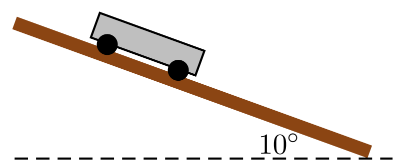
Laboratory 6: Newton's Second Law for a Single Object – Prelab

1 Cart sliding along a ramp.

The illustrated cart can slide along a frictionless inclined surface. The cart is released from rest.



a) Starting with a free body diagram and Newton's second law determine the acceleration of the cart if its mass is 0.500 kg.

b) Suppose that a block with mass 0.250 kg is placed on the cart. Will this change its acceleration? If so, what will the acceleration be? Explain your answer.

Laboratory 6: Newton's Second Law for a Single Object – Activity

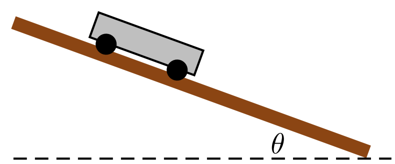
Newton's laws provide a framework for determining the acceleration of any object. The framework requires that all the forces, $\vec{\mathbf{F}}_1, \vec{\mathbf{F}}_2, \vec{\mathbf{F}}_3, \ldots$, that act on the object are known. The acceleration, $\vec{\mathbf{a}}$, of the object is given indirectly by Newton's second law,

$$\vec{\mathbf{F}}_{\text{net}} = m\vec{\mathbf{a}}$$

where m is the mass of the object and the net force is given by

$$\vec{\mathbf{F}}_{\text{net}} = \sum_i \vec{\mathbf{F}}_i = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + \vec{\mathbf{F}}_3 + \ldots.$$

You will observe a cart sliding along an inclined ramp. A motion sensor will record the velocity of the cart as time passes and you can use this data to determine the cart's acceleration, which can be compared against a value determined by applying Newton's laws to the cart.



1 Cart sliding along a ramp: theory

The first aim of the laboratory is to determine a general equation for the acceleration of the cart that applies for various ramp angles and cart masses. Consider a cart, of mass m, that slides up or down a frictionless ramp, whose surface is at an angle θ from the horizontal.

a) Draw a free body diagram for the cart.

b) Will the acceleration of the cart will be different when the cart is sliding up the ramp versus down the ramp? Explain your answer by using the free body diagram for the cart.

In terms of components, Newton's second law states that

$$\boxed{\begin{aligned} \Sigma F_x &= ma_x \quad \text{and} \\ \Sigma F_y &= ma_y. \end{aligned}} \qquad \begin{aligned} (1) \\ (2) \end{aligned}$$

c) Using "tilted axes" with the x-axis along the ramp determine expressions for the components of all the forces. Then use Eqs. (1) and (2) to determine an expression for the magnitude of the cart's acceleration, a. This should have the form

$$a = \text{formula where the only symbols allowed are } g,\ \theta \text{ and } m.$$

d) Does your formula predict that the mass of the cart will affect the acceleration? Explain your answer.

e) Does your formula predict that the acceleration of the cart as it ascends the ramp will be different from that when it descends? Explain your answer.

2 Cart descending a ramp: experiment

The experiment part of the laboratory exercise will investigate whether the predicted acceleration matches the measured acceleration for a cart sliding down a tilted track. A PASCO motion sensor will record position and velocity data for the moving cart. These data can then produce a velocity versus time graph for the cart's motion.

a) *(This part describes how to set up and run the lab and is for reference only.)*

   i) Start Capstone and connect the motion sensor. Set the sample rate to 25 Hz. Configure Capstone to display a graph of velocity versus time.

   ii) Tilt the track up so that the motion sensor is at the top of the resulting ramp.

   iii) Hold the cart at rest at a distance a little more than 20 cm from the motion sensor. Start data acquisition and release the cart. Save the data.

b) A short video will illustrate an example run of the lab. Watch the video. What is the approximate angle between the cart and the table as viewed from the video?

c) Describe how to determine the angle that the track makes with respect to the horizontal by using various measurements of lengths and heights (measuring the angle directly using a protractor will be much less accurate).

The experiment was done several times, the data was recorded and will be given to you. This data should be used in the follow parts. Note that the data will be given to you as an Excel spreadsheet. You should save this and create a copy of it as a backup.

d) Use the technique from part 2 c) to determine the angle that the track makes with respect to the horizontal.

e) Explain whether the graph of velocity versus time suggests that the acceleration is constant or not. Determine the acceleration of the cart from the graph of velocity versus time. Explain how you obtained this.

f) Predict the acceleration using the formula developed in part 1 c). Determine the percentage difference between the measured and predicted acceleration.

g) Repeat parts 2 d) to 2 f) for two other slope angles.

h) Repeat parts 2 d) to 2 f) for the same slope angle but with additional mass added to the cart. Does the additional mass change the cart's acceleration? Does it make the experiment more or less accurate?

3 Cart ascending and descending a ramp: experiment

In section 1 you applied Newton's second law to the cart for the cases where it **ascends or descends** the ramp and you predicted whether the acceleration would differ between these cases, given that the ramp angle is the same. The following experiment will investigate whether your prediction is correct.

a) *(This part describes how to set up and run the lab and is for reference only.)* Ensure that Capstone is still configured as before. Hold the cart at the bottom of the ramp. Start data acquisition and give the cart a gentle push up the slope. Capstone should produce a graph of velocity versus time.
Important: *the older versions of the* motion sensor *do not record position of an object that is closer to the sensor than* 50 cm *accurately. An example of this is illustrated in Fig. 1. Discard any run in which this or worse happens.*

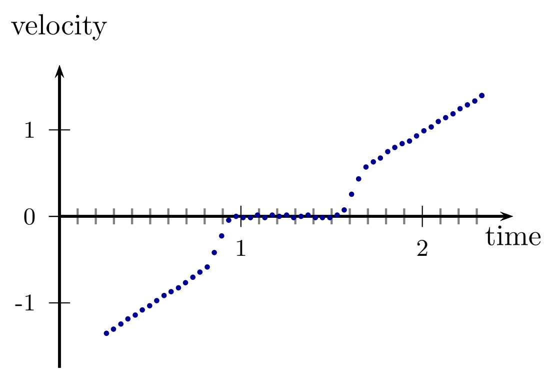


Figure 1: *Data recorded when the cart approached too close to the motion sensor. During the time interval from about* 0.8 *s to* 1.6 *s, the motion sensor did not record the cart's position or velocity correctly.* ***This is bad data!***

The experiment was done at different ramp angles, the data was recorded and will be given to you. Note that the data will be given to you as an Excel spreadsheet. You should save this and create a copy of it as a backup.

b) For the first ramp angle, use the graph to identify the period on the graph during which the cart ascends the ramp. Identify the period during which the cart descends.

c) Does the graph suggest that the acceleration while the cart ascends differs from that while it descends? Explain your answer.

d) Using the data table, create a graph of velocity versus time *only for the period while the cart ascends.* Determine and record the acceleration of the cart while it ascends. Include a copy of your graph with materials that you submit.

e) Using the data table, create a graph of velocity versus time *only for the period while the cart descends.* Determine and record the acceleration of the cart while it descends. Include a copy of your graph with materials that you submit.

f) How does the acceleration of the cart when ascending compare (same as, close to, larger, smaller, ...) to that when it is descending?

g) Repeat parts 3 b) to 3 f) for the other ramp angle. You should observe that there is always a discrepancy between the acceleration of the cart as it ascends the ramp compared to that as it descends. Is the acceleration as the cart ascends always larger than that as it descends or always smaller?

h) The forces that appear on your original free body diagram cannot explain this discrepancy; there must be an additional force present. This force is either friction or air resistance and it points directly opposite to the direction of motion.
Draw a corrected free body diagram that includes this force for the ascending cart. Repeat this for the descending cart. Are the free body diagrams the same or not? For which case (ascending/descending) will the net force be larger? Use this to describe for which case the acceleration will be larger. Does this agree with your observations?

4 Conclusion

a) What is the main conclusion of this entire laboratory exercise? What physics does it address and what does it say about that physics?

b) How could the conclusion be strengthened? What lab modifications would be useful to do this?