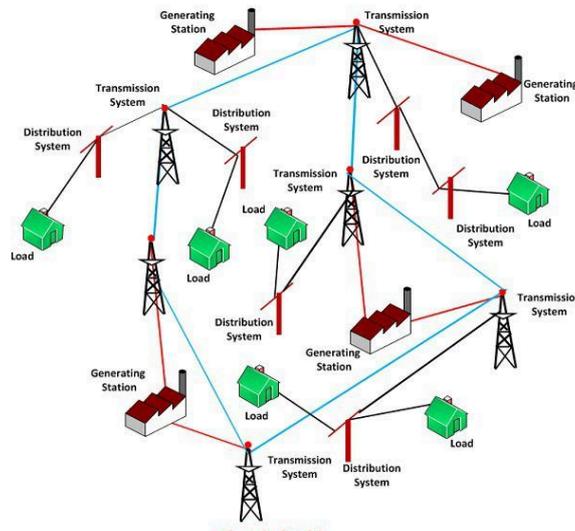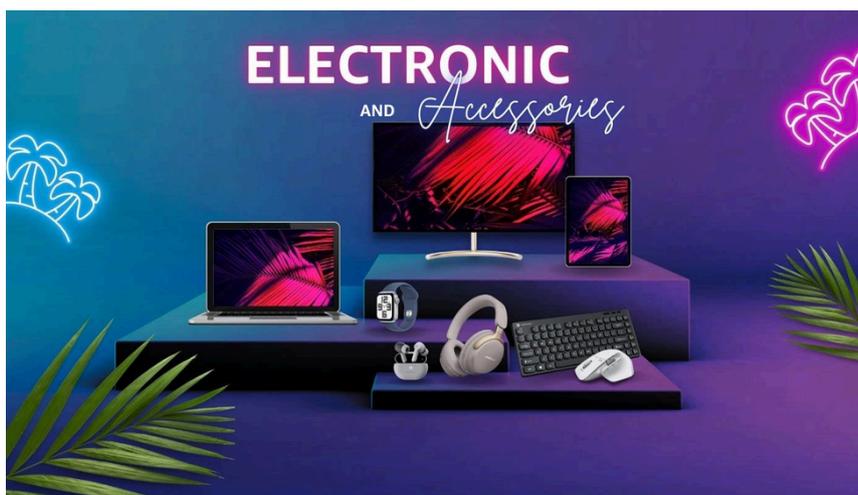# Electricity & Circuits

The core concepts

🔍 **Big Idea:** Electricity is the movement of charge and it powers nearly every modern technology. Understanding electrical behaviour lets us design everything from tiny microchips to massive power grids.

🌍 **Real-Life Connection:** Your phone, laptop, lighting, transport systems, and medical devices all rely on principles of electricity. Even static shocks when you touch a metal door handle follow the same rules.

📘**Key Concepts:** Charges interact to produce electric forces and currents. Circuits control how energy flows through systems. Digital logic underpins modern computing.
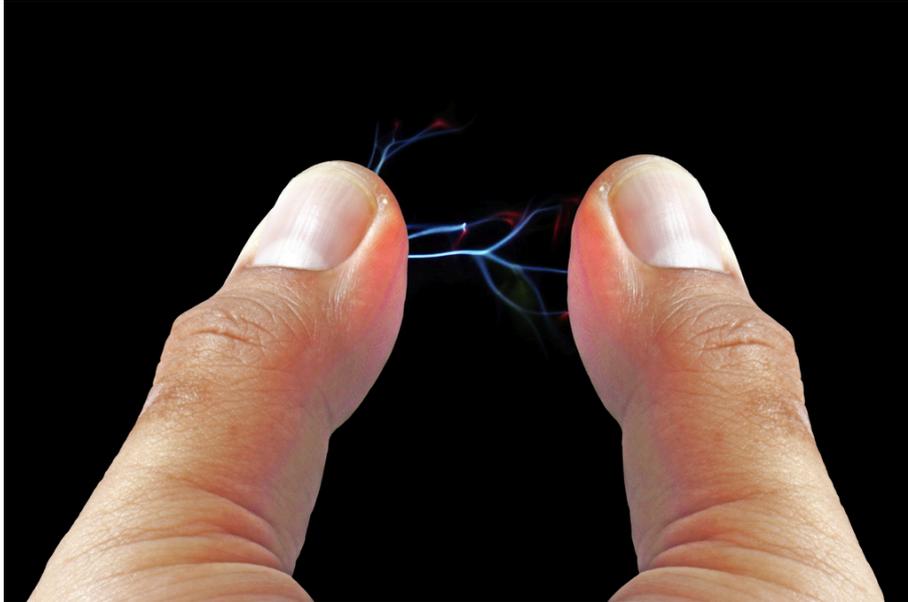
IB Key Concept: Electric circuits are systems where components interact to produce predictable outcomes.

Core Physics Summary

1. Static Electricity & Electric Charge

Charge can be positive or negative. Like charges repel; unlike charges attract. Rubbing materials transfers electrons → static build-up.

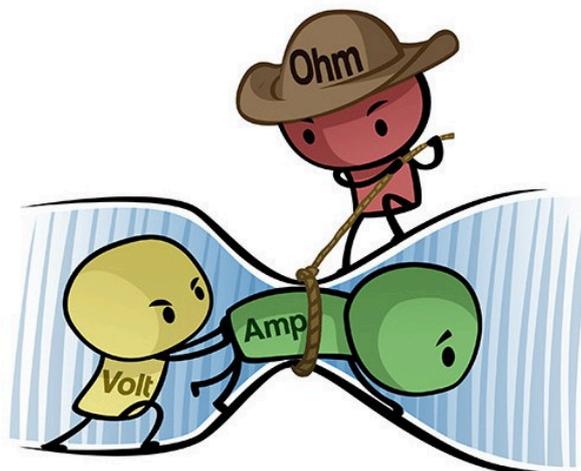**Applications:** photocopiers, paint spraying, lightning.

2. Current, Voltage & Resistance (Ohm's Law)

- **Current (I):** flow of charge per second (A)
    - $I = Q / t$
- **Voltage (V):** energy transferred per charge
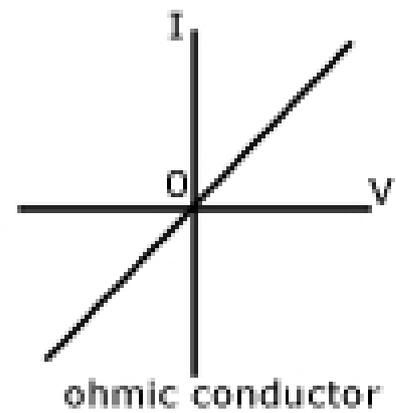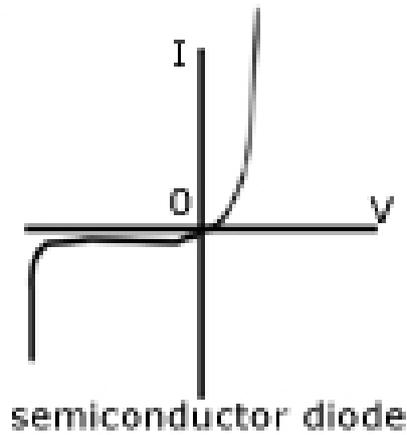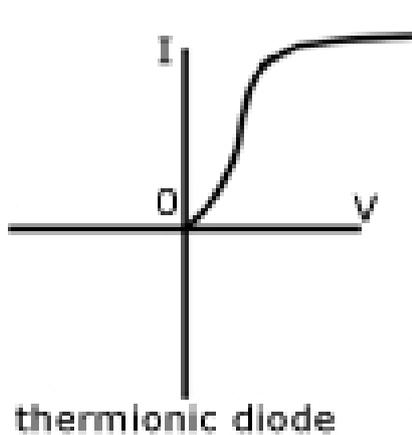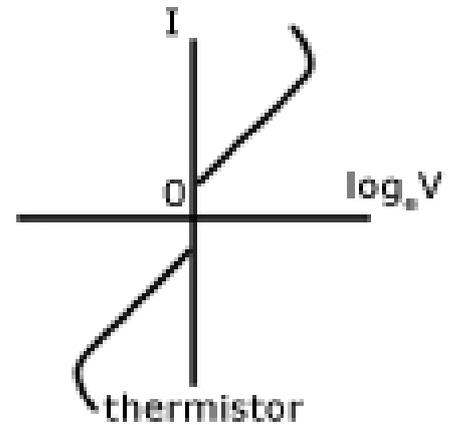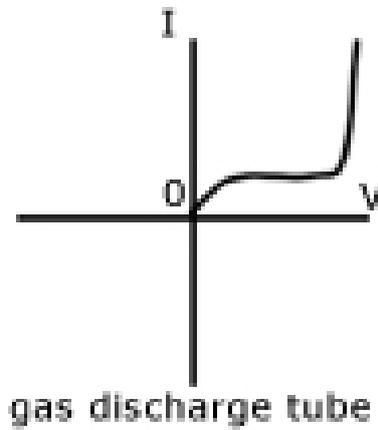- **Resistance (R):** opposes current (Ω)

Ohm's law: $V = I\,R$

(Applies to components with constant resistance.)

3. Ohmic & Non-Ohmic Conductors

- **Ohmic:** Follow V ∝ I
  - Straight-line graph
  - Examples: resistors, metals
- **Non-Ohmic:** Do not follow Ohm's law
  - Curved I-V graphs
  - Examples: diodes, filament bulbs.

filament lamp　　　gas discharge tube　　　thermistor

thermionic diode　　　semiconductor diode　　　ohmic conductor
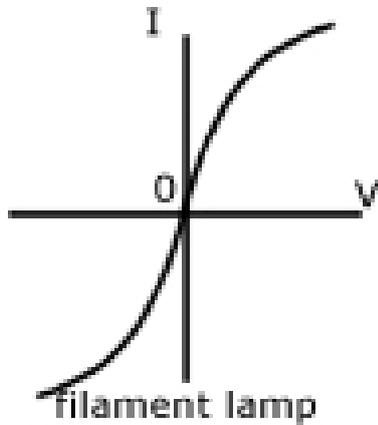
4. Series & Parallel Circuits

- **Series:** One path
  - Current same everywhere
  - Voltage shared between components
  - If one breaks → whole circuit stops
- **Parallel:** Multiple paths
  - Voltage same across branches
  - Currents split
  - Used in home wiring (lights stay on even if one fails).
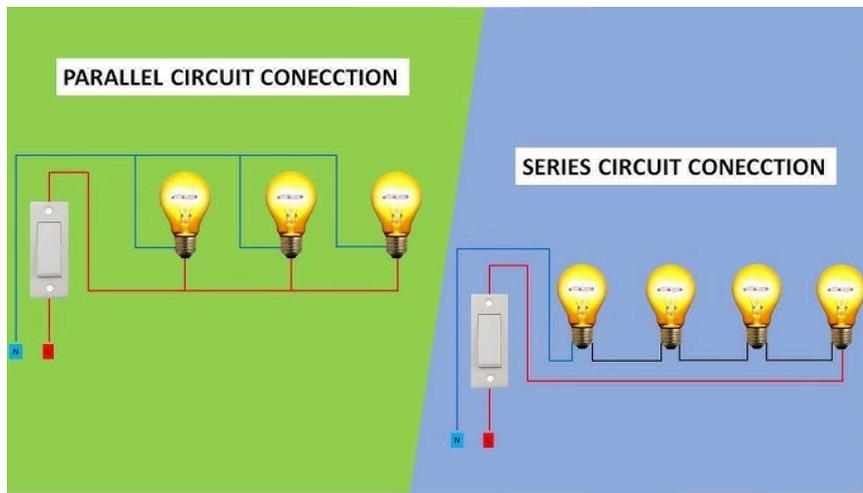
5. Kirchhoff's Laws

- **Kirchhoff's Current Law (KCL):** Sum of currents entering a junction = sum leaving.
- **Kirchhoff's Voltage Law (KVL):** Total voltage around a closed loop = 0 (gains = drops).

These laws govern all circuit analysis.
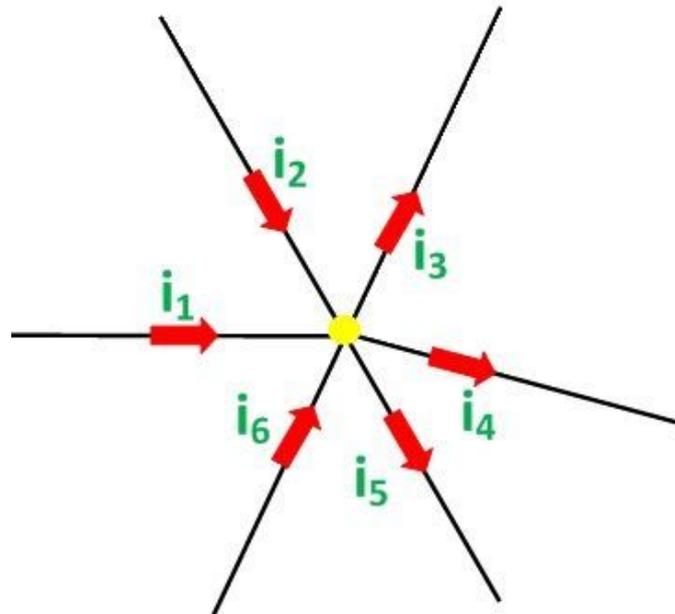
6. Electrical Power & Energy

- **Power:** $P = V\,I$ or $P = I^2\,R$
- **Electrical energy:** $E = P\,t$

Used in electricity bills (kWh).

kW vs. kWh

Power	Energy
kW	kWh
0.1 kW 2 kW	0.2 kW 4 kW

vs.

🕐 = 2 hours of use

7. Resistivity & Variable Resistors

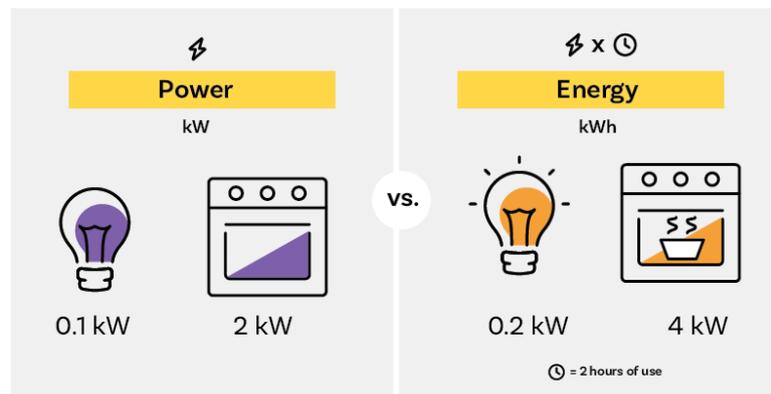- **Resistivity (ρ):** material property determining resistance.
  - R = ρ L / A (L = length, A = cross-sectional area)
- **Variable resistors include:** Rheostats, LDRs (light-dependent resistors), Thermistors.

They change resistance with light (LDR) or temperature (thermistor). Used in sensors, dimmer switches, automatic lighting.

$A = $ area

$L = $ length

$\rho = $ resistivity

$= \text{---}\!\bigwedge\!\text{---}$ R

$$R = \rho \frac{L}{A}$$
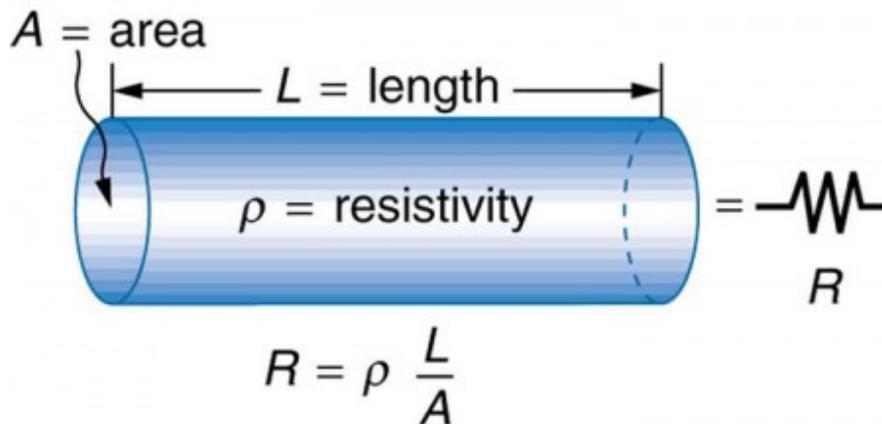
8. Capacitors & Diodes

- **Capacitor:** Stores electric charge. Used in smoothing circuits, camera flashes, filters.
- **Diode:** Allows current in one direction only. Used for rectification and protection circuits. LEDs emit light when forward-biased.
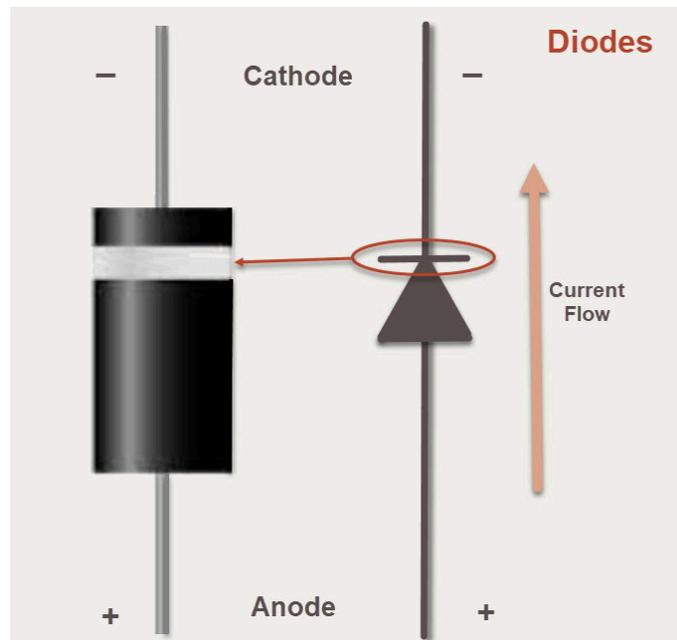
9. Rectifiers (Half-Wave & Full-Wave)

AC → DC conversion:

- **Half-wave rectifier:** Uses one diode. Only positive halves of AC pass.
- **Full-wave rectifier (bridge):** Uses four diodes. Both halves become positive.

Smoothing capacitors reduce ripple.
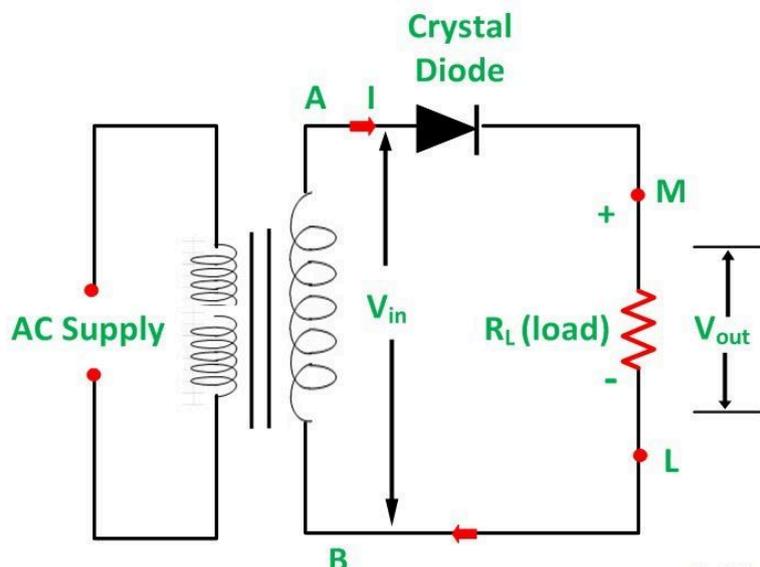
10. Logic Gates & Digital Circuits

Basic logic gates:

- **AND:** output 1 only if both inputs are 1
- **OR:** output 1 if any input is 1
- **NOT:** inverts the input
- **Combined to form:** Adders, Counters, Microprocessors. Binary states 0 and 1 are the basis of all digital technology.

| Logic Gate	Symbol	Description	Boolean
AND		Output is at logic 1 when, and only when all its inputs are at logic 1,otherwise the output is at logic 0.	$X = A \cdot B$
OR		Output is at logic 1 when one or more are at logic 1.If all inputs are at logic 0,output is at logic 0.	$X = A + B$
NAND		Output is at logic 0 when,and only when all its inputs are at logic 1,otherwise the output is at logic 1	$X = \overline{A \cdot B}$
NOR		Output is at logic 0 when one or more of its inputs are at logic 1.If all the inputs are at logic 0,the output is at logic 1.	$X = \overline{A + B}$
XOR		Output is at logic 1 when one and Only one of its inputs is at logic 1. Otherwise is it logic 0.	$X = A \oplus B$
XNOR		Output is at logic 0 when one and only one of its inputs is at logic1.Otherwise it is logic 1. Similar to XOR but inverted.	$X = \overline{A \oplus B}$
NOT		Output is at logic 0 when its only input is at logic 1, and at logic 1 when its only input is at logic 0.That's why it is called and INVERTER	$X = \overline{A}$

11. Superconductors & Applications

Superconductors have zero resistance below a critical temperature.
Benefits: No energy loss, extremely strong magnetic fields.
**Applications:** MRI scanners, maglev trains, particle accelerators.
Limitation: require extremely low temperatures → expensive cooling.

magnetic field

above critical temperature   below critical temperature
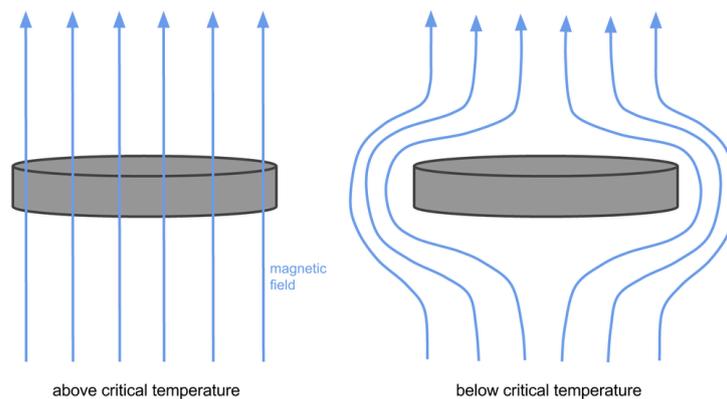
✿ **Everyday Example:** When you use your phone charger, AC from the wall is rectified into DC using diodes and capacitors. Inside the phone, logic gates in the processor make billions of decisions every second, all based on simple 0/1 electrical signals.

💭 **Think & Reflect:** Why do your lights at home not all turn off if one bulb breaks? What advantages might superconductors bring if room-temperature versions become possible?

N ⊡ ⊡ ⊡ N

L ⊡ ⊡ ⊡ L

From Supply

To other
Sub Circuits

Cut X

Bulb Glow   Bulb Glow   Bulb OFF
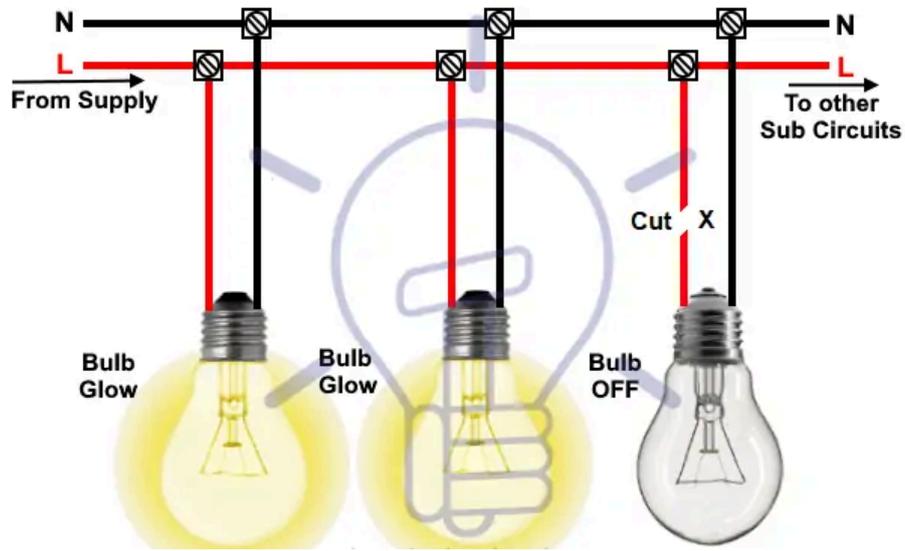
🎯 **Summary:** Electricity connects physics to modern technology. From analysing circuits to understanding digital logic, this unit explains how energy flows, how components behave, and how innovations like superconductors and diodes make advanced devices possible. Mastery of electricity empowers you to understand and design the systems shaping the digital world.

📢**Next Step:** To explore circuit problems, I–V graph analysis, and exam-style questions, check LumiKnow Premium Physics Notes.