VANCOUVER ISLAND
UNIVERSITY

Mechanical Reasoning Review

Work can be made easier or faster through practical applications of simple and/or compound machines. This is called “mechanical advantage” - in other words, using the principal of mechanics to your advantage to make the job easier.

Terms to Know

- Load: what is being moved
- Effort : the force required to move the load
- Distance: how far the load is moved
- Work: the product of Effort (force) x Distance.
- Note: Work is constant; it is the effort required that changes, not the work.
- Resistance: the weight of the load

Mechanical advantage makes the job easier, but there is a price to pay. This “price” is about the *relationship* between the “load” being moved, the “distance” it has to be moved along, and the “effort” that is needed to move it.:

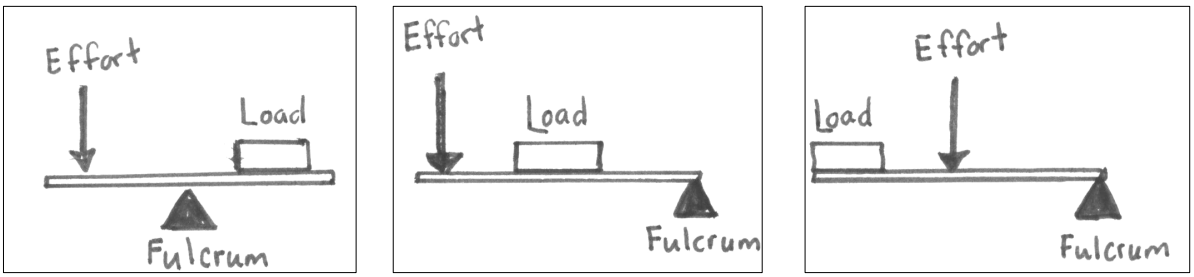
When a small effort moves a large load, the effort has to move farther than the load.

When reviewing the following information on simple and compound machines, think about the relationship between load, distance, and effort.

Simple Machines

1. **Lever**
    - A lever makes work easier by using force to move a load around a pivot.
    - A straight rod, a blade, or a board pivots on a point known as a fulcrum.
    - Pushing down on one end of a lever results in the upward motion of the opposite end.
    - The fulcrum can be moved depending on the weight of the object to be lifted or the force you wish to exert.
    - There are three “orders” of levers:

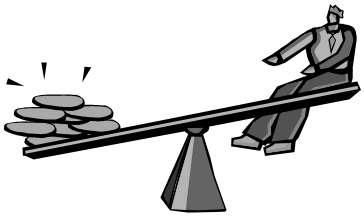
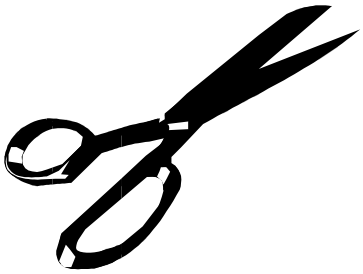
Figure 1 - Levers:



Order 1 Order 2 Order 3

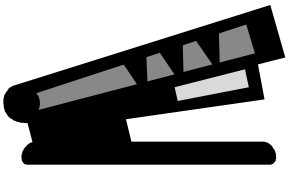
First Order Levers

- Look at the first picture in the diagram on the page one.
- The pivot (fulcrum) is between the load and the effort.
- In some cases, like a see-saw, the fulcrum is in the middle.
- In other cases it is off-centre, like in pliers. In these cases, the load is larger than the effort, but it is moved across a shorter distance.
- Some tools have more than one lever, such as pliers.
- Examples of first order levers: see-saw, scissors, pliers, pry bar.

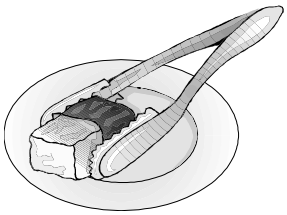

Second Order Levers

- Look at the second picture in the diagram on the page one.
- The fulcrum is at one end, the effort at the other end, and the load is in between.
- See diagrams below.
- Examples of second order levers: stapler, bottle opener, wheelbarrow, nutcracker, nail clippers.



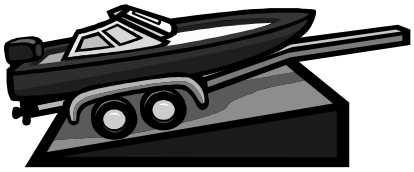
Third Order Levers

- Look at the third picture in the diagram on the page one.
- The fulcrum is at one end, the load at the other end, and the effort somewhere in between.
- See diagrams below.
- Examples of third order levers: shovel, fishing rod, tweezers, tongs.


Inclined Plane

- An inclined plane is a sloped surface, or a ramp, along which a load is moved.
- It allows one to overcome a large resistance by applying a relatively small effort across a longer distance than the load actually has to be moved.
- "Slope" is a measure of the angle by which an inclined plane is elevated from the horizontal.
    - The *greater* the slope, the *less* the advantage: *more* effort is required.
    - The *less* the slope, the *more* the advantage: *less* effort is required.
- "Effort" is the force required to move the load.
- Examples of inclined planes: ramps, switchbacks, ladders, dump trucks

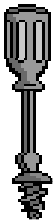
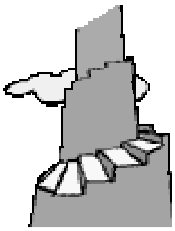
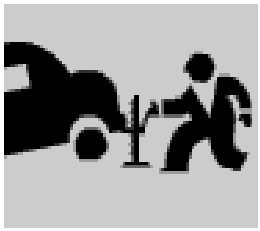


2. Wedge

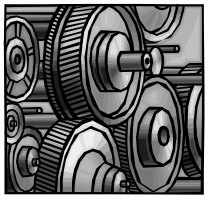
- A wedge is related to the inclined plane. It is a moving inclined plane.
- Generally it can be anything that splits, cuts, or divides another object (including air and water).
- It tapers from a sharp edge to a blunt end along its longitudinal axis.
- The more gradual the taper, the greater the mechanical advantage.
- A fairly weak force, applied to the wide end of a wedge whose narrow end is being pushed into something, will send a strong force pushing out at the sides.
- Applied to a ship's bow, a wedge divides the water smoothly, minimizing the energy required to push the water away so that the ship can move forward. Sometimes the tapered ends are pointed, and sometimes they are blunt
- Examples of wedges with pointed ends: bullets, nails, pencils
- Examples of wedges with sharp ends: axes, wedges, chisels, shovels, knives, the prow of a boat.



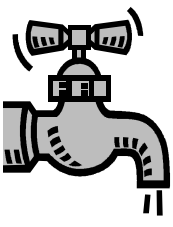

3. **Screw**
   - A screw is another form of an inclined plane.
   - A screw is an inclined plane (thread) wrapped around a rod to form a spiral.
   - This inclined plane allows the screw to move itself or to move an object or material surrounding it when rotated.
   - The less the slope on the plane, the less distance there will be between the threads of the screw, and less effort will be required to move the load. While turning, the screw converts rotary motion to forward or backward motion.
   - Example: screw, threaded bolt, spiral staircase, screw lid on jar, car or house jack

4. **Wheel And Axle**
- A wheel and axle is basically two circular objects of different sizes.
- The wheel is the larger object that turns the smaller object called the axle.
- When the wheel turns the axle, movement is created.
- The wheel is always larger than the axle, so it always moves a greater distance than the axle.
- Mechanical advantage depends on the radius of the wheel and the axle.
- A wheel and axle machine is used in two ways:
   1. To roll something along, cutting down on the amount of friction between the surface and the load. Generally, the bigger the wheel, the easier it is to move the load. Examples: wagon, dolly, truck, roller skates

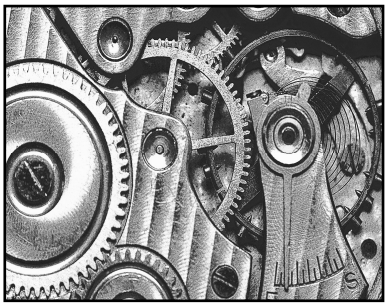


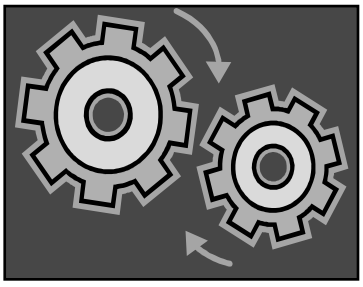

   2. Like a lever in the round that turns and has the fulcrum in the middle. The larger the diameter of the wheel, the less effort needed to turn it, but it has to be moved a greater distance to get the work done. The amount of work does not change. Examples: door knob, screwdriver, sink faucet, pencil sharpener, hand drill



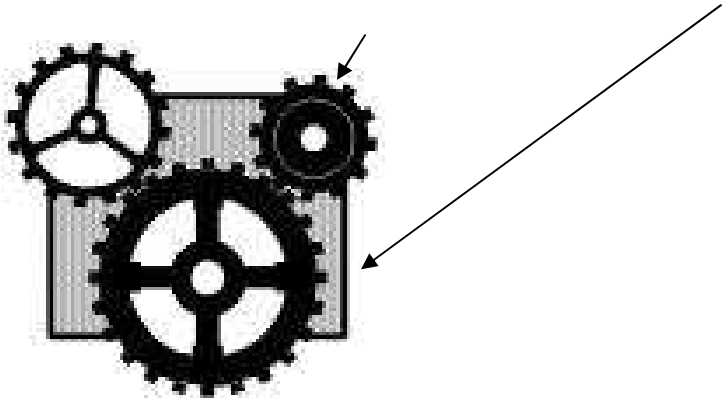
5. Gears

- Gears are wheels that that have "teeth" or "cogs" on their edges and are used in combinations of different sizes.
- There are different types of gears; the ones in the pictures below are spur gears.
- Intermeshing gears are used to transmit motion or force.
- They are used in three ways:
    1. to multiply or reduce speed and force
    2. to change direction of motion
    3. to transmit a force over a distance
- Gear terms:
    - → Train: A series of intermeshing gears. Gears turn in opposing directions.
    - → Driver: The gear in a train that has the force or motion input
    - → Driven: The gear that has the force or motion output (follower)
    - → Ratio: The number of teeth on the follower divided by the number of teeth on the driver.
    - → Rule: Low gear ratio = more speed = less force
      High gear ratio = less speed = more force.
- Examples of gears in use: wind-up clocks, bicycles, power meters.



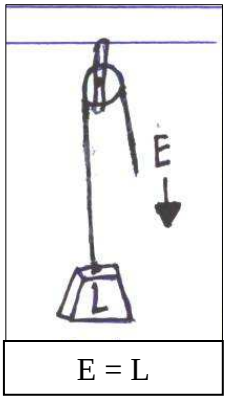


In the picture below, the smallest wheel has 12 teeth, while the largest wheel has 24 teeth. The small wheel rotates twice for each rotation of the large wheel.



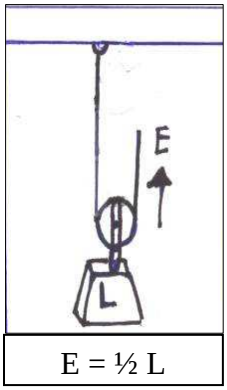
6. Pulley

- A pulley is a rope, chain, cable, or belt that is looped around a wheel. It is actually a wheel and axle with a rope (etc) attached.
- A pulley makes it seem easier to pull something because it changes the direction of the force.
- There are three different types of pulleys:
  1. Fixed pulley, which changes the direction of the lifting force, as in raising a flag on a flagpole or a sail on a mast. The load moves, but the pulley does not. There is no mechanical advantage with this type of pulley: the same amount of effort is required, though it can seem less because of gravity. In fact, the effort is more than the load.
  2. Moveable pulley is one that moves with the load. This type of pulley allows the effort to be less than the load. If you add a second pulley, the effort is even less.
  3. The combined pulley requires less effort to lift the load: the effort is less than half the load. The disadvantage is that the effort travels a longer distance.



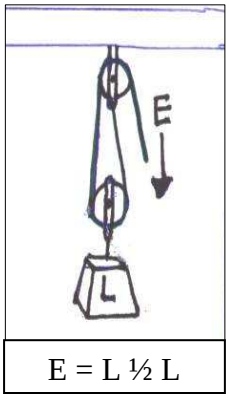
E = L

Single fixed pulley



E = ½ L

Single moveable pulley



E = L ½ L

Combined pulley

Block and Tackle

A block and tackle arrangement is when pulleys are used in combination and the pulley attached to the weight consists of two separate pulleys on the same shaft. This cuts the force in half and doubles the distance. A block and tackle can have any number of pulleys, but at some point, the amount of friction in the pulley shafts becomes significant.

To figure out the effort required to lift the load with a block and tackle, divide the load by the number of ropes used to move it. For example, if the load is 200 grams and there are 4 ropes running through the pulleys, the effort required is 200 ÷ 4 = 50.

Compound Machines

Simple machines can be combined to form compound machines, Here are some examples:

- Scissors: wedges (blades) and levers
- Hand meat grinder: wheel and axle (handle) and screw (grooved interior that moves the meat along)
- Wheelbarrow: levers (handles) and wheel and axle

For more information on simple machines and mechanical advantage, visit these websites:

www.fi.edu/qa97/spotlight3/spotlight3.html

Other Areas of General Science Knowledge

There are many other areas of science besides mechanical advantage that you might want to review:

1. Volume
2. Balancing Scales
3. Mirrors and reflection
4. Magnetism
5. Gravity
6. Electricity
7. Friction

More Resources:

General science and math textbooks and websites are available in the Learning Centre at Cowichan Campus - Room 131, Building 601 - to help you prepare for these types of questions.

- For downloadable mechanical reasoning practice tests, visit: www.psychometric-success.com/downloads/download-practice-tests.htm

Here are some additional resources that you will find useful to prepare for the mechanical reasoning portion of the assessment:

- Master the Mechanical Aptitude and Spatial Relations Tests, 6th Ed., Levy, Joan U. and Levy, Norman, Simon & Schuster, ISBN 0-7689-1699-2 (available in the Learning Centre and in the reference section at the Cowichan Campus Library)
- How to Prepare for the Mechanical Aptitude and Spatial Relations Tests, Wiesen, Joel P., Barron's 2003 ISBN 0-7641-2340-8 (available in the Learning Centre at Cowichan Campus)
- Downloadable mechanical reasoning tests: www.psychometric-success.com/downloads/download-practice-tests.htm