Lecture20: Physics of bipolar transistors (1)

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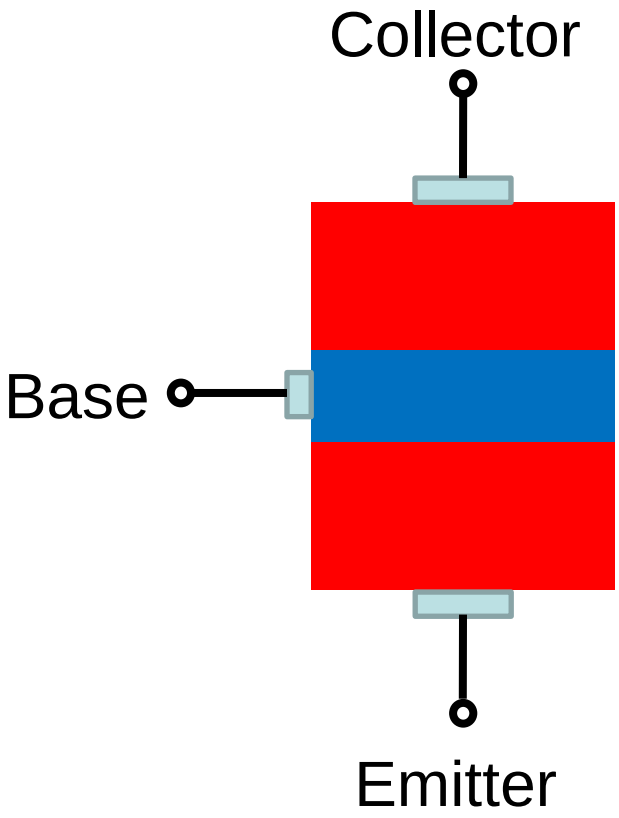
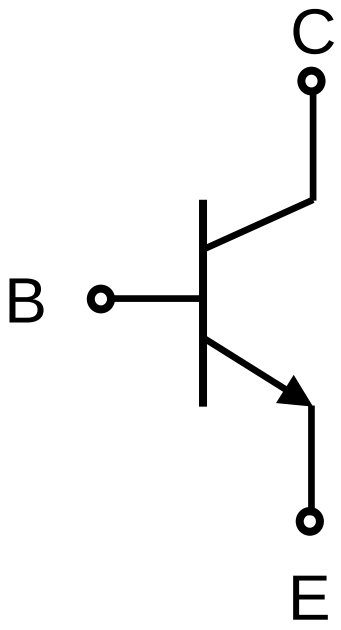
Bipolar transistor

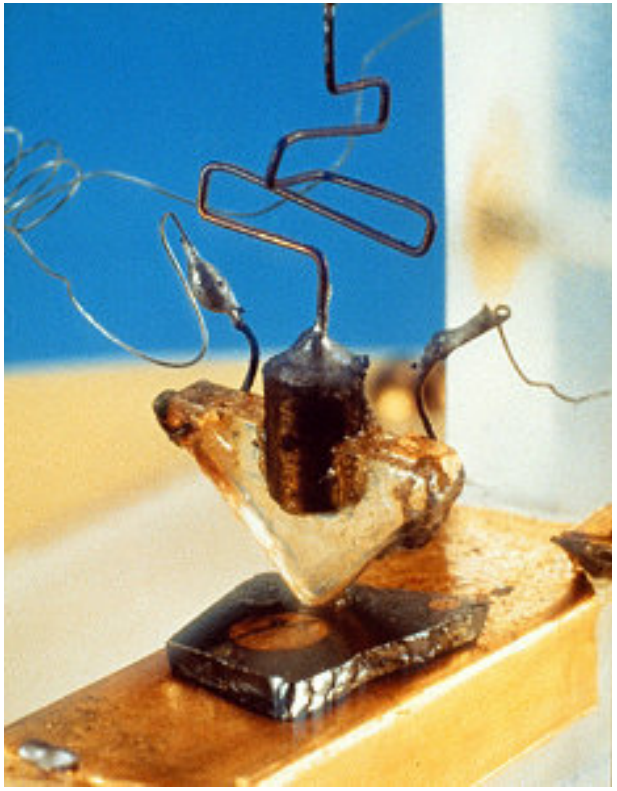
- Bipolar junction transistor (BJT)
  - Three doped regions forming a sandwich





The first transistor

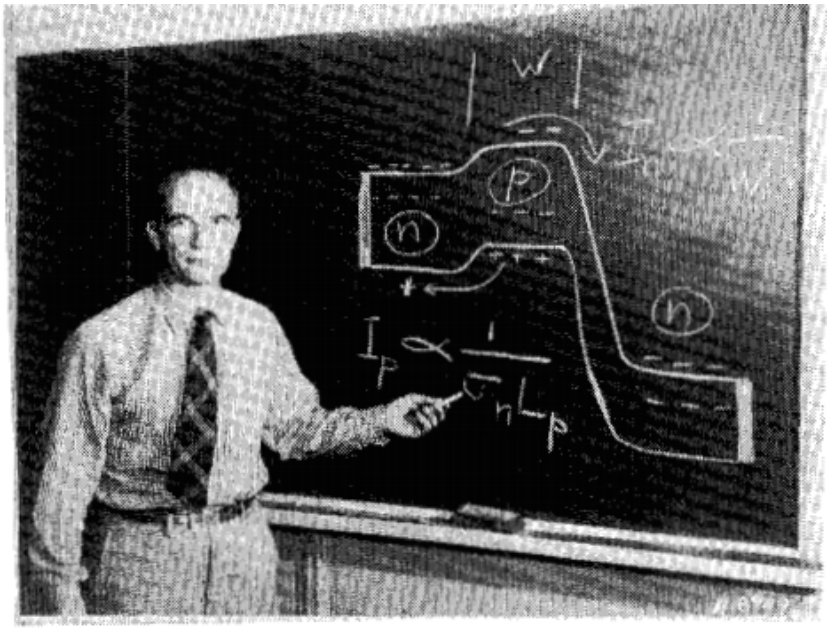
- Invented in 1947 by Shockley, Barttain, and Bardeen
  - To be specific, on December 16, 1947
  - Demonstrated to executives, on December 23, 1947
  - (Not 1945!)



Replica of the first transistor, the point-contact transistor (Google images)

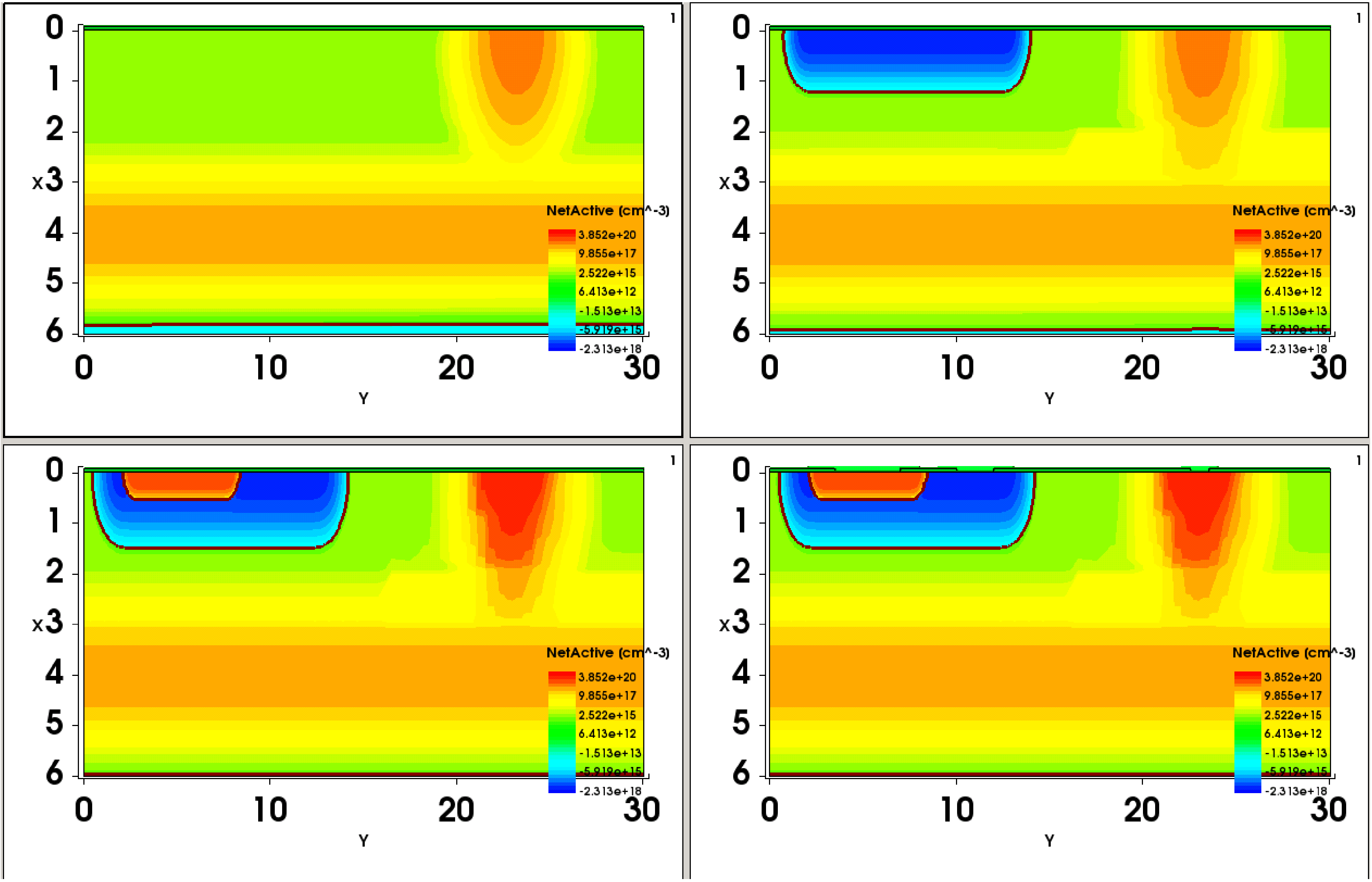
Three key concepts of BJT

- Emphasized by the inventor of the junction transistor
  - 1) Minority carrier injection into the base layer which increases exponentially with forward emitter bias
  - 2) Application of reverse voltage at the collector junction
  - 3) Favorable geometry and doping levels so as to obtain good emitter to collector efficiency



William Shockley, the inventor of the BJT (IEEE TED, vol. 23, p. 597, 1976)

How to fabricate it



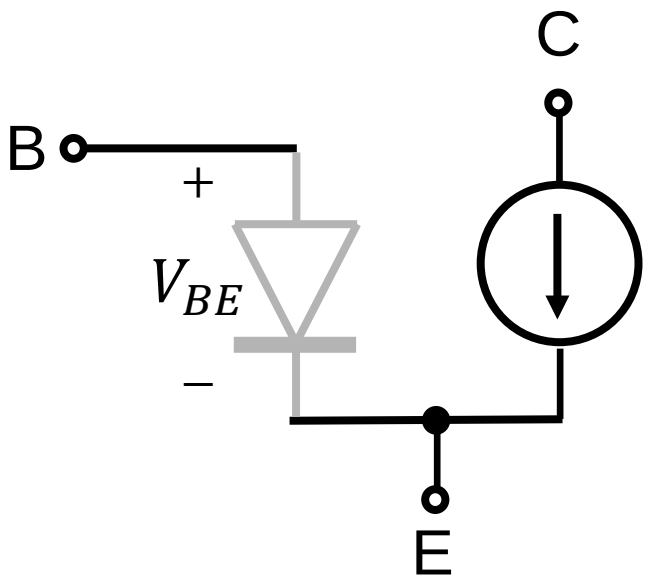
CMOS versus BJT

- Why do we still study the BJT? (Taken from Sedra and Smith)
  - The MOSFET is undoubtedly the most widely used electronic device.
  - CMOS technology is the technology of choice in the design of integrated circuits.
  - The BJT remains a significant device that excels in certain applications.
  - For instance, the reliability of BJT circuits under severe environmental conditions makes them the dominant device in certain automotive applications.
  - The BJT is the preferred device in very-high-frequency applications.
  - Finally, the BJT can be combined with MOSFETs. (BiCMOS)

We will show that…

- (a) The current flow from the emitter to the collector can be viewed as a current source tied between these two terminals.
- (b) This current is controlled by the voltage difference between the base and the emitter.

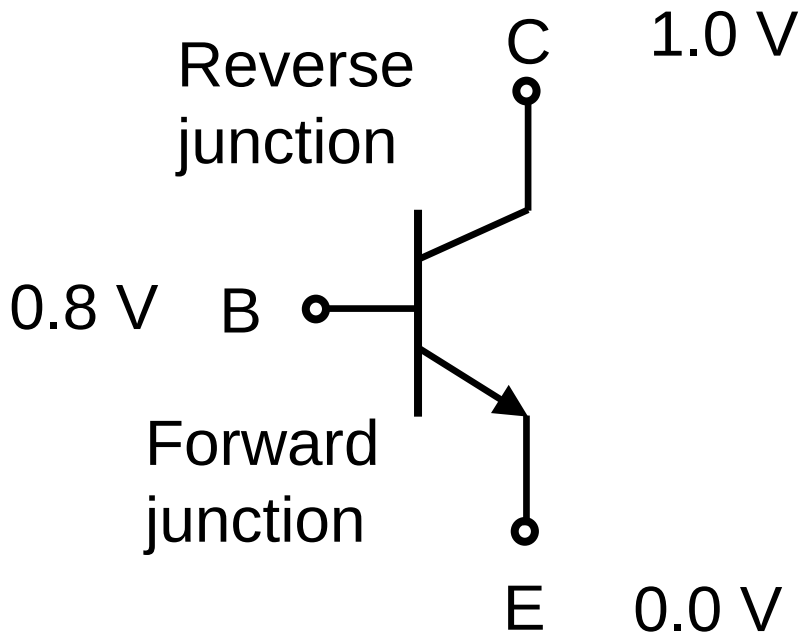
- In other words,
  - A voltage-controlled current source!



Assumption

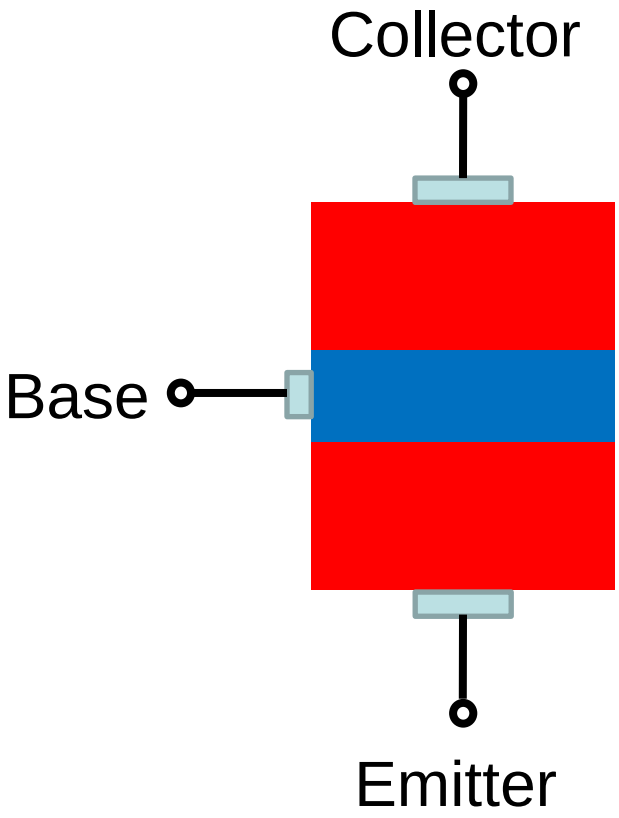
- Forward active region
  - Positive V_{BE}
  - Negative V_{BC}

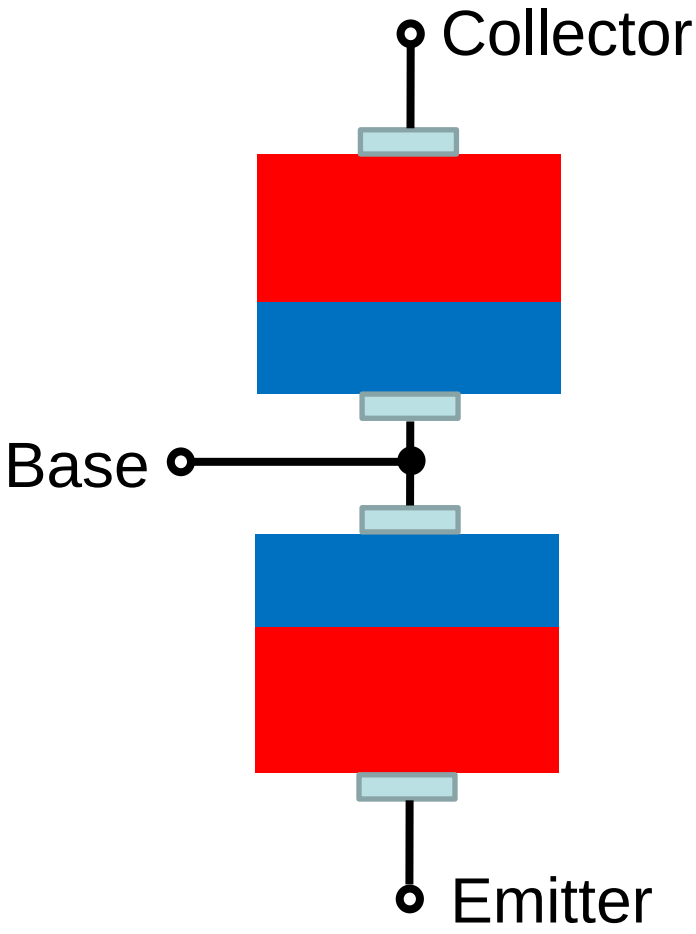
  - For example, in the figure,
$V_{BE} = 0.8\ \mathrm{V}$
$V_{BC} = -0.2\ \mathrm{V}$



Linux is not Unix.

- A bipolar transistor is not two connected diodes.
  - Positive





Analogy

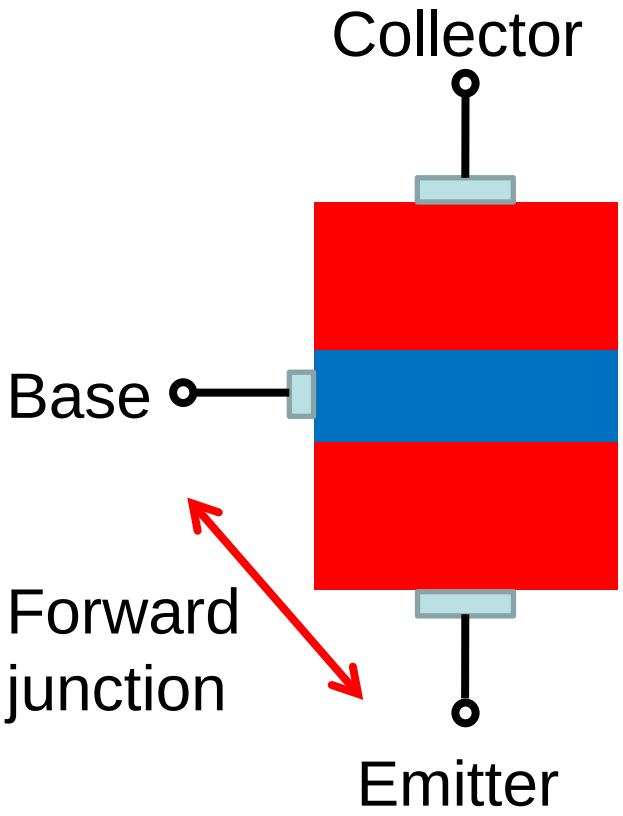
- A cliff
  - Potential barrier seen by electrons

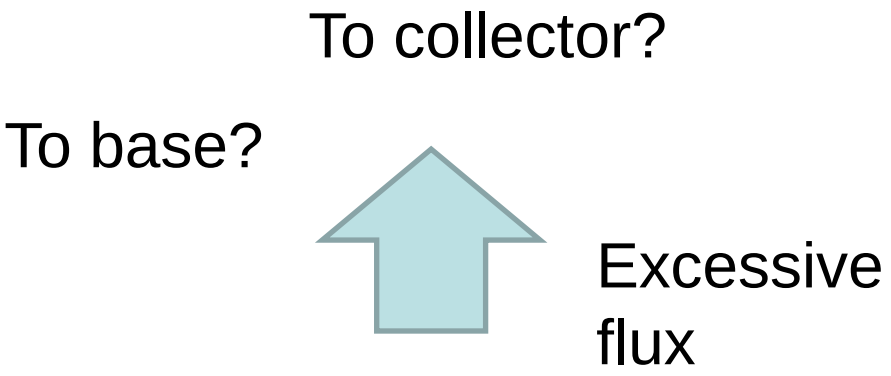
- Two ways on top
  - Narrow path (to base)
  - Broad path (to collector)

(Both taken from Google images)

Electron flux

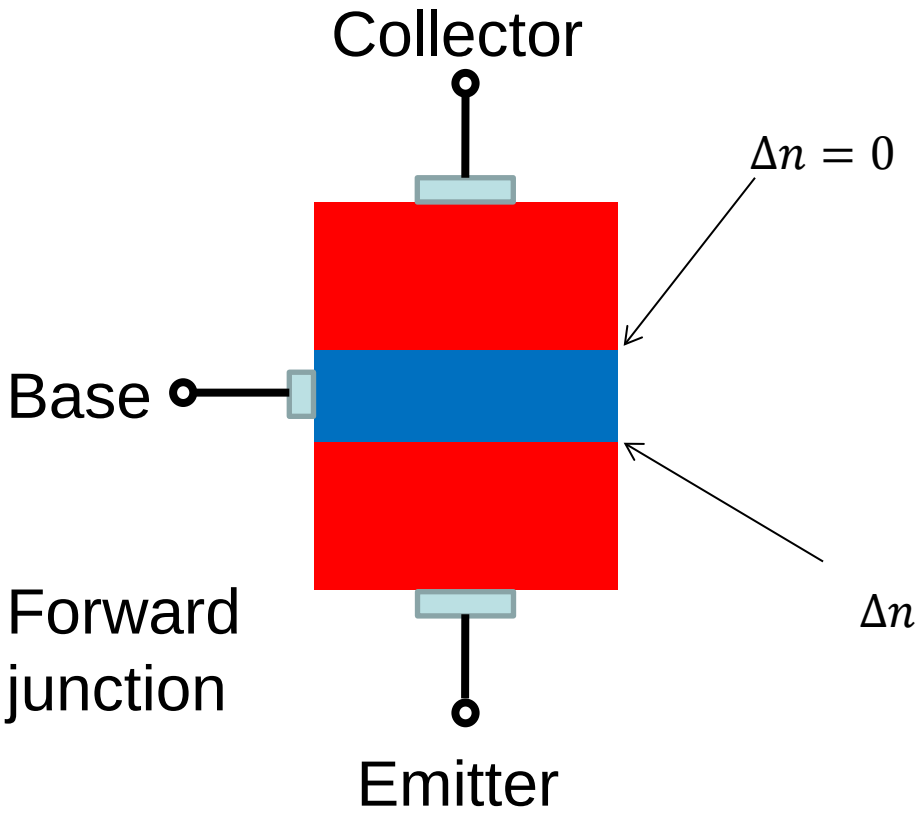
- First, consider the electron flux.
  - There will be the flux generated by a positive V_{BE}.





Collector current

- Calculate it using the diffusion current.



$$J_n = qD_n \frac{dn}{dx}$$

Check your (4.5)!

Read your textbook.

- Up to p. 118

- We will cover Sec. 4.4.
  - Models and characteristics
  - Up to p. 138