8.3 Lesson 2 Principles of Simple Machines

From the invention of the wheel and probably before that man has been utilising machines or tools that help him/ her to make life easier and reduce effort when doing work. (*Remember from Lesson 1 Work is done when energy is used up and objects move or change.)*

Imagine trying to push a wheelbarrow uphill without wheels? Imagine trying to lift that wheelbarrow without handles? Wheels and handles or levers are examples of simple machines that help to do work.

Other simple machines include axles, gears, pulleys, inclined planes and screws.

They are called simple because they contain only one machine type. If you look at more complex machines like wheelbarrows, bicycles, clocks and cranes etc. you will see many of these simple machines used together to assist with doing work.

Purpose of machines:
Must do at least one of:

1. To reduce effort force
2. To increase distance or speed
3. To change direction

Examples

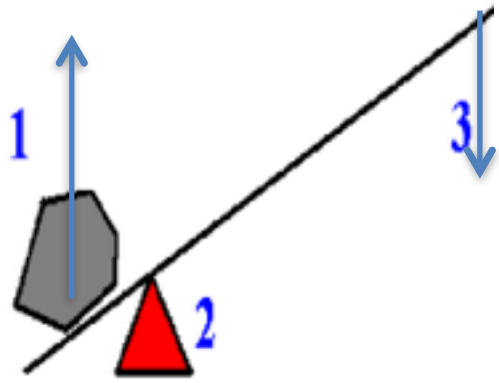
1. If you use a long handled socket spanner (wrench) to undo tight nuts on a car wheel, the longer the handle the easier it is because this is a machine that reduces force.

2. If you use a fishing rod that bends and the other end of the rod propels the tackle (hook, line, bait and sinker), as you flick your end, the longer the rod the further the tackle will go because this is a machine that increases distance.

3. If you hang a pulley with a rope on a beam and tie one end to a weight. You can lift the weight very high because you can pull down on a long rope rather than trying to push it up. This is a machine that changes direction.

1. Levers

Levers are just solid objects like planks and crowbars that can transfer a force from one place to another.



- A lever allows application of input force or effort 3 at a distance from the output force 1.
- A fulcrum or pivot 2 is where the lever sits and allows free rotation motion.
- The further away the application of force is from the pivot, the less input force is needed for a heavy load.
- The further away the load is from the pivot the further it will travel.

Q. How would you change the above diagram for a catapult?

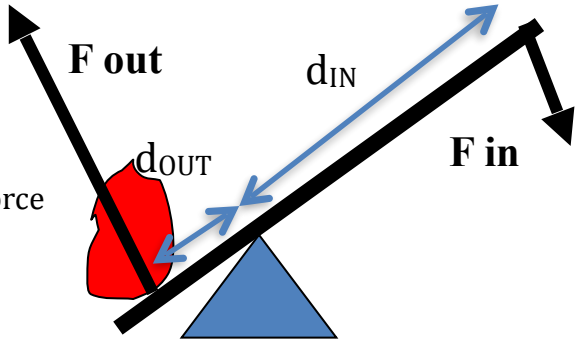
Types of Levers

1. **CLASS 1** (Pivot in the middle)

Two types:

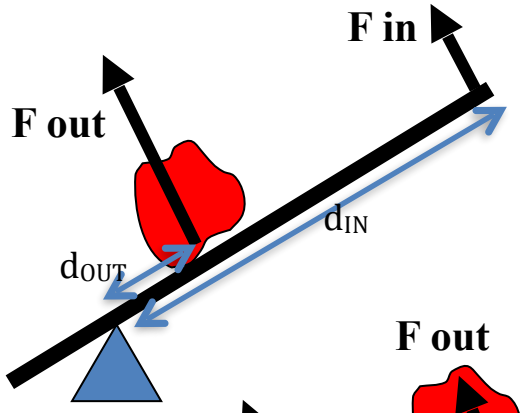
A. If $d_{IN} > d_{OUT}$ Input Force < Output Force

B. if $d_{IN} < d_{OUT}$ Input force > Output force



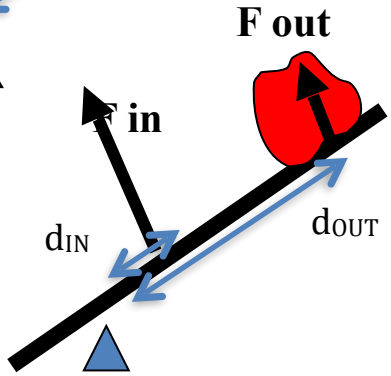
2. **CLASS 2** (Pivot on the end)

($d_{IN} > d_{OUT}$) Input Force < Output force



3. **CLASS 3** (Pivot on the end)

($d_{IN} < d_{OUT}$) Input Force > Output force



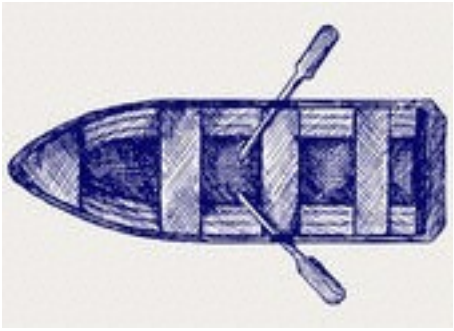
These levers then can be a:

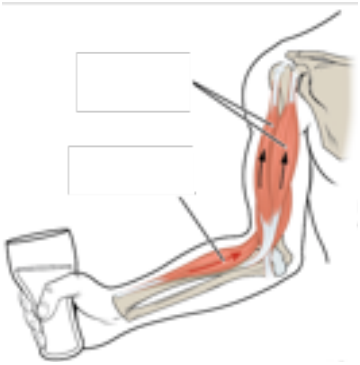
1. **Force advantage** (input force is less than output force so less effort is needed)
2. **Distance advantage** (input force is greater than output force so more effort is needed but the load goes further or faster)

Q1. Using the Lever Classes on previous page, categorise the classes below into their advantage type (Force or Distance):

Lever	Examples	Advantage
CLASS 1A	Crowbar prizing up a rock. Claw hammer removing a nail. Cutting with Scissors Gripping with pliers	
CLASS 1B	Using a Catapult	
CLASS 2	Lifting a Wheelbarrow Using a stapler Using a nutcracker Rowing a boat	
CLASS 3	Casting a Fishing rod Using the forearm to lift a rock Using BBQ tongs	

Q2. In the diagrams below; draw in the input force F_{IN}, output force F_{OUT} and Pivot **[?]**.





2. Pulleys

A pulley system uses at least one wheel and a rope that transfers the force from one side of the wheel to the other.

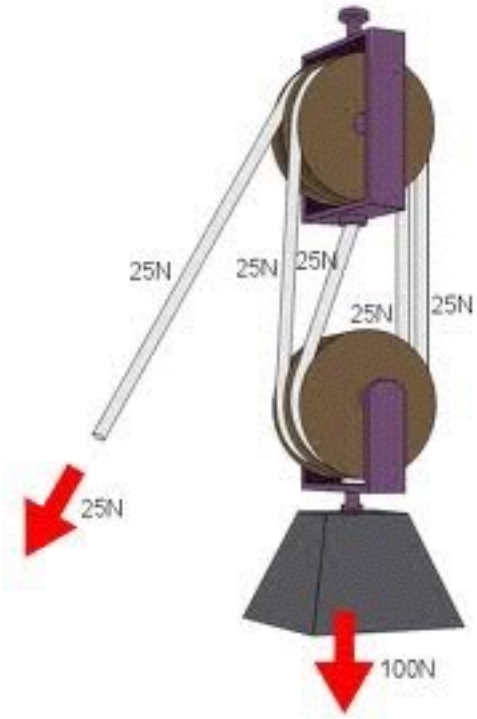
Single pulleys change direction of the force but have no force or distance advantage. The load moves the same distance and requires the same force to lift it, but for awkward heights or positions the single pulley is still useful.

Multiple pulley systems are more useful, not only providing change in direction if needed but also a force advantage.

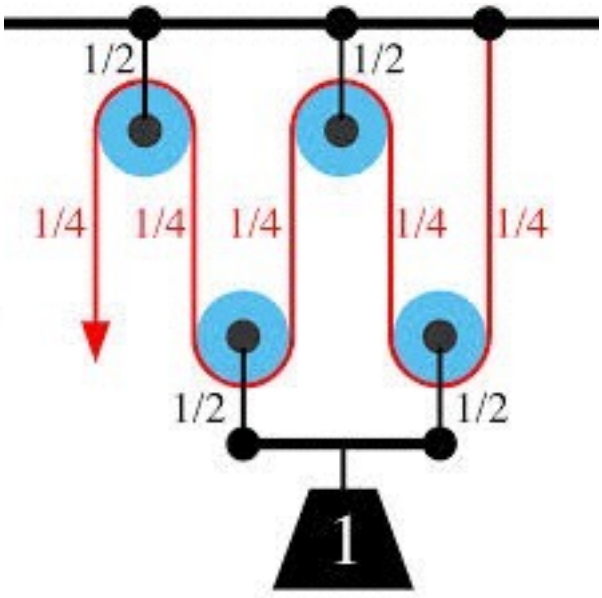
The force advantage is due to the number of rope sections lifting the weight. The more pulleys and ropes the greater the advantage:

"Block and Tackles" have two fixed pulleys (at the top) and two moveable pulleys that rise with the load.
The advantage is the much smaller force required to lift the load.
The disadvantage is the large distance needed to pull the rope, for a small rise of the load.
In the diagrams shown below, each rope section halves the force.
The Effort or input force is ¼ of the load or output force for a 4 pulley system.
In real pulley systems though, more than ¼ force is needed because of friction between the rope and pulleys.

Q. In the diagrams below label the input and output forces and label the fixed and moveable pulleys.



Block and Tackle System

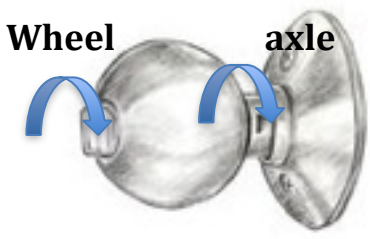


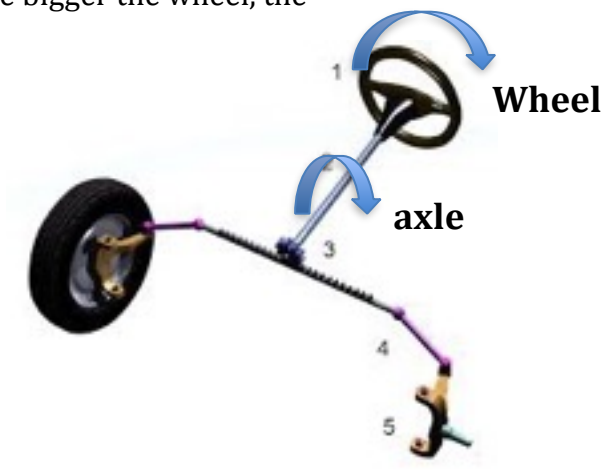
Block and Tackle System- expanded diagram

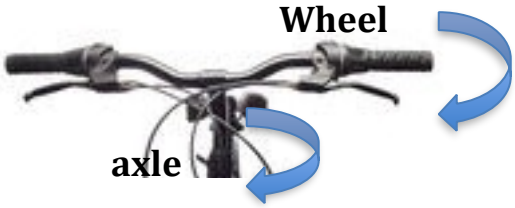
3. Wheel and Axles

Wheels and axles are similar to:

1. *A Second Class lever*. The pivot is in the middle. Effort on the wheel and load is on the axle. Example Steering wheels, bicycle handlebar, taps and door handles. The Wheels connected to axles turn a small force on the wheel into a large force on the axle. The bigger the wheel, the easier the force required to turn the axle.

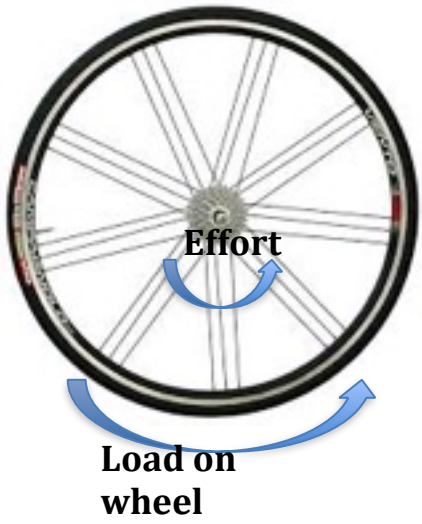






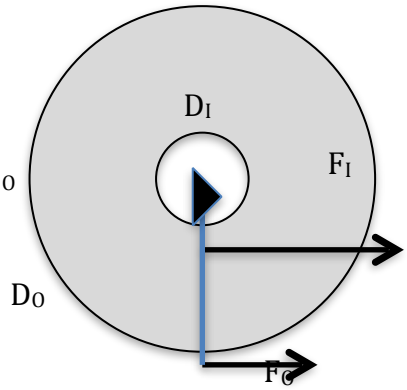
2. *A Third Class lever.* The pivot is in the middle. Effort on the axle and load is on the wheel. Example wheels of bicycles, cars etc. The axle connected to the wheel turns a small distance and the wheel on the edge turns a much larger distance, increasing the speed. The bigger the wheel, the faster it will go.

Train Engine turning axle **Cyclist turning pedals to turn axle of wheel**



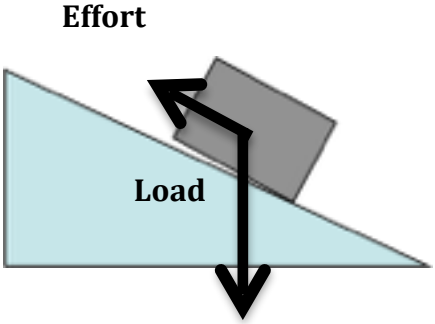
Q1. The outside of the wheel of a car moves further than the axle for each rotation so which one which one is faster?

Q2. Use the diagram showing F_I and F_O forces and the D_I and D_O circumferences to explain it.



4. Inclined Planes

Ramps, steps, wedges, axe heads, chisels and screws are all examples of an inclined plane, which is just a sloped edge or table.
The force advantage occurs because you have to push for a long distance.



The less the angle of the ramp the less the force is needed but you need a longer ramp.

- A Wedge (knife, chisel, axe head) is a single or double inclined plane, When you push it into a material , it

goes up a ramp making it easier.

- A screw is a spiral ramp, when you twist it into a material, the material is pulled up the ramp.

Q. How could you increase the force advantage of wedges and screws?

Do Investigation: 8.4 Analysing a machine