

## PHYSICS 151 – Notes for Online Lecture #2

**Estimation** is a useful technique for getting an approximate answer and for determining whether the answer you get is reasonable. Estimation is useful when you don't have – or need – exact numbers. For instance, you might be painting a room and all you need to know is how many gallons of paint you need. Since you can't buy a quarter of a gallon of paint, you don't need to know precisely how many tenths of gallons are needed.

Physicists like to use the phrase “Order of magnitude estimate”. This just means that the number is correct to within a factor of ten. Here are three examples of estimation:

**EXAMPLE:** You are working for a radio station. The general manager wants to do a promotional stunt: if the Huskers go undefeated, she wants to fill Memorial Stadium with Oreo cookies. How much would it cost to do this?

**Solution:** First, estimate the length, width and height of Memorial Stadium. We'll approximate Memorial Stadium as a box. The field is 100 yds. long, plus about 20 yd. for each end zone, and some extra. Let's say about 150 yd.

$$L = 1.5 \times 10^2 \text{ yards of where they may were}$$

The width is about 100 yards (40 yards for the field, plus sidelines)

$$W = 1.00 \times 10^2 \text{ yards}$$

The height is about 20 yards.

$$H = 2.0 \times 10^1 \text{ yards.}$$

So the volume of Memorial Stadium is:

$$\begin{aligned} V &= L \times W \times H = 1.5 \times 10^2 \text{ yd} \times 1.0 \times 10^2 \text{ yd} \times 2.0 \times 10^1 \text{ yd} \\ &= (1.5 \times 1.0 \times 2.0) \times 10^{(2+2+1)} (\text{yd} \times \text{yd} \times \text{yd}) \\ &= 3.0 \times 10^5 \text{ yd}^3 \end{aligned}$$

Oreo cookies are about 2" in diameter and 1/2" thick.

$$r = 1" = 1 \text{ in} \left( \frac{1 \text{ ft}}{12 \text{ in}} \right) = \frac{1}{12} \text{ ft} \left( \frac{1 \text{ yd}}{3 \text{ ft}} \right) = \frac{1}{36} \text{ yd}$$

$$h = \frac{1}{2} \text{ in} \left( \frac{1 \text{ ft}}{12 \text{ in}} \right) = \frac{1}{24} \text{ ft} \left( \frac{1 \text{ yd}}{3 \text{ ft}} \right) = \frac{1}{72} \text{ yd}$$

$$V_{\text{oreo}} = \pi r^2 h = 3 \left( \frac{1}{36} \text{ yd} \right)^2 \left( \frac{1}{72} \text{ yd} \right) = \frac{3}{36 \times 36 \times 72} (\text{yd} \times \text{yd} \times \text{yd})$$

$$\begin{aligned}
& \frac{1}{12 \times 36 \times 72} \text{ yd}^3 = \frac{1}{10 \times 40 \times 70} \text{ yd}^3 \\
& \frac{1}{1 \times 10^1 \times 4 \times 10^1 \times 7 \times 10^1} \text{ yd}^3 \\
& \frac{1}{28 \times 10^3} \text{ yd}^3 \\
& \frac{1}{2.8 \times 10^4} \text{ yd}^3 \\
V_{\text{Oreo}} &= \frac{1}{3} \times 10^{-4} \text{ yd}^3
\end{aligned}$$

Now: how many cookies fit in the stadium?

$$\begin{aligned}
\# \text{ cookies} &= \frac{V_{\text{stadium}}}{V_{\text{Oreo}}} = \frac{3.0 \times 10^5 \text{ yd}^3}{\frac{1}{3} \times 10^{-4} \text{ yd}^3} \\
&= \frac{3.0}{\frac{1}{3}} \times 10^{5-(-4)} \\
&= 9 \times 10^9 \\
&= 1 \times 10^{10} \text{ cookies}
\end{aligned}$$

About 10 billion Oreos could fit inside the stadium. If you figure an average bag has about 100 Oreos for \$3.00, this stunt would cost.

$$1 \times 10^{10} \text{ cookies} \left( \frac{\$3.00}{1 \times 10^2 \text{ cookies}} \right) = 3 \times 10^8 \text{ dollars!}$$

**EXAMPLE:** What is the total weight of all the people in Lincoln?

Lincoln has approximately 200,000 people. Given the distribution of men, women and children, we might estimate that the average weight of a person is 130 lbs.

$$\begin{aligned}
\text{Total weight} &= 130 \frac{\text{lbs}}{\text{person}} \times 200,000 \text{ people} \\
&= 1.3 \times 10^2 \times 2.0 \times 10^5 \left[ \frac{\text{lbs}}{\text{person}} \text{ people} \right] \\
&= (1.3 \times 2.0) \times 10^{(2+5)} [\text{lbs}] \\
&= 2.6 \times 10^{(7)} [\text{lbs}] - \text{or, about } \mathbf{26 \text{ million pounds.}}
\end{aligned}$$

**EXAMPLE:** Approximately what fraction of the area of the United States is covered by automobiles?

We can approximate the Area of the US as a rectangle about 3000 miles wide and 1500 miles tall.

$$\text{Area}_{\text{US}} = 4,500,000 \text{ mi}^2$$

We can estimate the Area of a car as a rectangle 20 feet long and 8 feet wide for an area of  $160 \text{ m}^2$ .

$$\text{Area} = 160 \text{ m}^2 \left( \frac{1 \text{ mi}}{1609 \text{ m}} \right)^2 = 6.2 \times 10^{-5} \text{ mi}^2$$

And assume 1 car for every other person of the 300,000,000 people in the US for a total area for cars of:

$$\text{Area}_{\text{cars}} = (6.2 \times 10^{-5} \text{ mi}^2)(150,000,000) = 9,270 \text{ mi}^2$$

Thus, the fraction of the area covered by cars is:

$$\frac{\text{Area}_{\text{cars}}}{\text{Area}_{\text{US}}} = \frac{9,270 \text{ mi}^2}{4,500,000 \text{ mi}^2} \approx 0.002$$



How many times does a person's heart beat in their lifetime?

So far we have applied this technique to problems resembling games, like the number of gumballs in the gumball machine. However, it is much more than that as it can be applied to realistic physical systems. For example, lets look at collisions in astronomy.

Our solar system is one of approximately 100,000,000,000 in the Milky Way Galaxy. Our Milky Way Galaxy is one of approximately 100,000,000,000 in the Universe. Do stars in these galaxies every collide? Do galaxies every collide?

One way to look at this problem is to calculate the ratio of the size of a star to its separation from the nearest star to it. This is a simplification of true problem which would need to involve other variables such as the velocities of the stars.

$$\text{Star Ratio} = \frac{\text{Typical Star Separation}}{\text{Typical Star Diameter}} = \frac{(4.3\text{ly}) \left( \frac{9.46 \times 10^{15} \text{m}}{1\text{ly}} \right)}{1.4 \times 10^9 \text{m}} = 2.9 \times 10^7$$

$$\text{Galaxy Ratio} = \frac{\text{Typical Galaxy Separation}}{\text{Typical Galaxy Diameter}} = \frac{0.66\text{Mpc}}{30\text{kpc}} = 22$$

Thus, this calculation suggests that Galaxies do collide and astronomers can actually take pictures of this happening.