Constant Velocity

Lesson Overview

This lesson is "**Lesson 2**" in a 3-lesson series exploring motion. In this lesson, students will record position and time data while observing a motorized cart moving at constant velocity in one direction and then observe a tennis ball being dropped using photo burst pictures. The observations and data collected are for 1 D Kinematics only where acceleration is constant is nonexistent (values of 0 or greater). Students will first, describe the motion qualitatively, then quantitatively with graphs and finally with equations. They will compare calculations from their data and graphs with those from the equations. They will create a story that will serve as a model of 1D Kinematics. The1 D Kinematics formulas align with the general mathematics formulas for linear and quadratic rates of change:

- Linear equations in slope-intercept form: y = mx + b; 1D Kinematics: $v = at + v_0$ & $d = ½ vt + d_0$ *(this variable is usually = to zero and is not represented in general physics 1 D Kinematic equations – it is show here to be representative of the linear equation).*
- Quadratic equations in standard form: $y = ax^2 + bx + c$; 1D kinematics: $d = at^2 + vt + d_0$ *(again usually = 0 so its omitted – shown here to be representative of the quadratic equation)*

Where **d** is final position, $\mathbf{d_0}$ is initial position (arbitrary, usually zero), **t** is time final, $\mathbf{t_0}$ is initial time, **v** is velocity final, $\mathbf{v_0}$ is initial velocity, and **a** is acceleration (for this investigation constant). Recommended The Physics Classroom 1 D Kinematics for Teacher background - http://www.physicsclassroom.com/Physics-Tutorial/1-D-Kinematics

NOTE: This lesson has been written for use without precision equipment. However, if you possess PASCO, Vernier, Pocket Lab, or other equipment – i.e. photogates, light sensors, radar, spark-timer, tickertape-timer, etc... It is recommended that you use them to produce precision data following the procedure for data collection. The rest of the lesson plan can be used with the data to develop the skills knowledge and characteristics presented in Profile of a SC Graduate.

Prerequisite knowledge

Students should be able to *(for 1 dimensional motion)*:

- Identify and accurately graph independent and dependent variables
- Identify and contrast vector and scalar quantities.
- Identify and contrast distance, displacement, and position
- Identify frames (points) of reference.
- Identify changes to distance, displacement and position when a frame of reference changes
- Add and subtract vectors
- Use a line of best fit on a graph of plotted data

Alignment

Science Standards

H.P.2A.3 Use mathematical and computational thinking to apply formulas related to an object's displacement, constant velocity, average velocity and constant acceleration. Interpret the meaning of the sign of displacement, velocity, and acceleration.

H.P.2A.4 Develop and use models to represent an object's displacement, velocity, and acceleration (including vector diagrams, data tables, motion graphs, dot motion diagrams, and mathematical formulas).

H.P.2A.5 Construct explanations for what is meant by "constant" velocity and "constant" acceleration (including writing descriptions of the object's motion and calculating the sign and magnitude of the slope of the line on a position-time and velocity-time graph).

Science and Engineering Practices

H.P.A.2 Develop and use models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.

H.P.1A.5 Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.

H.P.A.6 Construct explanations of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.

Crosscutting Concepts (from the SDE instructional unit resources document)

3. **Scale, proportion, and quantity**: The National Research Council (2012) states that "in considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance" (p. 84). The ideas of ratio and proportionality are important here along with being able to predict the effect of a change in one variable on another. For example, how will the speed of an object change if the time traveled is increased but the distance remains the same?

Math Standards

ACE.2 Create equations in two or more variables to represent relationships between quantities. Graph the equations on coordinate axes using appropriate labels, units, and scales.

FIF.8 Translate between different but equivalent forms of a function equations to reveal and explain different properties of the function.

SPID.7 Create a linear function to graphically model data from a real-world problem and interpret the meaning of the slope and intercept(s) in the context of the given problem.

Standards for Mathematical Practice

SMP.2 Reason abstractly and quantitatively.

SMP.3 Construct viable arguments and critique the reasoning of others.

SMP.4 Model with mathematics.

ELA Writing

Standard 6: Write independently, legibly, and routinely for a variety of tasks, purposes, and audiences over short and extended time frames.

6.1 Write routinely and persevere in writing tasks over short and extended time frames, for a range of domain-specific tasks, and for a variety of purposes and audiences.

ELA Communication

Standard 1 Interact with others to explore ideas and concepts, communicate meaning, and develop logical interpretation through collaborative conversations; build upon the ideas of others to clearly express one's own views while respecting diverse perspectives.

1.2 Initiate and participate effectively in a range of collaborative discussions with diverse partners; build on the ideas of others and express own ideas clearly and persuasively.

1.4 Engage in dialogue with peers and adults to explore meaning and interaction of ideas, concepts, and elements of text, reflecting, constructing, and articulating new understandings.

1.5 Synthesize areas of agreement and disagreement including justification for personal perspective; revise conclusions based on new evidence.

Connections

Content Area (2 or more) Connections

- Algebra II / Precalculus
- Physics

Content Connections

The use and graphing of linear equations in mathematics is the cornerstone skill of this lesson without that context the content for 1 D Kinematics is incomplete.

Active Learning Strategies (for Purposeful Reading, Meaningful Writing, and Productive Dialogue) – These will be hyperlinked in the lesson.

- Agreement Circles
- Frayer Model

Computational Thinking

The following computational thinking (CT) skills are used during this lesson:

- Logically organizing and analyzing data
- Representing data through abstractions such as models and simulations
- Automating solutions through algorithmic thinking (a series of ordered steps)
- Confidence in dealing with complexity
- Persistence in working with difficult problems
- The ability to deal with open ended problems
- The ability to communicate and work with others to achieve a common goal or solution

Lesson Plan

Time Required – Four 55-min class periods

Disciplinary Vocabulary –

average velocity, kinematics, frame or point of reference, constant velocity, instantaneous velocity, displacement, velocity, acceleration, constant acceleration, position, acceleration due to gravity, graphing, x-axis, y-axis, variable, average, constant, independent and dependent variables, slope, line of best fit, linear, quadratic, and rate (of change).

Materials Needed:

- Smooth flat surfaces (5-7meters for each group)
- Meter sticks (2 per group)
- Painter's tape (1 roll per group) *(NOTE: "blue painters tape from a home improvement store – doesn't leave a residue like masking tape)*
- Stop watches (1 per group) (accuracy to at least 1/10 of a second) – *Smart phones work exceptionally well*
- Graph Paper
- Copies of "Frayer Models" that students started in Lesson 1
- Copies of "Motion of Motorized Cart Activity" (1 per group)
- Constant velocity cart (1per group of 3-4 students) (Carts can be purchased for around $10. For example: Arbor Scientific $8.50 https://www.arborsci.com/constant-velocity-car.html)
- 10 Colored pencils (if you have groups of 4 you will need 2 identical sets), 4 markers and pairs of scissors per group
- Pack 1 two-meter piece of butcher paper cut into equal length strips, one per group (e.g. cut the butcher paper lengthwise so that each group gets a 2m long strip of paper)

- 1 tablet or smartphone per group of 2-3 students. Each device with either the Fast Burst Camera Lite App for android (Chromebooks and smartphones) or iPhone Burst (comes with most iPhones and iPads) but can also be downloaded. **FYI iPhones and iPads with burst CAN NOT be adjusted they are set at 10fps therefore android devices are preferred b/c you can 20fps and therefore more data points.**
- Computers, laptops, tablets or other devices with photo viewing software of app (Paint is fine) and screens large enough to take measurements.
- *OPTIONAL – Grid lined chart paper*

Formative Assessment Strategies:

- Frayer Model
  http://www.s2temsc.org/uploads/1/8/8/7/18873120/frayer_model_strategy.pdf
- Agreement Circles
  http://www.s2temsc.org/uploads/1/8/8/7/18873120/agreement_circles.pdf

Misconceptions:

Students have difficulty connecting motion graphs to physical concepts:

- Differentiating between slope and height
- Relating one variables graph with another (i.e. position, velocity (rate of change in position) and acceleration (rate of change in velocity))
- Matching narrative information with related features on a graph
- The meaning of the area under the graph
- Representing continuous motion with a line or curve
- Differentiating between the shape of the graph and the path of motion
- Negative velocity and acceleration & **constant acceleration (free fall – biggest misconception in 1D Kinematics)**

Safety Note(s): Students should wear appropriate safety equipment. *See MSDS and operating/safety instructions for all equipment and tools used.*

The is a 5E multiday lesson, daily opening and closing is up to the instructor –where time might be a factor we have included "re-engagement" and Exit Tickets. There is a suggested number of periods beside each "E" in the lesson plan – However, it is not advisable to move onto the next part until students have had enough time to process the current information**.**

Day One—Day Three

Engage:

- Ask students if they have or have ever had motorized vehicles
  - You should get a variety of answers some may include things like ATVs or JetSkis as well as remote controlled vehicles some that fly.
  - Accept any answer if it has a motor.

- Have them divide the "Examples" into 2 columns – "constant" and "changing" - they should do this for boxes in both Frayer models (Velocity and Acceleration that was created in *Lesson 1: "From Dot Motion to Graphing Velocity"*).

Explore:

- Have student return to their velocity Frayer models and have them add and explain the term "constant" to the characteristics.
- Have students relate the term constant velocity to motorized vehicles in general. Use the following questions:
    - When would the speed and direction of a motorized vehicle change?
    - When would it stay the same?
- Ask students to consider what happens to their bodies when the velocity (speed and/or direction) of the car changes?
- Ask them what happens to their bodies when they are in a car with the cruise control set?
- Have groups discuss point/frame of reference questions regarding the cruise control example, to set up the importance of vectors and point of view for the activity.
    - How would you describe the motion of this car if you were sitting in it?
    - How would describe the motion of this car if you were observing it from the side of the road?
    - What is the difference? Did the car change its motion?
    - Why is direction important?

Explain:

- Facilitate "The Motion of a Motorized Cart" Activity
- Groups will present their graphs (this is an ideal time to use the gridded chart paper if you have it) and explain them using the following terms & the guiding questions on the Student sheet:
    - Constant Velocity
    - Position
    - Time
    - Displacement
    - Area and Position
    - Linear
- Teacher will capture these explanations for use in the Agreement Circle

Day Four

Extend & Evaluate:

- Use "Agreement Circles" to identify the key points of 1D motion with a constant velocity. Use the students' explanations from the explain portion of the lesson.
  - Allow some time (no more than 15 min) at the beginning of the period to review the explanations – this could be tied into an opener/re-engagement activity
  - Be sure to get students to clarify their evidence for statements/explanations

Motion of a Motorized Cart Activity Sheet

Purpose:

- To use graphing as a model representing an object's motion (position, displacement, velocity and acceleration).
- To develop an operational definition for constant velocity.

Materials per group:

motorized cart	meter stick or metric tape
2 m of butcher paper & blue tape	graph paper
10 colored pencils or markers	stopwatch or smart phone timer

Description:

You will observe and measure the motion of a motorized cart by marking its position along a strip of butcher paper at regular time intervals. Note that you can adjust the speed of the cart using the small dial - find a speed that works well for you and then do not change the cart's speed during the remaining trials. The speed you choose should make it easy to mark the paper at the time interval given.

Once you have a record of the cart's motion on the butcher paper, you can measure and record its position in a data table and construct a position vs. time graph for the cart's motion. You can then create a velocity (position vs time) graph. The procedure is similar to the procedure we used to match the dot motion diagrams.

Although you will work as a team during this lab, each student will be assessed on their own individual graph and operational definition of velocity (Frayer Model).

Procedure:

Setup:

1. Fasten the 2-meter strip of butcher paper to your lab table with tape.
2. Place the motorized cart beside the tape, near one end. Mark the cart's starting position on the tape.
3. Adjust the speed of the cart so that it takes at least 30 seconds for the cart to move the length of the tape.
4. Assign the following roles:
    a. Time Keeper – starts the timer at the same time telling the driver to release the cart and calls out regular time intervals
    b. Driver – releases the cart from the starting position when instructed by the time keeper.

   c. Marker(s) – Records the carts position on the butcher paper at each time interval. (If you have 2 people marking be sure they have the same color)
5. As a group decide on a time interval to mark your cart's positions (HINT: you will be using this interval to graph and later to make calculations).

   Time interval: _______ seconds

6. As a group create a data table for recording 10 trials, position in meters, time in seconds and displacement (change in position) in meters. And enter the time intervals. For example, if the chosen time interval is 7 seconds and it takes the cart 49 seconds to get to the end, then enter 7, 14, 21, 28, 35, 42 and 49. The data table will need to accommodate 7 positions for each trial.

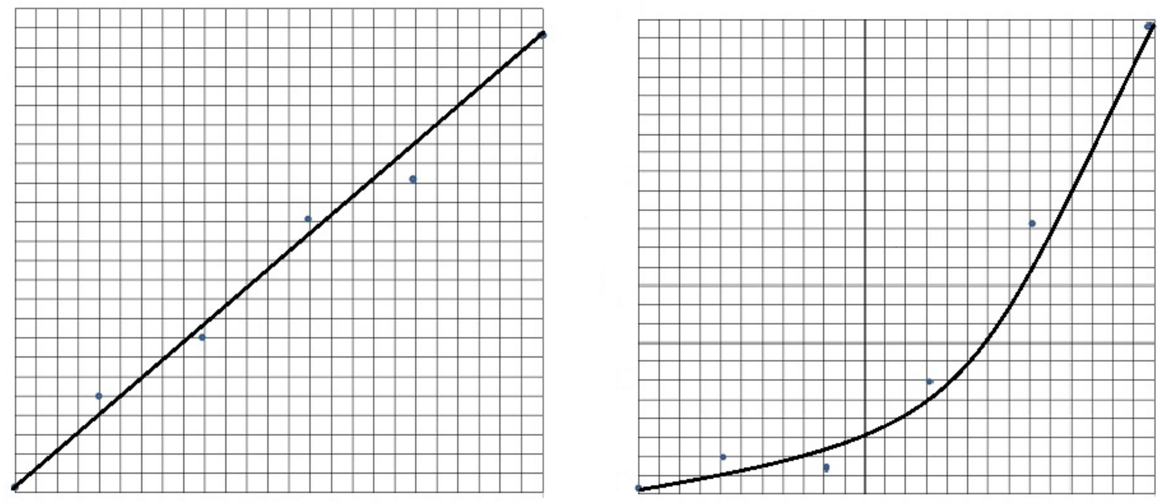
Data Collection:

1. You may want to make a couple of practice runs to get everyone coordinated. The paper has another side if you need it.
2. The timer starts and tells the driver to release the cart at the same time.
3. The timer calls out the timer interval and the marker, marks the position of the cart at that interval on the butcher paper. If you are using 2 timers be sure that both colored pencils are the same or similar colors.
4. ON the first trial write the time interval near each dot (This will help with recording position data with time data).
5. Repeat steps 7 - 9 using a different color pencil for each trial until you have 10 trials. (The different colors will help with distinguishing one trial from another.)

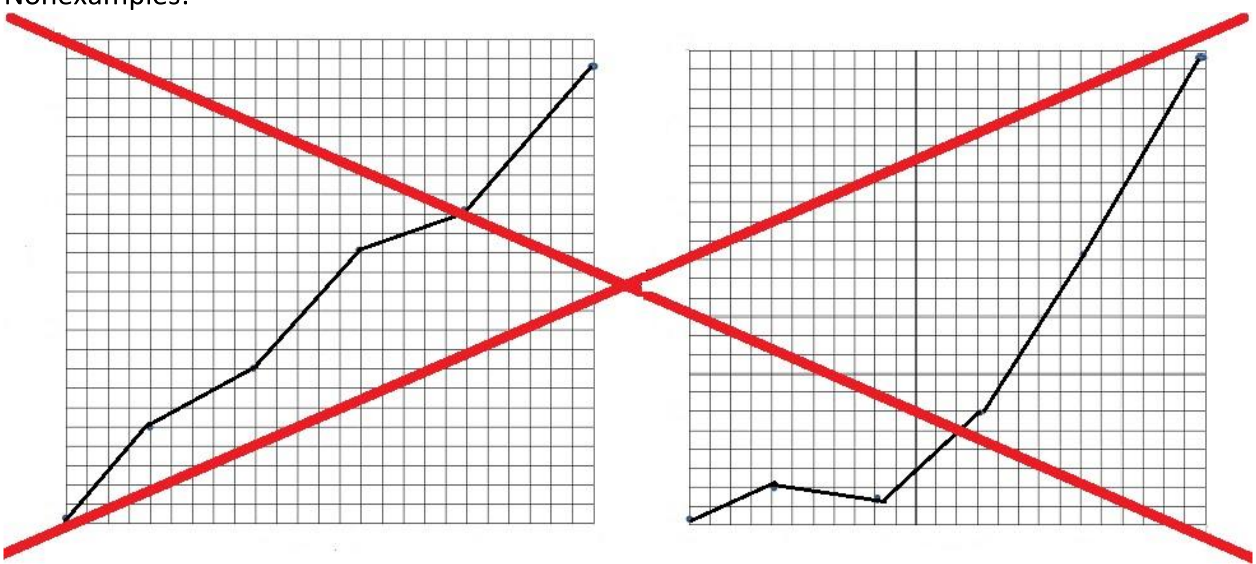
Analysis:

1. Measure each position of the cart from the start.
   a. Measure from the start to each to each colored dot – the different colors represent the different trials.
   b. It does not matter which color you assign to a trial, but it does matter that you keep the measurements for one trial, one color. For example, if on the third time we used a red pencil, we can assign red as trial one but when we enter the positions for trial one we only measure from the start to each RED dot and enter that data into the
2. Record your position data for each trial next to its corresponding time interval.
3. Calculate the average position at each time interval.
4. Plot the average of each position/time data pair on a position vs. time graph.
   a. Remember to label the graph and both axis.
   b. Include the proper units for each axis.
   c. You may ask your group members questions to assist you, BUT you must draw and label your own graph and plot the (time/position) ordered pair for each time interval
5. Draw a best fit line for the data points on your graph. See the examples below – Do your points fit best to a line or a curve?

Examples of Best Curves:



Nonexamples:



6. Calculate the slope using the y-intercept formula (y=mx + b). BE SURE TO KEEP THE UNITS!!!
7. Calculate the slope using the graph (rise/run OR $(y_2 – y_1)/(x_2 - x_1)$)
8. Substitute the independent and dependent variables into the y intercept formula – d is used to represent the position and d_0 represents the position at time = 0sec t is time and slope is velocity.

Results and Conclusions:

1. How does the displacement compare to the position? Why?
2. What does a linear velocity graph tell us about the motion of an object?
3. What does the slope of the graph tell us?