Phys 201A

Fall 2007

Homework 1 – Due Tuesday, October 2, 2007

Name ____________________________

Partners ____________________________

Show all steps clearly. Leave a line between answers to problems and questions.

Formulae for sphere: Circumference = $2\pi R$, Area = $4\pi R^2$, Volume = $\frac{4}{3}\pi R^3$

1. Earth is approximately a sphere of radius $6.37 \times 10^6$ m. What are
   a) its circumference in kilometers
   b) its surface area in square kilometers
   c) its volume in cubic kilometers

2. Antarctica is roughly semicircular with a radius of $2000$ km. The average thickness of its ice cover is $3000$ m. How many cubic centimeters of ice does Antarctica contain? (Ignore the curvature of Earth).
3. Hydraulic engineers in the United States often use, as a unit of volume of water, the acre-foot, defined as the volume of water that will cover 1 acre of land to a depth of 1 ft. A severe thunderstorm dumped 2.0 in of rain in 30 min on a town of area 26 km$^2$. What volume of water, in acre-feet, fell on the town?

4. In the United States, a doll house has the scale of 1:12 of a real house (that is, each length of the doll house is 1/12 that of the real house) and a miniature house (a doll house to fit within a doll house) has the scale of 1:144 of a real house. Suppose a real house (see below) has a front length of 20 m, a depth of 12 m, a height of 6.0 and a standard sloped roof (vertical triangular faces on the ends) of height 3.0 m. In cubic meters, what are the volumes of the corresponding

a) doll house

b) miniature house
5. The cubical dice that you use to play many games is approximately 1.0cm on an edge. If the dice are stacked into a cubical array, what is the length of the edges of the cubical array that contains Avogadro’s number of dice?

Avogadro’s number = $6.023 \times 10^{23}$ particles/mole

6. Cepheid variables are spherical stars that alternately increase and decrease their volume over time intervals ranging from days to weeks. If the volume of such a spherical star increases by 50% while in the expanding phase

a) by what factor does its radius increase?

b) by what factor does its surface area increase?

7a). What is the ratio of the surface area of the Earth, to the surface area of the Moon? Assume both are spherical and use the data on the inside covers of your textbook. Radius of the Earth = $6.37 \times 10^6$m, Radius of the Moon = $1.74 \times 10^6$m.

7b) Does your answer depend on the units used to measure the area? Explain.

7c) Calculate the ratio of the volume of the Earth to the volume of the Moon.
8) You may have seen or constructed a model of an atom. Suppose you model the nucleus with a marble that has a diameter of 1.0cm. Use the data on the inside cover of your book to determine the approximate diameter of the atom if your model is constructed to scale.

Diameter of the nucleus $\sim 10^{-14}$

Diameter of the atom $\sim 10^{-10}$

What does this imply about most models of the atom that you see?

Serway and Jewett: Page 18, problems 14, 16, 17.

14. Figure P1.14 shows a frustrum of a cone. Of the following mensuration (geometrical) expressions, which describes (a) the total circumference of the flat circular faces, (b) the volume, and (c) the area of the curved surface?

(i) $\pi(r_1 + r_2)[h^2 + (r_1 - r_2)^2]^{1/2}$  
(ii) $2\pi(r_1 + r_2)$  
(iii) $\pi h(r_1^2 + r_1 r_2 + r_2^2)$.

16. (a) A fundamental law of motion states that the acceleration of an object is directly proportional to the resultant force exerted on the object and inversely
proportional to its mass. If the proportionality constant is defined to have no dimensions, determine the dimensions of force. (b) The newton is the SI unit of force. According to the results for (a), how can you express a force having units of newtons using the fundamental units of mass, length, and time?

17. Newton’s law of universal gravitation is represented by

\[ F = \frac{GMm}{r^2} \]

Here \( F \) is the gravitational force exerted by one small object on another, \( M \) and \( m \) are the masses of the objects, and \( r \) is a distance. Force has the SI units kg \( \cdot \) m/s\(^2\). What are the SI units of the proportionality constant \( G \)?

Estimates:

State all assumptions clearly and show all work clearly. The important thing in the estimation exercise is to realize what numbers sound ridiculous and what numbers don’t.

1. Estimate the order of magnitude of the mass in kilograms of

   a) An adult elephant.
   b) A large salmon.
   c) A grape
   d) A grain of rice

As always, explain how you arrived at your answer.
2a). Estimate the number of heartbeats the heart performs during a typical lifetime (70 years).

**Assumptions:**

A heart beats about 60 times/minute.
An average life span is about 70 years.

2b) Estimate the number of breaths taken by a human being during a typical lifetime. (70 years).

3. A new tire of diameter 63.0cm has a tread depth of 1.00cm. The tire is designed to last $80 \times 10^3$ km before replacement, when the tread depth will be only 0.20cm.

a) Approximately how much does the radius of the tire decrease with each revolution of the tire?

b) How many molecules are worn off the radius of the tire in each revolution of the tire? Assume the average diameter of the molecules making up the tire is about $10^{-10}$ m.
46. Soft drinks are commonly sold in aluminum containers. To an order of magnitude, how many such containers are thrown away or recycled each year by U.S. consumers? How many tons of aluminum does this represent? In your solution state the quantities you measure or estimate and the values you take for them.

47. To an order of magnitude, how many piano tuners are in New York City? The physicist Enrico Fermi was famous for asking questions like this on oral Ph.D. qualifying examinations. His own facility in making order-of-magnitude calculations is exemplified in Problem 45.48.

Scaling Problem related to the handout

Find the scaling factor i.e. by how much was the original figure (the one that you used in the classroom on day 2 reduced to produce the figure that was handed out to you on Thursday?