BCT 2205 – Lecture 3.2

- **Semiconductor diodes and Transistors**

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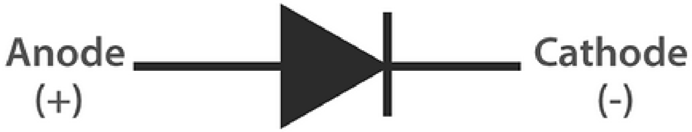
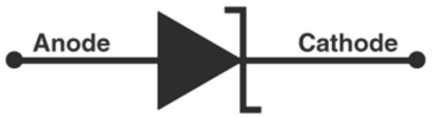
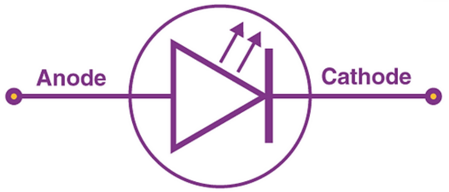
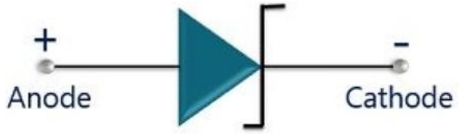
Semiconductor Diodes

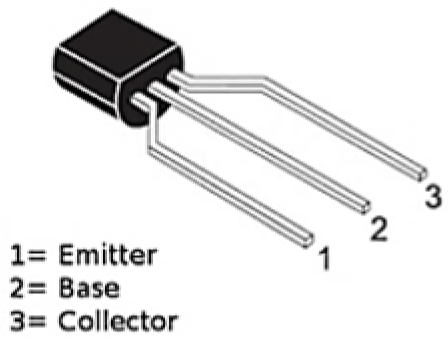
- When a junction is formed between p-type and n-type semiconductor materials, the resulting device is called a **semiconductor diode**.
- A diode offers no resistance to current flow in one direction and an extremely high resistance to current flow in the other.
- Diodes are used in applications that require a circuit to behave differently according to the direction of current flowing in it.
- The connection to the **p-type** material is referred to as the **anode** while that to the **n-type** material is called the **cathode**.



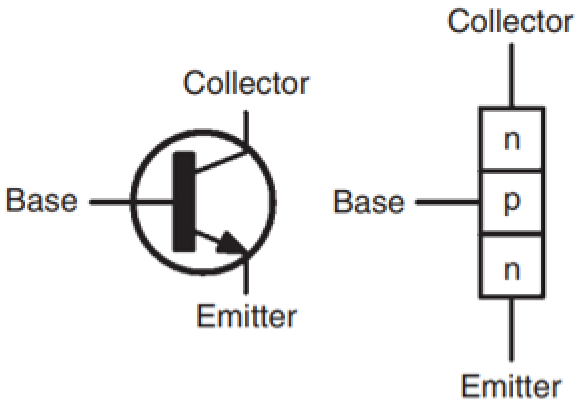
Zener diodes	*Varactor diodes*	*Light emitting diodes (LED)*	*Schottky diodes*
• Heavily doped silicon diodes which exhibit an abrupt reverse break-down at relatively low voltages.  	• Varying the width of the depletion region is equivalent to varying the plate separation of a very small capacitor. 	• General-purpose indicators which operate from smaller voltages and currents. • LEDs are reliable than filament lamps.  	• Uses a metal-semiconductor contact rather than a p-n junction. • Used to construct integrated circuits 

Transistors

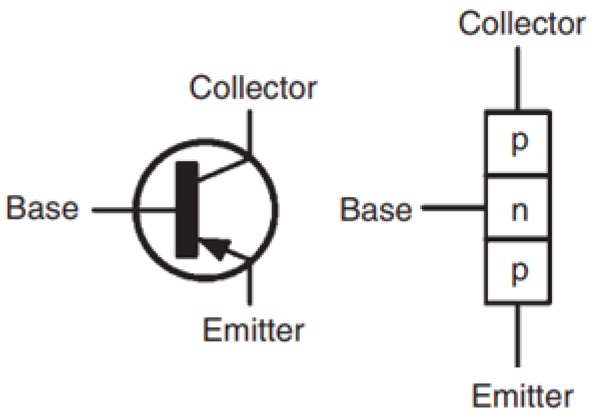
- The transistor is composed of a semiconductor material with three terminals for connection to an electronic circuit.
- Voltage or current applied to one pair of the transistor terminals controls the current through another pair of terminals.
- Bipolar transistors generally comprise n-p-n or p-n-p junctions of either silicon (Si) or germanium (Ge) material.



Typical transistor



n-p-n transistor



p-n-p transistor

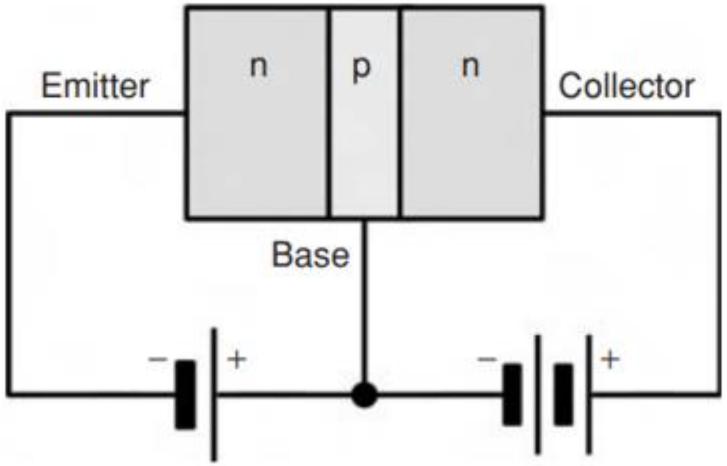
n-p-n transistor action

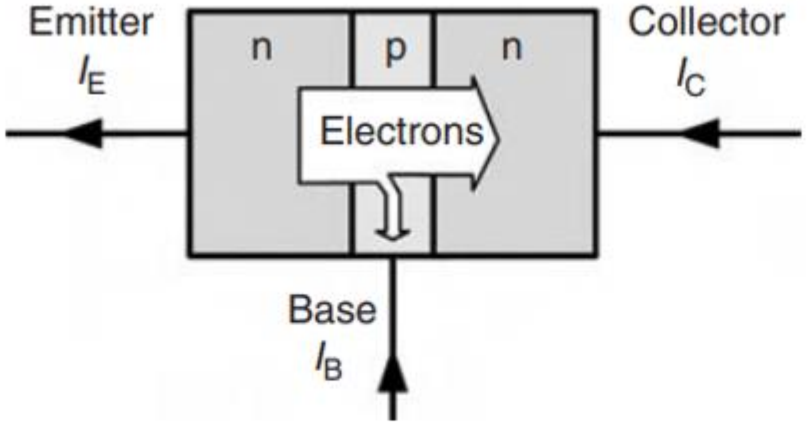
i. Majority carriers in the n-type material are electrons. Base-emitter junction is forward biased, and electrons cross the junction and appear in the base region

ii. Base region is very thin and lightly doped with holes. Some recombination with holes occurs but many electrons are left in the base region

iii. These electrons are attracted by the positive potential at the collector terminal

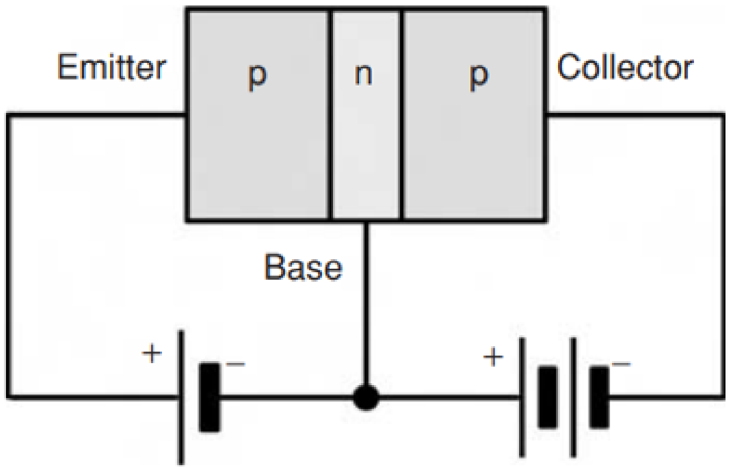
iv. Most electrons cross into the collector region, creating a collector current.

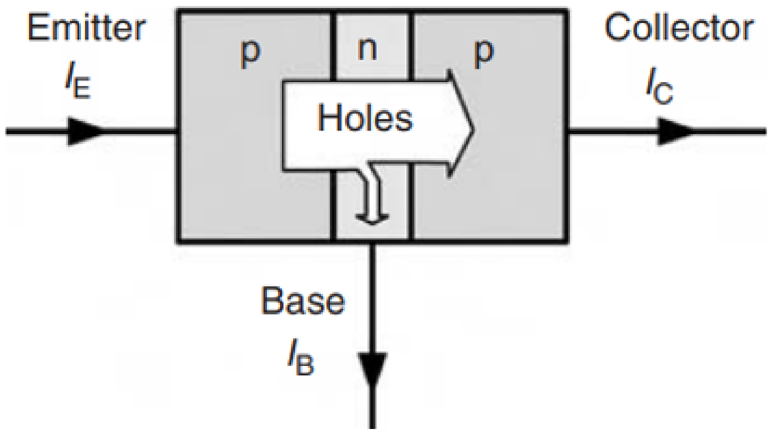




p-n-p transistor action

i. Majority carriers in the emitter p-type material are holes. Base-emitter junction is forward biased, and holes cross the junction and appear in the base region
ii. Base region is very thin and lightly doped with electrons. Although some electron-hole pairs are formed, many holes are left in the base region
iii. These holes are attracted by the negative potential at the collector terminal
iv. Majority of the holes cross the base-collector junction, creating a collector current.





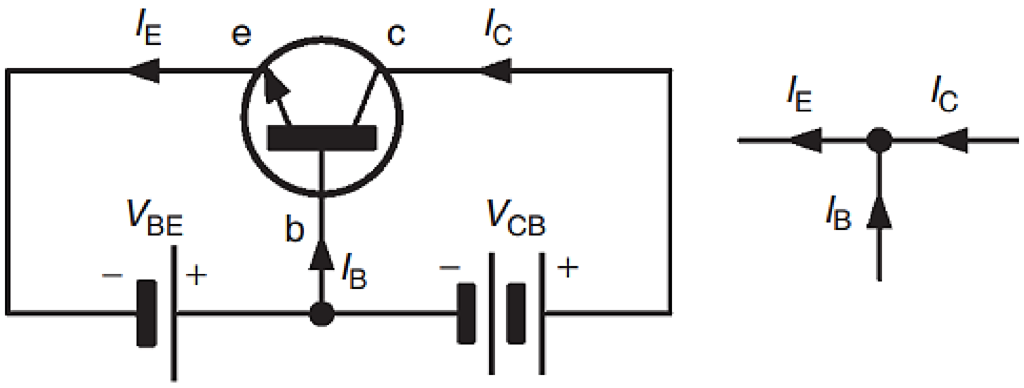
Bias and current flow

- Direction of conventional current flow is from emitter to collector for a p-n-p transistor, and collector to emitter for n-p-n device.

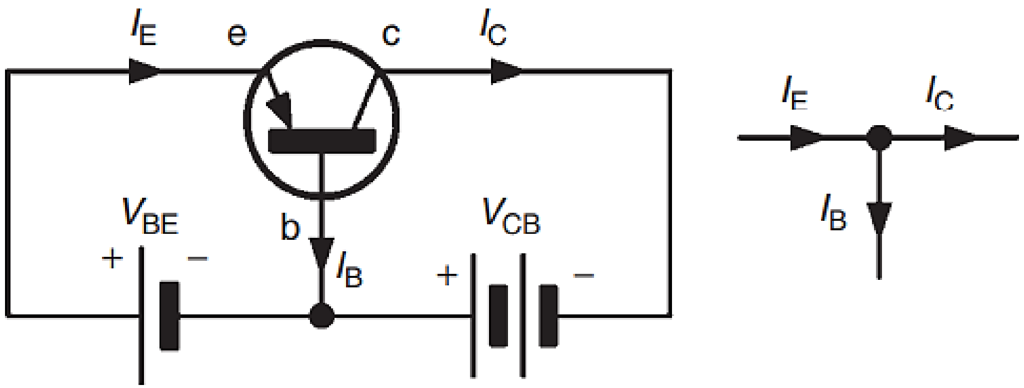
$$I_E = I_B + I_C$$

- A transistor operates with a collector current of 100 mA and an emitter current of 102 mA. Determine base current.

$$I_B = I_E - I_C$$
$$I_B = 102 - 100 = 2mA$$



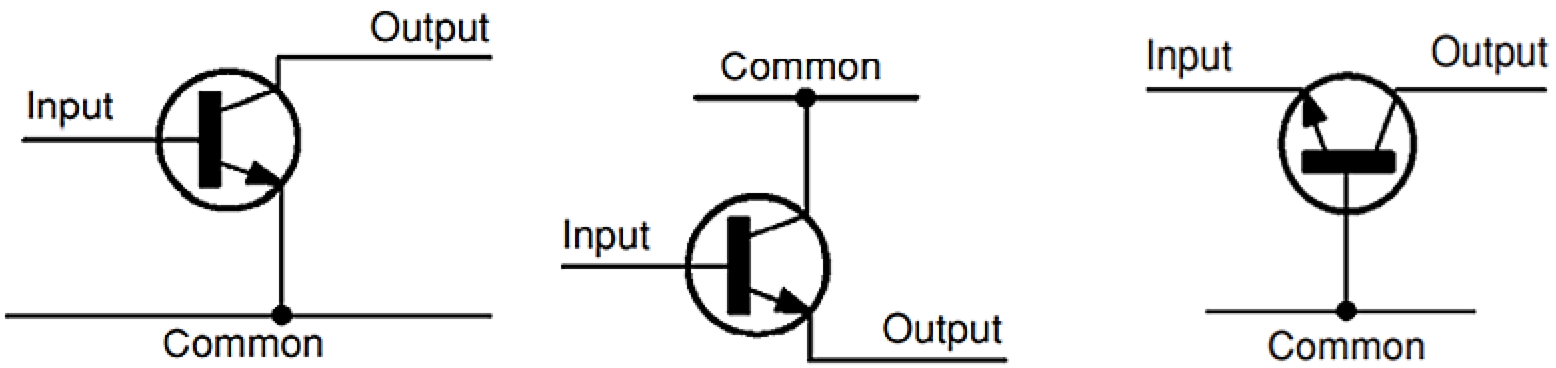
(a) n-p-n bipolar junction transistor (BJT)



(b) p-n-p bipolar junction transistor (BJT)

Transistor operating configurations

- Three basic circuit configurations are used for transistor amplifiers, depending on which transistor connection is common to input and output.
- The configurations are known as common-emitter, common-collector and common-base.
- The n-p-n transistor is more common than the p-n-p transistor and the most popular mode of configuration is the common-emitter mode.



(a) Common emitter

(b) Common collector

(c) Common base

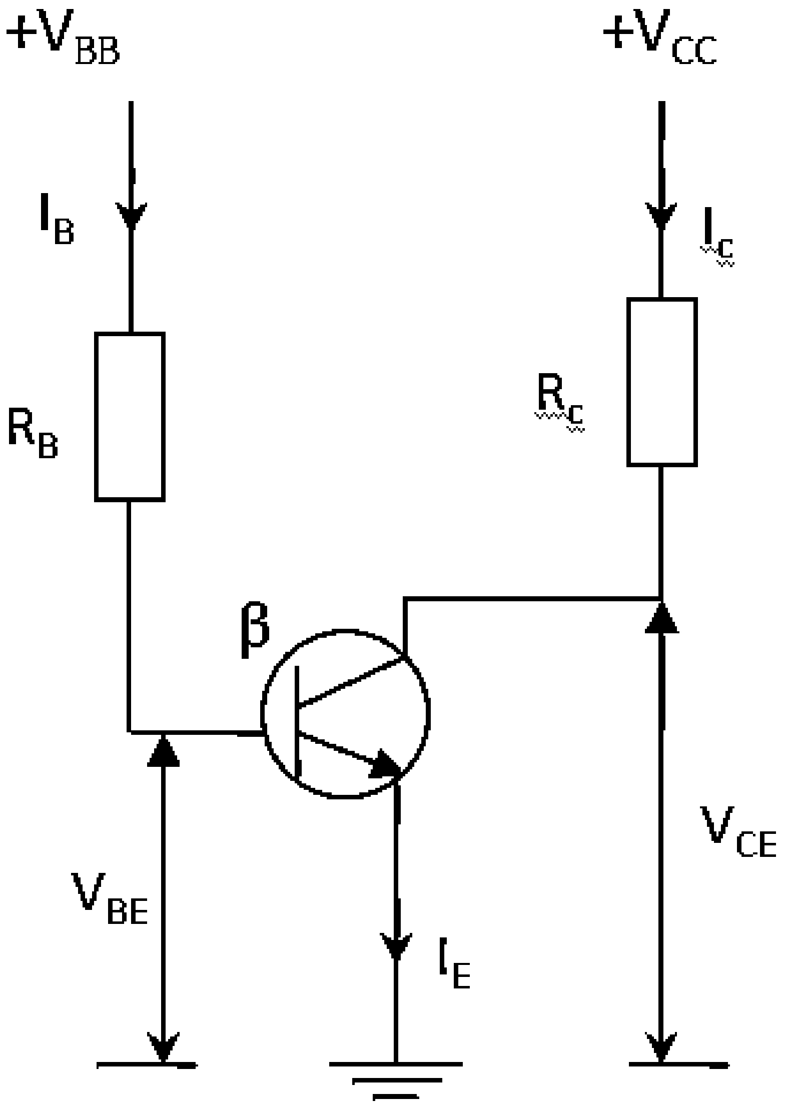
- In common emitter mode,

$$\beta = \frac{I_C}{I_B}$$

- β is the current gain.

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

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



Example

- A bipolar junction transistor operates with a base current of 1.2mA and a current gain of 100. Determine the emitter current.

$$I_C = \beta I_B = 100\ x\ 1.2m = 0.12A$$

$$I_E = I_B + I_C = 1.2m + 0.12 = 0.1212A$$

Example

- For the circuit given, neglecting V_{BE} find: I_B, I_C, I_E and V_{CE}.

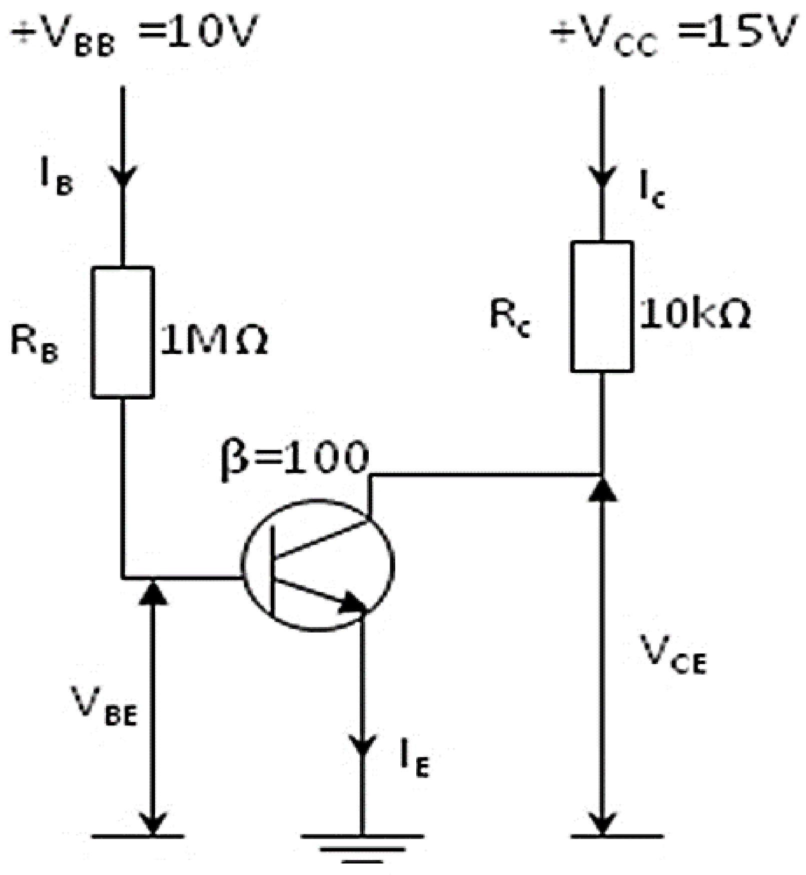
Solution

$$I_B = \frac{V_{BB}}{R_B} = \frac{10}{1M} = 10\mu A$$

$$I_C = \beta I_B = 100x10\mu = 1mA$$

$$I_E = I_C + I_B = 10\mu + 1m = 1.01mA$$

$$V_{CE} = V_{CC} - I_C R_C = 15 - (1m \times 10k) = 5V$$

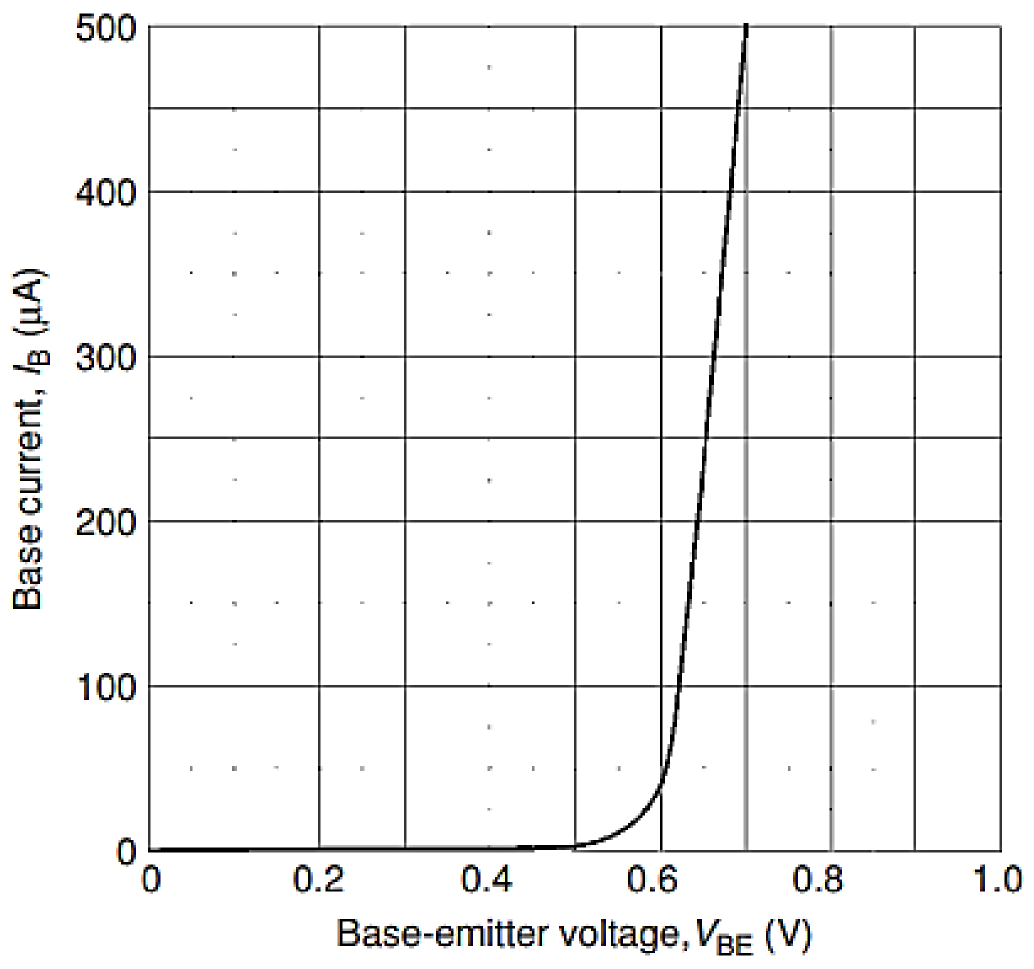


Input characteristics

- In CE mode, input current is applied to the base and output current appears in the collector.
- Very little base current flows until the base emitter voltage V_{BE} exceeds 0.6V.
- Characteristic resembles the forward part of the characteristic for a silicon diode.

i. Static (d.c.) input resistance $= \frac{V_{BE}}{I_B}$

ii. Dynamic (a.c.) input resistance $= \frac{\Delta V_{BE}}{\Delta I_B}$

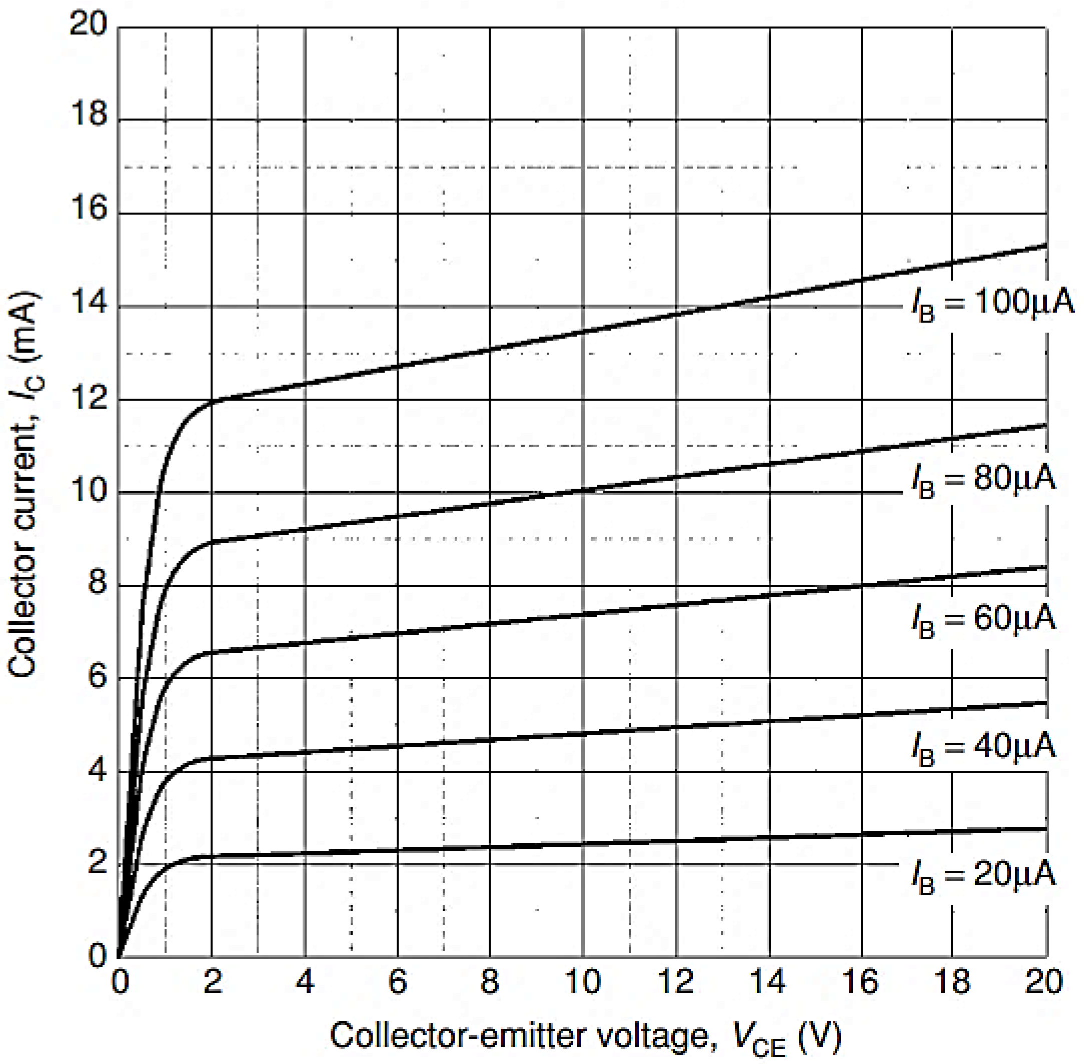


Output characteristics

- In output characteristics (I_C plotted against V_{CE}).
- Each curve corresponds to a different value of base current.
- The curves are quite flat; often referred to as constant current characteristic.

i. Static (d.c.) output resistance $= \frac{V_{CE}}{I_C}$

ii. Dynamic (a.c.) output resistance $= \frac{\Delta V_{CE}}{\Delta I_C}$

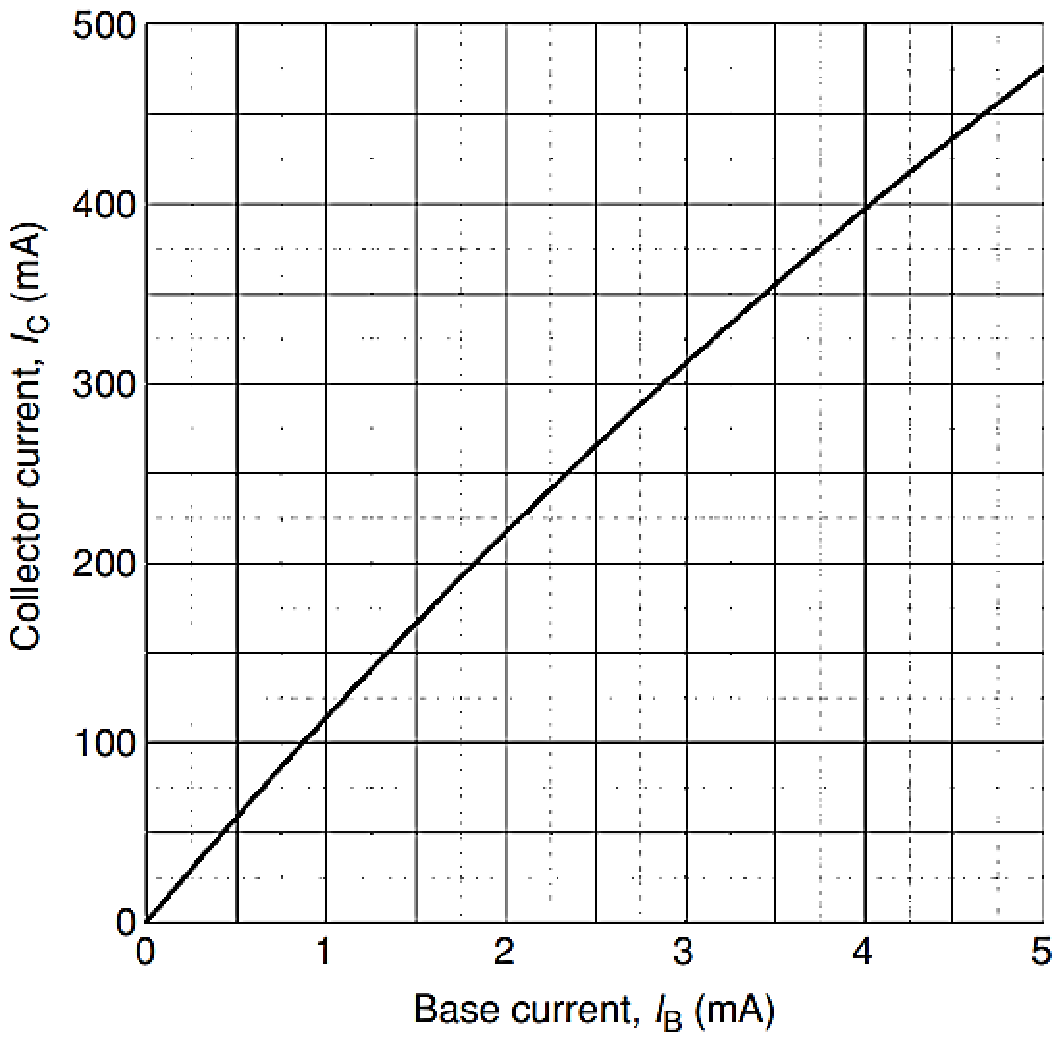


Transfer characteristics

- A transfer characteristic for an n-p-n bipolar junction transistor plots I_C against I_B.
- The slope of this curve (i.e., the ratio of I_C to I_B) is the common-emitter current gain of the transistor.

i. Static (or d.c.) current gain $= \frac{I_C}{I_B}$

ii. Dynamic (or a.c.) current gain $= \frac{\Delta I_C}{\Delta I_B}$



Example

- When the base-emitter voltage is 0.65V, determine, base current, static and dynamic input resistance.

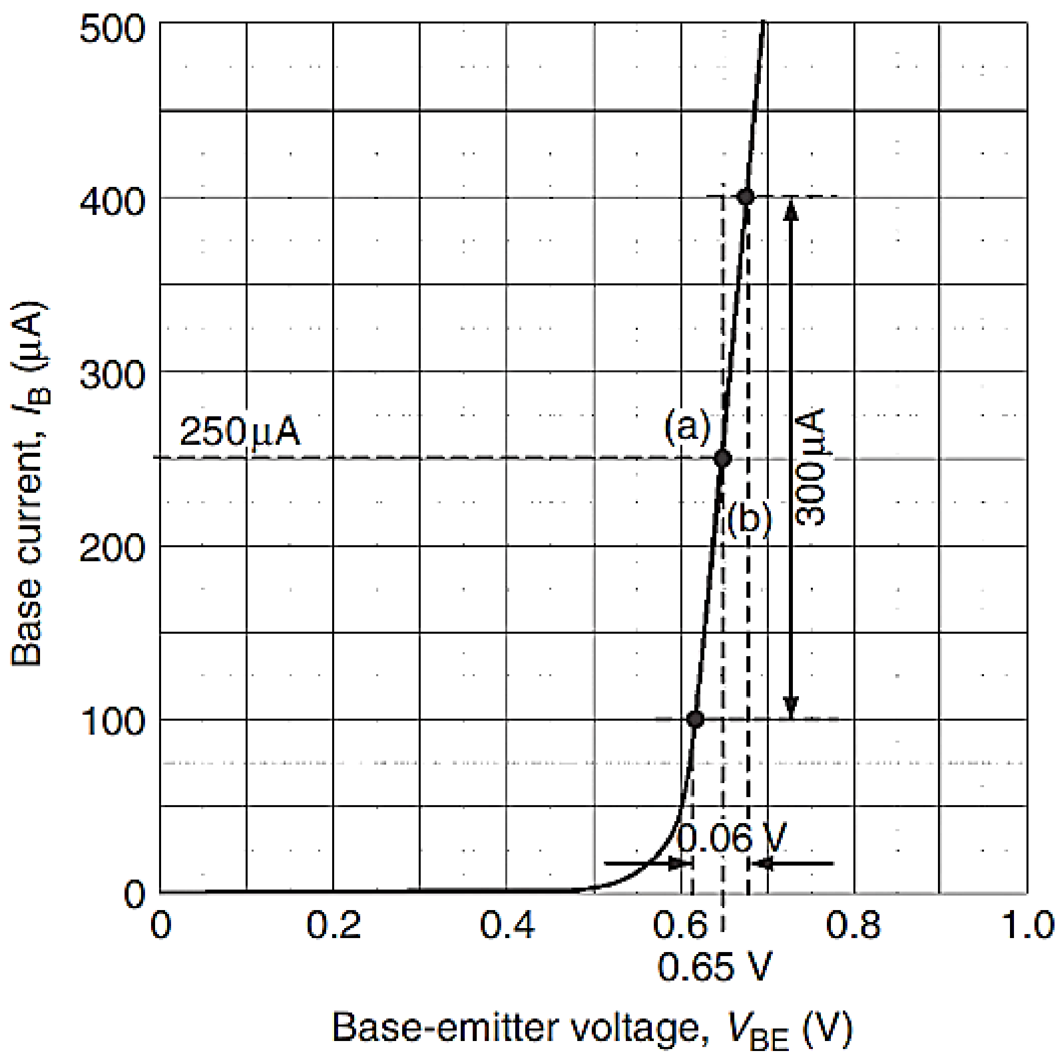
Solution

- When $V_{BE} = 0.65, I_B = 250\mu A$. Static input resistance

$$= \frac{V_{BE}}{I_B} = \frac{0.65}{250\mu} = 2.6k\Omega$$

- V_{BE} changes by 0.06V when I_B changes by 300μA. Dynamic value of input resistance

$$= \frac{\Delta V_{BE}}{\Delta I_B} = \frac{0.06}{300\mu} = 200\Omega$$



End of session

Questions....?