

You are here: [Home page](#) > [Engineering](#) > Cranks and cams

[Home](#) | [A-Z index](#) | [Random article](#) | [Timeline](#) | [Teaching guide](#) | [About us](#) | [Privacy & cookies](#)

Advertisement



Cranks and cams

by [Chris Woodford](#). Last updated:
January 6, 2021.

What sort of problems keep you awake at night? If you'd been an engineer

Sponsored | Business Focus

during the Industrial Revolution, tinkering with [steam engines](#) and such, **cams** and **cranks** were the kind of thing you'd have worried about. They're cunning [inventions](#) that convert the push-pull motion of engines and machines into the spinning and whirring motion of [wheels](#)—or vice-versa. Cranks and cams are just as useful today and you can find them in everything from [car engines](#) and [bicycle pedals](#) to [electric toothbrushes](#) and [sewing machines](#). Here's a quick look at how they work!

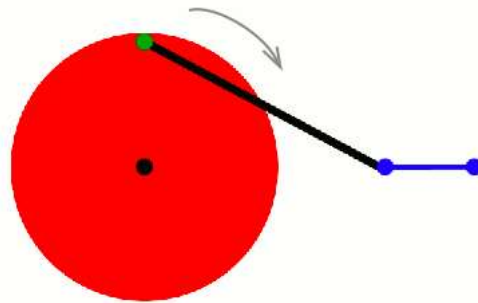
Photo: This [radio](#) doesn't need [batteries](#) because it's powered by a simple hand-crank: when you crank the handle, you spin a small [electricity generator](#) (dynamo) inside the case that stores [energy](#) in [rechargeable batteries](#). Although you're turning the crank, if you do it for a while you soon get a distinct feeling that you're moving your hand back and forth instead of round-and-round. So the crank is really converting a back-and-forth motion of your hand into rotary motion in the generator. Photo by Robert J. Fluegel courtesy of [US Navy](#).

Contents

1. [How do cranks work?](#)
2. [How do cams work?](#)
3. [Examples of cranks](#)
4. [Examples of cams](#)
5. [Force or speed?](#)
6. [Find out more](#)

How do cranks work?

[Engines](#) that make their power with pistons usually need a way of converting back-and-forth (**reciprocating**)



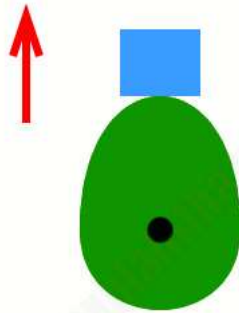
www.explainthatstuff.com

motion into round-and-round (**rotational**) motion—a way of driving a wheel, in other words. Most engines use cranks to do this. A crank is simply an off-center connection that provides energy to (or takes energy from) a rotating wheel. As the crank pushes back and forth, the wheel rotates (or vice-versa). In this example, as the red wheel rotates, the green crank pushes the black and blue connecting rods back and forth, converting the wheel's rotary motion into reciprocal motion. So the red wheel moves round, but the blue rod moves back and forth.

The same mechanism could be used the opposite way to drive the wheel from a piston. You'd just hitch the blue rod up to the piston so that as it moved in and out of its cylinder, the red wheel would go round and round. Steam engine wheels are driven exactly like this.

How do cams work?

Cams generally do the opposite job to cranks: they turn rotary motion into reciprocating motion. Whatever you need to move up and down (or back and forth) rests on top of an oval wheel, sometimes mounted off-center (the cam). As the cam rotates, the object it supports rises up and down. In this example, you can see the blue box rises and falls as the green cam turns round and round. But most of the time the box just sits there, motionless, with the cam slowly spinning beneath it. If you look closely at the way I've drawn the cam, you can see the secret of how it works. Three "quarters" of it is like a circle, so anything resting on it for three quarters of the time will neither rise nor fall, but stay motionless. The other quarter stretches out into an ellipse shape and that's the part that lifts and lowers every time it reaches the top.



Artwork: Cam shapes:
Here are eight typical designs, but you can make cams any shape and size you need to (even a completely irregular shape). The cam turns around the blue circle in each case.

The object that moves up and down, or otherwise tracks the cam's movement, is called (surprise, surprise) the

Sponsored links

the **RIDGE**

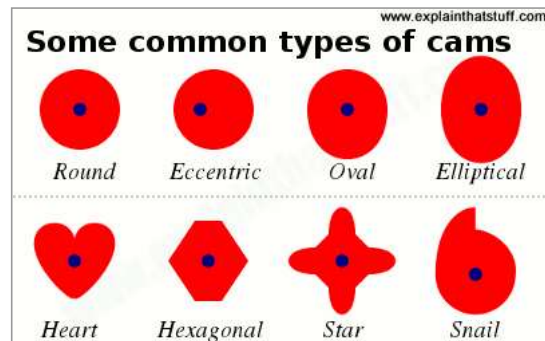
YOUR WALLET

OUR WALLET

MAKE THE SWITCH

www.explainthatstuff.com

follower. It could be a simple rod or lever (as I've shown here), a pointer, a rotating roller, or something more intricate and complex. The cam, too, can vary in design. A classic cam is oval (pear-shaped) like the one I've drawn here, but others are heart-shaped, hexagonal, round but eccentric (a circle that rotates about an off-centered point), elliptical (a more symmetrical oval than our pear-shaped cam), snail-shaped (a circle with a tail), or pretty much anything else you can think of. Where the shape of the cam controls the path that the follower traces, both its size and shape control the timing of its motion. So, for example, if I stretched my green oval taller, the blue box would not only move higher but take longer to return to position. That can be handy if cams are being used for things like opening and closing [valves](#) on engines (see the illustration further down this page under the [examples of cams](#)).



Examples of cranks

It's all very well to talk about things in theory with little animated graphics, but it's much more interesting to see how these things work in actual machines. The following selection of photos shows you some examples of cranks working hard in real life.



Engine crankshaft

Car and boat engines have multiple cylinders that turn a single drive shaft, called the crankshaft. Each cylinder fires at a slightly different time so, at any given moment, there's always at least one cylinder adding power and driving the vehicle along. The cylinders are attached to the crankshaft by rods that connect to the piston rods inside the cylinders.

Photo: The shiny crankshaft from a brand new marine engine. Picture by Marco Bernardini published on [Flickr](#) in 2009 under a [Creative Commons Licence](#).

Steam engine crankshaft

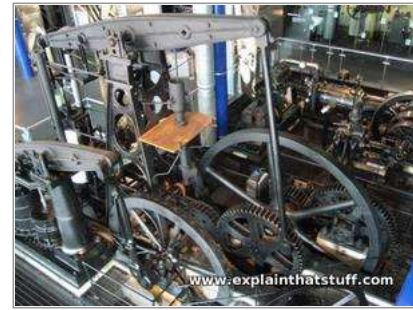
Photo: A fairly small beam engine in the engine hall at Think Tank, the science and engineering museum in Birmingham, England. You can just about see the cylinder and piston on the left, the rocking beam on top, and the crankshaft and connecting rod driving the wheel on the right.

Early [steam engines](#) were so big that they were permanently fixed in place, often occupying entire huge buildings. An engine like this typically makes power with a single piston moving in and out of a single cylinder. If you need it drive a wheel, you can attach the piston to a beam. As the piston moves up and down, the beam rocks back and forth, pulling on a crankshaft and connecting rod that turn the wheel.

Hand-cranked pump



Photo: Hand-cranked rotary pump.
Picture by Ian Schell courtesy of US Army.



Hand cranks are great ways to drive machines with the help of muscle power! Our top photo shows a hand crank being used to generate [electricity](#). Here we have a hand crank turning a [rotary pump](#) that's being used to transport fuel down a pipeline. The crank is turning an impeller (a kind of [turbine](#)-like device) sealed inside the red casing, which powers the fluid along.

Bicycle pedals

Photo: Bicycle pedals would be better referred to as "bicycle cranks," because it's the cranks attached to the pedals that do the work!

Here's one of the most familiar cranks of them all! We always talk about the "pedals" on a [bicycle](#) when we really mean the cranks—two [levers](#) that help to multiply the force supplied by our leg muscles as they pump up and down. In theory, the longer the cranks, the better—because that gives more leverage. In practice, though, the cranks have to be short enough for your legs to operate the pedals comfortably and not so long that they bang on the ground. The cranks combine with the gears to make the bicycle just about the most efficient form of transportation so far invented.



Electric shavers



Photo: Inside a shaver: A crank-like mechanism (a peg that engages in a slot) moves one of the cutting blades back and forth. The top photo shows a typical electric shaver as you look down on it; the bottom photos show you what you see when you pull the blades away for cleaning. The left photo shows the mechanism inside the shaver; the right photo shows the underside of the blades.

Electric shavers (and similar, powered chopping machines like garden hedge trimmers and electric carving knives) cut using two parallel sets of toothed blades: one stays static while the other slides past it from side to side. How does that work? An electric motor inside the case turns a wheel with an off-center peg attached, which works like a crank. The peg engages a slot in a piece of plastic attached to the lower set of blades. As the motor spins, the peg moves from side to side (and also up and down), pushing the slot from side to side in turn, causing the moving blades to slide back and forth against the static blades. Now this doesn't look like a crank at first sight, but if you think about the peg and the plastic slot, you can see that they work in the same way as the other crank mechanisms we explored up above.

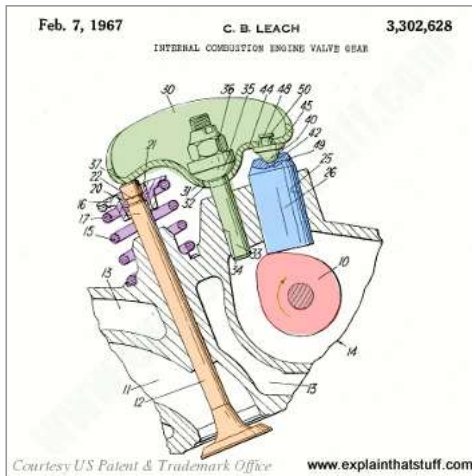
Examples of cams

From [door locks](#) and [prosthetic legs](#) to old-fashioned (gear-driven) [calculators](#) and [photocopiers](#), cams are working their magic inside all kinds of machines, turning rotation into back and forth motion. It's almost impossible to find good pictures of working cams, but I'm constantly looking out for examples; I'll post more here as I discover them.

Engine valves

[Car engines](#) burn fuel with air to release energy that roars us down the road. A typical car has 4–8 cylinders in which the power is made. They suck in fuel and air one minute, burn it to make power, and blast out exhaust gases the next. Little valves mounted on each cylinder allow fuel in and let the waste gases escape. The cylinders make power slightly out of step

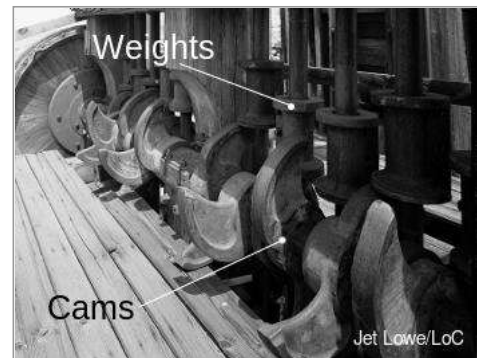
with one another, and their valves have to be opened and closed with meticulous timing by cams attached to a spinning axle called a camshaft.



Artwork: How a cam opens and closes the valves in a car engine. The cam (red) is rotated by a camshaft (gray) powered by a belt linked to the crankshaft (not shown). As it turns, the cam pushes a rod called a tappet (blue) back and forth. The tappet moves a rocker arm (green) which allows a poppet valve (orange) to move in and out against the pressure of a spring (purple). So the rotating cam makes the valve reciprocate (open and close). Artwork from [US Patent 3,302,628: Internal combustion engine valve gear](#) by Clayton Blaine Leach, General Motors Corporation, February 7, 1967, courtesy of US Patent and Trademark Office.

Stamping machine

Photo: A camshaft on an old stamping machine in a gold mill. As the shaft turns, the heavy weights slowly rise up and then suddenly drop down

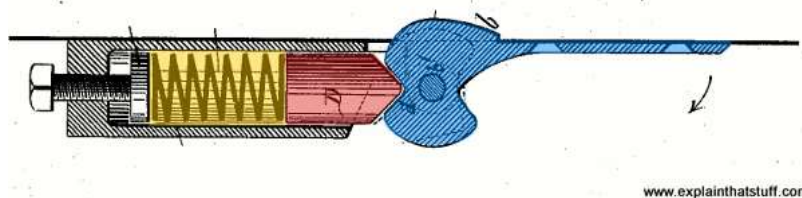


very hard. Picture by Jet Lowe, taken at Lost Horse Gold Mine, courtesy of [US Library of Congress](#).

Snail cams (sometimes called drop cams) are perfect for slowly lifting heavy machine parts that drop back down very quickly, hammering or stamping something in the process. With the green egg-shaped cam I've illustrated in my animation up above, the movement is perfectly symmetrical: the blue follower rises at exactly the same speed as it falls. With a snail cam, however, the rising happens slowly and gently, while the falling is quick and hard. You can see from this example why cams are sometimes very oddly shaped: although they follow a continually repeated cycle, some parts of the cycle might need to happen more quickly or abruptly than others.

Door locks, bolts, and hinges

When you turn your key, you make a bolt shift from side to side that either locks or unlocks your door. What converts the rotation of your key into a sliding motion of the bolt? Often it's a cam of some sort. Different locks and bolts work in many different—often mechanically intricate—ways (see our article on [door locks](#) for more details); here's one very simple example of how a cam can power a locking door hinge.

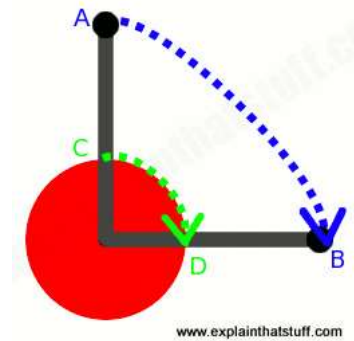


Artwork: The cam in a spring-loaded door hinge. Doors on closets need to stay closed—and this is one way to achieve that with what is effectively a spring-loaded cam follower. When the hinged door (blue) is open and pointing to the right, a notch in the cam follower (red) and a spring (yellow) hold it securely in place. When you close the door, you rotate the cam (clockwise), which moves the follower and pushes the spring in briefly, before it pops back out again and locks the cam (and the door) in the opposite, closed position. Artwork from [US Patent 324,444: Lock hinge](#) by J Wolf, August 18, 1885, courtesy of US Patent and Trademark Office.

Force or speed?

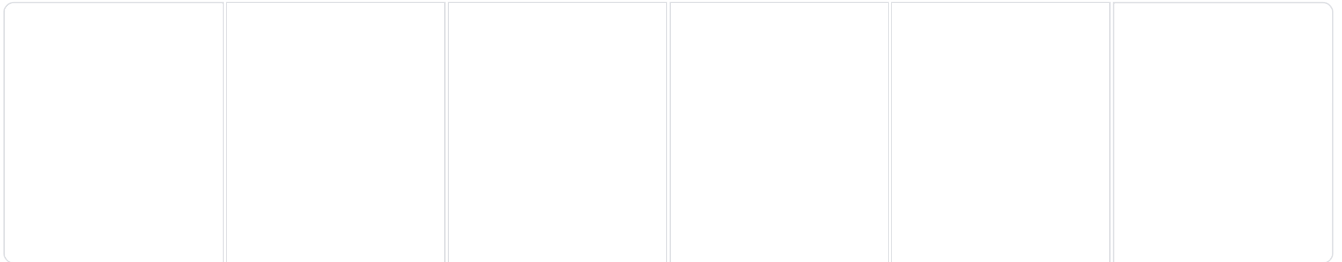
Crank and levers are closely related to levers and gears: all three of these can be used to magnify force or speed, although not both at the same time. Suppose you're turning the handle of the [clockwork](#) radio in our top picture. Your hand goes round in a larger circle than the mechanism in the center, so it's traveling faster. A crank used in this way reduces speed and increases force. Most cranks work like this, providing leverage to give extra force. A [coffee](#) grinder is another good example: it takes quite a lot of force to power the crushers (burrs) that smash the beans to pieces and the handle of the grinder multiplies the force you apply with your hands. If you use a crank the opposite way, using the power from a cylinder and piston to drive a rotating wheel, you can use it to increase the speed of a machine, although the force you get will be reduced at the same time.

Artwork: How a crank works: If you turn the outside of the crank through a quarter circle, it moves a distance from point A to point B. The inside of the crank moves a much shorter distance from point C to point D. Since the distance AB is much bigger than the distance CD, and both these distances are covered in the same time, it's clear the outside of the crank is moving faster than the inside, so the crank reduces speed at the center. What's less obvious is that the crank increases force in exactly the same proportion. So if it gives a ten-fold reduction in speed, it also gives a ten-fold increase in force.



Why can't you increase the speed *and* the force simultaneously? Because of a basic law of physics called the [conservation of energy](#). Suppose you're cranking the clockwork radio. You apply a certain force to the handle to move it a certain distance in one second. That takes a certain amount of energy, which your body supplies. Now the law of conservation of energy tells us nothing can magically create energy out of thin air: the energy you supply to the outside (the crank handle) must be the same (or a bit less) than the energy received at the inside (the center of the crank where the [clockwork](#) mechanism is located). We know we're getting more force at the center of the crank than at the outside; we also know that the inside of the crank turns more slowly (less distance each second) than the outside. So the greater force is compensated by that force moving a shorter distance each second. Every second, the energy supplied to the inner, clockwork mechanism at the center (the larger force times the shorter distance) is virtually the same as the energy we put in at the outer part of the crank (the smaller force times the longer distance).

Sponsored links



Find out more

On this website

You might like these other articles on our site covering related topics:

- [Clockwork \(windup\) mechanisms](#)
- [Engines](#)
- [Gears](#)
- [Laws of motion](#)
- [Sewing machines](#)
- [Steam engines](#)

On other sites

- [Photos of crankshafts](#): There are lots more good pics of cranks in action on Flickr.

- [Wright Flyer: Engine Timing System](#): There's a great animation on this NASA page showing how a camshaft and a series of cams open the valves on an engine—and not just any engine, but the one that powered the Wright brothers' pioneering plane into the air in 1903.

Projects

- [Linear Motion by Cam Mechanism](#) by dearhyunjoo, Instructables. A simple introduction to cams and some things you can build with them.
- [Agreeable Sheep](#) by Rob Ives, Instructables. A cut-out paper sheep that nods its head with a cam and follower.
- [Walking Papercraft Mech Warrior](#) by J_Hodgie, Instructables. A walking robot whose legs move up and down on cams.

Books

- [Engineering Design: An Introduction](#) by John R. Karsnitz, Stephen O'Brien, and John P. Hutchinson. Cengage Learning, 2013. A broader introduction to engineering principles for high school students. "Chapter 12: Designing Mechanical Systems" gives a deeper introduction to cams, cranks, gears, and the other key "ingredients" of mechanical engineering.
- [Making Wooden Mechanical Models: 15 Designs with Visible Wheels, Cranks, Pistons, Cogs, and Cams](#) by Alan and Gill Bridgewater, F+M Media, 2011. There's no better way to understand cams and cranks than building your own little machines that use them. This book is published by *Popular Woodworking* magazine and includes designs for simple engines, pumps, locks, governors (speed regulators), and oscillators.

Please do NOT copy our articles onto blogs and other websites

Articles from this website are registered at the US Copyright Office. Copying or otherwise using registered works without permission, removing this or other copyright notices, and/or infringing related rights could make you liable to severe civil or criminal penalties.

Text copyright © Chris Woodford 2010, 2020. All rights reserved. [Full copyright notice and terms of use](#).

Follow us

Rate this page

Please [rate or give feedback on this page](#) and I will make a donation to WaterAid.

Save or share this page

Press CTRL + D to bookmark this page for later or tell your friends about it with:

Cite this page

Woodford, Chris. (2010/2020) Cranks and cams. Retrieved from <https://www.explainthatstuff.com/cranks-and-cams.html>. [Accessed (Insert date here)]

More to explore on our website...

[Communications](#) | [Computers](#) | [Electricity & electronics](#) | [Energy](#) | [Engineering](#) | [Environment](#)

[Gadgets](#) | [Home life](#) | [Materials](#) | [Science](#) | [Tools & instruments](#) | [Transportation](#)

[Home](#) | [A-Z index](#) | [Send feedback](#) | [Random article](#) | [Timeline](#) | [Teaching guide](#) | [About us](#) | [Privacy & cookies](#)

[↑ Back to top](#)