Name **Period** **Date**

2. One-Dimensional Motion: Inclined Plane

Structured (S)

Objectives

A cart is released from rest down an inclined track. Derive two of the fundamental kinematic equation using linearized forms of position versus time and velocity versus time data acquired during the cart's travel.

The objective of this lab is to derive two kinematic equations that relate:

♦ Position and time for an object with constant acceleration

♦ Velocity and time for an object with constant acceleration

Materials and Equipment

For each student or group:

♦ Data collection system
♦ Motion sensor
♦ Dynamics track
♦ Dynamics cart
♦ End stop
♦ Large base and support rod
♦ Dynamics track rod clamp

Background

According to Newton's first law, an object moving without the influence of a net external force maintains a constant velocity. The following equation is used to relate position and time mathematically for an object demonstrating constant velocity (zero acceleration):

$$x = x_0 + vt \tag{1}$$

where x is the position of the object at time t and x_0 is the initial position of the object.

However, an object that experiences a net external force does accelerate. In this lab, students will derive two of the fundamental kinematic equations involving motion with a constant acceleration.

Relevant Equations

$$x = x_0 + v_0 t + \frac{1}{2}at^2 \tag{2}$$

Eq. 2 relates position x as a function of time t for accelerated motion. Assuming the initial velocity v_0 is zero, students will graph position versus time squared t^2 to derive the value for the slope, namely half of the acceleration, ½a. Theoretically, the vertical intercept of the graph is the initial position x_0.

$$v = v_0 + at \tag{3}$$

Eq. 3 relates velocity v as a function of time t for accelerated motion. Students graph velocity versus time to derive the value for the slope, namely acceleration, a.

Safety

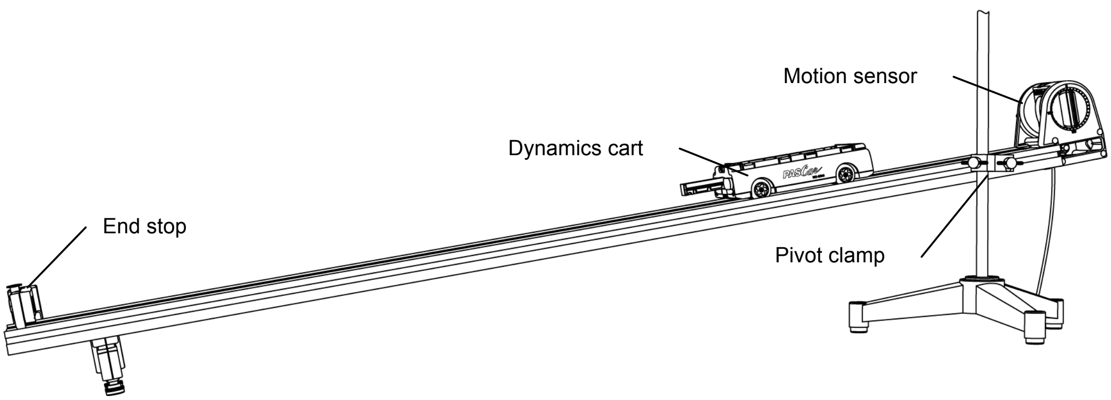
Follow all standard laboratory procedures

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "�" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Set Up



1. ☐ Attach one end of the dynamics track to the large base and support rod using the dynamics track rod clamp, inclining the track slightly.

2. ☐ Mount the motion sensor to the inclined end of the track with the sensing element on the sensor pointing down the length of the track. Make certain the switch on the top of the sensor is set to the cart icon.

3. ☐ Mount the end stop to the bottom end of the track.

4. ☐ Connect the motion sensor to the data collection system, �(2.1) and then change the sample rate to 20 Hz. �(5.1)

5. ☐ On the data collection system, create two graphs �(7.1.11): Graph 1 will have position on the y-axis and time on the x-axis. Graph 2 will have velocity on the y-axis and time on the x-axis. �(7.1.1)

Collect Data

6. ☐ Hold the cart stationary on the track approximately 15 cm in front of the motion sensor.

7. ☐ Simultaneously begin data recording �(6.2) and release the cart. Be sure to catch the cart before it reaches the end of the track.

8. ☐ As soon as the cart has reached the end of the track, stop data recording. �(6.2)

6. ☐ Save your data on the data collection system before proceeding to the analysis section. �(11.1)

Data Analysis

1. ☐ Apply a line of best fit to the velocity versus time data in your graph and determine the equation for that line �(9.6). Record the result here.

Best fit line equation: ________________________________
(velocity versus time)

2. ☐ Linearize your position versus time data by creating a calculation to convert the time measurements to time squared.

3. ☐ Using the calculator function on the data collection system, create the calculation: T2 = *Time*^2, where *Time* is defined as the time measurement from your data collection system. �(10.3)

Note: For DataStudio users, the calculation will need to read T2 = timeof(*Position*)^2 where *Position* is defined as the position measurements from the motion sensor.

4. ☐ On the data collection system, create a third (new) graph with Position on the y-axis and Time^2 (T2) on the x-axis. �(7.1.1)

5. ☐ Apply a line of best fit to the data in your new graph and determine the equation for that line �(9.6). Record the result here.

Best fit line equation: ________________________________
(position versus t^2)

Analysis Questions

1. What is the physical meaning of the slope of your graph of velocity versus time for the cart traveling down an incline?

2. What is the physical meaning of the vertical intercept of the graph?

3. Compare the slope of your velocity versus time graph to the slope of the graphs from other groups. What factors affect whether or not your value is greater than or less than theirs?

4. How does the slope of a velocity versus time graph compare to the slope of a position versus t^2 graph? What relationship exists between the two slopes?

5. What is the physical meaning of the slope of the graph from Table 1 data?

6. What is the physical meaning of the vertical intercept of the graph?

7. Use your responses from the previous questions and other information from your data to derive a mathematical equation relating velocity v at time t to the acceleration a experienced by the cart. Explain how you used your responses from the previous questions to derive this equation.

8. Use your responses from the previous questions and other information from your data to derive a mathematical equation relating position *x* at time *t* to the acceleration *a* experienced by the cart. Explain how you used your responses from the previous questions to derive this equation.

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Synthesis Questions

Use available resources to help you answer the following questions.

1. In the above analysis questions the following equations should have been derived: $x = x_0 + v_0 t + \frac{1}{2}at^2$ and $v = v_0 + at$. Do the versions you derived include a v_0 term, why or why not?

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2. Another kinematic equation is: $x = \frac{1}{2}(v_0 + v)t$. Use this equation in combination with one of the equations that you derived from this lab to derive a fourth equation: $v^2 = v_0^2 + 2ax$

3. Write the 4 kinematic equations:

4. A bicyclist accelerates from rest at a rate of 4.0 m/s^2. How far does he or she go after 5.0 seconds?

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