1. On page 47 we decided that "work" is done whenever a force causes something to move. According to #6 on RS IV, doubling either the propelling *force* OR the moving *distance* causes the amount of work to be multiplied by __. "Work" must then be defined with a formula involving those two variables.
   a. Let's use "F" to represent the force exerted on the object, and use "X" to represent the resulting displacement of the object. Please circle the formula below which agrees best with #1:
   W = F + X **W = F - X** **W = F ÷ X** **W = X ÷ F** **W = FX**
   b. If possible, list a few other work formulas consistent with #1: ____
   c. Choose the simplest of all those possible formulas as a *beginner's definition*: **W = ______**
   (It will have to be improved and clarified later.)
   d. A copy of that definition has been saved on RS ___. -Does it contradict #6 on RS IV? ____

2. A "kilogram" is a unit of ______. The SI unit of force is the ________. According to 1c, a work unit must be the _________ of a ________unit and a ________unit. *That's a clue for 2a & 2b.*
   a. Please circle *all* of the work units in the list below, and label the SI work unit. Then *cross out* the ones which are NOT work units:
   ft·pound **ft/pound** **kg·m** **kg/m** **newton/meter** **newton·meter**
   b. The SI unit of work is named after James Prescott Joule. Between 1840 and 1850 Joule carefully measured the heat produced by stirring various fluids and by rubbing various solids together. He found that the heat is always proportional to the work done, and he measured the proportionality constant in many ways. **One "joule" (J) must be defined as "one _______________."**
   c. The "cgs" system of units is based on centimeters, grams, and seconds. The cgs force unit is a "dyne". #2e on RS V says one dyne will accelerate one gram of matter at one _____ per _______.
   d. A spring scale shows that one newton is equal to _____ dynes. *Use power-of-ten notation!*
   e. The cgs *work* unit is called an "erg". One **erg** must be defined as one __________.
   f. The "British Engineering" system of units (or "redneck system") is based upon feet, pounds, and seconds. How must the redneck unit of work be defined? _________ -Does 2a agree? ___

3. Examples: *Please do NOT convert units here, and try not to contradict #2.*
   a. How much work is done when a two-pound object is lifted up three feet?_____ _____
   b. How much work is done when one kg of matter is lifted up one meter in New York?___ __
   c. How much work is required to drag a 100-kilogram machine 5.0 meters at constant velocity across a level floor in Ansonia with a friction coefficient of 0.20? (Use # 18 on RS III.) ____ _____
   d. How much work would have been required in 3c if the floor had been frictionless? ___

4. We know that one meter = 3.27 feet, that 9.8 newton = ____ pound, and that one dyne = ______ N. Therefore one ft-lb. = _____ J, one J = _____ ft-lb, and one J = _____ erg. *Explain and save.*

5. Suppose we decide that all upward vectors are "positive": Then *downward* vectors must be _____tive.
   a. The product of an upward vector and a downward vector must be ____tive.
   b. The product of a negative vector and a positive vector must be _____tive.
   c. The product of a negative vector and a ____tive vector must be positive.
   d. The mass of a falling object must be ____tive, but its acceleration must be _____tive.

6. Instead, we could have let *downward* vectors be positive. With that choice, the acceleration of a falling object must have a ____tive value, while its mass must still be ____tive. Reversing our "sign convention" made it necessary to reverse the sign of the _____________, but NOT the sign of the ______. That's because the ____________ is a vector, while the ____________ is a *scalar*.

7. Think about a brick coasting to a stop on a level tabletop, as on pages 23, 24, 37 and 50:
   a. The directon of the brick's displacement and the direction of the friction force acting on the brick are _________. (alike, opposite, perpendicular) Therefore their *signs* must be __________.
   b. If forward vectors are "positive" then the product of those two vectors is _____tive.
   c. If forward vectors are "negative", then the sign of the product is ____tive. Does 5b agree?___
   d. The "product" in 7a & b is called the "_____ done on the _____ by the______ _____".
   e. When we reverse our sign convention the sign of the product is _______ed. (reversed, unchanged)
   f. Therefore ____ must be a _______ . (vector, scalar) -Does this contradict #6 or #6 on RS IV? ___

1. A "Simple Machine" is any gadget that can be used to twist things, squeeze things, lift things, or otherwise produce movement that requires effort, without consuming any fuel other than the user's muscle energy. Levers, pliers, and pulley systems are good examples.
   a. A bicycle is a combination of several simple machines, i.e. pedals, sprockets, and gears.
   b. A motorcycle is *not* a simple machine because it uses fuel.
   c. A spring is not a simple machine because it *stores* energy.
   d. A hammer is a simple machine when it is being used as a lever to pull nails. It is *not* a simple machine when it is being used to hammer nails into wood, because the hammer stores kinetic energy before transferring it to the nail.

2. Give some other examples of simple machines.

* 3. Copy the beginner's definition of "work" from RS VI or from page 57. *Don't be vague!*

4. Are all simple machines supposed to help people do work? ____
   (If not, please give a counterexample.)

5. Are there any simple machines which do *not* require the user to do any work? ____
   (If so, please give an example. I'd like to buy one to install on my bicycle.)

* 6. The work done *by the user* can be called "**input work**". The work done *by the machine* can be called "**output work**". Can a simple machine's output work ever be greater than its input work? If so, give an example. (Use page 47.) *Don't make it easy for me to misinterpret your answer.*

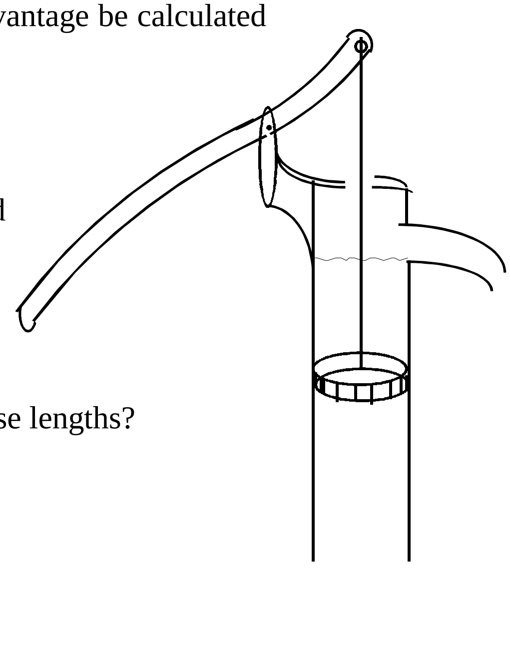
* 7. IF a simple machine does not waste any energy through friction, is it possible for its output work to be *less* than its input work? *Try not to mystify the reader.*

8. Imagine a person moving the handle of a simple machine ten centimeters by exerting a 30-newton force on it. That movement causes staples to be driven into wood to a depth of two centimeters.
   a. How much input work was done? ___ ____ (Use #3.)
   b. How much work must have been done on the staple by the machine if the mechanism did not waste a significant amount of energy?____ _____ (Use #7.)
   c. How much *force* must the machine have exerted on the staple? (Use #3.) ____ ____

9. For any *frictionless* simple machine, how must the ratio of output force to input force be related to the ratio of output distance to input distance? (Copy from page 46 or 47 or RSIV.)

10. Cross-multiply equation 9: ______ = ______ -Does it then agree with 6 and 7? ___
    -Does it also agree with 8c? ___ *If not, please explain or ask for an explanation in class.*

11. Which of the two ratios mentioned in #9 is equal to the mechanical advantage *by definition?* (See RS IV.) ________ -How can mechanical advantage be calculated from the other ratio? _______ *Answer clearly with one verb.*



12. When the handle of a water pump is moved down half a meter, a load of water is lifted ten centimeters.
    a. Calculate the mechanical advantage of this machine. _____
    b. How much force on the handle is needed to lift a seven-pound load of water if friction can be ignored? (Use #11.)
    c. Let "L_1" represent the distance from the pivot point (fulcrum) to one end of the handle. Let "L_2" represent the distance from the fulcrum to the other end. Which L is greater? ____ *Please illustrate by labelling the diagram.*
    d. How is the mechanical advantage of this "lever" related to those lengths?
       M.A. = ______
    e. Suppose the pump handle is curved, as in the illustration:
       Does that affect your answers? *If so, please explain.*

1. On page 32 we found that whenever object "A" pushes on object "B", then ___ pushes back on ___. We found that those two forces are always ________ in strength but _________ in direction. (See #2 on RS III.) Textbooks call this "Newton's third law of motion", although it says nothing about motion.

2. Suppose A pushes on B, causing B to move in the direction of that push:
   a. Is it correct to say that A has "done work" on B? _____
   b. We could also say that B did work on A. How must the signs of those two works compare? ___
   c. How must their magnitudes (absolute values) compare? _____

3. We know that whenever someone gains money in a transaction, someone else _______s an _________ amount. In other words, the total amount of money involved in a cash transaction is "*conserved*".
   In #2 we showed that "doing work" is *similar* to transferring money: whenever A does positive work on B, object B must do an _______ but ________ amount of work on A. *Does 2c agree?* ____
   a. If A does work on B, the intangible stuff that is transferred from A to B is called "**energy**". The amount of energy that A transfers to B is simply the amount of ______ that A does on B.
   b. Can energy be created or consumed? ___ (If so, give an example.) -Is energy conserved? ____ *If not, give an example.* -Can two energies be perpendicular to each other, as forces can be? ___

4. Imagine a cart with frictionless wheels resting on a level surface. Mr. A gives it a push. Let "F_a" represent the force exerted on the cart by Mr. A. While he is pushing, the cart moves forward a short distance called "D_a". (The work done *on the cart* by Mr. A is ____tive.) After he stops pushing, the cart continues to move because nothing causes it to stop. The cart coasts until Miss B reaches out and stops it. Let "F_b" represent the stopping force exerted on the cart by Miss B.
   a. Must the cart push Miss B's hand some distance "D_b" during that stopping process? ___
   b. How must the directions of F_b and D_b compare? ________ -What is the sign of their product? ___
   c. That product must be called the "______ done on the cart by Miss __", and 4b says it is _____tive.

5. Sketch a velocity-time graph describing the motion of the cart in #4. You may pretend that F_a and F_b were *steady* forces while they were acting, so the three sections of the graph are ______ lines. Label A's pushing time as "ΔT_a", and B's pushing time as "ΔT_b". (They are segments on the ___ axis.)
   a. If ΔT_a is *greater* than ΔT_b then F_a must be _______ ____ F_b. (stronger than, weaker than, equal to)
   b. Let "S" represent the coasting speed and let "M" represent the cart mass. Use Newton's second law to show how the two forces can be calculated from M, S, ΔT_a, and ΔT_b: *Be careful with signs.*
      F_a = ______, **F_b =** ______ -Does 5b contradict 4b or 5a? ____
   c. Obviously those two forces have opposite directions, as indicated (as in 4b) by their _______s.
   d. Use #2 on RS II to show how the pushing distances can be calculated from the *given* quantities.
      D_a = ______ **D_b =** ______
   e. Show how the works done by Mr. A and Miss B can be calculated from M, S, ΔT_a, and ΔT_b.
      Don't forget the signs! **W_a =** _____ **W_b =** ______
   f. If the wheels are frictionless and the surface is truly level, then the work done on the cart by B must be __________ ____ the work done by A. (less than, greater than, equal to, opposite to)
   g. The *total* work done on the cart by A *and* B must be ___ joules. Do 5e & 5f agree with 5g? ___

6. "Energy" is *ability to do work*. "**Kinetic energy**" is the type that a *moving* object has.
   a. What kind of energy did the moving cart have in 4 & 5? __________ _________ (Spell it right!)
   b. How can that energy be calculated from M and S? (Use 5e.) **KE =** _______
   c. This *discovery* is recorded in #__ on RS ___. The *definition* of energy is near the ____ of RS ___.

7. A nail is hot after being pulled out of a board because the work done on the nail could not give the nail any kinetic energy or potential energy. Instead, the worker gave the nail a third kind of energy called ______. (noun) Similarly, when we drag a brick across a level surface at constant velocity the work that we do is transformed into "________ energy". -Where is that energy located after the transformation? __________ *Hint: when you rub your hands together, how many of them get warm?*

8. When I stretch the rubber band on a slingshot am I doing work? ____
   a. Before release the rubber band stores _________ energy. (kinetic, potential, thermal)
   b. After release, the rubber band propels a pebble forward. Does it do work on the pebble? ____
   c. Does the pebble then have the ability to do work on the target, as in #6? _____
   d. The moving pebble's "ability to do work" is called "__________ energy". Is it a vector? __ (See 3b.)