1. If object A is touching object B, is it correct also to say B is touching A? ___

2. In Ch. II you were asked what can cause an obect to accelerate. It was decided that we cause things to accelerate by pushing or pulling on them. Pushes don't always cause acceleration, but it seems that an object's acceleration is always caused by something pushing or a pulling on that object.
   a. Are there any exceptions to that claim? ___ (If so, please explain.)
   b. If Object A pushes or pulls on object B, does B simultaneously push or pull on A? ____

3. A **"force"** is a push or a pull, as in #2. Describing a force is somewhat like describing an angle: To name or identify an angle, you must name two *intersecting lines*. To name or identify a force, you must name two *interacting objects*. In other words, you must say what the force is exerted ***BY***, and what it is exerted ***ON***. To be complete, you must also describe the *strength and direction* of the force.
   a. Is there any kind of force which is *not* exerted by an object? ___ -Does 2a agree? ___
   b. ***If*** such a force does exist, please describe it and explain how it can be measured with a spring scale.

* 4. After reviewing #3, explain what is wrong with these sentences:
"The force of the ball propelled it 200 feet." "An eastward force of 35.0 is required to drag that box."

5. In Ch. I you measured the strength of a force with a "spring scale". The important part is a *spring* which can be stretched or compressed by the force being measured. The amount of stretch is displayed on a dial which is calibrated in force units. Pounds, ounces, and newtons are common force units, although there are many others. Spring scales usually must be "zeroed in" before use.
   a. Hook two identical spring scales together and use one to pull on the other. When scale A pulls on scale B, does B pull back on A? ___ --Does your answer to 2b agree with this fact? ____
   b. How are those two forces related? Their strengths are ______. Their directions are __________.

6. *Two* forces act on an object when it is hanging from a spring scale. The spring scale pulls ____ward on the object, and the ____ exerts a _____ward "gravitational" force on the object. -Does #3 agree? __
   a. How do the strengths of those two forces compare when the object is not moving? _____
   b. How do they compare when the scale and suspended object are moving with a constant velocity, as they would if you held them while standing on an escalator? (See 1b on page 26.) _______
   c. If they are unequal in either case, please explain how you know which one is stronger.

7. If we made the earth's gravity weaker then objects near the surface of the earth would become ________er. (lighter, heavier, bigger, hotter)
   a. *How* can we make the earth's gravity weaker?
   b. Is there any *practical* way to change the weight of an object without transporting it to a new location and without altering the object itself? _____

8. Hang an object from a scale, as in #6. Make the scale and object accelerate upward.
   a. Are the two forces described in #6 still equal in strength while the object is accelerating? ___
   b. Does one of those forces change when you begin to accelerate the object?____
   c. To make the object accelerate upward, you __crease the ___ward force exerted on it by the ______. -Does this answer contradict #6? ____ --#7? ____ --8a? ____ --8b? ____
   d. Is there any evidence indicating that the other force acting on the object also changed when the acceleration began? ___ ** If so, please explain without contradicting #7.*

9. An object hangs from a string. If I reduce the ___ward force exerted on the object by the string (by cutting the string or by softening it with heat) the object will then ___________ ____ward. The first blank needs a *verb*. Please *copy* it from #2 or 8, and *use* it in 10d. -Does 9 agree with 8? ___

10. Miss A and Miss B pull on opposite ends of a long horizontal rubber band which is stretched between them. Miss A is standing on level ground, but the daring and talented Miss B stands on a skateboard with perfectly frictionless wheels, also on level ground. Using a spring scale, Miss B finds that she is pulling westward on the rubber band with a ten-pound force. Please *illustrate* with a labelled sketch.
    a. The rubber band must be exerting a ___-pound ______ward force on Miss A.
    b. The rubber band must be pulling on Miss B with a ___-pound ______ward force.
    c. Apparently the ground exerts a ___ -lb. _____ward friction force on __ to prevent her from slipping.
    d. The ***total*** force on _____ is zero. That's why she doesn't ___________. *That's a clue for 10e.*
    e. Miss __ accelerates _____ward *because* the ________ force on her is _____ward.

1. Tie a small, massive object like a pendulum bob to the end of the string. Drop it from one hand while holding the other end of the string in your other hand. Sketch a velocity-time graph describing the bob's motion while falling. (Copy it from RS I or RS II or from page 8.) *Extend* the sketched graph to show how the bob's downward motion stops quickly when the string becomes taut. Show clearly how the stopping process takes some time because the string stretches a bit.
   a. During the free-fall part of the motion the velocity is _____tive, meaning ____ward.
   b. The graph has a _____tive slope in that region, indicating an acceleration in the ____ward direction caused by a ____ward gravitational force exerted on the _____ by the earth.
   c. The second part of the graph describes the *stopping* process. It has a different slope. Label that part of the graph with the word "stopping". -Does that slope have the same sign as the slope in 1b? ___
   d. The sign of that slope indicates that the bob's *acceleration* was in the ____ward direction while its *velocity* was still in the _____ward direction during the stopping process. If that troubles you then you should review the definitions of "velocity" and "acceleration". They have different meanings.
   e. Does 1d contradict 1c or 1b? ___ --Does 1b contradict 1a? ___

2. During the stopping process there were *two* forces acting on the bob, exerted *by two other objects*:
   a. A _____ward gravitational force was exerted on the bob by the ____, as on p. 31. -Does 1a agree?__
   b. There was also an ___ward force exerted on the bob by the ______. *That force is called "tension".*
   c. The string will break if its tension becomes too ______. (great, small)
   d. The string tension is greatest while the bob is ________. (hanging, stopping, falling downward)

3. Does gravity change during the stopping process? ___ (See 7 & 8 on p. 31.) ***If*** the string is strong enough to stop the motion without breaking then the ___ward force exerted on the object by the _______ at that time must be stronger than the ____ward force exerted on the bob by the _______. That's why the bob's acceleration is ____ward during the stopping process. -Do 1d and 2d agree? ___

4. You know that an object suspended from a spring scale has *two* forces acting on it. One is an upward pull, and the other is downward. One of those forces is known as the object's "*weight*". The other is so often *confused* with weight that we shall call it the "**apparent weight**" of the object.
   a. According to 1b, the *downward* force is exerted by the _____. On p. 0 we called it the object's _____.
   b. According to #4, the strength of the *upward* force is called the object's "____________" weight.
   c. Which of those two forces changes whenever the object's acceleration changes? (Name it.) ________

5. An object's apparent weight is equal to its true weight *only if the object is not* ________ing. Does this agree with #3 on RS III? ___ --with 6-9 on page 31? ___ --with #3 above? ___
   This discovery has been recorded in # __ on RS___.

6. Sketching speed-time graphs will help you with these questions about riding in an elevator:
   a. When *starting* an upward motion you feel _______er than normal. (heavier, lighter)
   b. When *stopping* an upward motion you feel _______er than normal. -Does page 0 agree? ___
   c. When stopping a *downward* motion you feel _______er than normal.
   d. Acceleration is *not* velocity. In 6b the acceleration is ____ward, in 6c it is ____ward. -Does 1d agree?
   * e. Using 6a-c, explain how a passenger can determine the direction of an elevator's ***acceleration*** by feel. Remember to use some form of that ***italicized word*** in your explanation. *Don't contradict 6a-c.*
   f. Can you determine the direction of the elevator's *velocity* by feel? ____ (*If so, please explain how.)
   g. Do your answers to #6 agree with 5? ___ --with 4? ___ Do 6a-e contradict 6f? ___

7. Suppose we take a standard kilogram and an equal-arm balance to the moon, where gravity is roughly one-sixth as strong as it is here on earth. There we find a rock that balances the standard kilogram. We bring it back to the earth along with the balance and the standard kilogram.
   a. Will the rock and the kilogram still balance in the earth's gravity? ____ (See page 6.)
   b. Is the rock's weight *on the moon* equal to its weight *on earth?* ____ -Does page 6 agree? ____
   c. Did the balance measure the rock's weight? ____ -Can we measure weight with a balance? ___
   d. Suppose the balance arms are made much longer, so that one end supports the rock near the surface of the earth while the other end supports the kilogram near the moon: *Please illustrate with a simple diagram.* -Will it still balance if the arms have equal lengths? ___ -Does 7d contradict 7b? __
   e. Is it correct to say that the balance in 7d compared the *weight* of the rock with the *weight* of the standard kilogram, indicating which was greater at that time? ___
   (* If not, please explain what it really did, *without* contradicting 7c or 7d.)

* 1. In Chapter I you made a graph of **spring tension vs length.** Its slope is called a **"spring constant".**

a. Sketch it or repeat the measurements and make a new graph. (See #9 on RSI.)

b. The equation describing that graph was first discovered by Robert Hooke in the middle of the seventeenth century. Write Hooke's equation here *and* on RS III. Define your symbols:

c. A certain spring's unstretched length is 30 cm. and its spring constant is 2.5 N/cm. *Show* how you calculate the length it will have when stretched to a tension of 10 newtons. (Use algebra with 1b).

* 2. Find out if Hooke's equation describes the behavior of a rubber band stretched to its elastic limit. Don't worry about damaging the rubber band, but remember to make your graph *while* the experiment is in progress. Write your answer to this question as a clear statement *on the graph*.

3. **Simple Harmonic Motion:** Hang an object from a spring scale. Suspend the scale from a long spring tied with a long string to the ceiling. Pull the object down or up a few inches from its “equilibrium” position and release it so that it moves up and down with a smooth, repeating motion.

a. Sketch its displacement vs. time graph as you did on pages 17c and 29b. Treat upward displacements as positive. Show at least two identical cycles of the motion. (You may use a sonic ranger again.)

* b. Lightly draw a tangent line at the point where the object was released. (This can be done on the computer screen.) Draw *another* tangent line at a point just one cycle later. If the motion is periodic then those two lines must have ______ slopes. Those slopes indicate that the object’s velocity was ________ at the moment when the recording began. (upward, downward, zero)

c. There are many special moments when the velocity is maximum, minimum, or zero. Use the capital letters A, B, C, D, E, & F to label the first six of those special points ***on the TIME AXIS*** of the graph sketched in 3a. Are they evenly spaced? Use those same letters to fill in the blanks in 3d, e, & f.

d. The object's velocity is **upward** between times ___ and ___. Is it downward or zero at ***all*** other times displayed here? ____ *If not, please explain.*

e. The long spring is stretched beyond its equilibrium length between __ and ____. -Is that true also for the short spring which is inside the spring scale? ____

f. The scale reading is greater than the object’s weight between __ and ___.

4. Sketch the object's velocity vs time graph directly beneath the graph for #3, with the same time scale. Use the letters given in 3c to label the six special points on the time axis. Remember that ___ward velocities are positive. Use the instruction which you copied from page 29b onto RS II. (See p. 17c.)

a. The graph in #3 says the object’s velocity was ______ at time “A”, and ___ at B. (upward, downward, zero) -Does the graph in #4 agree with those facts? ___ *If not, please correct the mistake.*

b. The graph in #4 says the velocity shortly after release was ___ward. Does 3b agree? ___

c. On *both* graphs the acceleration is negative (meaning ____ward) in the interval between ___ and ___.

d. Is the acceleration positive or zero at *all* other times between A and F on *both* graphs? ____ (yes, no) Is the beginning of the second cycle similar to the beginning of the first? ___ *If not please explain.*

5. In 3f and 4 we see that the upward force exerted on the object by the scale is stronger than the downward gravitational force on the object *only* when the object's __________ (velocity, acceleration) is _____ward. Does this agree with 3f & 4c? ___ -with p. 31 & 32? ___ -with 4b & 5 on RS III? ___

6. Suppose an object is hanging from a string and we cut the string: Answer the following questions with phrases like "increases suddenly", "decreases gradually", or "remains constant". *Illustrate with graph*s.

a. The upward force exerted on the object by the string ________s _________ at that moment.

b. The downward gravitational force on the object ________s ________ at that moment.

c. The magnitude (absolute value) of the object's ____ward acceleration ________s ________ .

d. The magnitude of the object's ____ward velocity _________s _________ly *after* the cut.

7. On RS III we wrote that an object's "displacement" is two pieces of information in one package:

a. The **magnitude** of its displacement is the object's distance from the ______ of a coordinate system.

b. The _________ of its displacement can be described with words like "up", "____", "north", "_____", "east", or "_____". -Can a horizontal direction ever be the same as a vertical direction? _____

c. Which two directions in 7b are *vertical?* ________-Are the other four *always horizontal?* ______