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| **Name:** Amy Gunderman | **Contact Info:** agunderman11@gmail.com | **Date:** 02/13/15 |

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| **Lesson Title :** Different Function, Different Design, Different Velocity | **Unit #:** 1 | **Lesson #:** 1 | **Activity #:** 2 |
| **Activity Title:** Ticking the Tape of Motion |

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| **Estimated Lesson Duration:** | 4 days, 50 minute classes |
| **Estimated Activity Duration:** | 2 days, 50 minute classes |

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| **Setting:** | Classroom |

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| **Activity Objectives:** |

1. I can graphically represent acceleration and velocity of an object.
2. I can differentiate between examples of velocity and speed.
3. When provided with the necessary data, I can mathematically calculate the velocity of an object.
4. When provided with the necessary data, I can mathematically calculate the acceleration of an object.
5. When provided with a motion graph, I can describe the motion occurring, including the acceleration, in words.

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| **Activity Guiding Questions:** |

1. How can fluctuations in acceleration and velocity be represented in the form of a graph?

How is velocity different than speed and what do we need to know to calculate velocity?

What is acceleration and what do we need to know to calculate it?

How can we use a graph to tell if an object is moving at a uniform acceleration or not?

| **Next Generation Science Standards (NGSS)** | |
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| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☐ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☒ Developing and using models | ☐ Cause and effect |
| ☐ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☐ Systems and system models |
| ☒ Using mathematics and computational thinking | ☐ Energy and matter: Flows, cycles, and conservation |
| ☐ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☐ Engaging in argument from evidence | ☒ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

| **Ohio’s New Learning Standards for Science (ONLS)** |
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| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☐ Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| ☐ Demonstrating Science Knowledge **(D)** |
| ☐ Interpreting and Communicating Science Concepts **(C)** |
| ☒ Recalling Accurate Science **(R)** |

| **Common Core State Standards -- Mathematics (CCSS)** | |
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| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☒ Reason abstractly and quantitatively | ☐ Attendto precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☒ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, ONLS and/or CCSS):** |

(ONLS)

* Science Inquiry and Application:
  + Identify questions and concepts that guide scientific investigations;
  + Use technology and mathematics to improve investigations and communications;
  + Recognize and analyze explanations and models; and
* Motion Graphs:
  + Instantaneous velocity for an accelerating object can be determined by calculating the slope of the tangent line for some specific instant on a position vs. time graph.
  + Instantaneous velocity will be the same as average velocity for conditions of constant velocity, but this is rarely the case for accelerating objects.
* Position vs. time graph:
  + Increasing in speed, slope becomes steeper; Decreasing in speed become less steep.
* Velocity vs. time graph:
  + The slope indicates the acceleration:
    - Increasing in speed, slope away from the x-axis; decreasing in speed, slope toward the x-axis.
    - Straight line (not necessarily horizontal): acceleration is constant.
* Acceleration vs. time graph:
  + Objects moving with uniform acceleration will have a horizontal line on this graph.
    - This line will be at the x-axis for objects that are either standing still or moving with constant velocity.

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| **Materials**: (Link Handouts, Power Points, Resources, Websites, Supplies) |

* Worksheet Copies: “1. 1. 2d TickingTapeMotion\_Acc&Veloc\_AGunderman\_021415”
* Worksheet Copies: “1. 1. 2e TickingTapeMotion\_Acc&Veloc\_AGunderman\_021415”
* Ticker tape
* Timers
* Masking tape
* Books with the same mass (4 per group, text books work well for this step)
* Rubber bands
* Metric measuring devices
* Carts (1 per group of 4)
* This activity was adapted from a similar activity in *Active Physics*, by AAPT / AIP

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| **Teacher Advance Preparation:** |

* Acquire the necessary supplies (ticker tape, timers, masking tape, rubber bands, metric measuring devices, carts)
* Make copies of the two worksheets

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| **Activity Procedures:** |

**Day 1:** (50 minutes):

1. In this activity, students will be using ticker tape to learn about motion and graphing motion. Pair students up into groups of 2, and have each group get a timer with ticker tape. The timer will make a dot on a paper tape every 1/60 of a second. As the tape is pulled through the timer, the speed that the tape passes through the timer can be calculated by dividing the distance between two dots on the tape by 1/60 s. This ticker tape can be used to measure the speed of an object by attaching the tape to it, and then measuring the speed that the tape is pulled through the timer.
2. Pass out copies of the Ticking the Tape of Motion Worksheet #1 to each student and have each group record their answers to the following questions (already written on the worksheets) prior to starting the activity.
   1. What will the tape look like if you hold the end of it and pull it through the timer as you move?
   2. As you increase or decrease your movement, will the distance between the dots change? How will it change for each?
   3. If you begin walking at a constant speed, then increase your pace, how will the space between the dots change?
3. Have 1 student in the group, holding the end of the tape, walk forward at am much of a constant speed as he or she can manage, starting the timer at the same instant that the student begins walking.
4. The dots made on the tape are separated by equal amounts of time, and this time interval is referred to as a “tick,” and represents 1/60 of a second.
5. Remove the tape from the timer and use scissors to separate it into 6-tick sections (each section should be 6 spaces long).
6. Glue or tape the segments side-by-side on a plain sheet of paper to create a bar graph. Each of these bars represents the distance the student traveled in 1/10 of a second. (6 x 1/60 s). If the student actually managed to travel at a constant speed then the bars should all be exactly the same height. (Any groups that have vastly different heights of bars on their graphs may need to repeat steps 3-6). Have students answer question 1 on their worksheets.
7. Have groups repeat steps 3-6, except this time, have the student who is holding the tape and walking gradually and steadily increase his or her speed. (Obviously, the height of these bars should not all be the same).
8. Instruct the students to answer questions 2-6 on their worksheets. Student may need a brief review on calculating average speed and acceleration (see equations below).

Average speed (v) = Distance traveled (d) / Time elapsed (t)

Acceleration = Change in Speed / Time Interval

1. Have groups repeat steps 3-6 again, except this time, have the student holding the tape start moving at a high speed and gradually and steadily slow down. Have students answer questions 7-10 on their worksheets.
2. Have groups share their findings and facilitate a class discussion on acceleration.

**Day 2:** (50 minutes):

1. Have students get back into their same groups that they used the previous day. Have the guiding questions for this Activity clearly posted on the board as a reminder for the students the focus of this Activity. Take a few minutes to review these with the class.
2. Each group needs a large table top, a cart, a timer, ticker tape, a metric measuring device, 2 rubber bands, 4 books (all the same mass), and graph paper. Each student needs a copy of the Ticking Tape Motion worksheet #2 as well. Each group needs to delegate one student for each of the following jobs:
   1. Puller of the cart
   2. Catcher of the cart
   3. Keeper of the timer
   4. Keeper of the tape
3. Instruct the students to, side-by-side, attach two rubber bands to the front of the cart. Stretch each to a length of 60 cm, and practice pulling the cart carrying two books. Even while the cart is moving, keep the rubber bands stretched to 60 cm. After groups have mastered this task, they can proceed to step 4.
4. Next, have the students use masking tape to attach a 2-m long piece of paper tape to the back end of the cart. Thread the tape through the timer, turn it on, and pull the cart, keeping the rubber bands stretched to 60 cm.
5. As a group, have students perform the following experiments and label each tape:
   1. Experiment 1:
      1. 2 rubber bands, 1 book
      2. 2 rubber bands, 2 books
      3. 2 rubber bands, 3 books
      4. 2 rubber bands, 4 books
   2. Experiment 2:
      1. 2 books, 1 rubber band
      2. 2 books, 2 rubber bands
      3. 2 books, 3 rubber bands
      4. 2 books, 4 rubber bands
6. Students should make a graph of velocity vs time for each of the pieces of tape, following the same methods that they used on the previous day in the first half of this activity.
7. Students can complete this activity in groups, following the directions on their worksheets. They should complete all of the questions on their worksheets as well. Be sure to circulate the room and be ready to offer assistance. Ask probing questions while circulating to determine student understanding.
8. Collect student worksheets at the end of the class as a form of formative assessment. Determine from the worksheets whether or not the topic needs to be retaught prior to progressing on to Activity 3.

**Formative Assessments:** Link the items in the Activities that will be used as formative assessments.

* (Day 1) Creation of the three different graphs from the ticker-tape segments.
* (Day 1) Ticking Tape Motion worksheet #1 turned in with graphs at the end of day 1.
* (Day 1) Class discussion on acceleration.
* (Day 2) Probing questions as the students create graphs / answer questions on worksheet #2.

**Summative Assessments:** These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

* (Day 2) Ticking Tape Motion worksheet #2 turned in with graphs at the end of day 2.

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| **Differentiation:** Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

* Student ability levels were taken into account when grouping students (I paired highs with mediums, and mediums with lows), which successfully allowed the higher of the two in each group to help guide and bring the lower to a higher level of understanding and mastery.
* Visual learners’ needs were met through writing questions / notes on the board. Also, multiple class discussions took place as additional support for auditory learners. Kinesthetic learners’ needs were addressed through the hands-on activities with ticker-tape.
* More teacher modeling and assistance was provided for lower-achieving students.

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| **Reflection:** Reflect upon the successes and shortcomings of the lesson. |

* Successes:
  + When we finally got the marks to appear dark enough, the students were really engaged and understood the relationship between mark spacing (the distance from one mark to the next) and acceleration. Using the actual tape to produce the graph furthered this connection.
  + The intentional grouping of my students by academic ability level and social / behavioral tendencies (I paired highs with mediums, and mediums with lows) successfully allowed the higher of the two in each group to help guide and bring the lower to a higher level of understanding and mastery. To scaffold, I intentionally provided more assistance for medium – low groups.
  + Assigning tasks for each group member made sure that all members were fully engaged and participating, rather than one person taking over the entire project.
* Shortcomings:
  + Most of the middle-level students and all of the lower-level students struggled to follow the instructions for the ticker-tape lab. I had the directions projected onto the Smart Board in the front of the room, but this seemed to be of little help for them. On day two, I printed out student sheets of the directions for the lab and distributed these to all of the groups. The focus and following of instructions increased dramatically.
  + The timers used for this lab produced carbon spots that were so light the students really struggled to see them on the tape. Due to troubleshooting this issue, the students progressed slower through the lab and it ended up taking 3 days to complete.
  + The students also struggled with Day 2 of the activity because they were not sure exactly how to set up the carts and books. I paused the class and modeled the setup for the class as a whole.