Physics Notes (Electric Field)

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7. Electric Field (A Basic Introduction)

7.1 Electric Lines of Force (Field Lines)

- **Definition:** Imaginary lines used to visualize and map the direction and strength of an electric field.
- **Properties of Field Lines:**
    1. They start on **positive charges** and end on **negative charges** (or extend to infinity).
    2. The **tangent** to a line at any point gives the direction of the electric field intensity (E) at that point.
    3. The **density** of the lines (how close they are) indicates the strength of the electric field. A stronger field means closer lines.
    4. Electric field lines **never cross** each other.
- **Patterns:**
    - **Single Positive Charge:** Lines radiate outwards.
    - **Single Negative Charge:** Lines radiate inwards.
    - **Between Parallel Plates (Capacitor):** Lines are parallel, straight, and equally spaced, indicating a **uniform field** between the plates.

7.2 Potential Difference and Electric Current

- **Electric Potential Difference (PD) (Voltage, V):** The energy supplied per unit charge between two points in a circuit. It's the "push" that moves the charges.
    - **Unit: Volt (V)**, which is 1 Joule per Coulomb (1 J/C).
    - PD is maintained by a source of EMF (like a battery or generator).
- **Electric Current (I):** The rate of flow of electric charge.

- **Formula:** $I = \frac{Q}{t}$ (Charge Q passing a point in time t).
- **Unit: Ampere (A)**, which is 1 Coulomb per second ($1\ \mathrm{C/s}$).
    - Conventionally, current flows from positive to negative, even though electrons (negative charges) flow from negative to positive.

7.3 Production of Electric Current

- Electric current is produced when a source of **Electromotive Force (EMF)** converts another form of energy into electrical energy, creating a potential difference.
- **Sources of EMF:**
    - **Chemical Energy:** Batteries (Galvanic/Voltaic cells) convert chemical energy.
    - **Mechanical Energy:** Generators (dynamos) convert mechanical energy via **electromagnetic induction**.
    - **Light Energy:** Solar cells (photovoltaic cells) convert light energy.
    - **Heat Energy:** Thermocouples convert heat energy.

7.4 Principle of Production of Electricity from a Dam (Hydroelectric Power)

- **Energy Conversion:** The process involves converting **Gravitational Potential Energy → Kinetic Energy → Mechanical Energy → Electrical Energy**.
- **Mechanism:**
    1. **Water Storage:** A dam holds back a large volume of water, storing high Gravitational Potential Energy.
    2. **Water Flow:** When released, the water falls, and GPE is converted to Kinetic Energy.
    3. **Turbine Drive:** The fast-moving water hits the blades of a **turbine**, converting KE into Mechanical Energy (rotation).
    4. **Generator:** The rotating turbine shaft is connected to a **generator**, which uses the principle of **electromagnetic induction** to produce electric current.

7.5 Electric Circuit

- **Definition:** A complete, closed path through which electric current can flow.
- **Essential Components:**
    1. **Source of EMF (Cell/Battery):** Provides the potential difference.
    2. **Load (Resistor/Device):** The component that uses the electrical energy (e.g., bulb, motor).
    3. **Connecting Wires:** Provides the path for current flow (usually copper).
    4. **Switch (Optional):** Used to open or close the circuit.
- **Types:**
    - **Closed Circuit:** A complete path, current flows.
    - **Open Circuit:** An incomplete path (e.g., switch is open), no current flows.
    - **Short Circuit:** Current bypasses the load through a path of very low resistance, leading to excessive current.

7.6 Electric Conduction Through Materials; Ohm's Law

- **Materials Classification (by Conductivity):**
  - **Conductors:** Materials with many free electrons that allow current to flow easily (e.g., metals like copper, silver).
  - **Insulators:** Materials with very few free electrons that resist current flow (e.g., plastic, glass, rubber).
  - **Semiconductors:** Materials with conductivity between conductors and insulators (e.g., silicon, germanium).

- **Ohm's Law:** States that for a metallic conductor at **constant temperature**, the current (**I**) flowing through it is directly proportional to the potential difference (**V**) across its ends.
  - **Formula:** $V \propto I \quad \text{or} \quad V = IR$
  - **Resistance (R):** The constant of proportionality, representing the opposition to current flow.
  - **Unit of Resistance:** Ohm (Ω).

7.7 Electrical Work Done in a Given Circuit

- **Work Done (W):** The electrical energy converted into other forms of energy (like heat, light, or mechanical energy) by the load in a circuit.

- **Formulas for Electrical Work/Energy (W or E):**
  1. From the definition of PD ($V = W/Q$):
     $W = VQ$
  2. Using $Q = It$: $W = VIt$
  3. Using Ohm's Law ($V = IR$):
     $W = (IR)It = I^2Rt$
  4. Using Ohm's Law ($I = V/R$):
     $W = V(\frac{V}{R})t = \frac{V^2}{R}t$
- **Electrical Power (P):** The rate at which electrical work is done or energy is converted.
  - **Formula:** $P = \frac{W}{t} = VI = I^2R = \frac{V^2}{R}$
  - **Unit: Watt (W)**, which is 1 Joule per second (1 J/s).

7.8 Summary

- Electric fields are mapped by lines of force, showing direction and strength.
- Potential difference (V) drives the electric current (I).
- Electricity is generated by converting various energy forms, especially mechanical energy in a dam.
- An electric circuit is a closed path for current flow, obeying Ohm's Law.
- Electrical work is energy converted, calculated by W = VIt.

Comprehensive Summary for All Covered Topics

This concludes the detailed notes for the entire syllabus you provided. Below is a brief recap of the main concepts from all the chapters:

Chapter	Main Concept	Key Formula / Principle
3. Projectiles	Independent motion in 2D under gravity.	$v_x = \text{constant}, v_y = u_y - gt$
4. Equilibrium	Net force and net moment are zero.	$\Sigma F = 0, \Sigma\text{Moments} = 0, P = \rho gh$
5. SHM	Restoring force ∝ displacement.	$a \propto -x, T = 2\pi\sqrt{L/g}$ (simple penc
6. Momentum	Impulse = $\Delta\mathbf{p}$. Momentum is conserved in closed systems.	$\mathbf{F}\Delta t = \Delta\mathbf{p}, m_1u_1 + m_2u_2 = m_1v_1 +$
7. Mech. Energy	Work is force × displacement. Energy is conserved.	$W = Fd\cos\theta, E = \frac{1}{2}mv^2 + mgh$
8. Heat & Temp	Temperature is avg. KE. Heat is energy transfer.	$K = {}^\circ C + 273.15$
9. Heat Meas.	Specific heat causes ΔT. Latent heat causes phase change.	$Q = mc\Delta T, Q = mL$
10. Gas Laws	Relate P, V, T for a fixed mass of gas.	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
16. Fluid Press.	Pressure increases with depth and is transmitted undiminished.	$P = \rho gh$, Pascal's Principle
11. Waves	Transfer of energy by disturbance (transverse/ longitudinal).	$v = f\lambda$
12. Reflection	Light bounces off a surface.	$\theta_i = \theta_r$
13. Refraction	Light bends due to change in speed. Includes TIR and lenses.	$n_1\sin\theta_1 = n_2\sin\theta_2, \sin\theta_c = 1/n$
14. Light App.	Lenses in cameras, eyes, microscopes, and telescopes.	Correcting myopia (concave), hype
15. Sound	Longitudinal mechanical wave, requires a medium.	Pitch (f), Loudness (Amplitude), Qu
1. EM Waves	Transverse waves of $\mathbf{E}$ and $\mathbf{B}$ fields. All travel at c.	$c = f\lambda, c \approx 3 \times 10^8$ m/s
2. Gravity	Attractive force ∝ masses, ∝ $1/r^2$.	$F = \frac{Gm_1m_2}{r^2}, T^2 \propto r^3$
3. Electric I	Force between charges. Capacitors store energy.	$F = \frac{kq_1q_2}{r^2}, E = \frac{F}{q_0}, C = \frac{Q}{V}$
4. Electric II	Current flow, resistance, circuits.	$V = IR$ (Ohm's Law)
5. Electric III	Conduction through ions (electrolysis) and ionized gases.	Faraday's Laws ($m \propto Q$), Thermion
6. Magnetic	Field around magnets/currents.	Fleming's Left-Hand Rule, Right-Ha
7. Electromag	Interaction between fields/currents (motor effect, induction).	$F = BIL, E = -N\frac{\Delta\Phi}{\Delta t}, \frac{V_s}{V_p} = \frac{N_s}{N_p}$
8. AC Circuits	Alternating current in R, L, C circuits.	$V_{rms} = \frac{V_0}{\sqrt{2}}, Z = \sqrt{R^2 + (X_L -$