Force and Motion Module: Cycle I

Compiled by Allen Constant and Karen Stayer
Adapted from CPU Project
www.learningteam.org

Overview of the Force and Motion Unit

The Comprehending Physics Understanding (CPU) unit on Force and Motion enables students to change any preexisting ideas about motion that are incorrect and to gain experience with new ideas about motion. This is accomplished by using hands-on activities and computer-based activities to supplement the normal learning environment. CPU uses both individual and group activities in its constructivist pedagogy.

There are seven cycles in the CPU Force and Motion unit:

Cycle I: Representing One Dimensional Motion in One Direction

Cycle II: Connecting Forces and Motion in One Direction

Cycle III: Changing Direction

Cycle IV: Impulse and Momentum

Cycle V: Gravity

Cycle VI: Motion in Two Dimensions

Cycle VII: Energy Considerations

This module covers only Cycle I of the CPU Force and Motion unit.

Target Ideas for Unit

See CPU Project Curriculum for detailed target ideas.

1. **Distance-Time Graph Idea**
2. **Speed-Time Graph Idea**
3. **Strobe Diagram Idea**
4. **Speed, Change-in-Distance, Change-In-Time Equation Idea**
5. **Acceleration-Time Graph Idea**
6. **Acceleration, Change-In-Speed, Change-In-Time Equation Idea**

Cycle I Activities--cited and used from CPU curriculum folder

"Cycle I develops ideas and representations of uni-dimensional motion. This cycle uses only uni-dimensional motion so that students could become familiar with ideas about distance, velocity, and acceleration with appropriate representations for each. Two-dimensional motion is addressed in Cycle VI. In this cycle, the term distance is used to refer to the distance traveled away from the origin. Position is addressed later in the unit."

Elicitation Activity
Act I-E: How do you represent motion?

Development Activities
Act I-D Initial
Act I-D1: Can you represent motion with graphs?
Act I-D2: How can you describe motion with strobe diagrams, motion graphs and simple equations?
Act I-D3: How can you describe speeding up and slowing down?
Act I-D4: How can you represent motion with changing speeds in different ways?
Act I-D5: How are distance and speed related for an object that is accelerating?

Application Activities
Act I-A1: Motion Challenges
Act I-A2: Comparing Speeds

Teacher's Guide to the Force and Motion Unit: Cycle I

The teacher's guide for this module is found in the Force and Motion folder in the CPU Curriculum folder.

Materials Needed for Cycle I Activities

Demonstration equipment:

- Two Pasco tracks (or other dynamics track), minimum 1.2 meters long
- Two Pasco dynamics carts
- One fan unit (either a homemade fan unit or a Pasco fan unit)

Equipment for each group of three or four students:

- White board (24 in x 32 in)
- Four-color set of white board markers
- White board eraser
- Meter stick
- Vernier LabPro

- Motion detector
- 1 ft^2 white board or similar flat, hard object (to reflect the motion detector signals)
- Computer with CPU simulators (with a projector, one computer can be used to view simulations as a class)
- Dynamics cart
- Fan unit
- Dynamics track
- Masking tape
- Pair of safety gloves

Desired Outcomes and Student Objectives

Cycle I: Representing One Dimensional Motion in One Direction

Distance-Time Graphs

It is expected that the learner will be able to:

- Collect distance-time data
- Construct distance-time graphs to represent constant speed, increasing speed, and decreasing speed
- Analyze distance-time graphs qualitatively to determine when an object is speeding up, slowing down, or traveling at a constant speed.
- Analyze distance-time graphs quantitatively to determine:
    - an object's speed as represented by a linear graph
    - an object's instantaneous speed from a non-linear graph (slope of tangent)
    - an object's average speed

Speed-Time Graphs

It is expected that the learner will be able to:

- Collect speed-time graphs
- Construct speed-time graphs to represent constant speed, increasing speed, and decreasing speed
- Analyze speed-time graphs qualitatively to determine when an object is speeding up, slowing down, or traveling at a constant speed
- Analyze speed-time graphs quantitatively to determine:
    - an object's acceleration as represented by a linear graph
    - an object's instantaneous acceleration from a non-linear graph

Acceleration-Time Graphs

It is expected that the learner will be able to:

- Collect acceleration-time data
- Construct acceleration-time graphs to represent constant speed, increasing speed, and decreasing speed
- Analyze acceleration-time graphs qualitatively to determine when an object is speeding up, slowing down, or traveling at a constant speed

Strobe Diagrams

It is expected that the learner will be able to:

- Construct strobe diagrams to represent the motion of objects that are speeding up, slowing down, and traveling at a constant speed
- Analyze strobe diagrams qualitatively to determine if objects are speeding up, slowing down, or traveling at a constant speed
- Analyze strobe diagrams quantitatively to compare two objects' speeds or compare the speed of the same object at different times

Missouri's Assessment Annotations for the Curriculum Framework*I*

IV. Force, Motion, and Mechanical Energy

A. Relative Motion

"By the end of grade 12, all students should know that motion can be described in terms of velocity and acceleration and be represented by equations and vectors"

"By the end of grade 12, all students should be able to represent and analyze motion both quantitatively and graphically using velocity and acceleration (1.8; 2.4; 3.5; 4.1)"

Cited from Missouri Department of Elementary and Secondary Education website **www.dese.state.mo.us/**

Force & Motion Module: Cycle I

The following schedule is based on a ninety-minute class period. Adjustments may need to be made depending on the students' progression through the activities.

Day 1:

- Introduce motion (CPU F&M Act I-D Initial) and Idea Journal
- Allow 10-15 minutes for students to write down initial ideas
- Demonstrate motion of two carts and have students complete CPU F&M Act I-E (save question 6, the whole class discussion, until after completing development activities)

Day 2:

- CPU F&M Act I-D1: Can You Represent Motion With Graphs?
- CPU F&M Act I-D2: How Can You Describe Motion With Strobe Diagrams, Motion Graphs, and Simple Equations?

Day 3

- Using Strobe-Flash Diagrams to Find Speed (by Allen D. Constant)
- Sum up discoveries and have students write in their Idea Journals

Day 4:

- CPU F&M Act I-D3: How Can You Describe Speeding Up and Slowing Down?
- CPU F&M Act I-D4: How Can You Represent Motion With Changing Speeds in Different Ways?
- Sum up discoveries and have students write in their Idea Journals

Day 5:

- CPU F&M Act I-D5: How are Distance and Speed Related for an Object that is Accelerating?
- Whole class discussion—return to CPU F&M Act I-E question 6

Day 6:

- CPU F&M Act I-A1 Motion Challenges

Day 7:

- Changing Motion and Graphing (by Allen D. Constant)
- CPU F&M Act I-A2 Comparing Speeds

Day 8:

- Assessment: CPU F&M Cycle I Lab Quiz (either individual or group)

CPU Force & Motion Cycle I Activities
(reference from CPU curriculum folder)
&
Additional Activities

Using Strobe-Flash Diagrams to Find Speed.

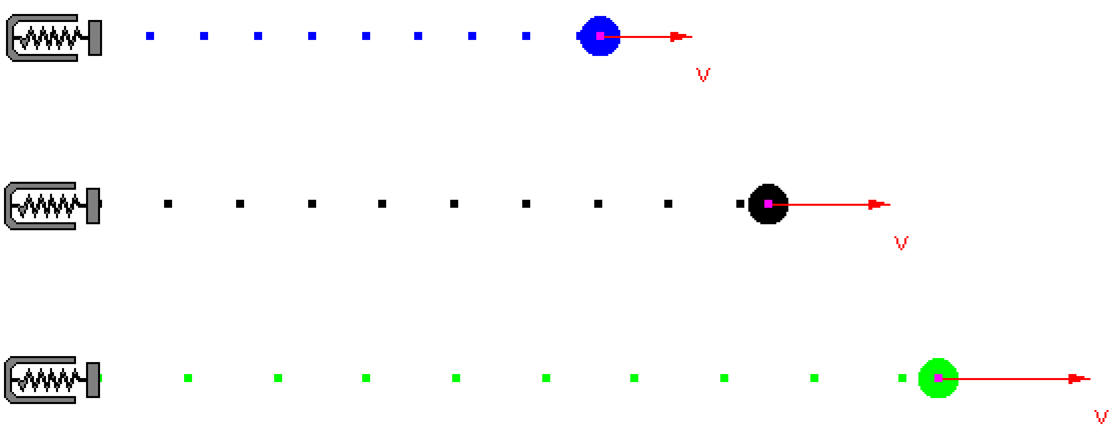
By Allen D. Constant

Materials Needed:

Worksheet, computer with graphing program, calculator, metric ruler.

Procedure:

In one of the previous activities we looked at graphing the results of an activity using a dynamics cart and one with a fan attached. In this activity we will look at strobe-flash diagrams showing the speed of three objects. We will assume that each of the objects has constant speed from the time it was launched, which means none of the objects has acceleration. You will to take you metric ruler and measure from each launcher to the center of the eighth dot to the right of the launcher and record that distance in the data table. We will assume that the distance between each dot is constant. Each dot represents one second of travel by that object. Find this average distance by dividing the total distance traveled by the number of seconds of travel and record this value. For this activity we are going to set a standard value for the motion of the middle (black) object and that value will be a speed of 10 m/s. You will be using this value and the distance traveled per second by the black object to determine the scale to be used for graphing. Using this value you will determine the average speed of each of the other two objects top (blue) and bottom (green). After completing you calculations for each object you will then prepare a line graph for the motion of all three objects.



Data Table:

Object	Total time of motion	Total distance covered	Average distance between dots	Average speed of the object
Blue				
Black				**10 m/s**

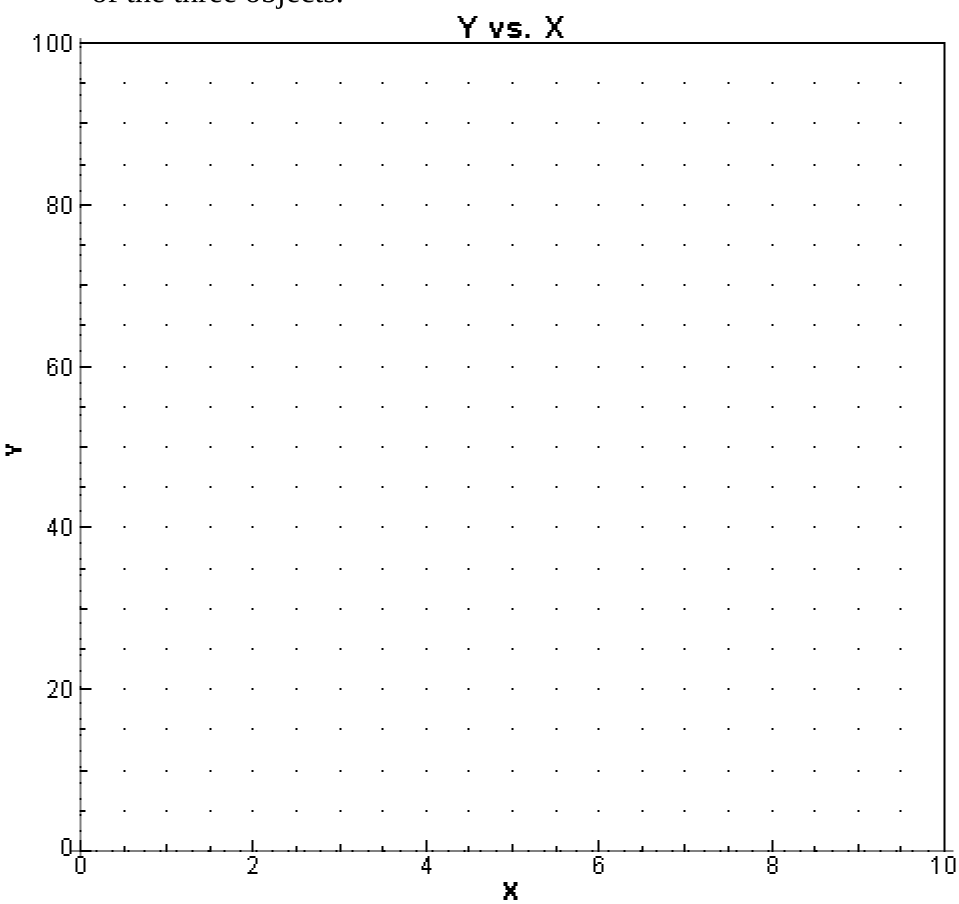
Green				

Questions:

1. How did you determine the average speed of the objects? Show your calculations here.
   a) average speed of top (blue) object __________________

   b) average speed of bottom (green) object ____________________

2. In the space below sketch what you think you graph will look like for the motion of the three objects.



   a) What value will be placed on the Y-axis?

   b) What value will be placed on the X-axis?

c) What scale will you use for your graph?

3. On the strobe-flash diagram you had an arrow with a v below it. What did this arrow represent?

Extension:

Now prepare a graph using either Graphical Analysis or Excel representing the above data and turn it in with the rest of your lab write-up.

Reference:

CPU Project curriculum materials on Force and Motion.

Changing Motion and Graphing

By Allen D. Constant

Objective:

You will graphically prove where two dynamics carts have the same velocity and when both are at the same location.

Materials needed:

Computer, graphing software, graph paper, pencil or pin.

Procedure:

Remembering the example of the pushed cart and the cart with the fan attached you will complete the following activity. We have talked about the use of two different graphing programs (Graphical Analysis and Excel), which you will use in this activity. In looking back at the activity using the fan cart you had to predict when the two carts had the same velocity. You had the choice of the following three statements:

a. The fan cart is further along the track than the regular cart.
b. The fan cart and regular cart are side by side.
c. The regular cart is further along the track than the fan cart.

During this activity you will use both Graphical Analysis and Excel to find the correct answer graphically. For the purpose of this activity we will assume that the regular cart is moving with a constant speed of 6 m/s and the fan cart is accelerating at rate of 2 m/s/s. Remember that acceleration is equal to the change in speed per unit time. You will be using three of the basic physics equations during this activity.

Distance = speed times time (d = v * t)
Distance = one half acceleration times time squared ($d = 1/2at^2$)
Final speed squared = initial speed squared plus two times acceleration times distance ($v_f^2 = v_i^2 + 2ad$)

In the third equation since the cart started from rest we don't use v_i^2 since it is equal to zero. We can rearrange the equation to solve for v_f. The equation now becomes $v_f = \sqrt{2ad}$ that will give us the velocity of the fan cart at each time interval.

You will use each graphing program to prepare distance-time graphs and speed-time graphs for each cart. First you will need to prepare a data table showing the location (distance) and speed of each cart for each time interval. Use the above equations to do this and you will need to include this data table in your lab write-up. You will also need to include the graphs produced in the write-up.

Time (s)	Distance of regular cart (m)	Distance of fan cart (m)	Speed of regular cart (m/s)	Speed of fan cart (m/s)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Questions:

1. At what time interval was each of the carts at the same location?

2. At what time interval was each of the carts going at the same speed?

3. If the times were different explain why.

4. If you were to take both graphs and produce overheads and place the overheads on top of each other how would the times line up?

Reference:

CPU Force and Motion Cycle 1 Activity I-E