Lesson 1 – Introduction

Today we want to discuss some of the basic things that you need to be thinking about for the duration of this summer course. This includes 1) How to think like an engineer, 2) How to approach word problems and 3) Some basic physic principles that describe motion.

Thinking like an engineer

You don’t have to be an engineer to think like one. There are some cases where thinking like an engineer is of no benefit, but there are many more cases where it is a definite advantage to think like an engineer. So, what does thinking like an engineer mean?

An engineer examines the process(es) involved in the problem to be solved. An engineer does not only look at the symptoms of a problem but looks at the processes involved to get to the root cause of the problem.

An engineer uses proven analysis methods. An engineer uses a set of methods that have been proven to work in analyzing problems. This means knowing how to apply those methods, but more importantly this means the engineer knows which methods to apply to a given situation. This also means that an engineer knows about and uses appropriate tools to carry those methods out.

An engineer learns why (not just how) something is done. If you only know how something is done, you will eventually do it wrong. You need to understand why something is done, to make sure that you are doing it correctly.

An engineer must come up with an answer to the problem. In math, it is possible to prove why something cannot be done. An engineer must come up with an answer.

An engineer keeps his/her skills updated. Applying an out-of-date solution is almost as bad as not providing any solution. An engineer constantly looks to see if new, better solutions to a problem exist.

Solving Word Problems

There are some general principles that can be applied to most word problems in math and physics. In practice, nearly every engineering problem can be stated as a word problem. So, it is important to have a general approach to solving word problems.

Start by identifying what you want to solve for. The first step is to identify what quantity or quantities you are trying to determine. A good practice is to carefully write out a definition of any variable you are trying to find the value for.

Write down pertinent equations that contain the variables you want to solve for. This may sound obvious, but most problems become easier to solve if you make a habit of doing this. Make sure that the equation(s) is/are pertinent in that they apply to the physical nature of the problem, and make sure the equation(s) is/are pertinent in that they represent
the equations that lead to the simplest correct solution to the problem. This requires several
different kinds of skills. The first skill is identifying the correct category of the problem, so
you can apply the right equations. The second skill is using the form of the equation that
involves the simplest math.

**Identify what is known in the equations from the previous step and use other
equations if necessary.** When you write down an equation that contains the variable you
want to solve for, look at each term in the equation and identify which terms are already
known (or given). If you have more than one unknown, you will have to come up with
additional equations. Remember that you need an independent equation for each unknown.
(Two unknowns means you need two independent equations.) At the same time, by
choosing the correct order of equations, it is often possible to be dealing with just one
unknown at a time.

**Physics of Motion**

Being able to describe motion of objects is an important skill in physics. Identifying the
forces that can produce that motion is also very important because that will also help us
analyze the forces needed to prevent motion.

- **Kinematics** – Describing motion of objects using quantities like position, velocity and
  acceleration.
- **Kinetics** – Identifying the forces that produce motion.
- **Statics** – Identifying the forces that prevent motion.

**Kinematics – Physics of motion**

To start a study of motion, we will look at motion in one dimension, or rectilinear motion. A
simple way to visualize this is motion that takes place horizontally, so that the object is
moving either to the right or to the left.

- \( x \) = the position of an object

Suppose we want to describe how far an object has moved. We could do this:

- distance moved = \( x_2 - x_1 \)
- where \( x_2 \) = position at time, \( t_2 \)
- and \( x_1 \) = position at time, \( t_1 \)

The average velocity of the object would be given by:

\[
\text{v}_{\text{ave}} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}
\]

The instantaneous velocity is the velocity at any instant of time. If the velocity is changing,
the instantaneous velocity is different from the average velocity. How can we get the
instantaneous velocity? One way is to graph the position versus time. The slope of the position versus time at any point in time would be the instantaneous velocity. If we know some calculus, we would write the instantaneous velocity as:

\[ v = \frac{dx}{dt} \]

Does an engineer have to understand calculus? Yes, but a good engineer understands calculus concepts but only uses analytical math methods when numerical math methods are insufficient. So, it is often good enough to be able to come up with numerical solutions to calculus problems. The key to understanding numerical solutions is to have a good understanding of the calculus concepts involved.

The average acceleration is given by:

\[ a_{ave} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t} \]

The instantaneous acceleration is the slope of the velocity versus time graph. It can also be expressed as:

\[ a = \frac{dv}{dt} \]

**Constant acceleration**

A class of problems that is often studied are problems where the acceleration is a constant. This simplifies the equations of motion. Recall that the acceleration is just the slope of the velocity versus time graph. For constant acceleration, the velocity versus time graph will just be a straight line:
The equation of this line (using the slope-intercept form) would be:

1. \( v = v_o + a t \)

The average velocity for a velocity that changes in a linear fashion would be:

2. \( v_{ave} = \frac{v_o + v}{2} \)

The distance travelled is always given by:

3. \( d = x - x_o = v_{ave} t \)

Substituting equation 2 into equation 3 gives:

4. \( x - x_o = \frac{v_o + v}{2} t \)

Substituting equation 1 into equation 4 gives:

5. \( x = x_o + v_o t + \frac{1}{2} a t^2 \)

Solving for \( t \) in equation 4 gives:

\[
 t = \frac{2 (x - x_o)}{v_o + v}
\]

Substituting this expression for \( t \) into equation 1 gives:
\[ v = v_o + a t \]

\[ x = x_o + v_o t + \frac{1}{2} a t^2 \]

\[ v^2 - v_o^2 = 2a (x - x_o) \]

Problems

An object has a uniform acceleration of \( 2 \text{ m/s}^2 \). If the velocity after 3 seconds is \( 7 \text{ m/s} \), what is the object's initial velocity?

If an object starts with an initial velocity of \( 10 \text{ m/s} \), and experiences a constant acceleration of \( -10 \text{ m/s}^2 \), at what time(s) is the object \( 2.1875 \text{ m} \) from its starting position.

An object undergoes motion in the following stages. Starting from rest, the object has a constant acceleration of \( 2 \text{ m/s}^2 \). The second stage lasts the same length of time as the first, but has the object going at constant velocity. The last stage lasts twice as long as the first stage an consists of a constant deceleration so that the velocity drops to zero. If the total distance traveled in the three stages together is \( 18.75 \text{ m} \), and the max velocity for the whole motion is \( 5 \text{ m/s} \), what is the total time for the whole motion? Also, what is the magnitude of the deceleration in the third stage?