# SKILLS YOU WILL NEED FOR THE FIRST MAY TEST (L-H, 2000)

1. Use algebra to solve a simple equation for its unknown and then plug in given data to determine the numerical value and units of that unknown quantity (rounding off properly) as on every previous test.

2. Calculate with scientific notation and units. Make uncertainty estimates in absolute form, in range form, and in percentage form, as on every previous test.

3. Use the definition of “average current” (on RS IX) as on previous tests.

4. Sketch any familiar voltage vs current graph, as in 1-3 on RS X.

5. Use Ohm’s equation and the definitions of “resistance” on RS X.

6. Use the water heating formula and the energy conversion formulas in #15 and 16 on RS IX.

7. Use the definition of power on RS VI and the power formula in #15 on RS IX and 8a on RS X.

8. Given a verbal description of a circuit, sketch a circuit diagram and and draw dots and arrows on the wires to indicate the direction of electron flow as we did on page 111. (Use the definitions of "series" and "parallel" on RS VIII.)

9. Use the energy conservation law and the capacitor energy storage formulas in #7 on RS XI.

10. Use the definition of “capacitance” and the capacitor laws on RS XI. For example, given a description of a capacitor’s current vs time graph, sketch its voltage vs time graph.

11. Using #8 on RS X, sketch a graph showing how a quantity must diminish with time if the rate at which it decreases is proportional to its value.

12. Sketch any of the graphs that we investigated in our capacitor experiments. For example, sketch a charging capacitor’s voltage-vs-time graph and its current-time graph as in #3 on page 98 and #9 on page 99.

13. Use the relationship among the voltages in a series circuit (#5 on RS IX) to determine the shape of an unknown voltage vs time graph as we did in #7 on page 106 and in 1-3 on page 98.

14. Use the definitions of “interest rate” and "exponential process" as we did on pages 102 and 103. (Given the percentage change that occurs during a certain time interval, predict the amount of change that will occur during the next interval or the amount of time that will be needed for another percentage change.)

15. Use the definition of "half-life" and the half-life formula on RS XI.

16. Use the resistor color code.

17. Predict the direction of the gravitational field produced by a planet at a given location. Use vector addition to determine the direction of the combined gravitational field produced by two different planets.

18. Use the concepts of “percentage” and “slope” as on previous tests.

19. Given any familiar graph, sketch a graph of its derivative or integral, as in Chapter II and on the April tests.

**First May Test (2000, Level H)** **name:__________________**

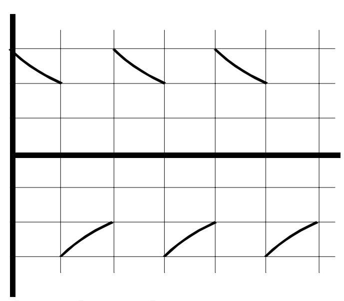
1. No battery is available for a certain electrical device. There is only a power supply that gives brief pulses of current. To smooth out those pulses we connect a "filter capacitor" in parallel with the device. Sketch a diagram of that circuit in the lower margin of this paper. Label the power supply as "PS" and label the device with a "D". (skills 8, 10)
   a. Each pulse delivers some charge in a very *short* time. The capacitor discharges through the device during the *longer* time intervals between the pulses. *The circuit's half-life is much longer than either of those intervals.* Sketch several cycles of the capacitor's voltage vs time graph, showing the difference between "long" and "short".
   b. The power supply produces 120 pulses per second. Each pulse delivers 4.5 x $10^{-5}$ coulomb to the capacitor. Calculate the average current in the device. (skill 3)
   c. The average voltage across the device is 15 volts. The peak voltage is 1% higher, and the minimum voltage is about 1% lower. Calculate the resistance of the device. (Sk. 5)
   d. Calculate the slope of the voltage vs time graph for the long sections between pulses. Remember to give its sign and units. (skill 10)
   e. Show *with a formula* how the capacitance can be calculated from the information given above. Use standard symbols. (skill 10)

2. A hot object is placed in a refrigerator which maintains its surroundings at zero degrees. The rate at which heat energy escapes from the object is proportional to the difference in temperature between the object and its surroundings.
   a. Sketch a graph of the object's temperature vs. time. (skill 11)
   b. In four seconds the object's celsius temperature decreases by 2.5%. How long will it take for that temperature to fall to 60% of its initial value? (skill 14)
   c. The initial slope of the object's temperature-vs-time graph was -0.45 degrees per second. Calculate or estimate its initial temperature. (skill 18)

3. Make a dot representing a planet at the lower right-hand corner of the answer space for #3. Make a second dot at the lower left-hand corner of that space to represent another planet with equal mass. Draw a ***short*** arrow through the circle in that space to show the direction of the gravitational field produced there by this pair of planets. (skill 17)

4. Imagine an uncharged capacitor and a resistor connected in series to a battery.
   a. Sketch the graph of capacitor voltage vs time that you saw when you tried this. (12)
   b. The "capacitor power" is the rate at which electrical energy is delivered to the capacitor. Use skill 7 to sketch the approximate shape of the capacitor's power vs time graph.
   c. Write a formula for the area under that curve and say what that area represents. (skill 9)

5. An oscilloscope shows the pattern at the right when connected across a resistor which is in series with a capacitor and a square wave generator set at 265 Hz. Use skill 13:
   a. Draw the capacitor's voltage-time graph with the same scale.
   b. Estimate the time this resistor and capacitor would need to discharge down to 20% of its initial voltage. (skill 14)
   c. The resistance is about 4.7 K. Estimate the capacitance. (15)



6. The stripes on that resistor are yellow, violet, red, and gold. When the voltage across it is 4.2 volts (± 2.0%) the current through it is found to be 0.88 ± .002 mA. Calculate the MLV and percentage uncertainty of its resistance. (skill 5, 2)

7. An inductor's voltage is proportional to the rate at which its current is changing.
   a. If we assume that the inductor's current vs time graph resembles a cosine curve, then what must the inductor's voltage -time graph look like? (Sketch it, using skill 19.)
   b. A capacitor is connected in series with the inductor. Sketch the capacitor's voltage-time graph, using the same time scale. (Skills 10 & 19)

ANSWER SPACE

1a)

1b)

1c)

1d)

1e)

2a)

2b)

2c)

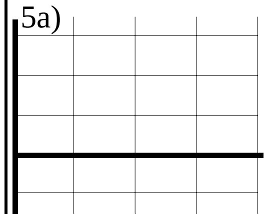
3) o

4a)

4b)

4c)

5a)



5b)

5c)

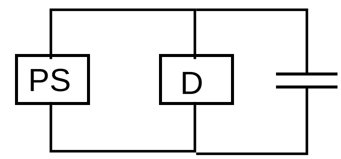
6)

7a)

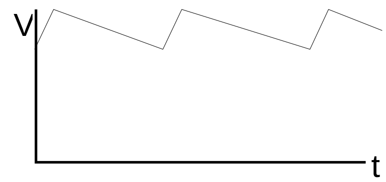
7b)

### *First May Test Solutions (2000, Level H)*

1. No battery is available for a certain electrical device. There is only a power supply that gives brief pulses of current. To smooth out those pulses we connect a "filter capacitor" in parallel with the device. Sketch a diagram of that circuit. Label the power supply as "PS" and label the device with a "D". (1 point)




a. Each pulse delivers some charge in a very *short* time. The capacitor discharges through the device during the *longer* time intervals between the pulses. *The circuit's half-life is much longer than either of those intervals.* Sketch several cycles of the capacitor's voltage vs time graph, showing the difference between "long" and "short". (1 pt)




b. The power supply produces 120 pulses per second. Each pulse delivers $4.5 \times 10^{-5}$ coulomb to the capacitor. Calculate the average current in the device. (2 points)

*(120 p/s)(4.5 x $10^{-5}$ C/p) =* ***5.4 x $10^{-3}$ C/s = 5.4 milliamp***

c. The average voltage across the device is 15 volts. The peak voltage is 1% higher, and the minimum voltage is about 1% lower. Calculate the resistance of the device. (2 points)

*(15 V) / (5.4 mA) =* ***2.77 kilo-ohm***

d. Calculate the slope of the voltage vs time graph for the long sections between pulses. Remember to give its sign and units. (2 points)

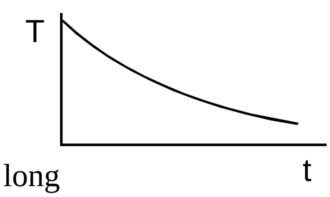
$\dot{V} = \Delta V/\Delta t = (-0.02)(15\ V)(120\ sec^{-1})$ = ***- 36 volts per second***

e. Show *with a formula* how the capacitance can be calculated from the information given above. Use standard symbols. (1 point)

*From the 2nd capacitor law,* $\mathbf{C = I/\dot{V}}$

2. A hot object is placed in a refrigerator which maintains its surroundings at zero degrees. The rate at which heat energy escapes from the object is proportional to the difference in temperature between the object and its surroundings.

a. Sketch a graph of the object's temperature vs. time. (1 point)




*This must be an exponential process because the rate is proportional to the value as the temperature approaches equilibrium.*

b. In four seconds the object's celsius temperature decreases by 2.5%. How long will it take for that temperature to fall to 60% of its initial value? (2 points)

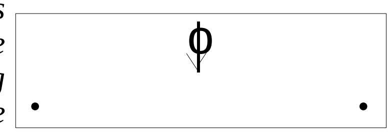
*"Decreasing by 2.5%" means multiplying by (1 - 0.025), or by 0.975. Starting with 1 and multiplying repeatedly by 0.975, we reach 0.60 after 20 steps. 20 x 4.0 sec =* ***80 seconds.***

c. The initial slope of the object's temperature-vs-time graph was -0.45 degrees per second. Calculate or estimate its initial temperature. (2 points)

*(0.025 T) / (4.0 sec) = 0.45 deg/sec (given) So T = (0.45 deg/sec)(4.0 sec) / 0.025 =* ***72 deg***

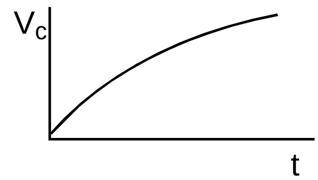
3. Make a dot representing a planet at the lower right-hand corner of the answer space for #3. Make a second dot at the lower left-hand corner of that space to represent another planet with equal mass. Draw a ***short*** arrow through the circle in that space to show the direction of the gravitational field produced there by this pair of planets. (1 point)

*A planet's gravitational field points toward its center. If the planets have equal masses and are equidistant from the circled region then the two gravitational fields there must have equal strengths. By adding the two "g" vectors we find that the combined field points toward the midpoint of an imaginary line connecting the two planets.*



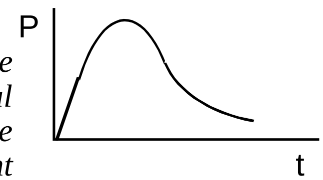
***First May Test Solutions, continued***

4. An uncharged capacitor and a resistor are connected in series to a battery.




  a. Sketch the graph of capacitor voltage vs time that you saw when you tried this. (1 point)

  b. The "capacitor power" is the rate at which electrical energy is delivered to the capacitor. Sketch the approximate shape of the capacitor's power vs time graph. (2 points)



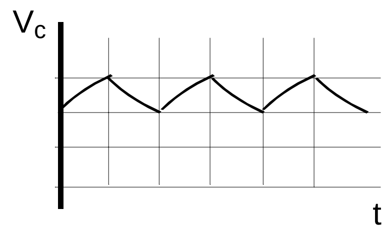

  *The capacitor power is the product of voltage and current. At the start of the process the capacitor voltage is zero, so the initial power is also zero. Both the voltage and current are positive thereafter until completion of the process, when the current approaches zero.*

  c. Write a formula for the area under that curve and say what that area represents. (2 points)

  *The area under the curve must be the energy stored in the capacitor when charging is complete. The three familiar energy storage formulas are* ***QV/2, CV²/2, and Q²/2C****.*

5. An oscilloscope shows the given pattern when connected across a resistor which is in series with a capacitor and a square wave generator set at 265 Hz.

  a. Draw the capacitor's voltage-time graph with the same scale.




  *The sum of the resistor and capacitor voltages must be equal to the sqare-wave voltage, and the capacitor's voltage-time graph must be continuous.* (1 point)

  b. Estimate the time this resistor and capacitor would need to discharge down to 20% of its initial voltage. (2 points)

  *From the given graph we know that the capacitor discharges to about 67% in 1/256 sec. 0.67 to the 4th power is about 0.2, so four such changes in a row will bring it down to about 20%.      4 x 1/256 sec =* ***0.015 sec****.*

  c. The resistance is about 4.7 K. Estimate the capacitance. (2 points)

  *The half-life is a bit less than 2/256 s because* $0.67^2 = 0.45$*. We know that half-life = 0.69 RC, so C = H/(0.69R) = (0.007 s) / (0.69 x 4.7 x* $10^3$ *ohm) =* ***2 x*** $\mathbf{10^{-6}}$ ***Farad***

6. The stripes on that resistor are yellow, violet, red, and gold. When the voltage across it is 4.2 volts (± 2.0%) the current through it is found to be 0.88 ± .002 mA. Calculate the MLV and percentage uncertainty of its resistance. (3 points)

  *The gold stripe tells us how much random variation we should expect in a set of resistors with the same label, but does not tell us how far off this particular resistor is from its nominal value. To find the resistance of this device we can use Ohm's equation. To find the uncertainty of the result we must add the percentage uncertainties of the current and voltage. The uncertainty of the current is 0.002/0.88 = 0.22%.  (4.2 V ± 2.0%) / (0.88 mA ± 0.22%) =* ***4.77 K ± 2.2%***

7. An inductor's voltage is proportional to the rate at which its current is changing.

  a. If we assume that the inductor's current vs time graph resembles a cosine curve, then what must the inductor's voltage -time graph look like? (1 point)

  *Differentiating a cosine curve shifts it 1/4 cycle to the left, giving us an* ***upside-down sine curve.***

  b. A capacitor is connected in series with the inductor. Sketch the capacitor's voltage-time graph, using the same time scale. (1 point)

  *Since the derivative of the capacitor's voltage-time graph is a cosine, the voltage-time graph itself must be a* ***sine curve****.*