Mechanical Tools

Ignoring friction, mechanical tools like a level bar, ramp, and pulley **allow a trade-off between force required and distance moved. The product of force multiplied by distance is not changed; this product is the mechanical work.**

A level can allow greater force on an object, but requires that applied lesser force act over a longer distance.

When a pulley system is used to lift a load using a force that is 10 times less than required to directly lift the load, the pulley rope must be pulled 10 times farther than the load is raised.

This also applies to a hydraulic lift. A small force can be used on the pump, but its lever must be moved a proportionately greater distance.

When pushing something up a frictionless slope (inclined plane), the weaker force must be applied for a longer distance and the amount that the object is raised.

The thread of a screw is an inclined plane wrapped into a spiral. It can apply greater force, but requires a proportionately greater turning distance.

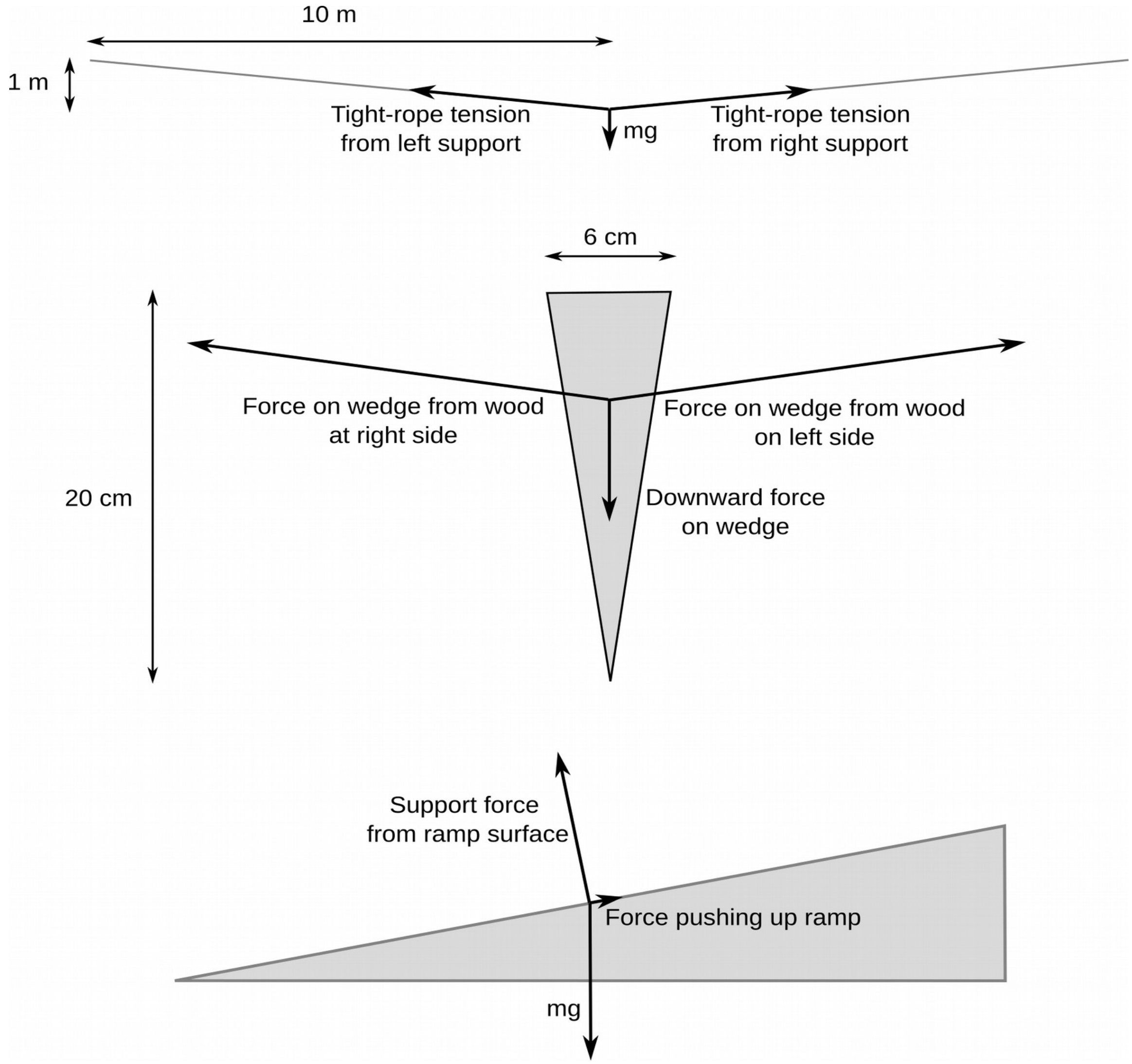
A wedge used to split wood can push the wood apart with several times greater force than is applied by the sledgehammer, but the wedge must move a proportionately larger distance than the wood is opened.

A knives and nails are fancy wedges.

A wrench multiplies a twisting force in proportion to the ratio of its handle length to its opening radius.

Balanced Forces – Tight-rope, Wedge, and Ramp

Consider the following 3 situations where forces on an object are balanced:



A tight-rope walker with a mass of 150 kg is on a massless rope that is 20 m long (and stretches to 20.1 m). When she is in the middle, her weight pulls the rope down by 1 m. How much tension is in the rope. Since tension is a force, its units will be newtons. Each half of the rope must provide an upward force equal to half of her weight. From the rules of similar triangles and the Pythagorean theorem the tension is

$$\text{tension} = \frac{1}{2}\frac{\sqrt{(10\,\text{m})^2 + (1\,\text{m})^2}}{1\,\text{m}} \cdot mg = 7394\,\text{N} \quad \text{using } g = 9.81 \text{ m/s}^2$$

The wedge has a similar magnifying effect on the force of the sledge hammer driving the wedge.

The ramp is a little bit different. It reduces the force from gravity since *mg* is the hypotenuse of the triangle. If the ramp is 2 m hight and 10 m long, then (ignoring friction), the pushing force is

$$F_{\text{push}} = \frac{2\,\text{m}}{\sqrt{(10\,\text{m})^2 + (2\,\text{m})^2}} mg = 0.196\, mg \quad .$$