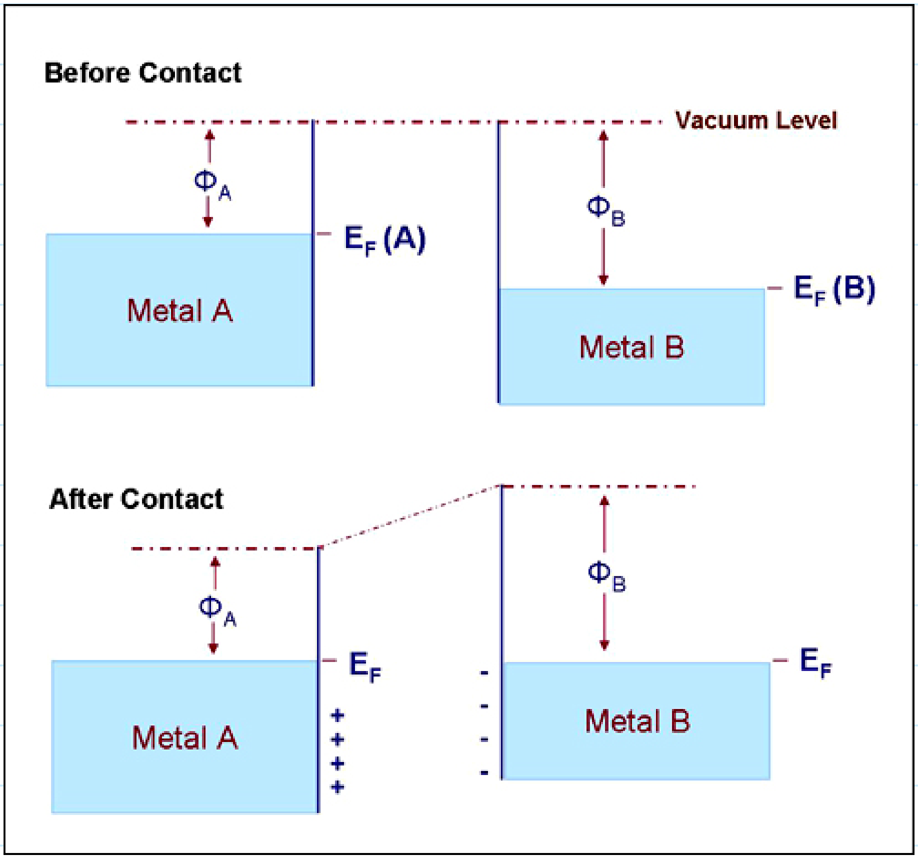
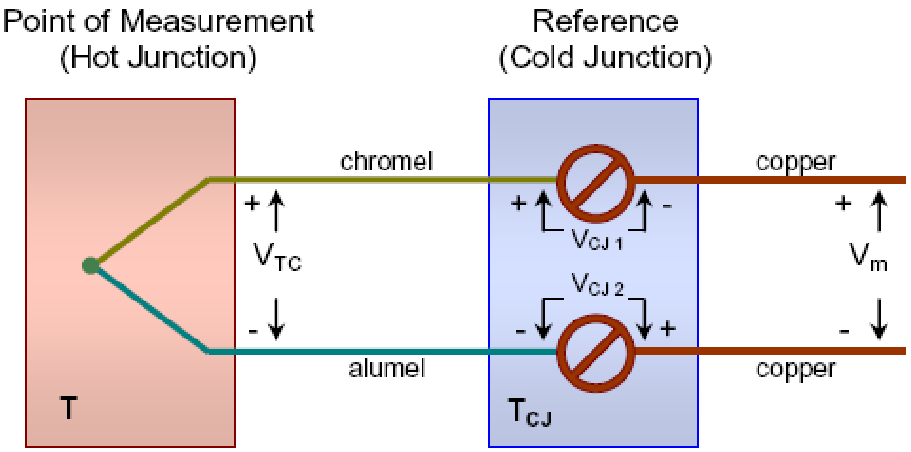
Unit 7 - Junctions and transistors

1. Contact potential



Thermocouple

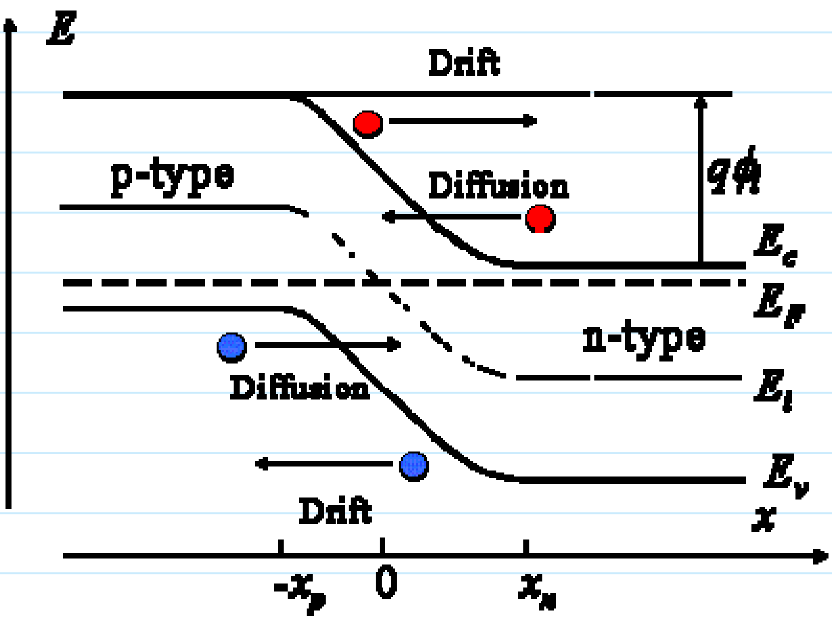


$$V_m = V_{TC} - (V_{CJ\,1} + V_{CJ\,2}) = V_{TC} - V_{CJ}$$

Temperature dependence

From <http://www.mosaic-industries.com/embedded-systems/microcontroller-projects/temperature-measurement/thermocouple/types-wire-element>

2. p-n junction



$$N_d l_n = N_a l_p \qquad (6.5)$$

We'll derive the following eqns in HW or exercises

$$\phi = \frac{e}{2\varepsilon\varepsilon_0}\left(N_d l_n^2 + N_a l_p^2\right) \qquad \phi = \frac{k_B T}{e}\ln\left(\frac{N_a N_d}{n_i^2}\right) \text{ or } (6.13)$$

$$l_p = \left(\frac{\phi 2\varepsilon\varepsilon_0}{eN_a}\frac{N_d}{N_a+N_d}\right)^{1/2}$$

$$l_n = \left(\frac{\phi 2\varepsilon\varepsilon_0}{eN_d}\frac{N_a}{N_a+N_d}\right)^{1/2}$$

$$n_n = N_c e^{(E_F - E_g)/k_B T}$$

$$p_n = N_v e^{-E_F/k_B T}$$

$$p_p = N_v e^{(e\phi - E_F)/k_B T}$$

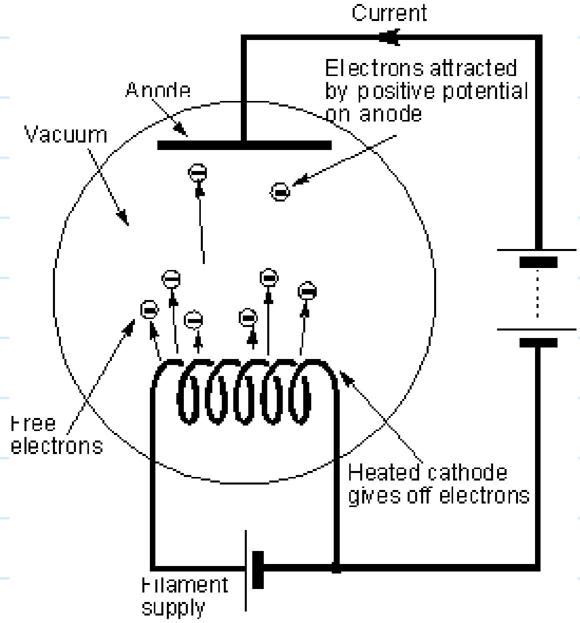
Group exercise

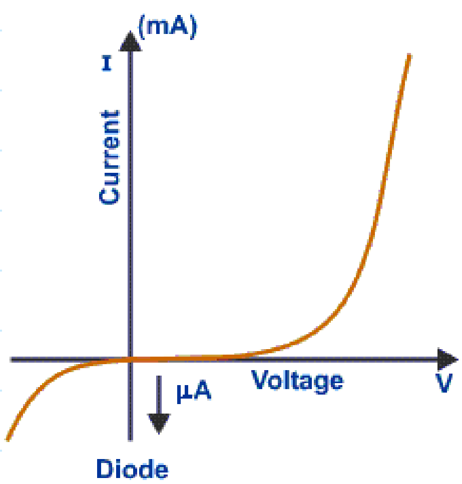
A silicon p-n junction has doping levels of $N_d = 2 \times 10^{22}\ \mathrm{m}^{-3}$ and $N_a = 4 \times 10^{21}\ \mathrm{m}^{-3}$. Determine the contact potential and the depletion layer widths at 300 K. Use $n_i = 1 \times 10^{16}\ \mathrm{m}^{-3}$ and dielectric

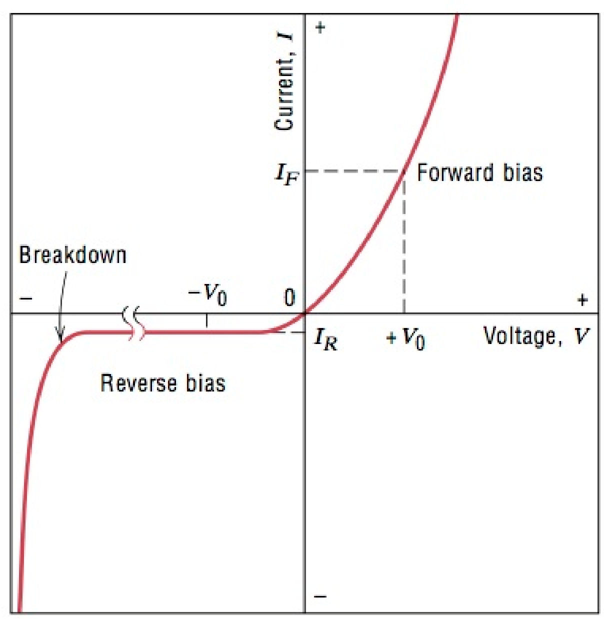
A silicon p-n junction has doping levels of $N_d = 2 \times 10$ m and $N_a = 4 \times 10^{21}\ \mathrm{m}^{-3}$. Determine the contact potential and the depletion layer widths at 300 K. Use $n_i = 1 \times 10^{16}\ \mathrm{m}^{-3}$ and dielectric constant = 11.7.

Diode (tube/valve)

The diode (vacuum tube) or Fleming valve (in England) was invented in 1904 using what was called the Edison effect. Edison (re)discovered this effect when perfecting the light bulb and patented it in 1884 although it is generally believed he had no idea how it worked.







3. p-n junction (rectifying)

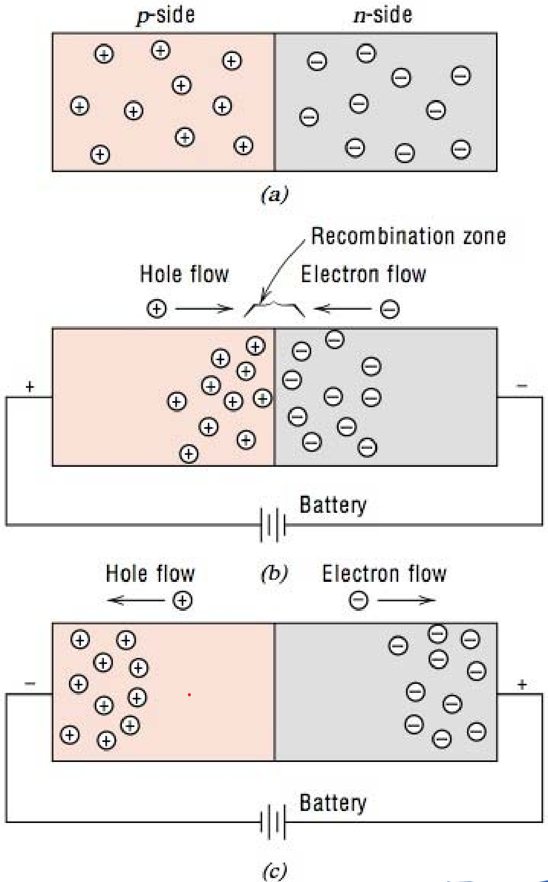
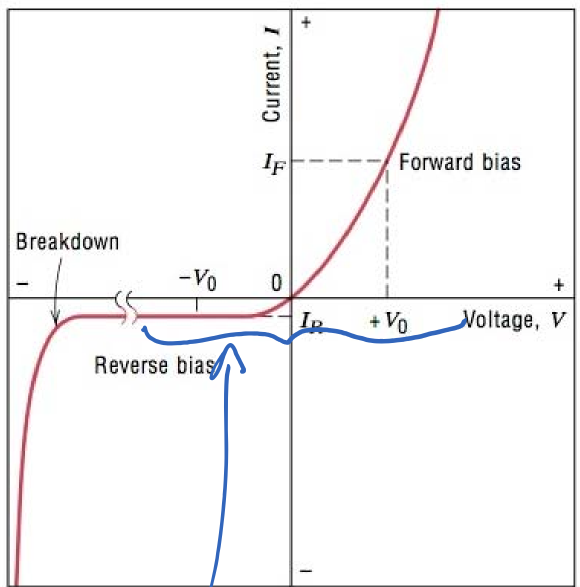
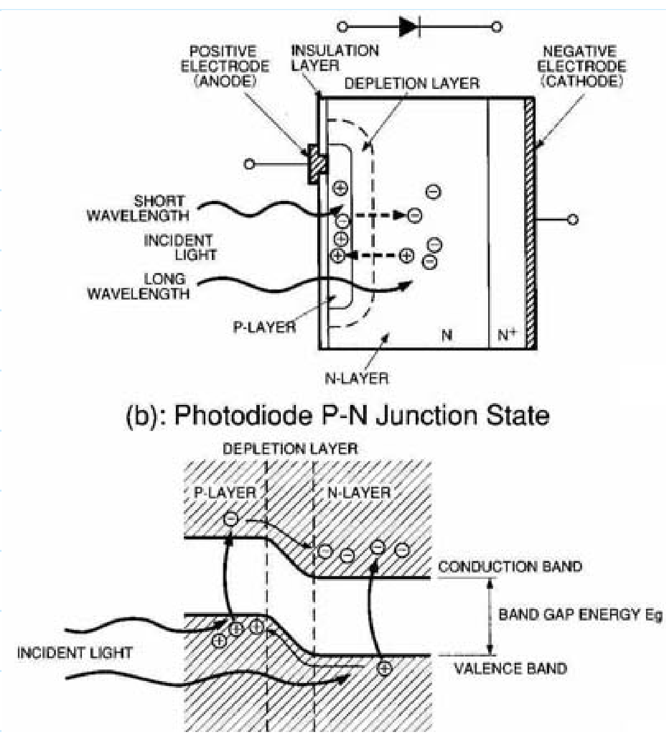


FIGURE 12.19 For a p–n rectifying junction, representations of electron and hole distributions for (a) no electrical potential, (b) forward bias, and (c) reverse bias.

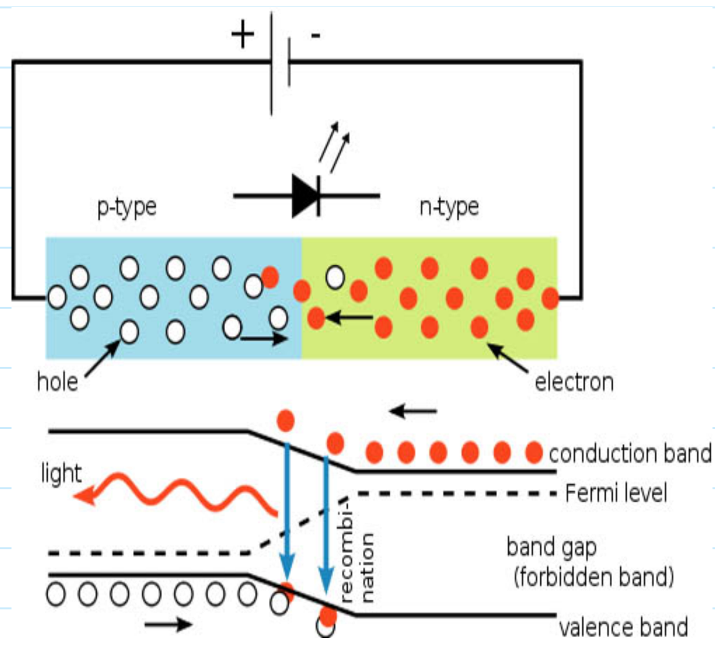


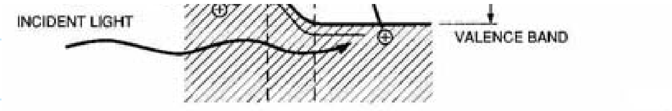
$$I = I_0\left(e^{eV/k_BT} - 1\right) = I_0\left(\exp(eV/k_BT) - 1\right)$$

4. Photodiodes & LEDs



(b): Photodiode P-N Junction State

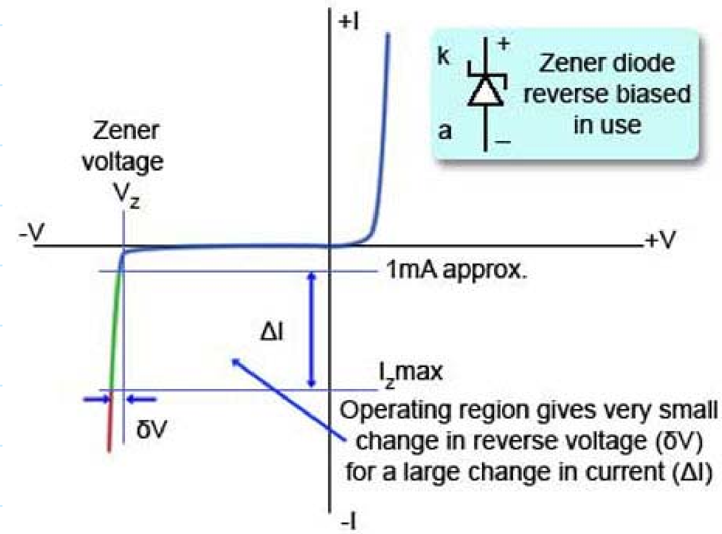




7-2 Transistors.

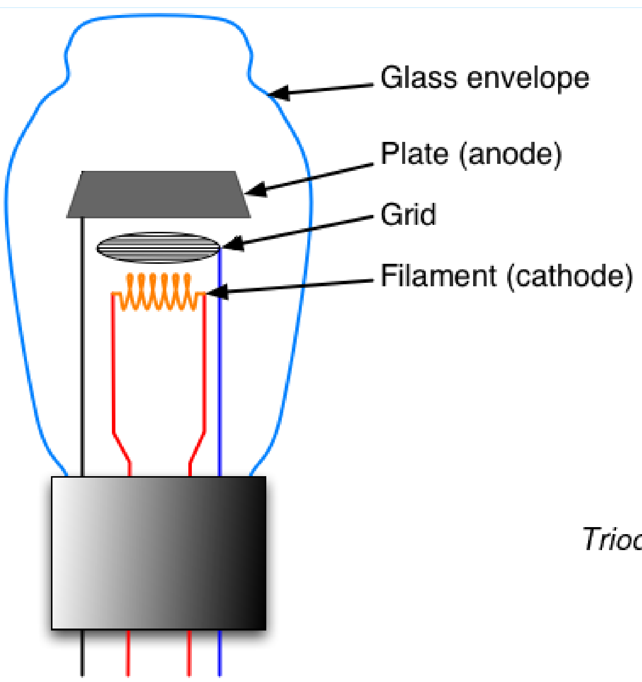
Zener diode

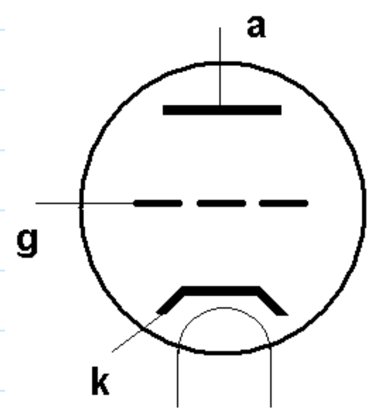
From <https://en.wikipedia.org/wiki/Zener_diode>



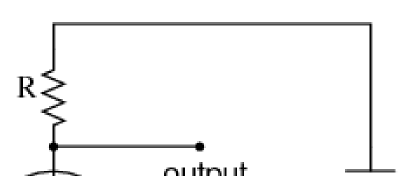
↑ due to quantum tunneling.

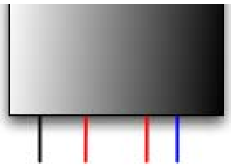
2. Triode vacuum tubes. (old school audio).

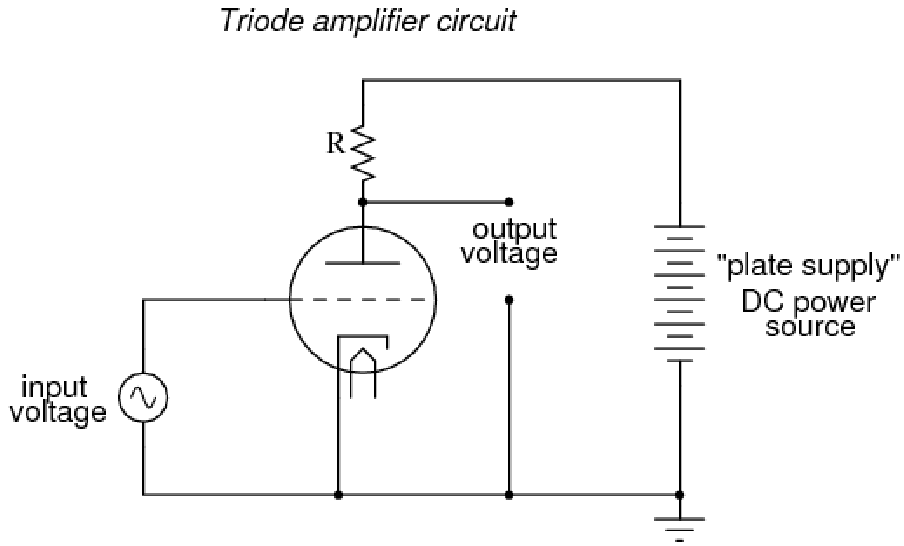




Triode amplifier circuit







The Triode

From <https://www.allaboutcircuits.com/textbook/semiconductors/chpt-13/the-triode/>

3. Bi-polar transistor.

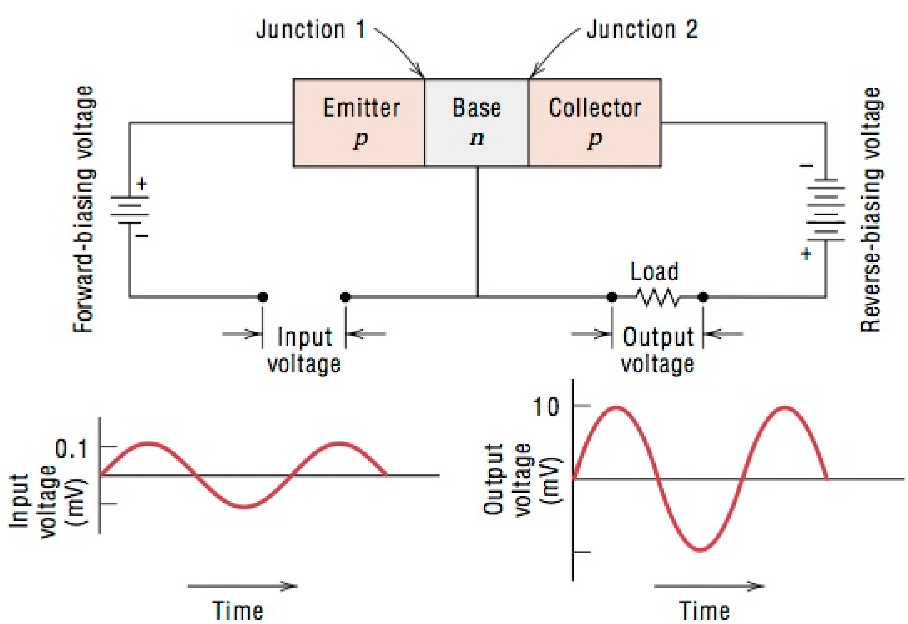
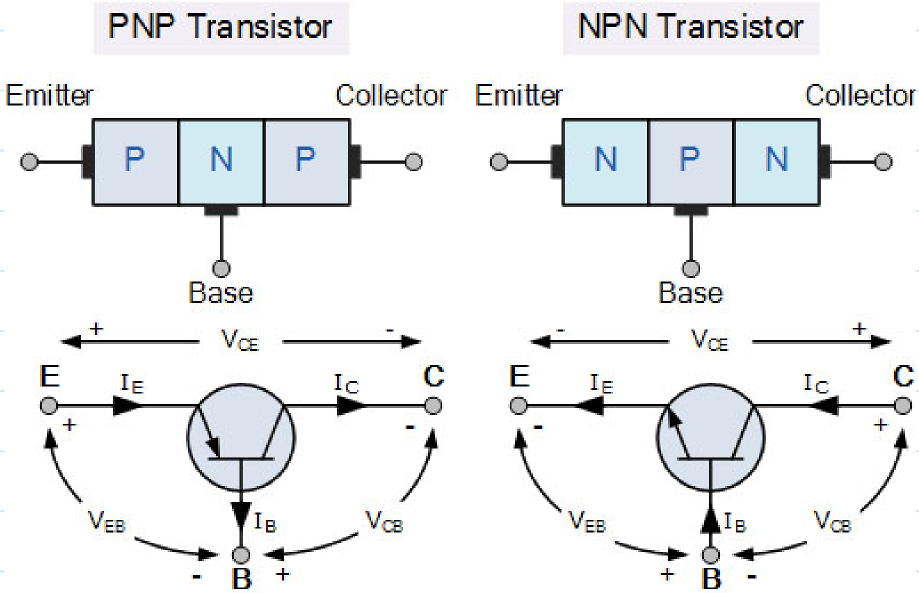
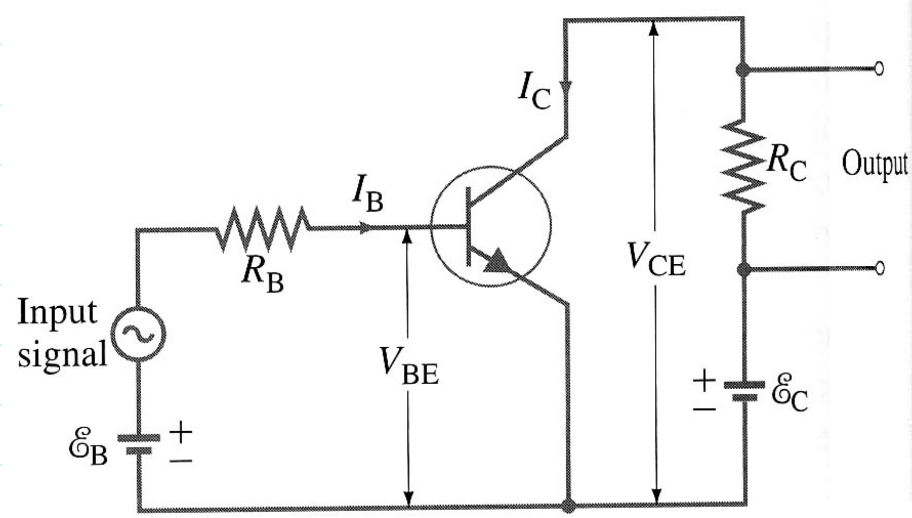


FIGURE 12.22 Schematic diagram of a p–n–p junction transistor and its associated circuitry, including input and output voltage–time characteristics showing voltage amplification. (Adapted from A. G. Guy, *Essentials of Materials Science*, McGraw-Hill Book Company, New York, 1976.)



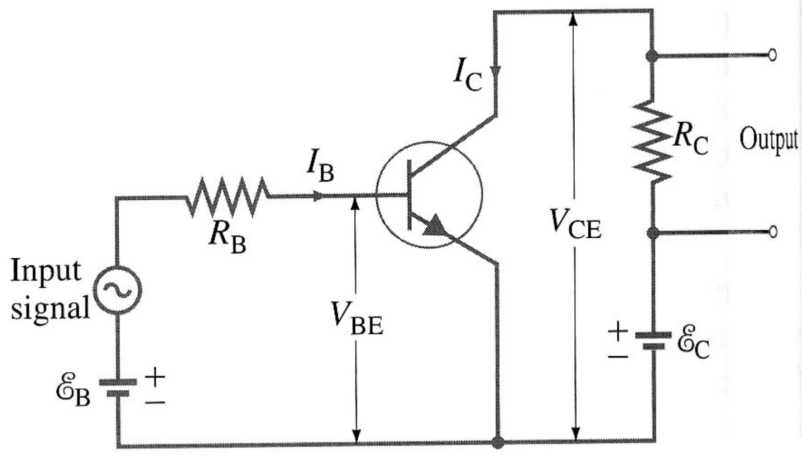
an n-p-n transistor used as an amplifier (from Giancoli)



An *npn* transistor used as an amplifier.

Group exercise – P40.57

If the current gain of the transistor amplifier in Fig. 40-43 is $\beta = \frac{i_c}{i_b} = 95$, what value must R_c have if a 1.0-μA ac base current is to produce an ac output voltage of 0.35 V?



An *npn* transistor used as an amplifier.

4. FET

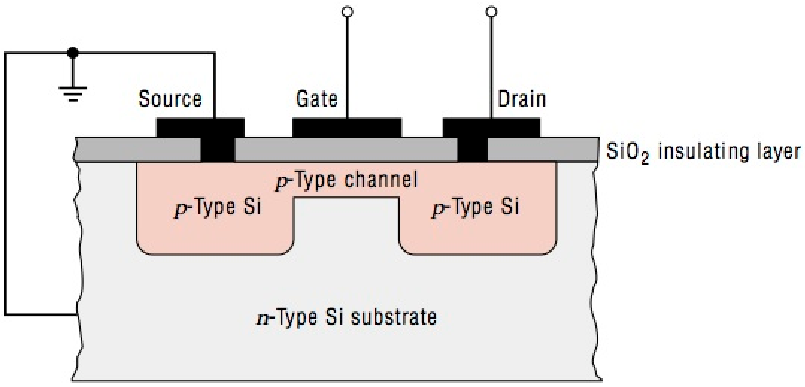
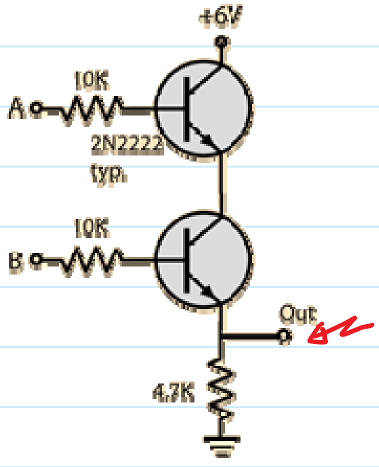


FIGURE 12.24 Schematic cross-sectional view of a MOSFET transistor.

AND gate.



A and B need to be high for output to be high. (otherwise output is low)

Transistor Gates

From <http://hyperphysics.phy-astr.gsu.edu/hbase/Electronic/trangate.html>