Lecture (06) Bipolar Junction Transistor

By:

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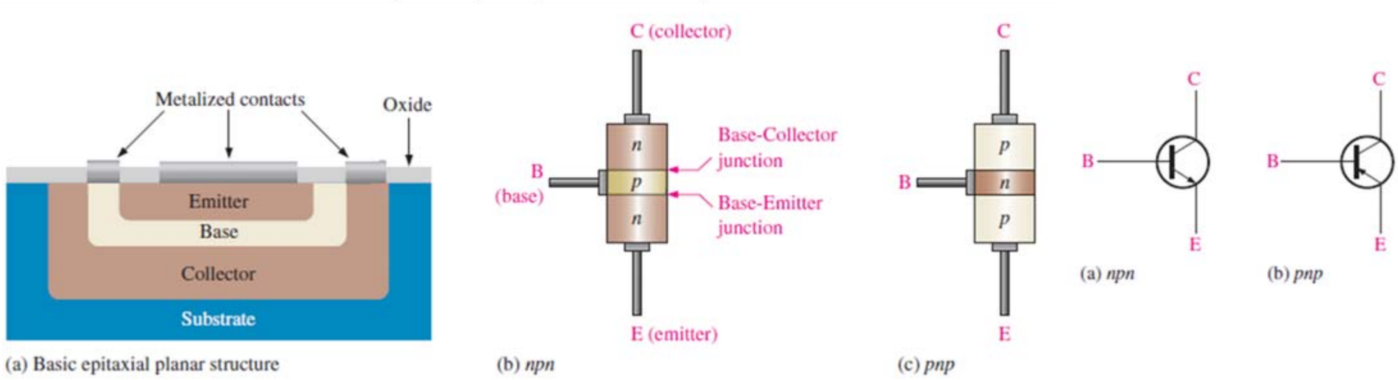
Agenda

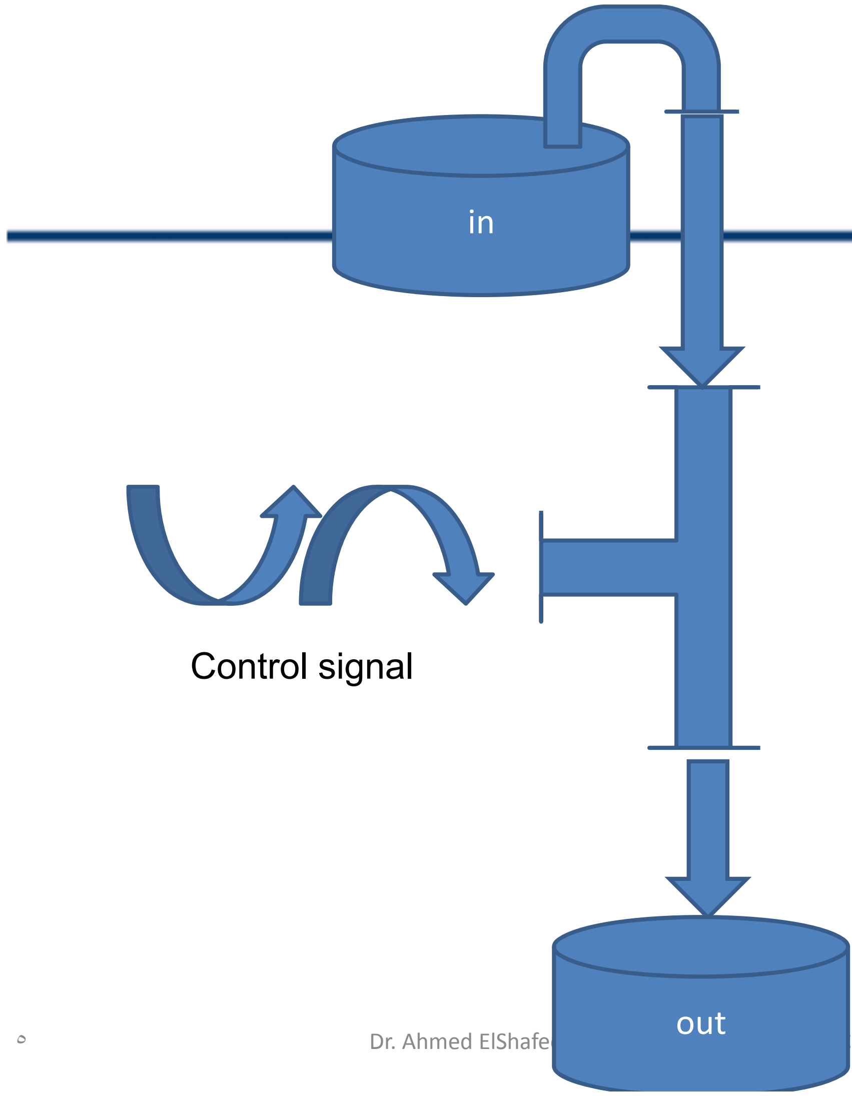
- BJT structure
- BJT operation

BJT structure

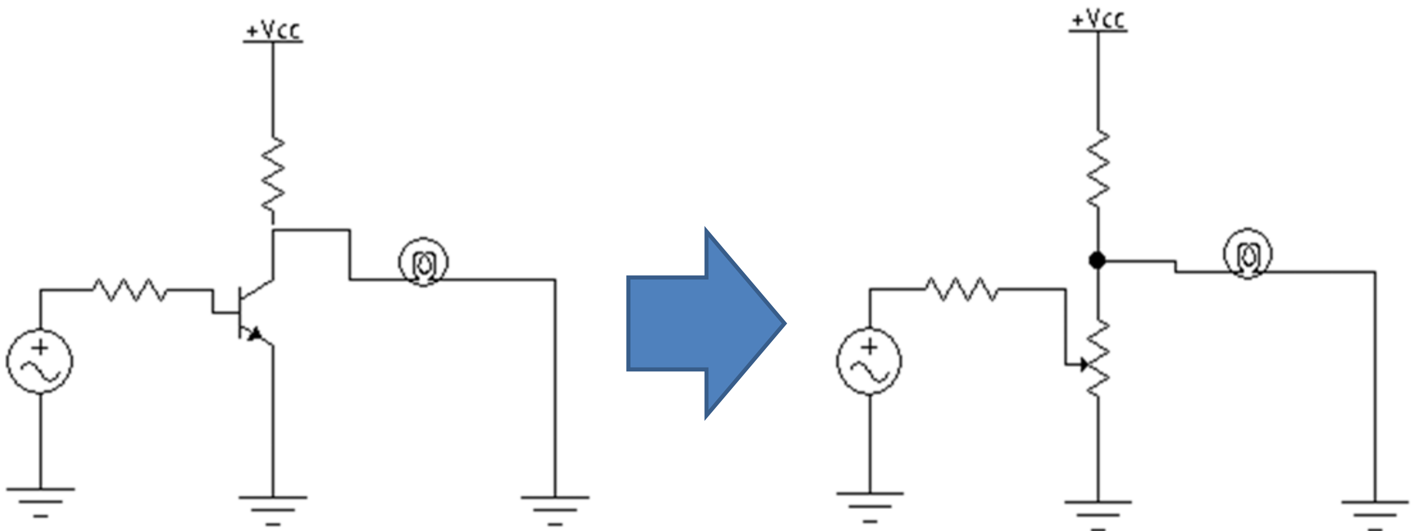
- The **BJT** is constructed with three doped semiconductor regions
- One type consists of two *n* regions separated by a *p* region (*npn*), and the other type consists of two *p* regions separated by an *n* region (*pnp*).
- The term **bipolar** refers to the use of both holes and electrons



- In order for a BJT to operate properly as an amplifier, the two *pn* junctions must be correctly biased with external dc voltages.
- In this section, we mainly use the *npn* transistor for illustration.
- The operation of the *pnp* is the same as for the *npn* except that the roles of the electrons and holes, the bias voltage polarities, and the current directions are all reversed.


in
Control signal
out

•

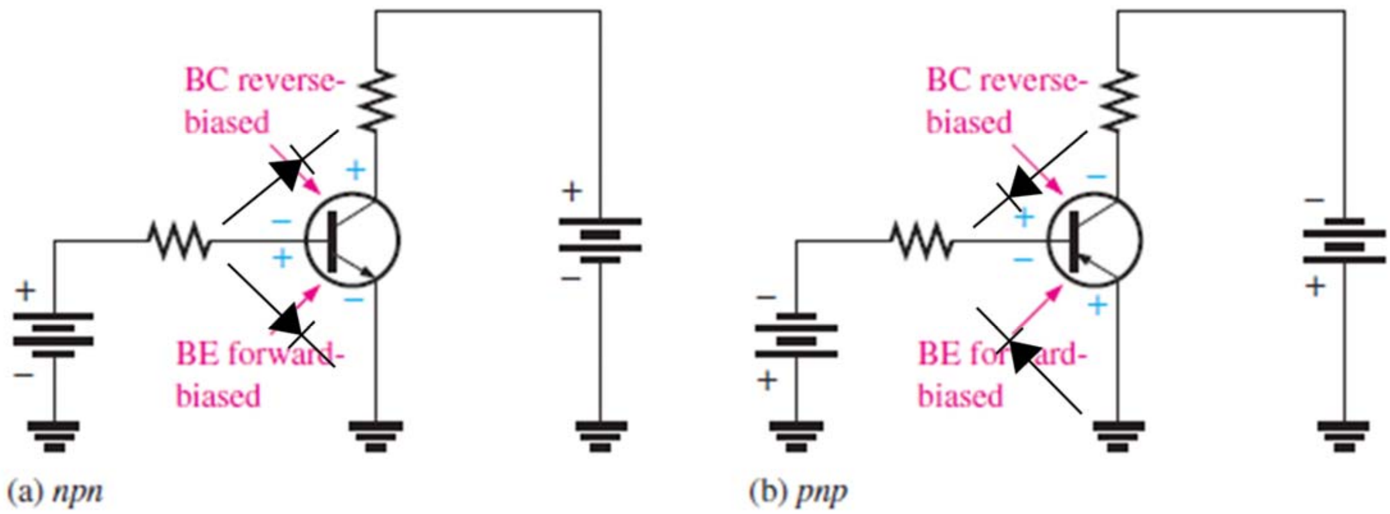

+Vcc
+Vcc

Biasing

base-emitter (BE) junction is forward-biased

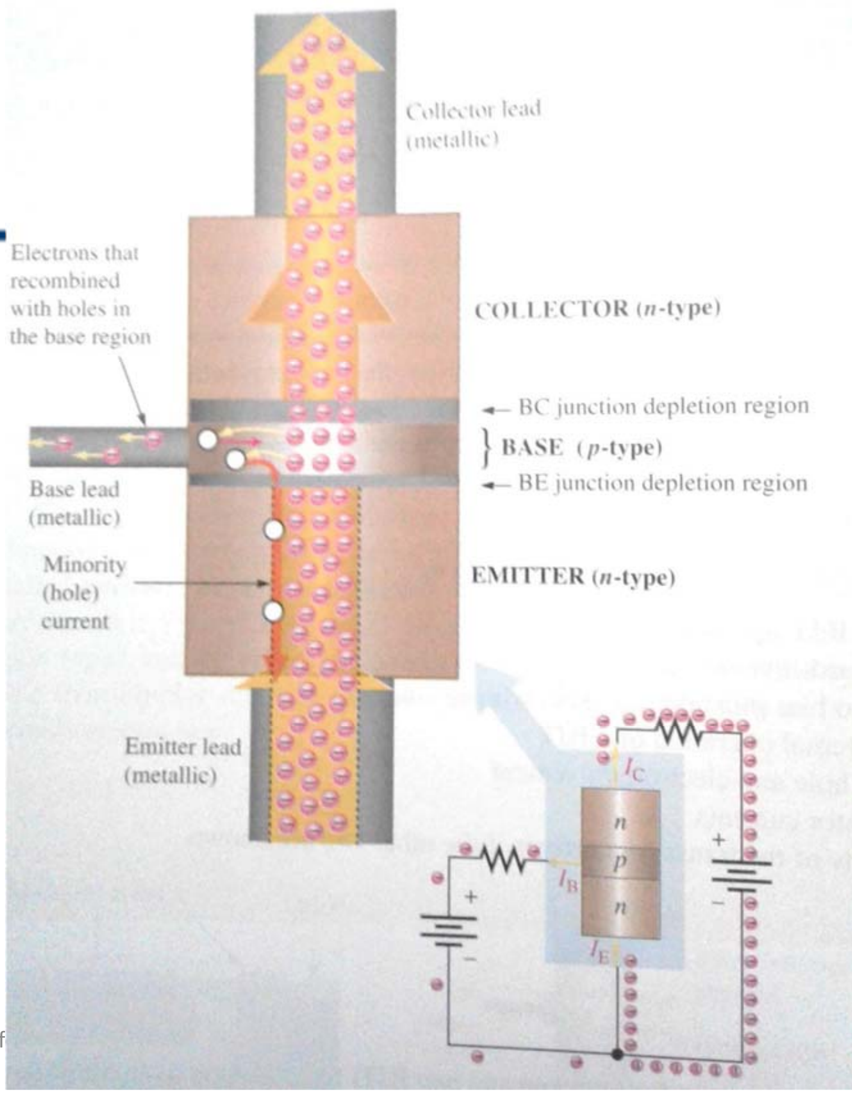
base-collector (BC) junction is reverse-biased

This condition is called *forward-reverse bias*

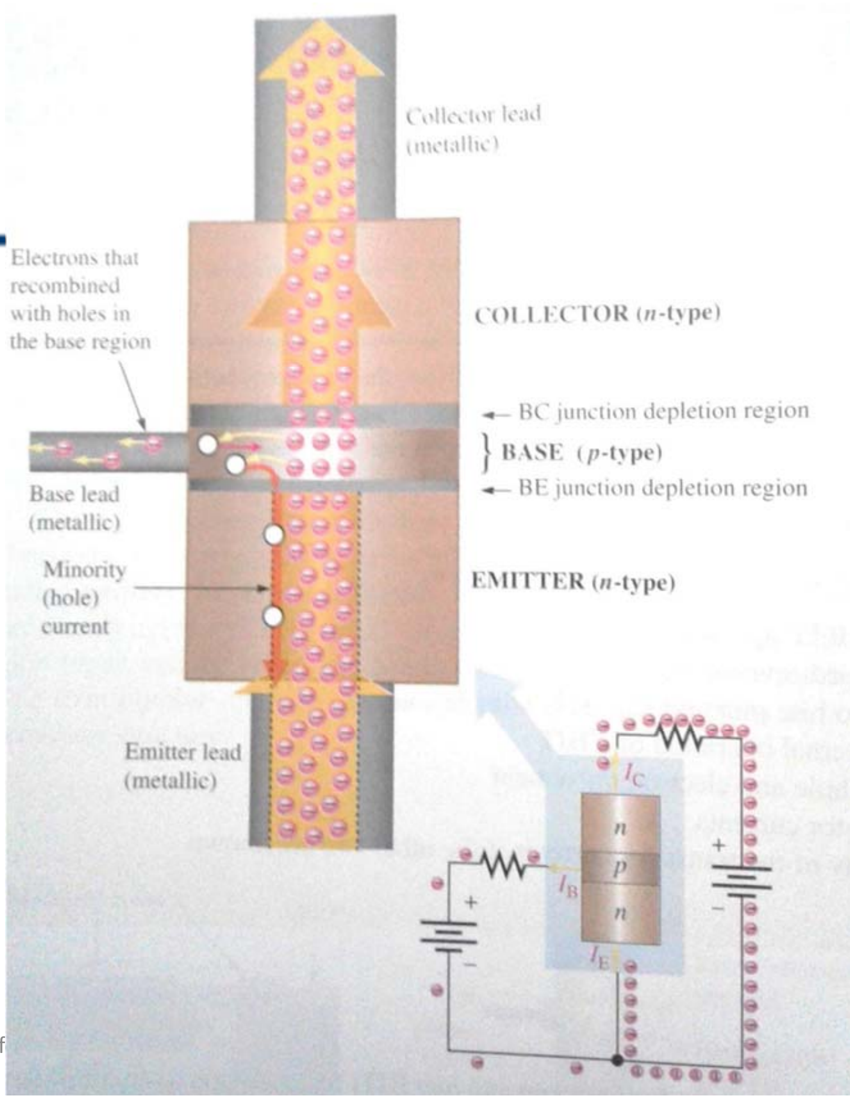


BJT **Operation**

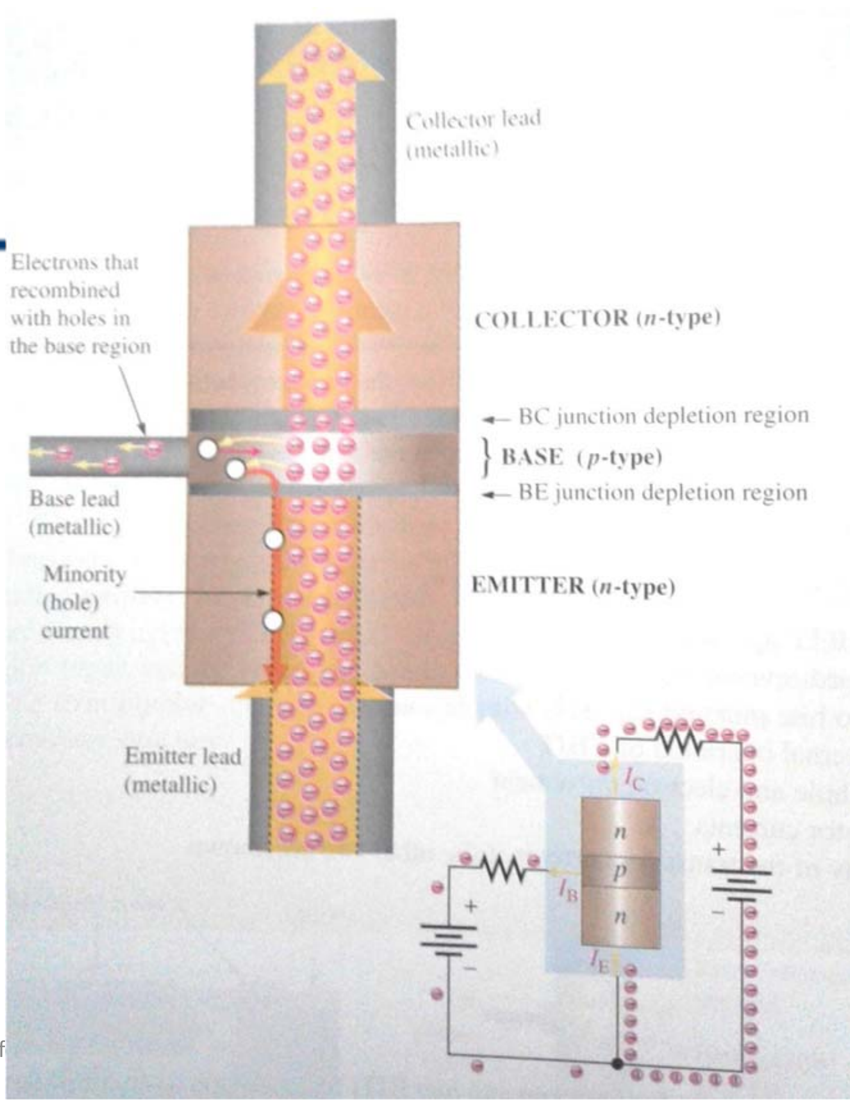
- CE battery +ve terminal attract electrons from the collector N-region.
- Collector N-region compensate electrons depletion region, which become more and more wider.



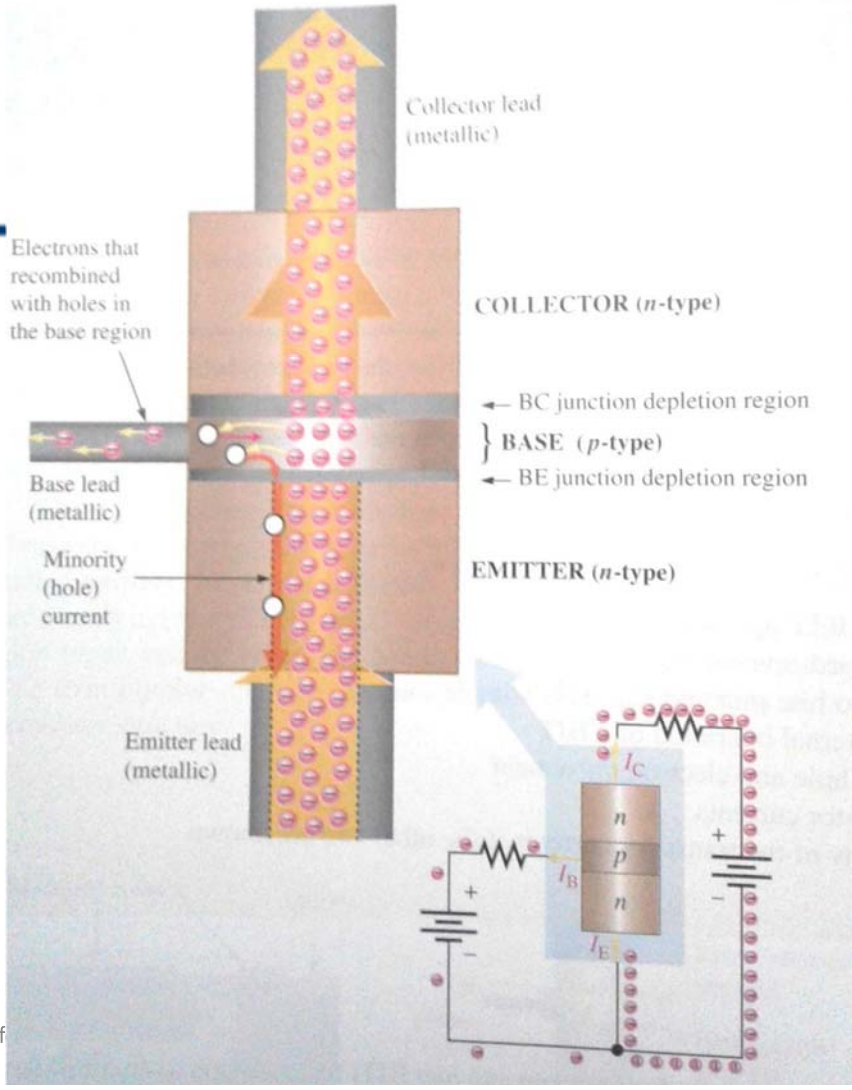
- BE battery +ve terminal start attracting the small amounts of electrons (minority carrier) from base p-type region, then starts attracting electrons from depletion region, which become thinner and thinner, then electrons start to flow from Emitter N-region



- Now base p-type now how a new electrons being transferred from CE battey –ve terminal through emitter n-type.
- Electrons stream divided between
  - Directly to BE battery +ve terminal
  - CE battery +ve terminal through emitter n-type

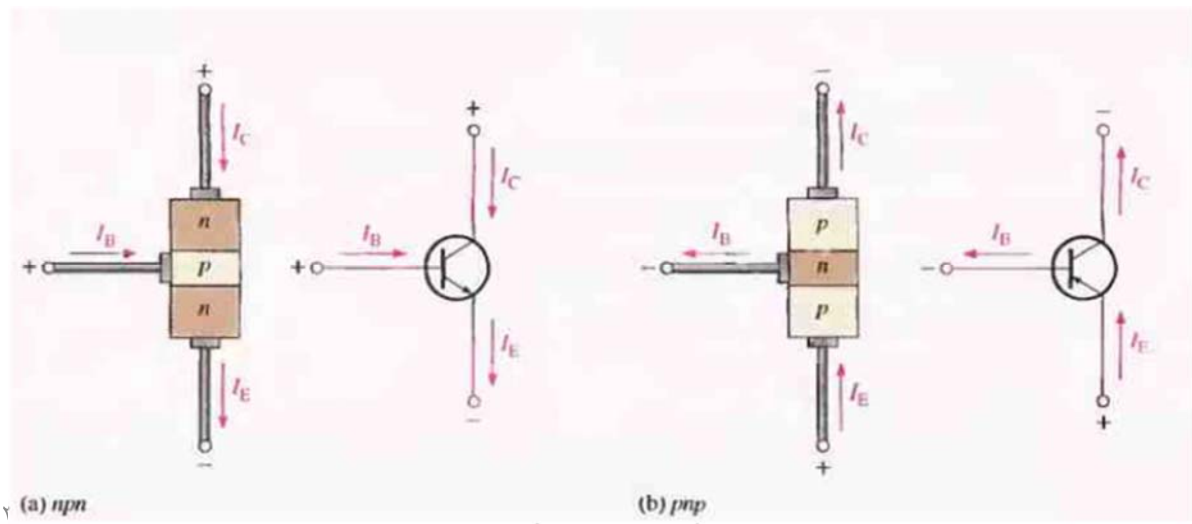


- The more +ve potential applied to base from BE battery +ve terminal, a more electrons being transferred from CE battery –ve terminal, through emitter N-region, a more electrons in turn flow to CE battery +ve terminal.

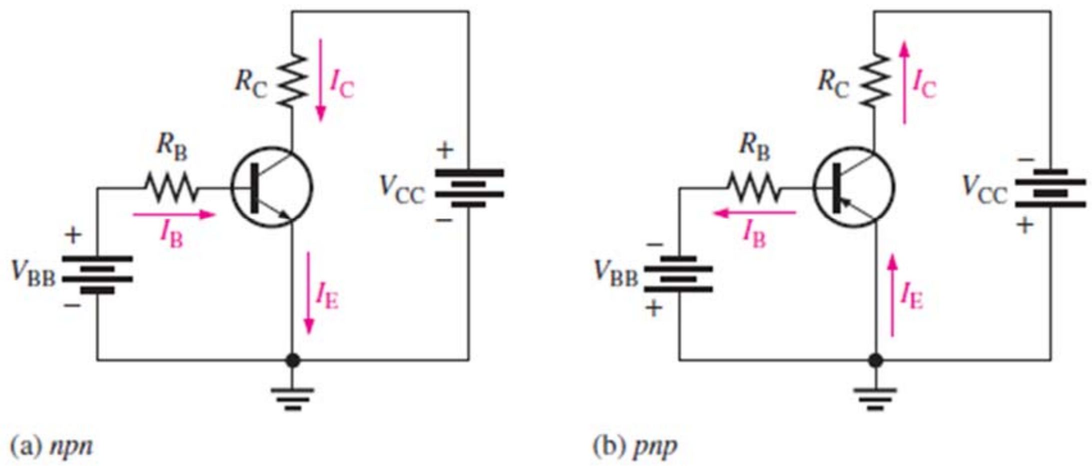


Transistor Currents

$$I_E = IB + IC$$



- *V*BB forward-biases the base-emitter junction,
- *V*CC reverse-biases the base-collector junction.
- In practice both VCC, and VBB derived from single battery with necessarily voltage divider on base terminal



- **DC Beta (β_{DC}) and DC Alpha (α_{DC})**
- DC gain called **(β_{DC})** is the ratio between IC/IB, which called h_{FE} in data sheet, range from less than 20 to 200 or higher.

$$\beta_{DC} = \frac{I_C}{I_B}$$

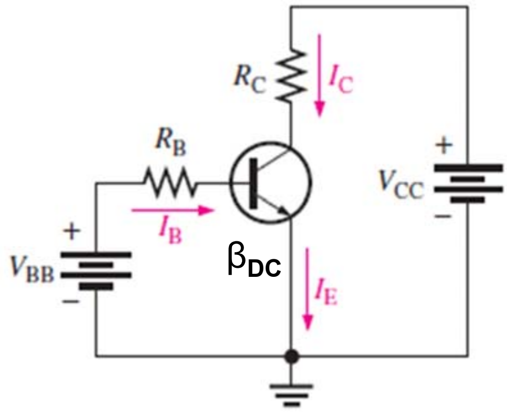
$$h_{FE} = \beta_{DC}$$

- **(α_{DC})** is the ratio between IC/IE, in range from 0.95 to 0.99 or greater

$$\alpha_{DC} = \frac{I_C}{I_E}$$

Example

Determine the dc current gain β_{DC} and the emitter current I_E for a transistor where $I_B = 50\ \mu A$ and $I_C = 3.65$ mA.

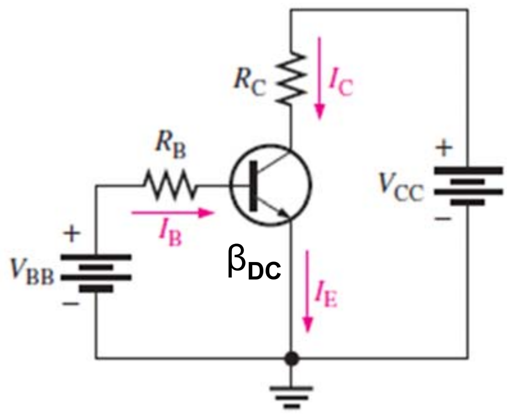


Example

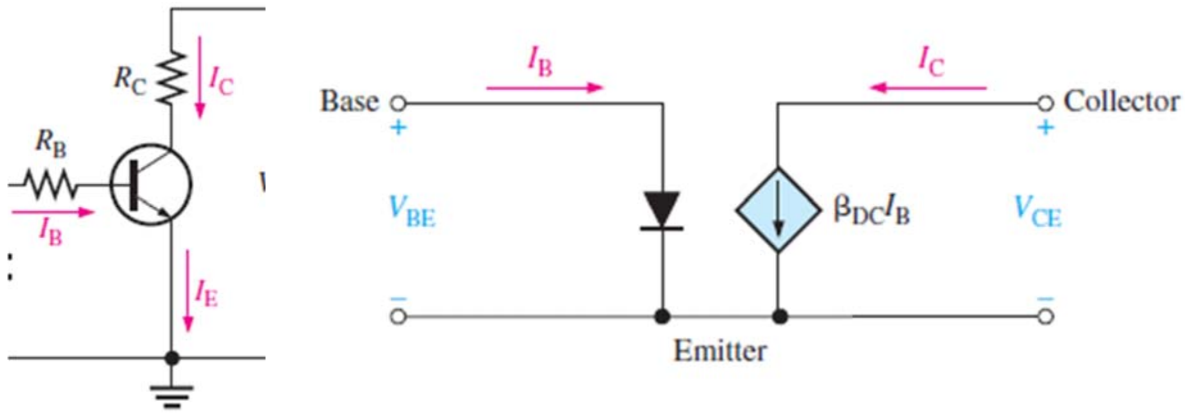
Determine the dc current gain β_{DC} and the emitter current I_E for a transistor where $I_B = 50\ \mu A$ and $I_C = 3.65$ mA.

$$\beta_{DC} = \frac{I_C}{I_B} = \frac{3.65\text{ mA}}{50\ \mu\text{A}} = \mathbf{73}$$

$$I_E = I_C + I_B = 3.65\text{ mA} + 50\ \mu\text{A} = \mathbf{3.70\ mA}$$



Transistor DC Model



BJT Circuit Analysis

- *V*BB, forward-biases the base-emitter junction, and the collector-bias voltage source, *V*CC, reverse-biases the base-collector junction.

$$V_{BE} \cong 0.7\ \text{V}$$

- Kirchhoff's voltage law @1

$$V_{R_B} = V_{BB} - V_{BE}$$

I_B: dc base current

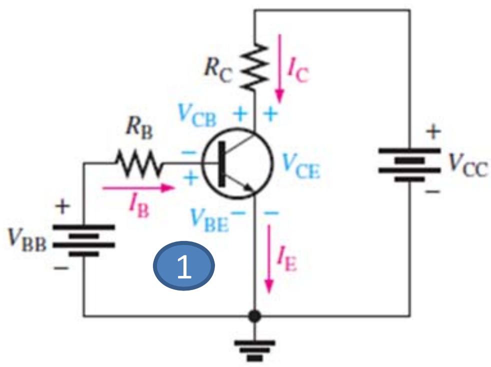
I_E: dc emitter current

I_C: dc collector current

V_{BE}: dc voltage at base with respect to emitter

V_{CB}: dc voltage at collector with respect to base

V_{CE}: dc voltage at collector with respect to emitter



- Ohm's low

$$V_{R_B} = I_B R_B$$

- Substitute

$$I_B R_B = V_{BB} - V_{BE}$$

- Finally

$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

$$I_C = \beta\, IB$$

$$I_E = IC + IB$$

I_B: dc base current

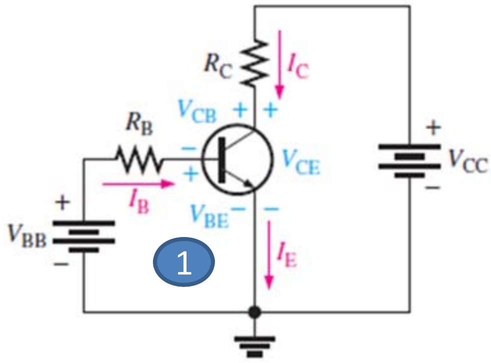
I_E: dc emitter current

I_C: dc collector current

V_{BE}: dc voltage at base with respect to emitter

V_{CB}: dc voltage at collector with respect to base

V_{CE}: dc voltage at collector with respect to emitter



- KVL @ 2

$$-VCC + VRc + VCE = 0$$

$$V_{CE} = VCC - VRc$$

- Ohm's

$$V_{R_C} = I_C R_C$$

- Substitute

$$V_{CE} = V_{CC} - I_C R_C$$

- But

$$I_C = \beta_{DC} I_B.$$

I_B: dc base current

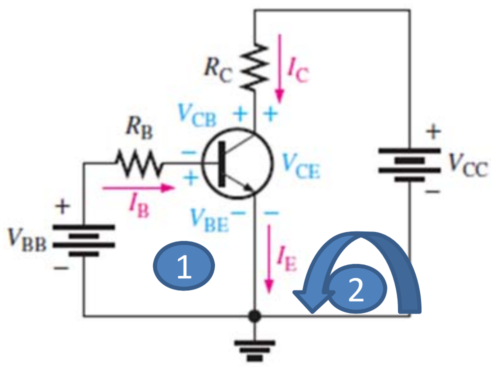
I_E: dc emitter current

I_C: dc collector current

V_{BE}: dc voltage at base with respect to emitter

V_{CB}: dc voltage at collector with respect to base

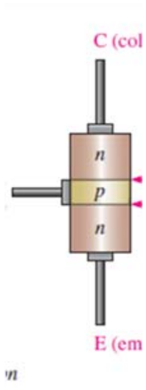
V_{CE}: dc voltage at collector with respect to emitter



- Consider the transistor itself

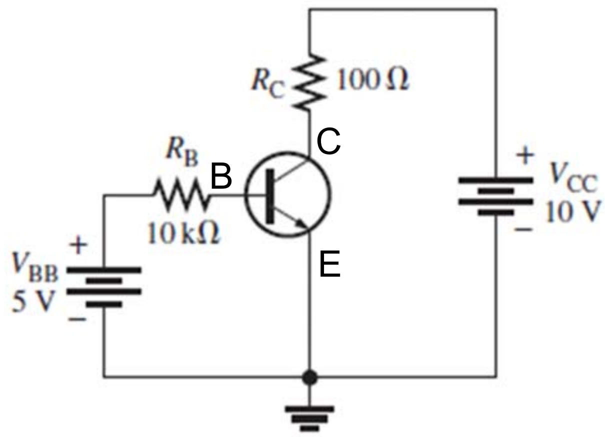
$$V_{CE} = VCB + VBE$$

$$V_{CB} = V_{CE} - V_{BE}$$



Example 02

Determine I_B, I_C, I_E, V_{BE}, V_{CE}, and V_{CB} in the circuit of Figure 4–9. The transistor has a $\beta_{DC} = 150$.



Example 02

Determine I_B, I_C, I_E, V_{BE}, V_{CE}, and V_{CB} in the circuit of Figure 4–9. The transistor has a $\beta_{DC} = 150$.

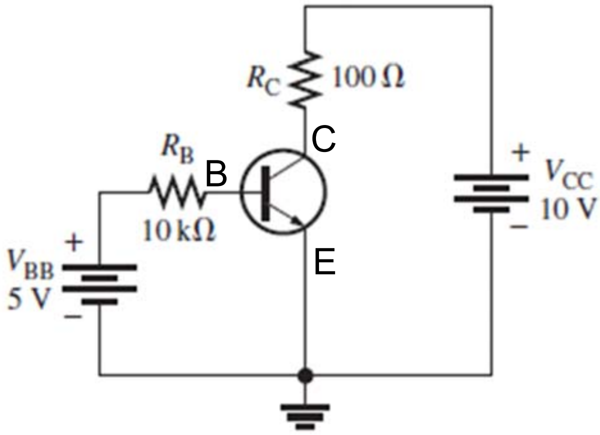
Answer

$V_{BE} \cong \mathbf{0.7\ V}$.

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5\ V - 0.7\ V}{10\ k\Omega} = \mathbf{430\ \mu A}$$

$$I_C = \beta_{DC} I_B = (150)(430\ \mu A) = \mathbf{64.5\ mA}$$

$$I_E = I_C + I_B = 64.5\ mA + 430\ \mu A = \mathbf{64.9\ mA}$$



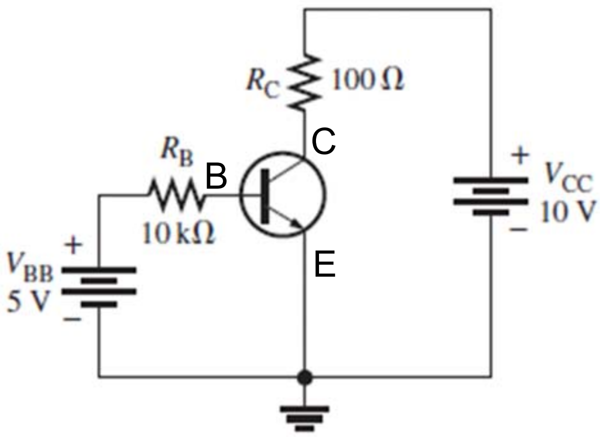
Example 02

Determine I_B, I_C, I_E, V_{BE}, V_{CE}, and V_{CB} in the circuit of Figure 4–9. The transistor has a $\beta_{DC} = 150$.

Answer

$$V_{CE} = V_{CC} - I_C R_C = 10\ V - (64.5\ mA)(100\ \Omega) = 10\ V - 6.45\ V = \mathbf{3.55\ V}$$

$$V_{CB} = V_{CE} - V_{BE} = 3.55\ V - 0.7\ V = \mathbf{2.85\ V}$$



Thanks,..

See you next week (ISA),…