Shedding Light on Energy
Episode 3:
Energy Efficiency

The **Shedding Light on Energy** series allows teachers to teach the topic of Energy without actually using much energy! With a perfect mix of biology, chemistry, and physics, we explore every aspect of energy including what it is and how we measure it.

In **Episode 3, *Energy Efficiency,*** we introduce students to the concept of efficiency, which is a measure of how much useful energy you get out of something compared to the amount of energy that you put into it. We answer a bunch of questions including:
How much light energy do we get out of light globes compared to the amount of electrical energy that goes into them? Hint: it's not much; they should be called heat globes!
How much kinetic energy do we get out of cars compared to the amount of chemical energy that we put into them? Hint: it's a bit more, but not that much more!
And how do our arched feet make us the long-distance running champions of the animal world?

This video is the most energy-efficient way of learning everything that you need to know about energy efficiency!

Contents:

Part A: Introduction. Energy is constantly transforming from one form to another, but it doesn't necessarily transform 100% into the form of energy that you want.

Part B: Power: A joule is a joule and a watt is a watt, but watt is a watt, I mean, what is a watt? A watt? Yes, a watt. A watt is a watt but a joule it is not. If you're transforming 1 Joule per second, a watt's what you've got. So, watt am I talking about? We have the power to clear things up!

Part C: Improving Efficiency: The humble incandescent light globe lit up our homes for more than a century, but why have LED globes taken over?

Part D: Heat Wastage and Energy "Loss": What happens to a car's kinetic energy when it comes to a stop? What happens to a basketball's kinetic energy when it hits the floor? And why can't a basketball bounce up and down forever?

Part E: Efficiency in Nature and Industry: How do the arches of our feet help us chase down horses? Yes, that's right… humans can outrun horses!

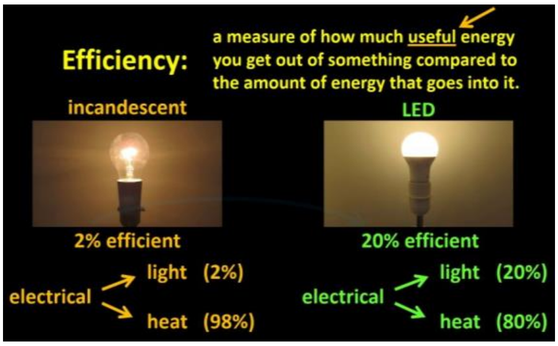
Shedding Light on Energy Episode 3: Energy Efficiency

Part A: Introduction

Energy can be transformed from one form to another. Our bodies, for example, transform the chemical energy that is in the food that we eat into kinetic energy and heat energy.

An electric motor transforms electrical energy into kinetic energy, and a solar panel transforms light energy into electrical energy. Energy cannot be created or destroyed, it can only transform from one form to another. We've seen lots of examples of energy transformations in the first two episodes of the Shedding Light on Energy series.

However, even though, for example, light globes are designed to transform electrical energy into light energy, no light globe can transform 100% of the electrical energy that goes into it into light energy. In most energy transformations, heat energy is also produced as an unwanted by-product. In this particular light globe, an older style incandescent light globe, only about 2% of the electrical energy that's going into is actually being transformed into light energy. The rest is being transformed into heat energy. It feels really hot if I put my hand here.



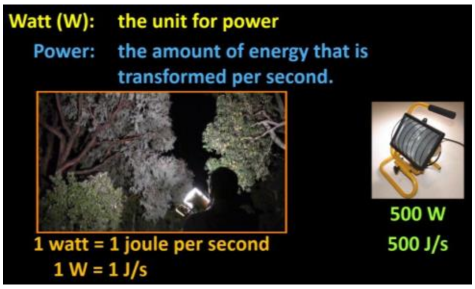
Efficiency is a measure of how much useful energy you get out of something compared to the amount of energy that goes into it. The emphasis here is on the word "useful". <u>All</u> the electrical energy that goes into a light globe gets transformed into other forms of energy, but since in the case of this incandescent globe only 2% is transformed into the type of energy that we want, light energy, the light globe has an efficiency of only 2%.

This LED light globe, however, has an efficiency of 20%, 10 times more than the incandescent.

An LED light globe can generate 10 times as much light using the same amount of electricity, or the other way of thinking about it is, it can generate the same amount of light using only 1/10 of the electricity.

In this lesson, we're going to take a look at this concept of efficiency, and at how scientists and engineers are continuously inventing new devices that become more and more efficient. So let's begin.

Part B: Power



This a 60 Watt incandescent light globe and this is a 500 Watt incandescent light globe. The 500 W light globe is obviously quite a lot brighter than the 60 W light globe. But what is a Watt? What does 60 Watts, for example, mean?

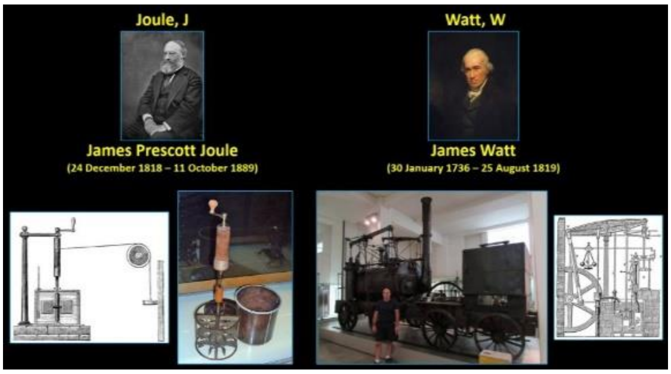
The watt, given the symbol W, is the unit for power and power is defined as the amount of energy that is transformed per second. So, one watt equals 1 joule per second. 500 W = 500 J/s.

Action	Approximate Energy Expenditure (Joules/Second)
Sitting still	100
Standing still	120
Walking 3 km/hr	210
Walking 5 km/hr	300
Running 9 km/hr	700
Running 16 km/hr	1300
Cycling 9 km/hr	300
Cycling 16 km/hr	500

In our last episode we saw that we use different amounts of energy per second depending on what we're doing. Walking slowly requires about 200 joules of energy per second. Another way of saying this is that when we're walking, our power output is about 200 Watts. 200 W = 200 J/s.

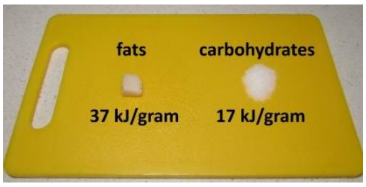
My power output when I'm running at this speed is about 700 W because I'm converting 700 Joules of chemical energy into kinetic and heat energy per second. 700 W = 700 J/s.

This electrical generator, which runs on diesel fuel, has a power output of about 4000 Watts. The electricity is used to run the lights and the fridges in this remote kiosk that is near this very remote beach miles away from anywhere. We might say that the generator is generating 4000 W of power, because it's generating 4000 J of electrical energy per second, but we just mustn't forget that the energy is coming from the chemical energy that is in the fuel that it's burning.



The Joule was named after English scientist James Prescott Joule, who studied heat and motion in the 1800s. He was the first to state that kinetic energy can be transformed to an equivalent amount of heat energy and that heat energy and kinetic energy are kind of the same thing: forms of energy.

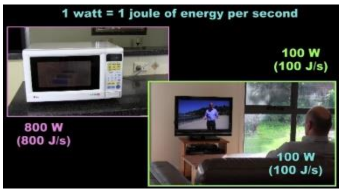
The Watt, was named after the Scottish engineer James Watt, who in the late 1700s made huge improvements to steam engines and improved their efficiency to the point where they started taking over from horses and windmills. That's me at the Science Museum in London standing in front of a 200-year-old steam engine that had incorporated many of Watt's innovations.



I said in our last episode that fats contain 37 kJ of energy per gram while carbohydrates like sugar for example contain 17 kJ of energy per gram, but that doesn't mean fats are better to eat before a sporting contest. Fats do have more energy than carbohydrates per gram, but the human body can burn carbohydrates faster than it can burn fats. The power that you get out of fats is less than what you get out of carbohydrates. So before your big game, eat carbohydrates like bread, or spaghetti.

It's a bit like petrol and olive oil. Both are flammable, but petrol burns much faster than the oil does. Here the oil in the oil lamp is being absorbed by the small wick and it's burning fairly slowly. Placing a lit match directly into the oil puts the flame out before the oil has a chance to catch fire. So energy is one thing, but power is a little different: power is the amount of energy transformed per second.

The Power of many electrical products is often stated on the packaging or on the product itself.



For example, this is an 800 W microwave oven and this is a 100 W television. Since sitting also uses about 100 J of energy per second, the television and I are both generating about the same amount of power.

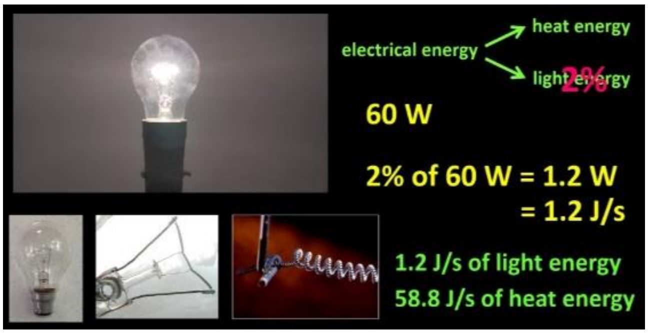
Remember, 1 watt = 1 joule of energy per second.

So, the 60 W light globe is producing 60 Joules of heat and light energy per second while the 500 W light globe is producing 500 joules of heat and light energy per second (and of course the energy is coming from the electrical energy that they're receiving).

However, only about 2% of the electrical energy is being converted into light energy, the type of energy that we actually want from a globe, which makes these kind of globes very inefficient. Inefficient is the opposite of efficient.

Incandescent light globes work by heating up a very very thin wire in the globe called the filament. The filament gets so hot that it glows. Here a metal rod is being heated with a gas flame and it gets so hot that it starts glowing. In an incandescent light globe, the heating is caused by electricity. However, this process produces far more heat energy than light energy.

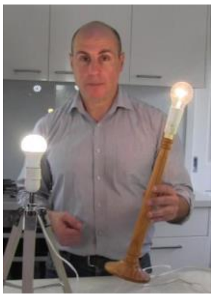
This is a 60 W light globe, but only about 2% of the electrical energy is being transformed into light energy. 2% of 60 W is only 1.2 W: 1.2 J/s. This light globe is only producing about 1.2 Joule of light energy per second but nearly 59 joules of heat energy per second. As I said, it's very inefficient.



So how do we get more light energy? Well, we can get more powerful light globes OR we can improve the efficiency of our light globes.

Part C: Improving Efficiency

Light globes that used filaments that heat up had been around since the early 1800s, but it was American inventor Thomas Edison and English scientist Joseph Swan who, working independently of one another in about the 1880s, about 140 years ago, created the first practical light globes that could be produced at a profit. That's Thomas Edison there, looking on as the globes are being made. Though this footage was shot many years later. The early globes didn't really produce a whole lot of light and very few ever lasted for more than a month or so, but they gradually got better.

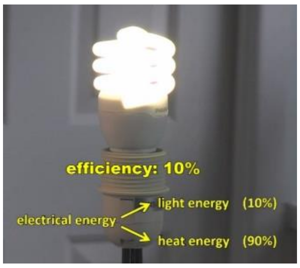


These kinds of globes have been in continuous production for more than a hundred years and billions of them have been produced, but they're being phased out because they are so inefficient.

As I said, only 2% of the electrical energy gets converted to light energy, and the other 98% to heat energy.

Because of their inefficiency, many homes and businesses turned, in about the 1930s and 40s, to fluorescent lights, like these ones here, because they were and still are much more efficient.

In the 1990s compact fluorescent lights were introduced which made fluorescent lighting even more popular.



Fluorescent lights have an efficiency of about 10%, that is, 10% of the electrical energy is converted into light energy and only 90% is wasted as heat, I say "only"! It's still a lot but it's better than wasting 98%. (I can actually touch this one for a short amount of time, but not this one.)

In the 2010s, household LED lights became cheap enough to mass produce. LED stands for Light-emitting diodes. These LED globes are about 20% efficient.

When you buy a light globe the packaging typically states what electrical power it will use, for example 15 W, and the amount of lumens that it will produce. The lumen is a unit for brightness. Its symbol is lm. The more lumens the brighter the light.

1000 lumens is fine for say, a bathroom light, whereas a table lamp only needs to produce about 500 lumens or so, but's it's a personal choice of course.

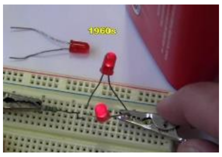
We can clearly see that, over time, light globes have become more and more efficient as new technology has been developed. The LED light globe can produce more light than an incandescent using only about 1/6 of the electrical power. When I talk about incandescent globes, I'm really giving you a history lesson, because as far as household lighting is concerned they're pretty much history, although they're still commonly used in car headlights, many specialised applications like

Globe Type	Incandescent	Halogen Incandescent	Compact Fluorescent (CFL)	LED (light-emitting diode)
Around Since…	1880s	1960s	1990s	2010s
Efficiency	2%	2.5%	10%	20%
Power	60 W	57 W	15 W	10.5 W
Light Output	730 lm	915 lm	950 lm	1055 lm

inside ovens and as bathroom heat lamps, that are fairly bright even though their main purpose is to actually produce heat energy to warm you up. These ones are 275 Watts each. LED lights cost a little more initially, but since they last much longer and use far less power for a given amount of light, it works out cheaper to have them.

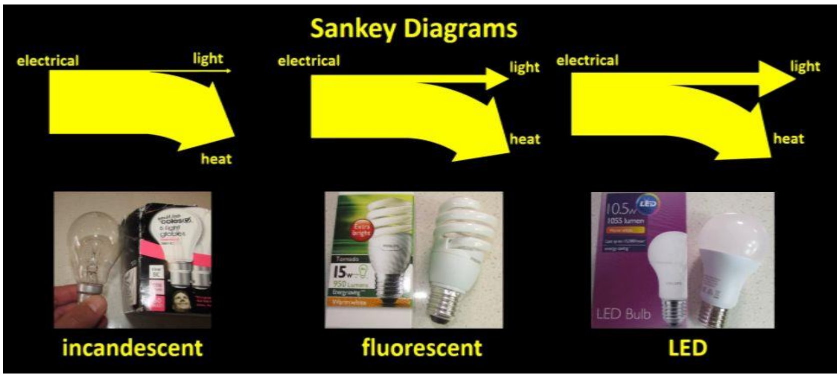
The 50 W LED spotlight here is generating about as much light as the 500 W incandescent spotlight while using only about 1/10 as much electrical energy. The 500 W lamp needs special handles to hold it because it gets so hot, while the LED light just felt warm as I held it. LED lights are good for the environment and good for your family budget.

Electricity isn't free of course. We pay for it. So if you can generate however much light you need with less electricity, you electricity bill is going to be a lot lower. Also we don't have to generate as much electricity in the first place, which means that we burn less coal and natural gas in our power stations and we don't have to build as many wind turbines and solar panels.

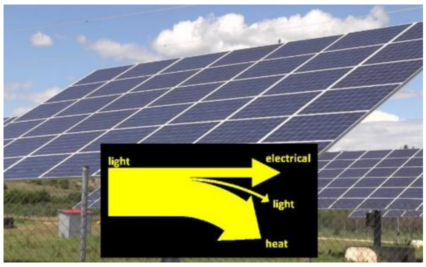


Small, red LED lights like these ones became commercially available in the 1960s, and they're still everywhere from "on" lights on electronic equipment, to digital clocks, to traffic lights. Yellow and green LEDs soon followed red LEDs, but the production of bright, blue-light LEDs proved very challenging and took three more decades to achieve.

It wasn't until the 1990s that Japanese scientists Hiroshi Amano and Isamu Akasaki, and Japanese-born but naturalised American scientist Shuji Nakamura overcame all the immense technical difficulties and developed an efficient and bright blue LED, the major breakthrough that led to the development of white LED household lights. It's thanks to these three scientists that we've had to build fewer power stations, and who knows how many millions of people in poorer countries now have access to lights in their schools and homes since LED lights use so much less electricity. LED lights have literally changed the world and how we see it.



To graphically express the efficiency of a process, we often use what are called Sankey diagrams, named after Matthew Sankey, an Irish-born engineer who improved various aspects of steam engines in the late 1800s. Sankey diagrams show the energy input and energy outputs of different devices or systems in this case of three different kinds of light globes and can therefore represent graphically the energy efficiency of the device or system. The width of each arrow is a scaled measure of how much energy we're talking about. You can clearly see that for an old incandescent light globe, hardly any of the electrical energy that you put ends up as light energy, whereas an LED globe produces a lot more light energy, with far less heat wastage.



Now all processes that involve energy transformations involve energy wastage. These solar panels, which convert light energy into electrical energy, are only about 20% efficient. Of all the light energy hitting them, only about 20% ends up being converted to electrical energy, the useful energy that you want from them. Some of the light is reflected, and the rest is absorbed without generating electricity, which results in the solar panels heating up.

A lot of companies are spending a lot of money on research to find ways of increasing the efficiency of the energy conversion and ways of producing solar panels more cheaply.

Part D: Heat Wastage and Energy "Loss".

Plants convert light energy into chemical energy, which is stored in the glucose that they make in photosynthesis, but the efficiency of this process is only about 1-2%. Of all the light energy that hits plants, only this tiny fraction is actually converted into chemical energy. However, it's enough to sustain every living thing on Earth!

Typical car engines are about 25% efficient. When petrol burns, the chemical energy is converted into heat energy, but when the petrol burns in the cylinder of an engine, the hot expanding gases push on the piston which gives the piston kinetic energy. However, only about 25% of the chemical energy in the fuel is converted into kinetic energy, the useful energy that you actually want. The rest is converted into heat energy that is basically wasted. The engine gets really hot and hot exhaust gases just come out of the exhaust pipe.

When cars were first invented in the 1800s, they were far less efficient, and they burned off huge amounts of fuel for very little movement. They're a lot better now of course.

Now if a car is travelling along, with kinetic energy, and the driver presses the brakes and the car comes to a stop, what happens to the kinetic energy that it had?

Energy can't be created or destroyed, so where does all the kinetic energy go? Well, the kinetic energy is transformed into heat energy in the brakes.

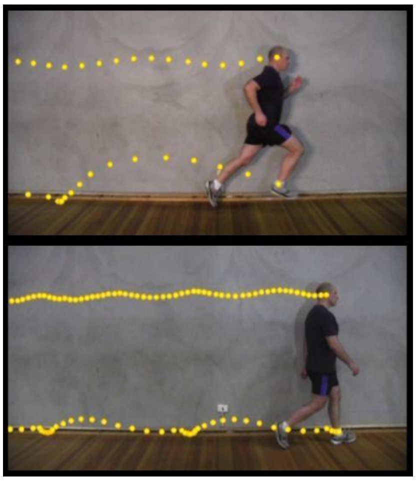
Removing the wheel reveals the so-called disc or brake disc that forms part of the wheel assembly. A brake disc spins as the wheel turns but when the driver presses the brakes, two brake pads inside this housing, one on each side of the disc, press against the disc and the frictional forces slow the wheel down.

It's exactly the same with the hand brakes of a bike, but on a bike the brake pads rub directly on the wheel. This process of using friction to brake generates heat, just like rubbing your hands together does. So, the kinetic energy is transformed into heat energy.

The brakes of race cars that brake heavily often glow red hot (you can see it here) since so much heat is generated.

The brakes cool down of course when they're not engaged and the heat energy ends up in the air.

Ultimately, nearly all of the original chemical energy that the petrol had ends up as heat energy, but along the way, some of it has been transformed into kinetic energy first, enough kinetic energy to move us around.



Humans are also, like cars, only about 25% efficient. Of all the chemical energy that we take in, only about 25% ends up as kinetic energy and the rest is converted directly into heat energy.

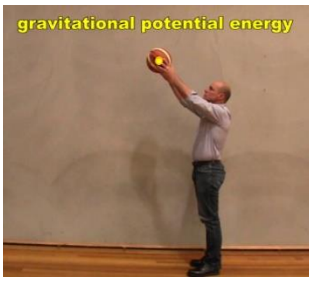
However, in a sense, the heat isn't really wasted because we actually need our bodies to stay at around 37°C to ensure that the chemical reactions that need to occur in our bodies actually do occur.

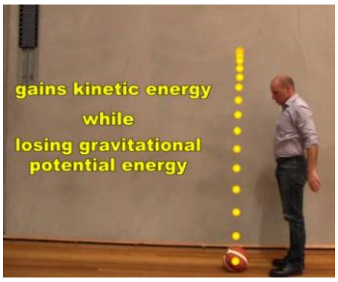
Running is less efficient than walking, that is you need more energy to cover a given distance if you run than if you walk. This is partly because running involves a lot more up and down movement than walking does. Not only does your whole body move up and down quite a lot, your swinging arms and legs move up and down even more, and all of that needs a lot more energy for a given distance than walking does.

The most efficient form of transport is riding a bike. There's very little up and down movement and you don't have to continuously exert energy because you can roll along for large sections of your journey. Getting around in a car uses less of your own energy of course, but it uses far more fuel than a human on a bike.

We can also apply the concept of efficiency to a bouncing ball.

When I lift a ball up, it gains gravitational potential energy. If I then drop the ball, it bounces up and down a few times with progressively smaller bounces before finally coming to rest. The ball's energy seems to be decreasing, so what happened to all the energy that the ball had when I first lifted it up?

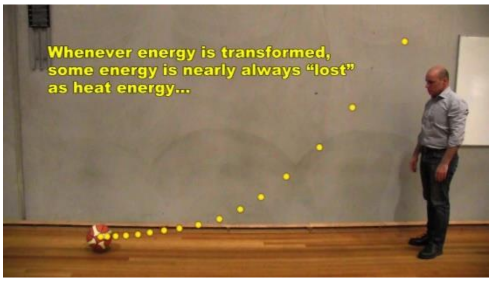




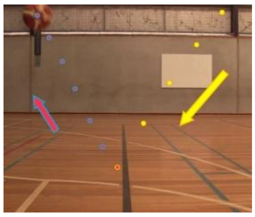
Well, let's start at the beginning. Here the ball has gravitational potential energy. When I drop it, the earth pulls it down and it gains speed as it's falling, which means that it gains kinetic energy while losing its gravitational potential energy. Now when it hits the gym floor, let me freeze frame it, it comes to a complete stop for a fraction of a second, so what happened to all its kinetic energy?

This ball was filmed in really slow motion. You can see that as it hits the surface, it deforms. The kinetic energy is transformed into elastic potential energy just like the energy stored in a bow. The elastic potential energy is returned to the ball as kinetic energy as the ball springs back to its normal shape and the ball bounces back up again. (As it rises into the air, the kinetic energy transforms back into gravitational potential energy again.)

The deformation is even more obvious with water balloons. Since the rubber that a balloon or a ball are made of has stretched and the atoms have kind of rubbed together when it deforms, some of the energy is converted into heat energy.



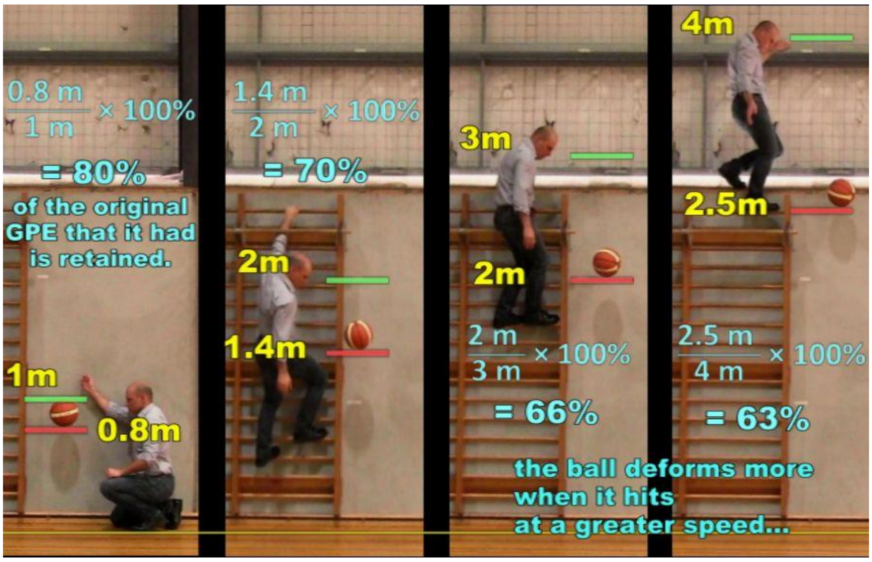
As a result, back to the basketball, after a ball bounces back up it has less speed and less kinetic energy than it had just before it hit. It therefore doesn't ever bounce back up to the height that it was dropped from. Whenever energy is transformed, some energy is nearly always "lost" as heat energy, and by "lost" in this case, I mean it becomes a form of energy that you don't want or need. After every bounce more energy is "lost", until all the gravitational potential energy that the ball started with is converted into heat energy. The ball ends up with no gravitational potential or kinetic energy, but it becomes ever so slightly warmer.



So, just repeating, whenever a ball bounces off a surface it will rebound with less speed and therefore less kinetic energy than it had immediately before it hit. You can see here that the dots that marked the position of the ball as the video was played frame by frame are closer together after the ball bounces since it was travelling more slowly.

The speed and energy loss varies depending on the original speed of the ball.

If I drop the ball from a height of 1 metre it rebounds to a height of about 0.8 metres which means that 80 percent of the original gravitational potential energy that it had is retained. The other 20% was lost as heat, and the ball and the floor got ever so slightly warmer. Dropping the same ball from a height of two metres results in a rebound height of 1.4 metres, which is 70% of the original height. This time only 70% percent of the original energy is retained. From three metres, the ball rebounds to a greater height of 2 metres, but as a percentage, less energy is retained (66%) and more energy is lost. This trend continues if I drop the ball from a height of 4 metres, where only about 63% of the energy is retained (2.5 metre rebound height). So, the higher you drop a ball from, the higher it



will rebound, but as a percentage of the original height, it will rebound by a smaller amount. This is because the ball deforms more when it hits at a greater speed and so more energy will be transformed into heat energy.

If I want the ball to rebound to the same height I have to give it a little extra energy by pushing down on it, not just dropping it. The extra energy I give it makes up for the energy that is "lost" as heat energy.

The same kind of thing happens, when you bounce on a trampoline

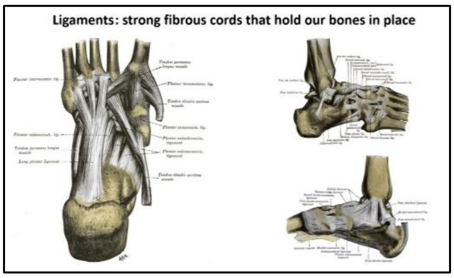
When you land on a trampoline, you temporarily come to a complete stop. What happens to all the kinetic energy that you had just before you landed? Well, once again, it is transformed into elastic potential energy which is stored in the stretched fabric and in the stretched springs. A lot of this stored energy is returned to you as the springs and the fabric unstretch and fling you back up again. However, the stretching and unstretching result in some of the energy being transformed into heat energy, so you don't get all of the energy back when you bounce back up. So, you have to push off a little bit each time if you want to keep jumping to any given height. If you then stop jumping you bounce up and down a few times, just like a ball does but eventually you come to a stop.

Depending on how high you're jumping, after you land on a trampoline and the springs stretch, about 3/4 of the energy that you land with is returned to you as kinetic energy, which allows you to bounce continuously with relatively little effort.

When you jump up and down continuously on a normal surface however and that includes running because running is really just a continuous series of jumps, it takes a lot more energy because most surfaces are far less springy than trampolines and so they don't return much energy to you after you land on them.

However, our feet have built in springs which actually makes them more efficient. Let's take a closer look.

Part E: Efficiency in Nature and Industry



The bones of our feet are held together with a whole bunch of ligaments. Ligaments are the strong fibrous cords that hold our bones in place and they're a little bit stretchy.

The ligaments and bones form this arch shape under our feet which acts like a spring.

Whenever we land after a jump, and when we're running and walking, the ligaments stretch a little bit and then spring back to their normal length, very similar to a ball bouncing, or to a person jumping on a trampoline.

It's not as obvious as a ball or a trampoline, but if it wasn't for the springiness of our arched feet we would need far more energy to get around than we do now, up to about 6% more.

Our calf muscles and the tendons that attach them to the heel bones, they're called the Achilles tendons, also stretch and then spring back, improving our efficiency even more. Tendons, by the way, are similar to ligaments, but

tendons connect muscles to bones. Here my Achilles tendons and my calf muscles stretch a little every time my foot lands and then catapult my body back up again.

So, if a single jump needs about 300 J of energy, if you do two in a row, the second jump needs only about 280 J or so because some of the energy of the first jump is returned to you thanks to, as I said, the ligaments, tendons, and muscles all stretching and then springing back, similar to what happens on a trampoline, but not to the same extent of course.

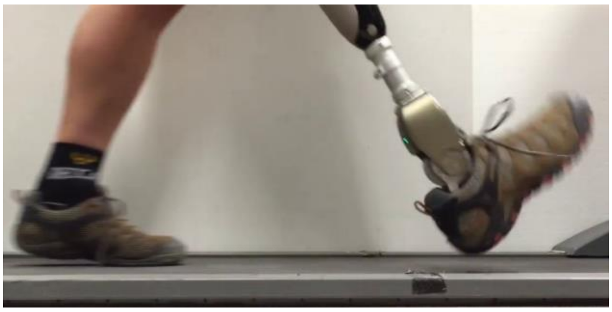
(The human foot actually has 26 bones and over a hundred tendons, ligaments, and muscles.)

Thanks in no small part to these features of our feet, humans can actually chase down horses.

Horses are faster and stronger, I really love horses, they're just such magnificent creatures, but they get tired relatively quickly because their hooves don't spring back as much as human feet do, and so horses are not as efficient when it comes to running long distances.

If a human tries to chase a wild horse, the horse will get away at first but then the human, running on springy feet, will catch up as the horse tires and slows down, although the human has to be fairly fit of course. This cycle might repeat a few times, but eventually the horse will get so tired that the human will be able to approach it. (Horses also overheat much more quickly than we do, because their cooling system, including the way that they sweat and the way blood is pumped to their skin, is not efficient as ours.

No one knows exactly when humans first chased down wild horses and started using them for transport and farming, but it was many thousands of years ago, thousands of years before even these ancient art works were created.



Kangaroos can't run like we can, but all the outstanding design features of our feet that make our feet a little bouncy are cranked up to the next level in their feet, allowing them to jump/bounce continuously at fairly high speeds.

When it comes to prosthetic limbs for people missing their feet due to for example injury or illness, scientists and engineers are using their knowledge of the human foot and ankle to incorporate energy-storing features that can absorb energy and then release it to help propel the person as they run or walk. This allows the wearer to move more efficiently and as a result to experience a much better quality of life. The technology still has a long way to go, but hats off to these amazing scientists who come up with this brilliant stuff.

We've certainly come a long way since the old wooden peg legs!

Now birds probably aren't all that efficient when it comes to walking, but most of them fly pretty well. Many, this is an eagle, have individual feathers at the end of their wingtips and for a long time scientists didn't know what purpose they served. They seemed a little too loose to contribute much to the function of the wings. It was then discovered though, that they improve air flow around the wing which helps the bird fly better.

In the 1980s, after a lot of research, plane manufacturers started adding these little winglets to the ends of the wings. Without the winglets, high pressure air under the wings flows around the sides of the wings and pushes downwards instead of upwards and that of course makes the wing less effective. The extra turbulence, that is the wild and unsteady air flow, also increases the air resistance of the wing. The winglets stopped this problematic airflow and improved fuel efficiency by about 4%. In other words, planes could travel any given distance using 4% less fuel than before. Over the lifetime of the plane, we're talking millions of litres.

Now I said earlier that in most energy transformations, heat energy is also produced as an unwanted by-product.

A gas fire's main purpose, though, is to produce heat, so you might think that this process is close to 100% efficient, since heat energy is the type of energy that you actually want.

However, not all of the heat produced ends up being absorbed by the water.

Some is absorbed by the pot, and some is absorbed by the air which then floats away taking the heat energy with it. Some of the water also evaporates and so heat is also lost in this way. A simple way of improving the efficiency of heat transfer is to put a lid on the pot, which reduces the evaporation.

When it comes to large scale production of plastics, other chemicals like fertilizers, and anything really, scientists and engineers spend a lot of time trying to make their processes as efficient as possible. If too much energy is wasted, then the plant might not be able to produce whatever it's producing at a profit.

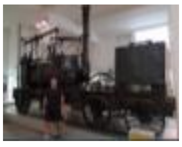
And so to summarize, energy efficiency is all about maximising the useful energy that you get out of something. Humans and animals have many built-in features that improve our efficiency when it comes to movement, and we as humans are continuously trying to improve the efficiency of all our technology, like, for example, aeroplane wings, prosthetic limbs, and as we saw earlier, light globes. Many of us have the idea that humans already know everything that we need to know and that we can find the answer to anything on the internet, but in fact, there's still a lot that we don't know and people are still discovering and inventing new things every day.

And that brings us to the end of the Shedding Light on Energy series. In this series, we've seen that energy is needed for things to change in some way and that it comes in different forms. It can be measured and it often ends up being transformed into a form that you can't use.

I'm off to use a little energy. I'll see you next time.

Wait for it…wait for it… There you go. I had never done a back somersault on a trampoline before the day we filmed this scene. I had only done a forward somersault. I was pretty proud of myself! After a bit of practise using the foam pit, I tried to land on the trampoline and I made it. Learning really is, or should be, a life-long process. Anyway, as I said, I'll see you next time.

Credits:



Science Museum, London, UK. https://www.sciencemuseum.org.uk/. LEM visited the Science Museum in London in June 2017 while we were filming the Shedding Light on Energy series in the UK, France, and Greece. It was an absolutely world-class museum with many awesome displays. I highly recommend it!!

Football Women's Bronze medals - 27th Summer Universiade 2013 - Kazan (RUS) by FISUTV. License: Creative Commons

Thanks to Jump Central, 2/117 Cochranes Rd Moorabbin 3189 VICTORIA, http://jumpcentral.com.au If you live in Melbourne, get down there and you're sure to have an awesome time. Mark Bradtke, Australian sporting legend, will look after you!

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"Shuji Nakamura - Facts". *Nobelprize.org.* Nobel Media AB 2014. Web. 18 Dec 2017. http://www.nobelprize.org/nobel_prizes/physics/laureates/2014/nakamura-facts.html

These three gifted and hard-working scientists have probably done more for the environment than anyone else ever!

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https://www.nature.com/articles/srep19403 Stearne, S. M. *et al*. The Foot's Arch and the Energetics of Human Locomotion. *Sci*. *Rep*. **6**, 19403; doi: 10.1038/srep19403 (2016).

Superfeet Carbon Insole by Ellis Brigham Mountain Sports. License: Creative Commons

 Boy with Horse & Chariot with Two Women: National Archaeological Museum, Athens, Greece. Chariot with two women: Archaeological Museum of Heraklion, Crete, Greece. These two museums are fantastic.

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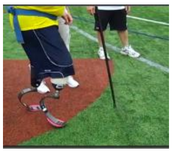
 Harry Potter's Hogwarts Express (The Jacobite Steam Train) on the Glenfinnan Viaduct (Bridge) by Kathir Vel. Creative Commons Attribution licence.

 24 Hours of Zolder 2013 - Glowing Brake Discs by Zeno Damoiseaux. Creative Commons Attribution licence.

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 Create your own images of whatever muscles and just about every other body part at http://lifesciencedb.jp/bp3d/?lng=en. I (Spiro Liacos) "created" the image of the skeleton with the calf muscles at their fantastic interactive website.