PHYS 1211 *University Physics I* — Problem Set 1

Winter Quarter, 2007 — SOLUTIONS

Instructor

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Fermi Problems

I picked the following four Fermi Problems:

1. How many bricks are in University Hall?

   Assume:
   - A simple rectangular building (try to make it slightly larger to take curved parts into account)
   - We are counting only exterior bricks.
   - U. Hall is 100 meters by 60 meters, 3 stories tall, and that each story is 7 meters (roughly 20 m total height)
   - Each of these rather large bricks is 1/2 m wide and 1/4 m tall

   Then: The total wall surface area is:

$$2(100 \text{ m} \times 20 \text{ m}) + 2(60 \text{ m} \times 20 \text{ m}) = 6400 \text{ m}^2 \cdot 0.125 \, \frac{\text{brick}}{\text{m}^2} = 51,200 \text{ bricks}$$

4. How many miles of Interstate highway are there in the continental United States?

   Assume:
   - The U. S. is a rectangle 3500 miles East-West by 2500 miles North-South.
   - There are roughly 6 main East-West interstate routes
   - There are roughly 10 main North-South interstate routes

   Then:

$$6(3500 \text{ miles}) + 10(2500 \text{ miles}) = 46,000 \text{ miles}$$

6. How much money was Todd Helton (the first baseman for the Colorado Rockies) paid per swing last baseball season?

   Assume:
   - Helton was paid roughly $12 Million last year
   - We will count swings only in a game, assuming he doesn't get paid to practice.
   - He played in all 162 games, and had 5 plate appearances (PA) in each game
   - The number of swings per plate appearance is a bit tricky, since good hitters tend to foul off many pitches if they get to a 2 strike count. We will say he swung on average 5 times per PA.

   Then:

$$\frac{12 \times 10^6 \text{ dollars}}{\text{season}} \cdot \frac{1 \text{ season}}{162 \text{ games}} \cdot \frac{1 \text{ game}}{5 \text{ PA}} \cdot \frac{\text{PA}}{5 \text{ swings}} \approx 3,000 \, \frac{\text{dollar}}{\text{swing}}$$

7. How many times has Britney Spears performed the song "Oops...I did it again" live?

Assume:
- The song debuted in roughly 2000, though I wasn't paying much attention...
- In those 6 years, assume Britney toured about 3 times.
- Each tour runs for 3 months, during which Britney performs 4 nights a week
- Each performance includes "Oops..."

Then:

$$3 \text{ tours} \cdot \frac{3 \text{ months}}{\text{tour}} \cdot \frac{4 \text{ weeks}}{\text{month}} \cdot \frac{4 \text{ concerts}}{\text{week}} \cdot \frac{1 \text{ Oops}}{\text{concert}} \approx 140 \text{ Oops}$$

Halliday, Resnick, and Walker (HRW), Chapter 1

1. How many microns in 1.0 km?

$$1 \text{ km} \cdot \frac{1000 \text{ m}}{1 \text{ km}} \cdot \frac{10^6 \ \mu\text{m}}{1 \text{ m}} = 1 \times 10^9 \ \mu\text{m}$$

What fraction of a centimeter is a micron?

$$1 \ \mu\text{m} \cdot \frac{10^{-6} \text{ m}}{1 \ \mu\text{m}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} = 1 \times 10^{-4} \text{ cm} = \frac{1}{10,000} \text{ of a cm}$$

How many microns in a yard?

$$1 \text{ yd} \cdot \frac{36 \text{ in}}{\text{yd}} \cdot \frac{1 \text{ m}}{39.4 \text{ in}} \cdot \frac{10^6 \ \mu\text{m}}{1 \text{ m}} = 913,706 \ \mu\text{m}$$

5. Earth is a sphere with radius $R = 6.37 \times 10^6$ m $= 6.37 \times 10^3$ km

a) Circumference in km?

$$2\pi R = 4.00 \times 10^7 \text{ m} \cdot \frac{1 \text{ km}}{1000 \text{ m}} = 4.00 \times 10^4 \text{ km}$$

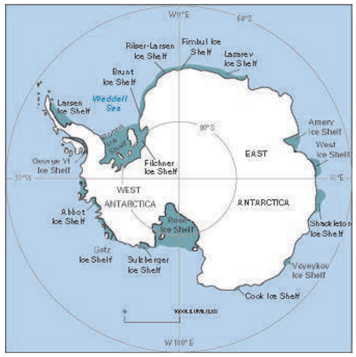
b) Surface area in km^2?

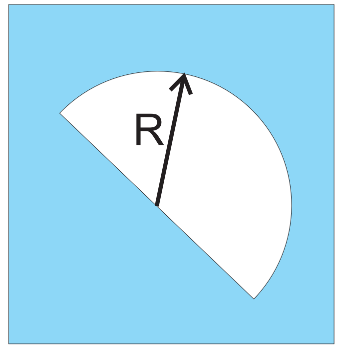
$$4\pi R^2 = 4\pi(6.37 \times 10^3 \text{ km})^2 = 5.10 \times 10^8 \text{ km}^2$$

c) Volume in cubic kilometers?

$$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi(6.37 \times 10^3 \text{ km})^3 = 1.08 \times 10^{12} \text{ km}^3$$

7. Antarctica is roughly semicircular, with radius ~ 2000 km, and is 3000 meters thick what is its volume in cm^3?





We assume Antarctica is a half-cylindrical slab of ice, as seen from above in the sketch. $R = 2000$ km $= 2 \times 10^8$ cm and $t = 3000$ m $= 3 \times 10^5$ cm. The volume is then:

$$V = \frac{1}{2}\left(\pi R^2 t\right) = \frac{1}{2}\left(\pi \left(2 \times 10^8 \text{ cm}\right)^2 \cdot 3 \times 10^5 \text{ cm}\right) = 1.3 \times 10^{25} \text{ cm}^3$$

9. When 2.0 inches of rain falls on a 26 km^2 area, how many acre-feet of water?

First, realize that 2.0 inches on 26 km^2 is the same volume as 12 inches on 26/6 km^2 (= 12 inches on 4.3 km^2). So how many acres is 4.3 km^2?

$$4.33 \text{ km}^2 \cdot \left(\frac{1000 \text{ m}}{1 \text{ km}}\right)^2 \cdot \frac{2.471 \text{ acre}}{10^4 \text{ m}^2} = 1.1 \times 10^3 \text{ acre}$$

So we have 1.1×10^3 acre-feet of water.

11. How many microseconds in a fortnight?

$$2.0 \text{ week} \cdot \frac{7 \text{ day}}{\text{week}} \cdot \frac{24 \text{ hour}}{\text{day}} \cdot \frac{60 \text{ min}}{\text{hour}} \cdot \frac{60 \text{ s}}{\text{min}} \cdot \frac{10^6\ \mu\text{s}}{1 \text{ s}} = 1.2 \times 10^{12}\ \mu\text{s}$$

12. a) How long is a microcentury in minutes?

$$1\ \mu\text{century} \cdot \frac{1 \text{ century}}{10^6\ \mu\text{century}} \cdot \frac{100 \text{ yr}}{1 \text{ century}} \cdot \frac{365.4 \text{ days}}{\text{yr}} \cdot \frac{24 \text{ hour}}{\text{day}} \cdot \frac{60 \text{ min}}{\text{hour}} = 52.6 \text{ min}$$

b) What is the percentage difference between 50 min and a microcentury?

$$\%\text{ difference} = \frac{(\text{actual} - \text{approximate})}{\text{actual}} \times 100 = \frac{52.6 \text{ min} - 50 \text{ min}}{52.6 \text{ min}} \times 100 = 4.9\%$$

14. The period of the pulsar is 1.5578×10^{-3} seconds.

a) How many rotations per week?

$$\frac{7.00 \text{ days}}{\text{week}} \cdot \frac{24 \text{ hours}}{\text{day}} \cdot \frac{3600 \text{ seconds}}{\text{hour}} \cdot \frac{1 \text{ rotation}}{1.5578 \times 10^{-3} \text{ seconds}} = 3.88 \times 10^{8} \ \frac{\text{rotions}}{\text{week}}$$

b) How long does it take the pulsar to rotate 1 million times?

$$1 \times 10^{6} \text{ rotations} \cdot \frac{1.5578 \times 10^{-3} \text{ seconds}}{1 \text{ rotation}} = 1557.8 \text{ seconds}$$

c) What is the associated uncertainty? The uncertainty is $\pm 3 \times 10^{-14}$ ms per rotation. The total uncertainty in 1×10^{6} rotations is $1 \times 10^{6} \cdot 3 \times 10^{-14}$ ms $= 3 \times 10^{-11}$ s. So the associated uncertainty is ± 30 picoseconds.

16. How many degrees longitude in a time zone? The Earth has 360^{o} longitude and rotates roughly once every 24 hours. If each time zone is 1 hour apart, we have 24 time zones and $360^{o}/24 = 15^{o}$ per time zone.

23. The mass of the earth is 5.98×10^{24} kg. If the Earth is made up of atoms with average mass 40 u, how many atoms are in the Earth?

$$5.98 \times 10^{24} \text{ kg} \cdot \frac{1 \text{ u}}{1.661 \times 10^{-27} \text{ kg}} \cdot \frac{1 \text{ atom}}{40 \text{ u}} = 9.0 \times 10^{49} \text{ atoms}$$

49. How many habanero's needed to replace the jalapeños? We know we need 2 jalapeños per person, we have 400 people in the party, and that a jalapeño is 4000 SHU, and a habanero is 3×10^{5} SHU. So:

$$\frac{400 \text{ people}}{\text{party}} \cdot \frac{2 \text{ jalapeños}}{\text{person}} \cdot \frac{4000 \text{ SHU}}{\text{jalapeños}} \cdot \frac{1 \text{ habanero}}{3 \times 10^{5} \text{ SHU}} = 10.7 \ \frac{\text{habanero}}{\text{party}}$$

Probably easier to just use 11 habaneros and heat things up a tiny bit. Though my wife, who grew up in Texas, says just to use 800 habaneros...