F. Kinetic Energy

1. A moving object is obviously capable of doing work, as you saw on page 59. For example, a coasting truck can really “do a job” on a parked car. This means that the moving object has some kind of energy. Since the energy has something to do with the motion of the object, we call it "kinetic" energy. ("Kinetic" is a greek adjective which means "pertaining to motion".)
   a. Does the kinetic energy of an object depend on the direction of its motion? ___
   b. Can a kinetic energy ever be negative? _____ (If so, please explain.)
   c. If you knew a lot about physics, what information about a truck would you need in order to calculate the truck's kinetic energy? (_______ , _______) -Does 1c contradict 1a? ___

2. Let's figure out how much work a coasting truck is capable of doing when it crushes a car parked beside a stone wall. The car is made of thinner metal than the truck, so it caves in like an accordion.
   a. Sketch a speed-time graph describing the motion of the truck while being stopped by the collision. (We can only guess its shape, but we are sure that every segment of the curve has a ____tive slope.)
   b. Label a *short* time interval "Δt" on the time axis, somewhere in the stopping process. Draw vertical lines from the two ends of that short interval up to the curve and shade in the area between those lines just as we did on page 60. Don’t hesitate to enlarge your sketch.

3. The area of that narrow vertical strip represents the ___________ covered by the truck during the short time interval. If "x" represents the truck's displacement, then that small *change* in displacement must be represented by ____.
   a. The length of the vertical line forming the left boundary of the strip represents the truck's ________ at the ________ (beginning, end) of the interval. Let "__" represent that quantity.
   b. The length of the other vertical line represents the _______ _______ at the _____ of the ______ ______, which we can represent with the symbol "___".
   c. Use those two symbols to label the two points on the vertical axis of your graph. (Use 3a and 3b.)

4. Use the symbols defined in 2b and 3 (with parentheses) to write the simplest possible formulas for the distance covered by the truck during that short part of the collision and for the truck's acceleration:

   Δx = ________ **a =** _______

5. The truck's acceleration is _____tive, meaning _____ward. (Please correct #4 if necessary.)

6. According to Newton's second law (#2 on RS V) we can multiply the *truck's* acceleration by the _______ of the _______ to determine the total ________ acting on the _______.
   a. That force was exerted on the ________ by the _______. According to 4b on RS III, the *direction* of that force must be the same as the direction of the truck's ________, which was ____ward in #5.
   b. According to Newton's *interaction* law (#2 on RS III) the force exerted *on the car by the truck* can be determined by *reversing* the _________ of the force described in 6a. Using “m” to represent the mass of the ______ (and using the symbols defined in 2b & 3) the result of that reversal is **F =** ___.

7. To calculate the "work" done on the car during the short time interval we must _________ the force in #6b by the ________ found in #___ above. Do it on the back of this paper, simplify, and record the result here: **dW = (____) - (____)** This amount is ____tive because __ > __. *Does 3c agree?*

8. Choose a new symbol for the speed at the end of the *next* short time interval: ___ Use that symbol along with the ones defined above to write a formula for the work done on the car during the *TWO* consecutive short time intervals. *Use #7. Simplify as much as you can.* **W =** _________

9. Let "__" represent the original speed of the truck, before it crushed the little car. *Use a single letter.*
   a. The numerical value of the truck's final speed after completing the destruction is ____.
   * b. Use 8 & 9a with 1c to create a formula for the total work done on the car by the truck during ALL of the short time intervals. If this result contradicts 1b then *correct your mistake.*
   c. The work which the coasting truck was capable of doing on the car (or on anything else that happens to be in its path) is called the "_______ _______" of the truck, as on page 59.
   d. We have just proved that the kinetic energy formula mentioned in 1c must be: **KE =** _______
   e. Do the units balance in your new kinetic energy formula? ___
   f. Does it agree with 1c? ____ -Does it agree with #7 on RS VI? ____
   g. What must we measure to *test* the K.E. formula, to find out if it is correct?

1. As you know, the earth's gravity is weak at locations far from the earth.
   a. Sketch a graph of "g" vs. distance from the surface of the earth, showing what you think it must look like in the range from zero distance out to several earth radii.
   b. Using #5 on RS VI, sketch a graph of an object's potential energy vs. its distance from the surface. Cover the same distance range.
   c. Can you prove (or demonstrate by measuring) that the GPE really is zero at the surface or any other special altitude?______ (If so, please explain how.)

2. If somebody claimed to have zero gravitational potential energy on the surface of Jupiter, then he would have to agree that his gravitational potential energy is non-zero when he is on the surface of the earth, because his gain in gravitational potential energy when leaving the big planet can't be equal to his loss in gravitational potential energy while descending to the small one.
   a. Will residents of another planet agree with you about your choice of a zero point in 1b?____
   b. Is there any way to decide who is right about the zero point, or is it a matter of opinion? __
   c. Are we free to choose any place in the universe as a standard reference point where an object can be said to have zero gravitational potential energy?______
   d. Which of the following locations is the most convenient choice? (This choice must be equally acceptable to everybody in the universe. It should also make the gravitational potential energy vs. distance graphs have the simplest possible shape.)

The surface of some insignificant planet	The center of some insignificant star
The center of some insignificant galaxy	Someplace far from all stars and galaxies

   e. If we adopt this new standard, how must we modify the gravitational potential energy vs. distance graph that you sketched in 1b? (Make a new sketch.) *Do not contradict 2d.*

3. Suppose you sit on a swing and I push you a distance "d" from your equilibrium position:
   a. Have I done work on you? ____ -Have I given you some energy? ______
   b. Do you do the same amount of work on me when you push me "back to the starting position?____
   c. There must be a force acting on you, trying to restore you to the equilibrium position. Is it a "conservative" force? _______
   d. Would that force mentioned in 3c still exist if gravity were switched off? _____
   e. Would that force still be the same if the ropes were removed? ______
   f. If the ropes do not stretch, can they store any potential energy? _____
   g. Does your altitude change in 3b?___ -What kind of potential energy is involved in 3b?______

4. Let's create a formula for the change in gravitational potential energy of a person on a swing. Begin with a diagram: Label the upper end of the rope with an "O", label the person's equilibrium position as "A", label the person's new position "B".
   a. The person's displacement vector is represented by an arrow from ___ to ___.
   b. Draw a horizontal line through A and a vertical line through B. Label their intersection "C".
   c. Bisect angle AOB. Let "E" be the point where the bisector intersects AB.
   * d. Use similar triangles to create an equation relating the person's change in altitude to the displacement mentioned in 4a.
   * e. Use that equation to figure out how the person's change in gpe is related to her displacement from equilibrium. Define all of your symbols and abbreviations clearly. Remember to check units.

5. Compare the gravitational potential energy formula created in 4e with the elastic potential energy formula in #4 on RSVI. (Both should be in terms of displacement.)
   a. Sketch graphs of potential energy vs. displacement for each case.
   b. Do the graphs differ in shape?___ -How must the shapes of their derivatives compare?_____
   c. What can we conclude about the shape of the swing's restoring force vs. "d" graph?_____ ____
   * d. Use the similarity between the swing and the spring. create a formula for the slope of that graph in terms of m, g, and the length of the rope. Explain your logic. (If you are interested, you might enjoy testing the prediction experimentally.)
   * e. To find the relationship between restoring force and "d" by a different method, draw the vector sum of the person's weight and the rope tension. Show that this triangle is similar to the one formed by the rope and the displacement vector. Does that similarity agree with 5d? __

1. Suppose several forces act on an object. The "total force" acting on the object has already been defined as the ______ _____ of those forces. (Copy from your own writing on RS III.)
   a. If the object's velocity is constant then the total *force* on it must be ____ _______.
   b. The total *work* done on the non-accelerating object by those forces must be ____ ___.
   c. When an object is not accelerating its kinetic energy ______ change. (must, may, cannot)
   d. Do the answers to 1a, 1b, and 1c agree with each other? ____ -Do they have the right units? ___

2. A 3.00-newton forward force was used to drag a brick 2.00 meter at constant velocity.
   a. How much work was done by the person who exerted that forward force on the brick? ____ ___
   b. The *total* work done on the brick was _____ ____. -Does 1b agree? ___
   c. How much work was done on the brick by the *friction* force? ____ ___
   d. Add the work done by the forward force and the work done by the friction force: ___ ___
   e. Does 2d contradict 2b? ____ (If so, please explain why that doesn't bother you.)

* 3. Show that the total work done in accelerating an object from one velocity to another is equal to the object's change in kinetic energy. Then *save* this "**Work-Energy Theorem**" for future reference.
   a. Must the speed vs time graph be linear? ___ -Do non-linear speed-time graphs violate the energy conservation law? ___ ** Please explain how you know.*
   b. Show that the theorem is dimensionally consistent for both SI and British units. (Use the short definitions of the "newton" and "slug" on RS V.)

4. Name the kind of energy that an object *gains* while falling freely downward: _______ ______
   Name the kind of energy that it *loses* while falling: _____________ __________ ______
   Is there any change in its *total* energy while falling freely? ___ -Is that conclusion still valid if the object is coasting upward after being thrown? ____ *If not, please explain.* (Saved in #__ on RS VI.)

5. When an object slides to a stop on a level surface its _______ energy is converted into _______, as in #7 on page 59. What happens to the *total* energy in this example? _______ Does #9 on RS III agree?

6. In #4 you saw how potential energy can easily be transformed into kinetic energy, and you saw how *that* process is easily reversed. Can you think of any efficient way to reverse the transformation process described in #5? ____ ** If so, please explain your idea on the back of this paper.*

7. Can you think of a process in which total energy is *not* conserved? ____ ** If so, please describe it.*

8. The sum of kinetic and potential energies is a conserved (constant) quantity only in systems which do not generate any other forms of energy such as _______ energy, as in #___ on this page. This means that only forces from a certain category can be allowed in such systems. What *name* did we give to that category on page 60b? (Copy it from RS VI.) ___________ _______

9. Imagine one end of a long rope tied to a high tree limb or to the ceiling of a gymnasium. The other end hangs without touching the ground. An athlete runs toward the rope, grabs it, and swings as high as possible. Let's pretend that the rope does not stretch and its mass is small enough to ignore.
   a. Does the rope do any work? ______ Does this answer contradict #4 on RS VI? ___
   b. While coasting upward the runner's kinetic energy is converted into __________ _________ energy.
   * c. How can you use the running speed to predict the gain in altitude? (Use #3, 7, & 9 on RS VI.)
   * d. Estimate your own best running speed and use that value to predict how high you would go.
   e. A two-percent increase in speed would cause a ____-percent increase in height. (See 17f on RS II.)
   * f. What must we measure to test the equation used in making that prediction? (See 9g on page 61.)

10. If we increase an object's speed by 1% then the object's kinetic energy must ___crease by ___%
    If we increase a spring's amount of stretch by 1%, its elastic potential energy ___creases by ___%. *Illustrate your answers with numerical examples.* (Use 17f on RS II with 4 & 7 on RS VI.)

11. A good pitcher can throw a 0.15-kg baseball at nearly 100 mph.
    * a. Using #3 above and #7 on RS VI, show how the work done by the pitcher on the ball is estimated.
    b. Does the pitcher exert any forward force on the ball after it has left his hand? ____
    c. Estimate how far the ball moves while the pitcher's hand is propelling it forward. ___ ___
    * d. Estimate the force exerted on the ball by the pitcher in newtons *and* in pounds. (Use 11a & 11c.)
    * e. How high will the ball go if thrown straight up at 100 mph in a vacuum? (Use #3, 7, & 9 on RS VI.)
    f. Did you round off all of the answers on this page properly? ____ If not, please explain.