

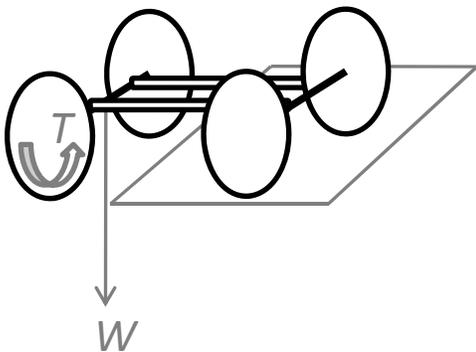
Spinners: Worksheet

Use your mousetrap cars for this experiment. Make sure you have the drive wheel(s) disconnected from the mousetrap.

Before Beginning:

1. If you have a rear axle with two fixed wheels, untie the string from the mousetrap.
2. Position the mousetrap car on a desk or table so that the rear axle can spin freely. Attach the car with duct tape.
3. Position a Motion Sensor directly below the rear axle.
4. Use string to attach a mass (weight) to the axle. Size the string so that the weight will not hit the motion sensor.

Calculate the torque caused by a load: $T = W \cdot r$



If the rear axle is extended from a desk in this position so that the wheels are free to rotate, the action of the weight makes the axle rotate.

Wind the wheels back, slightly, to confirm this. Ask for assistance if the axle does not turn freely.

In the last activity, Dragged Racers, We looked at how *forces* are involved in the *linear motion* of objects.

A force that causes **rotational motion** is known as a **torque**, T . The force W from the weight makes the axle rotate. This torque can be calculated as long as you know the **weight** and the **radius** of the axle.

Find the weight: $F = m \cdot a$

$$W = m \cdot g$$

$$W = \left(9.8 \frac{\text{m}}{\text{s}^2}\right) (\text{_____ kg})$$

$$W = \text{_____ N}$$

Find the torque: $T = F \cdot d$

$$T = W \cdot r$$

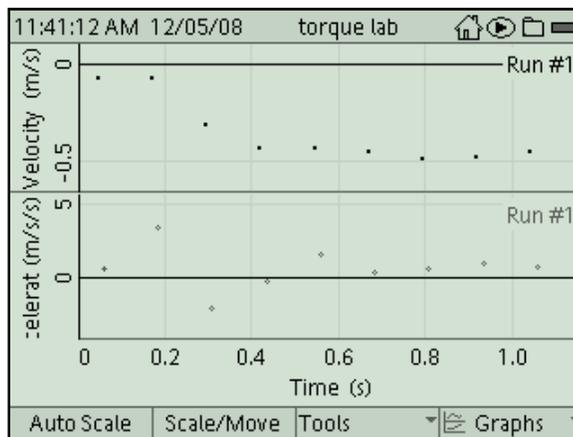
$$T = (\text{_____ N})(\text{_____ m})$$

$$T = \text{_____ N}\cdot\text{m}$$

Use the Torque-Angular Acceleration Relation: $T = I \cdot \alpha$ to find the Moment of Inertia, I , for the rear axle.

Follow instructions at beginning of worksheet before continuing!

5. Using a PASCO Explorer GLX, make sure "Torque lab" file is open.
6. From home menu, open "Graph" display (F1)
7. With the weight suspended, wind string around axle and hold.
8. When ready, release axle and record data (**START**) for 1 second.
9. Stop experiment or change weight once a good data run (no extreme points) is recorded:



Using the **Acceleration** graph (the bottom one), estimate or calculate the average acceleration of the falling weight.

Use the Smart Tool to find actual values: **F3** → $\sqrt{\quad}$. Toggle the display (also under the **F3** menu) to activate the Acceleration graph.

Convert Linear Acceleration to Angular Acceleration

If the axle is spinning about a central axis, the velocity and acceleration of the attached mass will vary with the radius. We use the equation $a = \alpha \cdot r$ to find angular acceleration.

$$\text{Average } a = \frac{\quad}{\quad} \frac{m}{s^2}$$

$$\text{Average } \alpha = \frac{\text{Average } a}{r} = \frac{\frac{\quad}{\quad} \frac{m}{s^2}}{\quad m} = \frac{\quad}{\quad} \frac{\text{rad}}{s^2}$$

Use the Torque-Angular Acceleration Relation: $T = I \cdot \alpha$

You've calculated the *torque* on the axle and the *average angular acceleration*. Use this information to calculate the averaged *moment of inertia*.

$$T = I \cdot \alpha$$

$$I = \frac{T}{\alpha} = \frac{\text{N} \cdot \text{m}}{\text{rad}/\text{s}^2} = \text{kg} \cdot \text{m}^2$$

Compare Calculated I to Theoretical Moment of Inertia

The *theoretical* value for the moment of inertia depends on the mass and shape of the object being rotated. For the mousetrap cars, we were rotating the axle (wood dowel or bolt) and the wheels (washers or CDs).

The moment of inertia for a composite object can be calculated using the equation $I = mr^2$ for each component, then adding the values together:

$$I = m_{\text{axle}} r_{\text{axle}}^2 + (\# \text{ wheels}) (m_{\text{wheel}} r_{\text{wheel}}^2)$$

Example: using two-wheel axle, with 4-cm diameter washer wheels and 0.5-cm diameter bolt axle:

$$I = m_{\text{axle}} (0.0025 \text{ m})^2 + (2) (m_{\text{wheel}} (0.02 \text{ m})^2)$$

(You need to find the mass of the parts used for the axle and wheel (in kg) in order to complete the calculations!)

$$I = (\quad \text{kg}) (\quad \text{m})^2 + (\quad) ((\quad \text{kg}) (\quad \text{m})^2)$$

$$I_{\text{wheel(s)+axle}} =$$