SKILLS YOU WILL NEED FOR THE SECOND MARCH TEST (2000, L-H)

1. Use algebra to solve a simple equation for its unknown.

3. Using scientific notation, plug given data with units into a given formula to determine the numerical value and units of that unknown quantity, rounding off properly.

4. Convert a given uncertainty from absolute to relative form or from relative to absolute form as on RS I, RS II, and every previous test. Use #26 on RS II to estimate the uncertainty of a sum, product, quotient, or square root.

5. Use the definition of “instantaneous acceleration” on RS IV.
   Given the forces acting on an object, predict the direction of its acceleration.
   Describe the direction of an acceleration as we did on page 41 and on previous tests.

6. Use the gravitational force formula and Hooke’s equation on RS II.
   Use Newton’s Laws of motion on RS V.
   Use the centripetal acceleration and force formulas on RS VII.

7. Use the definitions of “work”, “energy”, and “power”.
   Use the kinetic and potential energy formulas on RS VI.

8. Estimate the cost of a given amount of energy by using #13 on RS VI.

9. Use the definitions of “series” and “parallel” on RS IX.
   Given a verbal description of a circuit, draw the circuit diagram.

10. Use the definitions of “voltage” and “current”.
    a. Use the branch point law in #3 on RS IX.
    b. Use the voltage relations in #4 & 5 on RS IX.

11. Use the definitions of an “ampere”, “coulomb”, and “volt” on RS IX.

12. Sketch a voltage vs current graph describing the electrical behavior of any familiar device, as on RS X.

13. Use the definitions of "static resistance", "dynamic resistance" and "internal resistance" on RS X.

14. Use the resistor combination formulas in #9 on RS X.

15. Use the electric power formula and the electric energy formula on RS IX.
    Also use the three electric power formulas in #8 on on RS X.

16. Use the definition of “emf” on RS X. Given the emf and internal resistance of a battery or power supply, calculate its maximum current and maximum power. (Use #12 on RS X.)

17. Use the definition of “sensitivity” (of a voltmeter or ammeter) on RS X.
    Choose an appropriate “shunt” to reduce the sensitivity of an ammeter to a given fraction of its former value by the method on pages 92 & 95.

Second March Test (2000, Level H)   name:____________________

ANSWER SPACE
1a) ____
1b) ____
1c) ____
1d) on the back
2a) ____
2b) ____
2c) ____
2d) ____
3a) ____
3b) ____
3c) ____
3d) ____
4a) ____
4b) ____
4c) ____
5a) ____
5b) ____
5c) ____
5d) ____
5e) ____
6) ____
7) ____

1. Pee Wee Herman stands at the end of a diving board. Hulk Hogan pulls the tip down and then releases it, causing Pee Wee to fly upward. Let "kx" represent the upward force exerted on PeeWee by the board. Let "mg" represent the downward gravitational force on PeeWee.
   a. Just after release those two forces are unequal. Which is the stronger? (skill 5)
   b. Which force is the stronger one just before PeeWee loses contact with the board? (sk. 6)
   c. Describe the direction of PeeWee's acceleration just before losing contact. (skill 5)
   d. Sketch Pee-Wee's acceleration vs time graph on the back of this paper. Let upward accelerations be positive, and downward negative. Indicate the moment when he loses contact with the board. Also mark the time when he stops moving upward. Write "coasting upward" on the segment which describes that part of the trip. (sk. 6)

2. A cup of water is heated by a wire resistor. Before the switch was closed, the power supply voltage was 24 ± 0.2 volts. It became 21 ± 0.2 V when the switch was closed. The heater current was 4.2 ± 0.05 A. The heater was unplugged after 30 ± 0.2 seconds
   a. Calculate the heating power in SI units. Express the uncertainty as a percentage. (15)
   b. Calculate the resistance of the heater. Express the uncertainty in absolute form. (13)
   c. Calculate the internal resistance of the power supply as a **RANGE**. (skill 13)
   d. How much electric charge passed through the resistor? Just give its MLV. (skill 11)

3. If there were no atmosphere to interfere, we could put a rock into orbit by throwing it horizontally from the top of a mountain. Please use SI units:
   a. How much centripetal acceleration would it have while in orbit? (skill 6)
   b. The earth's radius is 1.6×10^6 meters. How fast must we throw the rock? (6)
   c. Imagine an electrical device that puts a *person* into such an orbit. Estimate the energy that it will use. *Please express 3c and 3d in range form, using powers of ten.* (7)
   d. Estimate the cost of that energy, if purchased from a local electric power company. (8)

4. The emf of a certain flashlight cell is 1.50 V. Its internal resistance is 0.65 ohm.
   a. Calculate the maximum power obtainable from such a cell. (skill 16)
   b. Calculate its short-circuit current. (skill 16)
   c. If we connect two such cells in series exactly how will the pair's short-circuit current compare with the current calculated in part b? (skills 10b, 14, 16)

5. When operated at 120 volts a certain light bulb has a dynamic resistance of 220 ohms.
   a. Its static resistance is half as much. Calculate the bulb current at 120 V. (skill 13)
   b. On scrap paper use standard symbols to write the definition of dynamic resistance. (13) Solve for the "change in current". Copy the resulting equation into the answer space. (1)
   c. Suppose the voltage is decreased from 120 volts to 117 volts. Use 5b to calculate the resulting change in current. Be sure to say whether it is an increase or a decrease. (3)
   d. Sketch a voltage vs current graph for this bulb. Make dots on the graph to represent the old and new operating points. Label them as "old" and "new". *Don't contradict 5c.* (12)
   e. Calculate this bulb's old power and new power. (skill 15)

6. Recently you showed that a 60-gram piece of ordinary copper wire is less than 100 meters long, and contains roughly 6×10^{23} conduction electrons. Use those clues to estimate the speed of the electrons when the current is one or two amps. (skill 11)

7. Was every numerical answer above rounded off properly? If not, give a good reason. (3)

8. How can I reduce the sensitivity of an ammeter to one fifth of its former value? Answer with a simple sentence or two in the lower margin. *Don't be vague.* (skill 17)

Second March Test (2000, Level H) *solutions*

1. Pee Wee Herman stands at the end of a diving board. Hulk Hogan pulls the tip down and then releases it, causing Pee Wee to fly upward. Let “kx” represent the upward force exerted on PeeWee by the board. Let “mg” represent the downward gravitational force on PeeWee.

  a. Just after release those two forces are unequal. Which is the stronger? (1 point)

His upward acceleration tells us that the ***upward*** *force on him is stronger than the downward force.*

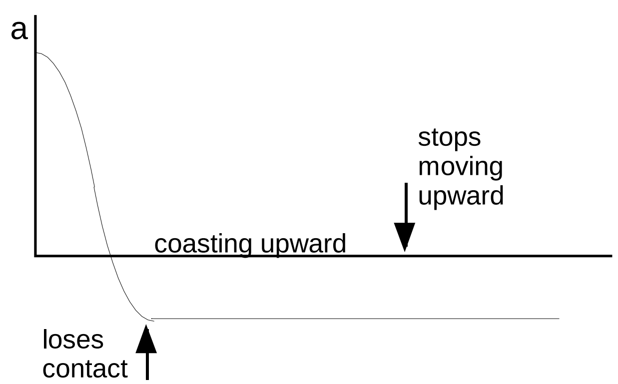
  b. Which force is the stronger one just before PeeWee loses contact with the board? (1 point)

The board is nearly unbent now, so it exerts a very small upward force. The ***downward*** *force is now the stronger one.*

  c. Describe the direction of PeeWee’s acceleration just before losing contact. (1 point)

His acceleration is in the direction of the total force on him, which is ***downward*** *at that moment.*

  d. Sketch Pee-Wee’s acceleration vs time graph. Let upward accelerations be positive. Indicate the moment when he loses contact with the board. Also mark the time when he stops moving upward. Write “coasting upward” on the segment which describes that part of the trip. (3 points)



While in contact with the board, PeeWee behaves like a mass on a spring, with a simple harmonic motion. After losing contact he has constant downward acceleration due to gravity while he coasts upward, stops, and falls back.

2. A cup of water is heated by a wire resistor. Before the switch was closed, the power supply voltage was 24 ± 0.2 volts. It became 21 ± 0.2 V when the switch was closed. The heater current was 4.2 ± 0.05 A. The heater was unplugged after 30 ± 0.2 seconds

  a. Calculate the heating power in SI units. Express the uncertainty as a percentage. (3 points)

Power = voltage x current = (21 V ± 1%)(4.2 A ± 1.2%) = ***88.2 Watts ± 2.2%***

  b. Calculate the resistance of the heater. Express its uncertainty in absolute form. (3 points)

Resistance = voltage/current = (21 V ± 1%)/(4.2 A ± 1.2%) = 5.0 V/A ± 2.2% ***= 5.0 ± 0.11 ohms***

  c. Calculate the internal resistance of the power supply as a **RANGE**. (3 points)

Internal resistance = abs. value of slope of the power supply’s voltage vs currant graph:

Ri = [(24 ± 0.2 V) - (21 ± 0.2 V)]/[(4.2 ± 0.05 A) - 0] = (3 ± 0.4 V)/(4.2 ± 0.05 A)

GLV of Ri = (3.4 V)/(4.15 A) = 0.82 ohms; SLV of Ri = (2.6 V)/(4.25 A) = 0.61 ohm

:. Ri is probably between 0.61 and 0.82 ohms.

  d. How much electric charge passed through the resistor? Just give its MLV. (2 points)

Current x time interval = (4.2 coulombs/sec)(30 sec) = ***126 coulombs***

3. If there were no atmosphere to interfere, we could put a rock into orbit by throwing it horizontally from the top of a mountain. Please use SI units:

  a. How much centripetal acceleration would it have while in orbit? (2 points)

The rock’s acceleration is caused by the earth’s gravity, so it must be ***9.8 m/s***^{2}.

  b. The earth’s radius is 1.6 x 10^6 meters. How fast must we throw a rock horizontally to put it into orbit? (2 points)

$v^2/R = g$, *so* $v = \sqrt{Rg} = \sqrt{(1.6 \times 10^6\ m)(9.8\ m/s^2)}$ = ***3960 m/s***

Second March Test (2000, Level H) *solutions, continued*

3c. Imagine an electrical device that puts a *person* into such an orbit. Estimate the energy that it will use. Please express 3c and 3d in range form, using powers of ten. (3 points)

mass of person = w/g = (around 150 pd)/(2.2 pd/kg) = between 50 and 100 kg
Kinetic energy = $mv^2/2 = (50\ kg)(0.396 \times 10^4\ m/s)^2/2 = 4 \times 10^8\ J$
= ***between*** $\mathbf{4 \times 10^8}$ ***and*** $\mathbf{8 \times 10^8}$ ***J***

d. Estimate the cost of that energy, if purchased from a local electric power company. (3 points)

$(4 \times 10^8\ J)(0.1\ \$/kW\text{-}hr)/(3.6 \times 10^6\ J/kW\text{-}hr)$ = *roughly $10*
Answer: ***probably between $10 and $20***

4. The emf of a certain flashlight cell is 1.50 V. Its internal resistance is 0.65 ohm.
a. Calculate the maximum power obtainable from such a cell. (2 point)

Maximum power is obtained when the load resistance = internal resistance.
Then load voltage = half of the emf = 0.75 V, and current = emf/(2 x Ri) = 1.5/1.3 = 1.15 A.
Load power = load voltage x current = 0.75 V x 1.15 A = ***0.865 watt***

b. Calculate its short-circuit current. (2 point)

1.5 V / 0.65 A = ***2.31 A***

c. If we connect two such cells in series exactly how will the pair's short-circuit current compare with the current calculated in part b? (1 point)

The emf and the internal resistance are each doubled, so their quotient is ***unchanged.***

5. When operated at 120 volts a certain light bulb has a dynamic resistance of 220 ohms.
a. Its static resistance is half as much. Calculate the bulb current at 120 V. (2 point)

Current = voltage/static resistance = 120 V / 110 ohm = ***1.09 amp***

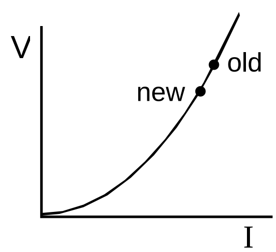
b. Write the definition of dynamic resistance and solve for "change in current". (1 point)

$R_d = \Delta V/\Delta I$, so $\mathbf{\Delta I = \Delta V/R_d}$

c. Use 5b to calculate the resulting change in current when the voltage is decreased from 120 volts to 117 volts. Be sure to say whether it is an increase or a decrease. (2 points)

$\Delta I = \Delta V/R_d = (3\ V)/(220\ ohm) = \mathbf{0.014\ A}$
This is a ***decrease*** *in current because the voltage decreased.*

d. Sketch a voltage vs current graph for this bulb. Make dots on the graph to represent the old and new operating points. Label them as "old" and "new". *Don't contradict 5c.* (2 point)



e. Calculate this bulb's old power and new power. (3 points)

Old power = (120 V)(1.09 A) = ***131 watts****; New power = (117 V)(1.09 - 0.014 A) =* ***126 W***

6. A 60-gram copper wire less than 100 meters long contains roughly 6×10^{23} conduction electrons. Estimate the speed of the electrons when the current is one or two amps. (2 points)

Travel distance = 10^2 *m; Travel time =* $(6 \times 10^{23}\ el.)/(6 \times 10^{18} el/sec) = 10^5\ sec$
Speed = travel dist/travel time = $(10^2\ m)/(10^5\ sec) = \mathbf{10^{-3}\ m/s}$

8. How can I reduce the sensitivity of an ammeter to one fifth of its former value? (3 points)
Select a shunt with four times the conductance of the ammeter and connect it in parallel with the ammeter.