SKILLS NEEDED FOR THE FIRST MARCH TEST (Level H, 2000)

1. Use algebra to solve a simple equation for its unknown and then plug in given data to determine the numerical value, units, and and uncertainty or range of that unknown quantity as on every previous test. Do such arithmetic with scientific notation and round off properly.

2. Use the definition of “rate”. Given the rate of a process and the amount of material to be processed, calculate the amount of time needed to complete the processing.

3. Use the definition of “density” that you learned in junior high school.

4. Esimate the volume of a familiar object, using any familiar units.

5. Solve routine proportion problems, using #17 on RS II.

6. Draw an arrow in a given direction or describe the direction of a given arrow, as on page 34R.

7. Draw an arrow to describe the instantaneous velocity or the acceleration of an object moving along a curved path with increasing, decreasing, or constant speed as you did on pages 41 and 42.

8. Use right-triangle trigonometry. (See pages 31R, 34R, and #12 on RS IV.)
   a. Given the ratio of the lengths of any two sides of a right triangle, determine the angles.
   b. Given the lengths of two sides of a triangle and given the angle between them, determine the length of the third side.

9. Name and describe the forces acting on an object which is coasting, swinging, or being dragged up or down a hill as on pages 36-38 and 41-42.

10. Use Newton's second law (#2 on RS IV) as on pages 52, 53, and previous tests.

11. Use the "work and energy theorem" and "energy conservation law" on RS VI. Also use the familiar formulas for kinetic and potential energy.

12. Use the power formulas in #12 on RS VI. Also use the electrical energy and power formulas in 14 and 15 on RS IX

13. Use the definitions of “series” and “parallel” on RS IX. Given a description of a simple circuit (using the word "series" or "parallel") diagram the circuit with standard circuit symbols, as on pages 80-85.

14. Decide if and how a given alteration in a simple circuit will affect the brightness of a light bulb or the battery current, as on pages 80 - 85.

15. Use #1, 2, 4, 5, & 6 on RS IX: Show how an ammeter or a voltmeter can be used to measure the current in a device or the potential difference between its terminals, as on pages 81 - 86.

16. Use the “branch point law” in #3 on RS IX.

17. Compare the sensitivities of two ammeters or two voltmeters and decide which is greater.

18. Use the definition of “voltage” as on page 83R. Given some of the voltages in a circuit, calculate the remaining ones.

19. Use the definition of “ampere” and “coulomb” on RS IX. Use the charge of an electron or proton recorded in #9 on RS IX.

20. Use the definition of “resistance” on RS IX and on RS X.

First March Test (2000, Level H) name:_______________

1. The periodic table tells us that the mass of a copper atom is roughly 60 times the mass of a hydrogen atom. A hydrogen atom's mass is one gram divided by Avogadro's number, which is roughly 6×10^{23}. Each copper atom has one "conduction electron" which is free to move around in the wire. Use powers of ten to answer the following:
   a. Roughly how many conduction electrons are there in a 60-gram piece of wire? (skill 1)
   b. Roughly how much time will it take to replace all of those conduction electrons with new ones if the current in the wire is one ampere? (Skills 1, 2, 19)

2. Suppose the 60-gram piece of wire in #1 has roughly the same thickness as a paper clip. Using range form with SI units, estimate its length. (Clues: Since it does not float, you know it is more dense than water. The densest metal known is about 20 grams per cm^3, and that is not copper.) *Round off properly.* (skills 1, 3, 4)

3. A certain aircraft is moving at 700 mph, 15 degrees down from north. At that moment its acceleration is directed 60 degrees up from south. Use skills 6 & 7:
   a. Let "up" be toward the top of this paper. Draw an arrow in the answer space to indicate the direction of the plane's velocity. Label it "V". Draw another arrow in that same answer space to indicate the direction of the plane's acceleration. Label it "A".
   b. Calculate the angle formed by those two vectors when they are tail-to-tail.
   c. Suppose that acceleration remains approximately constant for some short period of time. Draw a line (straight or slightly curved) in the answer space to show the path which the aircraft follows during that time interval. Do not contradict 3a or 3b. (skill 7)
   d. What can we conclude about the speed of the aircraft? (increasing, decreasing, constant)

4. An electrical toy is powered by four "D" cells connected in series. The emf of each cell is 1.4 volts. An "on-off switch" is in series with the toy.
   a. Calculate the potential difference between the terminals of that switch when it is "off".
   b. One of the cells is put in backward. Calculate the new open-circuit voltage. (18)

5. An electric teapot heats 0.60 liters of water from 20 degrees celsius to the boiling point in five minutes. Please use SI units and scientific notation (if appropriate) in making the following **estimates:** Round off properly.
   a. How much electrical energy does the teapot use? (skill 12)
   b. How much current must it use if it operates at 110 volts? (skill 12.)
   c. Imagine using the same energy to lift the water straight up. How high will it go? (11)
   d. If the same energy is used to accelerate the water from rest, what speed can it reach?

6. In the lower margin draw two light bulbs (A and B) connected in series to a battery. Draw a box representing device D connected across bulb B. Using the words "increase", "decrease", or "unchanged", describe what happens to the brightness of each bulb when device D is connected:
   a. -if the resistance of D is much greater than the bulb resistance.
   b. -if the resistance of D is less than the bulb resistance. (skills 14, 20)

7. Using a 0-1A ammeter, we found that the current through a voltmeter was too small to detect. Then we made the ammeter more sensitive by switching it to the 0-0.1A scale. We had to turn that knob two more times before we were able to see that the current was $0.81 \pm .02$ mA. The voltmeter reading was then 3.8 ± 0.05 V.
   a. Each turn of the knob increased the ammeter's sensitivity and decreased its range by a certain factor. Each turn made it how many times more sensitive? (skill 17)
   b. How many times did we apply that factor by turning the knob?
   c. Express the given ammeter current in SI units. Use scientific notation and express its uncertainty in percentage form. (skill 2)
   d. Calculate the voltmeter's resistance in SI units. Use scientific notation, express its uncertainty in percentage form, and round off both numbers properly. (skills 1, 20)

ANSWER SPACE

1a)

1b)

2)

3a)

3b)

3c)

3d)

4a)

4b)

5a)

5b)

5c)

5d)

6a)

6b)

7a)

7b)

7c)

7d)

8) Was every calculated answer rounded off properly?_____
If not, give a good reason.

First March Test (2000, Level H) *Solutions*

1. The periodic table tells us that the mass of a copper atom is roughly 60 times the mass of a hydrogen atom. A hydrogen atom's mass is one gram divided by Avogadro's number, which is roughly 6 x 10^{23}. Each copper atom has one "conduction electron" which is free to move around in the wire.

a. Roughly how many conduction electrons are there in a 60-gram piece of wire? (1 point)

[(6/60) x 10^{23} atoms per gram)][60 grams][1 electron per atom] = ***6 x 10^{23} electrons***

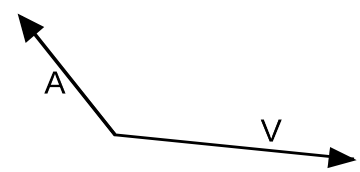
b. Roughly how much time will it take to replace all of those conduction electrons with new ones if the current in the wire is one ampere? (2 points)

(6 x 10^{23} electrons)/(6 x 10^{18} electrons per sec.) = roughly ***10^5 seconds***

2. Suppose the 60-gram piece of wire in #1 has roughly the same thickness as a paper clip. Using range form with SI units, estimate its length. Since it does not float, you know it is more dense than water. The densest metal known is about 20 grams per cm^3, and that is not copper. (2 points)

By definition, density = mass/vol., so V = M/D = [60 grams]/[between 1 and 20 gram/cm^3] = betwen 3 and 60 cm^3. That volume is the length of the wire times its cross-sectional area, so L = V/A. Since its thickness is roughly a millimeter (or 10^{-1} cm) its area must be roughly 10^{-2} cm^2. Therefore L = [between 3 and 60 cm^3]/[10^{-2} cm^2] = [between 3 and 60]x[10^2 cm] = ***between 3 and 60 meters.***

3. A certain aircraft is moving at 700 mph, 15 degrees down from north. At that moment its acceleration is directed 60 degrees up from south.



a. Let "up" be toward the top of this paper. Draw an arrow in the answer space to indicate the direction of the plane's velocity. Label it "V". Draw another arrow in that same answer space to indicate the direction of the plane's acceleration. Label it "A". (2 points)

b. Calculate the angle formed by those two vectors when they are tail-to-tail.

Imagine rotating the "A" arrow like the hand of a clock: 30 degrees will make it vertical, another 90 deg will make it point to the right, and another 15 deg will make it coincide with the "V" arrow.

30 + 90 + 15 = ***135 degrees****.*

c. Suppose that acceleration remains approximately constant for some short period of time. Draw a line (straight or slightly curved) in the answer space to show the path which the aircraft follows during that time interval. Do not contradict 3a or 3b. (2 points) *According to 3a, the initial velocity is slightly down from horizontal, and the centripetal acceleration is roughly upward. So the aircraft must be leveling off.*

d. What can we conclude about the speed of the aircraft? (1 point) ***decreasing.***

The acceleration has a backward component, so the aircraft is slowing down while leveling off.

4. An electrical toy is powered by four 1.4-V "D" cells connected in series with an "on-off switch".

a. Calculate the potential difference between the terminals of that switch when it is "off". (2 points)

The voltage across the toy is 0 because the current is zero. Therefore the voltage across the switch must be equal to the battery's open-circuit voltage: 4 x 1.4 V = ***5.6 volts***

b. One of the cells is put in backward. Calculate the new open-circuit voltage. (2 points)

[3 x 1.4 V] - [1.4 V] = ***2.8 V***

5. An electric teapot heats 0.60 liters of water from 20 degrees celsius to the boiling point in five minutes.

a. How much electrical energy does the teapot use? (2 points)

[0.6 liter][1000 gram/liter][100 - 20 degrees][4.2 J/cal] = ***2 x 10^5 J***

b. How much current must it use if it operates at 110 volts? (2 points)

Energy = VIΔt, so I = E/VΔt = [2 x 10^5 J]/[(110 V)(5 min)(60 sec/min)] = ***6 Amp***

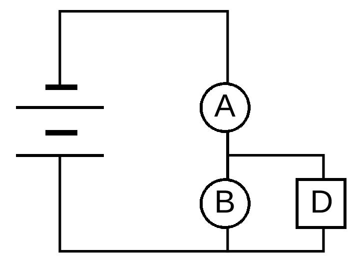
c. Imagine using the same energy to lift the water straight up. How high will it go? (2 points)

Work = mgh, so h = W/mg = [2 x 10^5 J]/[(0.6 kg)(9.8 N/kg)] = ***3 x 10^4 meters***

d. If the same energy is used to accelerate the water from rest, what speed can it reach?

KE = $mv^2/2$, so $v = \sqrt{2KE/m} = \sqrt{2(2 \times 10^5\ J/0.6\ kg)}$ = ***800 m/s***

First March Test (2000, Level H) Solutions, *continued*



6. Draw two light bulbs (A and B) connected in series to a battery. Draw a box representing device D connected across bulb B. Using the words "increase", "decrease", or "unchanged", describe what happens to the brightness of each bulb when device D is connected: (4 points)
 a. *If the resistance of D is much greater than the bulb's resistance then very few electrons go through D. The currents through the bulbs are not changed much, so* ***neither brightness changes****.*
 b. *If the resistance of D is less than the bulb's resistance then* ***B will become dimmer*** *(because most electrons will go through D instead of B) and* ***A will become brighter*** *because the extra path provided by D makes it easier for electrons to go from one end of the battery to the other.*

7. Using a 0-1A ammeter, we found that the current through a voltmeter was too small to detect. Then we made the ammeter more sensitive by switching it to the 0-0.1A scale. We had to turn that knob two more times before we were able to see that the current was 0.81 ± .02 mA. The voltmeter reading was then 3.8 ± 0.05 V.
 a. Each turn of the knob increased the ammeter's sensitivity and decreased its range by a certain factor. Each turn made it how many times more sensitive? (1 point)

    Each turn makes it ***10 times*** *more sensitive, decreasing its range by a factor of* ***10*** *because 0.1 A is one tenth of 1.0 A.*

 b. How many times did we apply that factor by turning the knob? (1 point)

    Three *turns of the knob are described above.*

 c. Express the given ammeter current in SI units. (3 points)
 Use scientific notation and express its uncertainty in percentage form.

    $0.81 \pm .02\ mA = [0.81 \pm .02] \times 10^{-3}\ A = \mathbf{0.81 \times 10^{-3}\ A \pm 0.25\%}$

 d. Calculate the voltmeter's resistance in SI units. Use scientific notation, express its uncertainty in percentage form, and round off both numbers properly. (3 points)

    $R = V/I = [3.8\ V \pm 1.3\%]/[0.81 \times 10^{-3}\ A \pm 0.25\%] = \mathbf{4.69\ ohms \pm 1.5\%}$