Physics: Chapter 1

Physics, by definition, is the study of matter and energy. Since the universe (as far as we know) is made up of these two things and nothing else, physics can accurately be described as the scientific study of *everything.*

Physicists conduct experiments and make observations in order to collection data about the universe. They then invent *theories* to collect and explain this information. No theory can ever be completely *proven*, because all observations are imperfect, but some theories (like Newton's theory of universal gravitation) are so well established by evidence that few people doubt their validity.

The ultimate goal of physics is to come up with a *theory of everything* or *TOE*. Such a theory would be able to explain every phenomenon in the universe in terms of some basic set of assumptions.

It is difficult to perform detailed experiments on physical objects in your head; it's too complicated and there are too many variables. Instead, scientists develop what are called scientific *models.* A *model* is a mental construct that represents some feature or features of the universe in terms of ideas that are already familiar. A useful model gets the gist of what's going on in the physical world, but doesn't get bogged down in details that aren't relevant to what you're modeling. One of the goals of a physicist is to develop ever more useful models to describe what happens in the universe.

Units

The *International System of Units* (or *SI Units* for short) uses seven *base units*.

SI base quantity	SI base unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

All other SI units can be derived from the seven base units. For example the SI unit of volume is the cubic meter or m^3, and the SI unit for velocity is the meter per second or m/s. We will learn many more SI derived units as we go along.

Dimensional analysis
Answers in physics must be given with the proper units in order to be correct. It is a good idea to include proper units throughout your calculations, because it gives you a way of checking if your work is correct: If the units are correct you know your answer is likely to be correct; if the units are incorrect, you should check your work. This technique is known as *dimensional analysis.*

Uncertainty

In physics, all measured quantities come with an uncertainty attached. Usually this is due to lack of knowledge (i.e. inadequate measuring equipment, human error, etc.), but we also know that there is an intrinsic randomness to the universe due to something called the *Heisenberg uncertainty principle*. Without uncertainty, all reported numbers would be meaningless, because we wouldn't have any idea of how accurate they are.

Ideally, uncertainty should be stated explicitly. For example, the length of a rod might be written as 0.85 ± 0.01 m, meaning that it's length is accurate to within 1 centimeter. There is a precise and correct way to deal with uncertainty, but we won't learn about it in this class. Instead we will use a rule of thumb known as *significant digits* (or *significant figures*).

<u>Significant digits</u>

Here are the rules for determining whether a digit is significant:

- All non-zero digits are significant.
- Any trailing zeros to the *right* of a decimal point are significant (e.g. the zeros in 3.500)
- Any trailing zeros to the *left* of a decimal point are *not* significant (e.g. the zeros in 2400)
- Any digit between two significant digits is significant

When you report your answers, make sure that they do not contain no more significant digits than any of the numbers used to calculate the answer. For example, if a problem required you to multiply 4.7 by 3.14 to calculate the circumference of a circle, your calculator would say 14.758, but you would round your answer to 15, because 4.7 had only two significant digits.

Examples:

Measurement	Number of significant digits
6500	2
6500.02	6
6500.0	5
0.0065	2
0.0065	3

Any numbers that are *counted*, not measured (such as the number sides of a polygon) are considered to have a an infinite number of significant digits.

<u>Scientific notation</u>

When you report your answers, make sure you use *scientific notation*.

In scientific notation, numbers are written in the form $a \times 10^n$ where a is a decimal number and n is an integer. The decimal point in the decimal part must be written immediately to the right of the first non-zero digit. If the decimal point is moved to the right, n must go down by one and if the decimal point is moved to the left, n must go up by one.

Therefore the number 354 can be written in scientific notation as 3.54×10^2, because the decimal was moved two spaces to the left to be in proper position.

The mass of an electron is approximately 0.000000000000000000000000000000091093822 kg. In scientific notation, this would be written as $9.1093822 \times 10^{-31}$ kg, because the decimal must be moved 31 spaces to the right to be to in the proper position.

Scientific notation is advantageous, because prevents any confusion about which digits are significant and which aren't. It is automatically assumed that all digits written in scientific notation are significant.

Examples:

Number	Equivalent in scientific notation
0.0000000124	1.24×10^{-8}
0.07940	7.940×10^{-2}
35000 (two digits are significant)	3.5×10^{4}
35000 (four digits are significant)	3.500×10^{4}