

- * 1. On page 88 we measured the conversion factor for converting energies from calories to SI units. Briefly describe one of the ways in which James P. Joule measured it. Please copy the most precise result that you can find onto this paper *and* onto RS IX. *Give credit to your source.*
2. Imagine repeating the electrical heating experiment with an electric motor instead of a resistor. The motor is placed in water and is used with a pulley system to lift an object at a steady speed.
- Let "___" represent the rate at which electrical energy is delivered to the motor. Let "___" represent the rate at which heat energy is generated, and let "___" represent the rate at which work is done.
 - Obviously the rate called ___ must be greater than either of the other two rates.
 - All three rates can be measured in _____ s or in _____ per _____. (Copy from RS IX.)
 - Using those symbols, write the equation which relates the three rates. *Don't contradict 2a or 2b.*
3. Now imagine using a light bulb instead of the motor. The container is transparent so that light can escape when the bulb is turned on. At 110 ± 0.5 volts the current is $1.00 \text{ amp} \pm 0.5\%$. The water mass is 100 ± 0.5 grams. Its temperature increases at 0.250 celsius degrees per second.
- At what rate does light energy escape? Using #1 & 2, *show* how you get your answer in SI units.
 - Determine the "efficiency" of the light bulb, i.e. the ratio of useful output power to input power:

$$\left(\frac{\text{_____}}{\text{_____}} \right) \div \left(\frac{\text{_____}}{\text{_____}} \right) = \text{_____} \pm \text{_____} \%$$
 - A more efficient light bulb with the same input power would produce _____ heat. (more, less)
4. An electric teapot heats about 0.8 liters of water from 20 degrees celsius to the boiling point in _____ minutes. Use scientific notation (if appropriate) to *estimate* the following. *Round off properly.*
- * a. How much electrical energy does the teapot consume if it operates at 110 volts?
 (Show how you get your answer, as in 3ab. Express it in joules, calories, and in kilowatt-hours.)
- Use #13 on RS VI to estimate the cost of that energy: (_____)(_____) = _____
 - How much current must it use? (Use #14 on RS IX. *Show* how you do it.) _____
 - Imagine using the same amount of energy to lift a load of bricks onto a shelf two meters above the floor. Estimate the weight of the bricks in SI units. $\left(\frac{\text{_____}}{\text{_____}} \right) \div \left(\frac{\text{_____}}{\text{_____}} \right) = \text{_____}$
5. A certain motor vehicle weighs 5000 N and carries enough fuel to do 10^6 J of work.
- Calculate the maximum altitude it can reach when driven uphill: _____
 - Let "mg" represent the car's _____, as on RS III. Let "___" represent the given amount of _____. Let "h" represent the height. Using those symbols, write the formula employed in 5a: $h = \text{_____}$
6. One gallon of gasoline weighs about 6 lb. and yields about 125 megajoules of energy when burned. On page 66b we found that an engine can convert that heat into roughly 22 megajoules of work.
- The rest of the energy supplied by the gasoline is dissipated in the form of _____.
 - Show how the engine's efficiency is calculated from the given data. (Use 3b.)
7. A conventional automobile has a fifteen-gallon fuel tank. Use SI units and scientific notation:
- How much work can its engine do before running out of fuel? (Use #6.) _____
 - The car weighs about 2200 lb. In SI its weight is about _____, and its mass is about _____.
 - Use 5b to estimate the greatest altitude it can climb to, in meters and in miles. (Show how.)
 - Use #7 on RS VI to estimate the speed that such a car could reach if it used all its fuel to accelerate from rest with no drag forces to impede its motion.
8. A 12-volt car battery weighs about 40 pounds and stores about 0.8 kW-hr. Million-dollar batteries can do about four times better. Use scientific notation to ESTIMATE the following. (Show how.)
- For roughly how many hours can the ordinary battery last if you leave a ten-amp set of lights on? _____
 - How many ordinary batteries are needed to store the energy equivalent to one gallon of gasoline?
 - That set of batteries will weigh about _____ lb. The gallon of gasoline weighs _____. (Use #6.)
 - A certain electric car has 10 batteries like the one described above. How much energy can that set of batteries deliver? (Use the given clues.) _____ Even if the car's engine, body, and passengers had no weight at all the battery pack would still weigh about _____ lb. or _____ N.
 - Roughly how high could this "ideal" electric car climb? (Use 5b.) _____ = _____ miles
 - Show how this car's theoretical top speed is estimated. Then compare it with 7d.
 - How would 8c - 8f be affected if we doubled the number of batteries? *Please explain.*

4. The density of water is ___ gram per milliliter. (That's the definition of a "gram".)
 There are ___ milliliters in a liter. (That's the definition of "milli".)
 To get the water mass we can _____ the given volume (in ___s) by ___ per _____.
 The result is (____) (____) = _____
 The given change in temperature is (____) - (____) = _____ C.

a. To calculate the heat energy delivered to the water we must _____ the water mass (in ___s) by the _____ in temperature:

$$(\text{____}) (\text{____}) = \text{_____}$$

To convert that result to SI units we must _____ it by ___ J per ____.

The result is _____.

To convert that result to kilowatt-hours we must _____ it by the number of joules in one _____, which you recorded in #1 on page 89:

Insert the correct sign, check units, and round off properly!

$$(\text{_____ J}) (\text{_____ J/kWhr}) = \text{_____}$$

b. In #13 on RS VI you recorded the price of electrical energy:

"One kWhr costs about _____."

To get the cost of the energy used in heating the water you must _____ the amount of energy used (in kWhr) by that price: *Insert the correct sign, check units, and round off properly!*

$$(\text{_____ kWhr}) (\text{_____ \$ per kWhr}) = \text{_____}$$

c. #14 on RS IX says that the electrical energy can be calculated with the equation **Energy** = _____. This question asks us to solve that equation for the unknown _____, so the new equation says _____ = _____.

Then we plug in the known values of the energy (in _____), the time interval (in _____), and the given _____.

Show how:

8b. The energy in one gallon of gasoline is given as _____ Megajoules.

To convert that amount to kWhr, we _____ by _____ MJ/kWhr.

The energy in one gallon is _____ kWhr.

The energy in one battery is given as _____ kWhr.

This question asks you to _____ those two amounts. *Show how.*

8c. Now we must _____ the weight of one battery by the number of _____s, which we found in 8b.

Note: This page asks for estimates.

Estimates should not have many bogus digits. Please round off properly!

1. In terms of hill-climbing ability, the _____ car in # ___ on page 89 is roughly ____ times better than the _____ car in # ____.
2. Battery-powered vehicles are often said to be “pollution-free”. People who make such claims seem to forget that the energy used to charge their car batteries must have a source.
 - a. What is that source?
 - b. Is it really pollution-free?
3. On page 89 we found that switching over to electric vehicles would require us to use heavier cars.
 - a. Will that cause our annual consumption of coal, oil, and uranium to decrease, or to increase?
 - b. Will that result in less pollution, or more?
4. In selecting batteries for future electric vehicles, it is important to consider their “energy density”, which could be expressed in joules per kilogram. (It could also be expressed in Watt-hours per kg., or kW-hr/kg., but why make it more complicated?) According to the May, 1992 issue of SCIENTIFIC AMERICAN, the energy density of a conventional “lead-acid” storage battery is roughly 1.4×10^5 J/kg. A new type, described in the New York Times, (4/6/95) is roughly four times more expensive and has roughly 50% greater energy density.
 - a. How high can it climb, and how fast can it go?
 - b. Are those results as good as a gasoline engine? (See page 89.)
 - c. How safe is it for the environment to have a ton of lead and sulfuric acid spilled on the road whenever there is a major collision?
5. The energy density of a conventional “alkaline D cell” (used in flashlights, not rechargeable) is roughly 3×10^5 J/kg. How high can an ideal “energizer bunny” climb, and how fast can it go?
6. Rechargeable “nickel-cadmium” cells have considerable smaller energy density, and contain extremely toxic chemicals. Nickel-metal hydride (Ni-H) cells used in laptop computers have better energy densities (roughly 3×10^5 J/kg) but are extremely expensive. A new type of “Sulfur-Aluminum” battery now under development has an energy density of roughly 8×10^5 J/kg. How high can it climb, and how fast can it go?
7. Various sodium and lithium batteries are under development with energy densities roughly five times greater than conventional lead-acid batteries, and with roughly the same cost per unit of energy storage capacity. Unfortunately, they require operating temperatures higher than 600 degrees Fahrenheit, and spectacular fireworks are produced whenever sodium or lithium come into contact with water. Perhaps Venus or Mercury might be good places for those batteries.
8. Use the data in #6 on page 89 to calculate the energy density of gasoline. How does it compare with the batteries discussed above?
9. A “hybrid” car has a battery pack that can run its electric motors for 50 to 100 miles and a small gasoline or diesel powered generator to recharge them whenever necessary. The small engine which runs the generator can run steadily at its most efficient rate, so that its power only has to match the car’s *average* power requirement, instead of the peak value. What advantages and disadvantages does this system have?