1. "Power" is the rate at which work is done, or the rate at which energy is transformed from one kind into another. Power must then be the slope of a tangent line on a graph of _______ or ________ vs. time.
   a. Write that definition concisely, using conventional symbols. (See #14 on page 54b.) P = ____
   b. Suppose an object is accelerated so that its kinetic energy is proportional to the square root of time. Sketch graphs of KE vs time and power vs time for this motion. (See page 29.)

2. By definition, a power unit must be a _______ unit divided by a _______ unit.
   a. In SI, power must be expressed in _______ per ______.
   b. In the old-fashioned British engineering system of units power must be in _______ per______.
   c. In the ancient "cgs" system of units, power must be in __________ per ____. (See 2e on RS V.)
   d. One "Watt" = one ______ per ______. One "horsepower" = 746 _____ or 550 ______ per___.

3. A "kilowatt" is a unit of ______, so a "kilowatt-hour" must be a unit of ______. (power, force, energy, time, speed) Using SI units, one kW-hr must be the product of ______ watts and _______ _____.
   a. Using scientific notation (and using 2d) we conclude that **one kilowatt-hour =** _______ ___.
   b. Use the information on a recent electric bill to find the price of one kW-hr. of electrical energy.

4. You use your strongest muscles when you climb stairs. It takes about ___ seconds to climb a flight of stairs to a height of about ___ meters. The average force with which you push down on the stairs while climbing is roughly ____ pounds, or ____ N. (See #8 on RS IV.) *Round off estimates properly.*
   a. To calculate the work done, you ______ that force by that distance. Using SI, **W =** _____ ___.
   b. To estimate your power, you must ______ that work by the time interval: **P =** _____ ___
   c. Solve eq. 4b for Δt. Then use it with the data in #3a and 4b to estimate the amount of time (in hr.) required for you to do *one kW-hr* of work. (Show how on the back.) **Δt =** _____ **hr.**
   d. For this kind of labor we should expect to pay roughly ____ dollars per hour, or $____ for one kW-hr.
   e. Conclusion: Human labor is *roughly* _____ times more expensive than electrical energy.

5. On page 52b we found that a small car travelling on a level road at 60 mph (88 ft/sec) has to overcome roughly 50 pounds of drag force and another 50 pounds of rolling friction. Such a car can be driven roughly ___ miles with one gallon of gasoline, which costs roughly $____ .
   * a. Show how that information is used to estimate the cost of work done with a gasoline engine.
   * b. Compare your result with the price of electrical energy found in 3b.

6. Choose a time interval arbitrarily and use it to answer these questions: (Use scientific notation.)
   a. How far does the car in #5 go during that interval? (____ ft/sec)(____ sec) = _____ ft.
   b. How much work is done by its engine? (_____lb)(____ ft) = _______ ft-lb.
   c. How much power did the engine develop? (____ ft-lb) ÷ (____ sec) = _______ ft-lb/sec.
   d. According to 2d, one horsepower = _____ ft-lb/sec, so the car uses _____ hp when cruising.
   e. Do you get a different engine power if you repeat 6a-d with a shorter time interval? _____

7. Notice that the engine power in #6 was calculated from the propelling force and the speed.
   a. Simplify that procedure on scrap paper, reducing it to a simple equation: **P =** ____
   b. In 7a the letter "___" represents power, "__" represents propelling force, and "___" represents speed.
   c. Show that this new power formula gives results with correct units.
   d. Equation 7a and the definitions in 7b have been copied into #___ on RS __. *Did you check units?*

8. An accelerating automobile's speed-time graph often resembles a square-root curve. Sketch it, as in 1b.
   a. That means its speed is roughly proportional to ____. In equation language, ___ = _____.
   b. In that equation the letter "__" represents a proportionality constant, and "__" represents time.
   c. The slope of tangent line at any point on the graph represents ________________. (See RS II.)
   d. Using equation 8a with #17f on RS II, we find that the slope can easily be calculated *from the quantities mentioned in 8b*: Slope = ___ *Did you check units?* _____
   e. If we multiply such a slope by the mass of the car then the product should be called ________.
   * f. *Use #12 on RS VI* to show how the engine power can be calculated from m, t, and the constant in 8b.
   g. Eq. 8f says the power ___________ as the car accelerates. (increases, decreases, remains constant)

9. (Extra Credit) Using 2d, estimate how much time it takes a horse to do one kWh of work. Then estimate how much it costs on average to feed and care for a horse for that amount of time. Use those results to compare the price of horse energy with that of gasoline. Explain your estimate clearly.

We often need to create an equation describing the *derivative* of a function. For example. in #8 on page 64 we had an equation describing a car's speed-time graph and we needed to transform it into a new equation describing the car's *acceleration* vs time graph. If you are taking calculus then you already know that mathematical trick. If not, you still have all the clues you need to figure it out:

1. If the car is being driven along a linear path, its instantaneous acceleration is just the slope of a _______ line on the speed-time graph, as in 8c on page 64.

2. The slope of such a line is the same as the slope of a chord connecting two points which are very close together on the curve, because a very short segment of any curve resembles a ______ line.)

3. The speed difference between those two points can be called "ΔS". The time difference is "Δt". To calculate the slope of the line connecting those points we must ____________ the ______ by the ____. (Please use the given symbols.)

4. Let "T_1" represent the time coordinate of one of those points on the graph. To make sure that the two points are really close together, our Δt value must be a very _____ percentage or fraction of T_1. For example, if T_2 is "1% greater than T_1" then T_2 = (____)T_1, and ΔT = (___)T_1.

5. We know that ***if*** the speed is proportional to the *time with some exponent* then the fractional or percentage change in speed must be equal to the corresponding fractional or percentage change in _______ multiplied by the _________. (That theorem is recorded in 17f on RS II.)

6. According to the given information reviewed in #5, that speed is equal to a constant multiplied by ____ with an exponent. What letter will represent the constant? ____ (It's your choice!)
   a. In #8 on page 64 the exponent was ____, so the equation of the speed-time graph is S = _____.
   b. In that equation the letters S and ___ represent variables, and __ represents a constant.
   c. Let "S_1" represent the speed that the object had at time T_1. (Please illustrate.)
   d. If $S_1 = k(T_1)^{1/2}$ then #4 tells us that $S_2 = k[($___$)T_1]^{1/2}$, or S_2 = (______)$(k)(T_1)^{1/2}$.
   e. By definition, $\Delta S = S_2 - S_1$ = ________ - ______ . (Use 6d.)
   f. When simplified, that becomes ΔS = (_______)$(k)(T_1)^{1/2}$

7. Now it's time to use the definition of acceleration: Use the time interval that you described in #4, and the change in speed that you described in #6f: a = (________) ÷ (_____) = _____

8. Does eq. 7 describe the car's acceleration vs time graph? ___
   If so, sketch the graph. If not, explain.

9. Does eq. 7 correctly describe *all* graphs of acceleration vs time? __ (It is valid only if S = ___.)

10. Is it possible to generalize the method described on this page so that it will work for *any* exponent? If so, show how by filling in the blank below. *Do not contradict #7.*

Differentiation rule: If an equation with the form $y = kx^n$ describes some graph, then its derivative will be described by the equation y´ = _____.
To get credit you must prove that this trick is valid.

11. A good way to check a newly-discovered rule like this is to test it on a familiar example:
    a. We know from chapter II that an object falling freely from rest has constant acceleration, so that its displacement-time graph is described by: $D = at^2/2$.
    b. The variables in that equation are "D" and "___". The proportionality constant is "___".
    c. If we *differentiate* that D-t graph, the result will be a graph (and equation) of _____ vs ______.
    d. The differentiation rule (when applied to this example) says we must change the exponent from ___ into ___, and we must __________ the proportionality constant by ___.
    e. The result is: __ = _______. -Is that a familiar result? _____ -Does it agree with RS II? ___
    If not, you need to invent a different rule in #10.