Transmission Investigation

What is a transmission?

The transmission in a solar car is the part that connects the motor shaft to the wheels or axle. In general, a transmission is any device which transmits mechanical power from one place to another. Power is the product of force x speed (or torque x rotational speed). Transmissions are also used to change the speed and force proportions while transmitting mechanical power.

Some transmissions are very complex, such as a transmission in a car which has several different speeds and shifts between them automatically, and some are very simple, such as the gears in a can opener. A vacuum cleaner has a belt transmission which transmits power from the motor to the beater bar which spins to brush dirt off a rug, and a mechanical clock has a transmission goes from the second hand to the minute hand. This transmission has a "transmission ratio" of 60 to 1. The second hand goes around 60 times to make the minute hand go around once.

What is the transmission for?

In addition to getting power from one place to another, the transmission can be used to trade speed for torque or torque for speed. Hook the motor up to the solar panel or a battery if it is not sunny. The motor spins very fast, doesn't it? Try to stop the shaft with your fingers –not very difficult. If you put the car's drive wheel directly on the motor shaft, it would spin very fast (good) and when you put the car on the ground, the weight of the car would probably be enough to stop the motor (bad). If we believe this motor is powerful enough to move the car, then what's wrong? The problem is the relative proportions of torque and angular speed are not suitable for this application.

The answer to some of these problems is a transmission. The transmission can be a belt, chain, puck, etc. drive that makes the wheels turn with higher torque (harder to stop), but at a slower speed than the motor shaft. Obviously there is a tradeoff here. High speed but not enough torque and the car won't start or accelerate quickly. Low speed and high torque and the car will accelerate quickly. Low speed and high torque and the car will accelerate quickly until it reaches its final, low speed. Then it will creep along the track at a snail's place.

To achieve a satisfactory tradeoff, or compromise, we can build a transmission with a "transmission ratio" that gives the car a medium acceleration and a medium top speed. (what "medium" is will depend on the rest of the car's design. A formula 1 race car and a farm tractor both have well designed transmissions that allow the them to get going and travel at the right speeds.) Transmission ratios are also commonly referred to as "gear ratios". This however is misleading in that it implies that only gears are used in transmissions. Belts, chains and friction drives, etc. are all common transmissions.

Transmission Investigation #1: Effect of transmission ratio

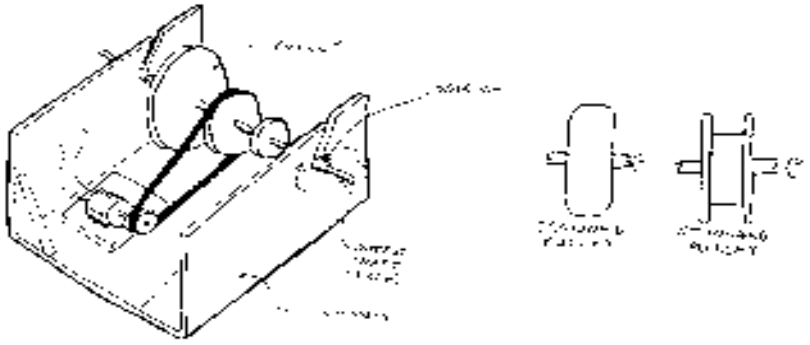
Building a car without any knowledge of the best transmission and ratio is risky because the car will not perform to its full potential (if it moves at all). The following test setup uses a belt and pulley transmission, but the ration of the pulley diameters applies to all of the other types of transmissions as well (gears, friction drive). The transmission ratio is critical for performance.

Materials:

Motor and 3V power source	Cardboard, foamcore, etc. for chassis
1 small pulley for motor shaft	Rubber band or belt
3 larger pulleys for output shaft	Hot glue
Shaft bearings	2 shaft axles

Finding materials:

Search local hardware and crafts stores for objects that can serve as pulleys, bearings, axles, etc. Some of the "pulleys" we used included: drawer pulls, videocassette reels, and thread spools. Videocassettes are also great sources of small smooth cylinders that can be used as bearings. Brass tubing (craft stores) or plastic tubing (drinking straws) can also make suitable bearings. You may want to find bearings before you select an axle. Possible axles include wooden rods from hardware stores, wire hangers, and metal or plastic tubing from craft stores. Note that shafts can be made larger (for mounting wheels, pulleys, etc.) by wrapping tape around the areas.



Build a test transmission like the one shown above. Mount the motor on a piece of stiff material (using hot glue, good tape, etc.) that is easy to grip or attach to the chassis

Things to try:

- Move the belt to different Pulleys to see the results of different Rations. See which ratios give the highest speed, and which make the shaft easiest to stop with your finger.
- Try different bearings between the axles and the frame.
- Try adding or removing weight from the output shaft to see the effect on acceleration.

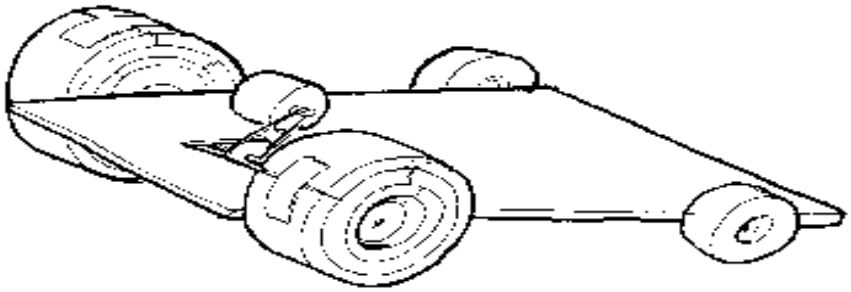
- Notice how flat rubber bands tend to crawl up the edges of a pulley – try a “crowned” pulley.

Transmission Investigation #2: Effect of wheel size

Try different wheels sizes on a sample car and see how the performance varies (acceleration and speed). Use a prototype car that you've built or a store-bought toy car. Wheel size is as important as a factor in a car's design as the transmission ratio: in fact, they are closely related. Try to calculate what distance your car travels per one revolution of the motor. The transmission ratio will tell you how many revolutions the wheel axles will turn per motor revolution, and the wheel size will tell what linear distance the car will travel per wheel revolution.

Materials

1 toy or prototype car
Lightweight foam tape



Things to try:

- Experiment with this concept by varying the wheel diameter on your car. If you start with a small wheel, you can build up the diameter with various materials, for example, weather-stripping foam tape. How much larger would the wheels need to be to make the car's top speed be twice as fast? Three times? How can large wheels hurt the performance of your car?

- Transmission ratios and wheel size combinations can produce cars with similar performance in terms of acceleration and top speed.

- A last note on wheel size, the faster the axle rotates in the bearing the more friction and drag it will have. A large wheel will allow the axle to rotate more slowly (if the car is to go at the same speed), and will waste less power in the bearings.

- In nature, an analogy for wheel size would be leg length. Just as a horse and a hamster will cover different distances if each takes one step per second, cars with large and small wheels will travel different distances with each wheel rotation.

Transmission Investigation #3: Multispeed bicycle

Experiment with a transmission that you're probably already familiar with, a multispeed bicycle.

Materials

1 multispeed bicycle
Tape to mark a point on the wheel

- Take a 10 speed bicycle and flip it upside-down so that it is resting on the seat and the handlebars.

- Hold the bicycle down and start pedaling by hand. (watch your fingers around the moving parts!)

- Try several different gears, both on the front gear rings and the back cluster. Each time see how fast you can go and how long it takes to get there from a complete stop.

Transmission Investigation #4: Multispeed bicycle races

A good experiment for students to do at home with their own bicycle:

Materials

2 multispeed bicycles
2 students of similar size and physical strength

- Get a friend or classmate and 2 multispeed bicycles. Put one in the highest gear (small sprocket in front, large sprocket in back) and the other in the lowest. Race to a specified point. Who got there first? Would the winner be different if the race were longer or shorter? Try it out!

Other examples of transmissions:

A full size car has a transmission with several gears so that you can choose the right ratio for the right time. When you start off, you want a high ratio for high torque and lots of acceleration (first gear) Once you get going, you shift (or the automatic transmission shifts automatically), to a lower ratio for less torque and acceleration, but a higher speed (second, third or fourth gear).

Did you know that a school bus and a sports car both have the same size engine but the transmission gives each of the vehicles its own driving characteristics?