1 inch = 2.54cm

1.   The string of a rubber band car pulls with a force of 49 Newtons. This string has negligible thickness, and it is
        wrapped around a 5/16" axle. The axle is fused to wheels that are 4" in diameter.
        a. What is the axle radius, in meters?

        b. How much torque does the string exert on the wheel and axle?

        c. What is the wheel radius, in meters?

        d. Assuming that there is sufficient friction between the wheels and the road, how much force does the
        wheel's torque exert on the floor?

        e. Suppose the normal force exerted on the drive wheels by the floor is 0.8N, and μ_s = 0.4...
                i. what is the maximum force of static friction between the wheels and the floor?

                ii. what minimum diameter must the drive wheels have in order to avoid slipping?

2.   A rubber band car has a mass of 0.15kg and a wheel base (distance between the centers of the wheels) of 8
        inches. If the center of mass is 3 inches from the center of the front wheels, what normal force is exerted
        by...
        a. the floor, against the back wheels

        b. the floor, against the front wheels

3. Suppose one rubber band has the force curve depicted here. The stretch distance describes how far the rubber band is stretched beyond its equilibrium point. Now suppose you create each of the configurations below, and you stretch each of them until they exert 30N of force. Determine the stretch distance (x, in meters), and the work that you would have to do (in Joules) in all three cases.
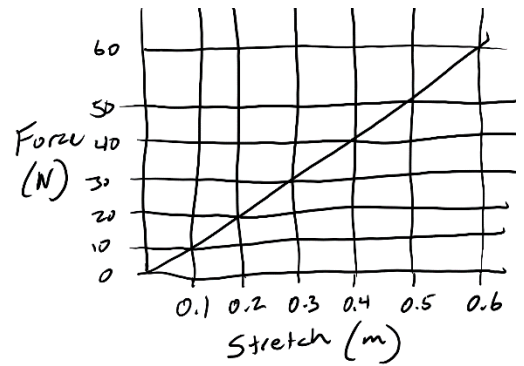
a. One rubber band, all alone.

b. Two rubber bands aligned with one another.

c. Two rubber bands linked together into a chain.

d. One rubber band cut to form a single strip.

4. A rubber band car is powered by 6 inches of string that is wrapped around a 5/16" drive axle. If the drive wheels are 4" in diameter, how far will the car travel as the string unwinds?

5. Suppose 1.9J of work is done in the process of winding a rubber band car. If 70% of that energy gets converted to KE, how fast will the car be moving when it reaches top speed? Assume that the car has the following characteristics: Mass = 200g. Front wheel/axle moments of inertia = 8×10^{-6} kgm^2. Rear wheel/axle moment of inertia = 5×10^{-5} kgm^2. The front wheels are 0.03m in radius, and the rear wheels are 0.05m in radius.

6.   A 15cm length of thread is wrapped around the motionless drive axle (r = 0.00397m) of a rubber band car. A 50g weight is attached to the end of the thread. When the system is released, the weight falls, and the wheel and axle rotates at an accelerating rate. The weight falls for 4.8 seconds, and at the end of this time interval the wheel and axle begins to decelerate. 25 seconds later (after the string and weight fall off) the wheel and axle comes to rest. The mass of the wheel and axle is 80g.

$\Delta y = -0.15m$

$\Delta t = 4.8s$
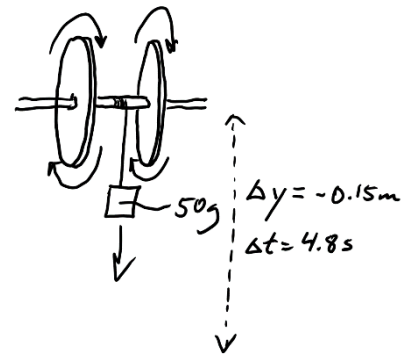
a. What is the linear acceleration of the falling weight? [This is also the tangential acceleration of the edge of the axle.]

b. What is the angular acceleration of the axle?

c. What is the tension in the string while the weight is falling?

d. What torque is exerted on the axle by the string tension?

e. What is the maximum angular velocity of the axle (at the point when the weight is released -- just before the axle begins decelerating)?

f. What is the angular acceleration of the axle during its deceleration period.

g. Use a system of equations to find the wheel and axle moment of inertia (I) and the Torque exerted by friction. During the acceleration period, both string tension and friction contribute to the net Torque. During the deceleration period, friction is the sole source of torque.

   i. Write a first equation for net torque during the acceleration period. Use $T_{net} = I\alpha$. Remember that, during the acceleration period, $T_{net} = T_{friction} + T_{tension}$

   ii. Write a second equation for net torque during the deceleration period. During the deceleration period, $T_{net} = T_{friction}$

7.   No rubber band car travels in a perfectly straight line. They all turn. Consider a rubber band car turns to the left. The curvature of its path can be described as following edge of a circle with a radius of 7m. If the car is to be released in a 3m wide hallway, where, and at what angle, should it be released in order to travel the farthest possible distance before crashing into a wall. Draw a diagram to show where the car should be released, how it should be aimed, and the path that it will follow before crashing. Precise numbers, angles, distances, etc. are not important.

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Lab Measurements: Complete on a separate sheet of paper

1. Make graphs of force vs stretch for rubber bands.
    a. Get a two rubber bands. Stretch them repeatedly until they loosen up and turn whitish.
    b. Create individual graphs of **force vs x** (stretch distance) for each of the following. Use weights between 0 and 9.8N (1kg).
            i. One band
            ii. One linked band
            iii. One cut band
2. Calculate wheel and axle moment of inertia and frictional torque. Follow the steps in problem number 6 (a-g), above.
3. Measure/find the coefficient of **static** friction between a rubber band-covered wheel and a floor tile.