Practice: Rubber Band Calculations With Energy

Physics 200

~~Rubber Band Car Energy Practice~~

Name: Key

Linear Distance / 1.21m

height

Drive Wheel Radius(m)	0.051
Time to roll down ramp (s)	1.79
~~Distance~~ descended by wheel and axle (m)	0.15
Wheel and Axle Mass (kg)	0.0878

Part 1: MOI Determination, Method 2:

Some students use a different method to find the moment of inertia of their drive wheel and axle. They remove the wheel and axle from their car and let it roll down a ramp. They release it from rest and record its vertical drop, time to descend, mass, and outer radius.

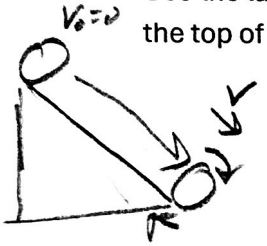
1. What is the average linear velocity of the wheel and axle as it rolls down the ramp?

$$\bar{V} = \frac{\Delta x}{\Delta t} = \frac{1.21m}{1.79s} = \boxed{0.676 m/s}$$

2. What is the final linear velocity of the wheel and axle when it reaches the bottom of the ramp?

$$\bar{V} = \frac{V_0 + V}{2} \Rightarrow 0.676 m/s = \frac{0 + V}{2} \Rightarrow V = \boxed{1.35 m/s}$$

3. Use the law of conservation of energy to write an equation comparing the wheel and axle's energy at the top of the ramp to its energy at the bottom. Assume that there is no non-conservative work done.



$$mgh_0 + KE_0 = PE + KE$$

$$mgh + 0 = 0 + \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$\omega = \frac{V}{r} \Rightarrow \omega^2 = \frac{V^2}{r^2}$$

4. Rewrite the equation, converting to all "linear" (not rotational) terms – except for moment of inertia (I).

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\frac{v^2}{r^2}$$

5. Plug-in the givens (data above) and solve for the moment of inertia of the wheel and axle.

$$0.0878kg\left(9.8 m/s^2\right)(0.15m) = \frac{1}{2}(0.0878kg)(1.35 m/s)^2 + \frac{1}{2}I\left(\frac{(1.35 m/s)^2}{(0.051m)^2}\right)$$

$$0.129 J = 0.08 J + 350 \frac{I}{s^2}$$

$$\boxed{I = 1.4 \times 10^{-4} kgm^2}$$

Part 2: Measuring Motor Output Energy:

The wheel and axle is returned to the car. The students use a marker to make a dark mark on one of the drive wheels. Wind up the car and "launch it" while holding the drive wheels in the air and recording slow motion video. By "scrubbing" carefully as they watch the video, they use the mark on the wheel to determine the number of video frames that elapse during one rotation of the wheel when it is at its maximum speed. Their data are on the right.

Video Frame Rate (fps)	240
Video Frames During 1 Rotation (at max speed)	15

6. How many seconds does 15 video frames represent?

$1\,s = 240\ frames$

$$15\ \text{frames}\left(\frac{1\,s}{240\ \text{frames}}\right) = \boxed{0.0625\,s}$$

7. What is the maximum angular velocity (in radians per second) of the drive wheel and axle during this test?

$$\boxed{\omega = \frac{\Delta\theta}{\Delta t}} = \frac{1\ \text{rotation}}{0.0625\,s}\left(\frac{2\pi\ \text{radians}}{1\ \text{rotation}}\right) = \boxed{101\ rad/s}$$

8. How much energy (output energy) does the motor give to the wheel and axle?

$$\boxed{KE_{rot} = \tfrac{1}{2} I \omega^2}$$

$$E = KE_{rot} = \tfrac{1}{2}\left(1.4\times10^{-4}\ kgm^2\right)\left(101\ rad/s\right)^2$$

$$\boxed{E = 0.714\ J}$$