Physics 2414 -Strauss
Chapter 1 Lecture Notes

1. WHAT IS PHYSICS?

1.1 Qualitative Description

The goal of physics is to understand and explain the physical universe. Physicists observe the physical world around them, and try to categorize and understand the phenomena they observe.

1.2 Quantitative Reasoning

In physics, we don't just want a general idea or description of how things work, we want a precise understanding of physical phenomena. To demonstrate that understanding, we need to be able to describe events quantitatively. For instance, if I drop a ball from a certain height, the ball will hit the ground after a short period of time. Now I know that if I drop the ball from a higher height, then the ball will take longer to hit the ground. But to demonstrate that I really understand the phenomena of the ball dropping, I have to be able to answer quantitative questions. If I drop the ball from twice the height, how much longer will it take for the ball to hit the ground? The answer is found in an equation we will encounter in chapter 2.

$$y = v_0 t + (1/2) g t^2$$

We will discuss this equation in detail in the coming weeks, but basically it says that if I double the height, the ball will take about 1.4 times longer to reach the floor. Without the quantitative equation, I can't really make precise statements about the physical phenomena. The goal of physics is to predict the future. That is given a known set of circumstances, what will occur as a result of the applicable physical phenomena. As a physicist, I only will say that I understand something if I can make quantitative predictions based on known laws and theories.

1.3 Interpreting Formulas

Some students think physics is difficult because of the mathematics used. Yet it is the mathematics itself which allows us to understand the world and make predictions about how things will behave. It is very important then, that you understand the equations and formulas. They have a meaning. For instance, in chapter 2 we will encounter the equation $\Delta x = vt$. This equation has a meaning. It says that if I am moving at a constant velocity v, then the distance I move Δx is equal to that velocity times the time. If I were to move for twice the time, I would cover twice the distance. If I double the velocity, I double the distance. If we cut the time in half, we cut the distance in half. It is quantitative. If I double my speed from 30 miles/hour to 60 miles per hour, then it only takes 1/2 the time to go 20 miles. Also, the symbol means something. As a student, you should always know what the symbol means or you can't use the equation. It doesn't matter which symbol is used as long as you know what it means. It makes sense to use t for time, but one could use anything.

1.4 Deriving Formulas

There are a few very fundamental laws in physics. Much of the rest of physics can be derived from these few fundamental laws. Occasionally, I, or the book, will actually derive one equation from a set of other equations. Why do we do this? To show the relationships between the more fundamental laws and the derived laws.

2. UNITS

Every measurement or quantitative statement requires a unit. If I say I am driving my car at a speed of 30, that doesn't mean anything. Am I driving it 30 miles/hour, 30 km/hour, or 30 ft/sec. 30 only means something when I attach a unit to it. What is the speed of light in a vacuum? 186,000 miles/sec or 3×10^8 m/sec. The number depends on the units.

2.1 SI Units

We will most use the International System of Units (Système International (SI)) units. These consist of the meter (length), the second (time), and the kilogram (mass). Each of these have prefixes and suffixes which you have encountered and should be familiar with. For instance, centi means 10^{-2}. So a centimeter is 1×10^{-2} meters = 0.02 meters. A kilogram is 1×10^3 grams = 1000 grams. There is a table in the front cover of the book of suffixes and prefixes.

2.2 Changing Units

Occasionally, you might have to change to a different set of units. Units behave like any algebraic quantity and cancel when multiplication is performed.

<u>Problem:</u> You are travelling 65 miles/hour. How fast is this in ft/second? meters/second?

2.3 Consistency of Units

When working with formulas and solving problem you must make sure that the units are always consistent.

<u>Problem:</u> You are travelling 30 meters/second. How far do you travel in one hour?

3. SOLVING PROBLEMS IN PHYSICS

3.1 Significant Figures

Notice in the above problem, I wrote 1.1×10^5 meters rather than 1.08×10^5 meters. Why did I do that? Because I can only know my answer to a specific accuracy. Every number has a number of significant figures. That is, what is the precision of the number. The number 25 has two significant figures. If a table is 25 inches wide, that means it is more than about 24.5 and less than about 25.5 inches. However, if the table is 25.0 inches wide, then I now have 3 significant figures. The table is more than about 24.9 inches wide and less than about 25.1 inches wide. 310.0 has four significant digits, but what about 310. Does it have two or three significant digits. One reason we use scientific notation is to clarify the number of significant digits. 3.1×10^2 has two significant digits while 3.10×10^5 has three significant digits.

Suppose I have a rectangular garden which is 10.3 by 4.2 meters. What is the area of the garden? My calculator says it is 43.26 square meters. But that is way too accurate. How could I know the area to .01 square meters when I only know the length to .1 meters.

The rules for using the correct number of significant figures are as follows:

1) When multiplying or dividing numbers, the answer has only as many digits as the number with the least number of significant digits. So $3.2 \times 5.63 = 18.$ (Only two significant digits because the 3.2 has only two significant digits).
2) When adding or subtracting, the number of decimal places in the answer should match the number with the smallest number of decimal places. So $3.26 + 4.3 = 7.3$.

3.2 Dimensional Analysis

This topic is covered in Appendix B of the textbook. Dimensional analysis helps you solve problems as well as check whether your solution is correct. Since most values have some kind of units, we can use these units to our advantage. Suppose you want to calculate how far a car will travel that is going a certain speed for a certain time. You can't remember if the equations for calculating this is $x = (1/2)vt^2$ or $x = (1/2)vt$. We write the dimensions of the quantities in square brackets using [L] for length and [T] for time.

$[L] = [L/T][T]^2 = [LT]$
or
$[L] = [L/T][T] = [L]$

so the correct equation must *not* have the t^2 term. This still doesn't guarantee that the relation is correct, only that it is not incorrect. For instance, the constant 1/2 doesn't have any dimensions, so we don't really know what the constant is. (In fact, it should be 1 here, not 1/2).

You can also use dimensional analysis to help check your answer. For instance, speed should be [L]/[T]. If it is not, then there is a problem with your answer.

3.3 Rapid Estimating (Order of Magnitude)

Many times it is important to get an idea of what an answer may be without actually working out the exact number. Often, the answer you get this way will be perfectly adequate for the question being asked. Even if it is not, a rapid estimate will help you know if the exact answer you calculate is reasonable.

Problem: How long would it take to drive a car around the world?

Problem: How many quarters would it take to fill up Owen field?