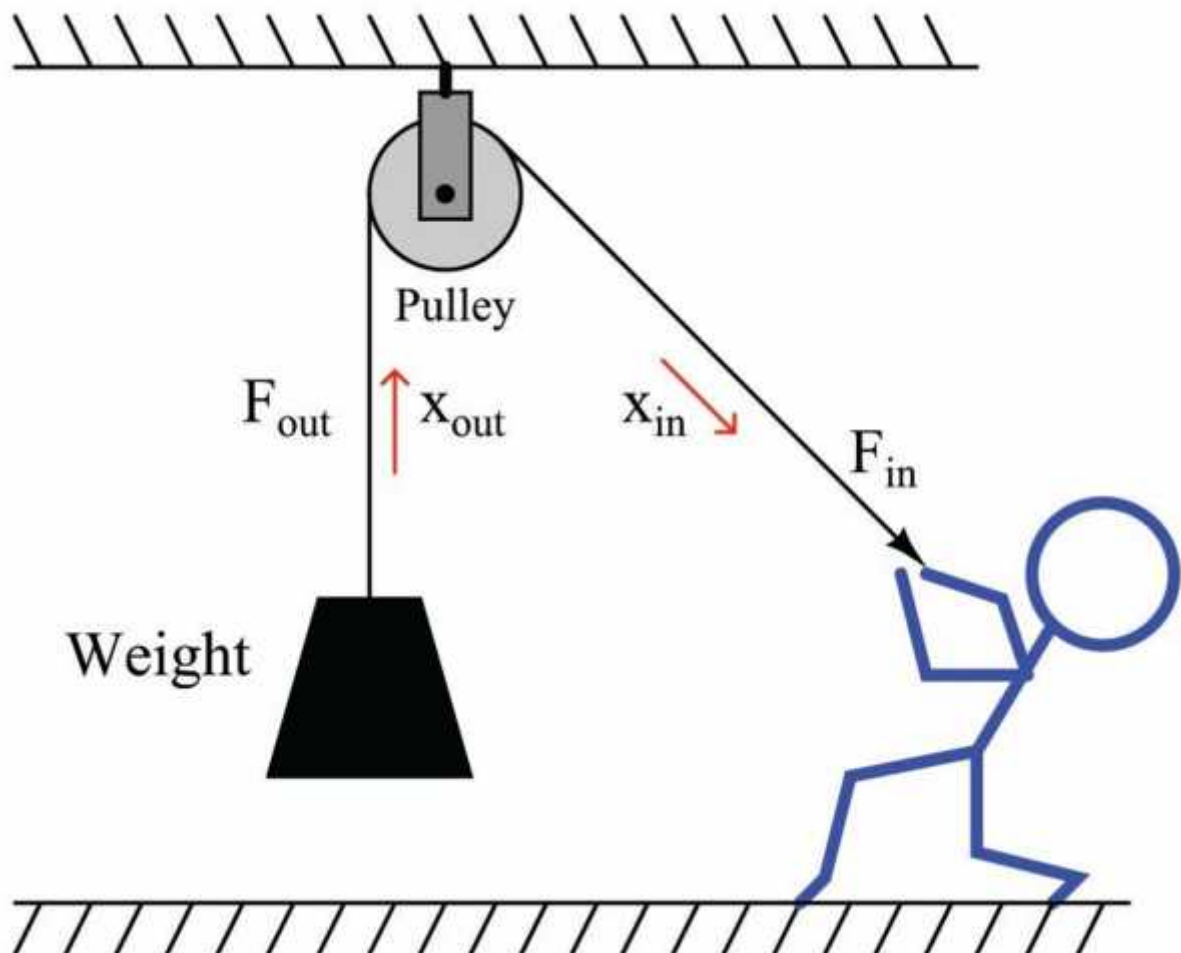
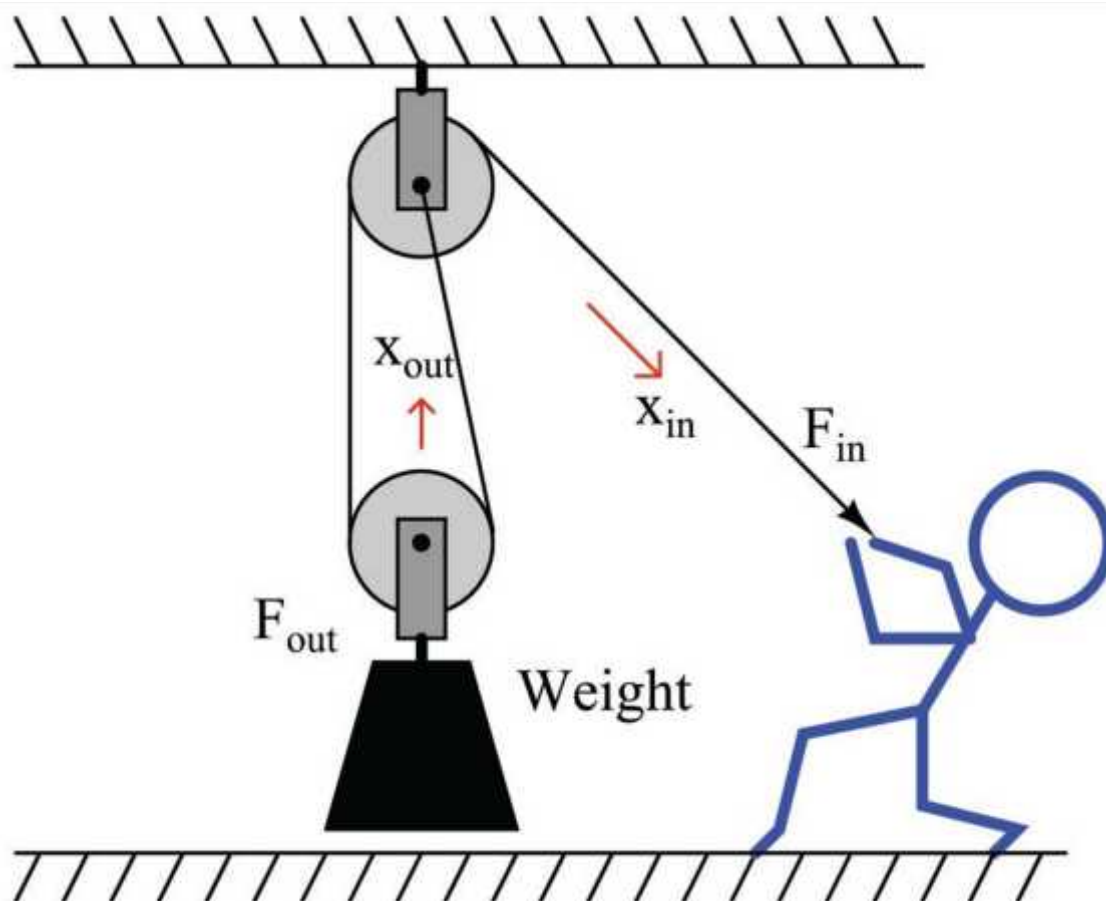


Pulleys

Another simple and useful machine is a pulley and rope. A “pulley” is nothing more than a wheel with a groove cut around its circumference to guide a rope or cable, a bearing and axle supporting the wheel and allowing it to freely turn. A single pulley hung from an overhead support has the ability to convert downward motion of a rope into upward motion to hoist a load:

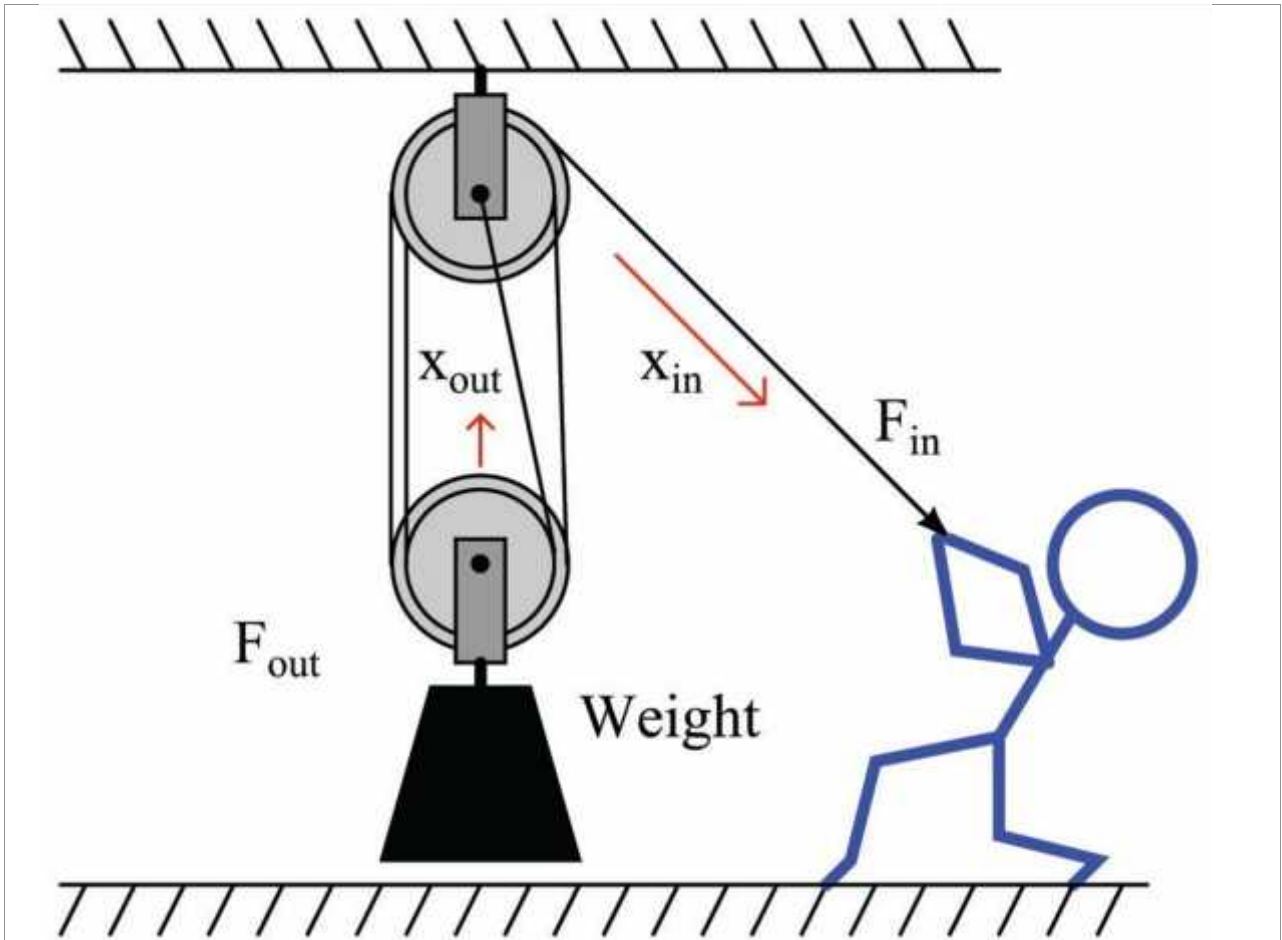


A single-pulley system such as this exhibits no mechanical advantage, because . If we get creative with multiple pulleys, however, we can achieve a mechanical advantage sufficient to hoist very heavy loads with modest input force:

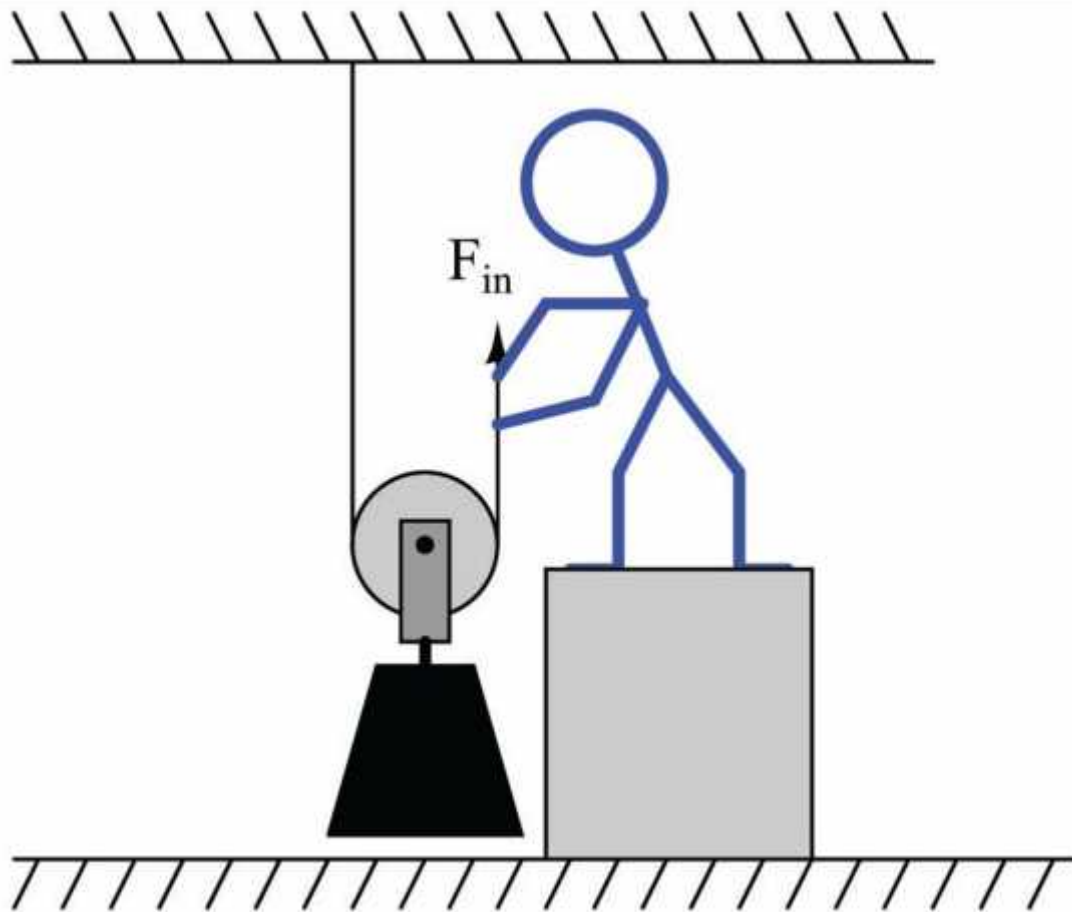


Here, the weight is being supported by the tension within two ropes, not just one rope. Since the person's force on the rope is what generates the rope's tension, F_{in} is equal to rope tension, while F_{out} is equal to twice the rope's tension. Thus, this simple machine has a mechanical advantage equal to 2. It also means the person's motion while pulling the rope will be exactly twice the motion of the hoisted weight. Remember that we cannot cheat the Law of Energy Conservation: work in cannot be less than work out. If the output force is twice as much as the input force due to mechanical advantage, the output motion can only be half as much as the input motion.

The mechanical advantage of a pulley system may be extended beyond two by adding even more pulleys. This pulley system has a mechanical advantage of 4, since the weight is being supported by the tension of four ropes, while the person pulling only feels the tension of a single rope:



Here is where one must be careful in analyzing pulley systems with regard to mechanical advantage. The mechanical advantage in each of these examples was based on the number of ropes supporting the weight. So far, this also happened to equal the number of pulleys in the system. Lest anyone be tempted to determine mechanical advantage by simply counting pulleys, here is an example that breaks the pattern:



Here there is only one pulley in the system, yet the weight is being supported by the tension in two ropes and the person pulling on the rope only feels the tension of one rope, which means the system has a mechanical advantage of 2.

This simple technology is commonly used on cranes to provide huge amounts of lifting force with modest amounts of cable tension. In this photograph you can see the multiple pulleys and lifting cable of a large industrial crane:

