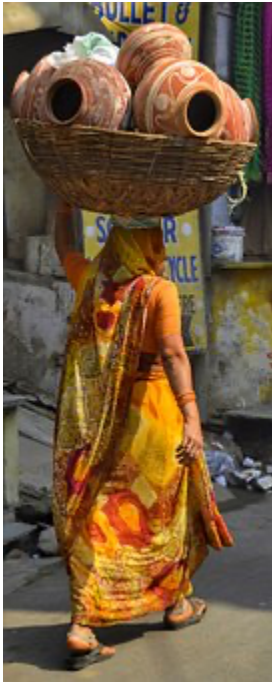


Simple Machines



Movement and lifting both require force.

What are Simple Machines?

Machines maximize **force**, or the push or pull on an object caused by interaction with another object. We exert force on things all the time. Movement requires force, picking things up requires force, writing and typing require force. Similarly, forces are exerted on us all the time, too. The force of gravity is the ever-present pull of the Earth on everything on Earth and even things relatively far away from Earth, like satellites, the International Space Station, and the moon. We'll be focusing on the forces that humans exert on objects. Machines help us move heavy objects and accomplish other tasks requiring force by magnifying the force that we exert. **Simple machines** are the most basic such devices, usually with few or no moving parts. Simple machines help people do **work** and form the basis of many more complex machines, such as construction equipment. **Work** is the product of force exerted and distance moved (and the cosine of the angle between the direction of force and the direction of motion).

$$W = F * d (* \cos\theta)$$

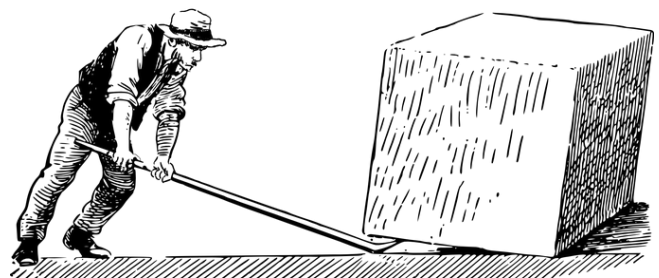
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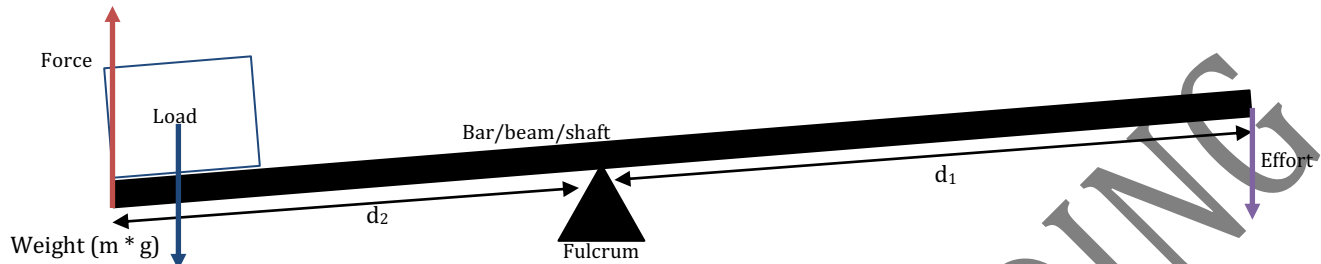
Lever

A **lever** adds force by increasing distance. Levers are **bars**, **beams**, or **shafts** that sit atop a support known as a **fulcrum**. By exerting a downward force on one end of the lever, a stronger upward force is felt on the other end. The force magnification through a lever depends on where along the length of the bar the fulcrum is. The farther the fulcrum is from the initial force (meaning the smaller the distance between the fulcrum and the object to



Levers make lifting easier.

be moved), the greater the magnification. The initial force is called the **effort** and the object to be moved is called the **load**. In the figure below, the work done is the same on either side of the fulcrum. Thus, the greater d_1 becomes, the lower the effort required to do the work, while the smaller d_2 becomes, the greater the force exerted on the load.



Examples of levers include seesaws (teeter-totters), scissors, the claw end of hammers, crowbars, nutcrackers, bottle openers, and fishing poles.

Inclined Plane

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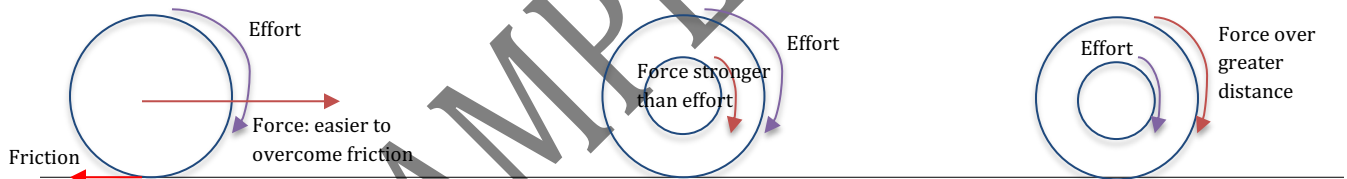
Examples of inclined planes include switchback roads/trails, boat ramps, stairs, and wheelchair ramps.

Wheel and Axle

A **wheel** is a round frame and an **axle** is the shaft/rod around which it turns. Considered one of the greatest inventions in human history, it minimizes force required by reducing friction. The part of the wheel touching the ground is small, meaning the force of friction is similarly small, and instead of sliding along on the ground, the wheel rolls, so friction is acting over a short amount of time. Imagine pushing a heavy box along the ground. Friction between the box and the ground pushes back, making it difficult to move the box. The entire bottom surface is subject to friction the whole time you're moving it. Now imagine putting that box on a wheeled cart (or even rolling it along on some logs). Friction is greatly reduced by both a smaller surface and a shorter contact time, making it much easier to move the box.



But this isn't all that wheels do. They also work much like a lever. As force is applied around the radius of a wheel, the work being done is equal to that being done on the smaller axle. Radius is distance. Therefore, more force is available from the axle than you put in to turn the wheel because it is working over a shorter distance. On the flip side, wheels can multiply distance. By turning a small wheel with great force, a larger wheel can



cover more distance. This is how bicycle and car wheels work.

Examples of wheel and axle systems include automobiles (the steering wheel transmits force to the wheels), bicycles, office chairs, shopping carts, strollers, wheelchairs, skateboards, roller skates, and hand trucks.

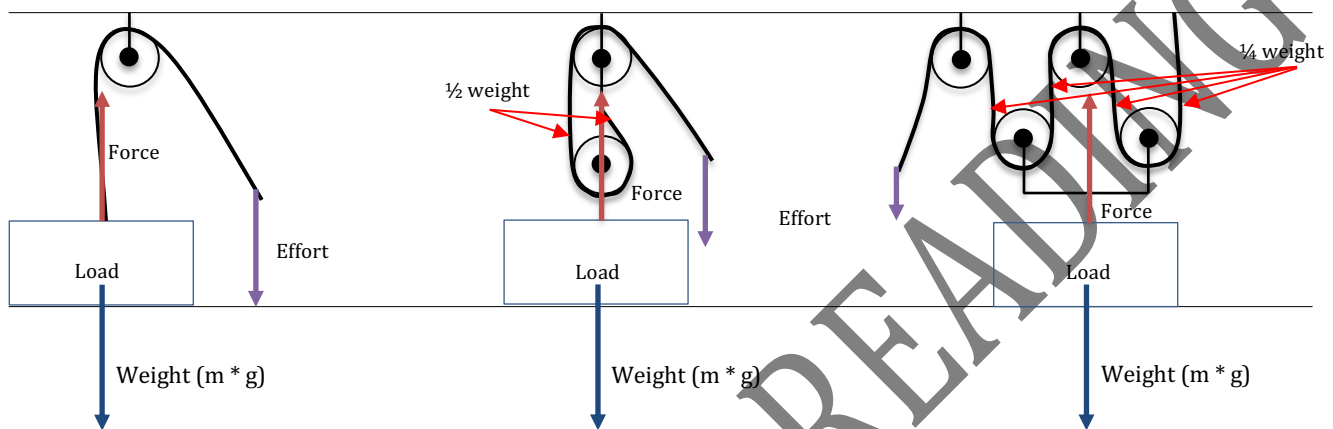
Pulley

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a **block and tackle**. Much like other simple machines we've covered, the trick is in increasing the distance. In a two-pulley system, one end of the rope is attached to a stationary beam or a block housing an overhead pulley. This rope is then looped around a pulley attached to the load and back up around the overhead pulley. This increases the length of rope attached to the load by adding a second section of rope. This second section takes half the weight of the load. To lift the load a specified distance, you have to move each section of rope by that distance, doubling the distance you have to pull the rope, but



halving the force that one pulley would require. With four wheels, you quadruple the distance and only have to apply one-quarter the amount of force.

Pulleys are used in window shades/blinds, elevators, flag poles, sailboat sails, fishing nets, rock climbing equipment, and cranes.

Screw



Screws are often used to fasten things.

A **screw** is essentially a shaft with a small, inclined plane wrapped in a continuous spiral around it from bottom to top. We're most familiar with the use of a screw for fastening, however screws can also be used to magnify force or transform motion. A device called a **water screw** is thought to have been invented by Archimedes in the 200s BC. It was a large screw inside a pipe. When the screw was turned, the plane collected water and transported it up the screw until it poured out the top.

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Wedge

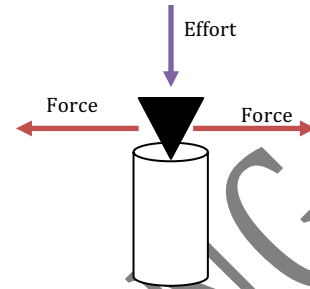
Wedges are tapered blocks, with one thick edge and the other thin and sometimes sharp.



An axe is a type of wedge.

Like levers and pulleys, they transform motion force. Pushing a wedge in a forward direction (force from wide to narrow edge) generates sideways force. They are used to lift loads, split objects, and hold things in place.

Examples of wedges include axes, nails, chisels, saws, jackhammers, zippers, knives, plows, ship bows, and doorstops.



Compound Machines

Some machines combine two or more simple machines. Such systems are called **compound machines**. Examples include wheelbarrows (lever + wheel and axle), can openers (lever + wedge), shovels (lever + wedge), wood screws (wedge + screw), car jacks (lever + screw), cranes (lever + pulley), and bicycles (wheel and axle + pulley).



A wheelbarrow is a compound machine.

Reading Comprehension Questions:

1. What are machines?
2. What are simple machines?
3. What
4. How does a lever work? Give 3 examples.
5. How do inclined
6. How do wheel and axle systems work? Give 3 examples.
7. How
8. How do screws work? Give 3 examples.
9. How
10. What are compound machines? Give 3 examples.

Extension Questions:

11. What
12. Choose one

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TWF SAMPLE

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