Module 1 – Motion

INTRODUCTION

One important topic of this module is motion. In this experiment, you will be studying two special types of motion.

1 Motion with constant velocity

2 Motion with constant acceleration

Sometimes the word "constant" is confusing to students. A constant velocity is a velocity that does not change; it is a constant and does not vary with time. Similarly, a constant acceleration does not change with time either.

Motion with constant velocity is familiar to you, since it exists any time you are driving or flying in a constant direction with a constant speed. Motion with constant acceleration is also familiar to you in everyday life. Anytime you drop something, its motion will be that of an object moving under constant acceleration.

Due to changes in driving surface or wind speed, it is often difficult to obtain a condition of constant velocity or constant acceleration, but in this experiment you will study the relationships between displacement, speed, and acceleration when constant velocity or constant acceleration exist.

NOTE:

Before proceeding to the rest of the experiment, make certain that you have read Section 1.4 in your text.

MOTION WITH CONSTANT VELOCITY

Motion with constant velocity is also called uniform motion. Let's take a look at some of the most important aspects of uniform motion which result from constant velocity.

1 Both the speed and direction of motion do not change.

2 The acceleration is zero.

3 The distance moved each second is the same.

4 The equation of motion which describes uniform motion is $d = vt$, where v is a constant value, such as 8 m/s.

Notice the form of the equation of motion. Remember from elementary algebra that the equation of a straight line through the origin is $y = mx$.

If you plot the distance an object moves along the vertical axis and the time it takes the object to move that distance along the horizontal axis, then the d vs. t graph of uniform motion will be a straight line with a slope equal to the velocity of the object. Take another look at the two equations.

$$\text{Equation of a straight line:} \qquad y = mx \tag{1}$$

$$\text{Equation of uniform motion:} \qquad d = vt \tag{2}$$

POSITION VS. TIME GRAPH OF UNIFORM MOTION

Look at the figure below. It illustrates how the shape of the d vs. t graph changes as the speed changes for a body with constant velocity.

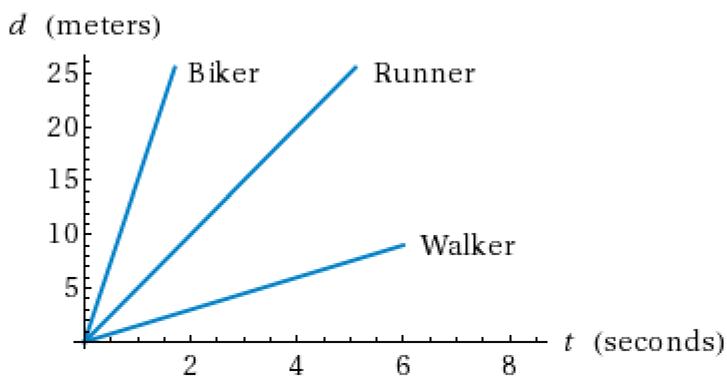

Figure 1

Remember that the steeper the line, the greater its slope. Since the slope in this graph is equal to the speed, it makes sense that the graph of the biker's motion is steeper than that of the person who is walking. The biker has a greater velocity than the walker, so each second the biker will move a greater distance and its graph will be steeper.

CALCULATING VELOCITY (UNIFORM MOTION)

Let's take a look at another illustration. This illustration shows you how to calculate the velocity of an object by finding the value of the slope of the position vs. time graph. Notice that the distance traveled each second is about 8 m. At the end of 1 second, the distance traveled is 8 m; at the end of 2 seconds, the distance traveled is 16 m, and so on. This is characteristic of uniform motion. Each second the distance traveled is the same.

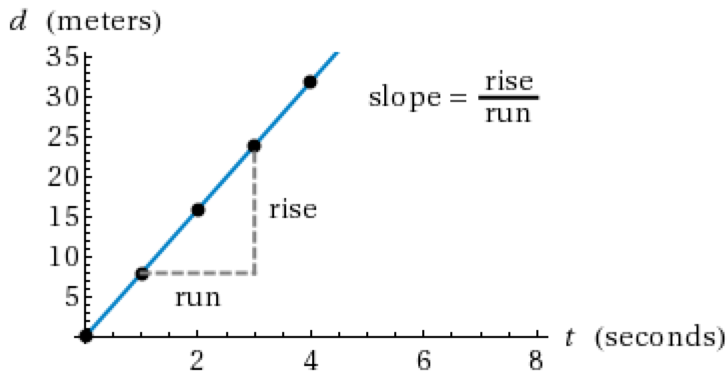

Figure 2

To calculate the velocity, simply calculate the slope of the graph. Solving the equation of uniform motion for velocity, we get $v = d/t$ or $v = \Delta d/\Delta t$.

The change in distance is just the rise of the graph between two points and the change in the time is the run of the graph between two points.

<u>FINDING VELOCITY FROM A POSITION VS. TIME GRAPH</u>:

$$\begin{aligned} \text{rise} &= 24 \text{ m} - 8 \text{ m} \\ &= 16 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{run} &= 3 \text{ s} - 1 \text{ s} \\ &= 2 \text{ s} \end{aligned}$$

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{16 \text{ m}}{2 \text{ s}} = 8 \text{ m/s}$$

$$v = \text{slope} = 8 \text{ m/s}$$

LINEAR MOTION WITH CONSTANT ACCELERATION

The second type of motion we will study is uniformly accelerated motion, or motion with constant acceleration in a straight line. The key aspects of this type of motion are:

1 The speed changes but direction does not change. The acceleration is not zero but it does not change.

2 The acceleration can be negative or positive.

3 The distance moved each second changes.

4 The change in velocity is the same from second to second.

5 The equation which describes velocity at any time is $v = at$, where a is a constant value, such as 3 m/s^2.

Again notice the form of the equation relating velocity to acceleration. You should be able to see that this is an equation of a straight line. If you plot the velocity vs. time graph, the graph will be a straight line with the slope corresponding to the acceleration.

Linear motion with constant acceleration is characterized by the same change in velocity each second. An acceleration of 3 m/s^2 means 3 m/s per second or, each second, the velocity changes by 3 m/s.

VELOCITY VS. TIME GRAPH OF UNIFORMLY ACCELERATED MOTION

The figure below shows the linear relationship between velocity and time when acceleration does not change. If we re-write the equation for velocity, we get: $a = v/t$ or $a = \Delta v/\Delta t$.

In other words, the slope of the velocity vs. time graph corresponds to the acceleration. This is true for all motions, not just uniformly accelerated motions.

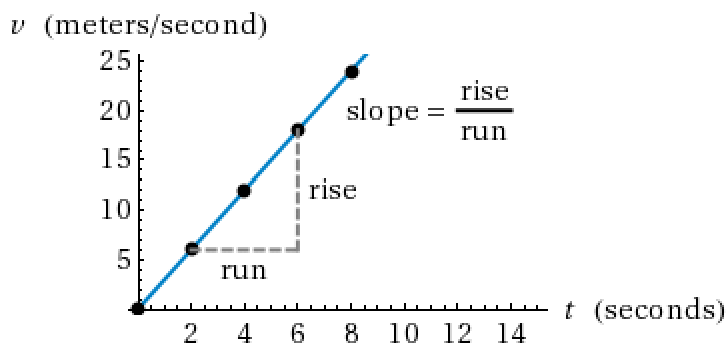

Figure 3

FINDING ACCELERATION FROM A VELOCITY VS. TIME GRAPH:

$$\begin{aligned} \text{rise} &= 18 \text{ m/s} - 6 \text{ m/s} \\ &= 12 \text{ m/s} \end{aligned}$$

$$\begin{aligned} \text{run} &= 6 \text{ s} - 2 \text{ s} \\ &= 4 \text{ s} \end{aligned}$$

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{12 \text{ m/s}}{4 \text{ s}} = 3 \text{ m/s}^2$$

$$a = \text{slope} = 3 \text{ m/s}^2$$

POSITION VS. TIME (UNIFORM ACCELERATION)

Some students wonder what the position vs. time graph looks like for uniformly accelerated motion in a straight line. After all, we discussed the position vs. time graph for uniform motion and some students wonder why we didn't discuss that graph for linear motion with constant acceleration. Let's take a look at the equation of motion which is relevant here. It turns out that the equation is $d = 1/2at^2$ and the graph looks like this:

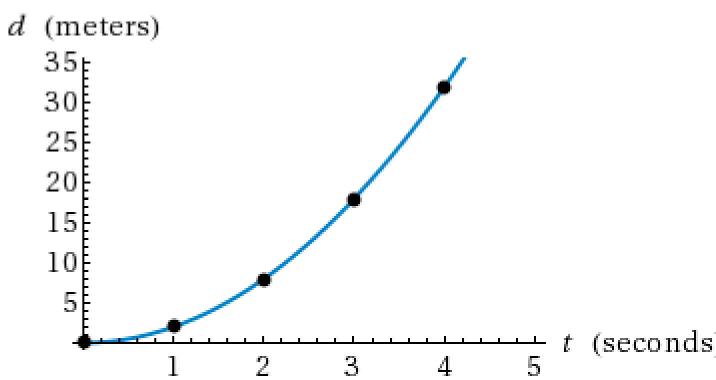

Figure 4

There are a few things to remember about this graph. First, notice that it is NOT a straight line. You may remember from your algebra classes that equations like $y = Cx^2$ are equations of parabolas. You may describe this graph as an increasing curve, if you wish, but the graph is also known as having a parabolic shape.

$$y = Cx^2 \quad (3)$$

Equation of Parabola:

$$d = \frac{1}{2}at^2 \quad (4)$$

Position Equation for Constant Acceleration:

The slope of this graph at any point will be the velocity of the object at that point. Notice how the slope of the curve is always increasing. That is because the velocity is increasing since the object is undergoing acceleration.

PROCEDURE

This experiment consists of three parts.

1 Open the experiment instructions and worksheet.

- Motion Experiment Instructions (HTML[1] or PDF[2])
- Motion Experiment Worksheet[3]

2 After you have thoroughly read the instructions and worksheet, open the experiment simulation[4] in which you will conduct the experiment and collect your data.

3 Record your data in the worksheet. (You will need it for the lab report assignment in WebAssign.)

[1] ../lab_2_1_procedure/manual.html
[2] ../lab_2_1_procedure/manual.pdf
[3] ../lab_2_1_procedure/worksheet.pdf
[4] http://www.walter-fendt.de/html5/phen/acceleration_en.htm