing through a certain point in one second. Its standard SI unit is Hertz (Hz).

12.7 What causes a tsunami in the ocean?

Answer: A tsunami is caused by large-scale, sudden disturbances of the ocean floor, most commonly triggered by undersea earthquakes, volcanic eruptions, or marine landslides that displace vast amounts of water.

C. Constructed Response Questions

12.1 Why sound cannot travel through space, but light can? Explain using the concept of wave types.

Answer: Sound is a mechanical wave, which strictly requires a material medium to propagate through the collision of physical particles. Light is an electromagnetic wave, consisting of self-sustaining oscillating electric and magnetic fields, allowing it to travel through the vacuum of space.

12.2 A student shakes one end of a rope and observes waves move along it. What kind of wave is this, and how do the particles move?

Answer: This is a transverse wave. The individual particles of the rope move up and down in a direction that is perpendicular (at right angles) to the horizontal direction in which the wave energy travels along the rope.

12.3 How does the amplitude of a wave relate to the energy it carries? Give an example to support your answer.

Answer: The energy carried by a wave is directly proportional to the square of its amplitude ($E \propto A^2$). For example, loud sound waves or high ocean storm waves have larger amplitudes and carry significantly more destructive energy than quiet sounds or gentle ripples.

12.4 Why do we still hear a person talking even if he is behind a wall? Explain using the concept of diffraction.

Answer: We can hear them because of diffraction, which is the bending of waves around obstacles. Sound waves have relatively long wavelengths that match common openings like doors and corners, allowing the sound waves to bend around the wall to our ears.

12.5 If size of slit a wave passes through is much smaller than the wavelength, what will happen to the wave after passing through the slit? Explain briefly.

Answer: When the slit size is significantly smaller than the wavelength, highly pronounced diffraction occurs. The wave will bend drastically upon passing through, spreading out wide in all directions and forming almost perfectly circular wave fronts.

D. Descriptive Questions

12.1 Explain how waves transfer energy without transferring matter. Give examples from daily life.

Answer: Waves transfer energy by causing the particles of a medium to vibrate temporarily around a fixed point, passing kinetic energy to their neighbors without moving away from their original positions.

Daily Life Examples:

- **Ripples on a Pond:** A passing water ripple causes a floating cork to bob straight up and down locally rather than pushing it forward to the shore.
- **Sound Waves:** Vibrating vocal cords bump air molecules back and forth in a domino effect to carry a voice across a room while the air itself stays in place.
- **Earthquakes:** Immense energy released deep in the crust shakes the ground violently back and forth, destroying structures miles away without physically moving the soil to a new city.

12.2 Describe the difference between mechanical and electromagnetic waves with suitable examples.

Answer:

- **Mechanical Waves:** Require a physical medium (solid, liquid, or gas) to travel because they rely on particle vibrations. Examples: Sound waves, water ripples, and seismic waves.
- **Electromagnetic Waves:** Do not require a medium and can travel through the vacuum of empty space at the speed of light. Examples: Visible light, X-rays, and radio waves.

12.3 What are transverse and longitudinal waves? Explain each with the help of diagrams and examples.

Answer:
Transverse Waves: Particles vibrate perpendicular to the direction of wave travel, creating crests and troughs. Examples: Light waves and plucked guitar strings.

- **Crests:** The highest points of displacement above the rest position.
- **Troughs:** The lowest points of displacement below the rest position.

Longitudinal Waves: Particles vibrate parallel to the direction of wave travel, creating compressions and rarefactions. Examples: Sound waves and pushed slinky springs.

- **Compressions:** Regions where the medium's particles are squished tightly together, resulting in high pressure.
- **Rarefactions:** Regions where the particles are spread far apart, resulting in low pressure.

- **Wavelength (λ):** The distance between the centers of two consecutive compressions or two consecutive rarefactions.

12.4 Discuss the properties of waves; such as reflection, refraction, and diffraction. Support your answer with examples.

Answer:

- **Reflection:** Waves bounce back when hitting a boundary surface without changing speed, like a sound echo off a cliff face or light reflecting in a mirror.
- **Refraction:** Waves bend as they change speed when passing from one medium into another, such as a straight straw appearing bent in a glass of water.
- **Diffraction:** Waves spread out or bend around obstacles or through narrow gaps, which allows you to hear someone talking from around a sharp hallway corner.

12.5 What is diffraction? How do wavelength and slit size affect the diffraction of waves?

Answer: Diffraction is defined as the bending or spreading out of wavefronts as they pass through narrow openings (slits) or sharp boundaries of obstacles. Significant diffraction occurs only when the slit size is roughly equal to or smaller than the wave's wavelength ($d \leq \lambda$). If the slit size is much larger than the wavelength, the wave passes straight through with minimal edge bending.

E. Numerical Problems

12.1 The wavelength of a wave is 2 metres and its frequency is 5 Hz. What is the speed of the wave?

Given: $\lambda = 2$ m, $f = 5$ Hz

Formula: $v = f \times \lambda$

Solution: $v = 5 \times 2 = 10$ m/s

12.2 A wave travels at a speed of 300 m/s and has a wavelength of 3 metres. Calculate its frequency.

Given: $v = 300$ m/s, $\lambda = 3$ m

Formula: $v = f \times \lambda \Rightarrow f = v/\lambda$

Solution: $f = 300/3 = 100$ Hz

12.3 A sound wave has a frequency of 250 Hz and a speed of 340 m/s. Find its wavelength.

Given: $f = 250$ Hz, $v = 340$ m/s

Formula: $v = f \times \lambda \Rightarrow \lambda = v/f$

Solution: $\lambda = 340/250 = 1.36$ m

12.4 A wave has a frequency of 50 Hz. How much time does it take to complete one wave?

Given: f = 50 Hz

Formula: T = 1/f

Solution: T = 1/50 = 0.02 s

12.5 A wave has a wavelength of 0.5 m and frequency of 200 Hz. Calculate the speed of the wave.

Given: λ = 0.5 m, f = 200 Hz

Formula: v = f × λ

Solution: v = 200 × 0.5 = 100 m/s

12.6 The time period of a wave is 0.02 seconds. Calculate the frequency of the wave.

Given: T = 0.02 s

Formula: f = 1/T

Solution: f = 1/0.02 = 50 Hz

Unit No. 13: Sound

A. Multiple Choice Questions

13.1 What is required for the production of sound?

- (a) A vacuum
- **(b) Vibrations of a medium ✓**
- (c) Only air
- (d) Light waves

13.2 An echo is produced due to:

- (a) refraction of sound waves
- **(b) reflection of sound waves ✓**
- (c) diffraction of sound waves
- (d) absorption of sound waves

13.3 An example of a longitudinal wave is:

- (a) light wave
- (b) water wave
- **(c) sound wave ✓**
- (d) radiowave

13.4 In which medium does sound travel the fastest?

- (a) Gases
- (b) Liquids
- **(c) Solids ✓**
- (d) Vacuum

13.5 What is the approximate speed of sound in air?

- (a) 150 m/s
- **(b) 330-350 m/s ✓**
- (c) 500 m/s
- (d) 1,000 m/s

13.6 Why is acoustic protection important in building design?

- (a) To increase noise pollution
- **(b) To reduce echo and improve sound quality ✓**
- (c) To amplify sound
- (d) To increase the speed of sound

13.7 For a normal person, the audible frequency range for sound waves lies between:

- (a) 10 Hz and 10 kHz
- **(b) 20 Hz and 20 kHz ✓**
- (c) 25 Hz and 25 kHz
- (d) 30 Hz and 30 kHz

B. Short Answer Questions

13.1 How does the medium affect the speed of sound?

Answer: The speed of sound depends on the elasticity and density of the medium. It travels fastest in solids because particles are tightly packed, slower in liquids, and slowest in gases due to weaker intermolecular bonds.

13.2 Does sound waves show reflection?

Answer: Yes, sound waves show reflection. When a sound wave strikes the surface of another medium, it bounces back into the first medium, which is commonly perceived as an echo.

13.3 What factors influence the loudness of sound?

Answer: The loudness of sound primarily depends on the amplitude of the vibrating body, the surface area of the vibrating body, and the distance of the listener from the source of the sound.

13.4 Why do we hear an echo when we clap near a building?

Answer: We hear an echo because the sound wave produced by the clap travels through the air, strikes the hard surface of the building, and reflects back to our ears as a distinct, delayed sound.

13.5 What is ultrasound, how is it used in medicine?

Answer: Ultrasound consists of sound waves with frequencies higher than the human audible limit (above 20,000 Hz). In medicine, it is used for diagnostic imaging of internal organs and treating various medical conditions non-invasively.

C. Constructed Response Questions

13.1 Why does a tuning fork placed on a wooden table produce a louder sound than when held in the air? What does this tell us about the role of surface area in sound propagation?

Answer: A tuning fork placed on a table sets the large wooden surface into forced vibration, displacing a much greater volume of air than the small prongs alone. This proves that a larger surface area intensifies sound propagation by moving more air particles.

13.2 If sound needs a medium to travel, how does the bell jar experiment prove this requirement? What happens when air is removed, and why?

Answer: The bell jar experiment shows that as air is pumped out while an electric bell rings inside, the sound grows fainter until it stops completely. This happens because sound waves are mechanical and require a material medium to propagate; without air, vibrations cannot travel.

13.3 A person hears his echo when shouting near a tall building. Why must the building be at least 17 metres away for the echo to be heard clearly?

Answer: The human brain retains a sound sensation for about 0.1 seconds. Since sound travels at roughly 340 m/s, it must cover a total round-trip distance of 34 meters (17 meters to the wall and 17 meters back) for the echo to be perceived as a separate sound. Thus, the minimum distance is 17 metres.

13.4 Why do voices of men sound deeper than those of women or children, even when they are speaking at the same intensity? Explain using the relationship between frequency and pitch.

Answer: Pitch directly depends on the frequency of the sound waves. Men have longer, thicker vocal cords that vibrate at a lower frequency, producing a lower-pitched, deeper voice compared to the high-frequency, high-pitched voices of women and children.

13.5 In what ways do soft materials like carpets or curtains improve the acoustics of a room? How do they affect echoes and sound quality?

Answer: Soft, porous materials absorb sound waves instead of reflecting them. By minimizing reflections, they significantly reduce unwanted echoes and reverberation, which eliminates distortion and drastically improves the overall sound clarity and quality of the room.

13.6 When a person claps near a canyon and hears the echo after a few seconds, how can they calculate the distance to the canyon? What principle is used in this method?

Answer: The distance can be calculated using the formula $d = (v \times t)/2$, where v is the speed of sound and t is the total time to hear the echo. This method is based on the principle of reflection of sound waves (echo ranging).

D. Descriptive Questions

13.1 What is the approximate speed of sound in air, and what factors affect it?

Answer: The approximate speed of sound in air is between 330 m/s and 350 m/s (commonly taken as 340 m/s at room temperature). The factors affecting it include:

1. **Temperature:** Speed increases as temperature rises because molecules move faster and transmit vibrations more quickly.
2. **Humidity:** Humid air is less dense than dry air, which increases the speed of sound.
3. **Medium Nature:** Elasticity and density determine how efficiently kinetic energy passes through the particles.

13.2 Why does sound travel faster in solids than in liquids and gases? Explain.

Answer: Sound is a mechanical wave that propagates through particle collisions. In solids, the atoms are highly organized and tightly bound together by strong intermolecular forces, allowing elastic deformations and vibrations to pass from one particle to the next much faster than in loosely packed liquids or widely dispersed gas molecules.

13.3 How do amplitude and frequency affect the quality of sound? Explain.

Answer: Amplitude determines the loudness of a sound; a higher amplitude carries more energy, producing a louder sound. Frequency determines the pitch; a higher frequency produces a shrill, sharp sound, while a lower frequency results in a flat, grave sound.

13.4 How does echo occur? Explain.

Answer: An echo occurs when sound waves traveling from a source strike a distant, hard, and smooth surface (like a cliff wall or large building) and bounce back due to the phenomenon of reflection. If the reflected sound wave reaches the listener's ear at least 0.1 seconds after the original direct sound, it is perceived as a distinctly separate sound.

13.5 How do reflection, refraction, and diffraction affect the behaviour of sound waves?

Answer:

1. **Reflection:** Causes sound waves to bounce off barriers, generating echoes and reverberations.
2. **Refraction:** Bends sound waves when they travel through regions of differing temperatures or densities, causing sound to travel further at night.
3. **Diffraction:** Enables sound waves to bend around corners and spread through small openings, allowing us to hear someone speaking from another room.

13.6 What are infrasound and ultrasound, and how are they used in different applications?

Answer:

1. **Infrasound:** Sound waves with frequencies below 20 Hz. Used by geologists to monitor earthquakes and volcanic activity, and by certain animals (like elephants) for long-distance communication.

2. **Ultrasound:** Sound waves with frequencies above 20,000 Hz. Extensively used in medical imaging (sonography), breaking kidney stones, industrial cleaning of delicate parts, and measuring underwater depths via SONAR.

E. Numerical Problems

13.1 At a particular temperature, the speed of sound in air is 333 m/s. If the wavelength of a sound wave is 3 cm, calculate the frequency of the sound wave. Is this frequency in the audible range of the human ear?

Given: $v = 333$ m/s, $\lambda = 3$ cm $= 0.03$ m

Formula: $v = f\lambda \Rightarrow f = v/\lambda$

Solution: $f = 333/0.03 = 11100$ Hz $= 11.1$ kHz

Yes, it is within the audible range of the human ear.

13.2 A clock chimes 48 times in 1 minute. Calculate the frequency and period of the chimes.

Given: $N = 48$, $t = 1$ min $= 60$ sec

Formula: $f = N/t$ and $T = 1/f$

Solution: $f = 48/60 = 0.8$ Hz and $T = 1/0.8 = 1.25$ s

13.3 A car horn emits a sound with a wavelength of 0.5 m. If the speed of sound in air is 340 m/s, calculate the frequency of the sound produced by the car's horn.

Given: $\lambda = 0.5$ m, $v = 340$ m/s

Formula: $v = f\lambda \Rightarrow f = v/\lambda$

Solution: $f = 340/0.5 = 680$ Hz

13.4 A wave travels with a speed of 500 m/s and has a wavelength of 2 metres. Calculate the time period of the wave.

Given: $v = 500$ m/s, $\lambda = 2$ m

Formula: $v = f\lambda \Rightarrow f = v/\lambda$ and $T = 1/f$

Solution: $f = 500/2 = 250$ Hz and $T = 1/250 = 0.004$ s

13.5 A research boat sends a sound wave straight to the seabed and receives the echo 2 seconds later. The speed of sound in seawater is 1600 m/s. Find the depth of the sea at this position.

Given: $t = 2$ s, $v = 1600$ m/s, $t' = t/2 = 1$ s

Formula: Depth (d) = $v \times t'$

Solution: $d = 1600 \times 1 = 1600$ m

13.6 A person claps his hands near a mountain and hears the echo after 6 seconds. If the speed of sound is 343 m/s, what is the distance of the mountain from the person?

Given: $t = 6$ s, $v = 343$ m/s, $t' = t/2 = 3$ s

Formula: Distance (d) = $v \times t'$

Solution: $d = 343 \times 3 = 1029$ m

Unit No. 14: Light

A. Multiple Choice Questions

14.1 What type of image is always formed by a convex mirror?

- (a) Real and inverted
- **(b) Virtual and diminished ✓**
- (c) Real and magnified
- (d) Virtual and magnified

14.2 The optical device which uses a convex lens to magnify an object by creating a virtual image:

- (a) camera
- (b) microscope
- **(c) magnifying glass ✓**
- (d) slide projector

14.3 Which statement best describes the phenomenon of total internal reflection?

- (a) Light bends when it enters a new medium
- **(b) Light is completely reflected at the boundary of two media ✓**
- (c) Light slows down as it enters a denser medium
- (d) Light passes through a medium without changing direction

14.4 A ray of light travelling from water to air bends:

- (a) toward the normal
- **(b) away from the normal ✓**
- (c) at 90° to the normal
- (d) parallel to the normal

14.5 The optical device which works on the principle of inverting an image for projection is:

- (a) magnifying glass
- (b) photograph Enlarger
- **(c) slide projector ✓**
- (d) plane mirror

B. Short Answer Questions

14.1 What happens when light passes from air to water?

Answer: When light passes from air to water, it slows down and bends toward the normal line because it is entering an optically denser medium. This phenomenon is known as refraction.

14.2 Define refractive index. What is the refractive index of air and water?

Answer: Refractive index (n) is the ratio of the speed of light in a vacuum (c) to its speed in a specific medium (v), represented as $n = c/v$. The refractive index of air is approximately 1.00, while the refractive index of water is approximately 1.33.

14.3 What is the principle behind optical fibres?

Answer: The principle behind optical fibres is total internal reflection. Light entering the fiber core hits the boundary at an angle greater than the critical angle, causing it to bounce continuously inside the core without escaping.

14.4 Describe briefly how a convex lens forms a real or virtual image.

Answer: A convex lens forms a real, inverted image when the object is placed beyond its focal length (F), as the light rays physically converge. It forms a virtual, upright, and magnified image when the object is placed inside the focal length (F).

14.5 How does the power of a lens relate to its focal length?

Answer: The power of a lens (P) is inversely proportional to its focal length (f) measured in meters ($P = 1/f$). A lens with a shorter focal length has greater optical power to bend light rays, measured in dioptres (D).

14.6 Write Snell's law and define the terms used in the equation.

Answer: Snell's law is expressed mathematically as $n_1 \sin(i) = n_2 \sin(r)$. Here, n_1 and n_2 are the refractive indices of the first and second media, i is the angle of incidence, and r is the angle of refraction.

C. Constructed Response Questions

14.1 When a pencil is partially dipped in water, it appears bent or broken. What principle of light explains this phenomenon, and how does it relate to changes in speed?

Answer: This phenomenon is explained by the principle of refraction. Light travels slower in water than in air; this abrupt decrease in speed causes the light rays coming from the underwater part of the pencil to bend away from the normal as they exit into the air, making the pencil look misaligned.

14.2 Why can a prism separate white light into its component colours while a plane glass slab cannot, even though both cause refraction?

Answer: A prism has non-parallel sides, so different colours bend at different angles and diverge further upon exiting, producing a spectrum. A glass slab has parallel faces, meaning the dispersion that occurs at the first face is perfectly reversed and recombined when exiting the second face.

14.3 Why does light undergo total internal reflection when travelling from water to air at a certain angle but not the other way around?

Answer: Total internal reflection can only happen when light travels from an optically denser medium (higher n, like water) to a rarer medium (lower n, like air). Going the other way (air to water), the light always bends towards the normal, making it impossible to reach a 90° angle of refraction.

14.4 Optical fibres use total internal reflection for signal transmission. What would happen if the cladding had a higher refractive index than the core, and why?

Answer: If the cladding had a higher refractive index than the core, total internal reflection would fail completely. Instead of reflecting internally, the light signals would refract and leak out into the cladding, destroying the signal transmission because the core must always be the denser medium.

14.5 A person uses a magnifying glass to read small print. What must be the relationship between the object distance and the focal length of the lens for the image to be upright and magnified?

Answer: The object distance must be less than the focal length of the convex lens ($p < f$). Placing the print inside the focal point ensures the lens functions as a magnifying glass, creating a virtual, upright, and magnified image on the same side as the object.

D. Descriptive Questions

14.1 Explain the terms: normal, angle of incidence and angle of reflection in the context of light reflection. Provide a diagram to illustrate these terms.

Answer:

- **Normal:** An imaginary perpendicular line drawn at a 90° angle to the reflecting surface at the exact point where an incoming light ray strikes.
- **Angle of Incidence:** The angle formed between the incoming incident light ray and the normal line.
- **Angle of Reflection:** The angle formed between the bouncing reflected light ray and the normal line. (According to the law of reflection, the angle of incidence equals the angle of reflection).

14.2 Define the terms critical angle and total internal reflection. Explain the conditions required for total internal reflection to occur.

Answer:

- **Critical Angle:** The specific angle of incidence in a denser medium that results in an angle of refraction of exactly 90° in the rarer medium.

- **Total Internal Reflection:** The phenomenon where light traveling through a denser medium hits the boundary of a rarer medium at an angle greater than the critical angle and is completely reflected back into the denser medium.

Conditions Required:

1. Light must travel from an optically denser medium to an optically rarer medium.
2. The angle of incidence must be strictly greater than the critical angle ($i > C$).

14.3 Derive the equation: $n = 1/\sin C$ for the refractive index in terms of the critical angle C. Include all steps and assumptions.

Answer:
Assumptions: Light travels from a denser medium with refractive index $n_1 = n$ into a rarer medium (air) with refractive index $n_2 = 1.0$. By definition, when the angle of incidence reaches the critical angle ($i = C$), the angle of refraction becomes 90° ($r = 90°$).

Steps:

1. According to Snell's Law: $n_1 \sin(i) = n_2 \sin(r)$
2. Substitute the assumed values: $n \cdot \sin(C) = 1.0 \cdot \sin(90°)$
3. Since $\sin(90°) = 1$, the equation simplifies to: $n \cdot \sin(C) = 1$
4. Rearranging the terms yields the final expression: $n = 1/\sin(C)$

14.4 Describe the structure of an optical fibre. Write its any two advantages.

Answer:
Structure: An optical fiber consists of three primary concentric layers:

1. **Core:** The innermost central cylindrical thread made of high-quality glass or plastic with a high refractive index (n_1) where light signals travel.
2. **Cladding:** An outer protective layer surrounding the core made of glass or plastic with a lower refractive index (n_2) to ensure total internal reflection.
3. **Coating/Buffer:** A plastic protective jacket that guards the fiber against moisture and physical damage.

Advantages:

1. They can carry massive amounts of data over long distances with minimal signal loss.
2. They are completely immune to electromagnetic interference (EMI).

14.5 What is long-sightedness? Discuss its causes.

Answer:
Long-sightedness (Hyperopia): A vision defect where a person can see distant objects clearly but struggles to focus properly on nearby objects.

Causes:

1. **Shortened Eyeball:** The physical eyeball is too short from front to back, causing light rays to focus behind the retina instead of directly on it.
2. **Low Lens Curvature:** The eye lens becomes too stiff or flat and cannot thicken sufficiently, giving it a longer focal length that reduces its ability to bend incoming light sharply.

E. Numerical Problems

14.1 The speed of light in water is 2.25×10^8 m/s. Calculate the refractive index of water.

Given: $v = 2.25 \times 10^8$ m/s, $c = 3.0 \times 10^8$ m/s

Formula: $n = c/v$

Solution: $n = (3.0 \times 10^8)/(2.25 \times 10^8) = 1.33$

14.2 A light ray in air ($n_1 = 1.0$) strikes a glass surface ($n_2 = 1.5$) at an incidence of 30°. Find the angle of refraction inside the glass.

Given: $n_1 = 1.0$, $n_2 = 1.5$, $i = 30°$

Formula: $n_1 \sin(i) = n_2 \sin(r)$

Solution: $1.0 \times \sin(30°) = 1.5 \times \sin(r)$
$1.0 \times 0.5 = 1.5 \times \sin(r)$
$\sin(r) = 0.5/1.5 = 0.3333$
$r = \sin^{-1}(0.3333) \approx 19.5°$

14.3 A beam of light in air hits a glass slab at an incidence angle of 40°. Find the angle of refraction inside the glass.

Given: $i = 40°$, $n_1 = 1.0$, $n_2 = 1.52$

Formula: $n_1 \sin(i) = n_2 \sin(r)$

Solution: $1.0 \times \sin(40°) = 1.52 \times \sin(r)$
$0.6428 = 1.52 \times \sin(r)$
$\sin(r) = 0.6428/1.52 \approx 0.4229$
$r = \sin^{-1}(0.4229) \approx 25°$

14.4 A ray of light travels from air into an unknown liquid. The angle of incidence in air is 45° and the angle of refraction in the liquid is 30°. Calculate the refractive index of the liquid.

Given: $i = 45°$, $r = 30°$, $n_1 = 1.0$

Formula: n = sin(i)/sin(r)

Solution: n = sin(45°)/sin(30°) = 0.7071/0.5 = 1.414 ≈ 1.41

14.5 A ray of light passes from air into a liquid. The angle of incidence in air is 50° and the angle of refraction inside the liquid is 32°. Calculate: (a) the refractive index of the liquid (b) the speed of light in the liquid.

Given: i = 50°, r = 32°, c = 3.0×10^8 m/s

Formulas: (a) n = sin(i)/sin(r) (b) v = c/n

Solution:
(a) n = sin(50°)/sin(32°) = 0.7660/0.5299 ≈ 1.45
(b) v = $(3.0 \times 10^8)/1.45 \approx 2.07 \times 10^8$ m/s ≈ 2.08×10^8 m/s

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14.6 Light travels inside a glass block of refractive index n = 1.6. It strikes the glass-air boundary. Calculate the critical angle for total internal reflection.

Given: n = 1.6

Formula: sin(C) = 1/n

Solution: sin(C) = 1/1.6 = 0.625 ⇒ C = $\sin^{-1}(0.625) \approx 38.68°$

14.7 An object is placed 15.0 cm in front of a convex mirror, forming a virtual image 7.5 cm behind the mirror. What is the focal length of the mirror?

Given: p = +15.0 cm, q = -7.5 cm (negative for virtual image behind the mirror)

Formula: 1/f = 1/p + 1/q

Solution: 1/f = 1/15.0 + 1/(-7.5) = 1/15.0 - 2/15.0 = -1/15.0 ⇒ f = -15 cm

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14.8 An object 30 cm tall is located 10.5 cm from a concave mirror with focal length 16 cm. (a) Where is the image located? (b) How high is it?

Given: h_o = 30 cm, p = 10.5 cm, f = +16 cm (Positive for concave mirror)

Solution:
(a) Find the location of the image (q):
1/f = 1/p + 1/q or 1/q = 1/f - 1/p
1/q = 1/16 - 1/10.5 = 0.0625 - 0.09524 = -0.03274
q = 1/(-0.03274) ≈ -30.54 cm ≈ -30.6 cm
(Note: The negative sign indicates that a virtual image is formed behind the mirror).

(b) Find the height of the image (h_i):
$h_i/30 = |q/p| = |(-30.54)/10.5| = 2.9086$
$h_i = 30 \times 2.9086 \approx 87.3$ cm

14.9 An object is placed at 30 cm to the left of a concave lens with focal length -15 cm. Find the image distance and describe the image.

Given: p = +30 cm, f = -15 cm

Solution:
$1/(-15) = 1/30 + 1/q$
$1/q = -1/15 - 1/30 = -2/30 - 1/30 = -3/30 = -1/10$
$q = -10$ cm

Image Properties: Virtual, upright, and on the same side as the object.

Unit No. 15: Electrostatics

A. Multiple Choice Questions

15.1 Electrical breakdown is:

- **(a) the process of ionizing a gas due to a strong electric field ✓**
- (b) the process of neutralizing a charged object
- (c) the process of charging an insulator
- (d) the process of discharging a conductor

15.2 Which of the following is a visible example of electrical breakdown?

- **(a) Corona discharge ✓**
- (b) Electric current
- (c) Magnetic field
- (d) Electric potential

15.3 What happens when two unlike charges are brought close to each other?

- **(a) They attract ✓**
- (b) They repel
- (c) They neutralize each other
- (d) Nothing happens

15.4 According to Coulomb's law, what happens to the attraction of two oppositely charged objects as their distance of separation increases?

- **(a) Decreases ✓**
- (b) Increases
- (c) Remains unchanged
- (d) Cannot be determined

15.5 The device which works on the principle of electrostatics:

- (a) electric bell
- **(b) photocopier ✓**
- (c) electric heater
- (d) transformer

B. Short Answer Questions

15.1 State Coulomb's law of electrostatics and write its mathematical form.

Answer: Coulomb's law states that the electrostatic force of attraction or repulsion between two point charges is directly proportional to the product of the magnitudes of charges and inversely proportional to the square of the distance between their centers.

Mathematical form: $F = k(q_1q_2/r^2)$

15.2 What is an electric field?

Answer: An electric field is a region or space around a charged particle or object within which it can exert an electrostatic force of attraction or repulsion on other charged bodies brought into that region.

15.3 Give two examples each of electrical conductors and electrical insulators.

Answer:

- **Electrical Conductors:** Copper and Aluminium (or Gold)
- **Electrical Insulators:** Rubber and Glass (or Plastic)

15.4 List some applications of electrostatics in daily life.

Answer: Electrostatics is widely used in technologies such as electrostatic photocopying machines (photocopiers), electrostatic paint spraying, and electrostatic smoke precipitators used to clean industrial emissions.

15.5 What happens when like charges and unlike charges are brought close to each other?

Answer: When like charges (e.g., positive and positive) are brought close to each other, they repel one another. When unlike charges (positive and negative) are brought close, they attract each other.

15.6 What is meant by electrical breakdown, and when does it occur?

Answer: Electrical breakdown is the process where an insulating material (like air) becomes electrically conductive due to intense ionization under a strong electric field, allowing current to flow. It occurs when the applied electric field strength exceeds the dielectric strength of the material.

15.7 What are the dangers of static electricity?

Answer: Dangers of static electricity include the risk of lightning strikes during thunderstorms, static spark-induced explosions or fires in dust-filled factories or refuelling stations, and potential damage to sensitive electronic components.

C. Constructed Response Questions

15.1 Why do some materials gain electrons while others lose electrons when rubbed together? What property of the materials determines this behaviour?

Answer: When rubbed, the material with a weaker hold on its outer electrons loses them to the material with a stronger attraction for electrons. This behaviour is determined by a physical property known as electron affinity (or work function) of the materials.

15.2 A charged comb attracts small pieces of paper, but after some time, the paper pieces fall off. Why does this happen?

Answer: Initially, the comb induces an opposite charge on the paper pieces, causing attraction. Upon contact, the paper pieces acquire the same charge as the comb through conduction; because like charges repel, they immediately fall off.

15.3 Why do dust particles often get attracted to television screens or computer monitors after they are turned ON?

Answer: When turned ON, monitors and screens build up a strong electrostatic charge on their surfaces. This charge induces an opposite charge on nearby neutral dust particles, attracting them dynamically to the screen.

15.4 If we rub a balloon on our dry hair and place it near a thin stream of water, the water bends toward the balloon. What does this tell us about the nature of water molecules?

Answer: This tells us that water molecules are inherently polar molecules (having distinct permanent positive and negative ends). The charged balloon polarizes or rotates the water molecules, causing net attraction and bending the stream.

15.5 A conductor and an insulator are both placed in an electric field. How will their behaviour differ, and why?

Answer: In the conductor, free electrons will easily migrate to one side, completely polarizing the object and cancelling the internal field. In the insulator, electrons cannot move freely; instead, individual atoms or molecules will just stretch or realign locally to form dipoles.

D. Comprehensive Questions

15.1 Discuss the working of a gold leaf electroscope. How can it be used to determine the nature and magnitude of charge on a body?

Answer:

1. **Working Mechanism:** The electroscope works on like-charge repulsion. When a charged body touches or comes near the brass disk, the charge transfers down the rod to both gold leaves; because they receive the same type of charge, they repel each other and diverge.
2. **Determining the Nature of Charge:** Charge the electroscope with a known charge (e.g., positive). Bring the unknown body near the disk: if the leaves diverge further, the body has the same charge (positive); if the leaves collapse, it has the opposite charge (negative).

3. **Determining the Magnitude of Charge:** The magnitude is determined by the angle of divergence of the leaves. A body with a small charge causes a slight separation, while a highly charged body exerts a stronger repulsive force, causing a wide divergence.

15.2 How does Coulomb's law help in understanding the interaction between charged particles? What factors affect the force between them?

Answer:
Interaction: Coulomb's law explains that charged particles interact by pushing or pulling each other through an electric force. It shows that like charges repel (push away) and opposite charges attract (pull together), with the force acting along a straight line between them.

Factors Affecting the Force:

1. **Magnitude of the Charges (q_1, q_2):** The force is directly proportional to the product of the magnitudes of the interacting charges.
2. **Distance between Charges (r):** The force is inversely proportional to the square of the distance between their centers.
3. **Nature of the Medium (k):** The permittivity of the intervening medium between the charges scales the force value; an insulating medium reduces the effective force compared to a vacuum or air.

15.3 Explain the concept of electric field intensity. How can the electric field of a point charge and a parallel plate capacitor be represented using field lines?

Answer:
Electric Field Intensity (E): Electric field intensity at any point in space is defined as the electrostatic force experienced per unit positive test charge (q_0) placed at that specific point ($E = F/q_0$). Its SI unit is NC^{-1} or Vm^{-1}.

Representation via Field Lines:

- **Point Charge:** The electric field of a single point charge is represented by straight, radial lines directed outward from a positive charge and inward toward a negative charge. The density of these lines decreases with distance, showing that the field strength weakens further away from the charge.
- **Parallel Plate Capacitor:** The field lines between two oppositely charged parallel plates are uniform, parallel, and equally spaced, running directly from the positive plate perpendicularly toward the negative plate (except for slight curving or "fringing" near the plate edges).

15.4 Explain how and why electrical conductors and insulators behave differently in terms of charge transfer and movement of electrons.

Answer:
1. Charge Transfer:

- **Conductors:** Let electric charge pass through them easily, spreading the charge quickly across their entire surface.

- **Insulators:** Block the free flow of charge, keeping any added charge stuck in one exact spot.

2. Movement of Electrons:

- **Conductors:** Have a large number of free electrons that are loosely bound to their atoms, allowing them to drift easily from atom to atom when an electric force is applied.
- **Insulators:** Have tightly bound valence electrons that are locked into localized chemical bonds, leaving no free electrons available to move and conduct electricity.

15.5 Discuss how electrostatics plays a role in real-life hazards, such as dust explosions in factories and static shocks from synthetic clothing. How can these hazards be minimized?

Answer:
Hazards:

- **Dust Explosions:** In factories (like flour or grain mills), floating dust particles rub against each other and machinery, building up large amounts of static charge. A sudden static spark can ignite the flammable dust cloud, triggering a massive explosion.
- **Static Shocks from Clothing:** Synthetic fabrics (like polyester or nylon) easily gain or lose electrons when they rub against skin or other layers. When you touch a conductor like a metal doorknob, this built-up charge rapidly discharges, causing a sharp static shock.

Minimization Techniques:

1. **Grounding/Earthing:** Ensure all factory machinery is grounded to dissipate static build-up safely into the earth.
2. **Humidification:** Moist air helps naturally dissipate static charges.
3. **Antistatic Materials:** Use antistatic wristbands, specialized footwear, and treat synthetic garments with antistatic sprays to prevent charge accumulation.

E. Numerical Problems

15.1 A positive test charge of 25 μC is placed in an electric field. The force on it is 0.500 N. What is the magnitude of the electric field at the location of the test charge?

Given: $q = 25\ \mu C = 25 \times 10^{-6}$ C, $F = 0.500$ N

Formula: $E = F/q$

Solution: $E = 0.500/(25 \times 10^{-6}) = 0.02 \times 10^{6} = 2.0 \times 10^{4}\ NC^{-1}$

15.2 Two point charges, $q_1 = 8\ \mu C$ and $q_2 = 4\ \mu C$, are placed at a distance of 120 cm. What will be the Coulomb's force between them? Also, find the nature of the force.

Given: $q_1 = 8 \times 10^{-6}$ C, $q_2 = 4 \times 10^{-6}$ C, $r = 1.2$ m, $k = 9 \times 10^{9}\ N{\cdot}m^2C^{-2}$

Formula: $F = k(q_1q_2/r^2)$

Solution: $F = (9 \times 10^9) \times [(8 \times 10^{-6})(4 \times 10^{-6})/(1.2)^2]$
$F = (9 \times 10^9) \times (32 \times 10^{-12}/1.44) = 288 \times 10^{-3}/1.44 = 0.2$ N

Nature: Since both charges are positive (like charges), the force is repulsive.

15.3 Two identical charges repel each other with a force of 0.2 N when they are 9 cm apart. Find the force between them when they are 3 cm apart.

Given: $F_1 = 0.2$ N, $r_1 = 9$ cm $= 0.09$ m, $r_2 = 3$ cm $= 0.03$ m

Formula: For identical charges, $F \propto 1/r^2 \Rightarrow F_1r_1^2 = F_2r_2^2 \Rightarrow F_2 = F_1(r_1/r_2)^2$

Solution: $F_2 = 0.2 \times (9/3)^2 = 0.2 \times 9 = 1.8$ N

15.4 A point charge q = 10 μC is placed in air. Calculate the electric field strength at a distance of 0.5 metres from the charge.

Given: $q = 10 \times 10^{-6}$ C, $r = 0.5$ m, $k = 9 \times 10^9$ N·m²C⁻²

Formula: $E = k(q/r^2)$

Solution: $E = (9 \times 10^9) \times (10 \times 10^{-6})/(0.5)^2 = (9 \times 10^4)/0.25 = 3.6 \times 10^5\ NC^{-1}$

15.5 Two small equally charged metal spheres having charge 3 μC are brought close together such that the distance between them is 2.0 cm. Calculate the magnitude of repulsive force that each sphere exerts on the other.

Given: $q_1 = q_2 = 3 \times 10^{-6}$ C, $r = 2.0$ cm $= 0.02$ m $= 2 \times 10^{-2}$ m, $k = 9 \times 10^9\ N{\cdot}m^2C^{-2}$

Formula: $F = k(q_1q_2/r^2)$

Solution: $F = (9 \times 10^9) \times [(3 \times 10^{-6})(3 \times 10^{-6})/(2 \times 10^{-2})^2]$
$F = 9 \times 10^9 \times (9 \times 10^{-12})/(4 \times 10^{-4}) = (81 \times 10^{-3})/(4 \times 10^{-4}) = 202.5$ N

15.6 Two small equally charged metal spheres repel each other with a force of 0.5 N when placed 3 cm apart in the air. Calculate the charge on each sphere.

Given: $F = 0.5$ N, $r = 3$ cm $= 0.03$ m $= 3 \times 10^{-2}$ m, $q_1 = q_2 = q$, $k = 9 \times 10^9\ N{\cdot}m^2C^{-2}$

Formula: $F = k(q^2/r^2) \Rightarrow q = \sqrt{(F \cdot r^2/k)}$

Solution: $q^2 = [0.5 \times (3 \times 10^{-2})^2]/(9 \times 10^9) = 0.5 \times 9 \times 10^{-4}/(9 \times 10^9) = 0.5 \times 10^{-13} = 5 \times 10^{-14}$
$q = \sqrt{(5 \times 10^{-14})} = 2.24 \times 10^{-7}$ C $= 0.224$ μC

15.7 A force of 85 N acts between two charges placed 3.2 cm apart. If one charge is 25 μC, determine the other charge.

Given: $F = 85$ N, $r = 3.2$ cm $= 0.032$ m $= 3.2 \times 10^{-2}$ m, $q_1 = 25 \times 10^{-6}$ C, $k = 9 \times 10^9$ N·m^{2}C^{-2}

Formula: $F = k(q_1q_2/r^2) \Rightarrow q_2 = F \cdot r^2/(k \cdot q_1)$

Solution: $q_2 = [85 \times (3.2 \times 10^{-2})^2]/[(9 \times 10^9) \times (25 \times 10^{-6})]$
$q_2 = (85 \times 1.024 \times 10^{-3})/(225 \times 10^3) = 0.08704/225000 = 3.87 \times 10^{-7}$ C $= 0.387$ μC

Unit No. 16: Current Electricity

A. Multiple Choice Questions

16.1 The direction of conventional current is:

- (a) from negative to positive terminal
- **(b) from positive to negative terminal ✓**
- (c) in both directions at the same time
- (d) it does not have a fixed direction

16.2 What type of electric current flows in one direction only?

- (a) Alternating current
- **(b) Direct current ✓**
- (c) Both
- (d) Neither

16.3 The device used to measure electric current:

- (a) voltmeter
- **(b) ammeter ✓**
- (c) ohmmeter
- (d) wattmeter

16.4 What is the function of an electromotive force (e.m.f.) source in a circuit?

- (a) To reduce resistance in the circuit
- **(b) To provide energy to drive charges through the circuit ✓**
- (c) To store electrical energy for later use
- (d) To convert electrical energy into mechanical energy

16.5 The relationship between voltage, current, and resistance is:

- **(a) $V = IR$ ✓**
- (b) $V = 1/R$
- (c) $V = I^2R$
- (d) $V = R/I$

16.6 What happens to the resistance of a metal conductor when its temperature increases?

- (a) It decreases
- (b) It remains constant
- **(c) It increases ✓**
- (d) It becomes zero

B. Short Answer Questions

16.1 How does an ammeter measure electric current?

Answer: An ammeter measures electric current by being connected in series with the circuit so that the entire current passes through it. It features a very low internal resistance to ensure it does not significantly alter or decrease the current it is measuring.

16.2 What is the main difference between direct current and alternating current?

Answer: Direct current (D.C.) flows continuously in only one constant direction through the circuit. In contrast, alternating current (A.C.) periodically reverses its direction of flow and changes its magnitude continuously over time.

16.3 Define electromotive force (e.m.f.)

Answer: Electromotive force (e.m.f.) is the total energy supplied by a source (like a battery) per unit charge to drive the electrical charges through the entire circuit. It is measured in volts (V).

16.4 State Ohm's law and define resistivity.

Answer: Ohm's law states that the current through a conductor is directly proportional to the potential difference across it, provided temperature and other physical conditions remain constant. Resistivity is the intrinsic property of a material that measures how strongly it opposes the flow of electric current, defined as the resistance of a conductor of unit length and unit cross-sectional area.

16.5 What is the formula for calculating the equivalent resistance of resistors connected in series?

Answer: The formula for calculating the equivalent resistance (Req) of resistors connected in series is the algebraic sum of their individual resistances: $R_{eq} = R_1 + R_2 + R_3 + ... + R_n$

16.6 How does temperature affect the resistance of a conductor?

Answer: As the temperature of a metal conductor increases, its constituent atoms vibrate more violently. This increases the frequency of collisions between the flowing free electrons and the vibrating atoms, resulting in an increase in the conductor's electrical resistance.

C. Constructed Response Questions

16.1 Why is it important that an ammeter has very low resistance and is connected in series, while a voltmeter has very high resistance and is connected in parallel? What would happen if they were connected incorrectly?

Answer: An ammeter is connected in series with a low resistance so all current passes through it without changing the circuit's total resistance. A voltmeter is connected in parallel with a high resistance to sample voltage without drawing significant current away from the component. If reversed, a series voltmeter blocks circuit current due to its high resistance, while a parallel ammeter creates a dangerous short-circuit that can burn out the meter.

16.2 If a copper wire is replaced with an aluminium wire of the same dimensions, how would the current and power consumption change in the same circuit? Explain using the concept of resistivity.

Answer: Aluminium has a higher resistivity (ρ) than copper, meaning an aluminium wire of identical dimensions will have a higher electrical resistance ($R = \rho L/A$). Consequently, by Ohm's law ($I = V/R$), the current flowing through the circuit will decrease, and the overall power consumption ($P = V^2/R$) will also decrease at a constant voltage supply.

16.3 In a household lighting circuit, what practical problems might arise if the bulbs were connected in series instead of parallel?

Answer: In a series connection, if a single bulb burns out or is switched off, the entire circuit breaks and all other bulbs go dark. Additionally, each bulb will split the total voltage, causing them to glow very dimly, and individual control of the bulbs via separate switches becomes impossible.

16.4 You are tasked with designing a fuse for a device that operates at 230V and 5 A. What rating would you choose for the fuse and why? What could go wrong if the rating is too low or too high?

Answer: A fuse rating slightly above the operating current, such as 6 A, should be chosen to handle normal operational fluctuations without breaking. If the fuse rating is too low (e.g., 4 A), it will blow continuously during normal operation; if it is too high (e.g., 15 A), it will fail to melt during an overcurrent surge, risking severe damage to the device or causing an electrical fire.

16.5 Explain why A.C is more suitable for power transmission across cities, even though D.C is used in batteries and portable electronic devices.

Answer: Alternating current (A.C.) can easily be stepped up to extremely high voltages using transformers, which minimizes current and dramatically reduces energy losses (I^2R) over long-distance transmission lines before being stepped down safely for city use. Direct current (D.C.) cannot be stepped up or down as efficiently, making it ideal only for local storage and low-power electronics.

D. Comprehensive Questions

16.1 Explain the concept of electric current. How is it related to the movement of charges, and how is it measured in a circuit?

Answer:

1. Current and Movement of Charges: Electric current (I) is defined as the rate of flow of electric charge through any cross-section of a conductor. It is directly related to the net movement of charges, where free electrons drift through a conductor when a potential difference (voltage) is applied across it. Mathematically, $I = Q/t$ where Q is the charge in coulombs and t is the time in seconds.

2. Measurement in a Circuit: Electric current is measured using an instrument called an ammeter, and its SI unit is the ampere (A). To measure the current, the ammeter must always be connected in series within the circuit so that the entire current flowing through the components passes directly through the meter.

16.2 Define electromotive force (e.m.f.) and potential difference. How does a battery create a potential difference, and what is the role of e.m.f. in maintaining the flow of current?

Answer:

- **Electromotive Force (e.m.f.):** The total energy supplied by a source (like a battery) per unit charge when no current is flowing in the external circuit.
- **Potential Difference (V):** The amount of electrical energy converted into other forms (like heat or light) per unit charge as it moves between two points in a circuit.
- **Creating Potential Difference:** Internal chemical reactions inside a battery continuously push positive charges to one terminal and negative charges to the other, creating a steady electrical imbalance (voltage) between them.
- **Maintaining Current Flow:** The e.m.f. acts as the "pump" that continuously supplies energy to charges, lifting them from low to high potential inside the battery so they can keep circulating through the external circuit.

16.3 State and explain Ohm's law. How does the resistance of a conductor affect the flow of current, and how can Ohm's law be applied in practical electrical circuits?

Answer:

1. Ohm's Law and Explanation: Ohm's law states that the electric current (I) flowing through a conductor is directly proportional to the potential difference (V) across its ends, provided the temperature and physical state of the conductor remain constant. Mathematically: $V = IR$ where R is the constant of proportionality known as electrical resistance.

2. Effect of Resistance on Current: Resistance is the opposition offered by a conductor to the flow of free electrons. According to Ohm's law ($I = V/R$), current is inversely proportional to resistance; therefore, a higher resistance restricts the movement of charges and reduces the current, while a lower resistance allows current to flow more easily.

3. Practical Application in Circuits: Ohm's law is used by engineers to calculate the required values of resistors needed to control current levels and protect delicate components (like LEDs) from burning out. It is also applied to determine the correct wire thickness for household appliances based on the voltage supply and current demands.

16.4 Differentiate between series and parallel combinations of resistors. Provide mathematical expressions for calculating the total resistance in both types of circuits.

Answer: In a series combination, resistors are connected end-to-end in a single pathway; the current remains the same through all resistors, while the total voltage is divided among them. In a parallel combination, resistors are connected side-by-side across the same two common nodes; the voltage across each resistor remains identical, while the total current splits along the multiple available branches.

- **Series Circuit:** $R_s = R_1 + R_2 + R_3 + ... + R_n$
- **Parallel Circuit:** $1/R_p = 1/R_1 + 1/R_2 + 1/R_3 + ... + 1/R_n$

16.5 What is meant by resistivity of a material? How does it depend on the material, and what role does temperature play in changing the resistivity of conductors and semiconductors?

Answer: Resistivity (ρ) is an intrinsic, characteristic property of a material that measures its fundamental capacity to oppose the flow of electric current, defined as the resistance of a sample with unit length and unit cross-sectional area ($R = \rho L/A$). It depends directly on the material's atomic structure and nature, with conductors having extremely low resistivities and insulators having very high resistivities.

Temperature plays contrasting roles in different materials:

1. **Conductors (Metals):** As temperature increases, atomic vibrations increase, leading to more frequent electron collisions, which increases the resistivity.
2. **Semiconductors:** As temperature increases, covalent bonds rupture and liberate more free charge carriers (electrons and holes), which dramatically increases conductivity and decreases the resistivity.

E. Numerical Problems

16.1 A charge of 25 coulombs passes through a circuit in 10 seconds. Calculate the current flowing through the circuit.

Given: $Q = 25$ C, $t = 10$ s

Formula: $I = Q/t$

Solution: $I = 25/10 = 2.5$ A

16.2 Three resistors of 4 Ω, 6 Ω, and 8 Ω are connected in series to a 24 V battery. Find the total resistance and the current flowing through the circuit.

Given: $R_1 = 4\ \Omega$, $R_2 = 6\ \Omega$, $R_3 = 8\ \Omega$, $V = 24$ V

Formulas: $R_s = R_1 + R_2 + R_3$ and $I = V/R_s$

Solution:

1. Total Resistance: $R_s = 4 + 6 + 8 = 18\ \Omega$
2. Total Current: $I = 24/18 \approx 1.33$ A

16.3 Two resistors of 10 Ω and 30 Ω are connected in parallel across a 20 V power supply. Calculate the total resistance and the current drawn from the power supply.

Given: $R_1 = 10\ \Omega$, $R_2 = 30\ \Omega$, $V = 20$ V

Formulas: $1/R_p = 1/R_1 + 1/R_2$ or $R_p = (R_1 \times R_2)/(R_1 + R_2)$, $I = V/R_p$

Solution:

1. Total Parallel Resistance: $R_p = (10 \times 30)/(10 + 30) = 300/40 = 7.5\ \Omega$
2. Current Drawn: $I = 20/7.5 \approx 2.67$ A

16.4 Four 1.5 V batteries are connected in series in a flashlight. Determine the total electromotive force (e.m.f.) supplied to the circuit.

Given: $E = 1.5$ V, $n = 4$

Formula: $E\_total = E_1 + E_2 + E_3 + E_4 = n \times E$

Solution: $E\_total = 4 \times 1.5 = 6$ V

16.5 A circuit has a 5 A current passing through a 7 Ω resistor. Calculate the power dissipated in the resistor and the energy consumed in 10 minutes.

Given: $I = 5$ A, $R = 7\ \Omega$, $t = 10$ min $= 600$ s

Formulas: $P = I^2R$, $E = P \times t$

Solution:

1. Power: $P = (5)^2 \times 7 = 25 \times 7 = 175$ W
2. Energy Consumed: $E = 175 \times 600 = 105{,}000$ J $= 105$ kJ

Unit No. 17: Magnetism

A. Multiple Choice Questions

17.1 Which statement is true about the magnetic poles?

- (a) Unlike poles repel
- (b) Like poles attract
- (c) Magnetic poles do not affect each other
- **(d) A single magnetic pole does not exist ✓**

17.2 A D.C motor converts:

- (a) mechanical energy into electrical energy
- (b) mechanical energy into chemical energy
- **(c) electrical energy into mechanical energy ✓**
- (d) electrical energy into chemical energy

17.3 The part of a D.C motor that reverses the direction of current through the coil every half-cycle:

- (a) the armature
- **(b) the commutator ✓**
- (c) the brushes
- (d) the split rings

17.4 The two main layers of the Earth's core that contribute to the generation of the magnetic field are:

- (a) crust and mantle
- **(b) inner core and outer core ✓**
- (c) lithosphere and asthenosphere
- (d) troposphere and stratosphere

17.5 What does a steady electric current in a conductor generate around it?

- (a) Electric field
- (b) Light
- **(c) Magnetic field ✓**
- (d) Sound waves

17.6 What happens to the magnetic field direction when the direction of the current is reversed?

- (a) The magnetic field remains unchanged
- **(b) The magnetic field also reverses direction ✓**
- (c) The magnetic field becomes stronger
- (d) The magnetic field disappears

B. Short Answer Questions

17.1 What is the direction of the magnetic field around a straight current carrying wire?

Answer: The direction of the magnetic field forms concentric circular loops around the wire. It can be determined by the Right-Hand Grip Rule, where pointing your thumb in the direction of the current causes your curled fingers to point in the direction of the magnetic field (clockwise or counter-clockwise).

17.2 What happens to the magnetic field if the magnitude of the current in a wire is increased?

Answer: If the magnitude of the current in a wire is increased, the strength of the magnetic field increases proportionally. The magnetic field lines become denser and more tightly packed around the conductor, indicating a stronger magnetic force.

17.3 How can you identify the north and south poles of an unmarked magnetized steel bar?

Answer: Suspend the unmarked steel bar horizontally by a thread so it can rotate freely; it will align itself along the Earth's north-south direction. The end pointing toward the geographical North Pole is the bar's North Pole, and the end pointing toward the geographical South Pole is its South Pole.

17.4 What rule determines the direction of force on a current-carrying conductor placed in a magnetic field? Explain briefly.

Answer: Fleming's Left-Hand Rule determines the direction of the force. If you stretch the thumb, forefinger, and middle finger of your left hand mutually perpendicular to each other, such that the forefinger points to the magnetic field and the middle finger to the current, then the thumb points in the direction of the magnetic force.

17.5 What role does the commutator play in a D.C motor?

Answer: The commutator (split rings) reverses the direction of the current passing through the armature coil every half-rotation (180°). This ensures that the magnetic forces on the sides of the coil continue to act in the same rotational direction, allowing the coil to spin continuously.

17.6 What is the source of the Earth's magnetic field according to the theory?

Answer: According to dynamo theory, the source is the convective motion of conductive liquid iron and nickel in the Earth's outer core. As the Earth rotates, these moving electrical charges create huge electric currents, which generate the planetary magnetic field.

C. Constructed Response Questions

17.1 Why does a magnetic field form around a conductor when current flows through it, but not when the current is OFF? What does this reveal about the nature of electricity and magnetism?

Answer: A magnetic field is only produced by moving electric charges (current); when the current is OFF, the charges stop moving forward collectively, causing the magnetic field to disappear. This reveals that electricity and magnetism are deeply interconnected components of a single unified force known as electromagnetism.

17.2 In a D.C motor, why does the coil stop turning after 90° if the direction of the current is not reversed? What mechanical feature solves this issue?

Answer: At 90°, the coil reaches a vertical position where the magnetic forces align vertically and oppose further rotation, locking it in place. The mechanical feature that solves this issue is the commutator (or split rings), which reverses the current direction at that moment to maintain continuous torque.

17.3 How does placing a wire at different angles to a magnetic field affect the magnetic force it experiences, and why is this important in designing motors?

Answer: The magnetic force is maximum when the wire is perpendicular (90°) to the field and zero when parallel (0°) to it. This angle dependence is vital in motor design to optimize armature layout, ensuring maximum torque is produced during rotation.

D. Descriptive Questions

17.1 How is a magnetic field created around a current-carrying wire, and what factors affect its strength?

Answer: A magnetic field is created because moving electric charges inherently generate magnetic lines of force forming concentric circles around the path of movement. The strength of this magnetic field depends on two primary factors:

1. **Magnitude of Current:** The field strength is directly proportional to the amount of current passing through the wire.
2. **Distance from the Conductor:** The field strength is inversely proportional to the distance from the wire; it gets weaker as you move further away.

17.2 Explain the concept of the right-hand grip rule and how it helps determine the direction of the magnetic field around a current-carrying conductor.

Answer: The right-hand grip rule is a visual helper used to link current direction with magnetic field direction. To apply it, imagine gripping the straight conductor with your right hand so that your thumb points in the direction of the conventional electric current. Your fingers will then naturally curl around the wire in the exact direction of the generated magnetic field lines. This determines whether the magnetic field loops around the conductor in a clockwise or counter-clockwise pattern.

17.3 Describe an experiment that demonstrates the magnetic field produced by a current-carrying conductor using a compass or iron filings.

Answer: Pass a straight thick copper wire vertically through a hole in the center of a rigid piece of cardboard held horizontally. Connect the ends of the wire to a battery through a switch. Sprinkle fine iron filings uniformly on the cardboard and turn the current ON. Gently tap the cardboard; the iron filings will align themselves into sharp concentric circles centered on the wire, visibly mapping out the magnetic field lines. Alternatively, placing a magnetic compass at different points around the wire will cause the needle to align tangentially to these circles, proving the presence and direction of the magnetic field.

17.4 Discuss the theory behind the Earth's magnetic field and the role of the Earth's molten core in generating it.

Answer: The Earth's magnetic field is best explained by the Dynamo Theory. The Earth possesses a solid inner core surrounded by a fluid outer core composed primarily of molten iron and nickel, which are excellent electrical conductors. Due to intense heat from the inner core, powerful convection currents are set up within this liquid metal layer. As the Earth rotates on its axis, these circulating streams of molten metal are subjected to rotational forces, creating moving electrical charges. These movements generate massive electric currents which loop throughout the core. Consequently, these currents set up a self-sustaining planetary electromagnet, giving the Earth its magnetic field and poles.

Unit No. 18: Electromagnetic Induction

A. Multiple Choice Questions

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

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

B. Short Answer Questions

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

Answer: According to Lenz's law, the direction of the induced current is always such that it opposes the change in magnetic flux that produced it. It acts as a statement of conservation of energy within electromagnetic induction.

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

Answer: Slip rings are used to provide a continuous electrical connection between the rotating armature coils and the stationary external circuit. This allows the naturally generated alternating current (A.C) to pass safely to the load without twisting the wires.

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

Answer: The induced e.m.f. is zero when the plane of the moving coil is perpendicular to the magnetic field lines. At this specific instant, the armature sides move parallel to the magnetic field, making the rate of change of magnetic flux zero.

18.4 Why is the sky red at sunset?

Answer: At sunset, sunlight must travel through a much thicker layer of the atmosphere. Most of the shorter blue wavelengths are scattered away out of our line of sight, leaving the longer red and orange wavelengths to pass straight through to our eyes.

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

Answer: A transformer is an electrical device used to step up or step down alternating voltage levels. It operates on the principle of mutual induction between two stationary coils linked by a common magnetic core.

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?

Answer: According to Faraday's Law, the magnitude of induced e.m.f. is directly proportional to the rate of change of magnetic flux. Moving the magnet more quickly decreases the time interval of the shift, which drastically increases the flux change rate, leading to a larger induced current.

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

Answer: Iron is a ferromagnetic material with high magnetic permeability, which easily concentrates and channels the magnetic flux from the primary to the secondary coil. Wood and plastic are non-magnetic materials that cannot guide magnetic lines of force, resulting in critical energy loss.

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

Answer: Photons are considered massless packets of light that still carry real momentum. When these photons strike and reflect off the shiny surface of a solar sail, they transfer their momentum to the sail, exerting a continuous radiation pressure that pushes the spacecraft forward without fuel.

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

Answer: A transformer requires a continuously changing magnetic flux to induce voltage in the secondary coil via mutual induction. Alternating current provides this continuous flux variation, whereas direct current produces a steady, unchanging magnetic field that cannot induce an e.m.f.

D. Descriptive Questions

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

Answer:
1. Lenz's Law and Conservation of Energy: Lenz's Law states that an induced current always opposes the magnetic change that created it. To overcome this opposition and move a magnet near a coil, you must do mechanical work; this mechanical energy is what converts into the electrical energy of the current, perfectly preserving the law of conservation of energy.

2. Real-Life Example - Regenerative Braking: In electric cars, when the driver brakes, the wheels force a generator to spin. According to Lenz's law, the induced current creates a magnetic opposition that slows the wheels down, successfully converting the car's kinetic energy into stored electrical energy for the battery.

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

Answer:

- **Step-up Transformer:** The number of turns in the secondary coil (N_s) is greater than the number of turns in the primary coil (N_p), meaning $N_s > N_p$. Consequently, the output voltage is higher than the input voltage ($V_s > V_p$). These are heavily used at power generation stations to raise voltages up to hundreds of kilovolts for efficient, long-distance transmission with minimal power loss.
- **Step-down Transformer:** The number of turns in the secondary coil is less than the number of turns in the primary coil ($N_s < N_p$), causing the output voltage to be lower than the input voltage ($V_s < V_p$). These are deployed at local electrical substations and inside consumer electronics chargers to drop hazardous high transmission voltages down to safe domestic levels (e.g., 220V or 5V/12V DC adapters).

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

Answer: This optical phenomenon is caused by Rayleigh scattering, which states that shorter wavelengths of light scatter much more efficiently than longer wavelengths when hitting tiny gas molecules in Earth's atmosphere.

- **Blue Sky During the Day:** When sunlight enters the atmosphere overhead, short-wavelength blue and violet light are scattered in all directions by atmospheric molecules. Because our eyes are much more sensitive to blue light than violet, the clear sky appears beautifully blue to us.
- **Red Sky at Sunset:** At sunset, the Sun sits low on the horizon, forcing its sunlight to pass through a significantly longer atmospheric path to reach our eyes. Along this extended path, almost all of the shorter blue wavelengths are completely scattered out and redirected away. The longer, less-scattered wavelengths like red, orange, and yellow pass through unimpeded, making the setting sun and surrounding clouds look deep red.

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

Answer: An oscilloscope is an electronic test instrument that visually displays electrical signal voltages as a two-dimensional plot on a screen, typically showing voltage changes over time (Y-axis vs. X-axis). It helps engineers and technicians analyze signals by revealing wave properties such as amplitude, frequency, period, noise, and distortion patterns.

Main Components:

1. **Cathode Ray Tube (CRT) or Display Screen:** The visual interface where the electron beam traces out the waveform pattern.
2. **Electron Gun:** Generates, accelerates, and focuses a narrow stream of electrons directed towards the screen.
3. **Deflection Plate System:** Consists of vertical plates (which move the electron beam up and down to represent voltage amplitude) and horizontal plates (which sweep the beam across the screen at a controlled rate to represent time).
4. **Time-Base/Sweep Generator:** Controls the horizontal movement rate of the beam to create a stable time scale for observation.

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.

Answer: The path followed by the electron is a perfect circle (circular path). Explanation: When an electron moves through a uniform magnetic field at a right angle (90°), it experiences a magnetic force ($F = qvB$). According to Fleming's Left-Hand Rule (adjusted for a negative electron charge), this magnetic deflection force acts exactly perpendicular to both the velocity vector of the electron and the magnetic field lines. Because the force is constantly perpendicular to the direction of motion, it changes only the electron's direction without altering its linear speed. This constant, perpendicular deflecting force fulfills the exact definition of a centripetal force, pulling the moving electron into a uniform circular orbit.

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: $N = 50$, $\Phi_1 = 0.3$ Wb, $\Phi_2 = 0.8$ Wb, $\Delta\Phi = 0.5$ Wb, $\Delta t = 0.4$ s

Formula: $E = -N(\Delta\Phi/\Delta t)$

Solution: $E = -50 \times (0.5/0.4) = -50 \times 1.25 = -62.5$ V

(The negative sign represents the direction of opposition as stated by Lenz's Law.)

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: $r = 0.2$ m, $R = 5\ \Omega$, $B_1 = 0.5$ T, $B_2 = 0$ T, $\Delta B = 0.5$ T, $\Delta t = 0.1$ s
$A = \pi r^2 = \pi \times (0.2)^2 \approx 0.1257\ m^2$, $N = 1$

Formulas: (a) $E = N(\Delta B \cdot A/\Delta t)$ (b) $I = E/R$

Solution:
(a) $E = 1 \times (0.5 \times 0.1257)/0.1 = 0.06285/0.1 = 0.6285\ V \approx 0.63$ V
(b) $I = 0.6285/5 = 0.1257\ A \approx 0.126$ A

Direction: The induced current flows clockwise to create a magnetic field into the page (opposing the decrease in the external field).

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: $N_p = 500$, $N_s = 100$, $V_p = 220$ V

Solution:
(a) $V_s = V_p \times (N_s/N_p) = 220 \times (100/500) = 220 \times 1/5 = 44$ V
(b) Since $V_s < V_p$ and $N_s < N_p$, this is a **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: $N_p:N_s = 2:100$, $V_p = 25$ V

Formula: $V_s/V_p = N_s/N_p$

Solution: $V_s = 25 \times (100/2) = 25 \times 50 = 1250$ 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: $N_p:N_s = 100:5$, $V_p = 190$ V

Solution: $V_s = 190 \times (5/100) = 190 \times 0.05 = 9.5$ V

Unit No. 19: Electronics

A. Multiple Choice Questions

19.1 A diode allows current to flow in:

- (a) both directions
- (b) neither direction
- **(c) one direction only ✓**
- (d) random directions

19.2 What is the primary function of a light-emitting diode?

- (a) To block current in both directions
- **(b) To emit light when current passes in one direction ✓**
- (c) To amplify electrical signals
- (d) To convert light into electrical energy

19.3 The output of a two inputs NOR gate is '1', when:

- (a) A is '1' and B is '0'
- (b) A is '0' and B is '1'
- **(c) both A and B are '0' ✓**
- (d) both A and B are '1'

19.4 The output of a NAND gate is '0', when:

- (a) both of its inputs are '0'
- **(b) both of its inputs are '1' ✓**
- (c) any of its inputs is '0'
- (d) any of its inputs is '1'

19.5 How many bits make up a byte in Boolean logic?

- (a) 2
- (b) 4
- (c) 6
- **(d) 8 ✓**

B. Short Answer Questions

19.1 What is the function of a semiconductor diode?

Answer: The primary function of a semiconductor diode is to allow electric current to flow easily in one direction (forward bias) while blocking it in the opposite direction (reverse bias).

19.2 What happens when a diode is forward biased?

Answer: When a diode is forward biased, its depletion region narrows down, lowering its potential barrier. This allows a significant amount of current to flow easily through the circuit.

19.3 What is the function of an LED?

Answer: The function of a Light-Emitting Diode (LED) is to efficiently convert electrical energy directly into light energy when a current passes through it in the forward-biased direction.

19.4 Why does an LED emit light when current passes through it?

Answer: An LED emits light because forward-biased electrons cross the junction and recombine with holes, releasing energy in the form of photons instead of heat.

19.5 What does an analog-to-digital converter (ADC) do?

Answer: An analog-to-digital converter (ADC) samples a continuously varying analog signal (like sound or temperature) and converts it into a discrete sequence of binary numbers (0s and 1s).

19.6 What is the difference between analog and digital signals?

Answer: Analog signals are continuous and vary smoothly over a range of values, whereas digital signals are discrete, changing in steps between two specific states (typically 0 and 1).

19.7 What is Boolean logic in digital electronics?

Answer: Boolean logic is a system of mathematical logic where variables can only have two possible values True (1) or False (0) used to design processing states in digital circuits.

19.8 What does a NOT gate do in a digital circuit?

Answer: A NOT gate serves as an inverter; it takes a single input and produces an opposite output, changing a '1' to a '0' and a '0' to a '1'.

19.9 What is the role of an AND gate in digital circuits?

Answer: The role of an AND gate is to perform logical multiplication, giving a high output ('1') only when all of its input signals are simultaneously high ('1').

C. Constructed Response Questions

19.1 Why would a diode be damaged if it is connected in reverse bias with a very high voltage? What does this tell us about the diode's physical limits?

Answer: A very high reverse voltage causes a sudden, massive surge of current known as avalanche breakdown. The resulting excess heat destroys the crystalline structure, showing that diodes have strict physical limits for reverse electrical stress.

19.2 What makes an LED glow brighter or dimmer depending on the voltage applied? How is this property used in adjustable display brightness?

Answer: Higher voltage increases the forward current, causing more electron-hole recombination and releasing more photons. Modulating this electrical flow allows electronic displays to dynamically adjust their brightness levels.

19.3 Why are digital systems more reliable than analog systems when transmitting signals over long distances?

Answer: Digital signals are made of distinct high/low states, making it easy for receivers to distinguish between 1s and 0s even with added background noise, whereas analog noise permanently degrades continuous waveforms.

19.4 Why is the NOT gate also called an inverter, and how can such a simple function have a major role in digital decision-making?

Answer: It is called an inverter because it flips the input to its exact logical opposite. This basic operation is vital for creating alternative conditions, timing pulses, and building more complex processing logic.

19.5 Why would a security system use NAND gates instead of OR or AND gates for certain logical conditions?

Answer: NAND gates are universal gates that can trigger an alarm for multiple fault conditions (like a broken circuit or open sensor) while keeping component count minimal and fail-safe designs simple.

D. Descriptive Questions

19.1 Explain how the depletion region of a diode changes in forward and reverse bias. What effect does this have on current flow?

Answer:
1. Forward Bias: The positive terminal of the battery connects to the p-side, and the negative terminal connects to the n-side. This arrangement repels the majority charge carriers (holes on the p-side, free electrons on the n-side) toward the center junction, narrowing and collapsing the depletion region.

Effect on current: The internal barrier potential is easily overcome (requiring roughly 0.7V for Silicon). Resistance drops to almost zero, allowing a large, continuous forward current to flow through the circuit.

2. Reverse Bias: The positive terminal connects to the n-side, and the negative terminal connects to the p-side. This setup pulls free electrons and holes away from the junction toward the battery terminals, widening the depletion region.

Effect on current: The wider barrier creates exceptionally high resistance. As a result, no major current flows through the diode. Only a microscopic, negligible reverse leakage current exists, carried by minority charge carriers.

19.2 How does an LED produce light, and how does the type of semiconductor material affect the colour of the light?

Answer:
How an LED Produces Light:

1. **Forward Bias:** Voltage pushes free electrons (n-side) and holes (p-side) toward the junction.
2. **Recombination:** Electrons fall into holes across the junction.
3. **Photon Release:** As electrons lose energy to settle into the holes, they release that energy directly as packets of light called photons.

How Material Determines Color: The color depends entirely on the band gap energy (the size of the energy drop) of the semiconductor material:

- **Narrow Band Gap:** Small energy drop → longer wavelengths (Red/Infrared).
- **Wide Band Gap:** Large energy drop → shorter wavelengths (Blue/Ultraviolet).

Note: Compound materials like Gallium Arsenide Phosphide are used because standard Silicon or Germanium release this energy as heat instead of light.

19.3 What is Boolean logic? Discuss its importance in solving complex digital problems with examples.

Answer: Boolean logic is a mathematical system where variables can have only two states: 1 (True/ON) or 0 (False/OFF). It processes these states using three fundamental operations: AND, OR, and NOT. In technology, these operations are executed by hardware components called logic gates.

Importance & Examples: Digital systems cannot process nuance; they only handle binary electrical signals. Boolean logic allows engineers to reduce complex, multi-condition decisions into simple, reliable mathematical equations that a circuit can instantly calculate.

- **AND Operation (Safety System):** A high-voltage industrial machine activates (Y) only if the safety door is closed (A) AND the power button is pressed (B). Equation: $Y = A \cdot B$
- **OR Operation (Security System):** A home alarm (Y) triggers if the front door opens (D) OR a motion sensor detects movement (M). Equation: $Y = D + M$
- **NOT Operation (Inversion):** A car's warning light (Y) turns ON only when the seatbelt sensor (S) is NOT buckled. Equation: $Y = \overline{S}$

19.4 What are logic gates? Describe the working of NAND and OR gates with the help of truth tables and circuit symbols.

Answer: Logic gates are the basic building blocks of digital circuits. They are electronic components that perform logical operations on one or more binary inputs (0s and 1s) and produce a single binary output based on Boolean logic.

1. OR Gate

- **Working:** The output is 1 (High) if at least one input is 1. It only outputs 0 (Low) when all inputs are 0.
- **Boolean Expression:** Q = A + B

Input A	Input B	Output Q
0	0	0
0	1	1
1	0	1
1	1	1

2. NAND Gate

- **Working:** "NAND" stands for NOT-AND. It performs an AND operation and then completely inverts the result. The output is 0 (Low) only when all inputs are 1. If any input is 0, the output is 1 (High).
- **Boolean Expression:** Q = A · B

Input A	Input B	Output Q
0	0	1
0	1	1
1	0	1
1	1	0

19.5 How does a NOR gate work, and how can it be used to build other basic logic gates?

Answer: A NOR gate (NOT-OR) is a universal gate that outputs a high signal (1) only when all inputs are low (0). If any input is 1, the output is 0.

Boolean expression: X = A + B

Input A	Input B	Output X
0	0	1
0	1	0
1	0	0
1	1	0

Implementing Other Gates Using Only NOR Gates:

1. **NOT Gate (Uses 1 NOR Gate):** Connect all inputs of a single NOR gate together to a single input line (A). Result: $\overline{A + A} = \overline{A}$
2. **OR Gate (Uses 2 NOR Gates):** Pass inputs A and B through a first NOR gate, then feed that output into a second NOR gate wired as a NOT gate to reverse the inversion. Result: $\overline{\overline{A + B}} = A + B$
3. **AND Gate (Uses 3 NOR Gates):** Invert input A using one NOR gate and input B using a second NOR gate. Feed both inverted outputs ($\overline{A}$ and $\overline{B}$) into a third NOR gate. Result: $\overline{\overline{A} + \overline{B}} = A \cdot B$

19.6 How can a burglar alarm be designed using a NAND gate and an LDR? Explain.

Answer: A NAND-gate burglar alarm uses an LDR (Light Dependent Resistor) as a light sensor and a NAND gate configured as an inverter (NOT gate) to switch the alarm on.

1. Circuit Design:

- **The Inverter:** Both input pins of the NAND gate are connected together to form a single input line.
- **The Potential Divider:** A fixed resistor is connected to the positive supply rail, and the LDR is connected to the ground rail. The junction point between them connects directly to the NAND gate's input.
- **The Output:** A buzzer or bell is connected to the output pin of the gate.

2. Working Principle: A continuous beam of light (like a laser) is pointed directly at the LDR. The alarm triggers the moment a burglar interrupts this beam.

Condition	LDR Resistance	Voltage at Gate Input	NAND Gate Output	Alarm Status
Normal State (Light on LDR)	Very Low	Low (0)	High (1)	OFF
Intrusion (Light blocked)	Very High	High (1)	Low (0)	ON

Summary: When the burglar steps into the light beam, the LDR goes dark. Its resistance instantly spikes, changing the input signal from Low to High. The NAND gate inverts this signal, forcing the output Low to complete the circuit and fire up the alarm.

Unit No. 20: Nuclear Physics

A. Multiple Choice Questions

20.1 What did Rutherford's alpha particle scattering experiment reveal about the structure of the atom?

- (a) Electrons are distributed evenly throughout the atom
- (b) Protons and electrons are located in the nucleus
- (c) Atoms are indivisible and indestructible
- **(d) The nucleus is small, dense, and positively charged ✓**

20.2 The atomic number of an element represents:

- (a) number of neutrons in the nucleus
- **(b) number of protons in the nucleus ✓**
- (c) total number of protons and neutrons
- (d) number of electrons and neutrons

20.3 Which type of radiation is positively charged and consists of two protons and two neutrons?

- **(a) Alpha (α) ✓**
- (b) Gamma (γ)
- (c) Beta (β)
- (d) Neutron emission

20.4 The process by which an unstable nucleus emits radiation and transforms into a more stable nucleus is called:

- (a) nuclear fusion
- (b) nuclear fission
- **(c) radioactive decay ✓**
- (d) isotopic exchange

20.5 Nuclear fission involves:

- (a) combining light nuclei to form heavier ones
- **(b) splitting heavy atomic nuclei into smaller ones ✓**
- (c) absorbing gamma radiation to increase stability
- (d) none of the above

20.6 What does Einstein's equation: $E = mc^2$ explain?

- (a) The energy released in chemical reactions
- **(b) The equivalence of mass and energy ✓**
- (c) The rate of radioactive decay
- (d) The conversion of mass into momentum

20.7 Which of the following is a practical application of nuclear radiations?

- (a) Cooking food in microwave ovens
- **(b) Medical imaging and cancer treatments ✓**
- (c) Solar energy generation
- (d) Airplane navigation systems

20.8 What are the potential effects of ionizing nuclear radiation on biological tissues?

- (a) Increased cellular regeneration
- **(b) DNA damage and cancer ✓**
- (c) Enhanced immune system response
- (d) Improved metabolic activity

B. Short Answer Questions

20.1 Define the atomic nucleus. What are its two main characteristics?

Answer: The atomic nucleus is the small, central core of an atom containing protons and neutrons. Its two main characteristics are that it carries a positive electrical charge and contains almost all of the atom's total mass.

20.2 What is the structure of an atom according to Rutherford's model?

Answer: According to Rutherford's model, an atom consists of a tiny, dense, positively charged nucleus at its center. Positively charged protons are located inside the nucleus, while negatively charged electrons revolve around it in empty space.

20.3 How does alpha radiation differ from beta radiation?

Answer: Alpha radiation consists of heavy, positively charged helium nuclei containing two protons and two neutrons, moving at lower speeds. In contrast, beta radiation consists of light, fast-moving, negatively charged electrons emitted from the nucleus.

20.4 What is the primary energy source of the Sun and other stars?

Answer: The primary energy source of the Sun and other stars is nuclear fusion. In this process, extreme gravity and temperatures force light hydrogen nuclei to combine into heavier helium nuclei, releasing massive amounts of energy.

20.5 Name the equation proposed by Einstein that relates energy and mass.

Answer: The equation proposed by Albert Einstein that relates energy and mass is $E = mc^2$. In this equation, E represents energy, m represents mass, and c represents the constant speed of light.

20.6 What is the principle behind carbon dating and its applications?

Answer: Carbon dating is based on measuring the residual amount of radioactive carbon-14 remaining in an organic sample compared to its steady atmospheric level. It is used to estimate the age of ancient biological artifacts such as fossils, wood, and bones.

20.7 Define nuclear fusion with an example.

Answer: Nuclear fusion is a reaction where two or more light atomic nuclei combine at very high temperatures to form a single, heavier nucleus while releasing large amounts of energy. An example is the fusion of Deuterium and Tritium isotopes to form Helium and a neutron.

20.8 Americium-241 (${}^{241}_{95}Am$) undergoes alpha decay and produces an alpha particle. Write down the chemical equation for it and name the nucleus formed.

Answer: The chemical equation is: ${}^{241}_{95}Am \rightarrow {}^{237}_{93}Np + \alpha$

The nucleus formed during this alpha decay process is Neptunium-237 (${}^{237}_{93}Np$).

C. Constructed Response Questions

20.1 If an atom is mostly empty space, why do we not fall through solid objects or pass through walls?

Answer: We do not pass through walls because the high-speed electron clouds of adjacent atoms repel each other via strong electrostatic forces. This mutual electromagnetic repulsion prevents atoms from passing through one another, creating the sensation of solidity.

20.2 Imagine a new radioactive element is discovered. How could scientists estimate its half-life without waiting thousands of years?

Answer: Scientists can measure the current activity (decays per second) of a known sample size using radiation detectors. By calculating the rate of decay relative to the total number of atoms present, they can mathematically compute the element's half-life.

20.3 If gamma rays do not change the number of protons or neutrons in a nucleus, why are they still considered dangerous?

Answer: Gamma rays are dangerous because they carry extremely high energy, high frequency electromagnetic radiation with strong penetrating power. They easily pass through human skin, ionizing cellular molecules, breaking chemical bonds, and causing severe DNA damage.

20.4 If carbon-14 stopped forming in the atmosphere today, how would that affect the use of carbon dating in the future?

Answer: If formation stopped, the global equilibrium level of carbon-14 would consistently drop, making it impossible to establish a baseline value for living organisms. Consequently, carbon dating would become inaccurate and eventually unusable for tracking the age of future artifacts.

20.5 What is the difference between nuclear fission and nuclear fusion in terms of process and energy release?

Answer: Fission splits a heavy, unstable nucleus into smaller fragments, while fusion combines light nuclei into a heavier one. Gram for gram, nuclear fusion releases significantly more energy than nuclear fission, without producing long-lived radioactive waste.

D. Comprehensive Questions

20.1 How does the structure of an atom determine its chemical properties? Explain with reference to the arrangement of protons, neutrons, and electrons?

Answer:

- **Protons** determine the atomic number (Z), which dictates the total number of electrons in a neutral atom.
- **Electrons** occupy energy levels; those in the outermost shell (valence electrons) participate in bonding. An atom's chemical reactivity depends entirely on gaining, losing, or sharing these electrons to achieve a stable outer shell.
- **Neutrons** sit in the nucleus to provide stability via the strong nuclear force. Because they have no charge, they do not affect the electron configuration or chemical behavior.

20.2 Explain Einstein's equation: $E = mc^2$, and its significance. How does this equation relate to nuclear reactions?

Answer:

- **Meaning:** Energy (E) and mass (m) are interchangeable forms of the same physical quantity, scaled by the speed of light squared (c^2).
- **Significance:** Because c^2 is an immense value, a tiny amount of mass converts into a massive quantity of energy.
- **Nuclear Reactions:** In fission and fusion, the products weigh slightly less than the reactants. This missing mass (mass defect) is converted directly into kinetic and thermal energy using this equation.

20.3 Describe the process of radioactive decay and how it leads to the emission of alpha, beta, and gamma radiation?

Answer: Radioactive decay is the spontaneous process where an unstable nucleus releases particles or energy to become stable:

- **Alpha (α) Decay:** A heavy nucleus ejects an alpha particle (2 protons, 2 neutrons; a Helium nucleus ${}^{4}_{2}He$). Mass decreases by 4, atomic number decreases by 2.
- **Beta (β) Decay:** A neutron converts into a proton and throws off a high-energy electron (beta particle, ${}^{0}_{-1}e$). Mass stays the same, atomic number increases by 1.
- **Gamma (γ) Decay:** An excited nucleus drops to a lower energy state by emitting a high-energy photon (gamma ray). Mass and atomic number remain unchanged.

20.4 Why do different isotopes of the same element have similar chemical properties but different physical properties? Explain.

Answer:

- **Similar Chemical Properties:** Isotopes of an element have the exact same number of protons, which means they have the identical arrangement of electrons. Since chemical properties depend entirely on electron interactions, they react identically.
- **Different Physical Properties:** Physical properties (mass, density, boiling points) depend on the total mass of the nucleus. Because isotopes have different numbers of neutrons, their masses vary, altering these physical behaviors.

20.5 Explain how carbon dating uses carbon-14 to estimate the age of artifacts. Discuss its reliability, considering the influence of carbon-14's half-life.

Answer:

- **Process:** Living organisms absorb stable Carbon-12 and radioactive Carbon-14 in a constant ratio. Upon death, intake stops, and Carbon-14 decays into Nitrogen via beta emission. Measuring the remaining ratio reveals the time elapsed since death.
- **Reliability:** Driven by a half-life of 5,730 years, it is highly reliable for organic artifacts up to 50,000 years old. Beyond this limit, too little Carbon-14 remains to measure accurately. It requires calibration because historic atmospheric carbon levels have fluctuated slightly over millennia.

E. Numerical Problems

20.1 Find the number of protons and neutrons in the nuclide defined by ${}^{21}_{9}X$

Given: Nuclide = ${}^{21}_{9}X$, Z = 9, A = 21

Solution: N = 21 - 9 = 12

20.2 A fossil is found to have 25% of the carbon-14 compared to a living sample. How old is the fossil?

Given: Remaining percentage of carbon-14 = 25%, $T_1/_2$ = 5,730 years

Solution: 100% → 50% → 25% (It takes 2 half-lives to reach 25%)
t = 2 × 5730 = 11,460 years

Therefore, the fossil is 11,460 years old.

20.3 A sample initially contains 400 g of a radioactive isotope with a half-life of 10 years. How much remains after 30 years?

Given: N_0 = 400 g, $T_1/_2$ = 10 years, t = 30 years

Formula: $n = t/T_1/_2$

Solution: n = 30/10 = 3 half-lives
After 3 half-lives: 400 → 200 → 100 → 50 g

Therefore, the remaining mass is 50 g.

20.4 A radioactive substance has a half-life of 64 months. In how much time, one-eighth of the substance will be left?

Given: $T_1/_2$ = 64 months, remaining fraction = 1/8

Solution: 1 → 1/2 → 1/4 → 1/8 (n = 3 half-lives)
t = 3 × 64 = 192 months

Therefore, the required total time is 192 months.

20.5 In a nuclear reaction, 4 μg of mass is converted into energy. Find the energy.

Given: m = 4 μg = 4×10^{-9} kg, c = 3×10^{8} m/s

Formula: $E = mc^2$

Solution: $E = (4 \times 10^{-9}) \times (3 \times 10^{8})^2 = (4 \times 10^{-9}) \times (9 \times 10^{16}) = 36 \times 10^{7}$ J = 360 MJ

Therefore, the energy released is 360 MJ.

20.6 In 420 days, one-eighth of polonium (Po) remains un-decayed. Calculate the half-life of polonium.

Given: t = 420 days, un-decayed fraction = 1/8

Solution: 1 → 1/2 → 1/4 → 1/8 (n = 3 half-lives)
$T_1/_2$ = 420/3 = 140 days

Therefore, the half-life of polonium is 140 days.

20.7 Three-fourth of the initial mass of a certain radioactive isotope decay after one hour. Find half-life of isotope in minutes.

Given: Decayed fraction = 3/4, t = 1 hour = 60 minutes
Remaining fraction = 1 - 3/4 = 1/4

Solution: $1/4 = (1/2)^2$ so n = 2 half-lives
$T_{1/2} = 60/2 = 30$ minutes

Therefore, the half-life of the isotope is 30 minutes.

Unit No. 21: Nuclear Energy and Environment

A. Multiple Choice Questions

21.1 What process generates energy in the Sun?

- (a) Nuclear fission
- **(b) Nuclear fusion ✓**
- (c) Radioactive decay
- (d) Chemical reactions

21.2 The factor which primarily determines a planet's surface temperature:

- (a) its density
- **(b) its orbital distance from the Sun ✓**
- (c) its gravitational field strength
- (d) the number of moons it has

21.3 What is the primary reason cyclones form over warm ocean waters?

- (a) The presence of strong winds
- (b) The high atmospheric pressure
- **(c) The rising of warm, moist air creating low pressure ✓**
- (d) The gravitational pull of the moon

21.4 Which of the following gas contributes the most to global warming?

- (a) Oxygen
- **(b) Carbon dioxide ✓**
- (c) Nitrogen
- (d) Argon

21.5 How does the Coriolis effect influence cyclones?

- **(a) It causes cyclones to spin in opposite directions in different hemispheres ✓**
- (b) It strengthens cyclones over land
- (c) It prevents warm air from rising
- (d) It stops the formation of low-pressure areas

21.6 A major cause of rising sea levels is:

- (a) increased volcanic activity
- (b) the Earth moving closer to the Sun
- **(c) melting glaciers and ice sheets ✓**
- (d) decreased solar radiation

21.7 A significant source of background radiation is:

- (a) oxygen in the air
- **(b) cosmic rays from space ✓**
- (c) sound waves in the atmosphere
- (d) light from the Sun

B. Short Answer Questions

21.1 What are the two main elements that make up the Sun?

Answer: The two main elements that make up the Sun are hydrogen and helium, which constitute almost all of its mass and fuel its nuclear core.

21.2 What factors are used to compare planets in terms of their characteristics?

Answer: Planets are compared using physical factors like mass, diameter, density, surface temperature, atmospheric composition, orbital distance, and gravitational field strength.

21.3 Explain how global warming increases the intensity of hurricanes.

Answer: Global warming raises ocean surface temperatures, which provides extra thermal energy, increases evaporation, and fuels stronger, more intense hurricanes.

21.4 What is background radiation, and what are its natural sources?

Answer: Background radiation is the low-level ionizing radiation constantly present in the environment, primarily originating from cosmic rays and terrestrial radioactive isotopes.

21.5 Name three safety measures used to handle radioactive materials safely.

Answer: Three key safety measures include maintaining maximum distance using remote handling tools, keeping exposure times brief, and using heavy lead or concrete shielding.

21.6 Why do cyclones weaken when they move over land?

Answer: Cyclones weaken over land because they are cut off from their primary energy source (warm ocean moisture) and experience increased surface friction.

21.7 How does the Coriolis Effect influence the movement of cyclones?

Answer: The Coriolis effect deflects moving air currents, causing cyclones to rotate counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

21.8 What is the primary cause of rising sea levels due to global warming?

Answer: The primary causes are the melting of terrestrial glaciers and ice sheets combined with the thermal expansion of seawater as oceans absorb heat.

C. Constructed Response Questions

21.1 Why do gas giants like Jupiter, despite their larger size, have lower densities than rocky planets such as Earth and Mars? What does this tell us about their internal structure?

Answer: Gas giants like Jupiter are composed mostly of hydrogen and helium, which are much lighter than the silicate rocks and metals that make up Earth. This indicates that Jupiter has a small, dense core surrounded by massive layers of liquid and gaseous elements, rather than a solid surface.

21.2 If two planets receive the same amount of sunlight but have different atmospheric compositions, why might their surface temperatures still differ significantly?

Answer: This is due to the Greenhouse Effect. If one planet has an atmosphere rich in greenhouse gases (like CO_2), it will trap more heat than a planet with a thin or non-absorbent atmosphere, even if both receive the same solar energy.

21.3 How does the Coriolis effect play a role in creating the spiraling motion of cyclones, and what might happen to cyclone formation if the Earth stopped rotating?

Answer: The Coriolis effect deflects air moving toward a low-pressure center, causing it to spiral instead of flowing straight in. If Earth stopped rotating, there would be no Coriolis effect, so cyclones would not develop their characteristic spin; they would just collapse inward symmetrically.

21.4 Compare the ways radiation, conduction, and convection each contribute to geothermal activity. Why is convection considered the primary driver of tectonic plate motion?

Answer: Heat moves from the core to the surface via conduction through solid rock and convection in the mantle. Convection is the primary driver of plate tectonics because the circular movement of molten rock (magma) acts like a conveyor belt, dragging the lithospheric plates above it.

21.5 Explain why background radiation is always present in our environment and how cosmic and terrestrial sources balance each other despite fluctuations in human activity.

Answer: Background radiation is always present because cosmic rays are constant and radioactive isotopes in the Earth's crust have very long half-lives. While human activity (like medical X-rays or nuclear testing) adds fluctuations, the "baseline" remains dominated by natural cosmic and terrestrial sources.

D. Descriptive Questions

21.1 Describe the process of nuclear fusion in the Sun and explain how it generates energy.

Answer: In the Sun's core, extreme pressure and temperature (15 million °C) force hydrogen nuclei to fuse into helium. A small amount of mass is lost in this process and converted into a massive amount of energy according to $E = mc^2$.

21.2 How does a planet's orbital distance affect its surface temperature and the amount of solar energy it receives?

Answer: The Inverse Square Law applies here; as distance increases, the intensity of solar radiation decreases significantly. This makes inner planets (Mercury, Venus) extremely hot and outer planets (Neptune) extremely cold.

21.3 Explain the role of convection in the formation and strengthening of cyclones.

Answer: Warm sea air rises (convection), creating a low-pressure area at the surface. More air rushes in to fill the gap, is warmed, and rises in a continuous cycle, creating the towering clouds and intense energy of a cyclone.

21.4 What are the major sources of background radiation, and how do human activities contribute to it?

Answer:

- **Natural:** Cosmic rays, Radon gas, Potassium-40 in food (bananas)
- **Human:** Medical procedures (X-rays, CT scans), nuclear power plant emissions, and historical fallout from weapons testing

21.5 Explain how radiation exposure can be harmful and describe three key safety measures used to minimize its risks.

Answer: Ionizing radiation can damage DNA, leading to mutations or cancer. Safety is managed through the ALARA principle (As Low As Reasonably Achievable):

1. **Time:** Keeping the duration of exposure near radioactive sources as short as possible reduces the cumulative dose absorbed by the body.
2. **Distance:** Increasing distance from a radiation source drops exposure levels exponentially.
3. **Shielding:** Placing absorbing barriers such as lead sheets, thick concrete walls, or specialized water tanks.