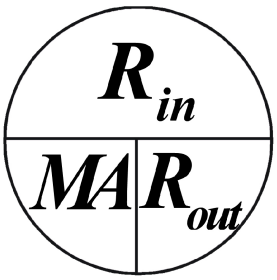
Wheel and Axle

A wheel and axle consists of two objects of different size attached in such a way that they rotate around the same axis. Examples include a screw driver, a steering wheel, and a bicycle wheel. A wheel and axle functions similarly to a 2nd or 3rd class lever depending on whether the wheel turns the axle (wheel = input), or the axle turns the wheel (axle = input). The input radius is like the effort arm, while the output radius is like the resistance arm. The ideal mechanical advantage of a wheel and axle is the ratio of the input radius to the out put radius.

$$IMA = \frac{input\ radius}{output\ radius}$$

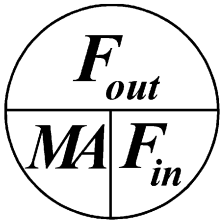
$$IMA = \frac{R_{in}}{R_{out}}$$



Turning the wheel by the axle results in a mechanical advantage less than 1, but it also increases the speed. That's why it's easier to walk than ride a bike uphill . But the bike is faster.

Sample Problem

A bucket holding 300 N of water hangs in a well by a rope wrapped around a barrel with a diameter of 4.0 cm. It is raised from the well by a crank with a radius of 50.0 cm. How much force is needed to raise the bucket?



Step 1: Determine the mechanical advantage.

$$MA = \frac{R_{in}}{R_{out}} = \frac{50cm}{4cm} = 12.5$$

Step 2: Determine the output force.

$$F_{in} = \frac{F_{out}}{MA} = \frac{300N}{12.5} = 24N$$

Based on the example above, solve the problems below. Show your work. Use the proper units in your answers.

1. A screw can be turned with a force of 50 N using a screwdriver that has a handle with a 1.24 cm radius and a blade with a 0.31 cm radius. How much resistance does the screw provide?

2. A bicycle has 70 cm wheels (R = 35 cm). The wheel is turned by a gear with a radius 7.0 cm. If a girl can be rolled up a hill on the bike with a force of 150 N, with how much force does she need to pedal?

3. A 350 N crate is attached to a rope wrapped around a bar with a radius of 12.5 cm. It can be lifted by applying a force of 50 N to a crank. How long is the crank?

4. A bank vault is opened by turning a wheel with 10 cm radius. The wheel turns an axle with a 2 cm radius. The axle, in turn, moves some gears. If a 22 N force needs to be applied to the wheel, how much force is needed to move the gears?