Homework I: Areas of Physics, Units, Scales, and Philosophy

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You should read Chapters 1 and 3 of Weinberg's *Dreams of a Final Theory* before the second afternoon section. You'll have a chance to discuss the ideas from the reading today and tomorrow, but feel free to bring any physics questions to class tomorrow.

Question 1 Size scales

a) Make a chart showing various things you have learned about in the past, either at school or on your own. Organize this chart by size and give the size of each approximately using orders of magnitude. How does the smallest thing on your chart compare to the smallest things that physicists are interested in? Make a similar comparison for the largest.

b) Come up with a few reasons why physicists often consider orders of magnitude to be more important than precise numbers.

Question 2 A Fermi Problem

Estimate the number of gallons of gas used by motor vehicles in the U.S. per year. I will tell you the answer tomorrow at the beginning of class.

Question 3 Dimensional analysis practice

Use dimensional analysis to estimate how long it takes a bowling ball to fall from the top of a building to the ground below. You must figure out which quantities are pertinent to the problem, and how to combine them make something with the units of time. **Hint:** The appropriate property of gravity to consider on Earth is $g = 9.8\text{m/s}^2$.

Question 4 Planck units

The natural units described in the notes are one possible choice of units, in that case primarily motivated by simplification of equations. Another choice are the so-called *Planck units*. Using the following fundamental physical constants, derive the simplest possible quantities with the units of energy and length. Give the numerical values of these quantities, called the *Planck energy* and *Planck length*, in SI units. Why do you think physicists consider these quantities to be interesting?

Name of Constant	Symbol	Value in SI Units
Gravitational Constant	G	$6.67 \cdot 10^{-11} \mathrm{m}^3\mathrm{kg}^{-1}\mathrm{s}^{-2}$
Speed of Light in Vacuum	c	$3.00 \cdot 10^{8} \mathrm{m\,s}^{-1}$
Dirac Constant	$\hbar$	$1.05 \cdot 10^{-34} \mathrm{J{\cdot}s}$
Boltzmann Constant	k_B	$1.38 \cdot 10^{-23} \mathrm{J/K}$

Question 5 Restoring constants

Although particle physicists typically use natural units and suppress factors of c and $\hbar$, it's easy enough to restore them in final expressions should they be needed. Restore the units in the following expressions:

a) $E = NT$, where T is the temperature and N is a number of particles.

b) $E = \sqrt{m^2 + p^2}$, where m is a mass and p is a momentum.

Question 6 What makes a theory good?

Come up with a set of criteria which a physical theory should satisfy to be satisfactory. Do this for both a "fundamental" theory (one which seeks to describe how the universe works from the bottom up) and an "effective" theory, which describes something at a larger scale (like Newtonian mechanics).