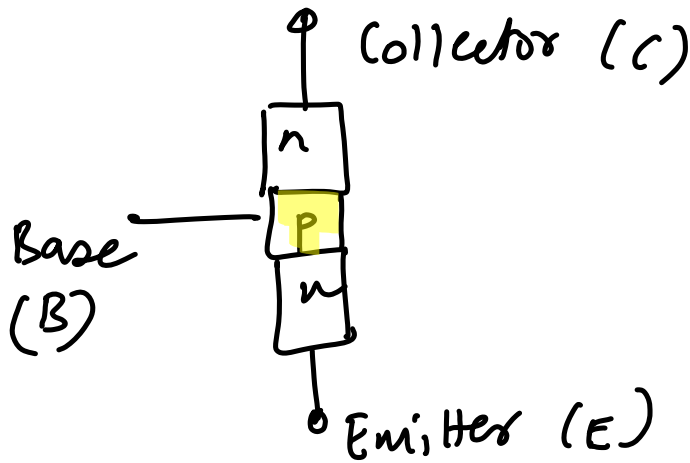# Bipolar Junction Transistors
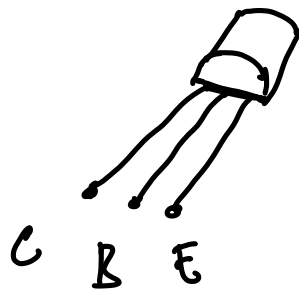
npn   transistor

pnp   transistor

Schematic
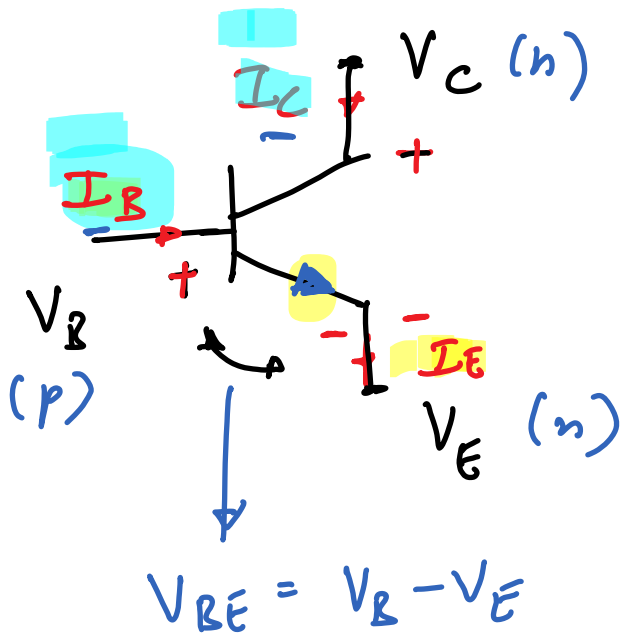
Collector (C)

n

p

n

Base
(B)

Emitter (E)

Collector (C)

p

n

p

Base
(B)

Emitter (E)

Symbols

V_C

V_B

V_E

V_C

V_B

V_E

2 N 3904

C B E
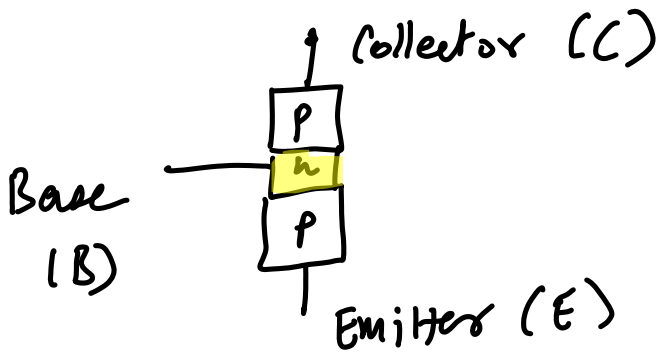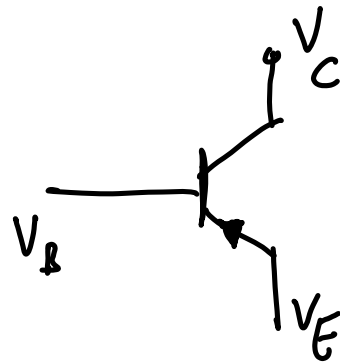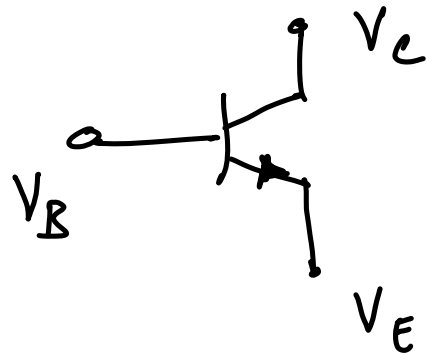
Emitter is
more heavily
doped than the
collector

V_C (n)

I_C

I_B

V_B

(p)

I_E

V_E (n)

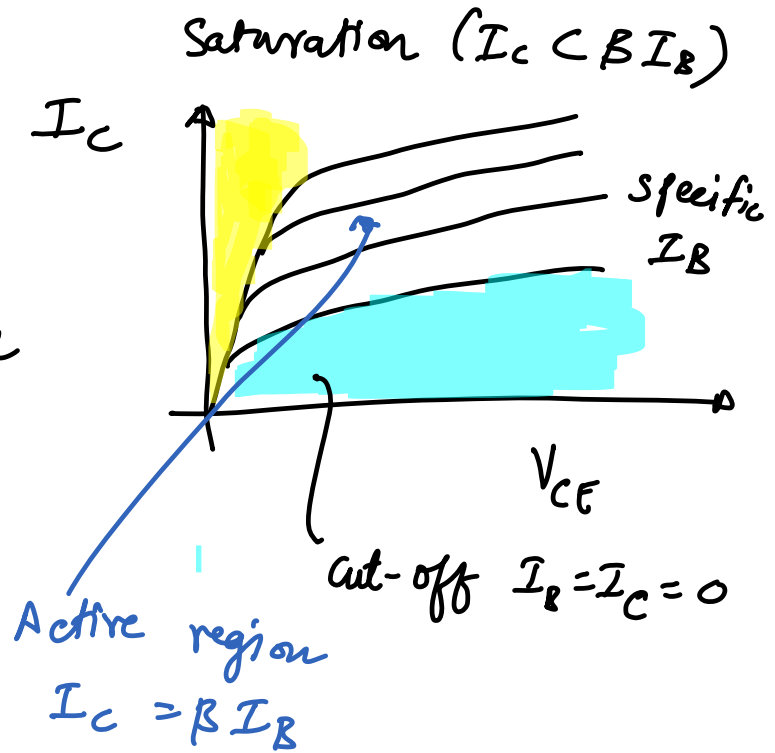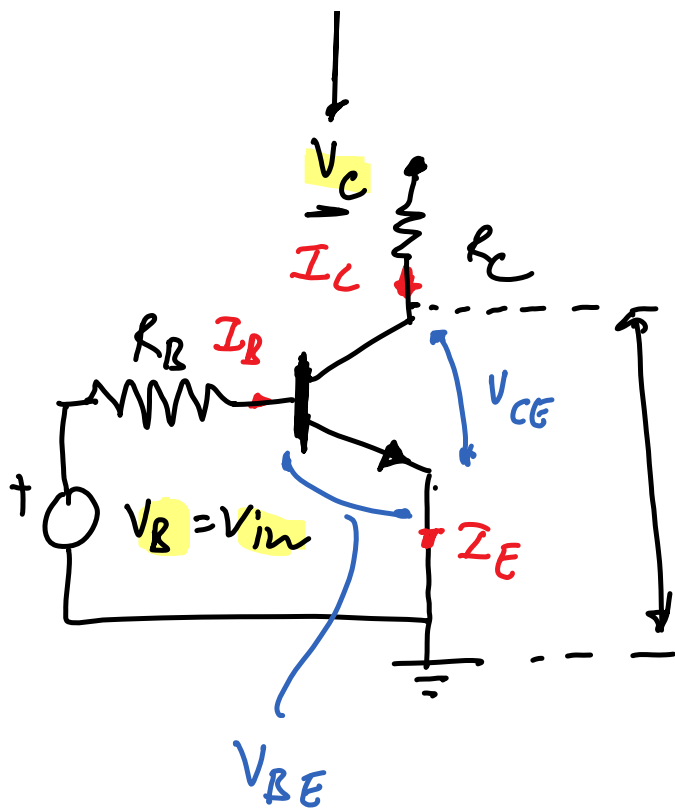$$V_{BE} = V_B - V_E$$

- BE is forward biased

- BC is reverse biased

- Electrons flow from E to B   OR

  Current flows from B to E

- $I_E = I_C + I_B$

- $I_C = \beta I_B$ (Active mode)

  $\beta \approx 100$

  small I_B leads to a big I_C

BJT working

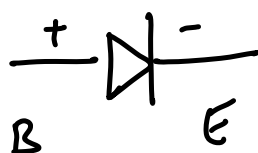3 modes

① Cut-off mode

② Saturation mode

③ Active mode

Saturation $(I_c < \beta I_B)$

I_C

specific I_B

V_{CE}

Cut-off $I_B = I_C = 0$

Active region
$I_C = \beta I_B$

① **Cut-off**

$$I_B = I_C = 0$$

$$V_{BE} < 0.7$$

V_{out}

$$V_{out} = V_C$$

connect to LED

B $+$ ▷|− E

$$V_{BE} = 0.7$$

② **Saturation**

$$I_B > 0 \quad I_C > 0$$

$$V_{BE} \geqslant 0.7 \, V$$

$$V_{out} = V_{CE} = 0.2 \approx 0$$

BJT as a switch by cycling between cut-off & Saturation

③ Active mode

$$I_B > 0 \; ; \; I_C > 0 \; ;$$

$$\Rightarrow \quad V_{BE} \geqslant 0.7 \, V$$

$$0.2 \leq V_{out} = V_{CE} \leq V_C$$

$$I_C = \beta I_B$$

$$I_E = I_C + I_B$$

always true

By changing $V_B = V_{in}$ we are able to vary V_{out} from 0.2 to V_C

BJT is a linear amplifier in the active mode