

CHAPTER 15 -- SEMI-CONDUCTING DEVICES

QUESTION & PROBLEM SOLUTIONS

15.1) What is the difference between a conductor and a semi-conductor?

Solution: A conductor is a metallically bonded structure. Current can flow through it because the valence electrons in its atomic structure are free to migrate through the material. A semi-conductor is an insulating material that has been doped with some kind of impurity. The impurity provides extra electrons or a lack of electrons (i.e., holes) within the structure. These "extras" are not strongly bound to their host atom and, hence, can break loose and migrate through the structure when placed in an electric field.

15.2) What is the difference between an *n-type* semi-conductor and a *p-type* semi-conductor?

Solution: An *n-type semi-conductor* is a semi-conducting material through which *negative charge* appears to flow. The doping atoms in this type of semi-conductor have one more electron than is normal for the host material (in the case of a silicon host doped with phosphorus, the silicon has four valence electrons whereas the phosphorus has five valence electrons). A *p-type semi-conductor* is a semi-conducting material through which *positive charge* appears to flow. (Called *holes*, these are really the absence of electrons.) The doping atoms in this type of semi-conductor have one less electron than is normal for the host material (in the case of a silicon host doped with boron, the silicon has four valence electrons whereas the boron has only three valence electrons).

15.3) How are diodes built?

Solution: A diode is a *p-type* and *n-type* semi-conductor "glued" together (actually, they aren't glued--they manufacture them by layering one material on top of the other material).

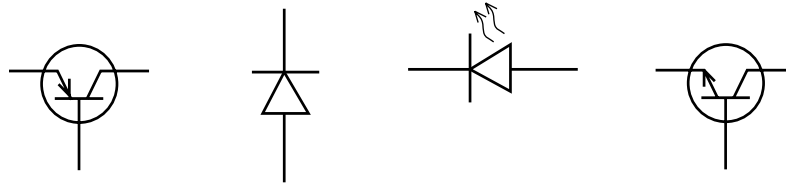
15.4) Why do LEDs give off light?

Solution: When the holes and electrons meet at the depletion junction between the two materials, the structure gives up energy. If the energy bundles are the right size, we sense them as light, hence the *light emitting diode* (LED).

15.5) How are transistors built?

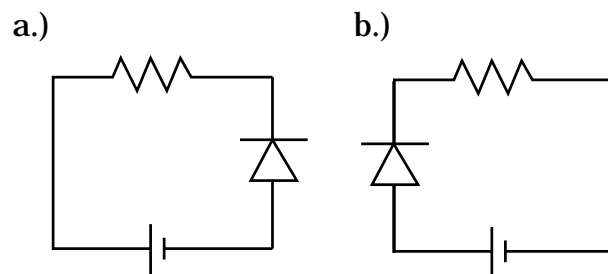
Solution: A transistor is effectively two diodes placed back to back. They are manufactured by either layering a *p-type semi-conductor* on either side of an *n-type semi-conductor* (this is called a *pnp transistor*) or by layering an *n-type semi-conductor* on either side of a *p-type semi-conductor* (this is called an *npn transistor*).

15.6) Identify the electrical symbol shown below.



Solution: The first is a *pnp transistor*. The second is a *diode* positioned to allow conventional current to flow in the upward direction (i.e., in the direction of the arrow head). The third is an *LED*. The fourth is a *nnp transistor*.

15.7) In the two circuits shown, the diode is silicon, the resistor's resistance is 20 ohms, and the power supply is an 8 volt source.



a.) Will current flow through the first circuit shown? If not, why not? If so, how much?

Solution: Conventional current in a diode circuit can flow only in the direction of the arrow head. If the power supply tries to force current to flow in the opposite direction, the diode depletion zone set up in the diode will stop the flow. In this case, the battery is trying to force current to flow clockwise while the diode is set up to allow only counterclockwise flow. There will be no current in this circuit.

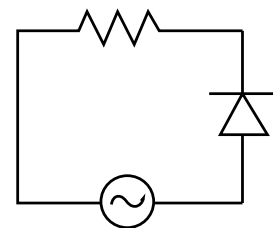
b.) Will current flow through the second circuit shown? If not, why not? If so, how much?

Solution: In this case, the battery is trying to force current to flow clockwise while the diode is set up to allow clockwise flow. There will be current in this circuit. If we ignore the voltage drop across the depletion zone (remember, it is approximately .6 volts), which is relatively usual practice, the current will equal the battery voltage divided by the resistor's resistance, or $i = V/R = (8 \text{ volts})/(20 \text{ ohms}) = .4 \text{ amps}$.

15.8) For the circuit shown:

a.) What will the *voltage versus time* graph look like for the power supply in the circuit?

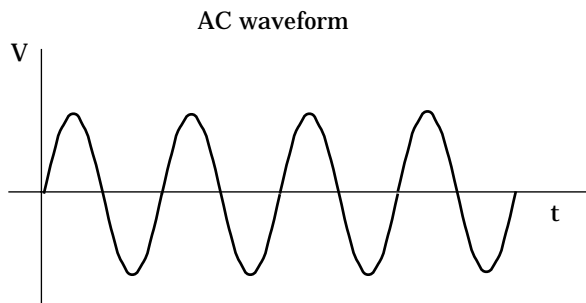
Solution: See the graph on the next page.



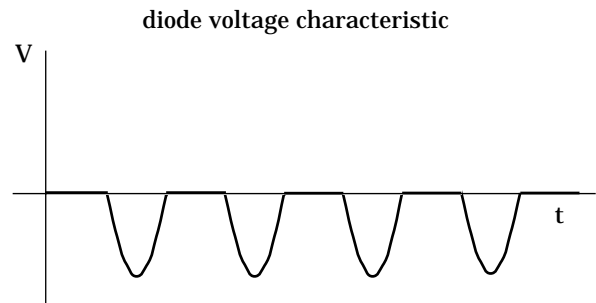
b.) What will the *voltage versus time* graph look like for the resistor in the circuit?

Solution: See the graph below.

a.)



b.)



15.9) What is a half-wave rectifier? That is:

a.) How is it built?

Solution: A half wave rectifier is simply a single diode.

b.) What might it be used for?

Solution: A half wave rectifier turns AC into DC, but it isn't very pretty and it's very energy inefficient. That is, it is lumpy DC and half of the source's power, minimum, is lost in the process.

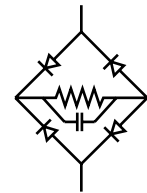
c.) If you placed a half-wave rectifier in a circuit with an AC power supply and a resistor, what would the graph of the current through the circuit look like (don't mess with actual numbers--just make this a general sketch)?

Solution: See sketch in Solution 15.8b.

15.10) What is a full-wave rectifier? That is:

a.) How is it built?

Solution: A full wave rectifier is a diode bridge with capacitor.



b.) b.) What is its output in an AC circuit look like and what might it be used for?

Solution: A full wave rectifier turns AC into DC without losing half the power. The bridge essentially flips half of the wave over so that all of the power is utilized. The output will still be lumpy, but that's life.



c.) If you placed a half-wave rectifier in a circuit with an AC power supply and a resistor, what would the graph of the current through the circuit look like (don't mess with actual numbers--just make this a general sketch)?

Solution: See sketch.



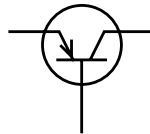
15.11) It is not unusual to place a capacitor across the load of a full wave rectifier. What does this do?

Solution: A charged capacitor keeps the voltage across the load (read this *the output*) high even when the voltage across the source is low.

15.12) What is ripple? (No, I don't mean the wine!)

Solution: Ripple is due to the natural variation in the load voltage as the capacitor slowly discharges through the load (this happens when the voltage across the source is low).

15.13) For the transistor shown:



a.) Name the parts (i.e., the leads).

Solution: The arrow head is always associated with the *emitter*. On the other side of the *emitter* is the *collector*. Between the *emitter* and the *collector* is the *base*.

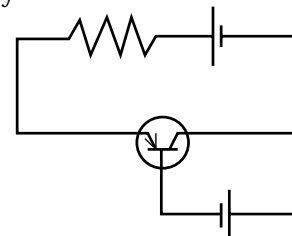
b.) In what direction would current flow if it could flow through the upper section?

Solution: Conventional current flows in the direction of the arrow. In this case, that would mean flow from the left to right.

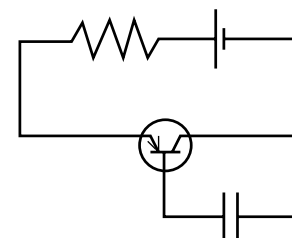
c.) Create a circuit in which current will flow through the upper section.

Solution: To make current flow in the upper circuit through the *emitter/collector* junction, you need some way to make the *base* electrically *negative* relative to the *emitter* (that is what a *npn transistor* needs to turn on the *emitter/collector* current). Two ways are shown. The first simply biases the base with a battery. The second circuit is more exotic. It uses a capacitor. In it, the capacitor initially charges up until its low voltage plate is negative enough to allow current to flow through the transistor's *emitter/collector* junction. As this happens, the capacitor begins to discharge. When it has discharged enough, the base loses the necessary negative polarity to allow the *emitter/collector* current and the current in the upper section ceases until the capacitor charges up again. It is a clever way to generate pulsing DC in the upper circuit.

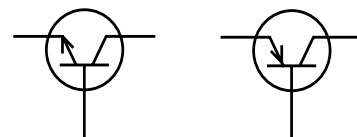
base biased with a battery



base biased with a capacitor



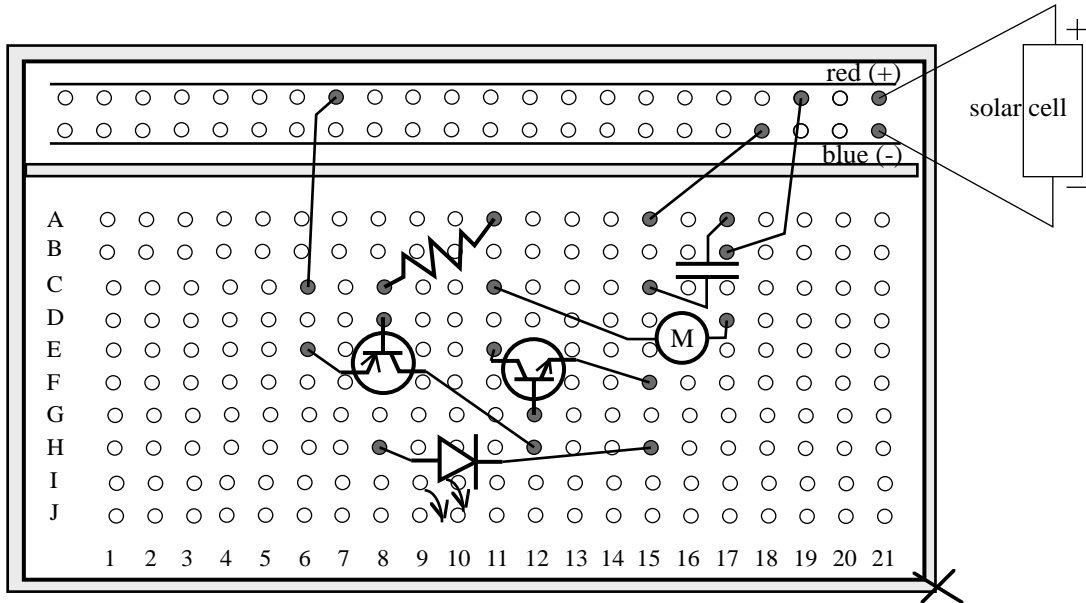
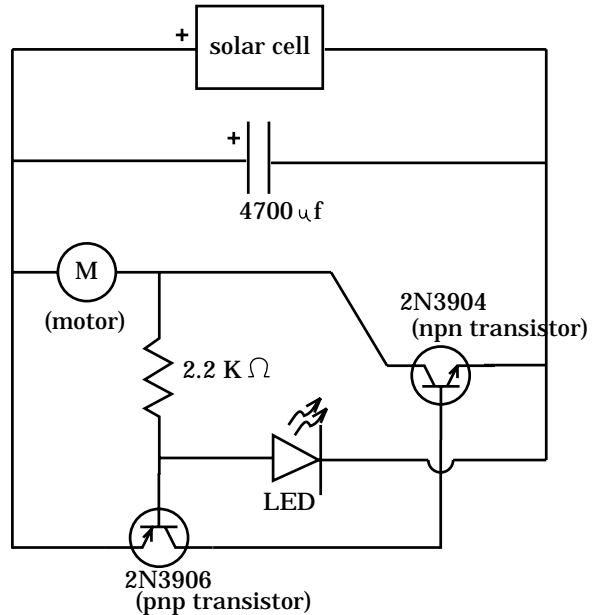
15.14) For each of the devices shown, determine what the base's bias must be (i.e., positive or negative) for current to pass through the upper section.



Solution: The first transistor is an *npn transistor*. To get conduction through the *emitter/collector* junction of this kind of transistor (i.e., to get current flowing through the upper section), the base has to be biased electrically *positive* relative to the *emitter*. The second transistor is an *pnp transistor*. To get conduction through the *emitter/collector* junction of this kind of transistor, the base has to be biased electrically *negative* relative to the *emitter*.

15.15) The circuit shown has two transistors, a solar cell, a capacitor, a motor, a resistor, and an LED. Assuming you take the solar cell to be your power source, use the sketch of a breadboard shown on the next page to sketch out how you would breadboard this circuit. (In fact, this exercise will be more useful than you think--you will have to do this in real life as you prepare to wire your robot circuit.)

Solution: See the breadboard shown below. (I have used the symbol for a diode instead of an LCD. I'd fix it but I've lost the original graphic. Bad teacher!)



Note: The vertical columns are common.

