An Experiment in Rotational Dynamics that Emphasizes the NGSS Science and Engineering Practices

Comments for Teacher

There is often some surprise when students see the wheels and axle take off with relatively high speed upon contacting the table surface. This investigation provides a nice opportunity for the students to (1) suggest hypotheses as to what will happen upon contact with the table, (2) design an experiment to test their hypotheses, (3) analyze and interpret their data, and (4) use principles of physics to explain their observations quantitatively.

Here are answers to the seven discussion questions:

1. *What do each of the points A, B, C, and D represent in the motion of the wheels and axle?* Point A represents the systems starting to roll down the inclined plane. Point B is when the wheels make contact with the table top. Point C is where the system takes off with relatively high speed as the wheels roll along the table top. Point D is when the system encounters the pillow bumper and stops.
2. *Why is there a sort of sine wave feature in angular velocity from points A to B, and from points C to D?* With the PocketLabs attached to the wheels there is not a uniform distribution of mass, resulting in a "wobble" of the system's angular velocity.
3. *What is the angular velocity of the wheels and axle system just before making contact with the table top?* Based upon the provided graph and gyroscope.csv file, the angular velocity just before contacting the table top is about 1830 °/s, or $1830/360 \times 2\pi = 31.9$ rad/s.
4. *What is the speed of the center-of-mass of the system just before making contact with the table top?* Since $v = \omega R$ and we know ω from the answer to question 3, we need the **radius of the axle, which is the current moment arm of the system**. It is about 2.56 mm. Therefore, the speed of the center-of-mass just before the system makes contact with the floor is $31.9/s \times 2.56$ mm = 81 mm/s, less than a tenth of a meter per second.
5. *What is the angular velocity of the wheels and axle system at point C?* Based upon the provided graph and gyroscope.csv file, the angular velocity at point C is about 500 °/s, or $500/360 \times 2\pi =$ 8.73 rad/s.
6. *What is the speed of the center-of-mass of the system at point C?* Again, since $v = \omega R$ and we know ω from the answer to question 5, we need the **radius of the wheels, which provide the current moment arm of the system**. The radius is about 42.7 mm. Therefore, the speed of the center-of-mass while the system rolls along the table top is $8.73/s \times 42.7$ mm = 372 mm/s, or about one-third of a meter per second
7. *Explain the physics of why the speed of the center-of-mass of the system increased upon contacting the table top.* The speed of the center-of-mass of the system has increased $372/81 =$ 4.6 times. While some of the original rotational kinetic energy the system gained while rolling down the incline may have been lost to friction when contacting the floor, enough of this rotational kinetic energy has been transferred to translational kinetic energy of the system rolling on the table top to increase translational speed noticeably.