

Simple and compound machines

Mechanical advantage

- ✓ $MA = \frac{\text{output force}}{\text{input force}}$, with no unit: 100 N out for 20 N in is 5
- ✓ A machine trades **distance for force**: it never gives out more work than you put in
- ✓ **Ideal MA**: with no friction; **actual MA**: with it, so always less; less friction raises it
- ✓ **Efficiency** is always under 100%
- ✓ **Compound machine**: multiply the parts' MAs: $3 \times 4 = 12$

Ramps, wedges, and screws

- ✓ **Inclined plane**: a ramp or stairs; less force over a longer distance; $MA = \frac{\text{length}}{\text{height}}$
- ✓ **Wedge**: two inclined planes meeting at an edge, to split things: knife, chisel, axe
- ✓ **Screw**: an inclined plane wrapped around a cylinder; turns rotation into straight-line motion: bolts, jar lids

Levers

- ✓ A rigid bar on a pivot, the **fulcrum**; name the class by what is in the **middle**:

Class	In the middle	Examples
1	Fulcrum	Seesaw, scissors, crowbar
2	Load	Wheelbarrow, bottle opener, nutcracker
3	Effort	Broom, shovel, your forearm

- ✓ **Balanced** when $\text{effort} \times \text{its distance} = \text{load} \times \text{its distance}$
- ✓ $MA = \frac{\text{effort arm}}{\text{load arm}}$: 50 lb 2 ft from the fulcrum balances 25 lb at 4 ft

Wheel and axle

- ✓ Turning the larger wheel turns the axle with more torque: steering wheels, doorknobs
- ✓ $MA = \frac{\text{wheel radius}}{\text{axle radius}}$

Gears

- ✓ Meshed gears turn in **opposite directions**, so every other gear in a chain turns the same way
- ✓ **Small driving large**: slower, more torque; **large driving small**: faster, less torque
- ✓ Teeth $\times$ speed is the same for both gears: a 10-tooth gear at 60 rpm turns a 30-tooth gear at 20 rpm
- ✓ Kinds:
 - **Spur**: straight teeth, parallel shafts
 - **Bevel**: shafts that meet at an angle, as in a hand drill
 - **Rack and pinion**: rotation to straight-line motion, as in steering
 - **Worm and wheel**: a large speed reduction; the wheel cannot turn the worm, so it locks

Pulleys

- ✓ **Fixed**: changes the direction of the force only, MA 1
- ✓ **Movable**: rides on the load, which two strands hold up, MA 2
- ✓ **Block and tackle**: fixed and movable together; **MA = the number of rope strands holding the load**
- ✓ Less force means pulling more rope

Compound machines

- ✓ Two or more simple machines working together
- ✓ **Bicycle**: wheels and axles, gears, lever handlebars
- ✓ **Scissors**: a class 1 lever with wedge blades
- ✓ **Wheelbarrow**: a class 2 lever on a wheel and axle