TEACHERS GUIDE

LARGE INCLINED PLANE
ITEM # 3481-20

MECHANICS - DEMONSTRATION DEVICES

Demonstrate one of the simple machines that have been used to throughout history; the inclined plane. The inclined plane provides a smooth surface that can be adjusted to any height (with a ring stand) to demonstrate the effect of gravity, friction, collision forces, or simple machines. By using the attached pulley or the inclined plane, simple machines can be used to investigate mechanical advantage. Using an engineering context, students can investigate scenarios that use the inclined plane as part of a solution to a variety of criteria.

Materials

- stopwatches
- weight set
- pulley set
- simple tool set
- force spring
- protractor
- weight cart
- toy cars

Goals & Objectives

See page 7 for Next Generation Science Standards (NGSS)

HISTORY

Inclined planes have been used since ancient times to move heavy objects such as the building of the Egyptian pyramids with very large stone blocks. Modified inclined planes are used in many modern inventions such as screws, playground slides, and even jet engines (turbines).

How It Works

The inclined plane works by decreasing the amount of force required to move an object vertically. It does this by changing the angle of an applied force from directly vertical (pull it straight up and work directly against the gravity force) to also include a horizontal component (work against friction and a fraction of the gravity force).

ACTIVITIES

1a Introduce students to forces by rolling a cart down the inclined plane at different heights.

Observe the time it takes to roll a certain distance and the speed at the bottom of inclined plane. Connect the force of gravity to the height of the inclined plane and the speed of the cart; it is a direct relationship.

Gather data about the height of the inclined plane and the distance the cart rolls or measure the time that the cart takes to roll a certain distance.

b Begin to connect evidence for a claim and data gathered by measuring the time to travel the inclined plane (or the speed of the car) compared to a student's claim (or prediction).

Students can challenge their understanding of the effects of mass on the speed of a moving cart and begin to connect the concept of a moving mass with force (kinetic energy).

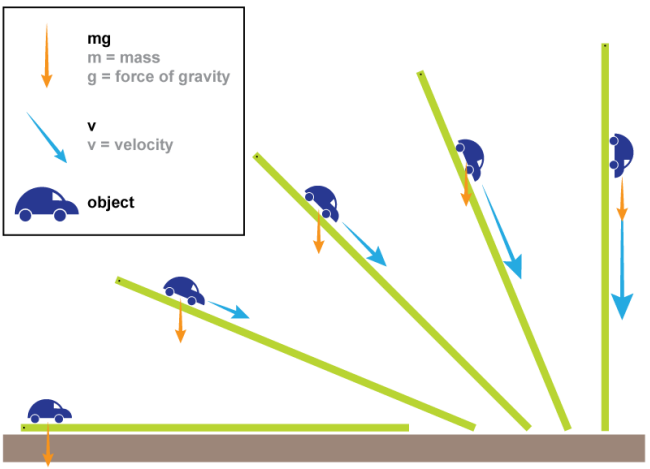
2a Students can roll a cart with different masses down the inclined plane and collide it with another cart with different masses.

Students can manipulate many variables and calculate the forces involved in simple collisions by measuring the mass of the colliding carts and the distances they move after the collision.

b If possible, video tape the collisions and slow down the frame rate to observe the small changes that occur during a collision and measure the time it takes for the carts to move immediately after the collision.

c After an initial investigation, change the height of the inclined plane and measure the effect on the colliding carts.

- What is the relationship between mass and height in a



ACTIVITIES

Activities continued

collision?

- Can students create an equation that approximates the forces involved or the distance a cart might move after a collision?
- How accurate is their equation?
- What are the assumptions and when would the equation not work?

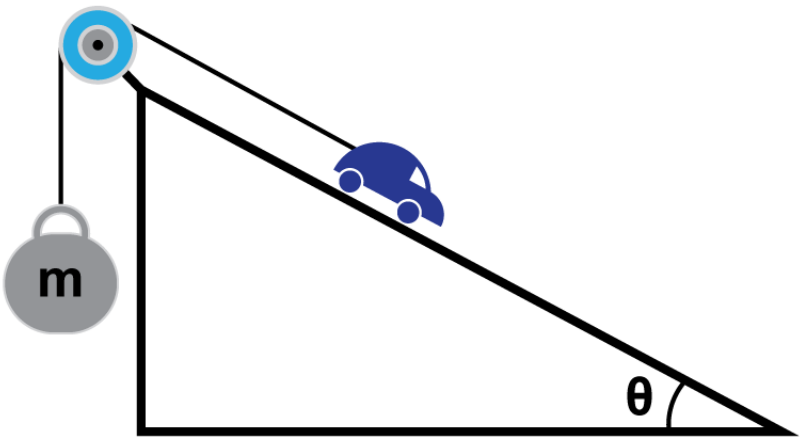
3 Demonstrate a simple machine by using a pulley with a cart.

Add different masses in the cart and determine how much hanging mass is required to move the cart up the inclined plane.

Vary the height of the inclined plane up or down and calculate the forces and work required to move up the cart to a certain height; compare the values with or without the inclined plane. A protractor can be used to measure the angle of the inclined plane.

- How do the forces or the work change if a pulley set is used?
- How does friction affect the movement of the cart up the inclined plane?

The students can draw a free body diagram to help understand the forces affecting the movement of the cart. Also, students can graph the mechanical advantage using the inclined plane with different heights and develop an equation to help predict the forces for moving objects up the inclined plane.



ACTIVITIES

Activities continued

4 Students can investigate mechanical advantage by using the inclined plane with the pulley (or set of pulleys) to measure the applied force compared to the effort force. Changing the height of the inclined plane will show how height is directly related to the amount of force required to lift an object. When the inclined plane is combined with a pulley set, students can investigate different combinations of simple machines to make a complex machine.

Ask students to predict which combination of machines will require the smallest force to move an object over a certain distance.

- What could be changed about the machines that could further decrease the force required?

Using these situations can expand student understanding of friction and real world situations.

5 For enrichment, students can create scale models of the building of Egyptian pyramids. Students can investigate how to use an inclined plane combined with other simple machines (rollers, pulleys, etc) can be used to move heavy objects with relatively small forces.

In this situation, students can use engineering principles to solve problems such as:

- How can friction be decreased to use a certain amount of force to move a heavy block?

Student can gather evidence from their model to justify an explanation for how such large blocks at the Egyptian pyramids could be moved by only using simple machines and human power.

***Note**

It is always wise to DO an experiment ahead of time to be able to best present it to the class.

DISCUSSION

Additional Discussion and Real Life Applications

1. How does the height of the inclined plane affect the forces to move an object up the inclined plane?
2. What are ways to slow an object moving down the inclined plane?
3. How does an inclined plane and a pulley work together to decrease the forces to move an object up the inclined plane?
4. How does mass and height affect collision forces?

GLOSSARY

Vocabulary:

- balanced forces
- collision
- complex machine
- force
- friction
- gravity
- kinetic energy
- Newton's Laws
- potential energy
- pulley
- simple machine
- unbalanced forces

RESOURCES

- http://physics.kenyon.edu/EarlyApparatus/Mechanics/Inclined_Plane/Inclined_Plane.html
- http://mocomi.com/inclined-plane/ (includes video)
- http://www.leboat.com/vacations/destinations/france/alsace-lorraine/cruises/the-arzviller-experience (moving a boat uphill with an inclined plane)
- https://www.youtube.com/watch?v=Ke9dvfJtqWQ (video about alsace-lorraine boat lift)
- http://archive.archaeology.org/0705/etc/pyramid.html (building the pyramids)

Next Generation Science Standards

Students who demonstrate understanding can:

Grade K-5

K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

K-PS2-2. Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-2. Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.

4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

Grade 6-8

MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

Standards Key

K = Kindergarten
3 = 3rd Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science
ETS = Engineering, Technology, and Applications of Science

MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Grade 9-12

HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.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