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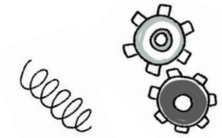

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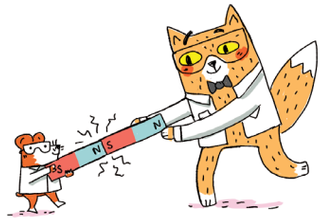

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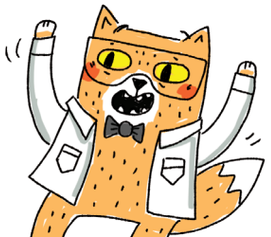


PROFESSOR ALBERT KATZENSTEIN'S

Foreword to

Phenomenal Physics

Welcome! I'm Professor Albert Katzenstein, here to introduce you to the wonderful world of physics.

AHEM

And this is my eager young lab assistant, Scooter the guinea pig.

Pleasure to meet you.

I've been fascinated by science since I was a kitten.

I remember the first time I fell out of a tree and discovered gravity.

Are you *sure* you discovered gravity?

Through study and experiments, scientists like me have discovered a lot about how our world and the greater Universe works.

I helped, too.

I'd like to share what I've learned with you.

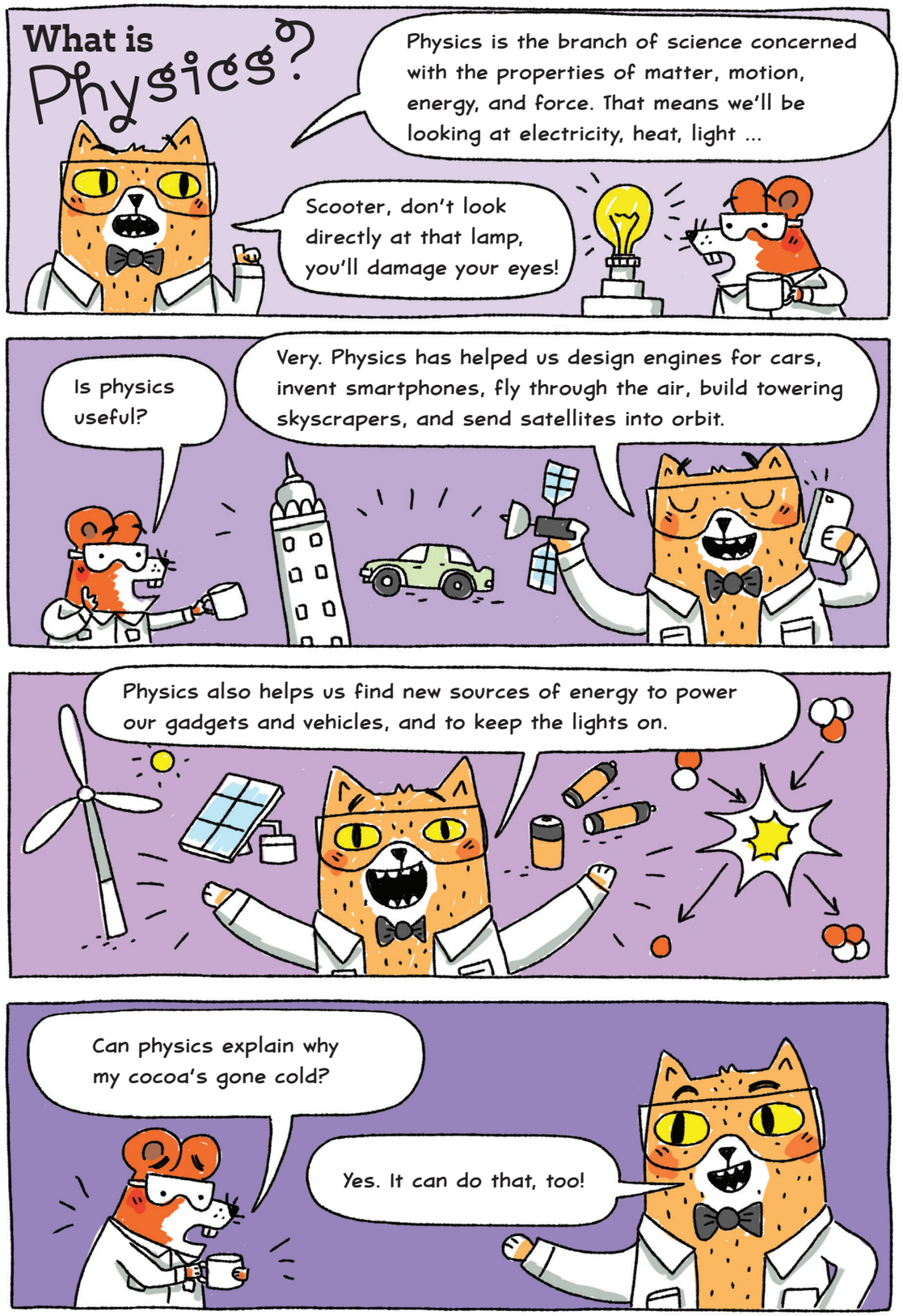
If you want to know how to build a rocket, move at super speeds, and, indeed, how to walk on the Moon, you're in the right place.

Yay!

Physics, like all branches of science, is about looking for the answers to difficult questions. And we've got lots of answers for you.

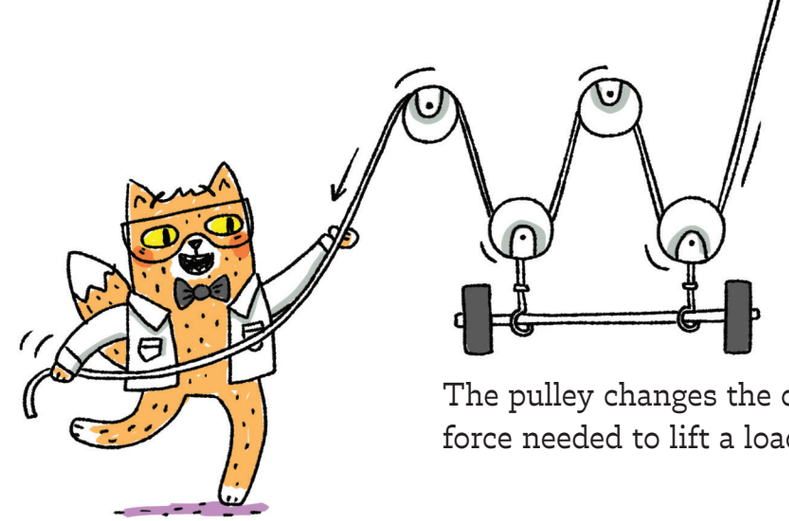
What is physics?

Good question, Scooter!



Super Powers

(Energy and Forces)

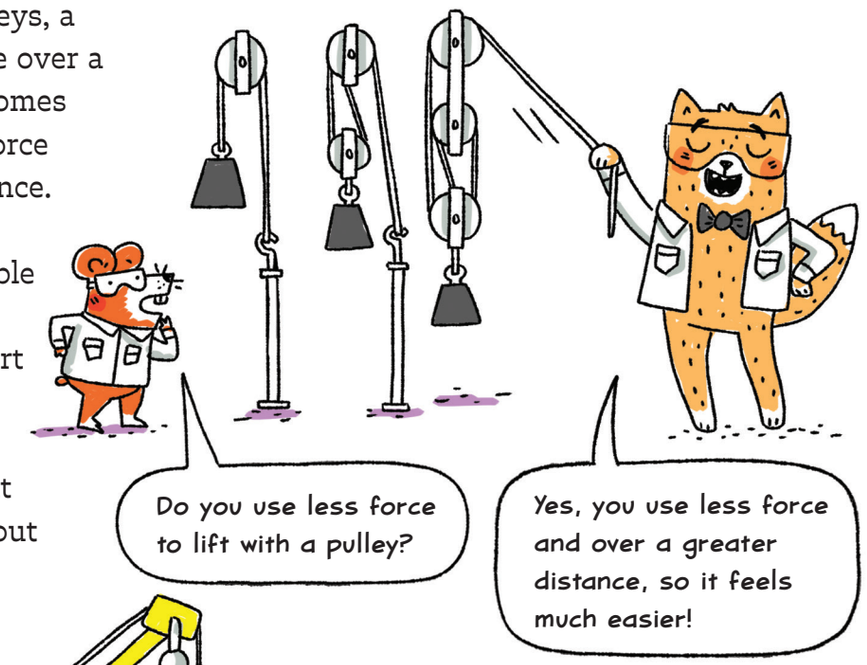


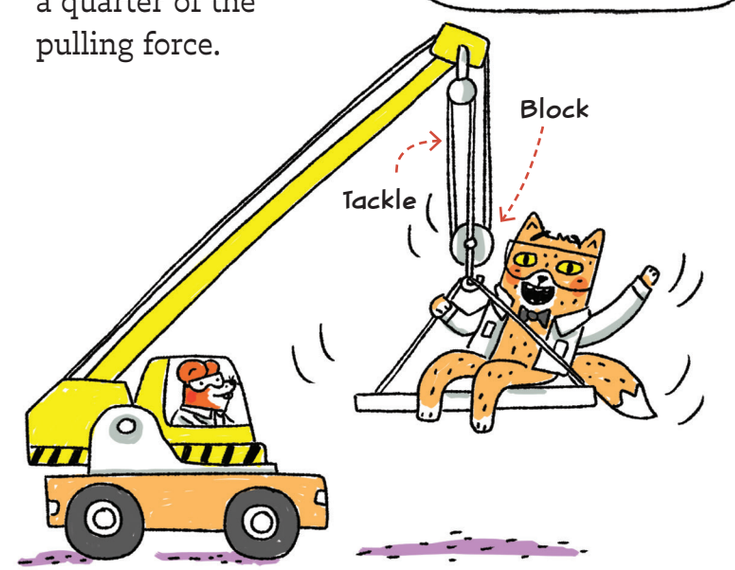
Pulleys are simple machines that help make lifting easier. They are made up of a cable running over one or more wheels.

The pulley changes the direction of the pulling force needed to lift a load.

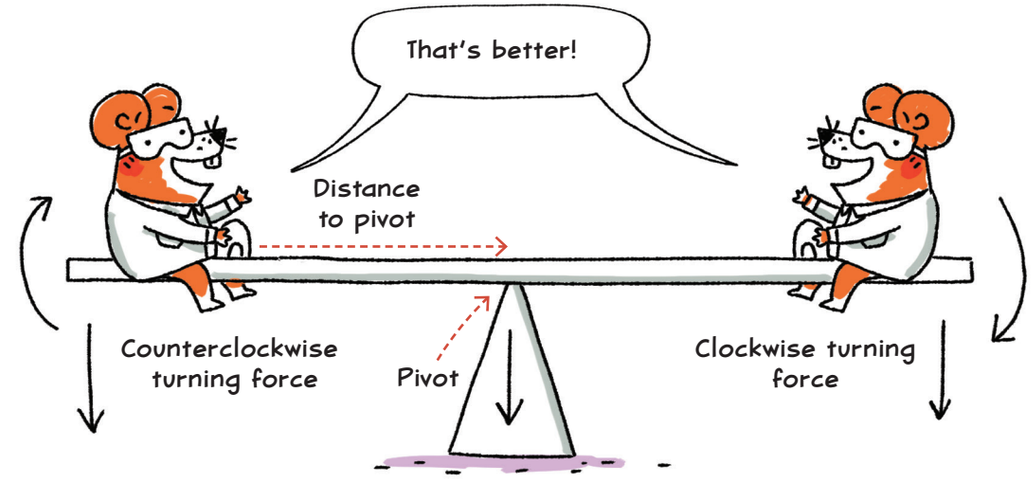
With a set of pulleys, a weak pulling force over a long distance becomes a strong pulling force over a short distance.

Using a longer cable over two wheels can halve the effort needed to lift a load. Using four wheels means that you only need about a quarter of the pulling force.



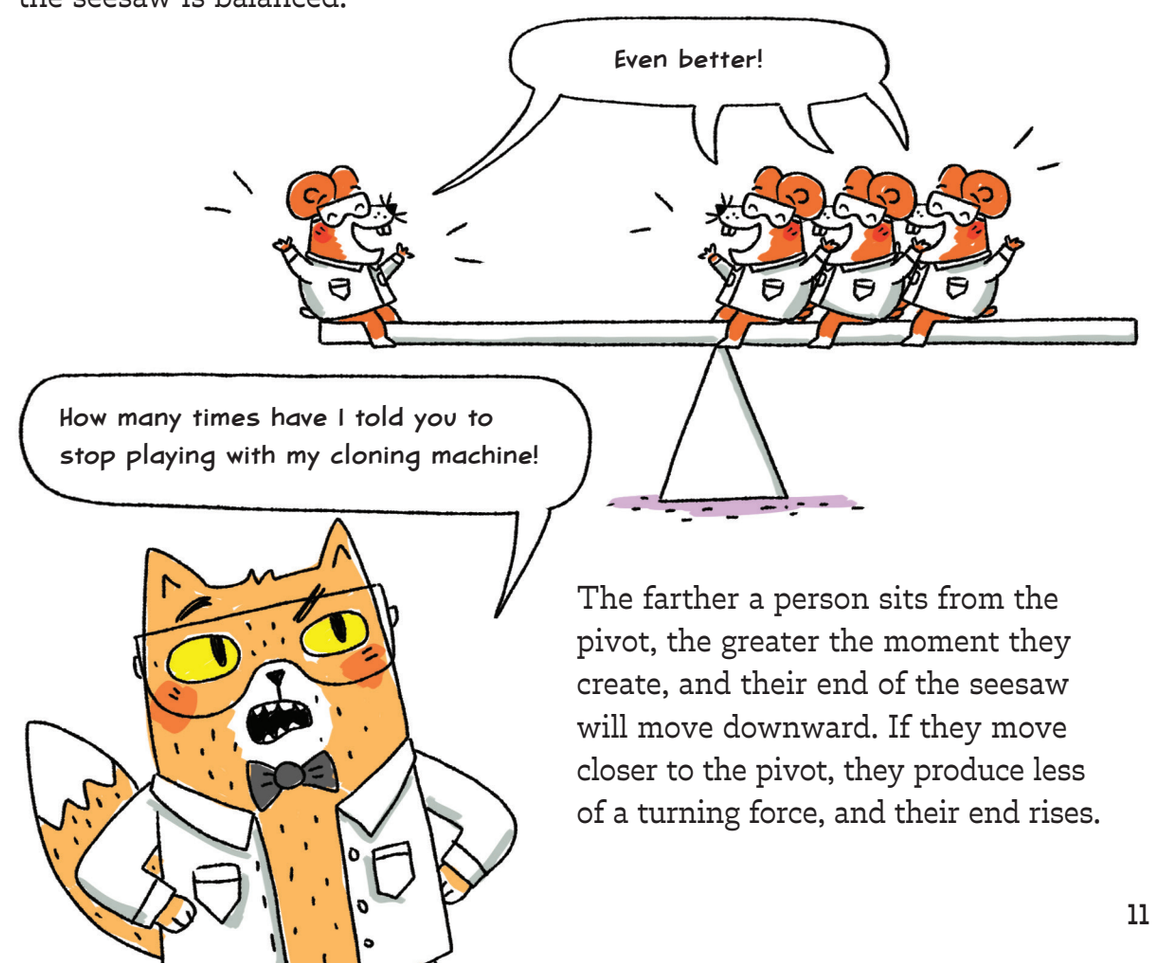


The more cable and wheels used in a pulley system, the heavier the weight that can be lifted. Cranes use a pulley system called a **block** and **tackle** to help lift heavy loads.

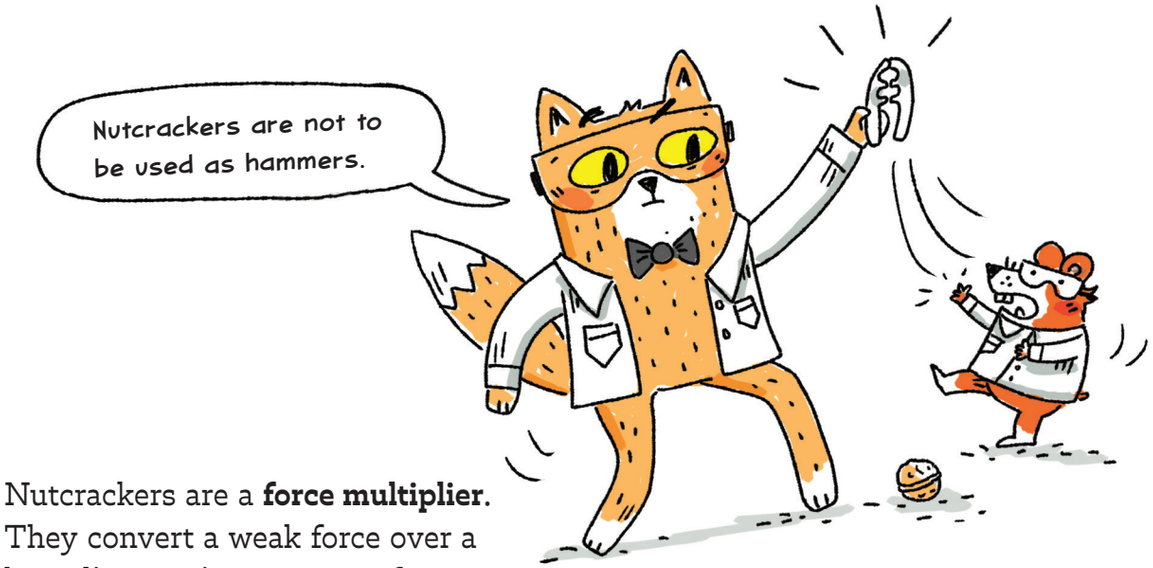


The weight of people on a seesaw creates a **downward force**, which turns the seesaw around its pivot. When the turning forces at each end are equal but in opposite directions, the seesaw is balanced.

The turning effect of a force is called the **moment** of the force. The moment is calculated by multiplying the turning force by the distance from the pivot.



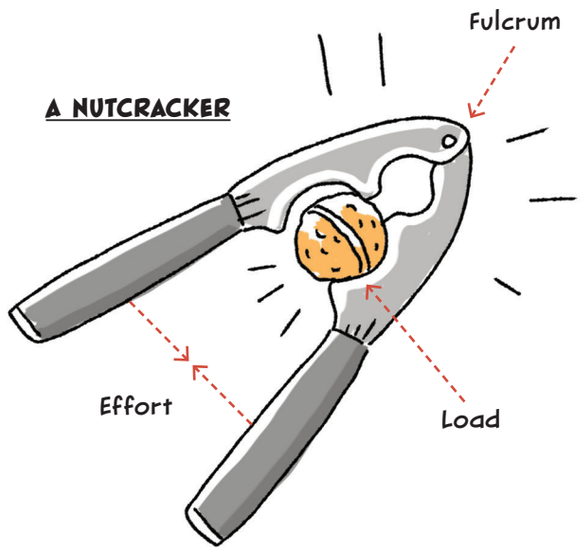
The farther a person sits from the pivot, the greater the moment they create, and their end of the seesaw will move downward. If they move closer to the pivot, they produce less of a turning force, and their end rises.



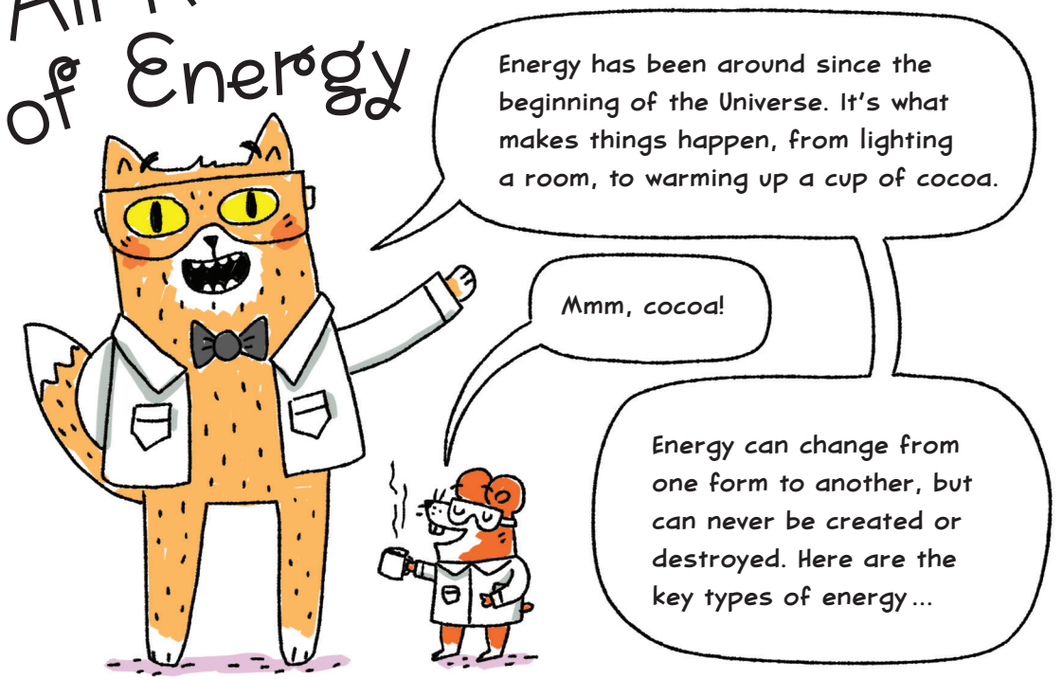
Nutcrackers are a **force multiplier**. They convert a weak force over a long distance into a strong force over a short distance. A light squeeze on the handles becomes a hard squeeze around the nut.

They work as a pair of **levers**, or rigid bars, that move around a fixed point called a **fulcrum**. The nut fits between the levers. When the levers are squeezed together, they press on the nut, causing its shell to crack open.

Other kinds of levers include pliers, wrenches, and bottle openers.

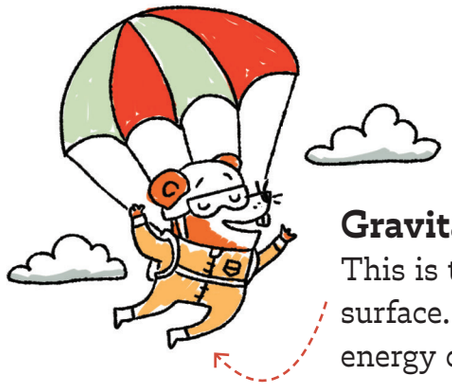


All Kinds of Energy



Chemical
This is energy stored in the bonds between atoms and released through chemical reactions. Chemical energy is held in batteries, fuel, and food.

Kinetic
Kinetic energy is stored in a moving object. This depends on the object's speed and mass. The faster an object moves or the greater its mass, the more kinetic energy.



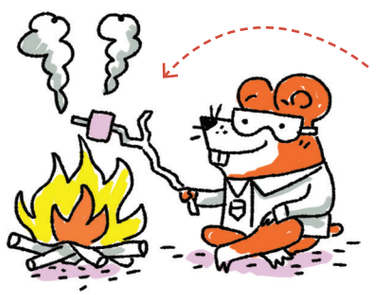
Gravitational
This is the energy of an object above the Earth's surface. The amount of an object's potential energy depends on its position.

Elastic
This is the potential energy held in an elastic object, such as a spring, when it is compressed or stretched. The energy is released when the elastic object springs back to its original shape.

Acoustic
Sound energy is made when an object, such as a guitar string, vibrates.

Radiant
All objects give off radiant energy, carried by electromagnetic waves such as light, radio waves, or X-rays.

Electrical
Electrical energy is the movement of electrons, which can pass through a wire as electricity, or hit the ground as lightning.



Thermal
Heat energy is produced by vibrating atoms in a substance. The faster they vibrate, the hotter the substance becomes.

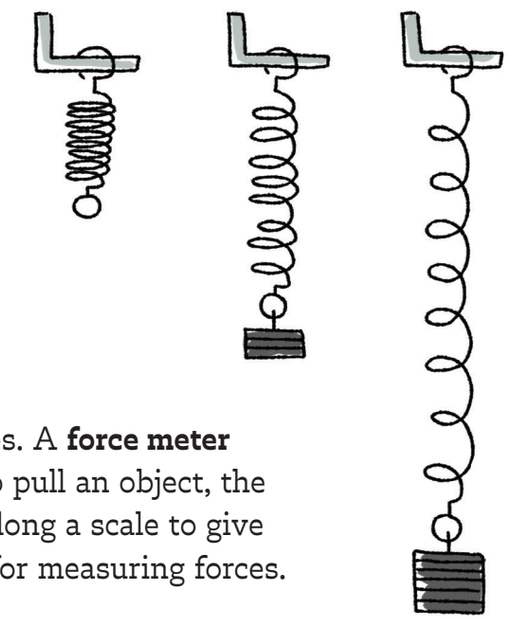
Magnetic
This is the energy stored in the magnetic field surrounding two magnets that attract or repel each other.

Nuclear
Stored in atoms, nuclear energy is released when the atoms are fused together or split apart through nuclear fusion or fission.

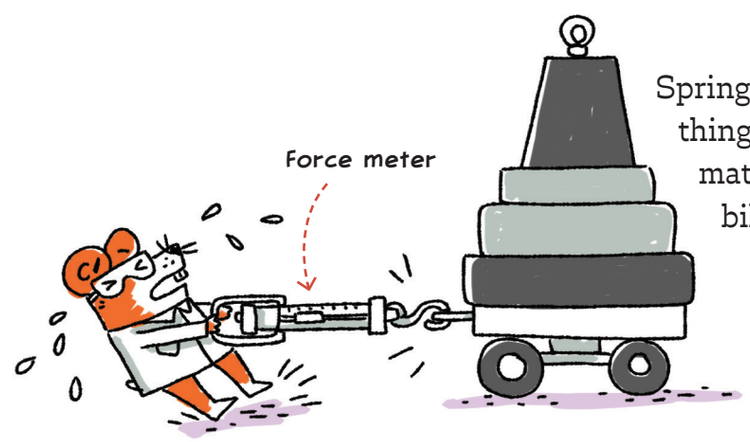
A spring is an elastic object that returns to its original shape when stretched, compressed, or bent.

Stretching or compressing a spring gives it elastic potential energy that will pull it back to its original position.

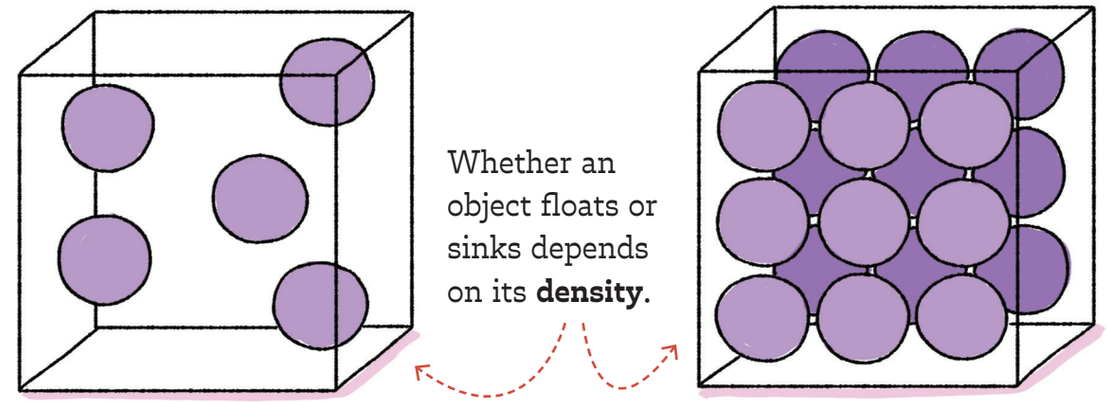
The stretch of a spring is proportional to the stretching force applied to it. This is **Hooke's Law**. If a weight stretches a spring by one length, twice the weight will stretch it by twice the length.



Springs are useful for measuring forces. A **force meter** has a spring inside. When it is used to pull an object, the spring is stretched, pulling a marker along a scale to give a measure in **Newtons** (N), the units for measuring forces.



Springs are used in many things, such as scales, mattresses, and mountain bike suspensions.

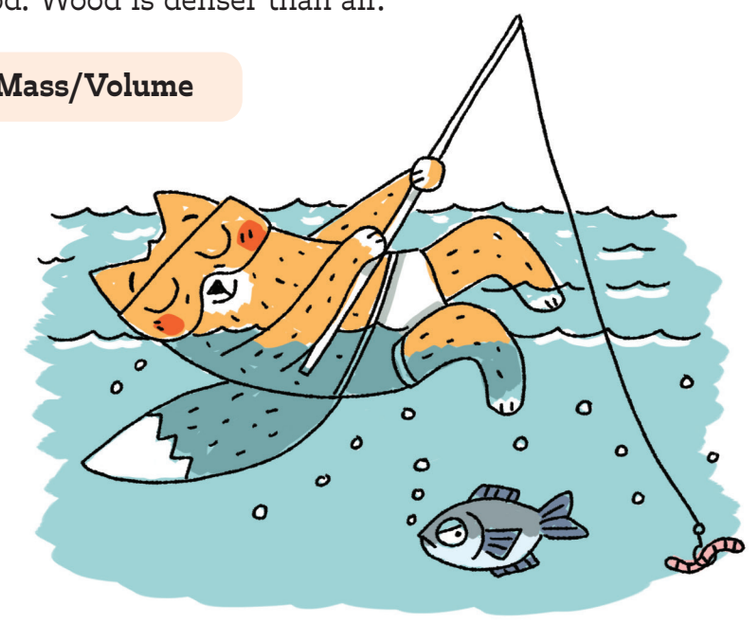


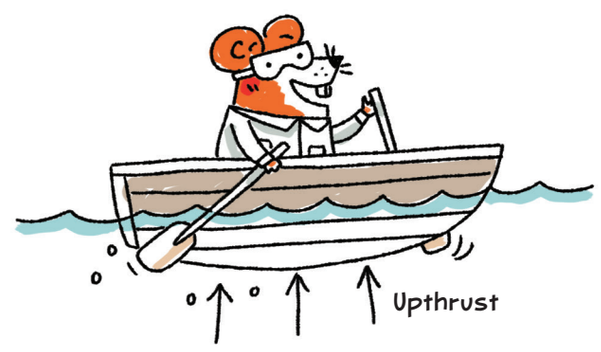
Whether an object floats or sinks depends on its **density**.

Density is how much mass is contained in an object. Steel is denser than wood. Wood is denser than air.

Density = Mass/Volume

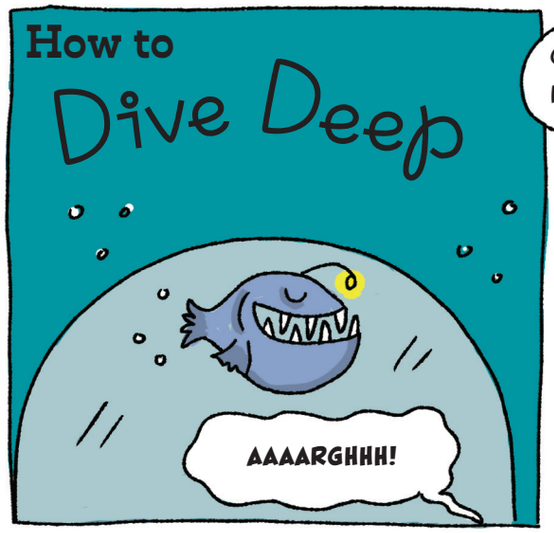
For an object to float in water, its average density needs to be less than that of water. While a metal coin may be denser and sink, a metal ship is full of air so its average density is less than water.

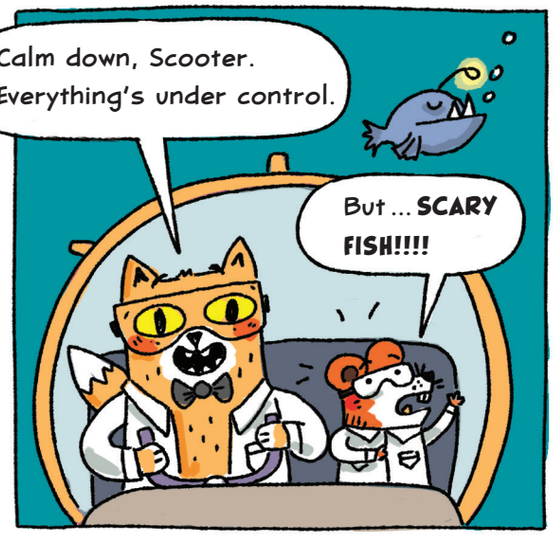


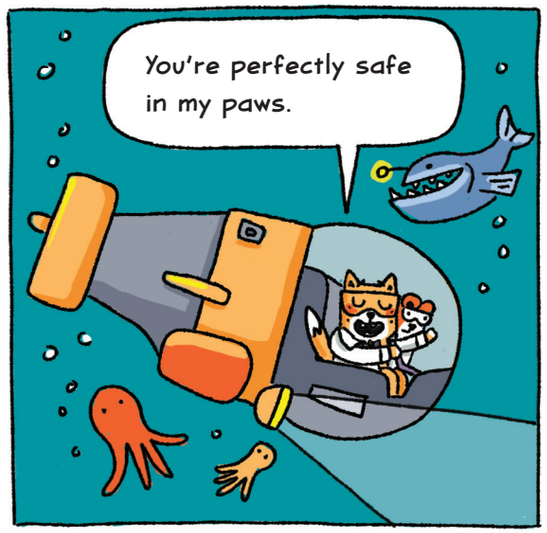


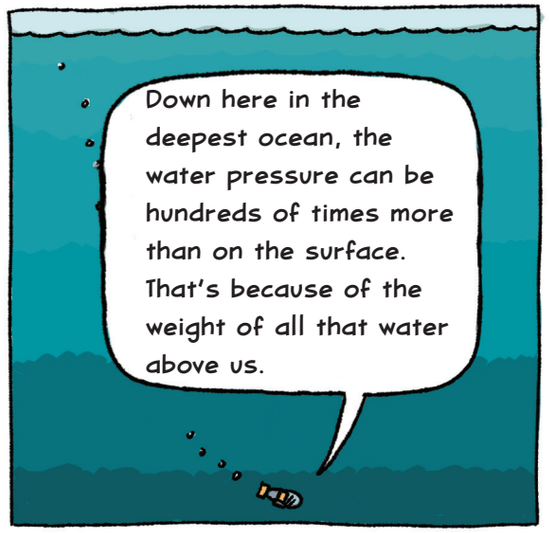
A boat floats because of a force called **upthrust**. This upward force is equal to the weight of the water that the boat displaces. If the weight of the boat is less than the upthrust, it will float.

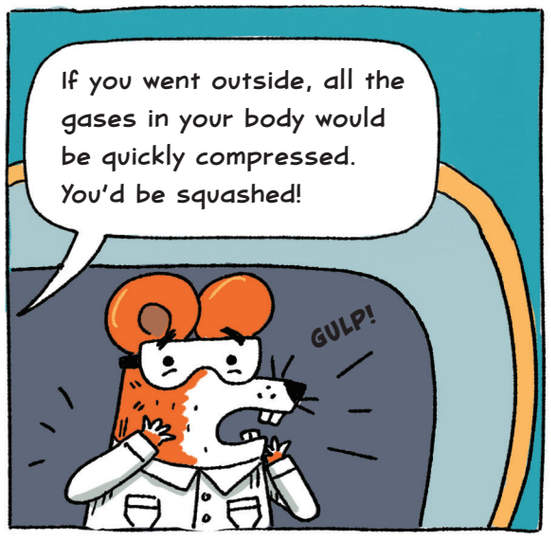
How to Dive Deep

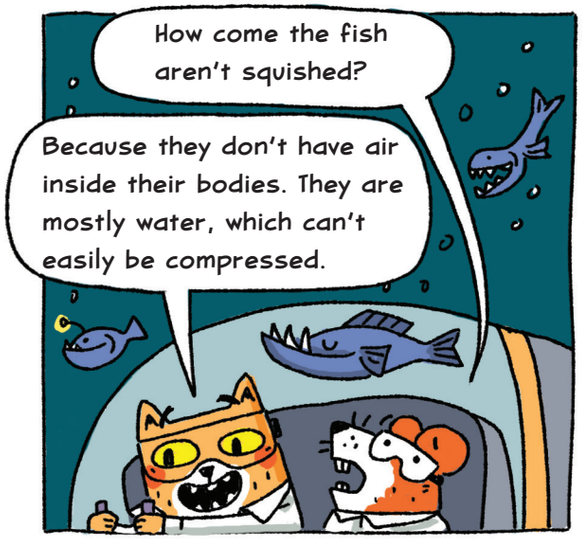


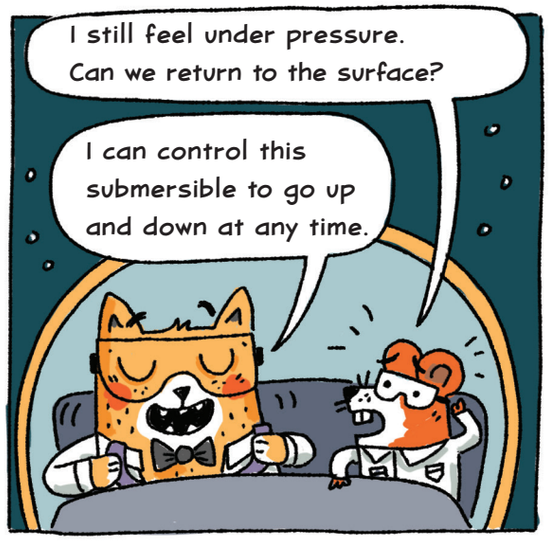


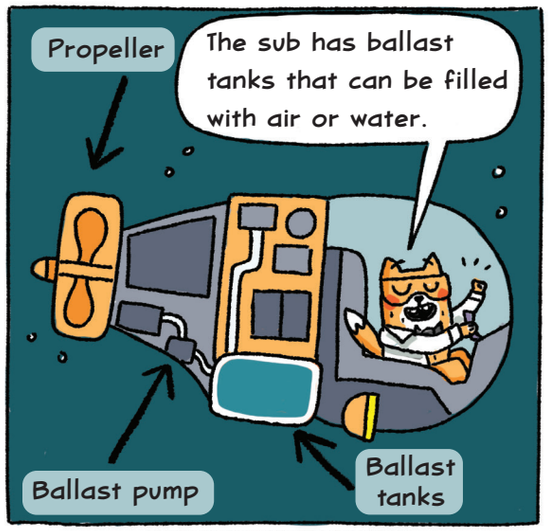


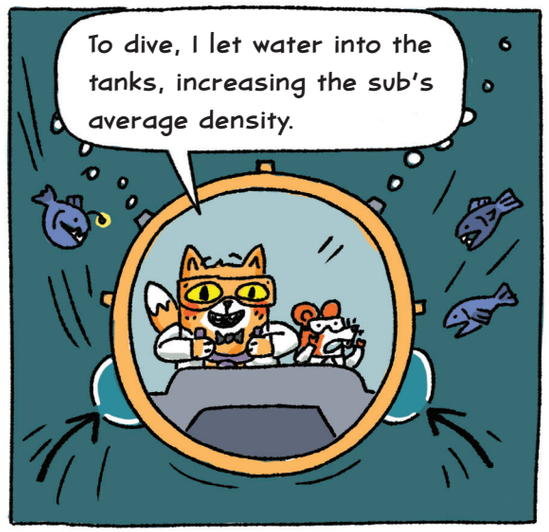


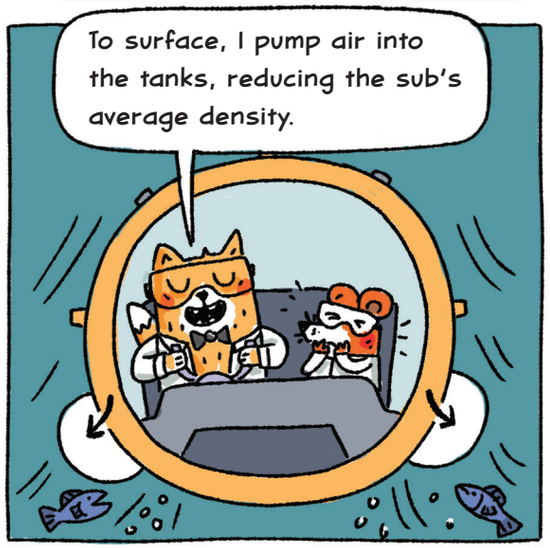


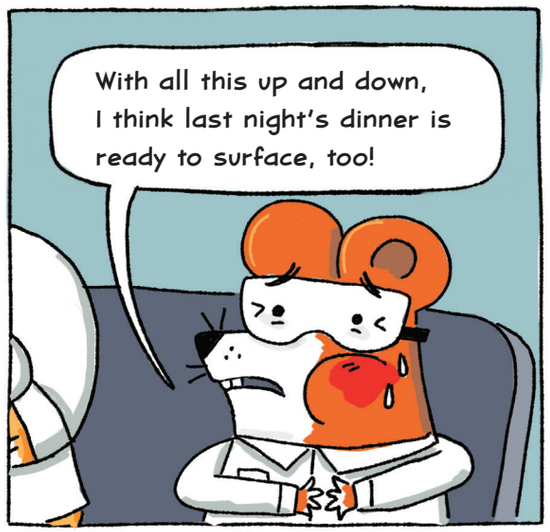


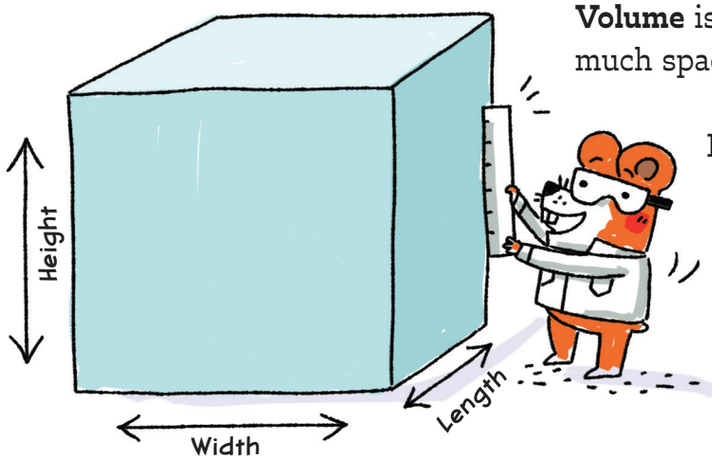












Volume is the measure of how much space an object takes up.

For a simple shape like a cube, you can measure the length of each side to find out its volume.

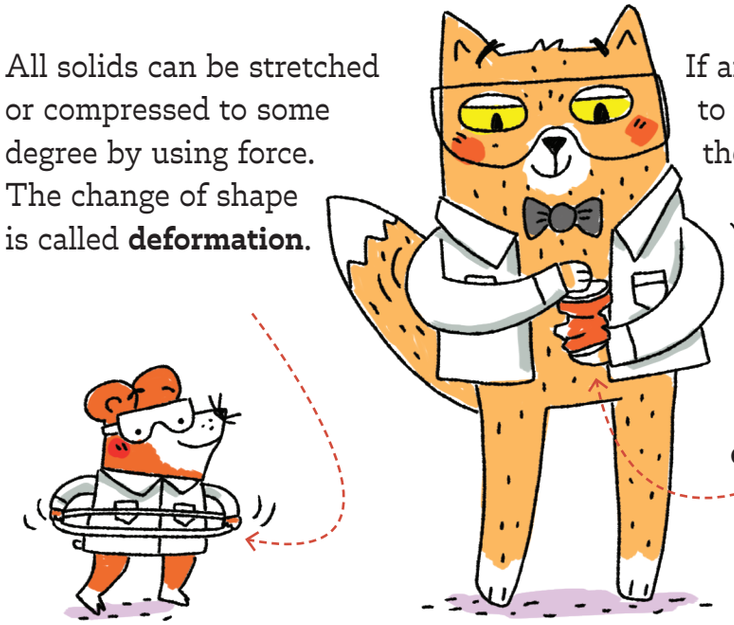
Length x Width x Height = Volume

But for a complex shape, you can use the water displacement method.

A submerged object displaces a volume of liquid that matches its own volume.

So, if you drop an orange into a pitcher of water and measure the difference in water level, that's the volume of the orange.

All solids can be stretched or compressed to some degree by using force. The change of shape is called **deformation**.

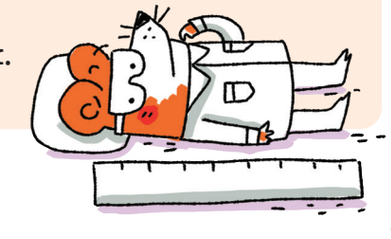


If an object springs back to its original shape after the force is removed, this is called **elastic deformation**. If the object stays stretched or compressed, this is called **plastic deformation**.

An elastic band shrinks back after stretching, so this is **elastic deformation**.

Brittle materials, such as glass and ceramics, break very quickly if stretched or compressed.

A squashed soda bottle stays squashed, so this is **plastic deformation**.

Elastic materials have an elastic limit from which they will not spring back. If a spring is stretched to this limit, it will no longer act as a spring.

The disks between human backbones or vertebra act like a spring and are compressed by gravity. After a night's sleep, you might gain a tiny amount in height as the disks between your vertebrae stretch out, but once you're up they become compressed again, and you shrink.