P-N-P-N Switching Device

①

Electronic device → switching is very important (most common application)

⇓

Device change an 'off' or blocking state to 'on' or conducting state.

Switching device :- ① Transistor → Base current drives the device from cut-off to saturation.

② Diodes

Device ; Remain blocking state under forward bias

⇓ Triggered by an external signal.

Switched to

Conducting state.

SCR ⇒ Semiconductor Controlled rectifier

or

sillicon controlled rectifier (As si is the common material used)

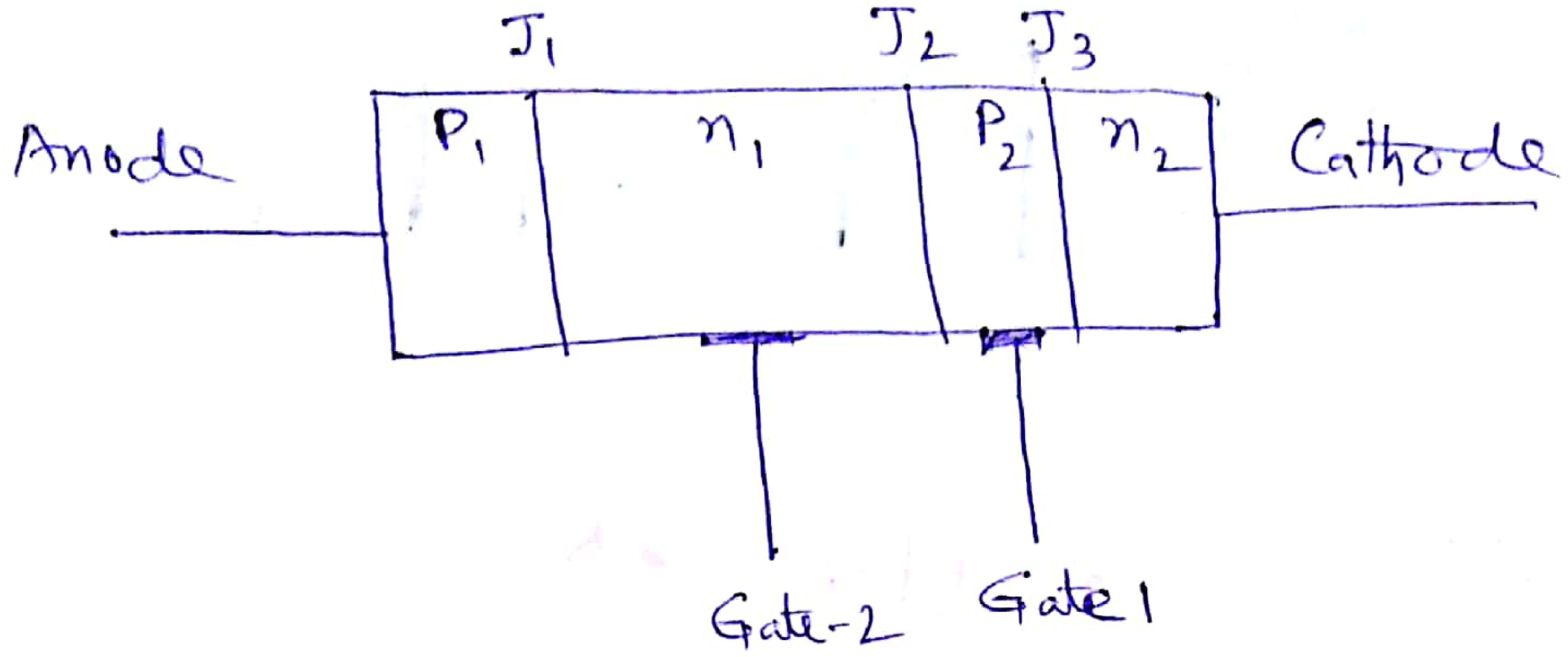
under forward bias :- High impedance ie 'off' condition (untill a switching signal applied)

After switching → Low ~~exhibitis~~ impedance (ON condition)

Signal → (for switching) → may be apply or vary → externally.

These device → Block/Pass current at predetermined levels.

Basic Structure



4-layer p-n-p-n device.

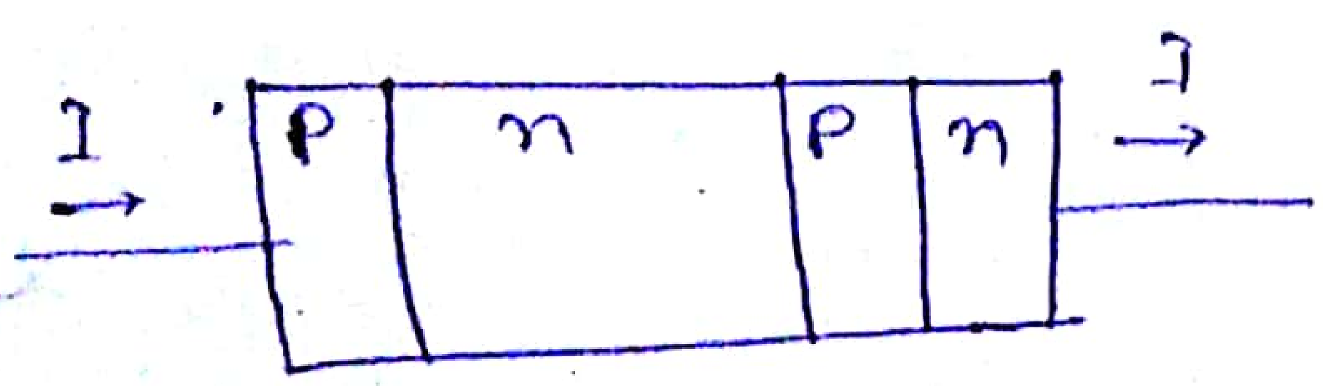
3- p-n junctions J_1, J_2 and J_3 in series.

Contact electrodes.

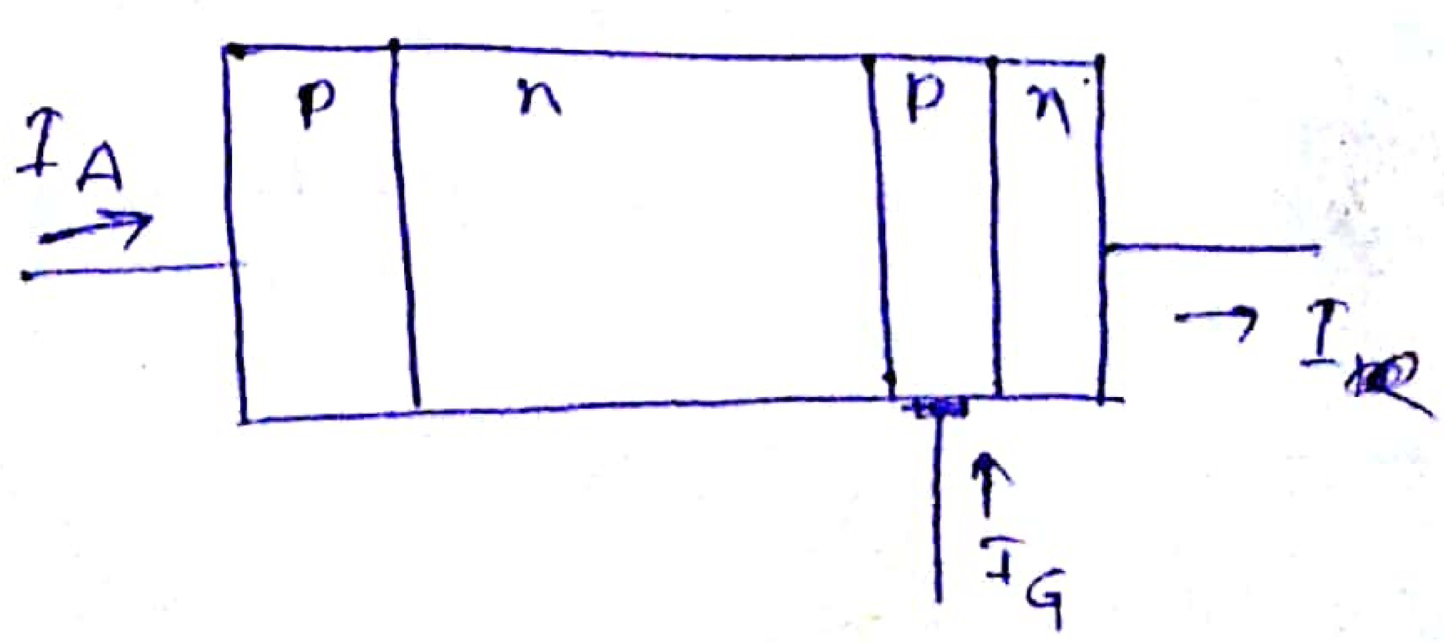
1. Anode → electrode attached outer p-layer
2. Cathode → " " " n-layer
3. base → Two gate electrodes (Gate-1 & Gate-2)

without gate electrode:- The device is operated as a two terminal p-n-p-n ~~or sh~~ diode or shockley diode.

with one gate electrode: Three terminals device, Called SCR or thyristor.

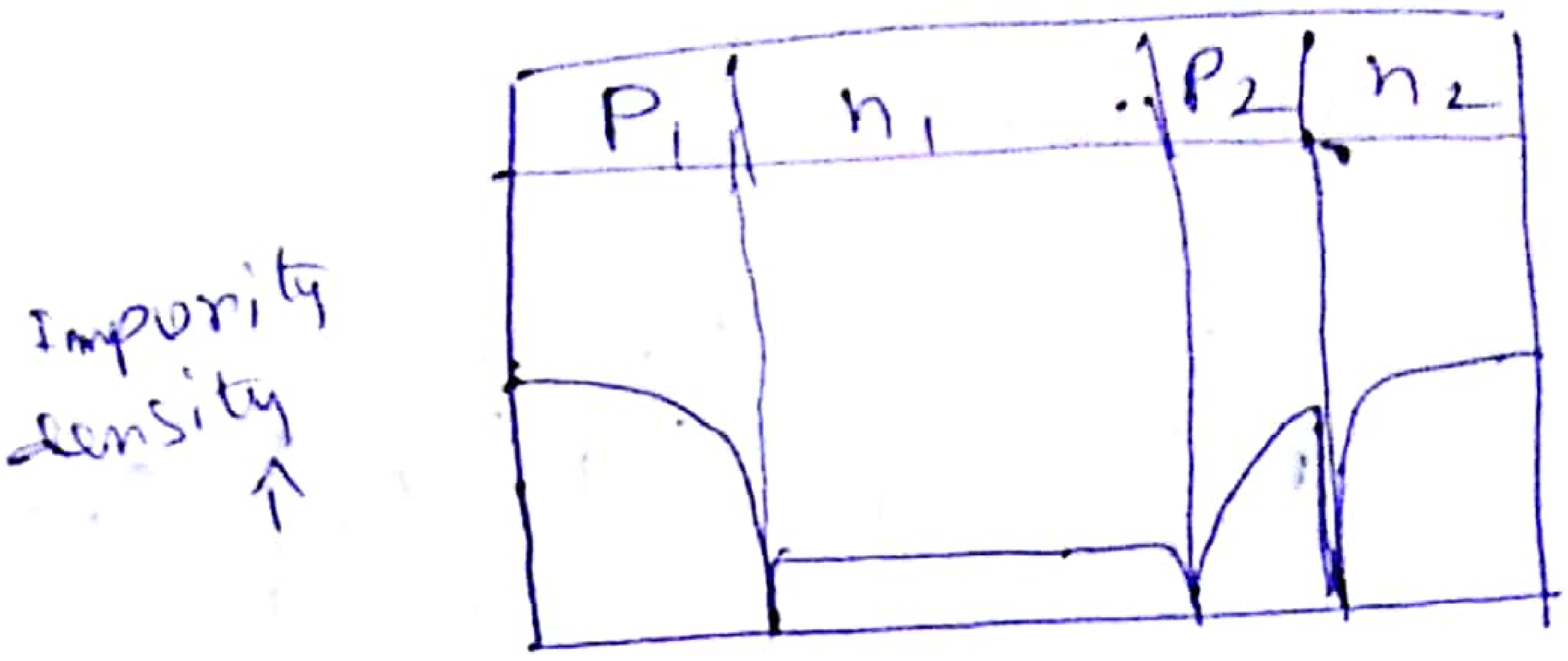


2-terminal p-npn-diode ~~or~~ shockley diode



3-terminal thyristor

Doping profile



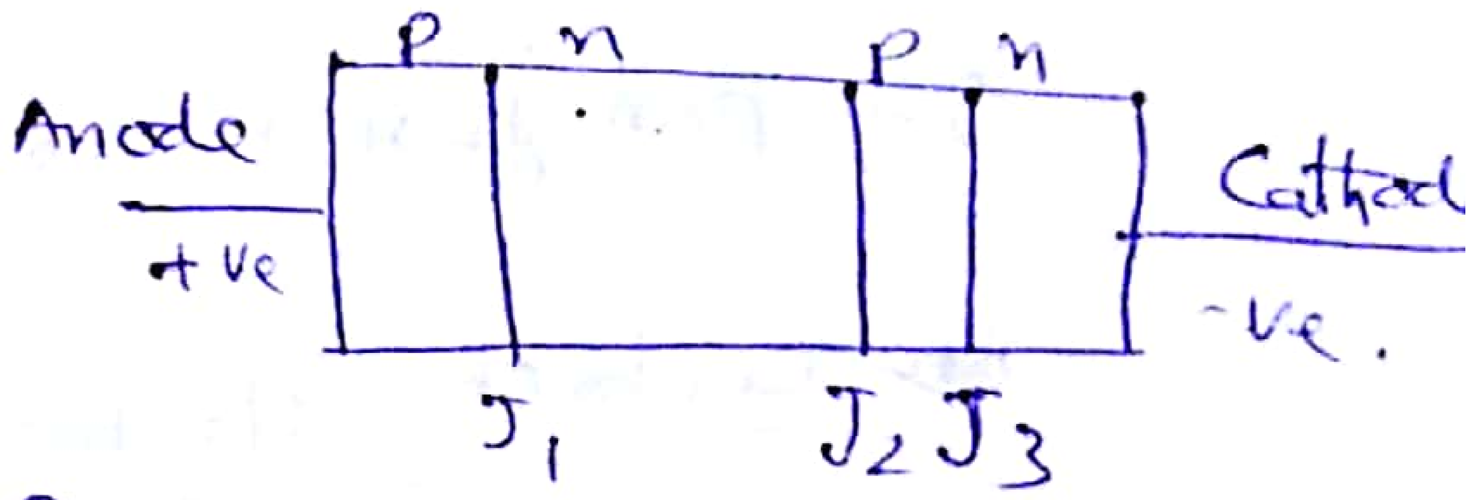
Common - circuit symbol :

Forward bias :-

Anode is +vely biased w.r.t. Cathode.

Anode → +ve

Cathode → -ve.



Here → junction J_1 & J_3 → Forward bias

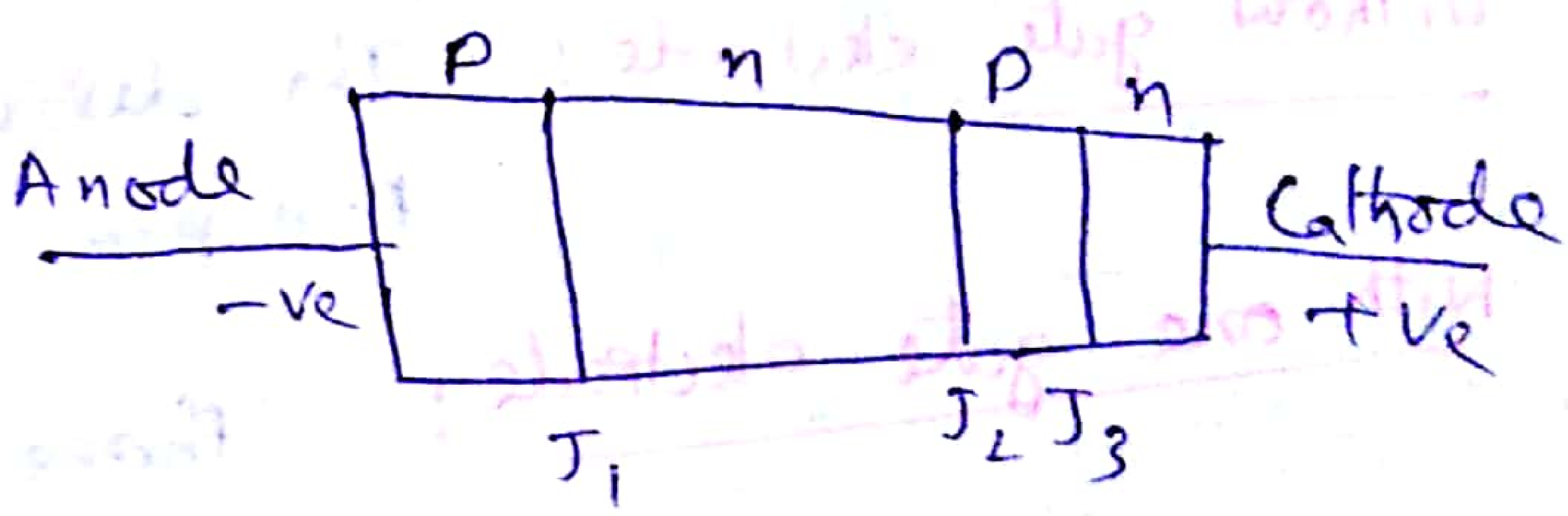
J_2 → Reverse bias

Reverse bias :

Anode is -ve w.r.t. cathode.

Anode → -ve

Cathode → +ve



J_1 & J_3 → Junction → Reverse bias

J_2 → Forward bias.

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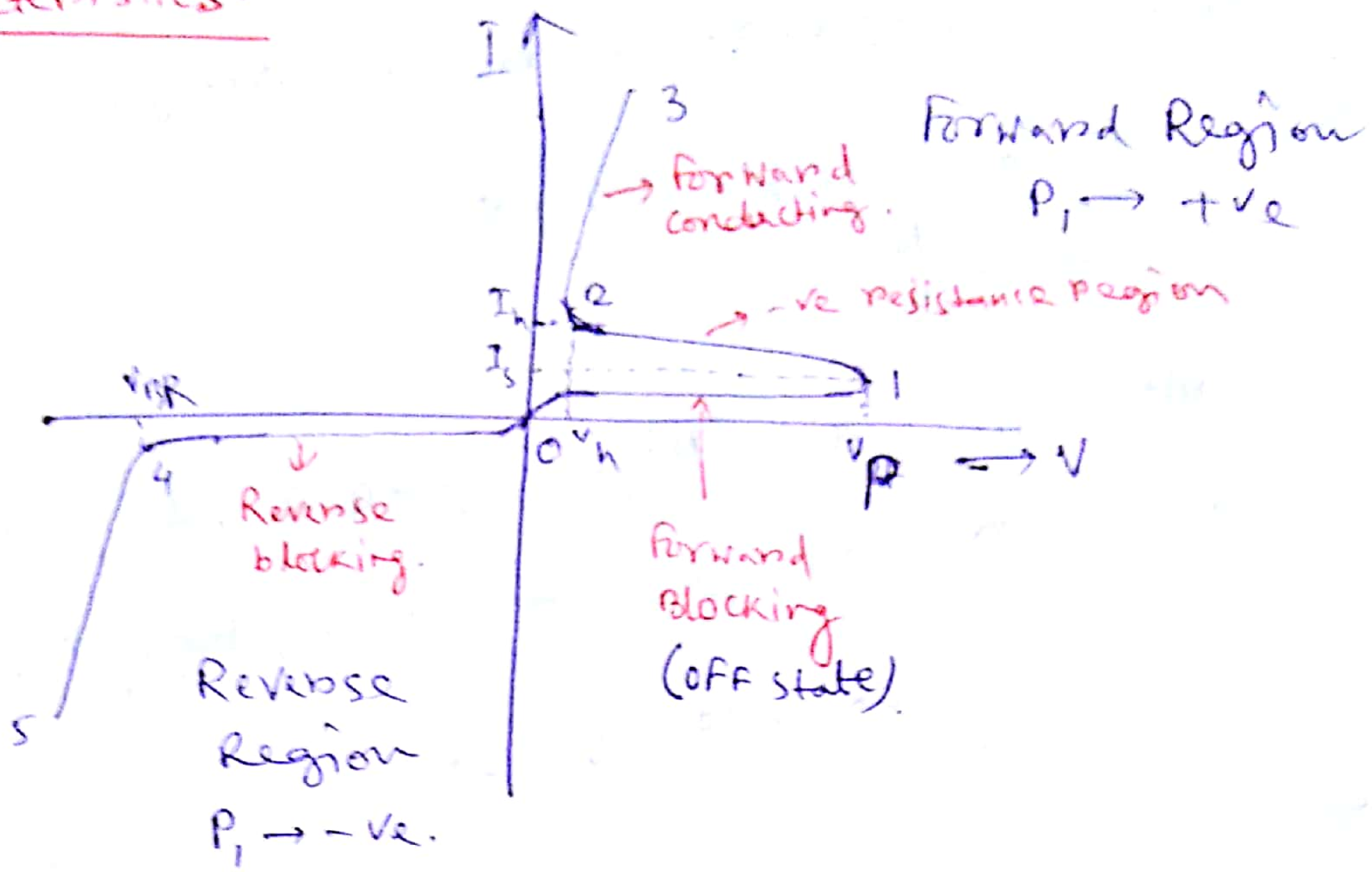
I-V - Characteristics :-



Region

$0 \to 1 \Rightarrow$ Forward Blocking or OFF State

very High impedance state

At 1 ⟶ forward Breakover or switching occurs

Here $\frac{dV}{dI} = 0$ at V_P

$V_P \Rightarrow$ Device switches from blocking to conducting state.

called → critical peak forward voltage or forward breakover voltage.

$I_s \to$ switching current or turn-on current.

$1 \to 2 \Rightarrow$ -ve resistance region

$2 \to 3 \Rightarrow$ Forward conducting or ON state.

At point 2 $\Rightarrow \frac{dV}{dI} = 0$, $I_h \to$ holding current

$V_h \to$ holding voltage.

Reverse Region

$0 - 4 \Rightarrow$ Reverse blocking state

$4 \to 5 \Rightarrow$ Reverse breakdown region.

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Thyristor → operated in forward region.
⇓
a Bi-stable device
cause ⇓
⇓
Switch from a ⇒ High impedance, low current OFF state
Switch to ⇒ low impedance, high current ON state
OR vice versa.

In forward blocking state: when voltage increase, → most of forward voltage → appear across the reverse-biased junction J_2.

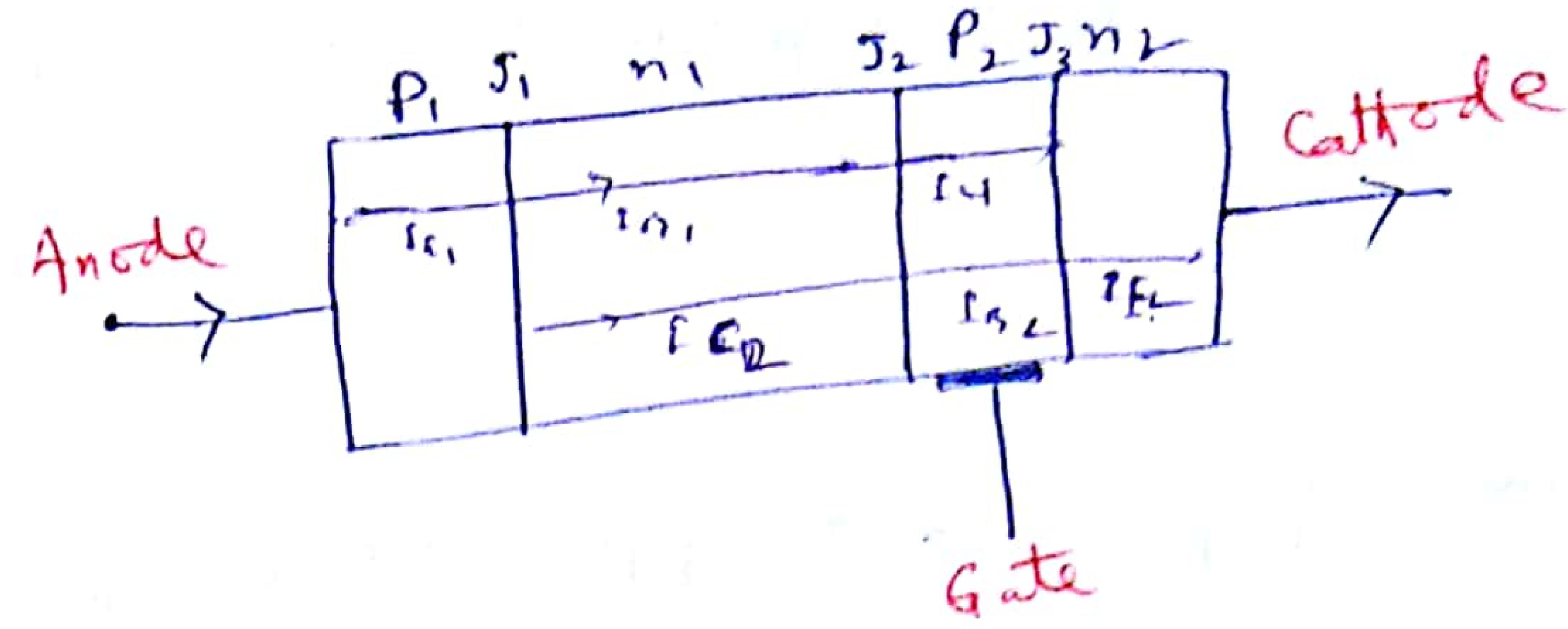
In Forward-Conducting State: All 3-junctions must be forward bias.

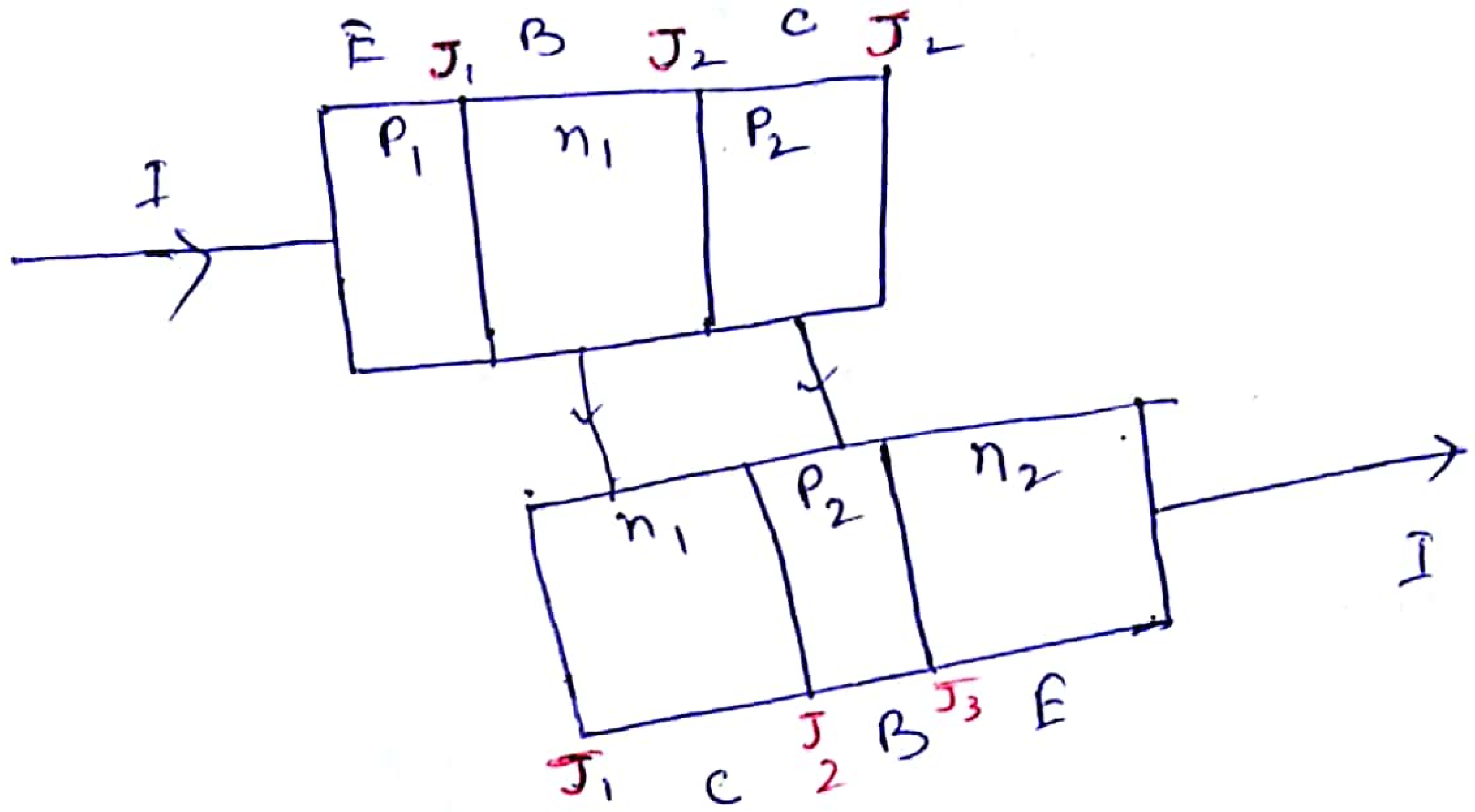
In Reverse-blocking State:- supply of electron & holes to J_2 is restricted by the reverse-biased junction on either side.
current is limited to → small saturation current. arising from thermal generation of EHP.

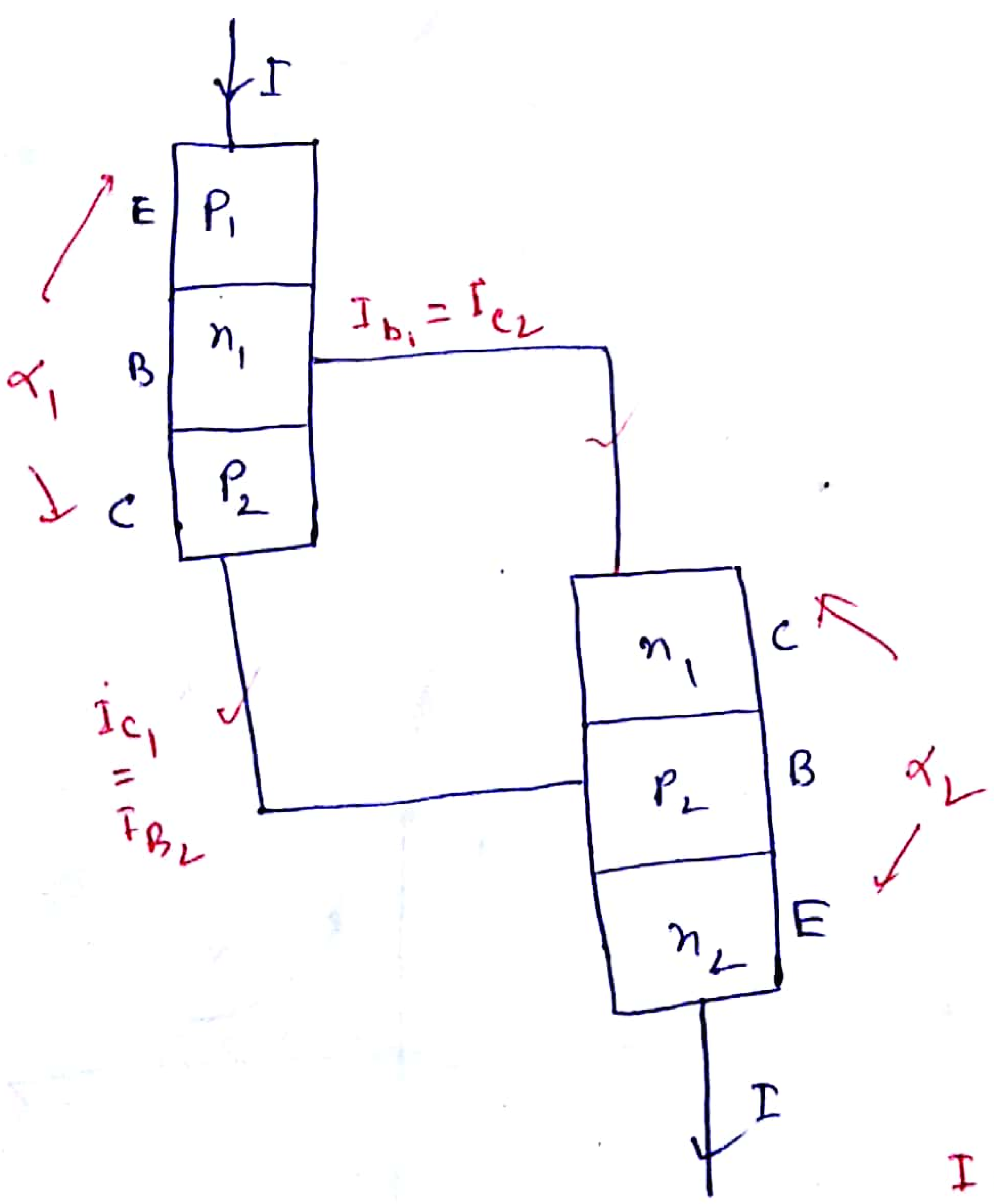
Reverse breakdown → Breakdown (avalanche) occurs.

At forward break down voltage → The current reaches I_S, → break down occurs → characteristic curve traversed rapidly (within μs) to reach I_h.

Two-Transistor Analogy







I_{CO} → Reverse saturation current

$$I_{C_1} = \alpha_1 I + I_{CO_1} = I_{B_2}$$

$$I_{C_2} = \alpha_2 I + I_{CO_2} = I_{B_1}$$

α → ratio of collected current to injected current.

$I = I_{C_1} + I_{C_2}$ (According to KCL)

$$I = (\alpha_1 + \alpha_2) I + I_{CO_1} + I_{CO_2}$$

$$\Rightarrow I = \frac{I_{CO_1} + I_{CO_2}}{1 - (\alpha_1 + \alpha_2)}$$

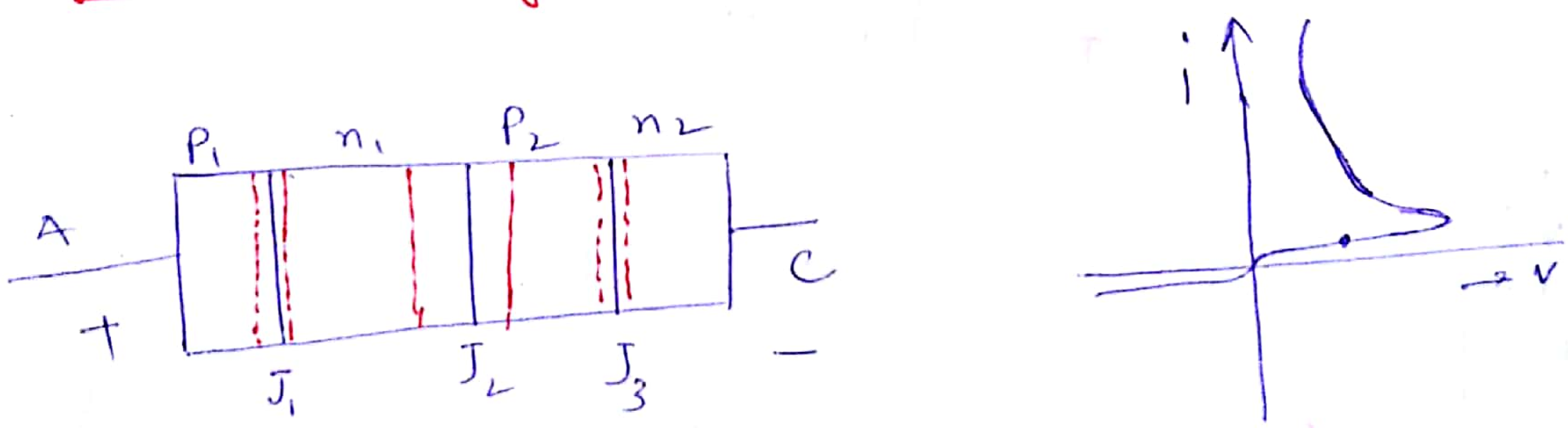
current I, through the device is small → As $(\alpha_1 + \alpha_2)$

α is small compared to unity.

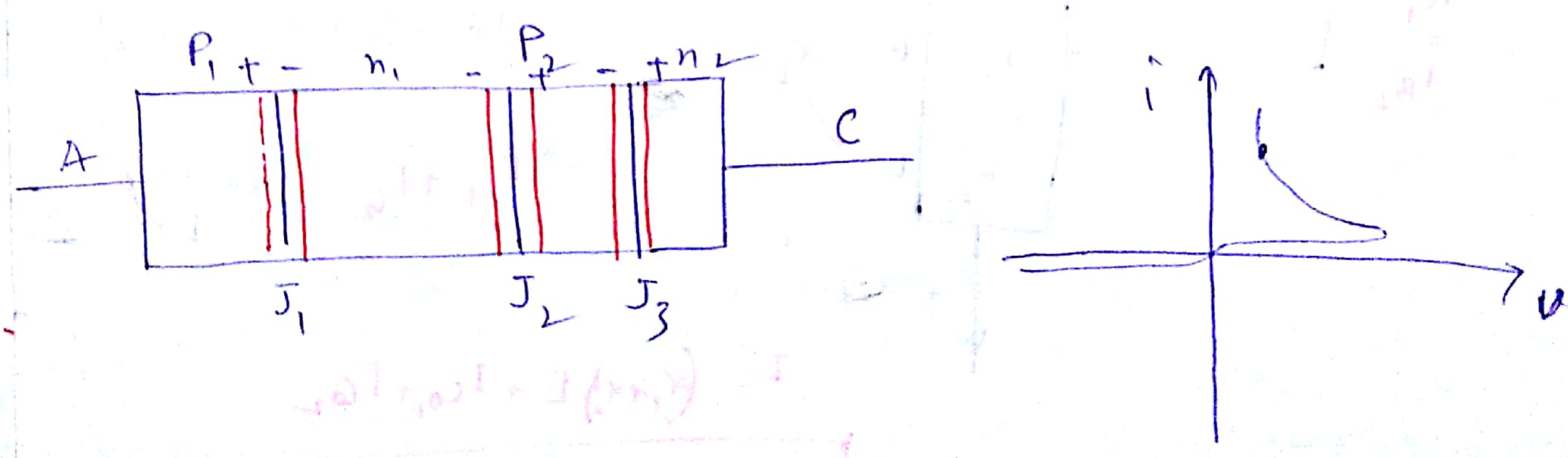
When $(\alpha_1 + \alpha_2)$ → approaches to unity, then this derivation is no longer valid.

Three bias states of p-n-p-n diodes

1) Forward blocking state



2) Forward-conducting state



3) Revers

3) Reverse Blocking State