AP Physics 1 - Introductory Material

This material should mostly be review. However, there is a chance you may not have studied it before this course. Regardless, this information is important and lays a foundation for our studies this year.

1 What is Physics?

While it is difficult to concisely define Physics, Physics is described by some as the most fundamental of the physical sciences. One of the main goals in physics is to explain with mathematical precision why the physical world works the way it does. For example, if you drop your pencil it falls in a predictable manner. In Physics we want to know why the pencil falls, the rate at which it falls, what parameters effect its fall, whether or not other objects will fall in a similar manner, and the ultimate question…why? In many ways, you can think of Physics as the science of answering the question "Why?" in terms of our observations of physical phenomena. In answering the question, "Why?" we also seek mathematical precision in our answers. Thus, we will use a lot of equations to model the world around us. As we will see, all models have uses (pros) and limitations (cons).

Learning Physics is exciting as it will change the way you view the world around you. As you learn to view the world through the "eyes of Physics," you will view the world with new appreciation and understanding. Learning Physics is also challenging. There are times where "common sense" and society in general have created misconceptions that you will have to "unlearn." The mathematics of the course doesn't exceed Algebra 2 in terms of concepts, but you will likely work with more symbols and literal equations in this course than you are used to. The mathematics will always be used in some real physical context – which may be new to you as well. With a lot of practice, you will see how mathematics and physics harmonize to give you (and mankind in general!) powerful tools that can be used in many fields of study and careers.

This course corresponds to a first semester university-level algebra-based course. Typically such a course is for those declaring a non-physics or non-engineering major. However, this course gives a valuable foundation for anyone who needs or wants a knowledge of physics. This course focuses mostly on classical mechanics – the study of the motion of macroscopic objects without regard for relativistic of quantum effects.

1.1 What Will We Study This Year?

The course can be broken down into 9 major units of study, as listed below. For a more detailed list, please consult the course syllabus.

1. Linear Kinematics (also known as rectilinear motion)
   1.1. We will study 1D and 2D motion without regard for the cause of the motion or the effects of an object's mass.
2. Linear Dynamics
   2.1. Here we will mostly focus on Newton's three main laws of motion.
3. Uniform Circular Motion, Gravitation, and Kepler's Laws
4. Work and Mechanical Energy
5. Linear Momentum
6. Simple Harmonic Motion
7. Rotational Motion
   7.1. Rotational kinematics, rotational dynamics, angular momentum, rotational energy
8. Mechanical Waves
9. Basic Electrostatics and Circuits

2 STANDARDS OF MEASUREMENT AND PREFIXES

Since Physics' ultimate goal is to describe the physical world, we measure everything we possibly can. As you know, a measurement without units is meaningless. If I tell you I'm a little over 6.5 tall, what does that mean? Five and a half feet, centimeters, meters, miles? You also have to consider that the Physics community is international. Thus, someone finally said, "Hey, we need one standard way of doing things the world around[1]." Enter the Système International – better known to us as SI. The SI is the international standard of units in science[2] and what we will be using in AP Physics.

There are seven basic units that all others are composed of. For now we will focus on length, time and mass (we'll deal with the others later on). The SI units and the abbreviations for these three are:

- Length and Distance – meter (m)
- Time – second (s)
- Mass – kilogram (kg)

Later on, we will learn about the unit of force called the Newton. However a Newton is actually composed of the three units above:

$$1\,N = 1\frac{kg\cdot m}{s^2}.$$

To get an intuitive feel for these units, I recommend visiting http://htwins.net/scale2/ and http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/.

3 SCIENTIFIC NOTATION AND PREFIXES

Using Scientific Notation helps make very large numbers (1,000,000,000,000,000 kg [the mass of a small satellite in space]) and very small numbers (0.000000001 m [the size of an Atom]) more manageable whenever a number must be written down or used in a calculation. We will use scientific notation heavily in this course. It saves a lot of writing and often makes the math easier. If you're not familiar with scientific notation I recommend the following sources in conjunction with the example problems that are to be worked in class:

- http://www.purplemath.com/modules/exponent3.htm
- https://www.khanacademy.org/math/cc-eighth-grade-math/cc-8th-numbers-operations/cc-8th-scientific-notation/v/scientific-notation
- Your text book likely has an appendix covering scientific notation. If not, there are dozens of good resources readily found with an Internet search engine.

*Note: Another phrase for powers of ten is "order of magnitude."

The SI is composed of prefixes attached to base units that can be expressed as abbreviations. The base units represent the measurement that you are making (meter for length, second for time, etc…) while the prefix tells you how much of the base unit that is being considered. You should also be familiar with what the powers of ten mean in terms of "regular" numbers based on the common prefixes used in AP Physics and other sciences. The table below is worth memorizing.

[1] The actual history and development of the SI is slightly more complex.

[2] Interestingly, certain types of engineers still work in Imperial/US Engineering units.

Table 1 - Unit Prefixes

10^{-9} (nano)	One one-billionth of base unit	10^{2}	One hundred bases of base unit
10^{-6} (micro)	One one-millionth of base unit	10^{3} (kilo)	One thousand bases of base unit
10^{-3} (milli)	One one-thousandth of base unit	10^{6} (mega)	One million of base unit
10^{-2} (centi)	One one-hudredth of base unit	10^{9} (giga)	One billion of base unit

There are times when we deal with very large or very small units. Instead of repeatedly saying "five times ten to the sixth pascals," we could say, "Five megapascals." These prefixes are simply "verbal shortcuts" and knowing them is important.

*Note: We will most often use the prefixes from micro to mega.

4 Dimensional Analysis and Unit Conversions

We often use the word "dimension" when discussing units. The phrases "dimensional analysis" and "unit analysis" are synonymous in this course. Unit conversion is a fairly simple but crucial skill in physics. On the theoretical side, problems will often provide values in one unit and require the answer in another unit. Practically speaking, in the lab you may have equipment that only allows you to measure in a certain unit, but you may desire a different unit in your final result. Mathematically, we treat units just like algebraic variables. We convert units by applying some basic algebraic properties. Dimensional analysis will not be used in each problem on the AP Physics exam, but we do need to learn the method of converting units in the rare situations in which it is necessary. In case you are still unfamiliar, Dimensional Analysis looks a bit like this:

$$Given\ Units \times \frac{Wanted\ Units}{Given\ Units} = Given\ Units \Rightarrow \text{Example: } 40\ km \times \frac{1000\ m}{1\ km} = 40{,}000\ m$$

It's expected that you already know how to perform unit conversions. However, if you need some help, the following links below offer great resources on how to complete these problems:

- http://www.alysion.org/dimensional/fun.htm
- https://www.khanacademy.org/math/pre-algebra/rates-and-ratios/metric-system-tutorial/v/unit-conversion

The following sources may prove useful to double check your work when unit conversions are involved:

- Google will perform unit conversions for you. For example type "5 feet in meters" in the search bar and you will receive "5 meters = 16.4041995 feet" as a result.
- Wolfram Alpha (www.wolframalpha.com) will perform unit conversions very similarly to Google.

*Note: I mentioned Google and Wolfram Alpha as convenient tools to double check your calculations on your homework and labs, but **DO NOT COMPLETELY RELY ON THEM**. Your quizzes, exams, and the AP Exam will require you to know how to convert units without any assistance from a computer.

5 LITERAL EQUATIONS

The method of using literal equations is related to dimensional analysis in that we will often be concerned with the “unit” of the measurement or quantity that we are looking for. When using this method, you will algebraically rearrange an equation to solve for an unknown variable WITHOUT substituting numbers into the equation.

While you are allowed to use a calculator on the Multiple Choice section of the exam AND the Free Response section of the exam, MANY problems can only be worked without the aid of a calculator. Showing your work will be a requirement in order to receive credit – no exceptions.

There are a few key principles to keep in mind:

- Both sides of an equation must be dimensionally balanced (“equals” means equal in value and in units).
  - Being dimensionally balanced does not automatically make an equation valid.
- We treat units exactly like algebraic variables.
  - You can only add or subtract like units.
- You “cancel” units or calculate their exponents as if they are algebraic variables.
- Some equations contain constants. There are two main types of constants:
  - Fundamental Physical Constants
    - They have units!
    - For example, the speed of light in a vacuum is roughly $3.00 \times 10^8 \frac{m}{s}$.
  - Constants of Proportionality
    - They may or may not have units.
    - They are numbers we multiply an equation by to make the equation match the experimental observations.
- When performing dimensional analysis and/or utilizing the method of literal equations, we write the physical variable in brackets [ ] to separate it from the units themselves.

The following source may prove useful in understanding the algebraic handling of units:

- https://www.khanacademy.org/math/algebra/introduction-to-algebra/units-algebra/v/dimensional-analysis-units-algebraically

6 Reasoning and Proportionality

Throughout this class, you will need to develop a sophisticated ability to understand how one number in an equation affects another number in the same equation. Such questions can be qualified as “proportionality problems.” Developing a sense of how one quantity can numerically effect another quantity will be heavily tested on the AP Physics exam. As we work example problems throughout the year, you will repetitively be asked how changing one variable in an equation changes the final answer and/or changes the physical system that is being studied. For example, consider the following equation:

$$\frac{7A}{4B} = C$$

What happens to C if A is doubled?

What happens to C if B is tripled?

What happens to C if B is reduced by one-fourth?

What happens to A if C is held constant and B is doubled?

What happens to B if C is held constant and A is reduced by one-half?

7 Uncertainty and Significant Figures

Significant Figures ARE NOT tested on the AP Physics exam(s). When solving a problem, (within reason) **do not round any values except for your final answer**. Rounding intermediate calculations may result in an erroneous answer. A good general rule is to “be reasonable.” If most values provided in a problem contain 2 or 3 significant digits, then report your answer to 2 or 3 significant digits. As long as the amount of digits recorded is reasonable and accurate then you should not worry about losing any points on the AP Exam.