

MEEM 3501

Product Realization I

H06: Power Transmission Components

Power transmission devices — gear transmissions, belt and chain drives, hydrostatic transmissions, power screws, etc. — are among the most important mechanical components. They have some things in common:

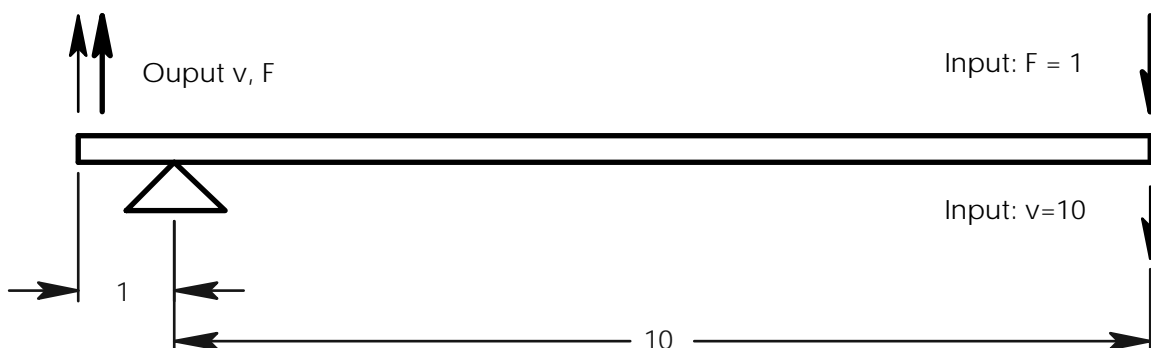
- Their inputs and outputs are mechanical motions, at some speed and force or torque.
- The output power — the product of output speed and force or torque — equals the input power, minus small losses for inefficiency.
- The main purpose is normally defined by the transmission ratio — the ratio between input and output speed. Because power losses are small, the transmission ratio is also nearly equal to the output torque (or force) divided by the input torque (or force). This *torque multiplication* is usually why we want the transmission, because most power sources — electric motors and gasoline engines — operate best at speeds much higher than most loads operate.
- The transmission may also convert from torque to force — important because most power sources are rotary, but we often want to move things in a straight line — or change the direction of the torque or force.

Exercise 1: *Basic Power Transmission Component* — What is the most simple power transmission, or force multiplication, device you can think of?

Levers, Belts, Gears and Chains

If you understand levers, you can understand any power transmission device. A lever has an input speed and force, and an output speed and force. The ratio is just the ratio of the lengths of the arms.

Exercise 2: *Speed and Force Ratios for Levers* — Use geometric reasoning — i.e., the speed of an object moving in a circle equals its angular velocity times its radius — to find the output speed of this lever. Use the moment equation from statics to find the ratio of forces. Does the speed reduction ratio equal the force multiplication ratio?

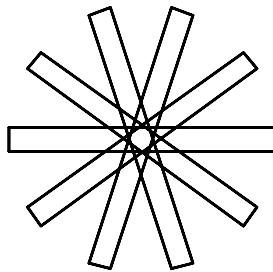


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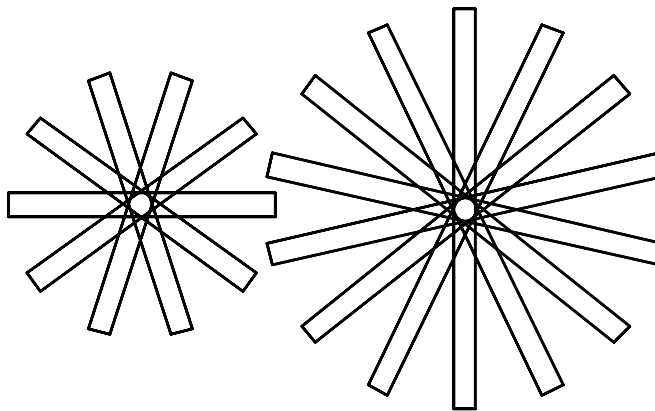
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Determine the distance traveled by the input force if the lever is pushed all the way around in a complete circle around the pivot. Does the product of the input force and this distance equal the input torque about the pivot, times 2π – the amount of a full rotation?

The problem with levers is that they apply the output, and take the input, in places and directions that change while the machine is running. The solution is to find something that works like a lever, but is *symmetrical*, so that the motion does not change the point of application? Perhaps we could just have a lot of levers arranged in a circle.



We will be able to push down on one side, and get an upward force on the other, all right, but it does us no good — the input and output forces are the same. However, if we use *two* wheels of levers, as shown below, we will be able to apply a torque to a shaft through the center of one wheel, and take out a torque at the shaft of the other. The ratio will just be the ratio of the length of the levers.

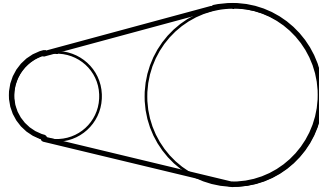


Exercise 3: *Speed and Torque Ratios for Gears* — Prove that the ratio between shaft speeds and torques is the ratio between lever lengths (or wheel radii or diameters).

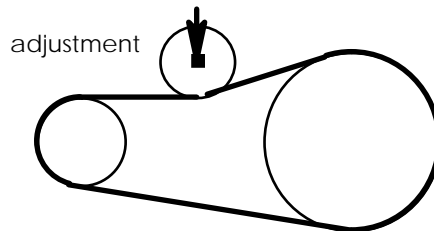
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We have just reinvented the gear pair, but there are some problems. First, the load must be transmitted through point contact at the sharp corners of the levers, creating high stresses, so these gears can't carry a heavy load. Second, there is a lot of "backlash" in the gear — wasted motion when we change direction — so they can't be used for precise positioning in two directions. Third, the speed ratio will change slightly as the contacting corners slide in and out on the lever surface, which will act as a dynamic load that will cause vibrations at high speeds. At another point we will learn how to round off the corners in a special way to minimize (never eliminate) all these problems. We can also make one of the circles a straight line — a circle of infinite radius — creating a "rack" that works with the "pinion" gear.

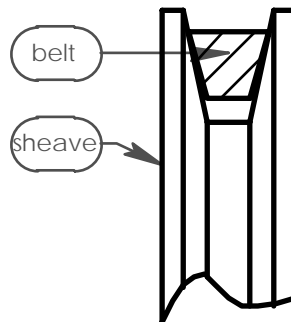
There is a simpler way to achieve this kind of pairing, by using a flexible belt to connect two completely smooth wheels (generally called sheaves).



But, since the belt turns the sheave only by friction, it must be pulled tight, so we usually use an adjustable "idler" sheave that takes up the slack in the belt.



We can increase the power transmission for a given size, while also increasing the friction, by pinching the belt between the sides of a V-shaped circumferential groove.



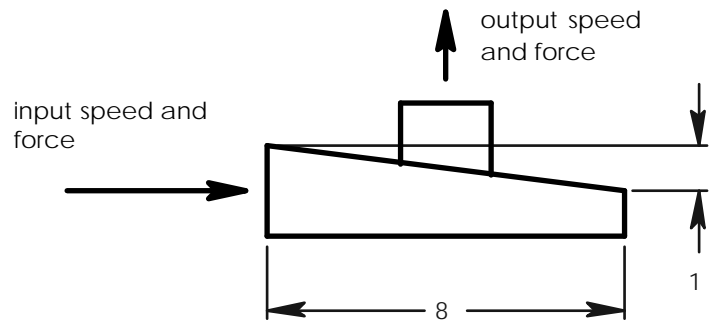
We can also put teeth on the belt and sheaves, or replace them with a "chain" and "sprockets" to increase the amount of power they can transmit, or maintain synchronization of the input and output. Stretching of the belt as the transmitted load changes causes the input and output to lose synchronization.

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Wedges and Screws

The speed reduction that can be achieved by a gear pair or belt- or chain-drive in a reasonably compact package is limited, to, say, 10 to 1. Wedges provide a way out. Wedges, however, require a linear input, which is rarely available. Usually, therefore, we wrap the wedge in a circle, forming a screw. This is more useful packaging of a wedge, just as a helical spring is better packaging of a torsion bar.

Exercise 4: *Speed and Force Ratios for Wedges* — What is the ratio between the input speed and the output speed for this wedge?



If you ignore friction, what is the ratio of the forces?

What is the limit on how much speed reduction can be achieved with a wedge?

Exercise 5: *Force Ratio for Power Screws* — The pitch of the screw is the distance the nut travels in one rotation of the screw. If you ignore friction, and the pitch is one inch, what is the ratio of the forces?

