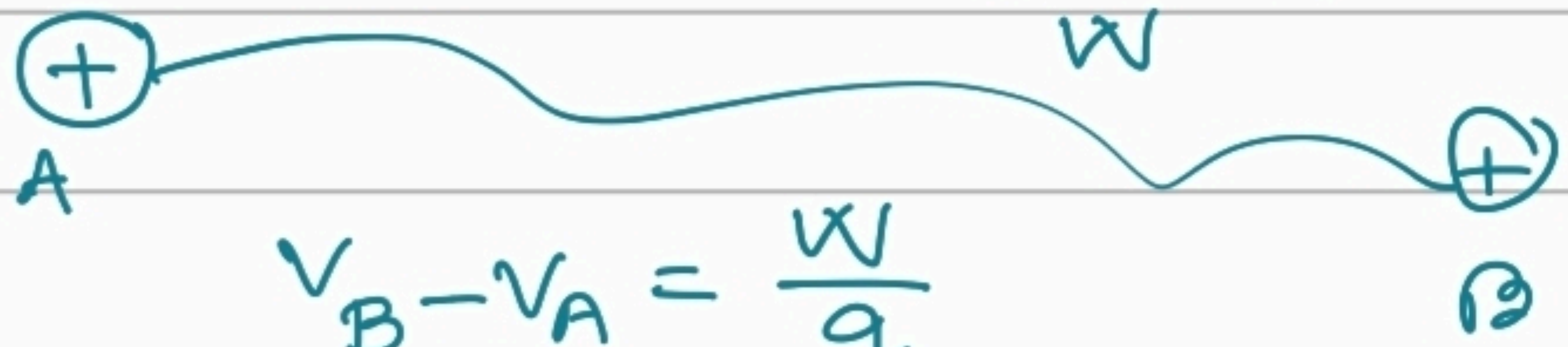
Node, KVL, KCL, Nodal Analysis

Charge: Fundamental property of elementary particles.

Atom ← {electron (−e), proton (+e), neutron (0)}

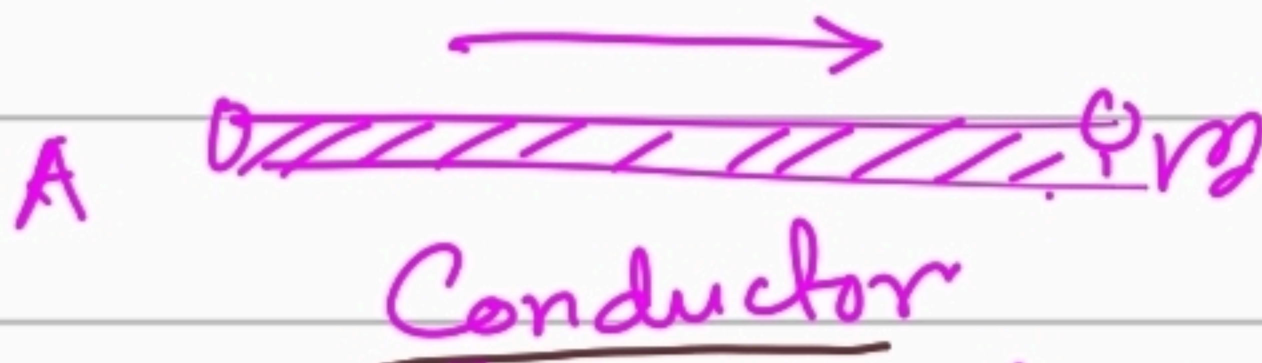
Coloumb's law is used to calculate the force between charged particle.

Voltage: The amount of work (1 J) needed to displace a unit (1 C) charge from one point to another is called voltage. (1 V)



$$V_B - V_A = \frac{W}{q}$$

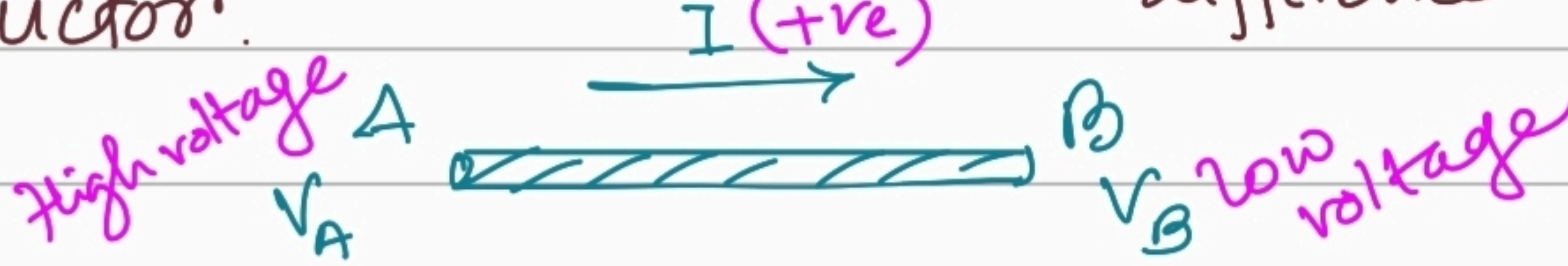
Current: The rate of flow of charge within a conductor is called current.



$$\boxed{\frac{dq}{dt} = i}$$

SI unit of current is ampere.

Ohm's law: For a certain temperature the amount of current flows through a conductor is proportional to the voltage difference across the conductor.



$I \propto (V_B - V_A) \Rightarrow I = G(V_B - V_A)$

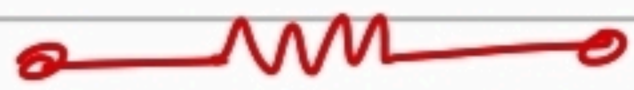
$G \rightarrow$ conductance

$R \rightarrow$ resistance

$\underbrace{(V_B - V_A)}_{V_{BA} = RI} = RI = \frac{1}{G} I$

Electrical Components :-

① **Resistor :**

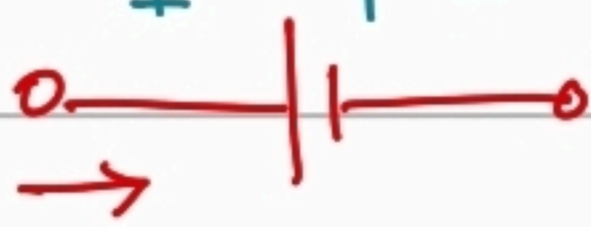


$R \neq 0$

Perfect conductor

$R = 0$

② **Voltage source :**



V_1 doesn't depend on current.

← Practical case

internal resistance / source resistance

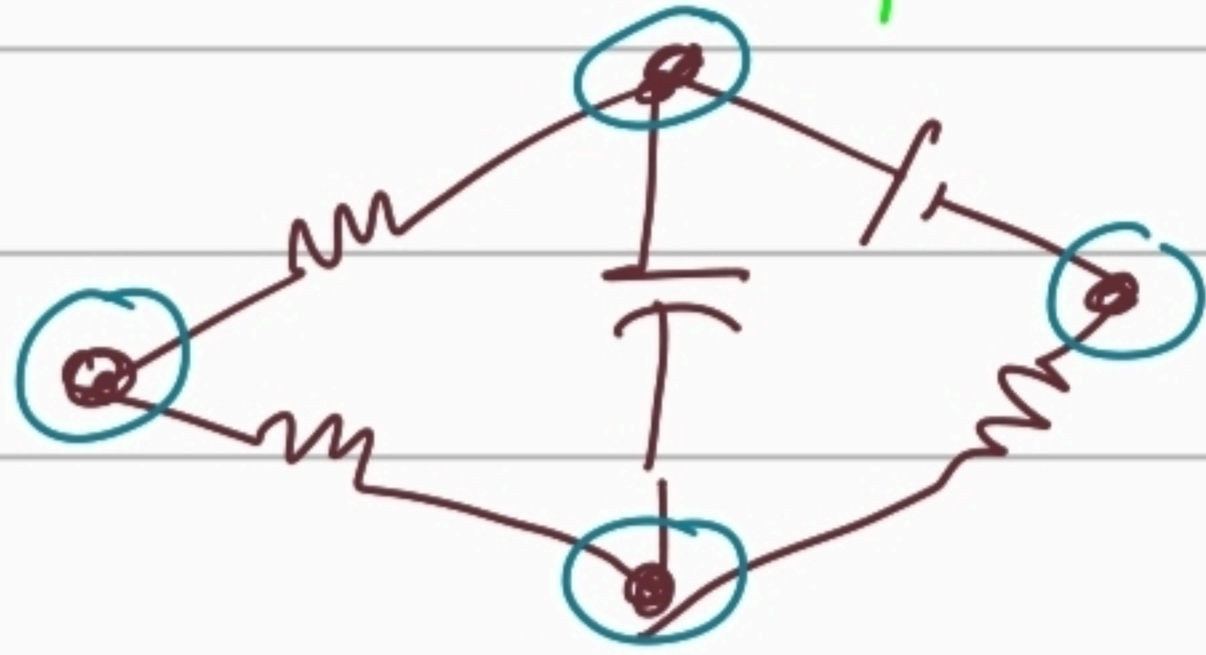
③ **Capacitor :**

← parallel plate capacitor

The amount of charge stored in a capacitor is proportional to the voltage difference across the capacitor.

$Q \propto V \Rightarrow Q = CV \mid C \rightarrow$ capacitance

Node: The interconnection point between more than electrical component is called a node.



4 nodes

KCL : Kirchoff's Current Law

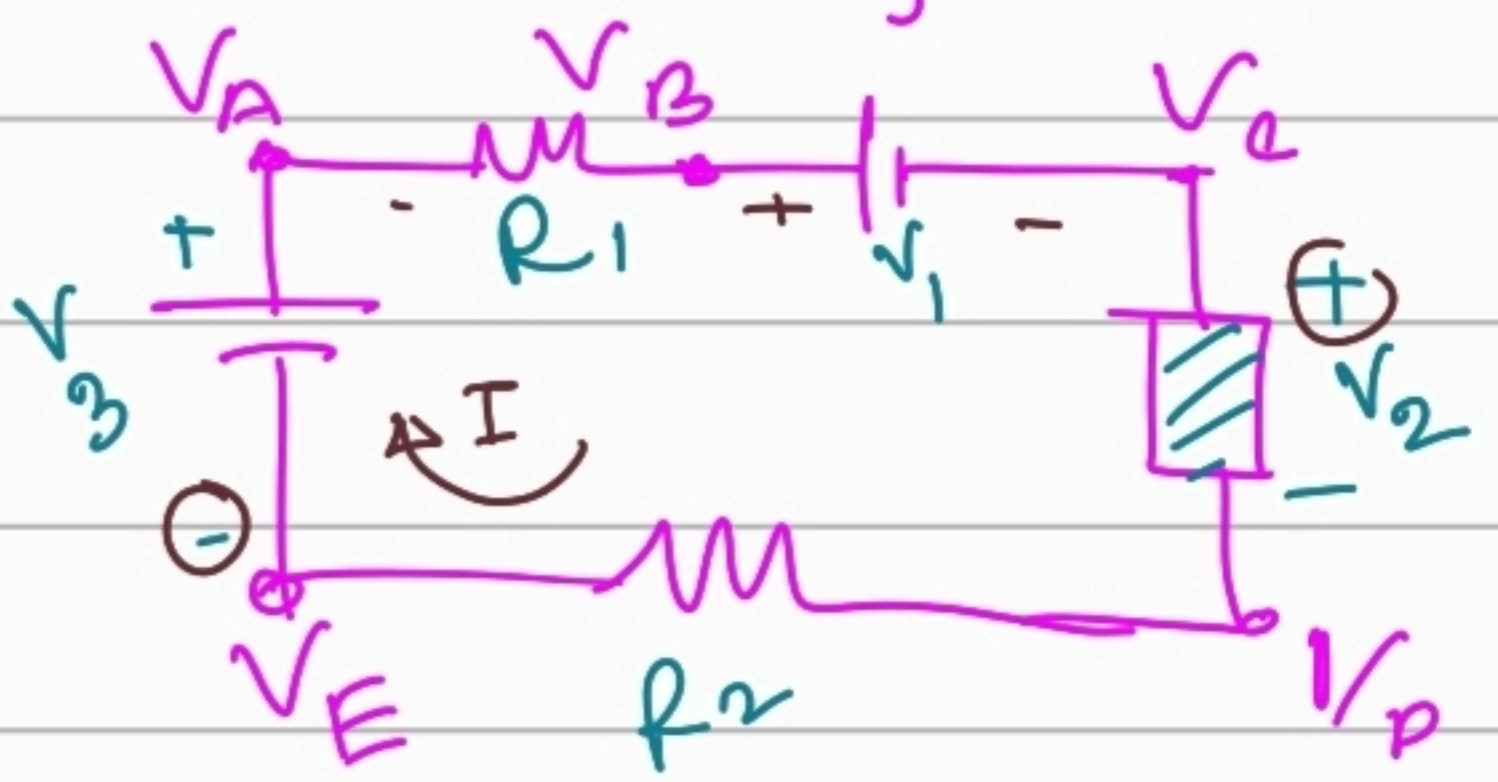
The algebraic sum of currents on a node is zero.

$-i_1 + i_2 + i_3 - i_4 + i_5 = 0$

[• current entering a node would be <u>negativ</u> current

[• current exiting a node would be <u>positive</u> current.

KVL : The voltage droop across a loop inside a electric circuit is zero.



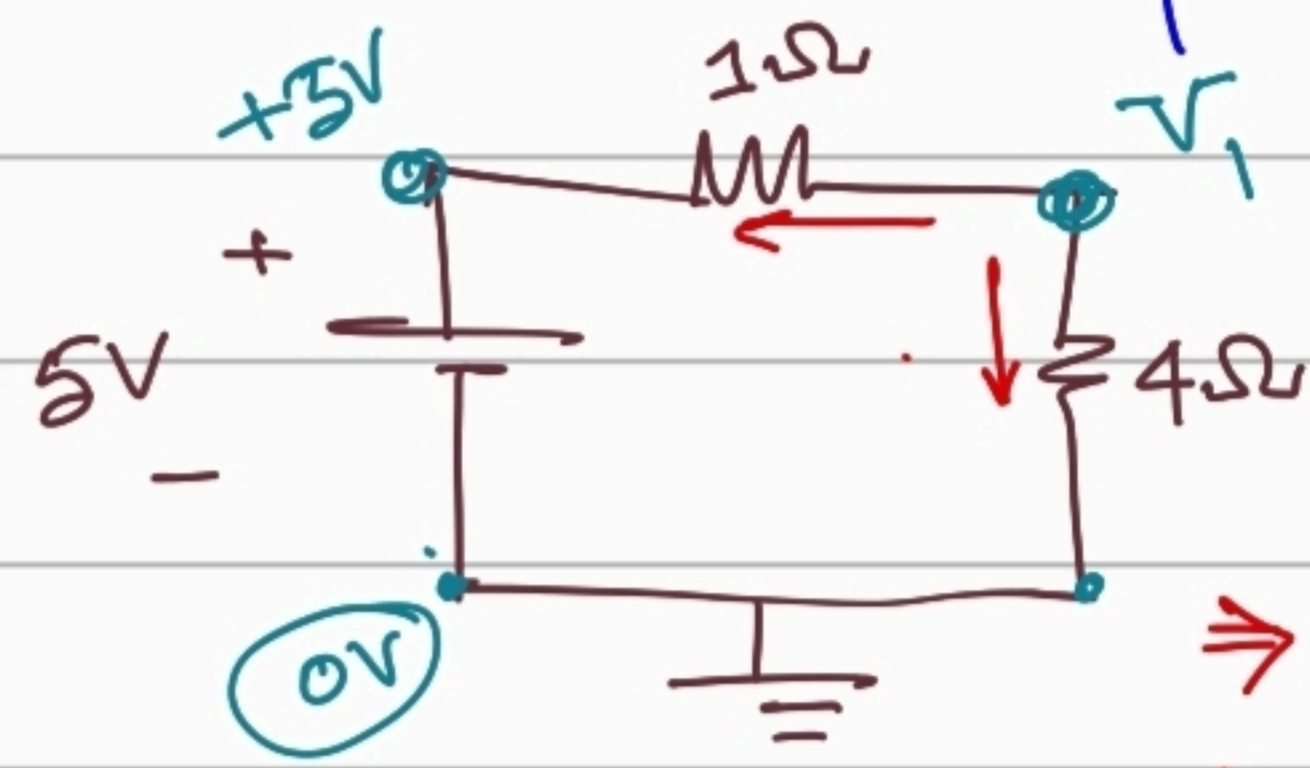
$\underline{V_{AB}} + V_{BC} + V_{CD} + V_{DE} + V_{EA} = 0$

$IR_1 + V_1 + V_2 + IR_2 - V_3 = 0$

NODE ANALYSIS :

1. Identify a reference node (ground)
2. Identify all the unknown node
3. Write the nodal equation
4. Solve the nodal equations together.

Example 1 :



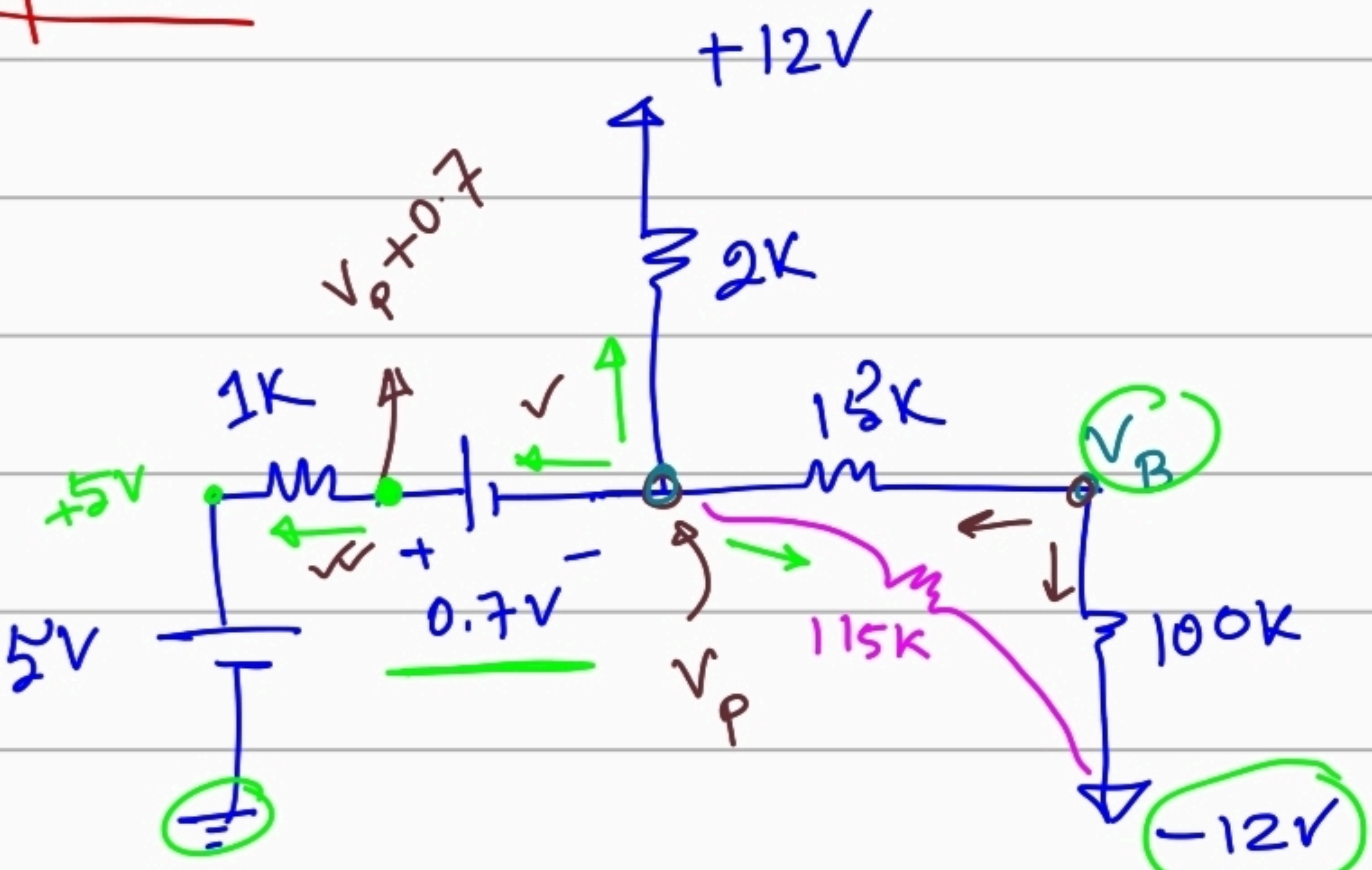
V_1 :

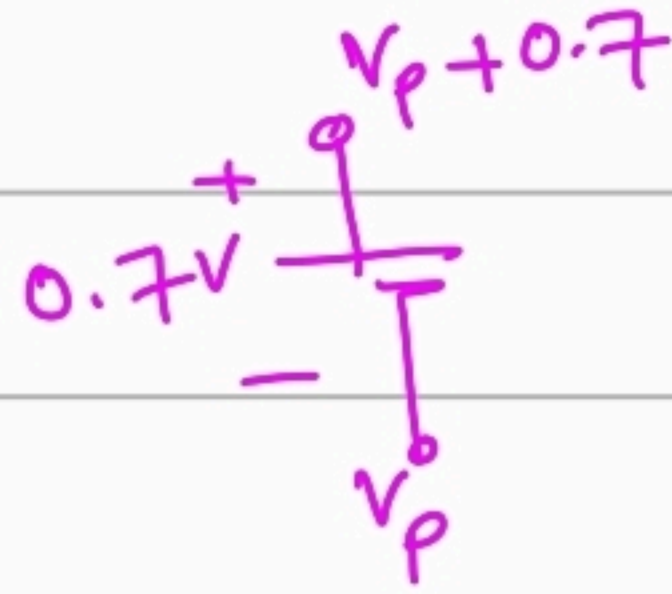
$$\frac{V_1 - 0}{4} + \frac{V_1 - 5}{1} = 0$$

$$\Rightarrow V_1\left(\frac{1}{4} + 1\right) = 5$$

$$\Rightarrow V_1 \frac{5}{4} = 5 \Rightarrow V_1 = 4V$$

Example : 2





~~Online Calculator~~

KCL $\dfrac{V_p-(-12)}{115} + \dfrac{V_p-12}{2} + \dfrac{(V_p+0.7)-5}{1} = 0$

V_p: $\dfrac{V_p - V_B}{15K} + \dfrac{(V_p-12)}{2} + \dfrac{(V_p+0.7)-5}{1} = 0$

V_B: $\dfrac{V_B-(-12)}{100} + \dfrac{(V_B-V_p)}{15} = 0$

[redacted] CSE 251 Review

Electronic Circuits and Devices.

Electronic : The method or process by which we can control the flow of electron using external forces / voltage.

Spintronics, | Photonics. | Twistronics, Valleytronics
|opto electronics|

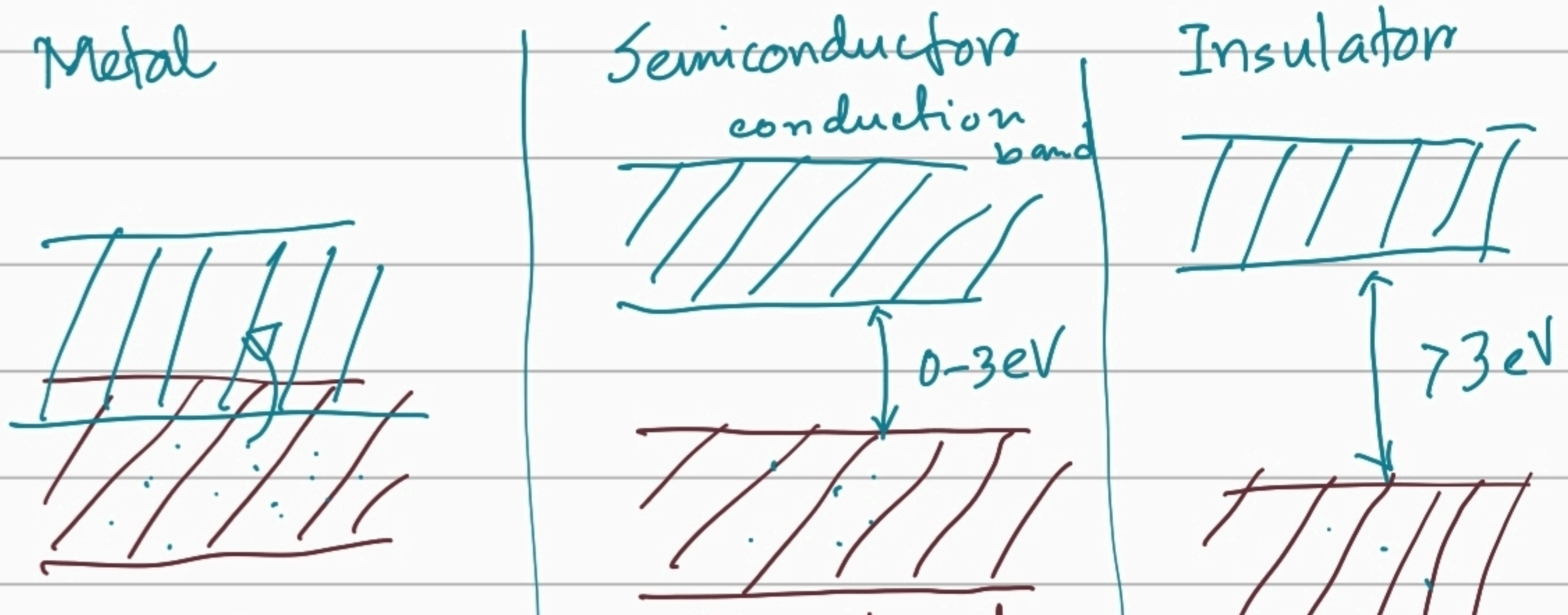
Materials can be classified into roughly three categories based on their conductivity.

1. Metal (Good conductor)

2. Semiconductor

3. Insulator (Bad conductor)

Electron's energy levels form energy bands within a solid. (Quantum Mechanics)



Ex: Ag, Au, Al, Na, Mg, K

Ex: Si, Ge, GaAs, GaN, InSb,

Ex. SiO_2, SiN, Al_2O_3

Intrinsic Semiconductor :- pure semiconductor crystal. (Si)

Si : $\underline{1s^2\ 2s^2 2p^6}$ $3s^2 3p^2$

Valence electrons

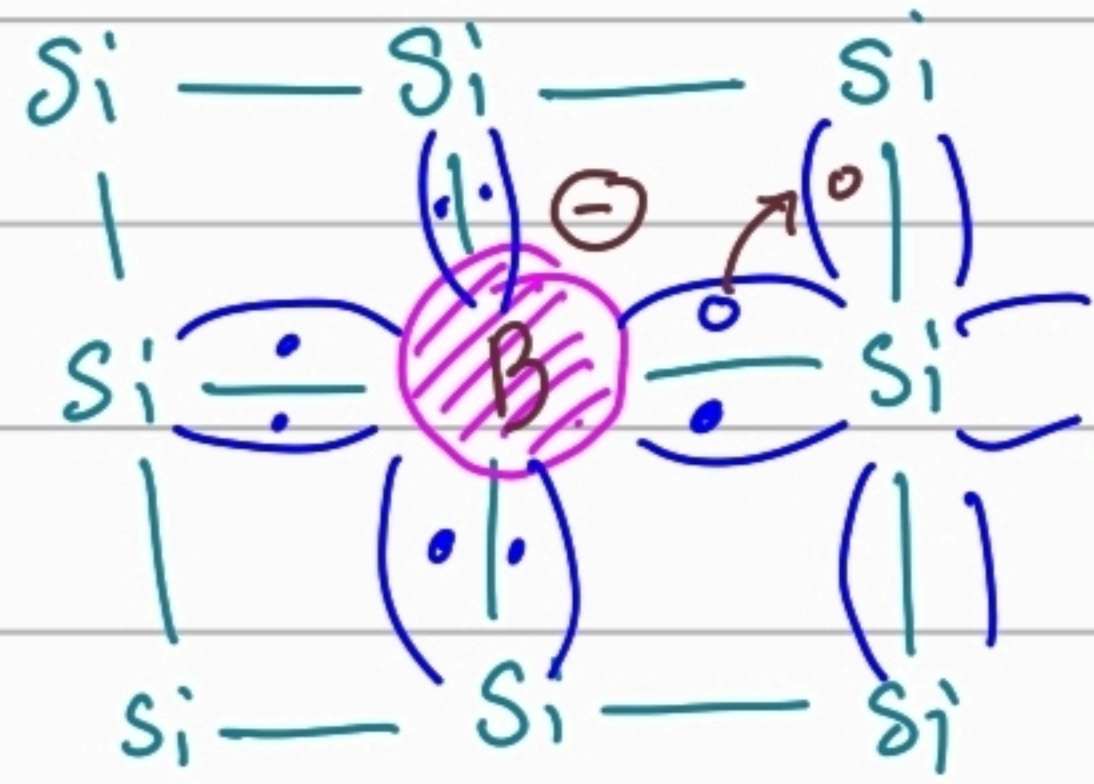
covalent bond

Extrinsic Semiconductor :- impurities are introduced artificially.

① P-type semiconductor: Doping → introduction of different atom in pure crystal.

Dopant atom : Group III A, Group 13 (B, Al)

ns^2np^1 $n = 2, 3, 4 \ldots$

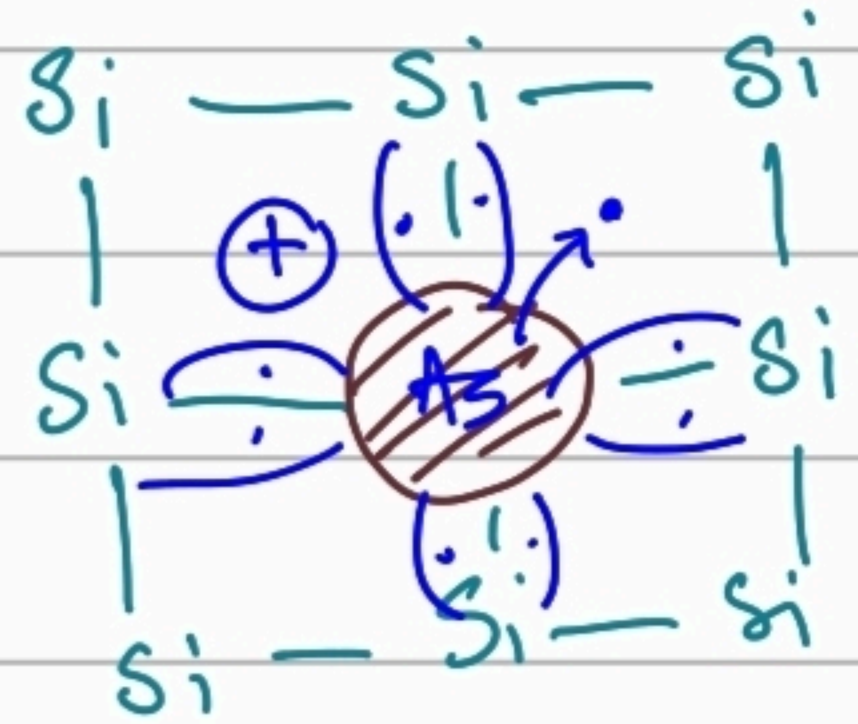


majority charge carrie[r] is called hole (h^+)

bound charge (-ve)

N-type Semiconductor :- Dopant atom : Group V, G-15

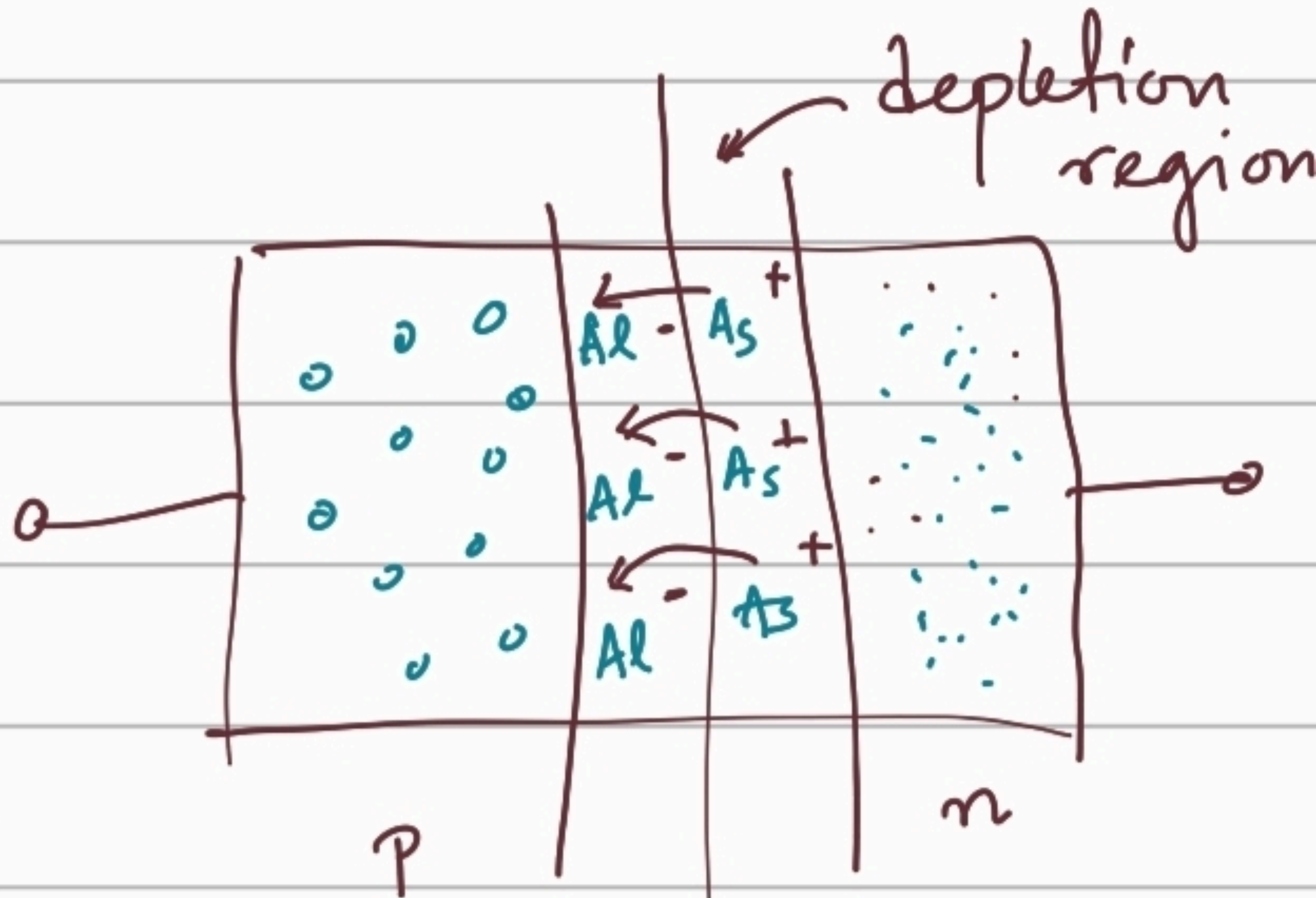
(As, P, Sb) ns^2np^3



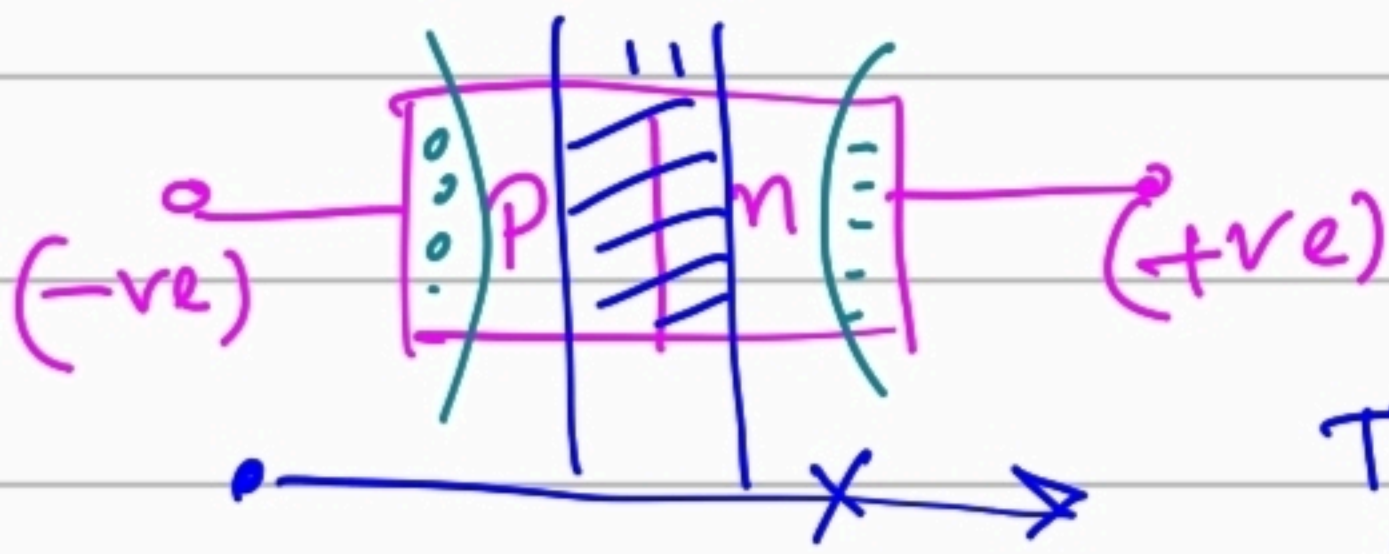
majority carrier ⇒ electron

bound charge is (+ve)

P-n junction diode :-

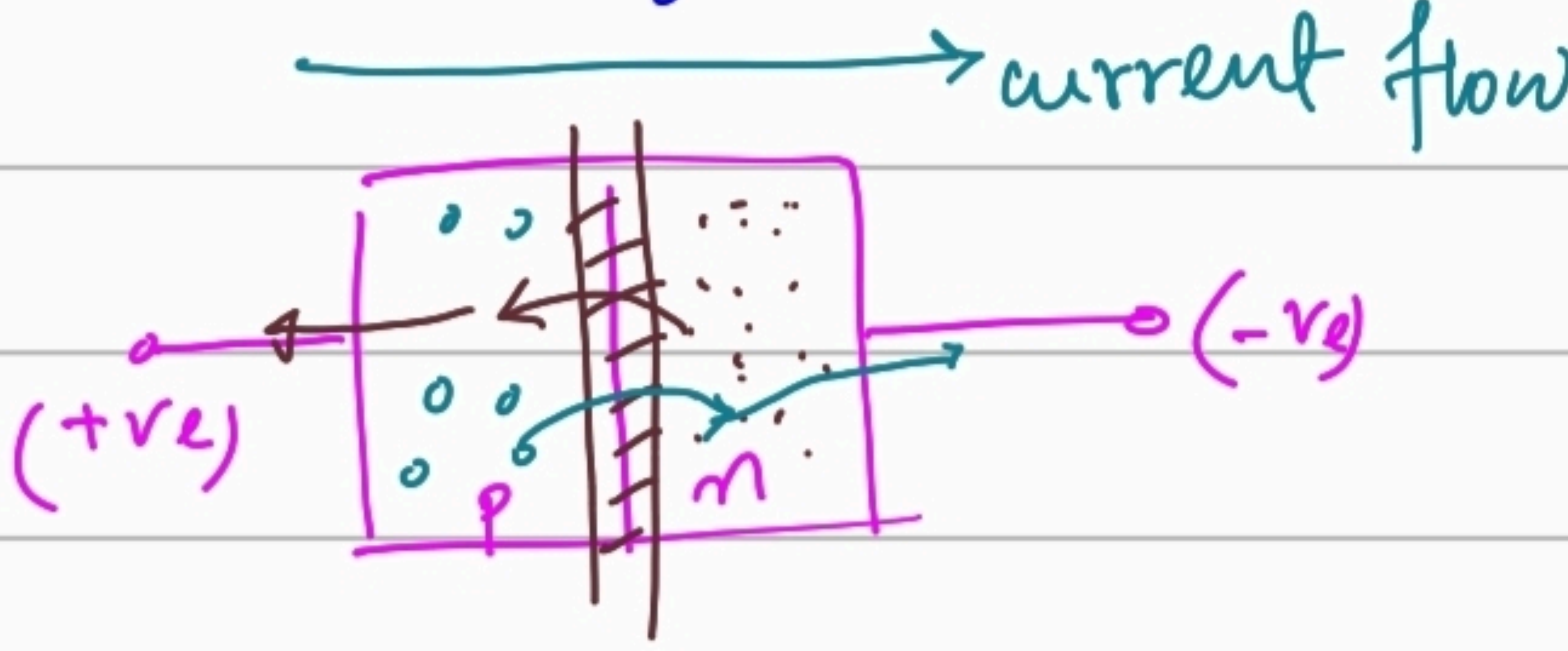


① Reverse Bias :-



There is no current conduction in case of reverse bias.

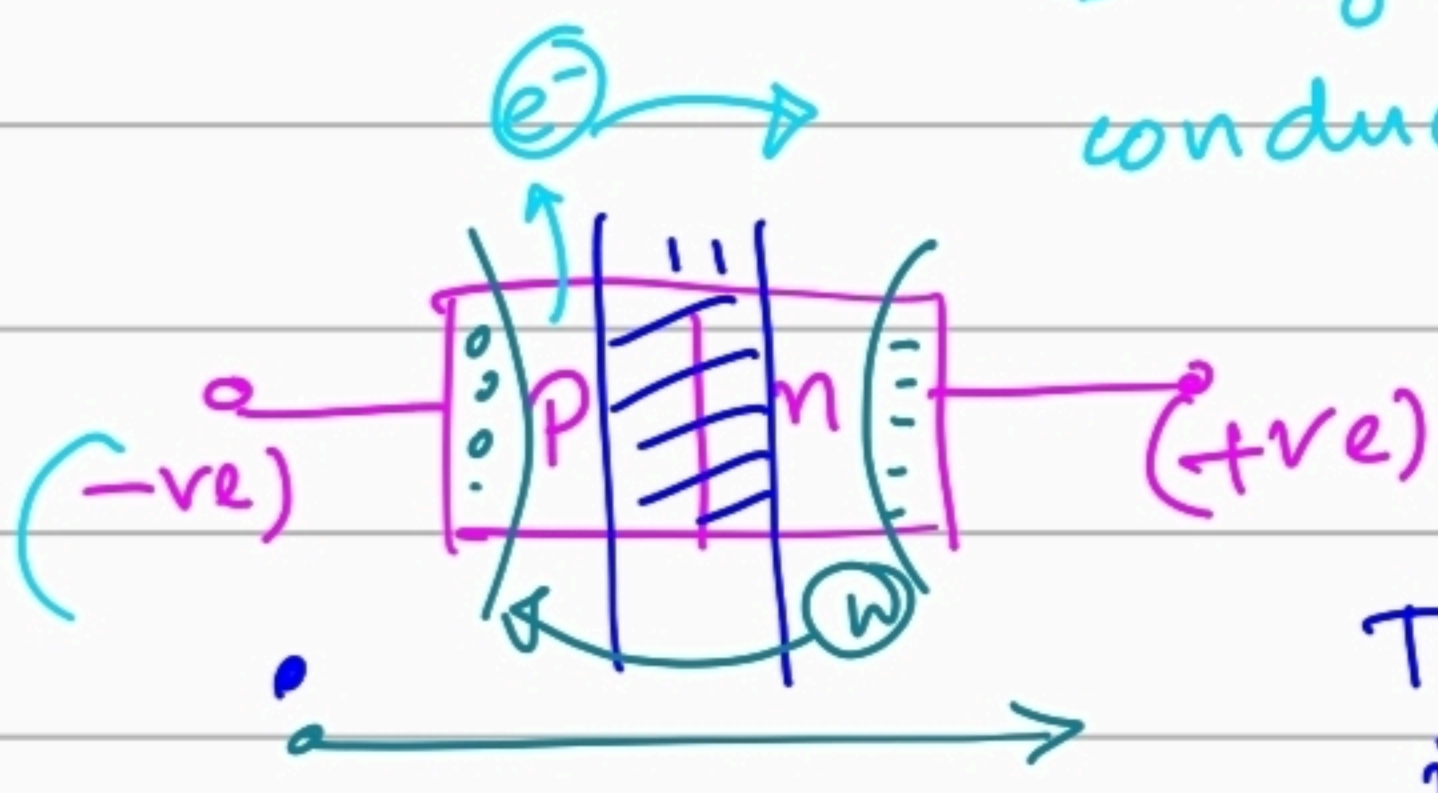
Forward bias :-



Si, $V_D > 0.6 \sim 0.7V$

Ge V_D $0.2 \sim 0.3V$

Breakdown :- If the applied reverse bias voltage is high then diode might start conduction.



typical Si diode 25V

Zener diode ~ 5V, 10V

Diode → constant voltage drop model

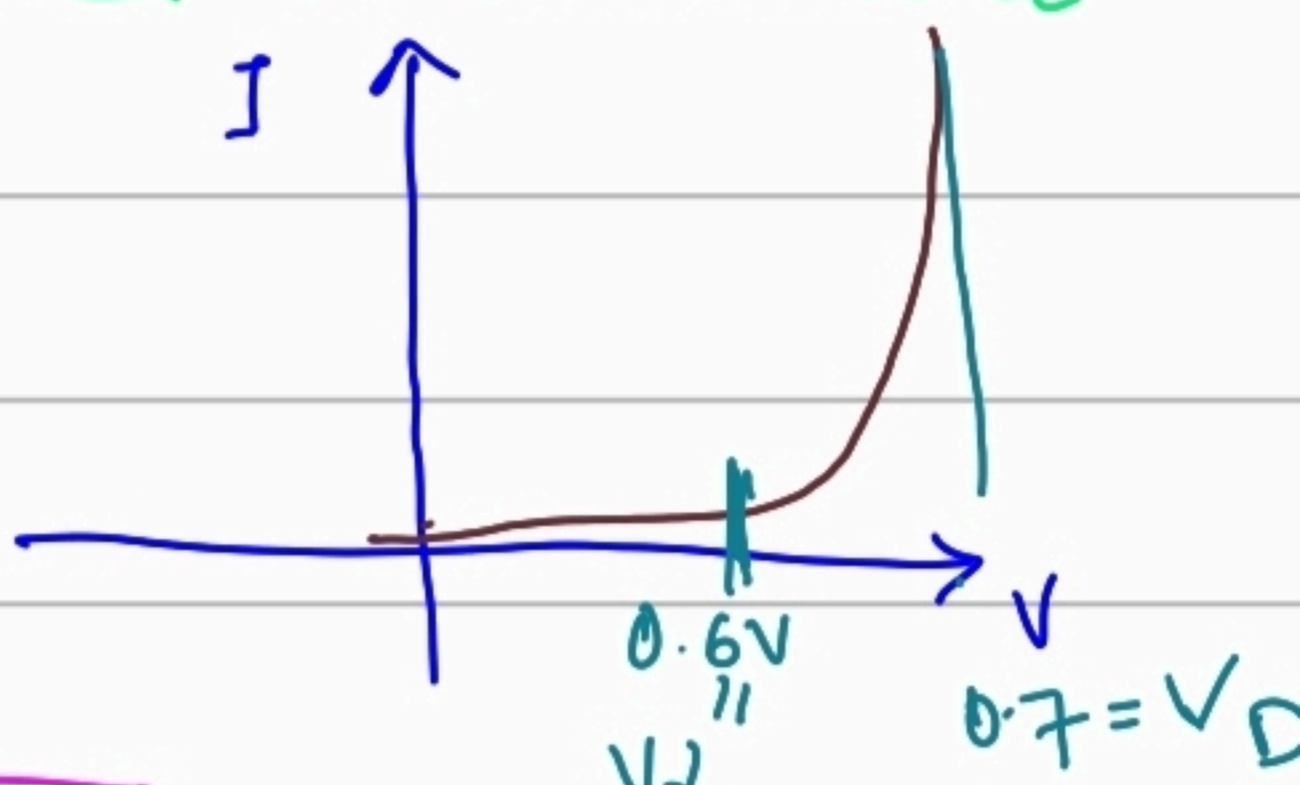
①

Diode conduction voltage, $V_D = 0.7V$

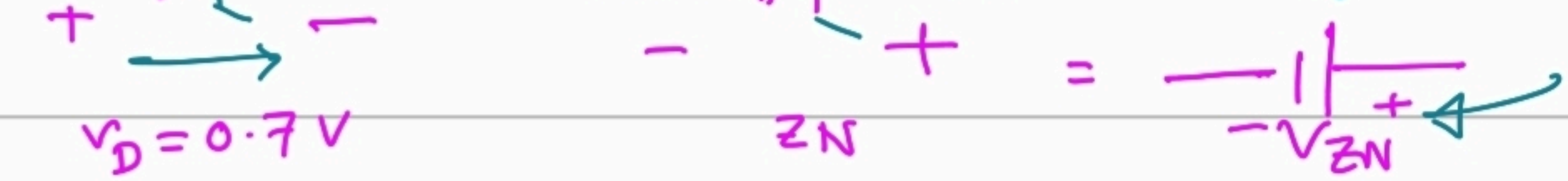
②

③ Activation / Threshold / Turn on voltage:

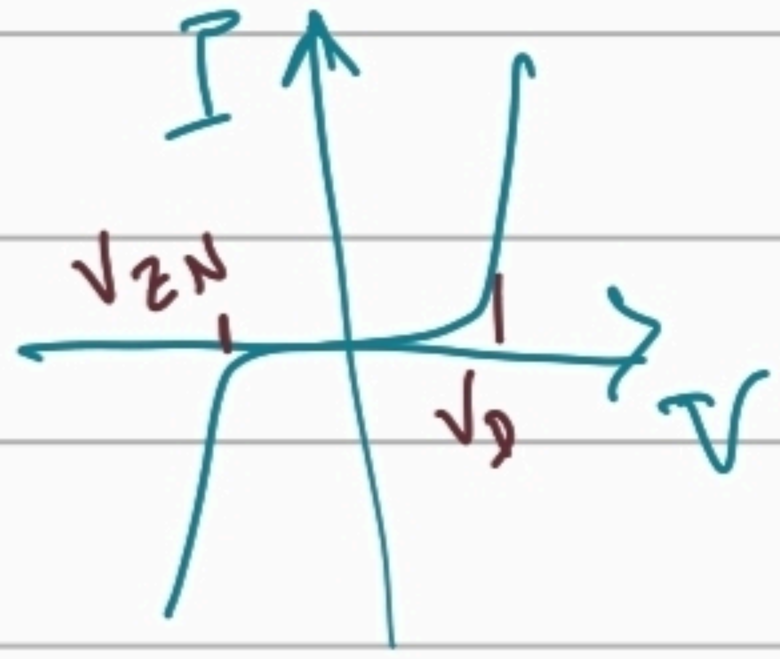
The minimum voltage required to turn on a diode. V_γ (diode) $= 0.6V$



④ Zener Diode:



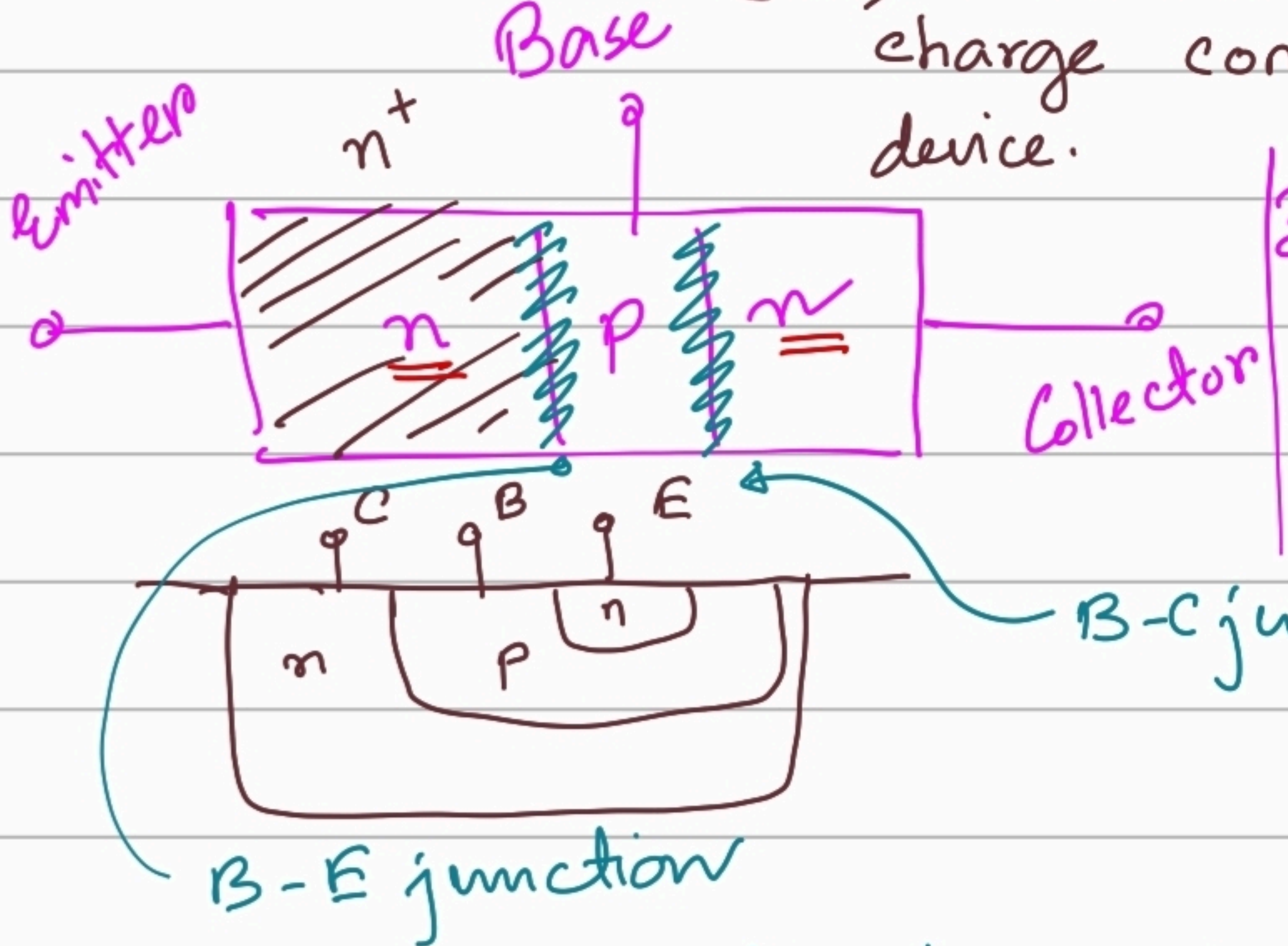
If the applied reverse bias voltage is higher than V_{ZN}, Zener diode starts conducting.



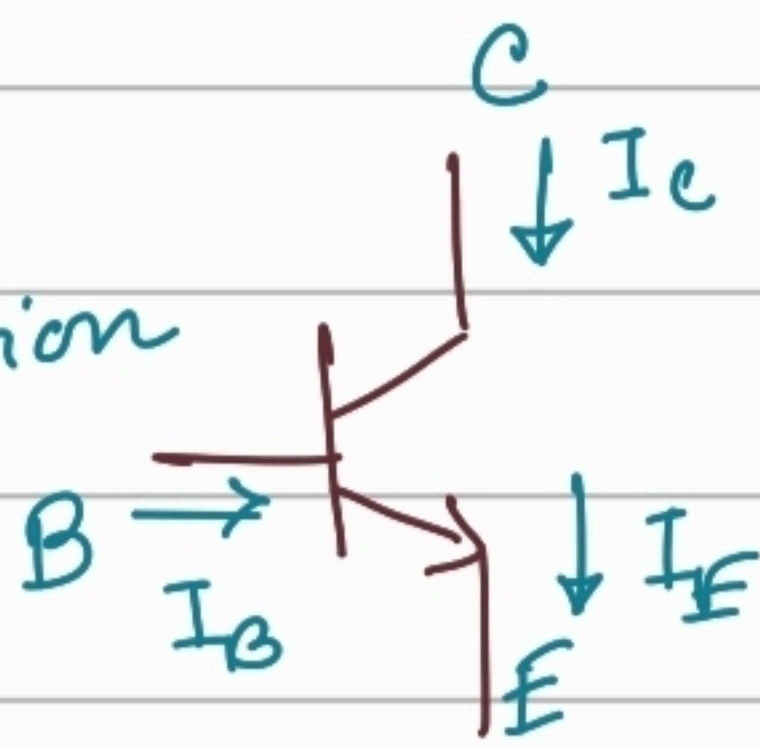
Transistor: Switching Device (~~Amplification~~)

n-p-n | Bipolar Junction Transistor (BJT)

(e–h) both are responsible for charge conduction in this device.



3 terminal devices



Depending junctions' operating mode BJT's operating mode can be classified into four different categories.

B-C junction	B-E junction	mode
Reverse	Forward	Forward Active (FA)
Forward	Forward	Saturation (S)
Reverse	Reverse	Cutoff (C)
Forward	Reverse	Reverse Active (RA)

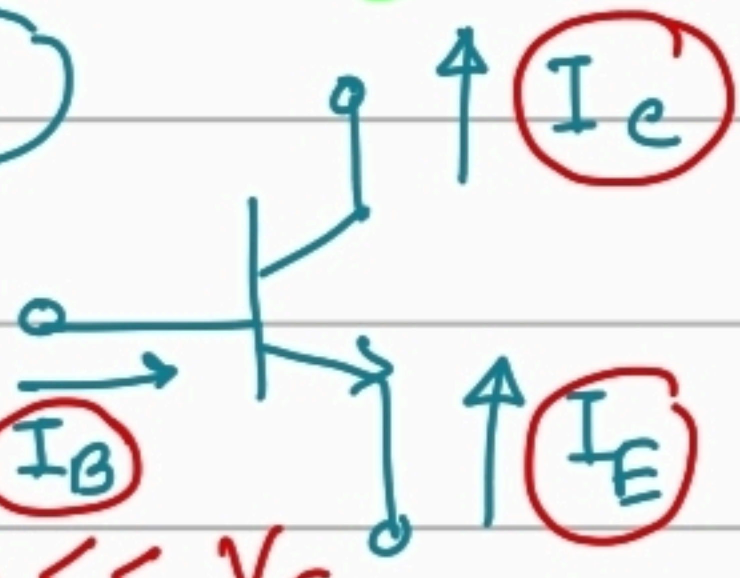
Reverse Active:

Emitter and Collector switche their roles.

$V_{BC} = 0.7V$, $\frac{I_E}{I_B} = \beta_R$

reverse β

$\beta_R \sim 0.1, 0.2, 0.3$



$V_C < V_B << V_E$

Saturation

$V_{BE} > 0$, $V_{BC} > 0$

$\boxed{V_{BE} = 0.8V}$, $\boxed{V_{CE} = 0.2V / 0.1V}$

$V_{BC} = V_{BE} - V_{CE} = 0.6/0.7$

Checking condition:

$I_C / I_B = \beta_{forced} < \beta_F$ (Forward)

V_{BE}, V_{BC}

Cutoff: ($V_{BE} < 0$, $V_{BC} < 0$)

$V_{BE} < V_\gamma$ (transistor)

= cutin voltage / turn on voltage $= 0.5V$

0.5

$\boxed{I_C = I_B = I_E = 0}$

Forward Active

$V_{BE} > 0$, $V_{BC} < 0$

$\boxed{V_{BE} = 0.7}$, $\boxed{\frac{I_C}{I_B} = \beta_F}$ 30, 50, 100

Forward β, common emitter current gain

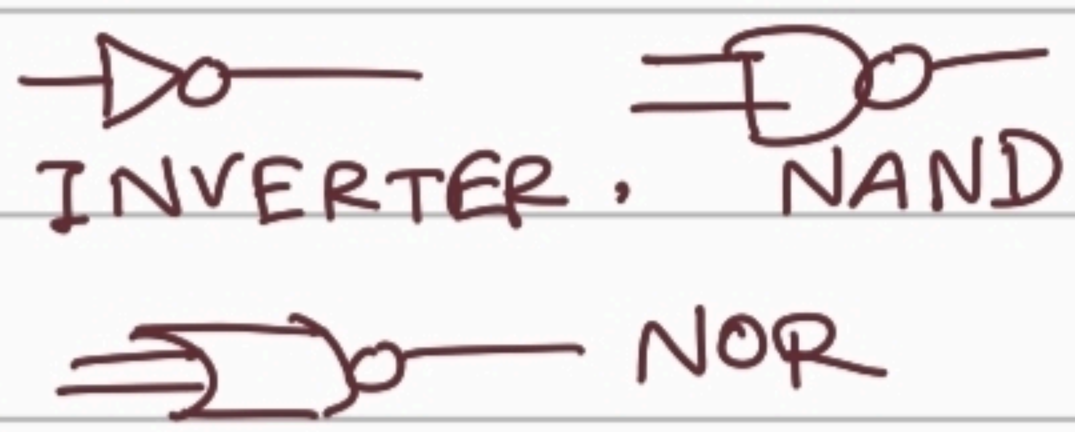
Checking condition:-

$V_{CE} > 0.2V$

$I_C + I_B = I_E$

Introduction to Digital Logic Families

Digital logic design →



Digital logic family are different groups of electronic circuits that can be used to construct digital logic gates.