

Gears

Teeth, speed and force

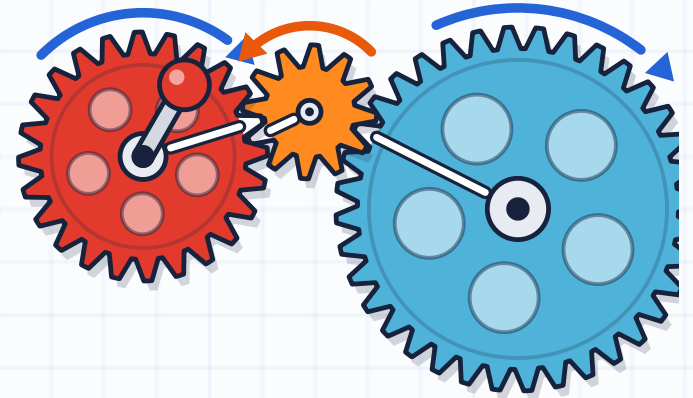
How can a little crank lift a heavy load, or make a wheel spin super fast?

1 Wheels with teeth

2 Which way?

3 Faster or stronger?

4 Chains, belts, screws and racks



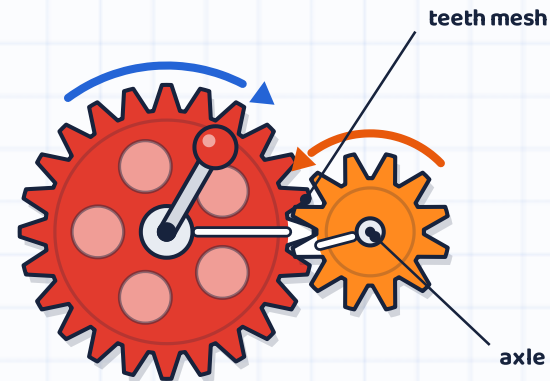
A wheel with teeth

A **gear** is a wheel with **teeth** all around it. Gears pass a turning motion from one axle to another.

- When two gears touch, the teeth of one fit into the gaps of the other: they **mesh**.
- The gear you turn is the **driver** gear. The gear it turns is the **driven** gear.
- The smaller gear of a pair is often called the **pinion**.



Build gears in the Workshop



driver gear

24 teeth

driven gear

12 teeth

Teeth that don't slip

Two smooth wheels that rub together can also pass on a turning motion: they are **friction wheels**.

- With a heavy load, friction wheels **slip**: the second wheel stops while the first one keeps turning.
- Gear teeth push on each other, so they can't slip. Every tooth that goes by pushes one tooth of the other gear.
- To mesh, two gears need teeth of the **same size**.



A gear with big teeth and a gear with tiny teeth: can they mesh?

No. The big teeth don't fit in the tiny gaps, and the tiny teeth don't fill the big gaps.

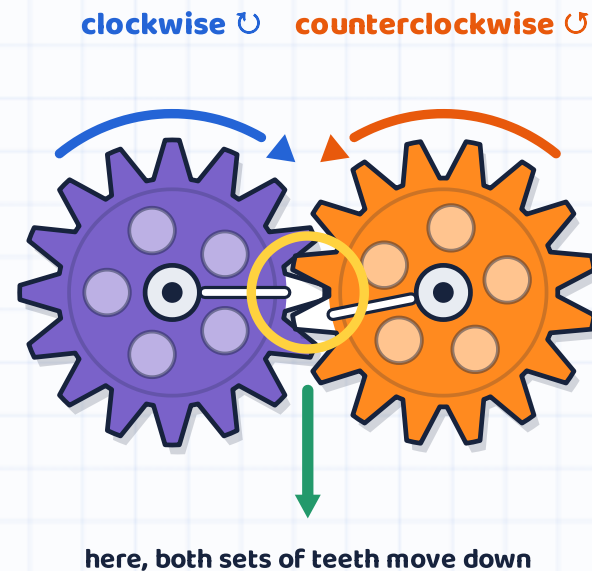


Each one its own way

Look closely at two gears that mesh. They never turn the same way!

Two gears that mesh turn in opposite directions.

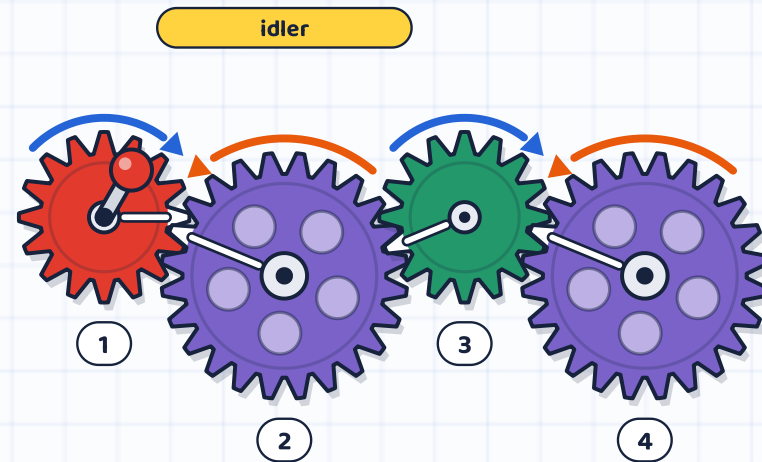
- Like the hands of a clock: **clockwise** ↻. The other way: **counterclockwise** ↺.
- Where the gears touch, their teeth move together in the same direction. So the two wheels turn opposite ways.



A gear in between

Put a gear between the two, and the last gear turns the **same way** as the first one.

- The gear in the middle is called an **idler**.
- Number the gears in a row. Odd numbers (1, 3, 5...) turn like gear 1. Even numbers (2, 4, 6...) turn the other way.
- An idler doesn't change the speed of the last gear, only its direction.



Guess the direction

Guess first, then tap a card to check.

5

A row of 5 gears.

Gear 1 turns clockwise. And gear 5?

Clockwise, like gear 1: 5 is an odd number.

8

A row of 8 gears.

Gear 1 turns clockwise. And gear 8?

Counterclockwise: 8 is an even number.



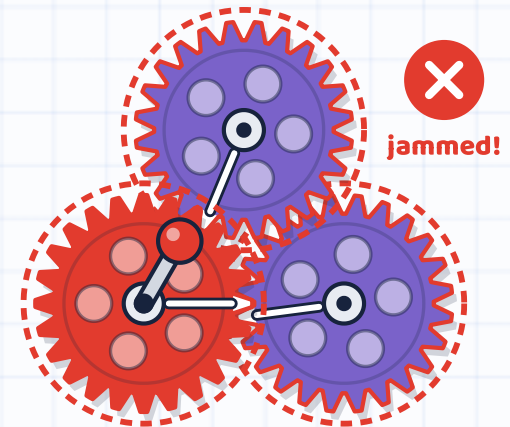
Three gears all touch each other in a triangle. What happens?

They jam! Each gear would have to turn against both of its neighbours: impossible.



Four gears in a square, each touching two others. Do they jam?

No! ↻ ↻ ↻ ↻, and gear 4 turns gear 1 ↻: it all agrees. Only a loop of an **odd** number of gears jams.



Unjam it in Puzzles

Count the teeth

When gear A makes one turn, all its teeth go past the meeting point. So gear B moves by the same number of teeth.

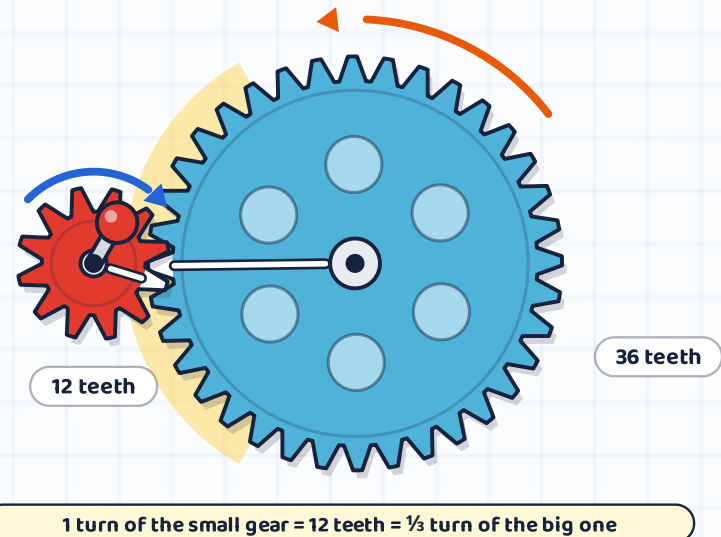
$$\text{turns of B} = \text{turns of A} \times \text{teeth of A} \div \text{teeth of B}$$

- A 12-tooth gear turns a 36-tooth gear: 12 teeth go by, only $\frac{1}{3}$ of a turn of the big gear.
- The small gear turns 3 times for each turn of the big one.

10

A 10-tooth gear drives a 40-tooth gear.
How many turns of the small one for 1 turn of the big one?

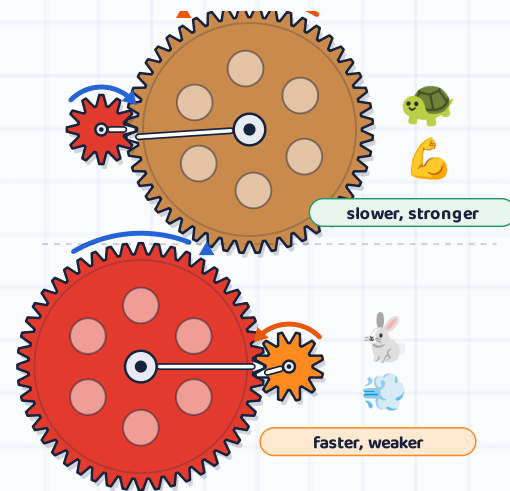
4 turns: $40 \div 10 = 4$.



Speed or force: you choose

Gears can make a motion faster or slower. But there's a trade: what you gain in speed, you lose in force.

	Small gear turns a big one	Big gear turns a small one
Speed	slower 🐢	faster 🐰
Force	stronger 💪	weaker
Good for	lifting heavy things: cranes, winches, a car's first gear	going fast: egg beaters, fans, a bike on flat ground



Same size, same speed

Two gears with the same number of teeth turn at the same speed, with the same force. Only the direction changes.



Lift the crate in Puzzles (level 4)

Bike gears

On a bike, a chain links the **chainring** at the pedals to a **sprocket** on the back wheel.

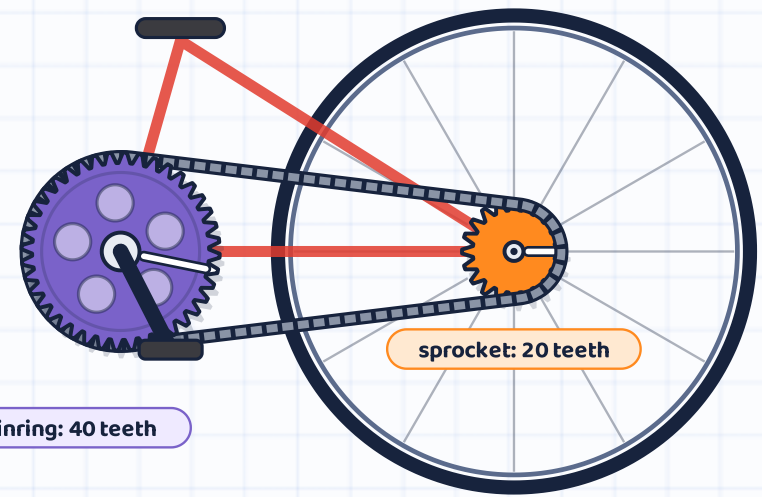
- Chainring with 40 teeth, sprocket with 20 teeth: 1 pedal turn = 2 turns of the back wheel.
- To climb a hill: a **big sprocket**. The bike goes slower, but pedalling is easier.
- On flat ground: a **small sprocket**. Each pedal turn takes you farther, but pedalling is harder.

Cars do it too

A car starts in first gear (slow and strong) and drives on the highway in its top gear (fast).



Shift gears on the Bike ride



chainring: 40 teeth

sprocket: 20 teeth

$$40 \div 20 = 2 \text{ wheel turns per pedal turn}$$

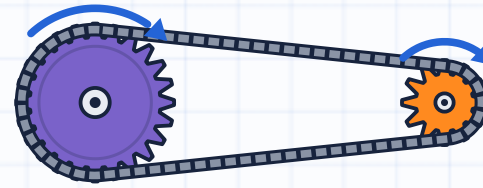
Chains and belts

When two axles are far apart, a chain or a belt carries the motion from one wheel to the other.

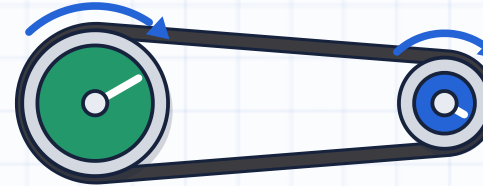
- **Sprockets and chain:** both wheels turn the same way, and nothing slips. You find them on bikes.
- **Pulleys and belt:** the same way too, but a smooth belt can slip under a heavy load. You find them in car engines and old sewing machines.
- Cross the belt, and the second pulley turns the other way!



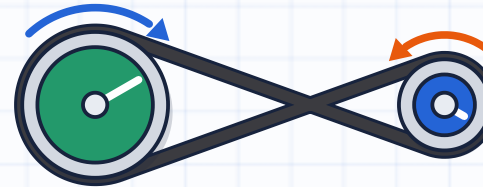
Try them in Machines



Sprockets and chain:
same way



Pulleys and belt:
same way

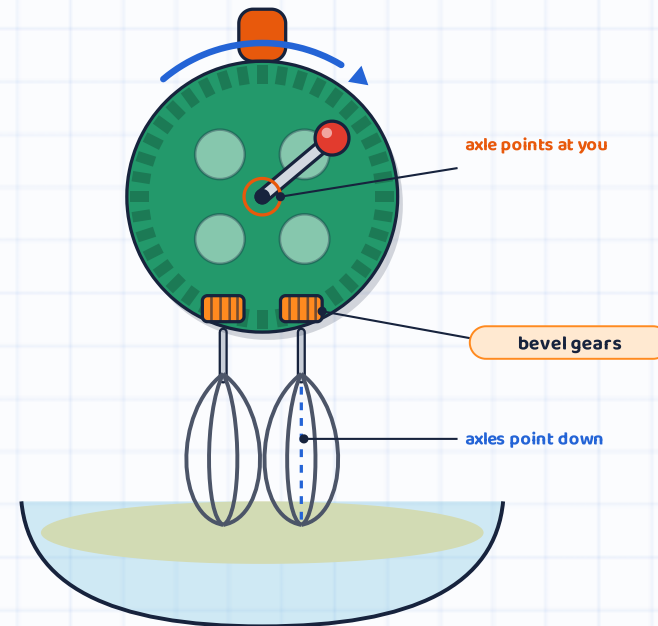


Crossed belt:
opposite ways

Around the corner: bevel gears

In a **bevel gear**, the two wheels sit at a right angle. The turning motion goes around a corner.

- In an egg beater, you turn the big wheel around an axle that points at you. The beaters spin around axes that point down.
- The big wheel has many more teeth than the small ones, so the beaters spin about 4 times faster than the crank.
- The two beaters turn in opposite directions.
- A hand drill works the same way: the crank turns sideways, but the drill bit turns straight ahead.



Turn the egg beater in Machines

The worm gear

A **worm** is a screw that meshes with a gear. Each turn of the screw moves the wheel by only **one tooth**.

- With a 20-tooth wheel, it takes 20 turns of the screw to turn the wheel once: very slow, but very strong.
- It only works one way: the wheel can't turn the screw. A load stays up by itself.

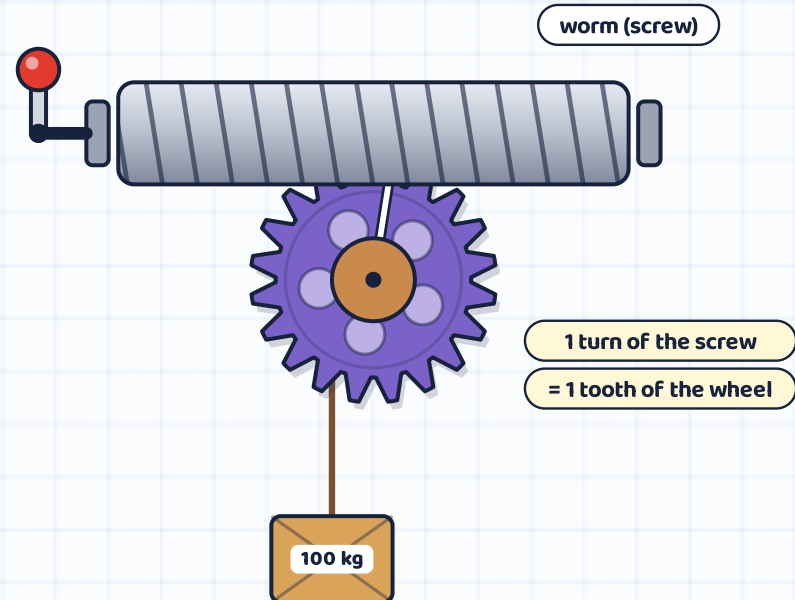


Guitar tuning pegs use a worm gear.
What would happen without it?

The string would pull the peg back around, and the guitar would go out of tune.



Lift the weight in Machines



Rack and pinion

A **pinion** (a small gear) turning along a **rack** (a toothed bar) moves in a straight line.

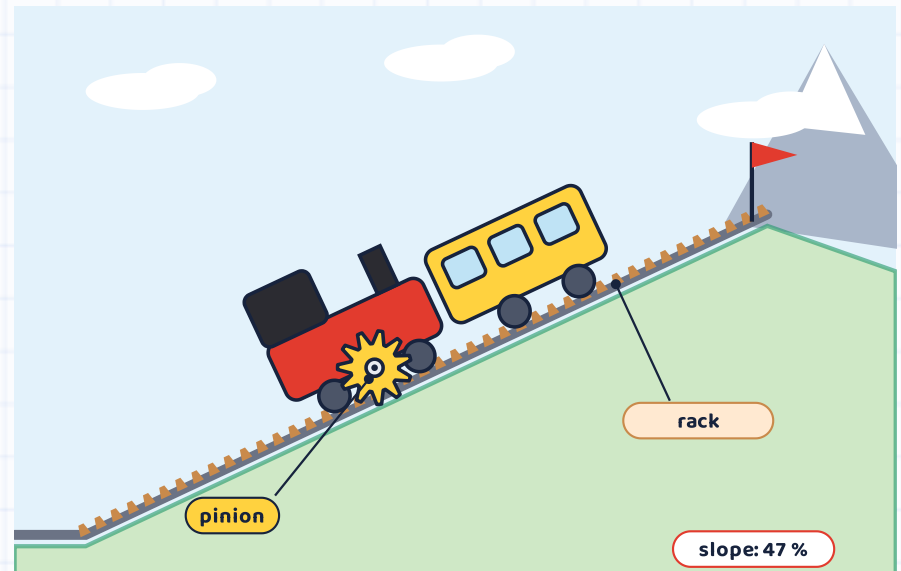
- Gears, chains, belts and worms **transmit** a turning motion. The rack and pinion **transforms** it.
- In many cars, the steering wheel turns a pinion that slides a rack left or right.

Trains that climb

Smooth wheels would slip, so mountain trains climb with a cog. The first one reached the top of Mount Washington (New Hampshire) in 1869. The steepest, on Mount Pilatus (Switzerland), climbs slopes of 48 %.



Drive the train in Machines



Gears all around you

Which system hides inside? Guess, then tap to check.



A wall clock

A train of gears. The minute hand turns 12 times while the hour hand turns once.



A bicycle

Sprockets and chain. The chainring and the back sprocket turn the same way.



A hand egg beater

Bevel gears. The motion turns a corner, and the beaters spin faster than the crank.



Guitar tuning pegs

Worm gears. The strings can't turn the pegs back.



A car's steering

Rack and pinion. The turning steering wheel slides a bar left or right.



An old sewing machine

Pulleys and belt. A belt carries the motion from the big wheel to the needle's mechanism.

Three big ideas

What you've learned

1

Teeth that mesh

Gears pass on a turning motion without slipping. Their teeth must be the same size.

2

Opposite directions

Two meshing gears turn opposite ways. An idler makes the last gear turn like the first. A triangle jams.

3

Speed or force

Count the teeth: a small gear turning a big one is slower but stronger. You can't win both!

Now play Gear Lab



Workshop



Puzzles



Machines



Bike ride



Quiz