Drexel-SDP GK-12 ACTIVITY

Activity: Dragged Racers

Subject Area(s) Data Analysis & Probability, Measurement, Number & Operations, Physical Science, Science and Technology

Associated Unit Forget the Chedda!

Associated Lesson Forces, Forces Everywhere

Activity Title Dragged Racers

Student taking force and motion data on mousetrap racer.

Grade Level 7 (6-12)

Activity Dependency
Construct A Car, Quantify It, Convert It

Time Required 45 minutes

Group Size 2 people

Expendable Cost per Group US$0

Summary

Students will use their built cars to measure the force required to drag the cars along floor surfaces, allowing them to investigate frictional forces, which scale with the weight of the object and vary with the surfaces in contact.

Engineering Connection

Frictional force is both a necessity and an obstacle. In terms of our engineered system, a mousetrap car, *friction* allows the contact between the wheel and the ground to create motion. However, too much friction decreases the energy efficiency of the car.

Friction is considered in the *mechanics* of an object or structure – students may see friction as an obvious challenge that automotive engineers face, but aerospace engineers deal with friction's fluid analog, *drag*.

Keywords

car, forces, friction, mousetrap, acceleration, motion, mechanics, mechanical engineering

Educational Standards

- PA Math:
  - 3.1.7: Unifying themes
  - 3.2.7.B: Apply process knowledge to make and interpret observations
  - 3.7.7.D: Apply computer software to solve specific problems
  - 3.7.10.D: Utilize computer software to solve specific problems
- PA Science:
  - 2.4.5.B – Use models, number facts, properties, and relationships to check and verify predictions and explain reasoning
  - 2.5.8.B – Verify and interpret results using precise mathematical language, notation and representations, including numerical tables and equations, simple algebraic equations and formulas, charts, graphs, and diagrams
  - 2.5.8.C – Justify strategies and defend approaches used and conclusions reached
  - 2.7.8.D – Compare and contrast results from observations and mathematical models

Learning Objectives

After this activity, students should be able to:

- Identify friction as a force that occurs between two surfaces in contact
- Understand that frictional force increases with surface roughness
- Identify coordinate pairs on a graphical display
- Calculate the coefficients of friction from collected data (Normal Force, Lateral Force at instant of lateral displacement)

Materials List

Each group needs:

- Wire twist ties

To share with the entire class:

- Meter stick
- Motion Sensor
- Force Sensor

- PASCO Explorer GLX (or sensor interface with computer)
- "Dragged Racers" worksheet in DataStudio file

Introduction / Motivation

In our previous lesson we talked about one force we encounter every day: our weight. What factors affect our weight? (mass and acceleration/gravity). Like our weight, *friction* is another force use every day, whether we know it or not. We count on static friction for traction in everyday occurrences such as keeping car tires on the pavement when driving or our shoes on the ground when walking. Kinetic friction can be good: it allows us to generate heat when we rub our hands, or it can be bad: when cars or our feet unintentionally slide.

Do you think that friction helps or hinders your mousetrap car? (Both; need friction to keep wheels moving, but too much friction wastes energy that could be used to coast with built-up speed). Engineers can optimize the design of a vehicle by considering how the forces contribute to the overall energy. In this case we're trying to optimize the energy stored in the mousetrap spring, but if too much energy is released all at once, the wheels will spin without moving the car.

We don't want this! We want our car to move, so there has to be some force keeping the wheel in touch with the ground. This force is static friction, and is proportional to the *normal force*, which, on a flat surface, is equal to the weight of the car. We call the factor of proportionality the coefficient of friction. For static friction, it is known as the *coefficient of static friction*!

We are going to experiment with friction by examining the force needed to move the wheels of your mousetrap racer (3 or 4) on the ground, with the axles and wheels fixed in place. The axles need to be fixed so that one data run can represent static and kinetic friction -- if the wheels are turning on the floor, we're only measuring static friction!

At the end of this experiment, we will be able to calculate the coefficients of friction between your car and the floor, which can be compared and later be used when we are calculating the total energy used by your mousetrap racer.

Vocabulary / Definitions

Word	Definition
Friction	Force that occurs between two surfaces in contact
Mechanics	Study of how objects or materials deform or move in response to applied forces.
Weight	Also known as 'body force,' the inherent force an object has due to its mass responding to a gravitational field. The reason we *weigh* less on the moon is not because our mass changes; the moon's gravitational field is not as strong as the Earth's.
Normal Force	Amount of force exerted by a surface on an object. Flat surfaces exert a *Normal Force* equal to the *Weight* of an object.
Drag	The force exerted by a fluid (gas or liquid) on a solid object. We experience *drag* on our bodies when the wind blows against us.

Procedure

Background

There are two types of friction: static and kinetic, and each is mathematically represented by a coefficient, the lowercase Greek letter mu (μ), with a subscript denoting whether it is static (s) or kinetic (k). Static friction is the force on object at rest; it scales with the normal force (N) by the factor of the coefficient of friction: $F = \mu_s N$. We normally refer to static friction as ***traction***.

Kinetic friction has a similar relation, $F = \mu_k N$, but kinetic friction only occurs when an object is in motion. ***Skidding*** occurs when kinetic friction occurs between moving objects.

This activity explores the concept of friction keeping a perspective of how this may impact a mousetrap racer. The worksheet is intended to step through the concepts of forces and differentiate the types of friction by comparing the different magnitudes of forces required to start and keep an object in motion.

Before the Activity

- Interface computer with PASCO Explorer GLX (or other unit) using USB port
- Plug Force Sensor and Motion Sensor into GLX sensor ports.

With the Students

1. Open "Dragged Racers" worksheet in DataStudio file chedda_456_activity_worksheet.ds
2. Distribute twist ties for students to affix to the front (or non-drive) axle.
3. Help students constrain their rear (or drive) axle or wheels. Kinetic frictional force can only be measured if the wheels do not rotate.
   a. Bolts can be tightened
   b. Dowels can be tied with string to an unloaded mousetrap and pulled against the string, or the dowel can be directly attached to the force sensor.
   c. If all else fails, duct tape can be used to adhere the bolts/dowels to resist rotation.
4. Follow instructions and examples in "Dragged Racers" worksheet
5. Make sure to **ZERO** the Force sensor. Pressing the ZERO button tares the recorded measurement.
6. Enter the forces identified in the "Force vs. Position" graph.

Attachments

chedda_456_activity_worksheets.ds
(contained in chedda_456_activity_worksheets.zip; see **Curricular Unit: Forget the Chedda!**)

Assessment

1. **What is the relation between mass and weight?**
   Gravitational acceleration. For Earth, this is 9.8 m/s^2 or 32.2 ft/s^2, but varies by planet.
2. **Why was the "normal force" equal to the weight?**
   The car was on a flat surface. If the car was on an incline, the normal force would be less than the weight.
3. **Why must objects overcome static friction before slipping?**
   If objects did not have to overcome static friction, they would slip first and not be able to gain traction because kinetic friction requires lower forces to continue.

4. **What kind of friction -- static or kinetic -- will you want your mousetrap car to experience?**
   A static friction condition allows the wheels to keep contact with the ground such that it will move the car forward (or backward, depending on how you wound the string). Otherwise, if the wheels slip on the ground, the car will not move in a desired manner.

References

Hebrank, M., *Sliding and Stuttering*, Duke Center for Inquiry Based Learning, Duke University. http://www.ciblearning.org/pdf/Exercise.SlidingandStuttering.pdf

Owner

Drexel University GK-12 Program

Contributors

John C. Fitzpatrick, Mechanical Engineering and Mechanics, Drexel University

Copyright