1. Connect a resistor across a sine wave generator. Use an oscilloscope to observe its voltage vs time graph. Mr. Ohm says the resistor current vs time graph must have a _______ shape. *(similar, different)*

* 2. Describe how a diode in series with the resistor in #1 will alter the current-vs-time graph. Illustrate your prediction with sketches, labelled clearly. (See page 80.) Show how the hump width compares with the space between humps. Then use an oscilloscope to test your prediction.

3. Describe and *illustrate* what happens to the resistor voltage vs time graph in #2 when a capacitor is connected across the resistor. Try it with two or more different capacitors.
   a. It seems that the capacitor ________es during the times between the humps. (charges, discharges)
   b. Put signs on the capacitor plates in your circuit diagram and arrows on the wires to indicate the electron flow in 3a. Put *dots* on the wires with no electron flow. (Omit the oscilloscope.)
   c. The capacitor _________s during the times when it is not discharging. Draw another diagram with arrows or dots on ***each*** wire showing how that happens. *Label both diagrams clearly.*
   d. The capacitor charges whenever the absolute value of the emf is ________ than the ______ voltage.
   e. The capacitor discharges at times when the absolute value of the emf is ____ than the _____ _____.
   f. When the capacitor is discharging, electrons travelling from one plate to the other must pass through the ________ because the only other route is blocked by the ________. *Do your arrows show that?*

4. Suppose the internal resistances of the generator and the rectifier (diode) are insignificant compared to the resistance of the resistor: How must the capacitor voltage and the emf be related when the capacitor is charging? _____ -If there *is* some internal resistance then V_c must be _____er than ____.

5. What law predicts the slope of the capacitor voltage vs. time graph during the discharging part of the cycle? Copy the law from #6 on RS XI and solve it for the unknown slope. Define your symbols.

6. The capacitor voltage is always equal to the ________ voltage in this circuit. To make the resistor voltage decrease *very gradually* during the discharging part of the cycle we must choose a capacitor with very _______ capacitance. Will the discharging voltage vs. time graph be almost linear? ____ *Show (with a sketch) how the graph will differ from the ones in #3.*

7. At a certain time in each cycle the diode cuts off the generator current. When does that happen?
   -when the generator emf reaches zero? -when the emf reaches its maximum?
   -when the emf becomes less than the capacitor voltage? (Clue: See #3)
   -when the capacitor voltage becomes greater than the generator voltage amplitude?

8. Use dotted lines to sketch the rectified emf vs. time graph. (It's similar to the graph that you saw in #2.) Make dots at the points described in #7. Then draw solid lines onto this graph to show the resistor voltage vs. time during the discharging parts of the cycle. *Do not to contradict #2, 3, 6 or 7.*
   a. Which is longer: the charging time, or the discharging time? __________
   b. Use an oscilloscope to verify that prediction. Describe what you *did* and what you *saw*.
   c. At what place must the linear part of the solid line end? *Label it as "point 8c".*
   d. Show how the charging and discharging processes repeat over several cycles.
   e. Label the points where the generator current is cut off by the diode and where it resumes.

9. How does the addition of a filter capacitor affect the load (resistor) voltage vs time graph?
   a. According to #4, it causes a slight ___crease in the peak value, but causes the average to ___crease.
   b. It causes the amount of "ripple" (periodic fluctuation in load voltage) to be ___creased.
   c. Check here ___ when you have verified those predictions, using a voltmeter and an oscilloscope set on "DC". *If your observations do not agree with your predictions, please explain.*

10. Use the second capacitor law to figure out what the capacitor current vs. time graph must look like. Then use the branch point law (#4 on RS IX) and the definition of a "diode" to sketch the diode current vs. time graph carefully, using the same time scale as in #8. Try *not* to contradict 8a.

11. How is the shape of the *diode current vs time* graph affected by an increase in filter capacitance?
    a. The peak current in the diode must ___crease when the capacitance is increased.
    b. The width of the current pulses must ___crease, and the time interval between pulses must ___crease slightly. (The sum of those two intervals is the generator's ________.)
    c. The interval between pulses is *always* _______ than the pulse width, but slightly _____ than the generator period. -Do your sketches agree? ____
    d. Show how the predictions in #10 & 11 can be tested with an oscilloscope. (See #3 on RS XII.)

1. The fluctuations in load voltage mentioned in 9b on page108 are called "ripple". The ratio of the ripple voltage (RMS value) to the average load voltage is called the "ripple factor". The purpose of a filter capacitor is to reduce the ripple factor to an acceptable amount.
   a. What happens to the capacitor's discharge rate if you double the load resistance? _____
   * b. What does this tell you about the relation between ripple factor and load resistance?
   * c. Use similar reasoning to figure out how the ripple factor must be related to capacitance and generator frequency. *Please explain your logic.*
   * d. Do you get a complete formula when you combine 1b & 1c, or is there still something missing?

2. With several diodes it is possible to make a "full-wave rectifier" which leaves no spaces between the current pulses in the device. In effect, it flips over the negative portions of the sine curve instead of erasing them. If you can figure out how to make one, you will always remember your invention with pride. Don't worry if you can't figure it out for yourself; you can copy it from page 80.

3. Suppose the generator and rectifier have internal resistances that are small compared to the load resistance, as on page 108. (If not, energy will be wasted in heating the generator and rectifier.) Give one answer for half-wave rectifiers *and another* for full-wave rectifiers for each part below:
   a. How can the time interval from one pulse to the next be calculated from the generator frequency?
   b. In #6 you saw that under certain conditions the capacitor can discharge almost uniformly between pulses. Show how the load resistance and voltage can be used to calculate that discharge rate.
   c. Knowing the capacitor current for the discharging part of the cycle, you can use the capacitor law to find the rate at which the capacitor voltage is falling. *Show how.*
   * d. Knowing that rate and the time interval between pulses, you can predict how much the capacitor voltage will decrease between pulses. Show how. *Please remember to define your symbols.*
   * e. Use these results to complete the formula discovered in 1d. *Please remember to explain your reasoning and to give two versions of the formula.*

* 4. How can an oscilloscope be used to test the theories developed above?

5. Let's design a filter to be used with a full-wave rectifier at 60 Hz with a 200-ohm load. We want to supply 10 volts DC to the load, with a ripple factor of five percent. Show how you calculate your answers to the following questions, assuming that the internal resistance is insignificant:
   a. Roughly how much capacitance will we need? (Use the ripple factor formula.)
   b. For approximately what fraction of each cycle will the rectifier carry current? (This should be easy because you know everything there is to know about the emf vs. time graph, and you also know approximately where on that graph the charging process begins and ends.)
   c. Show how the maximum diode current during the charging part of the cycle is estimated.

6. Suppose the internal resistances of the generator and rectifier are NOT small enough to ignore. The average load voltage will then be somewhat less than the peak emf of the generator. Let "T_c" represent the time spent charging the capacitor. Let "T_d" represent the time spent discharging, between pulses. Let V_o represent the average load voltage, (unknown) and let ΔV represent the ripple voltage. Let "R_i" represent the combined internal resistance of the generator and diodes.
   a. The charge passing through the diode during each pulse will be equal to the product of the average rectifier current and ___: ΔQ = _____
   b. The average rectifier current during a charging pulse is equal to the average voltage across the ________ divided by ___.
   * c. Prove that when the ripple factor is small, this average voltage is approximately two-thirds of its peak value, or $2(E_o - V_o)/3$, where E_o represents the emf amplitude. (The exact value of the averagiing factor ranges from 2/3 to $2/\pi$, depending on how far V_o is from E_o.)
   d. The decrease in load voltage during T_d must be equal to the increase during ___. The rate at which this decrease occurs depends on the values of V_o, R_L and ___. There is only one V_o value at which this balance can occur, and only one corresponding ΔV value. Show how they can be computed.