Rotational Motion / Rubber Band Car Name: ______________________
Individual Test -- Practice

Predict the speed of a rubber band car based on the data provided below. For each set of data, the collection process is described. Perform the calculations required on the back of this sheet.

Data Set 1: These data were collected to determine the moment of inertia of the car's rear wheels and axle. This is a rear wheel drive car, so this is the "drive wheel and axle." A string was tied to the axle and wound around it, and a weight was allowed to accelerate the axle by falling and unwinding the string. The weight fell until it reached its low point, and then the weight rose until the wheels and axle stopped spinning.

Mass of falling weight (kg)	0.4
Distance descended by weight (m)	0.64
Descent time (s)	6
Distance risen by weight (m)	0.41
Number of Wheel and Axle Rotations During Weight Descent	23.7

Calculations Part 1: Finding the Drive Wheel and Axle Moment of Inertia – use data from data set 1.

1. What was the angular displacement of the drive wheel and axle during the interval when the weight was descending? **147.9 rad**

2. Use the data provided to calculate the axle's radius. **0.004298m**

3. Find the angular acceleration of axle during the interval when the weight was descending. **8.27rad/s^2**

4. Find the linear acceleration of the falling mass by converting the previous angular acceleration to a linear quantity. **0.0356m/s^2**

5. Calculate the tension in the string while the weight was falling. **3.91N**

6. Calculate the non-conservative work done on wheel and axle from the time the weight began to fall until it rose again to its highest point. **-0.902J**

7. Calculate the total angular displacement of the wheel and axle from the time the weight began to fall until it rose again to its highest point. **244.3 rad**

8. Calculate the torque that was applied to the wheel and axle by friction from the time the weight began to fall until it rose again to its highest point. **0.00369Nm**

9. How much torque did the string tension exert on the drive wheels and axle? **0.0168Nm**

10. What was the net torque that was applied to the drive wheels and axle as the weight descended? **0.0131Nm**

11. What is the moment of inertia of the drive wheels and axle? **1.58 x 10^{-3} kgm^2**

<u>Data Set 2:</u> These data were collected to determine the moment of inertia of the car's front wheels and axle. In this step, the wheels and axle were removed. Their radii and masses were measured.

Front Wheel Radius (m)	0.0254
Mass of one front wheel (kg)	0.0113
Axle mass (kg)	0.034
Axle radius (m)	0.004

<u>Calculations Part 2:</u> Use the data from data set 2 for these problems.

12. What was the moment of inertia of one front wheel? **3.65×10^{-6}**

13. What was the moment of inertia of an axle? **2.72×10^{-7}**

14. What was the total moment of inertia of the front wheels and axle (two wheels and an axle, together) **7.56×10^{-6}**

<u>Data Set 3:</u> These data were collected to determine two things: the distance that the car would accelerate and the amount of kinetic energy the car's motor produces. First, the car's bands were attached, and the car was wound up as if it were going to race. Instead of racing, the drive wheels and axle were allowed to accelerate without any resistance. A slow motion video was used to determine how fast the drive wheels were rotating when they reached their top speed.

Number of Drive Wheel and Axle Rotations to Wind Up Motor	15
Video Frame Rate (fps)	240
Number of Video Frames Elapsed during one wheel rotation at top speed (frames)	16
Drive Wheel Radius (m)	.12

Calculations Part 3: Most of data that you will need for these calculations will come from data set 3, but you will also need data from one of the other previous data sets.

15. When the drive wheels and axle reached top speed, how many seconds did it take them to complete one rotation? **0.0667s**

16. When the drive wheels and axle reached top speed, what was their angular velocity? **94.2 rad/s**

17. Calculate the rubber band motor's energy output. When the drive wheels and axle reached top speed, how much kinetic energy did they have [Hint: you will need information from a previous data set for this one.]? **7.03J**

18. What distance will the car roll while it is accelerating? **11.3m**

Data Set 4: These data were collected to determine the car's maximum torque and maximum "motive force." "Motive force" is the force that the car uses to push the road backward, and it is the force that the road uses to push the car forward. A spring scale was used to measure the amount of tension in the bands when the car is fully wound. Also, when the car was fully wound, the bands were wound on top of one another, increasing the radius at which the bands were acting. This new radius was measured and recorded.

Maximum Band Force -- measured with force meter or other scale (N)	30
Radius at which bands apply their maximum force to axle (m)	0.0042
Drive Wheel Radius (m)	0.12

Calculations Part4: Use the data from data set 4 for these problems.

19. Calculate the drive wheel torque when the bands are fully wound. **0.126Nm**

20. Calculate the maximum "motive force" that the car's wheels apply to the floor. This is the same friction force that the floor applies to the car, making it move forward. **1.05N**

<u>Data Set 5:</u> The final step of the project calculations required a prediction of top speed. All of the necessary data had already been collected, except for the car's overall mass. Here is the car's total mass…

Car's Overall mass (kg)	0.4

Calculations Part 5: Most of data that you will need for this calculation can be found in previous data sets. The only new data that you need is the car's overall mass, provided above.

21. Predict the car's maximum velocity. Assume for this question that when the car is at top speed it has all of the energy that you calculated in problem number 17. **5.24m/s**