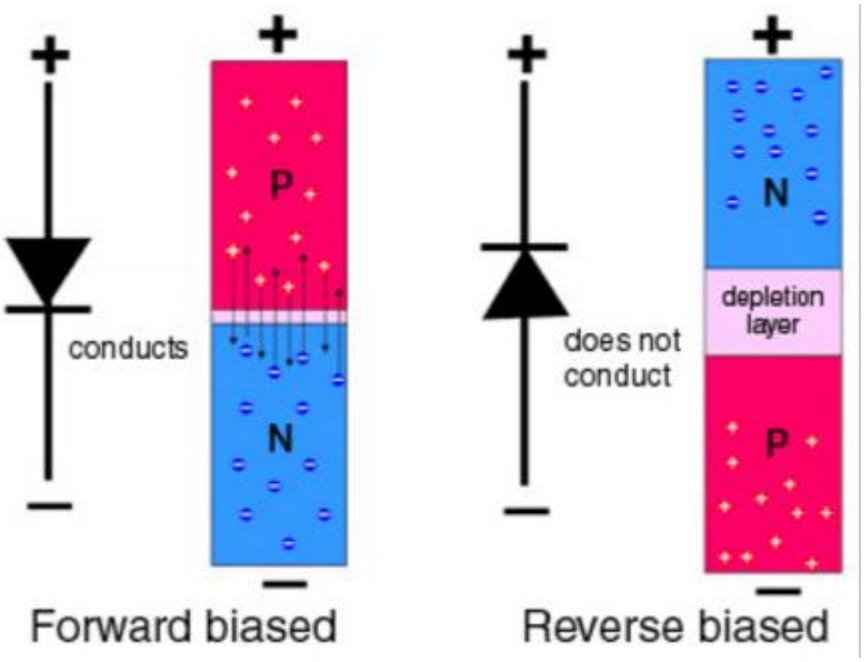
Semiconductor electronics

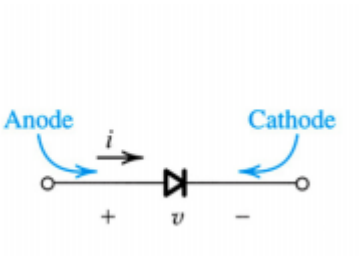
Diode:

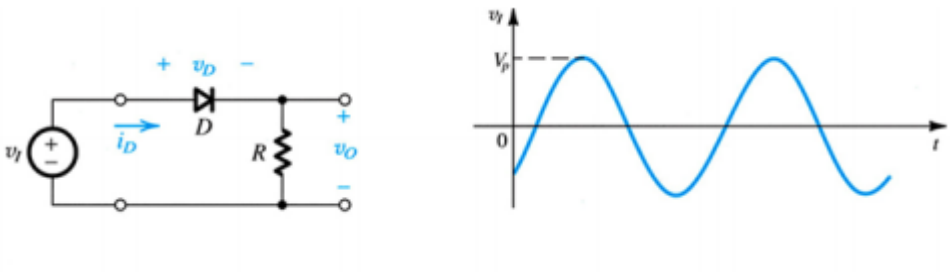
A diode is a basic semiconductor device that allows current to pass in only one direction. They are formed from a *pn* junction, a p-type region of silicon adjacent to an n-type region of silicon. The *p*-type region contains "holes" due to missing electrons in the material lattice, while the *n*-type contains extra electrons that have some freedom to move around. The holes in the *p*-type material prevent current flow unless the junction is forward biased, caused by a voltage field with negative field on the *n* side.

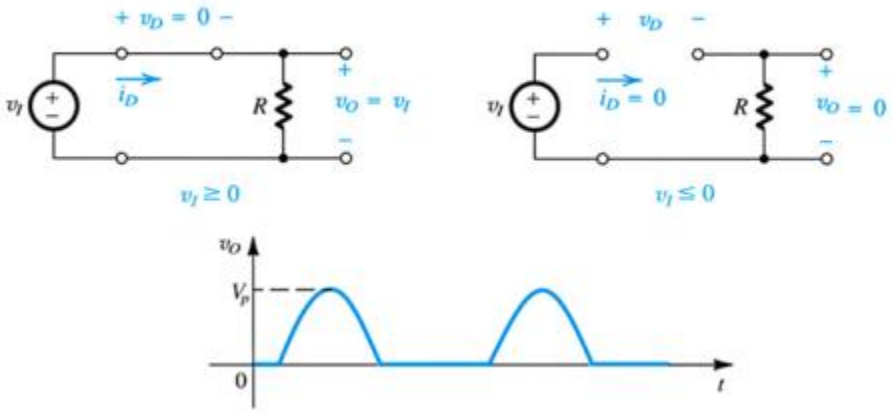


A typical diode has two terminals:
Anode – the positive terminal
Cathode – The negative terminal
The diode is forward biased (turned on or short circuit) at approximately 0.7 V and has a voltage drop of approximately 0.7 V (when forward biased).
The diode is reverse biased (turned off or open circuit)

The figure below demonstrates one use of diodes in creating a half-wave rectifier (converting ac voltage to semi-dc voltage):





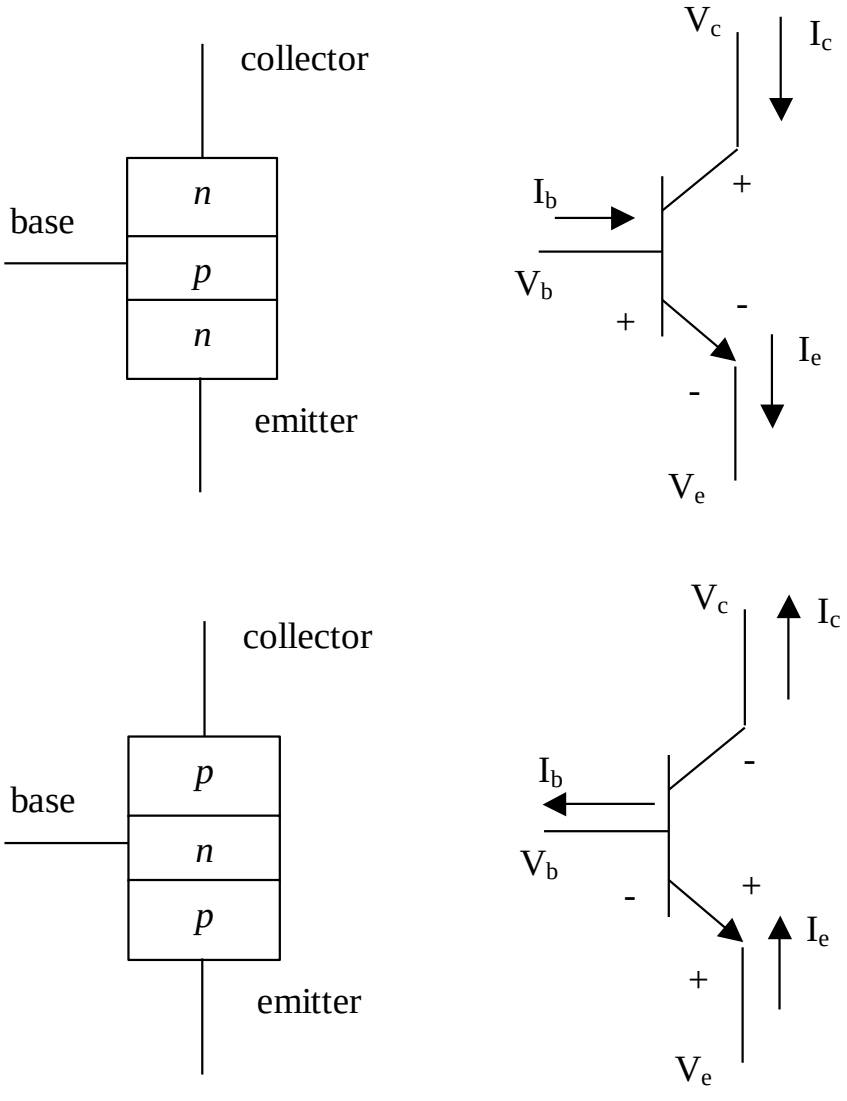


LED:

Light-emitting diodes (LEDs) are a common diode that emits light when forward biased. Note: the longer lead is the positive (anode) lead. LED's have a voltage drop of about 1.5-2 Volts when forward biased, and can handle approximately 100 mA current to avoid being destroyed. Therefore, be certain to include an appropriate resistor in an LED circuit to exactly specify the current (generally, a 250-300 □ resistor in a 5V circuit). Remember, the general purpose of resistors in circuits is to control or set a desired voltage current in a circuit (often called current-limiting resistors). All circuits should have a resistor since a circuit without resistance will have infinite current flow (theoretically).

Transistors:

Transistors consist of multiple layers of *n*- and *p*- silicon, for example in an *npn* configuration or a *pnp* configuration in the bipolar junction transistor (BJT). A small amount of current introduced at the base (center) of the transistor will cause the overall device to be forward biased and allow current to flow (see figure)



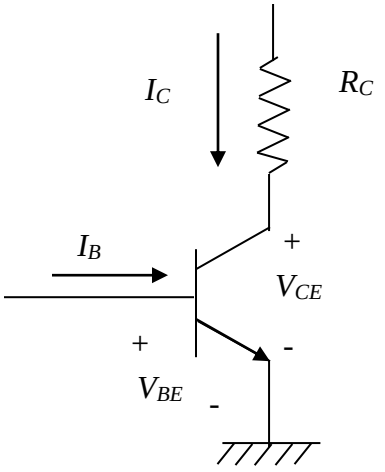
npn BJT (top), pnp BJT (bottom)

The following equations define transistor voltages and current flow:

$$I_E = I_C + I_B$$
$$V_{BE} = V_B - V_E$$
$$V_{CE} = V_C - V_E$$
$$I_C = \beta I_B$$

with β the current amplification factor for the transistor. A small amount of current applied to the base of the transistor allows a larger amount of current to flow through the body of the transistor, in a somewhat linear relationship as shown in the equation for I_C above. When the base current is large enough, the transistor is saturated and the transistor acts as a short circuit with small voltage drop (approximately .2V for bipolar junction transistors (BJTs)). It is this form that we will use transistors, as a switching device in which the junction between the collector and base acts either as an open or short circuit controlled by the base voltage.

Consider an npn transistor. The transistor is forward biased when the base-to-emitter voltage is 0/7 V.
The common emitter transistor circuit is shown below, where the emitter is attached to ground. When designing a transistor switch, the transistor must be fully in saturation when it is on (note that for BJT's, bipolar junction transistors, the V_{CE} at saturation is about .2V).



Common emitter switch:

Example designing a switch:
Given a typical signal transistor, 2N3904 in a circuit as shown below with specifications from the package as: Max. collector current, $I_{C(max)}$ = 200mA, V_{CE} at saturation = 0.2V, $h_{FE} = \beta$ = 100 (approximately, amplification factor for base-to-collector current), find the necessary input voltage to ensure saturation:

Since V_{CE} is .2 V, I_C is 9.8 mA. Thus, the base current must be 9.8/β or 0.098 mA and i: I_β=(Vin-.7)/10kΩ: V_{in} = 1.68 V.
Note that the base resistor is necessary to limit the base current since the BE junction behaves as a diode.

Remember these guidelines for a transistor switch:

1. The base-to-emitter voltage must be 0.7 V to be on.
2. Maximum values of I_C, I_B and V_{CE} must be observed and maintained.
3. There must be sufficient base current to ensure saturation ($I_B > I_C/\beta$, and V_{CE} = 0.2 V))
4. Collector current is independent of base current at saturation.

Other Transistors:
Other transistors include phototransistors and Mosfets. We will see more of these in the labs.