

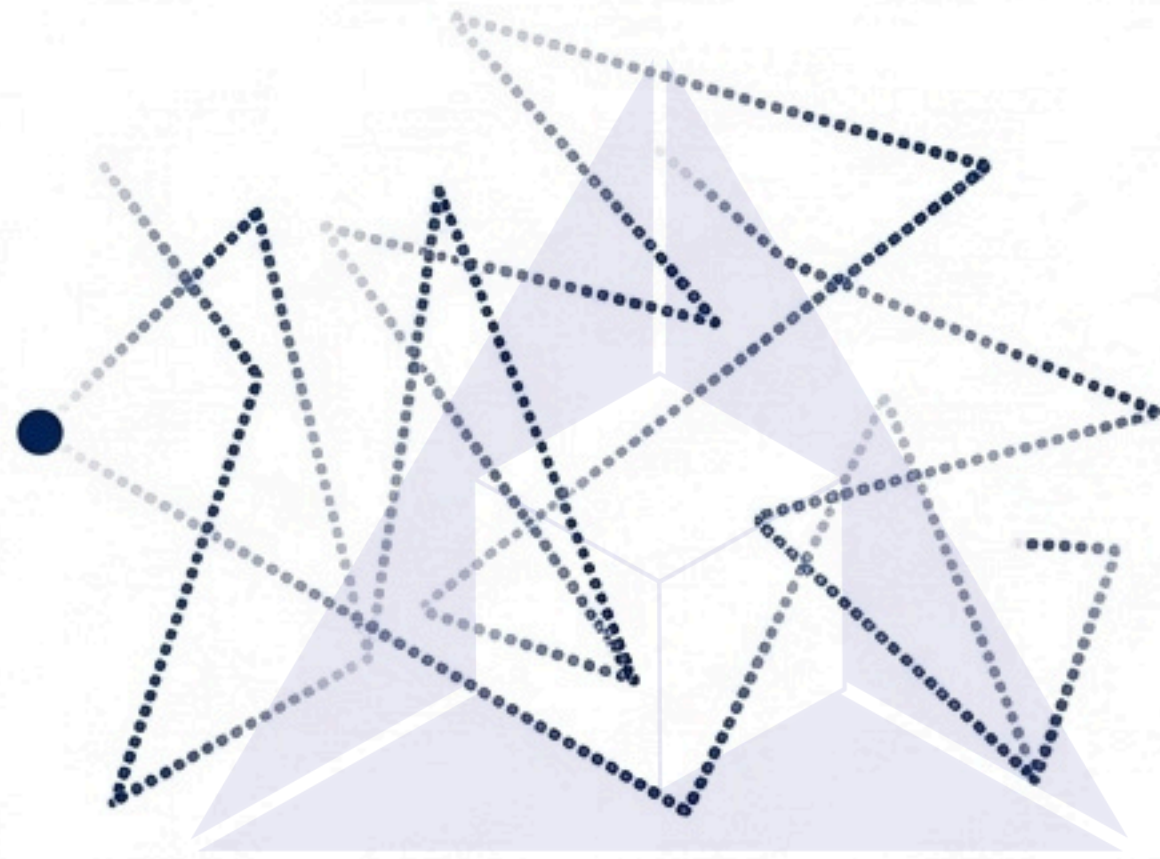
[NEET/JEE CORE CONCEPT]

Drift of Electrons and the Origin of Resistivity

Demystifying the microscopic mechanics of steady electric current.

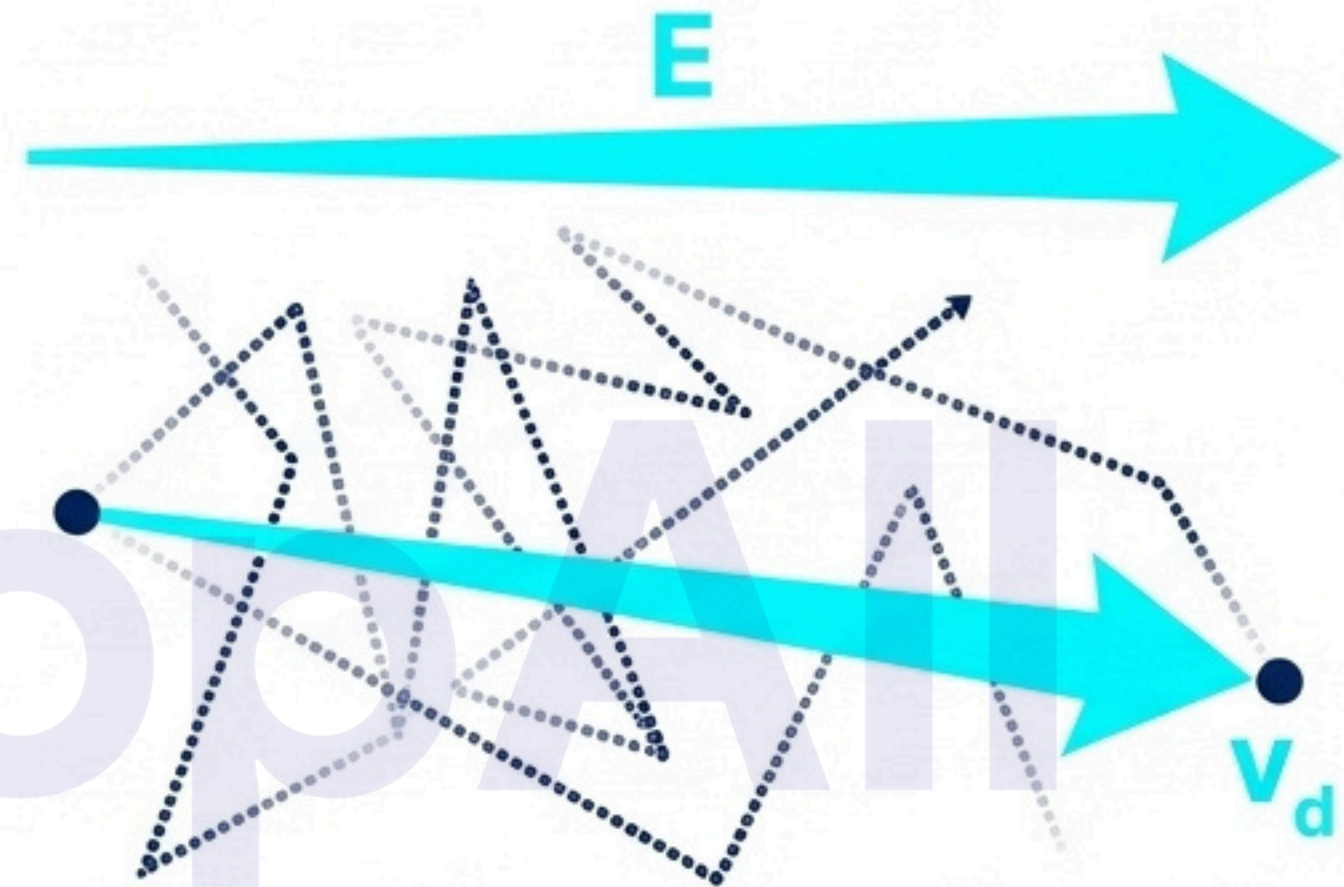


NO ELECTRIC FIELD



Average Velocity = 0. Speed is massive ($\sim 10^5$ m/s) but totally random.

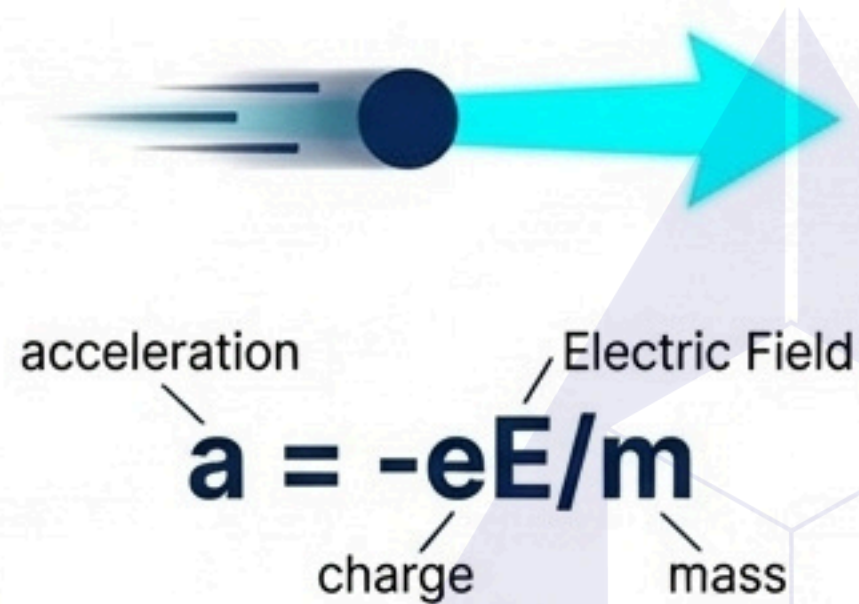
ELECTRIC FIELD APPLIED



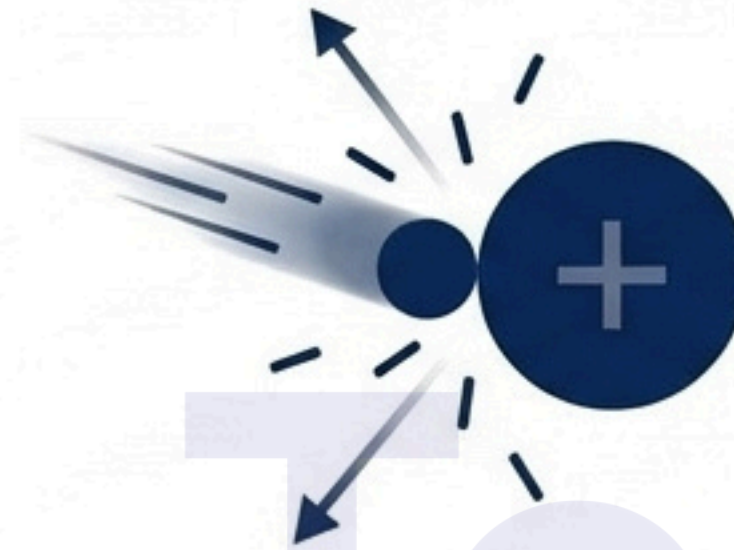
Net displacement occurs. Drift speed is tiny ($\sim 10^{-3}$ m/s).

Drift is incredibly slow compared to thermal motion, yet it creates the currents we use daily.

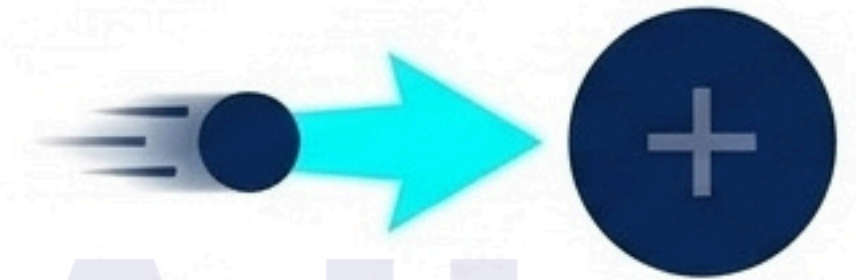
1. Accelerate



2. Collide

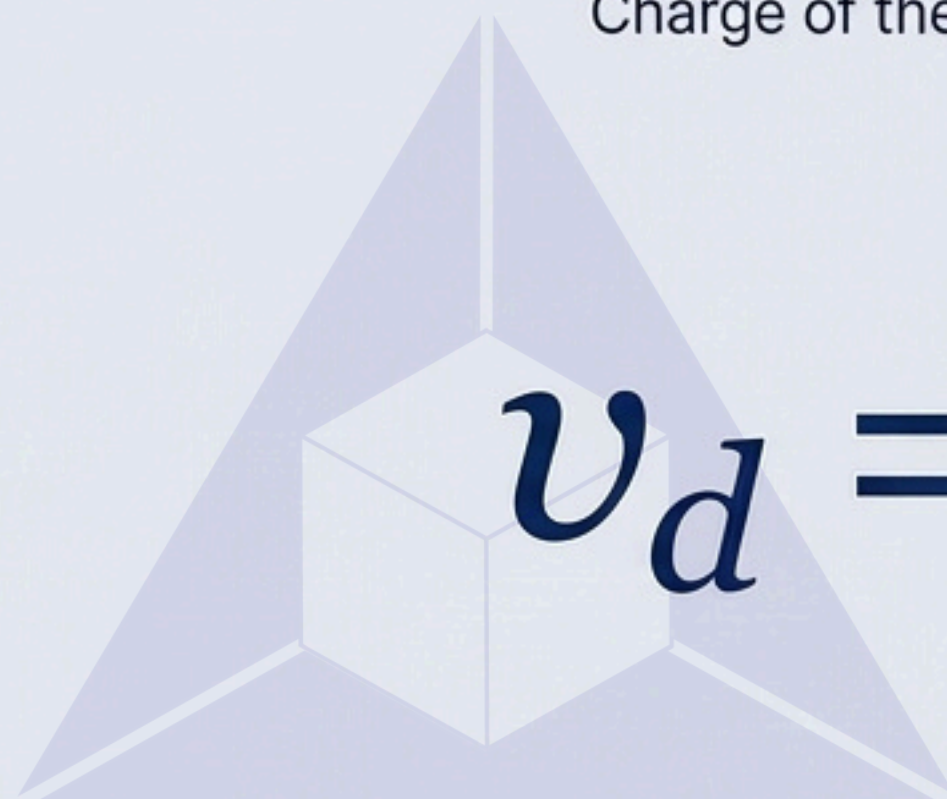


3. Repeat



τ = Average time between collisions.

Collisions act as internal “friction.” They prevent continuous acceleration, resulting in a steady average velocity instead of an infinitely increasing one.


$$v_d = - \frac{eE}{m} \tau$$

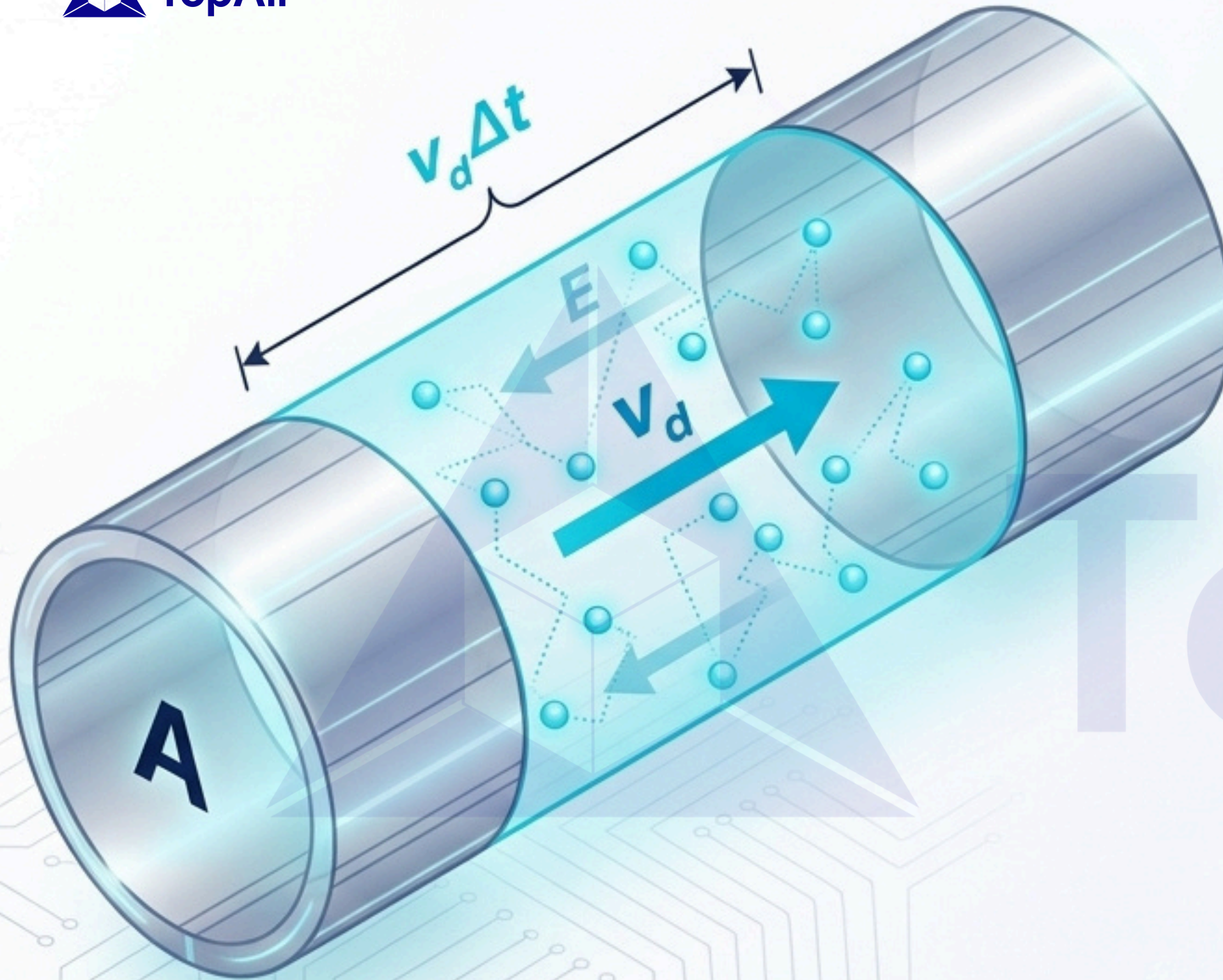
Charge of the electron. — e

The external nudge
(Electric Field) — E

Relaxation time
(The limiting factor / free time) — τ

Mass — m
(Inertia resisting the pull)

ⓘ The negative sign simply dictates that electrons drift in the opposite direction of the Electric Field.



1. Volume crossed in time
 $\Delta t = A(v_d \Delta t)$

2. Total Electrons = $n \times \text{Volume}$
 (where n = electron number density)

3. Total Charge (ΔQ) = $e \times (n A v_d \Delta t)$

4. Current ($I = \Delta Q / \Delta t$) $\rightarrow$

$$I = n e A v_d$$

I n e A v_d

How does a ~ 1 mm/s drift create a 1 Ampere current? Because n is enormous ($\sim 10^{29}$ electrons/m³ in copper)!

Derivation of Resistivity from Microscopic Parameters

Start with Current Density:

$$j = nev_d$$

Plug in the drift formula ($v_d = eE\tau/m$):

$$j = ne \frac{eE\tau}{m}$$

$$j = \frac{ne^2\tau}{m} E$$

Grand Unification

Compare to Ohm's Law: $j = \sigma E$

$$\text{Conductivity } (\sigma) = \frac{ne^2\tau}{m}$$

$$\text{Resistivity } (\rho) = \frac{m}{ne^2\tau}$$

Resistivity isn't a random constant. It is dictated entirely by how many electrons are available (n) and how frequently they crash (τ).

Key Takeaways

Conceptual Truths

- **Speed vs Drift:** Thermal speed is random and massive ($\sim 10^5$ m/s); drift is directional and tiny ($\sim 10^{-3}$ m/s).
- **Instant Current:** Current establishes at the speed of light because the E-field propagates instantly, even though **individual** electrons drift slowly.
- **Origin of Resistance:** Collisions with positive ions prevent infinite acceleration, defining the relaxation time (τ).

MUST MEMORIZE

$$v_d = \frac{eE}{m}\tau$$

$$I = neAv_d$$

$$\rho = \frac{m}{ne^2\tau}$$