**Physics 100 Rubber Band Car Practice Quiz**  Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Formulas:**

T = fr

W = fd

KE = ½ mv2

PE = mgh

Efficiency = (energy output / energy input) \* 100%

Energy Output = Efficiency \* energy input/100

Energy Input = Energy output\*100/efficiency

Video time elapsed = # of frames/frame rate

V = d/t

F = ma

1000g = 1kg

W = ΔEnergy

**Problems:**

|  |  |  |
| --- | --- | --- |
|  | **Consider a rubber band car with these attributes...** |  |
|  | Axle radius (m) | 0.002 |
|  | Wheel radius (m) | 0.08 |
|  | Force of friction between wheels and floor -- traction -- (N) | 1.2 |
|  | Rubber Band Maximum Force (N) | 35 |
|  | Rubber Band Minimum Force (N) | 5 |
|  | Rubber Band Stretch Distance (m) | 0.35 |
|  | Car mass (g) | 160 |
|  |  |  |
|  | Video Frame rate (frames per second) | 240 |
|  | Minimum time to cross one floor tile (video frames) | 18 |
|  |  |  |
|  | Horizontal distance rolled when released from a ramp during friction test (floor tiles) | 24 |
|  | Height of friction test ramp (m) | 0.3 |
|  | g = value of acceleration of earth's gravity to use in these problems (m/s^2) | 10 |
|  |  |  |
| **1** | What is the maximum torque on the car's drive wheels and axle? (N•m) |  |
| **2** | For this particular car, what is the lower limit for the radius of drive wheels that will not "spin out?" (m) |  |
| **3** | What is the maximum force with which the car pushes backward against the road? (N) |  |
| **4** | What is the car's mass, in kg ? (kg) |  |
| **5** | Assuming that the wheels do not slip, what is the car's approximate maximum acceleration? (m/s^2) |  |
| **6** | What is the average force that is required to stretch the rubber bands? (N) |  |
| **7** | How much work is done in stretching the rubber bands during the winding of the car's "motor?" (j) |  |
| **8** | How much energy is stored in the rubber bands when car when the car is wound up? (j) |  |
| **9** | Based on the video, what was the minimum time required for the car to cross one floor tile, in seconds? (s) |  |
| **10** | Each floor tile is one foot across. How many meters is one floor tile? (m) |  |
| **11** | Based on the video, what is the car's maximum velocity? (m/s) |  |
| **12** | What is the car's maximum kinetic energy? (j) |  |
| **13** | What is the car's efficiency? (%) |  |
| **14** | How much Potential Energy did the car have when it was held at the top of the ramp? Use g=10m/s^2. (j) |  |
| **15** | How far, in meters, did the car roll horizontally when it was allowed to roll down the ramp and onto the floor?(m) |  |
| **16** | When the car was allowed to roll down the ramp, friction ultimately caused the car to stop. How much work did friction do in the process of bringing the car to a stop? (j) |  |
| **17** | What was the force that friction exerted as it was slowing down the car? (N) |  |
|  |  |  |
| 18-20 | Suppose you wanted to modify the car from the previous questions so that it would travel with the velocity listed on the right (m/s) |  |
| **18** | How much output (kinetic) energy would this car need in order to travel at that velocity? (j) |  |
| **19** | At the efficiency you calculated, how much input energy would that require? (j) |  |
| 20-21 | In the next two lines, suggest a combination of rubber band stretch distance and average rubber band force that would provide the exact amount of input energy that would allow the car to travel at the velocity listed above. |  |
| **20** | Rubber band stretch distance (m) |  |
| **21** | Average Rubber band force (N) |  |

**Answers:**

|  |  |  |
| --- | --- | --- |
| **1** | What is the maximum torque on the car's drive wheels and axle? (N•m) | 0.07 |
| **2** | For this particular car, what is the lower limit for the radius of drive wheels that will not "spin out?" (m) | 0.058333333 |
| **3** | What is the maximum force with which the car pushes backward against the road? (N) | 0.875 |
| **4** | What is the car's mass, in kg ? (kg) | 0.16 |
| **5** | Assuming that the wheels do not slip, what is the car's approximate maximum acceleration? (m/s^2) | 5.46875 |
| **6** | What is the average force that is required to stretch the rubber bands? (N) | 20 |
| **7** | How much work is done in stretching the rubber bands during the winding of the car's "motor?" (j) | 7 |
| **8** | How much energy is stored in the rubber bands when car when the car is wound up? (j) | 7 |
| **9** | Based on the video, what was the minimum time required for the car to cross one floor tile, in seconds? (s) | 0.075 |
| **10** | Each floor tile is one foot across. How many meters is one floor tile? (m) | 0.305 |
| **11** | Based on the video, what is the car's maximum velocity? (m/s) | 4.066666667 |
| **12** | What is the car's maximum kinetic energy? (j) | 1.323022222 |
| **13** | What is the car's efficiency? (%) | 18.90031746 |
| **14** | How much Potential Energy did the car have when it was held at the top of the ramp? Use g=10m/s^2. (j) | 0.48 |
| **15** | How far, in meters, did the car roll horizontally when it was allowed to roll down the ramp and onto the floor?(m) | 7.32 |
| **16** | When the car was allowed to roll down the ramp, friction ultimately caused the car to stop. How much work did friction do in the process of bringing the car to a stop? (j) | 0.48 |
| **17** | What was the force that friction exerted as it was slowing down the car? (N) | 0.06557377 |
|  |  |  |
| 18-20 | Suppose you wanted to modify the car from the previous questions so that it would travel with the velocity listed on the right (m/s) | 16 |
| **18** | How much output (kinetic) energy would this car need in order to travel at that velocity? (j) | 20.48 |
| **19** | At the efficiency you calculated, how much input energy would that require? (j) | 108.3579683 |
| 20-21 | In the next two lines, suggest a combination of rubber band stretch distance and average rubber band force that would provide the exact amount of input energy that would allow the car to travel at the velocity listed above. |  |
| **20** | Rubber band stretch distance (m) | One Example: 2 |
| **21** | Average Rubber band force (N) | One Example: 54.17898414 |

**Torque**

Torque *can be thought of* as a rotating or twisting force\*. The asterisk is there because *torque is not actually a force*; it is a force multiplied by a radius (a.k.a. “lever arm”). The torque formula is **T=fr**.

Any time you grab something and attempt to rotate or twist it, you are applying a torque, and that torque is transmitted through the entire object. For example, if you grab a screwdriver by the handle and twist the handle, you are applying a torque to the entire screwdriver. This torque can be measured at the handle, or it can be measured at the “skinny end” of the screwdriver, where it meets the screw. The important thing to remember here is that the torque is the same throughout the entire screwdriver.

The effects of torque within a rotating object are different depending on where you measure those effects. As I mentioned above, in the case of a rotated screwdriver, the torque (product of force times radius) is exactly same throughout the entire screwdriver. However, the individual quantities of radius and force are not the same at every part of the screwdriver. The handle has a big radius. The tip has a small radius. In order for the torque to be the same throughout the object, the torque force at the handle must be small, and the torque force at the tip must be big. Handle torque = (big radius x small force) = tip torque = (small radius x big force).

To give a numerical example, if you apply a 10N twisting force to the handle, which has a radius of 0.03m, then you apply a torque of 10N x 0.03m = 0.3Nm. If the torque is the same throughout the object, the torque at the tip of the screwdriver is also 0.2Nm. The tip is skinnier, with a radius of only 0.005m. This means that the force at the tip of the screwdriver must be 60N, because 0.005m x 60N = 0.3Nm. **T=fr**, so f and r can be calculated by the formulas **f = T/r** and **r = T/f**.

**Work and Energy**

“Doing work” means applying a force over a distance. For example, you do work when you grab onto a shopping cart and push it through a store. You apply a force to the cart, and you do this for some distance. The formula for work is **W=fd**. If you push a shopping cart a distance of 20 meters, and you push with a constant force of 3N, the work you have done is 3N x 20m = 60j.

The units of work are joules, which are also the units for energy. This makes sense, because work requires energy. Work can also be used to store energy. **When you “do work,” on an object you change the energy of that object** and you also change your energy. If you did 60j of work pushing a hovercraft, the hovercraft would then be moving along with 60j of kinetic energy. However, in the process of doing the work, you lost 60j of energy. As you did work on the cart, it gained energy and you lost energy.

Work can add energy to an object, but it can also reduce energy. When friction does work on a car, it slows the car down. If a constant 10N force of friction acts on a car over a distance of 5m, the friction will do 10N x 5m = 50j of work on the car. This will cause the car to lose 50j of kinetic energy. This would also hold true if *you* tried to stop a moving car. To stop the car, you wouldn’t be able to stop the car instantly. You would have to apply some force over a distance. If the car starts out with 1000j of KE, you will have to keep pushing until the product of your pushing force and your pushing distance (force x distance) equals 1000j. At that point, the car will have no kinetic energy.

**Law of Conservation of Energy**

The total amount of energy in a system remains constant. While this is true, energy can change form. The energy of a bowling ball swinging on a cable changes back and forth between kinetic energy (energy of motion) and potential energy (stored energy). If there were no friction, the ball would swing forever with the same total amount of energy. But since there is friction, the ball eventually slows down and stops at its lowest point. Both the potential and kinetic energy become zero. Even though both of those forms of energy are gone, the energy still exists. In the slowing down process of ball, the cable, the air, and the support beam get heated up by friction. The energy exists in the room in the form of heat.