

## SKILLS NEEDED FOR THE FIRST DECEMBER TEST (1999, L-H)

1. Convert uncertainties from absolute to percentage form or from percentage to absolute form.
2. Add, subtract, divide or multiply numbers which have uncertainties and units, giving the MLV, GLV, SLV, range, absolute uncertainty, or percentage uncertainty of the result, along with its units. (Use # 16 - 20 on RS I or #25-27 on RS II.)
3. Convert units as we did in Ch. I and II.
4. Use the information about "gravitational field strength in #12 on RS I and in #8-9 on RS III.
5. Use the definitions of "acceleration", "velocity", "average velocity", "change in velocity" and "average speed" which you recorded on RS I, RS II and RS III.
6. Name and describe the force which causes a freely-falling object to accelerate. (#8 & 9 on RS III)  
Copy the acceleration of a freely-falling object from #15 on RS I. Predict how far or how fast an object will fall freely in a given amount of time by using #6 on RS II.
7. Given a verbal description of a graph, draw the graph. Sketch a graph of velocity vs time OR displacement vs time to describe the motion of a freely falling object, an object tossed straight up, or an object coasting to rest on a level surface as on pages 23-26.
8. Solve routine motion problems by the procedure reviewed in #8 on RS II.  
Solve routine proportion problems by using 17d on RS II.
9. Use a protractor and ruler to draw a vector in any given direction or to describe the direction of a vector *clearly* by the method explained on page 34R.  
Make such a diagram with precision better than 1% by using #12 on RS III.
10. Given two sides of a familiar right triangle, determine its angles. Given one side and one acute angle, determine the length of either remaining side. (Use a protractor & ruler OR use the information about special triangles on pages 31R and 34R, OR use trigonometry.)
11. Use vector addition as on pages 31, 32, 33, 34, and 34R. (See # 11 on RS III.)  
Use vector subtraction as on page 41, 41R, and 41RR. (See #1 on RS IV.)
12. Describe the forces acting on an object which is resting on a surface, sliding on a surface, hanging from a string, or flying through the air as we did on page 40 and on the previous test.
13. Use the definitions of "friction coefficient" on RS III.  
Also use the facts about friction that you recorded in 13-19 on RS III.
14. Use the definition of "total force" on RS III.
  - a. Describe the total force on a non-accelerating object. (Use #3 and 16 on RS III.)
  - b. Given all of the forces acting on an object, predict the direction of the object's acceleration as on pages 32, 38, and in 4b on RS III.
15. Use the "pulley principles", the definition of "mechanical advantage", and the definition of "work". (See # 5 on RS IV.)
16. Use the definition of "momentum" and the "momentum conservation law" in #2 on RS IV.
17. Use Newton's three laws of motion, as recorded on RS V.
18. Copy an equation from RS I, RS II, RS III, RS IV, or RS V, solve it for an unknown, and *then* plug in given data to calculate the value of that unknown quantity with units and uncertainty estimate.

**First December Test (Honors level, 1999) name \_\_\_\_\_**

**ANSWER SPACES**

1. An automobile skids to a stop on a level surface in 4.2 seconds. During the last 2.1 seconds it skids 12.5 meters. Sketch its speed-time graph on the *back* of this paper.
  - a. How far did it skid during the *first* 2.1 seconds? *Shade in that part of your graph.*
  - b. Calculate the car's acceleration while skidding. (Skills 7 & 8)
  
2. A speedboat is moving northwest with a speed of 29 knots. Ten seconds later it is moving northeast at the same speed. (A "knot" is a speed unit used by sailors.)
  - a. Sketch a vector diagram showing how you SUBTRACT one of those velocities from the other to determine the boat's CHANGE IN VELOCITY. Let north be toward the top of your map. Draw a *dotted* arrow to represent the change in velocity. Each arrow must have a *pointed end* and a *label*. In this example the labels are  $V_1$   $V_2$  and  $\Delta V$ , but *one of those labels must have a negative sign*. (Skills 9-11)
  - b. Describe the magnitude and direction of the boat's change in velocity. Do *not* convert units. Instead, use the units that were given. (skill 11)
  - c. If you divide that change in velocity by the ten-second time interval you get a new vector with the same direction. Write the **name** of the new vector and give its **units** as you would in the column heading of a data table. Do *not* convert units. (Sk 5.)
  
3. A  $4.7 \pm 0.1$ -newton horizontal force is used to drag a brick at constant velocity across a level surface. After three seconds that force is suddenly changed to  $6.5 \pm 0.1$  newtons. That new force is maintained for two more seconds.
  - a. Sketch a graph of forward force vs time for the full five seconds. (skill 7)
  - b. Sketch the brick's speed vs time graph for the same five seconds. (skill 7)
  - c. Calculate the total force acting on the brick during the last two seconds. (skills 11-14)
  - d. Calculate the percentage uncertainty of the total force found in part c. (skills 1,2)
  - e. The original velocity of the brick was 0.75 m/s. Its final velocity after the five seconds described above was 2.13 m/s. Calculate the MLV of its mass. (skills 17, 18)
  
4. A hockey puck sliding northward at 6.0 m/sec on smooth ice collides with an octopus sliding eastward. After colliding they slide together in a direction 37 degrees north from east. The octopus is twice as massive as the puck.
  - a. Sketch a vector diagram showing how the final momentum is related to the two original momentums. Let "north" be toward the top of your paper. Label the puck's original momentum with a "P", the octopus' original momentum "O", and the final momentum of the combined puck and octopus "F". (skills 9, 11, 16)
  - b. Use your knowledge of triangles to determine the ratio of the octopus's original momentum to the puck's original momentum. (skill 10)
  - c. Use the given data with the ratio in 4b to calculate the original speed of the octopus.
  
5. A frictionless pulley system is used to lift 200 kilograms of iron ( $\pm 1\%$ ) from the surface of a planet. We find that when the rope is pulled two yards the object rises two feet. (One yard = 3 feet.) The force used to pull the rope was  $22 \pm 1$  pounds.
  - a. Calculate the mechanical advantage of this pulley system. (skill 15)
  - b. Calculate the gravitational force on the object. (Use 5a. Please do *not* convert units.)
  - c. How strong is the gravitational field at the location where this job was done? (skill 4)
  - d. How does the work done by the pulley system on the iron compare with the work done on the rope by the person who pulled it? (skill 15)
  
6. An object slides down a ramp, accelerating all the way. A second object made of the same material but with 3.2 times as much mass slides down the same ramp.
  - a. Determine the ratio of the second normal force to the first. (Use skills 8, 12.)
  - b. Determine the ratio of the second friction force to the first. (skill 13)
  - c. Determine the ratio of the second total force to the first. (Use skill 14.)
  - d. Predict the ratio of the second acceleration to the first.  
*Remember that the two masses are not equal.* (skill 17)

1a) \_\_\_\_\_

1b) \_\_\_\_\_

2a) \_\_\_\_\_

2b) \_\_\_\_\_

2c) \_\_\_\_\_

3a) \_\_\_\_\_

3b) \_\_\_\_\_

3c) \_\_\_\_\_

3d) \_\_\_\_\_

3e) \_\_\_\_\_

4a) \_\_\_\_\_

4b) \_\_\_\_\_

4c) \_\_\_\_\_

5a) \_\_\_\_\_

5b) \_\_\_\_\_

5c) \_\_\_\_\_

5d) \_\_\_\_\_

6a) \_\_\_\_\_

6b) \_\_\_\_\_

6c) \_\_\_\_\_

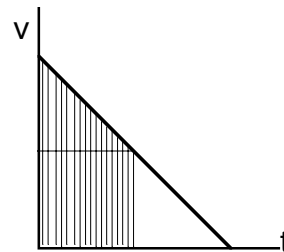
6d) \_\_\_\_\_

## First December Test Solutions (Honors level, 1999)

1. An automobile skids to a stop on a level surface in 4.2 seconds.  
Sketch its speed-time graph.

- a. During the last 2.1 seconds it skids 12.5 meters.  
How far did it skid during the *first* 2.1 seconds?

*The shaded part of the graph is a triangle and a rectangle. The triangle is identical to the unshaded one, which has a given area of 12.5 m. The rectangle area is twice as much, or 25 m. By adding we find that the car skids 37.5 m during the first 2.1 seconds.*

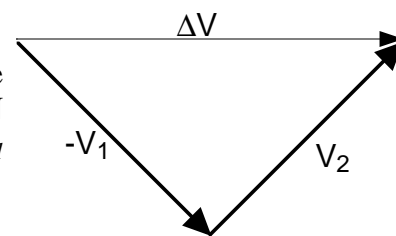


- b. Calculate the car's acceleration while skidding.

*One familiar formula for any triangular area on a speed-time graph is  $D = a\Delta t^2/2$ , so  $a = 2D/\Delta t^2 = 2 \times 37.5 \text{ m}/(4.2 \text{ s})^2 = -4.25 \text{ m/s}^2$*

2. A speedboat is moving northwest with a speed of 29 knots.  
Ten seconds later it is moving northeast at the same speed.  
(A "knot" is a speed unit used by sailors.)

- a. Sketch a vector diagram showing how you SUBTRACT one of those velocities from the other to determine the boat's CHANGE IN VELOCITY. By definition,  $\Delta V = V_2 - V_1$ . So we must reverse the  $V_1$  arrow and then add it to  $V_2$ , as illustrated at the right.

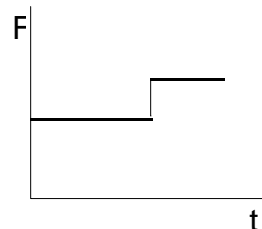


- b. Describe the magnitude and direction of the boat's change in velocity.

*The  $\Delta V$  arrow is the hypotenuse of a 45-45-90 triangle, so its size is 29 knots times the square root of 2, which comes out to 41 knots Eastward.*

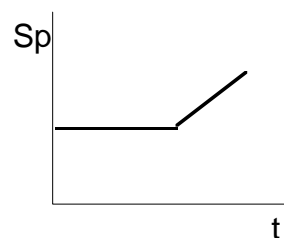
- c. If you divide that change in velocity by the ten-second time interval you get a new vector. Write its **name** and its **units**. By definition,  $\Delta V/\Delta t = \text{acceleration}$ . In this example it is in **knots per second**.

3. A  $4.7 \pm 0.1 \text{ N}$  horizontal force is used to drag a brick at constant velocity across a level surface. After 3 sec that force is suddenly changed to  $6.5 \pm 0.1$  newtons. The new force is maintained for two more seconds.



- a. Sketch a graph of forward force vs time for the full 5 sec.  
*The given description is complete.*

- b. Sketch the brick's speed vs time graph for the same five seconds.  
*The speed is constant for the first three seconds (given) and it increases steadily during the last two sec. because the new total force is forward and constant.*



- c. Calculate the total force acting on the brick during the last two seconds.

$$(6.5 \pm 0.1 \text{ N forward}) + (4.7 \pm 0.1 \text{ N backward}) = 1.8 \pm 0.2 \text{ N forward.}$$

- d. Calculate the percentage uncertainty of the total force found in part c.

$$0.2/1.8 = 0.11 = \pm 11\%$$

- e. The original velocity of the brick was 0.75 m/s. Its final velocity was 2.13 m/s. Calculate the MLV of its mass.

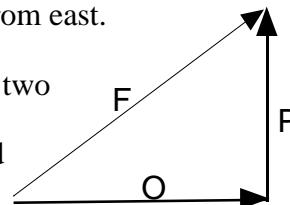
$$TF = ma = m\Delta v/\Delta t, \text{ so } m = TF\Delta t/\Delta v = (1.8 \text{ N})(2.0 \text{ s})/(2.13 - 0.75 \text{ m/s}) = 2.6 \text{ kg}$$

## First December Test Solutions, continued

4. A hockey puck sliding northward at 6.0 m/sec on smooth ice collides with an octopus sliding eastward. After colliding they slide together in a direction 37 degrees north from east.

The octopus is twice as massive as the puck.

- a. Sketch a vector diagram showing how the final momentum is related to the two original momentums. Label the puck's original momentum with a "P", the octopus' original momentum "O", and the final momentum of the combined puck and octopus "F".



- b. Determine the ratio of the octopus's original momentum to the puck's original momentum.

*The given angles tell us that it's a 3-4-5 triangle and that P is the shortest leg, so the ratio O/P must be 4/3, or 1.33.*

- c. Calculate the original speed of the octopus.

*Let "m" represent the puck mass, so the octopus mass is 2m.*

*Equation 4b then says  $O/P = 2mv/(m \times 6.0 \text{ m/s}) = 4/3$ , so  $v = (4 \times 6.0 \text{ m/s})/(3 \times 2) = 4.0 \text{ m/s}$*

5. A frictionless pulley system is used to lift 200 kg  $\pm$  1%.

Pulling the rope is pulled 6 ft raises the object 2 ft.

- a. Calculate the mechanical advantage of this pulley system.  $M.A. = ID/OD = 6 \text{ ft}/2 \text{ ft} = 3$

- b. The force used to pull the rope was 22  $\pm$  1 pounds.

Calculate the gravitational force on the object.

*By definition,  $M.A. = OF/IF$ , and  $OF = mg$ , so  $mg = IF \times M.A. = (22 \pm 1 \text{ pd})(3) = 66 \pm 3 \text{ pd}$ .*

- c. How strong is gravity there?

$g = w/m = (66 \pm 3 \text{ pd})/(200 \text{ kg}) = 0.33 \pm 0.7 \text{ pd/kg}$

- d. How does the work done by the pulley system on the iron compare with the work done on the rope by the person who pulled it? *The must be equal if the system is frictionless, by the 4th pulley principle.*

6. An object slides down a ramp, accelerating all the way. A second object made of the same material but with 3.2 times as much mass slides down the same ramp.

- a. Determine the ratio of the second normal force to the first.

*The gravitational force is proportional to the object's mass, and the normal force is a constant fraction of that weight. Therefore the ratio of the normal forces is equal to the mass ratio:*

$$N_2/N_1 = M_2/M_1 = 3.2$$

- b. Determine the ratio of the second friction force to the first.

*Sliding friction is proportional to normal force, so  $F_2/F_1 = N_2/N_1 = 3.2$*

- c. Determine the ratio of the second total force to the first.

*Each force on the second object is 3.2 times greater than the corresponding force on the first object, so*

$$TF_2/TF_1 = 3.2$$

- d. Predict the ratio of the second acceleration to the first.

*The acceleration of an object is equal to the total force on it divided by its mass. (Newton's 2nd law)*

*Therefore  $a_2/a_1 = [TF_2/m_2] / [TF_1/m_1] = [TF_2/TF_1] \times [m_1/m_2] = (3.2) \times (1/3.2) = 1$*

*The accelerations are equal, as you can easily demonstrate by sliding a dime and a quarter down a steep ramp.*