Physics 200 Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Rubber Band Car Problems and Questions #1

1. **Finding the Moment of Inertia of a Wheel/axle:**

A 50g weight is attached to the end of a thin thread of negligible thickness and mass. The string is wrapped around a rubber band car’s rear axle, and the string is then wound up so that the weight is near the axle. Next the car is supported so that its rear wheels and axle do not touch any surface. A vertical meter stick is placed adjacent to the weight. The weight is released and its fall is timed, with the timer stopping at the moment when the weight has descended 0.5m. The fall time is 4.8 seconds, and the radius of the car’s axle is 5/16”.

a. What is the linear acceleration of the falling weight?

b. What is the angular acceleration of the rear wheels/axle while the weight falls?

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

d. While the weight is falling, how much torque is exerted on the axle by the string?

e. What is the moment of inertia of the wheel and axle?

2. **Finding Distance, Maximum KE, Average Power, and rolling Friction:**

A rubber band car’s front wheels and axle are identical to its rear wheels and axle. Both sets of wheels have radii of 0.07m and moments of inertia of 0.0001kgm2. Both axles have radii of 0.008m. The car’s total mass is 100g. The car is powered by rubber bands that are connected to the rear axle with a string that is wound around the axle. In order to prepare the car for action, the string had to be wound, and the rubber bands had to be stretched to accomplish that winding. During the winding process, the average amount of tension in the free (unwrapped) portion of string was 15N. 10cm of string was wrapped around the axle during the winding process. The car’s performance was recorded by slow motion video at a frame rate of 240fps. The cars wheels did not slip. Starting from rest, the car took 0.5s to reach top speed. At top speed the car took 22 video frames to cross one floor tile. After it reached top speed, it rolled 50m before coming to a stop.

a. Through what angle θ did the car’s wheels and axles rotate as the string was unwound from the drive axle?

b. Assuming that no slippage of the wheels occurred, how far did the car travel as it accelerated?

c. How much work was done in the process of winding the string?

d. What was its top speed?

e. What was the car’s translational kinetic energy when it reached top speed?

f. What was the car’s rotational kinetic energy when it reached top speed?

g. What was the car’s **total** kinetic energy when it reached top speed?

h. % Efficiency = (Energy output/Energy Input) \* 100%. What was the car’s % efficiency based on its maximum speed?

i. What is the net work that was done on the car while it is accelerating?

j. Calculate the average power output of the car during its acceleration period. Express that power in both Watts and horsepower.

k. What force of friction acted on the car after it reached top speed (while it was rolling to a stop)?

Answers to #1:

|  |  |  |
| --- | --- | --- |
| a | Linear acceleration (m/s/s) | -0.04340278 |
| b | Angular Acceleration (rad/s/s) | -5.46806649 |
| c | String Tension (N) | 0.48782986 |
| d | Torque on Axle (Nm) | -0.00387215 |
| e | Wheel & Axle Moment of Inertia (kgm^2) | 0.00070814 |

Answers to #2:

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| --- | --- | --- |
| a | Rotational distance during acceleration (rad) | 12.5 |
| b | Travel distance during acceleration (m) | 0.875 |
| c | Work done by string winding (J) | 1.5 |
| d | Top Speed (m/s) | 3.32727273 |
| e | Top Translational Kinetic energy (J) | 0.55353719 |
|  | Top rotational speed (rad/s) | 47.5324675 |
| f | Top Rotational Kinetic energy (J) | 0.22593355 |
| g | Top Total Kinetic Energy (J) | 0.77947074 |
| h | % Efficiency (%) | 52% |
| i | Net work done on car during acceleration (J) | 0.77947074 |
| j | Average power output (W) | 1.55894147 |
| k | Force of friction during stopping period (N) | 0.01558941 |