Class One: General Physics 3114
Kigali Institute of Science and Technology

Professor David Feldman. 6 December 2011

Introductory Remarks:

- Welcome to KIST and welcome to General Physics 3114!
- Instructor: Dr. David Feldman. I am a professor of Physics and Mathematics at College of the Atlantic in the U.S.A. I am a visiting professor at KIST in the Applied Physics Department.
- What is Physics?
  1. The scientific study of matter, energy, and their interactions.
  2. A style of thinking : using math and physical laws to figure things out. Physics = Math + Reality.
- My goals for the course:
  1. Teach you the basic course content
  2. Teach physics and math skills that are useful across the sciences

Course Outline

1. Units and Physical Quantities
   (a) Dimensional Analysis and Units
   (b) Scalars and Vectors
2. Mechanics
   (a) Kinematics of translational and rotational motion. *Describing motion.*
   (b) Dynamics of translational and rotational motion. *Explaining motion with forces.*
   (c) Simple oscillations and waves.
3. Properties of Matter
   (a) Dimensional Analysis and Units
   (b) Scalars and Vectors
4. Fluid Flow
   (a) Dimensional Analysis and Units
   (b) Scalars and Vectors

Some Conversion Factors: [1]

- 39 inches = 1 meter.
- 1 foot = 12 inches.
- 1 kilogram = 2.2 pounds.
- 1000 liters = 1 m^3.
- 1.6 km = 1 mile.
- 1 km = 10^3 meters.
- 1 cm = 10^{-2} meters.
- 1 hectare (ha) = $10,000$ meters.

Fundamental Physical Quantities: The three fundamental physical quantities we will use in this course are length, mass, and time. The standard units for these are meters, kilograms, and seconds. This is known as the *mks* or *Systém International* (SI) system of units.

When reporting a physical property, we always need units as well as numbers. E.g., the height of Fabien is 1.8 meters. All terms in an equation must have the same units:

$$2\text{meters} + 3\text{meters} = 5\text{meters} \quad \longleftarrow \text{Correct!} \tag{1}$$

$$2\text{meters} + 3\text{kilograms} = \text{?!?!} \quad \longleftarrow \text{Wrong!} \tag{2}$$

Converting Units. Example: Jean-Luc is 2 meters tall. How many inches is this?

$$2\text{m}\left(\frac{39\text{in}}{1\text{m}}\right) = 78\text{in}\,. \tag{3}$$

The term in parentheses is a *conversion factor*. It is "1 in disguise." The quantities in the numerator and denominator of the fraction have the same value, since 39 inches equals 1 meter. Thus, the value of the conversion factor

[1] Inches, feet, miles and pounds are units that are commonly used in the U.S.

is 1, and if we take a length and multiply it by the conversion factor it does not change the length's value, only the units.

Note that $2 \neq 78$, but that 2 m = 78 in. Units change the meaning of equations.

Here is one more example. A physics lecture is 2 hours long. How many seconds is this?

$$2\text{hrs}\left(\frac{60\text{min}}{1\text{hr}}\right)\left(\frac{60\text{s}}{1\text{min}}\right) = 7200\text{s} . \tag{4}$$

Note how the units cancel.

Complex Unit Conversions. Here is a more complex example. A moto travels at 60 km/hr. How many m/s is this?

$$\left(\frac{60\text{km}}{1\text{hr}}\right)\left(\frac{1000\text{m}}{1\text{km}}\right)\left(\frac{1\text{hr}}{60\text{min}}\right)\left(\frac{1\text{min}}{60\text{s}}\right) = 16.7\text{m/s} . \tag{5}$$

Again, note how the units cancel. Let's now try converting areas. How many square centimeters (cm^2) are in 1 square meter (m^2)?

$$1\text{m}^2\left(\frac{100\text{cm}}{1\text{m}}\right)^2 = 10,000\text{cm}^2 \tag{6}$$

Another example: Rwanda is $26,000\ \text{km}^2$. A guy from the U.S. doesn't understand this. How many square miles is Rwanda?

$$35,000\text{km}^2\left(\frac{1.6\text{km}}{1\text{mi}}\right)^2 = 10,200\text{mi}^2 . \tag{7}$$

Finally, a slightly more complex example. The yield of corn in Rwanda is approximately 200 g/m^2. If you wanted to row 220 pounds of corn, how much land would you need, in hectares and square meters?

$$220\text{lbs}^2\left(\frac{1\text{kg}}{2.2\text{lbs}}\right)\left(\frac{1000\text{g}}{1\text{kg}}\right) = 100,000\text{g} . \tag{8}$$

Now we got rid of those annoying pounds. Let's convert to square meters and then hectares.

$$100,000\text{g}\left(\frac{1\text{m}^2}{200\text{g}}\right) = 500\text{m}^2 = 500\text{m}^2\left(\frac{1\text{ha}}{10,000\text{m}^2}\right) = 0.05\text{ha} . \tag{9}$$

Note that the statement "the corn yield is 200 g/m^2" functions as a conversion factor. Note also that paying attention to units guides us to the correct way to do the problem. Keeping track of units makes work problems much less difficult.

Scientific Notation. Useful for working with very large and very small numbers. Some Examples:

$$4,500 = 4.5 \times 1000 = 4.5 \times 10^3 . \tag{10}$$

$$0.0003 = 3 \times 0.0001 = 3 \times \frac{1}{10,000} = 3 \times 10^{-4} . \tag{11}$$

Another example: David is 10,000 kilometers from home. How many centimeters is this?

$$10,000\text{km}\left(\frac{1000\text{m}}{1\text{km}}\right)\left(\frac{100\text{cm}}{1\text{m}}\right) = 1 \times 10^4 \times 1 \times 10^3 \times 1 \times 10^2\text{cm} = 1 \times 10^9 . \tag{12}$$

And one last example. The mass of a water molecule is around 3×10^{-26} kg. How many molecules are in 1 kg of water?

$$1\text{kg}\left(\frac{1\text{molecule}}{3 \times 10^{-26}\text{kg}}\right) = \frac{1}{3} \times 10^{26} = 0.33 \times 10^{26} = 3.3 \times 10^{25} . \tag{13}$$

That's a lot of molecules.

[2] lbs is the abbreviation for pounds.