

# Fermi Questions

Larry Weinstein, Column Editor  
Old Dominion University, Norfolk, VA 23529;  
weinstein@odu.edu

## Answers to November 2009 Questions

### Question 1: Gym Power

How much energy would the U.S. generate per year if we connected all of our stair-steppers, rowing machines, treadmills, etc to electrical generators? How much money would one person save by generating their own electricity that way? Assume that the number of people working out does not change when we do this. (Thanks to Chuck Adler of St. Mary's College of Maryland for the question.)

**Answer:** To answer this we need to estimate the power output per person, the time spent working out, and the number of people working out. There are a few ways to estimate the power output. You can visit a science museum that has a stationary bicycle connected to generators and electric light bulbs. The brightest possible bulb is almost always 100 W. You can start with our basic metabolic rate of 100 W (2500 kcal per day) and assume that vigorous exercise would double that. Or you can time your students as they run up six flights of stairs and use  $P = mgh/t$ . All of these methods will give answers that are definitely greater than 10 W and less than 1 kW (or 1.4 horsepower) so we won't be too incorrect if we use 100 W.

The people who work out using exercise equipment probably work out about two hours per week (more than one and less than five). The proportion of the population that works out is almost certainly more than 1% and less than 100% of the population so we will estimate 10% or  $3 \times 10^7$  Americans.

This means that the electrical energy that we could generate per year would be

$$E = (100\text{W})(2 \text{ hr/wk})(50 \text{ wk/yr})(3 \times 10^7)$$
$$= 3 \times 10^{11} \text{ W-hr} = 3 \times 10^8 \text{ kW-hr}$$
$$= 1 \times 10^{15} \text{ J}$$

This looks like a large number. It is a large number. It is equivalent to 100 kilotons of TNT.

But let's look at it in a little more detail.

Let's assume that you are one of the hard-working people who work out two hours per week. In one week, you will generate 200 W-hr of electricity or 0.2 kW-hr. At \$0.10 per kW-hr, you will have saved approximately two cents. This will hardly pay for the generator needed to convert your hard work into electrical energy.

I guess this is what people mean when they refer to 'putting your two cents in.'

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### Question 2: Hair Clippings

What is the total length of all cranial hairs clipped in the United States every day?

**Answer:** To answer this question, we need to estimate how much each hair grows daily, the number of hairs per person, and the number of people who get their hair cut. My beard grows a noticeable fraction of a millimeter every day (more than 0.1 mm and less than 1 mm) and my hair grows about 1 cm per month (which would be about 0.3 mm per day). These numbers are consistent so I will use 0.3 mm/day.

A typical head has about  $10^5$  hairs (more than that for very fine hair). We can estimate this from the area of a head and the hair density. The area of my scalp is about four times the area of one of my hands, which is 10 cm by 15 cm. Thus, my hairy head area (not including my beard) is about  $6 \times 10^2 \text{ cm}^2$ . You can ask a very good friend to let you closely examine their scalp to estimate their hair density. At more than 1 hair per  $\text{mm}^2$ , this will give more than  $6 \times 10^4$  hairs, which is pretty close to the accepted number. I will assume that the effects of beards and bald spots cancel each other and I will completely neglect armpits and legs.

There are  $3 \times 10^8$  people in the United States and almost all of them have their hair cut (rather than letting it grow to its maximum length and then fall out). Thus, the total length of hair cut daily is

$$L = (3 \times 10^{-4} \text{ m/day})(10^5 \text{ hairs/head})(3 \times 10^8 \text{ heads}) \\ = 10^{10} \text{ m/day.}$$

That is 25 times the distance from the Earth to the Moon. Think what a rope we could weave! On an individual basis, we each grow about 30 m of hair per day. That is still a lot.

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