Homework 1

Practice with rates, unit conversion factors, efficiency fractions

Due Friday January 12th at 5pm

Instructions

You will be graded on how you explain your logic, how you check your units, the order of magnitude of your numerical answers, and how you make sense of your answers. These are meant to be approximate calculations. It is fine if your numbers are 30% higher or 30% lower than what is given in the model answers. For extra guidance on this type of question, see the two videos: https://media.oregonstate.edu/media/t/0_pay9ftjz https://media.oregonstate.edu/media/t/0_48aucv3m

1. Piano tuners in Chicago

In a fabled story about Enrico Fermi (famous physicist), Fermi was asked how many piano tuners there are in Chicago. Fermi did some mental arithmetic and quickly answered the question with surprising accuracy. He multiplied the population of Chicago by his best guesses of 5 different rates (or the inverse of these rates). These rates included:

- persons per household
- hours of work per piano tuning job
- total hours worked by a piano tuner per year

a) Describe the two other rates that Fermi needed for his estimate

b) Try doing the calculation yourself.

Note: Fermi was fluent in thinking this way. He used these techniques everyday in his job as a physicist.

2. Nuclear energy

The fission of one atom of uranium-235 gives off energy of approximately 3 x 10^{-11} J. This energy goes into heating the reactor core of a nuclear power plant. A typical nuclear power plant "burns" uranium-235 at a rate of 4 kg per day. The atomic weight of uranium-235 is part of its name, i.e. 235 g/mol. The heat from fission is converted to electrical energy with an efficiency fraction of 0.3 (i.e. 0.3 J of electrical energy per 1 J of heat energy). What is the electrical power produced? Give your answer in Watts (or kW, or MW or GW or TW).

3. Tea kettle

The specific heat capacity of water is 4.2 J/(g·K). A tea kettle adds heat to the water at a rate 1000 J/s. If there is 1 kg of water in the kettle (4 cups of water), calculate the rate that the temperature rises. Give your answer in units of Kelvin/s.

Sense-making: Put it in context - At this rate, how long would it take to heat up a kettle for making tea? Does this seem like a realistic number?

4. Wave energy

The rate that deep-water ocean waves carry energy across an imaginary line in the ocean (**energy** per **time** per **length**) is

$$\frac{1}{4}\rho g h^2 v$$

where ρ is the density of water, g is acceleration due to gravity, h is the height of the wave crest compared to flat water, v is the velocity of the wave crest. If you use SI units, the final quantity has units of J/(s·m). Note that the length is measured perpendicular to the direction that the waves are traveling. This equation is derived on page 307 of "Sustainable Energy" by David McKay.

A good device for harvesting wave energy can achieve an efficiency fraction

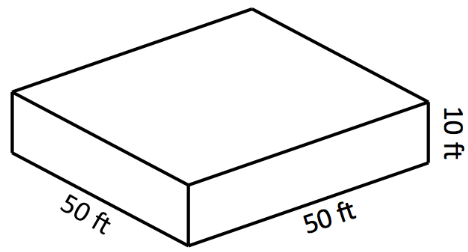
$$\frac{0.5 \text{ J (electrical energy)}}{1 \text{ J (wave energy)}}$$

Assume that typical Oregon deep-water waves have v = 15 m/s and h = 1 m. Estimate the electrical energy per day per capita that Oregon could capture if we built wave farms along the entire coast. Express your answer in units of kWh/day per person.

Useful unit conversion factor: 1 kWh/day = 42 J/s.

Sense-making: Make a Comparison - How does your answer compare to other methods of power production (per capita) that we calculated in class or in question 2? Does harvesting wave energy seem like a viable alternative?

5. Heat loss from in a single-family home in winter



A typical house is thermally insulated with R-15 wall and a R-30 ceiling. Translating the R-values in standard-international (SI) units.

$$\text{Walls:} \quad 0.4\ \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$

$$\text{Ceiling:} \quad 0.2\ \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$

Based on the units listed above, and the context (thermal insulation), you can visualize their meaning of these rates. For example, if there is a 1 K temperature difference between inside/outside the house, a wall area of 1 m^2 will leak energy at a rate of 0.4 W. Doubling the temperature difference, or doubling the wall area, will double the leak rate.

If indoor temperature is 300 K, and the outdoor temperature is 270 K, how fast does heat energy leak out of the house (Joules/second)?

Sense-Making: Put it in context - How many small, portable heaters are needed to heat this house? (Assume the heaters convert electrical energy to thermal energy with an efficiency fraction of 1 and a rate of 1 kW). Does this seem like a realistic number of heaters?