CAST 2023
Houston, TX

Hitting the Slopes: Explorations in Kinematics, Force, and Mass

Experiments

Motion on an Incline: ***Coasting Up and Down***

- Go Direct Sensor Cart

Inertial and Gravitational Mass: ***What's the Difference?***

- Go Direct Sensor Cart

Hooke's Law: ***Stretching Rubber Bands***

- Go Direct Sensor Cart

Workshop Presenter

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INVESTIGATION 3

Motion on an Incline: *Coasting Up and Down*

INTRODUCTION

Skateboarders and snowboarders must have the most experience and understanding of the sensations encountered during half-pipe rides. They know when to expect maximum forces and points of weightlessness. Some roller coaster rides offer similar experiences to the passengers but not with the repetitiveness encountered by boarders who have mastered the half-pipe. You might wonder how professional boarders like Shaun White are able to increase their height above the pipe's rim as they make their way down the slope. Whether half-pipe riders know it or not they are using two basic physics principles, the Conservation of Energy and the Conservation or Rotational Momentum. Riders on half-pipes add energy to the system by pumping their legs and arms. The physics of skateboarding on half-pipes is more fully explained here. These principles will be studied later in your physics course but for now understanding position, velocity and acceleration graphs of carts rolling up and down an incline will assist with understanding the great conservation laws of physics.

In this lab you will collect position, velocity and acceleration data as you observe the Sensor Cart coasting up and down an incline.

Before collecting data, observe your Sensor Cart rolling up and down the incline, then sketch graphs of your predictions for the shape of position vs. time, velocity vs. time and acceleration vs. time graphs that describe the motion of the cart.

RESEARCH QUESTIONS

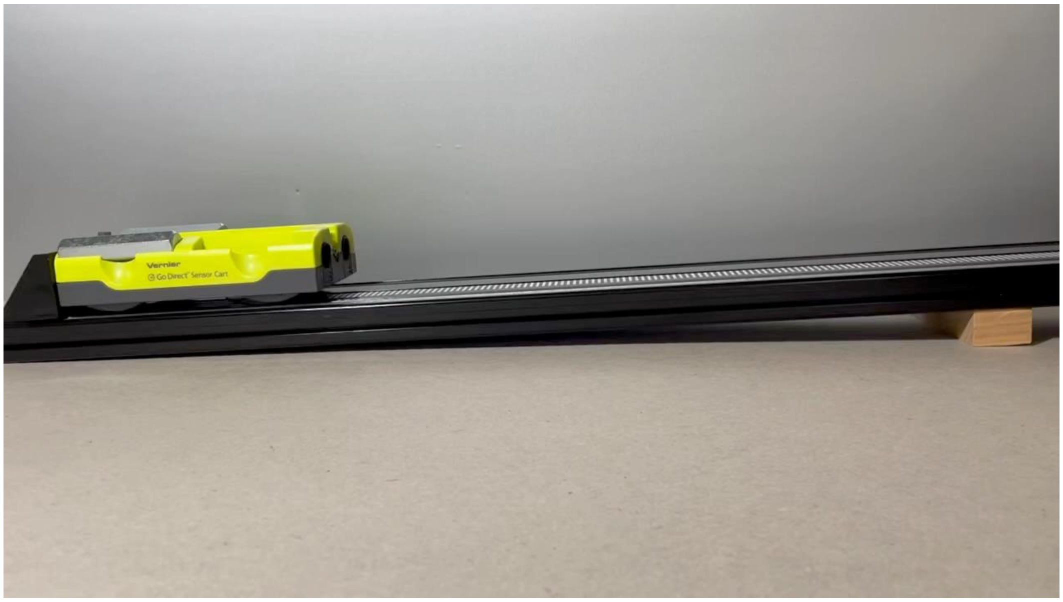
1. When the cart rolls up and down the incline where on the ramp will the speed of the cart be zero?
2. Where on the ramp will the cart be traveling with maximum speed?
3. How does the acceleration of the cart coasting up the ramp compare to the value when coasting down?

PREDICTED OUTCOME

PART 1: KINEMATICS

EXPERIMENTAL DESIGN

SETUP (Double click to view the event)



The sensor cart's plunger launches the cart. It then coasts up and down the incline.

MATERIALS Sensor Cart, tilted track with end stop

PROCEDURE (Designed with student team collaboration)

ANALYSIS (Include graphs, and sample calculations)

CONCLUSION (Respond to the research question, include results with error analysis)

EXTENSIONS (Questions for further research)

INVESTIGATION 8

Inertial and Gravitational Mass: *What's the Difference?*

INTRODUCTION

The measure of mass, matter, the amount of substance, is important whether you want to know the amount of material in a planet or you're on the wrestling team and determined to qualify for the 120-pound (54.43 kg) weight class. Inertial mass and gravitational mass both use the kilogram as the standard unit of measure, are represented by the letter 'm' for mass but are measured in different ways. They represent different properties of matter. Gravitational mass is proportional the force of attraction between two objects. Inertia describes resistance to changes in velocity. Thus, mass can be measured two ways: by its gravitational attraction and by its resistance to change in motion.

When studying Newton's Laws of Motion, you learned the second law of motion can be represented as ($m = F_{net}/a$). In this form the second Law is referred to as "The Law of Inertia". When mass is determined from the quotient of (F_{net}/a), the calculated mass is known as the inertial mass. Astronauts in the weightless environment of the International Space Station use an oscillating device to measure their inertial mass. You can also 'feel' an object's inertia, when oscillating it back and forth in your hand. Try this for both a 100 g mass and a 1,000 g mass. The 1,000 g (1 kg) mass obviously feels heavier and is also more difficult to oscillate back and forth quickly as it has more inertia. The amount of inertia of an object is a measure of its resistance to change velocity. Some physics textbooks opt to use the term 'inertia' instead of 'mass' when describing Newton's 2nd Law of Motion, e.g. a hockey player has 100 kg of inertia. Here is a classic demonstration illustrating the difference between inertia and weight.

Equal arm balances are used to compare and measure gravitational mass. If you took an equal arm balance to the moon or another planet, it would behave in the same way as it does on earth. Obviously, balances do not work in weightless environments. Equal arm balances compare known masses on one side to an unknown mass on the other side. Common digital balances and spring scales measure the weight (F_w) of an object. They are usually calibrated to report the gravitational mass in grams. The equation ($m = F_w/g$) is used to calculate the gravitational mass. When on the earth's surface g = 9.81 N/kg.

Your task is to measure and compare the inertial mass of the Sensor Cart to its gravitational mass.

PART 3: FORCES

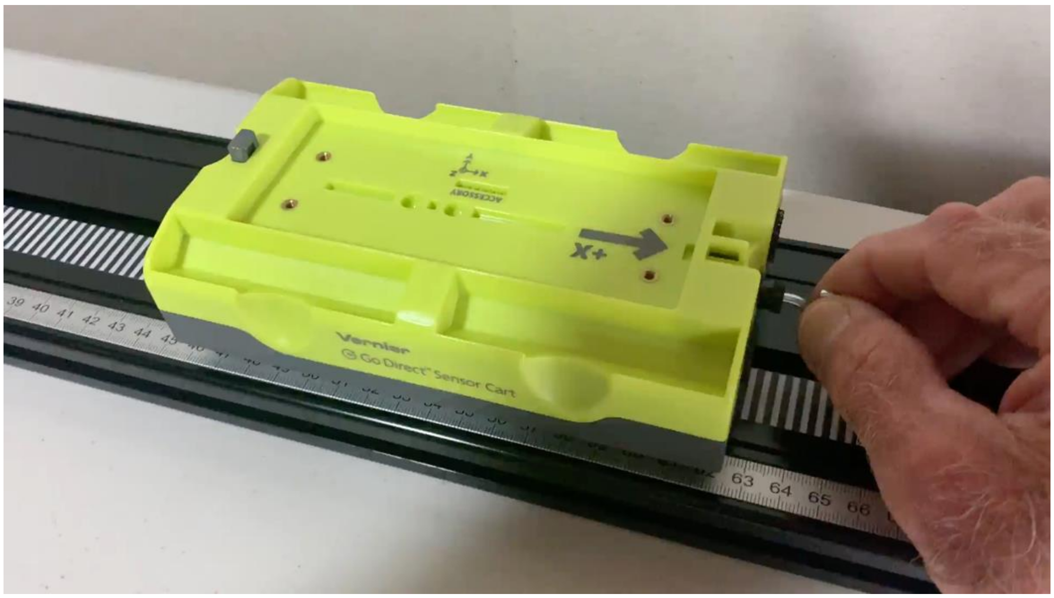
RESEARCH QUESTION

How do the measures of inertial and gravitational mass compare?

PREDICTED OUTCOME

EXPERIMENTAL DESIGN

SETUP (Double click to view the event)



While holding the hook of the force sensor, the Sensor Cart is oscillated back and forth. The force sensor reports the force exerted to constantly change the velocity of the cart. The motion encoder wheel calculates and reports the resulting acceleration of the cart.

A digital scale reports the gravitational mass of the Sensor Cart.

PART 3: FORCES

MATERIALS Sensor Cart with hook, level track or table, digital scale

PROCEDURE (Designed with student team collaboration)

ANALYSIS (Include graphs and sample calculations)

CONCLUSION (Respond to the research question, include results with error analysis)

EXTENSIONS (Questions for further research)

INVESTIGATION 9

Hooke's Law: *Stretching Rubber Bands*

INTRODUCTION

It would be rare to find a home or office that didn't have a few rubber bands hiding in a drawer or cabinet. We find all sorts of uses for these stretchy loops. Large elastic bands 5 cm wide and 30 cm long and larger are now popular and used by physical therapists for strength training exercises. A 20-pound barbell always exerts a force of 20 pounds whether you hold it at shoulder level or above your head. On the other hand, does an elastic band always exert the same force as it is being stretched? Robert Hooke, a contemporary of Isaac Newton is given credit for first exploring this question. The relationship describing the force and stretch distance of elastic materials is known as Hooke's Law.

The Sensor Cart is the perfect tool to measure the force applied and the resulting change of position while stretching a rubber band. Your task is to use the Sensor Cart and a rubber band to determine the relationship between forces applied and the resulting amount of stretch of a rubber band.

Before collecting data view the event video below and then sketch a graph of force vs. position that describes the stretching of a rubber band. Place your graph in the Predicted Outcome section of your lab report.

RESEARCH QUESTION

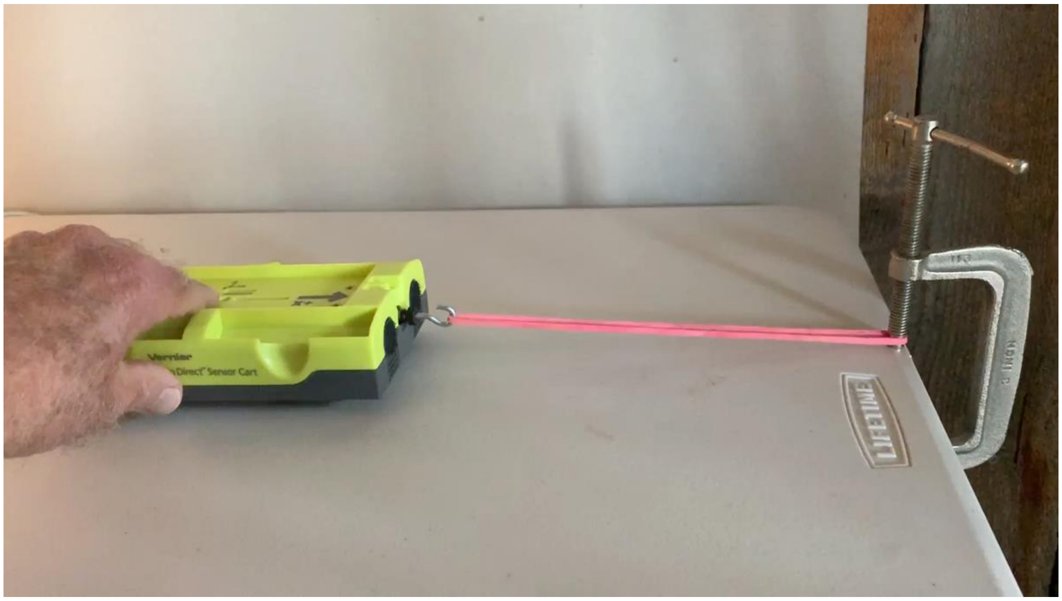
> What mathematical function best describes the relationship between the applied force and the resulting amount of stretch of a rubber band?

PREDICTED OUTCOME

PART 3: FORCES

EXPERIMENTAL DESIGN

SETUP (double click to view the video)



With the rubber and attached but not under stress, zero the Force and Position Sensors. Tap 'Collect' and collect both force and position data.

MATERIALS Sensor Cart with hook, rubber band, C-clamp

PROCEDURE (Designed with student team collaboration)

ANALYSIS (Include graphs and sample calculations)

CONCLUSIONS (Respond to the research question, include results with error analysis)

EXTENSIONS (Questions for further research)