Drexel-SDP GK-12 ACTIVITY

Activity: Spinners

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

Associated Unit Forget the Chedda!

Associated Lesson Torqued

Activity Title Spinners

Work in groups to assure proper alignment of the motion sensor and weight.

Grade Level 7 (6-12)

Activity Dependency
Construct A Car, Quantify It, Convert It, Dragged Racers

Time Required 45 minutes

Group Size 2 people

Expendable Cost per Group US$0

Summary

Students will use their mousetrap racers to experiment with the torque-acceleration relation in order to find the *moment of inertia* of the rear axle assembly. Similar to the concept of *mass* in linear systems, the moment of inertia is a measure of how quickly an object will accelerate due to an applied loading. However, the net loads that cause rotation are known as torques, and the moment of inertia applies to the distribution of mass of an object rotating about a specific axis (in this case, the mousetrap car axle).

A small mass can be attached to the axle, which provides a known torque and target for a motion sensor. The linear acceleration of the mass can be converted to angular acceleration, and the Torque-Angular Acceleration relation can be used to experimentally determine the moment of inertia for an axle assembly.

Experimental results can be compared across groups' different axle designs and to theoretical calculations based on wheel geometry. These comparisons will reinforce the concept that wheels having a larger radius and/or mass will be more difficult to accelerate than those with a smaller radius and/or less mass.

Engineering Connection

When "heavy-duty" was the auto industry's key buzzword, many companies' advertisements boasted the amount of torque their pickup trucks could produce. Larger numbers sound good from a marketing point of view, but they are meaningless if viewed from an engineering perspective.

Torque, and the external power that is produced by it, is dependent on the moment of inertia of the object it is rotating. If automakers had to re-design an axle or wheels to support these higher magnitudes of torque, the resulting acceleration may be negligibly larger than it was originally because the moment of inertia was increased.

For a rear-drive vehicle to move, the torque acting on an axle must oppose and overcome static friction acing on the wheels. If too much torque is applied, the wheels slip on the floor (spin-out).

Keywords

car, forces, torque, mousetrap, moment of inertia, angular acceleration, linear acceleration, rotational motion, linear motion

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
  - 2.6.5.A – Organize and display data

- 2.6.8.F – Use scientific and graphic calculators and computer spreadsheets to organize and analyze data
- 2.7.8.D – Compare and contrast results from observations and mathematical models
- 2.8.8.B – Discover, describe, and generalize patterns, includeing linear, exponential, and simple quadratic relationships

Pre-Requisite Knowledge

Students should have completed the "Dragged Racers" activity and understand forces well enough to relate the concepts of linear motion to rotational motion.

Learning Objectives

After this activity, students should be able to:

- Identify torque as a loading that causes rotation
- Understand that torque is related to the moment of inertia of a rotating object
- Convert linear acceleration to angular acceleration
- Calculate the experimental moment of inertia from a given relation
- Estimate the theoretical moment of inertia based on a formula
- Compare experimental and theoretical results of differing designs
- Identify factors that influence the performance of their mousetrap car

Materials List

To share with the entire class:

- Mass/weight set (200g – 500g) or coins with plastic sandwich bags
- Meter stick
- Motion Sensor
- Force Sensor
- PASCO Explorer GLX (or sensor interface with computer)
- "Spinners" worksheet in DataStudio file

Introduction / Motivation

How many of you have heard of "torque" before? (Maybe they heard it on a truck commercial…). I'm sure you've seen or heard cars "peeling out." That's an example of too much torque being used to turn the wheels of a car when accelerating. Maybe when you were building the mousetrap cars you were excited because you were close to finishing, and attached the string to the axle, wound it back, and watched the wheels spin? That's a similar case, but with a much lighter car. Today we're going to experiment with torque and give some pointers about how your car can efficiently use the torque generated from the mousetrap.

Everyone's going to support their car on a desk – either attach it with duct tape or hold it – so that the rear axle is free to spin. We'll attach small weights to the rear axle and then set up a motion sensor to record the velocity and acceleration data of the falling weight. If we know the weight we attached to the axle, this data can be used to calculate an experimental *moment of inertia* for your vehicle's rear axle. You can combine this information with the frictional forces calculated for the car (in the previous activity) to optimize the car's design. This can be done in a couple of ways.

You can re-design your rear axle (change the moment of inertia), make the car lighter (lower frictional forces), or extend the moment arm of the mousetrap (decrease torque applied to the axle). However, you should run an experiment or two in order to see what works best!

Vocabulary / Definitions

Word	Definition
Torque	Loading that causes rotational motion.
Moment of inertia	The degree to which an object will "resist" rotational acceleration when acted upon by a torque.
Linear acceleration	The rate of change of velocity along a linear path.
Angular acceleration	The rate of change of angular velocity.

Procedure

Background

A relation between torque and acceleration can be expressed as: $T = I\alpha$, where I is the moment of inertia of the object, or the resistance the object has to rotate.

We can relate linear and angular distances quantities by relating the amount of rotation (degrees or radians) to a linear distance that corresponds to the perimeter of a circle (circumference). For this activity, we need to know that, for rotation about a fixed axis (like rear wheels to an axle) linear acceleration is equal to the product of angular acceleration and the radius: $a=\alpha*r$.

The moment of inertia is analogous to rotational motion as mass is to linear motion: it is a measure of the amount of resistance the object has to move. The moment of inertia is shape-dependent, and depends on how its mass is distributed about the rotational axis. Consider the case of two circular objects with the same, evenly-distributed weight: a *smaller* circular object will a *lower* moment of inertia than a larger circular object.

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 "Spinners" worksheet in DataStudio file based on chedda_456_activity_worksheet.ds *corresponding to student's or group's initials*.
2. Help students attach weights to the rear axle of their cars with string. The weight should be suspended at a point that it will not hit the sensor.
3. Hold/attach the front portion of the car to a desk or table with duct tape, making sure the rear axle is free to move.
4. When taut, wind the string attached to the weight around the axle
5. Hold the wheel until ready to start recording data. Press the "Start" button on the GLX Explorer or DataStudio software panel.
6. Release the wheel and record data for ~1 sec.
7. Repeat data run if it is erratic (due to wheel motion starting or stopping).
8. Follow instructions contained in "Spinners" worksheet.

Attachments

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

Assessment

Check last page of "Spinners" worksheet – is Moment of Inertia, I, calculated?

Owner

Drexel University GK-12 Program

Contributors

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