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How do solar cookers work? - a simple explanation

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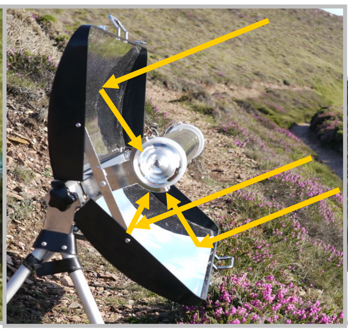
In our experience, when people see a solar cooker working for the first time, they are surprised. They can't believe that you can cook with the small amount of warmth they can feel on their bare arms on a sunny day. So we thought we would write a short piece to explain how solar cooking is possible.

To understand it fully, you need to know some Physics, and we go into that in a bit more detail in our article about minimising energy losses[1], but here we take a simpler approach. You already know a lot of things about how energy works from your own experiences, so we'll use those common experiences in our explanations.

Let's talk about sunlight. You can feel it on your bare arms on a sunny day, but if you step into the shadow of a tree, that warmth disappears immediately, like somebody turning off a light. So the warmth you feel on your arm is not due to the air around you being warmed by the sun, but it is due to something travelling directly to you from the sun, and striking your arm. You have probably also had the experience of warming your hands on a radiator. You don't have to touch the radiator - the heat somehow travels through the air between you and the radiator, just as the sun's energy travels across space to strike your arm. So, visible light (like sunlight) doesn't have to be present for your hands to receive transmitted heat. The radiation energy we get from the sun includes some energy that you can see (visible light – all the colours of the rainbow), and some that you can't see (mainly infra-red radiation – the heat you can feel by putting your hand near a radiator in your home). All of these energetic waves are travelling at the speed of light when they get to the earth, and about a quarter of the energy is absorbed by the gases in our atmosphere, but, even so, a lot of energy gets through to ground level, and that is what you feel on your bare arm when the sun shines on it. This is the energy we use for solar cooking.

Almost all solar cookers have reflectors. Their job is to direct the maximum amount of solar energy (visible and invisible) towards the cooking pot, or cooking chamber. You know from experience that some materials make good reflectors – shiny metals, for example, and that some materials make poor reflectors – blackboards, for example. The reflectors used in solar cookers are usually made of materials that can reflect between 80% and 95% of the sunlight that strikes them. Below you can see four types of solar cooker. The yellow arrows show how each type uses reflectors to direct the parallel rays of the sun onto the cooking pot, or into the cooking chamber.

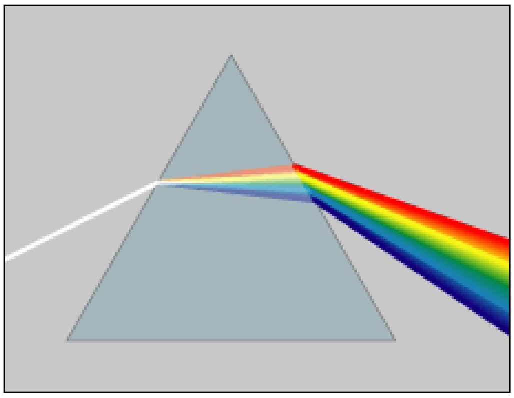



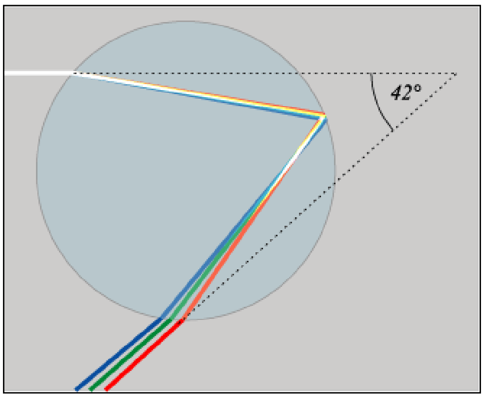
Although you may not have done this yourself, you are probably aware that if you hold a small magnifying glass in the sunlight and alter the distance between it and a piece of wood, you can see a very bright image of the sun on the wood. Furthermore, there is enough energy to char a small section of the wood until smoke appears, or even set fire to it. It doesn't take much imagination to consider what would happen if the magnifying glass was twice as big, or a foot across, or two feet across. So you already know that it is possible to concentrate sunlight from a large area and focus it onto a small area. This is what solar cookers do. They concentrate the sunlight from a large area into a smaller area. The greater the area, the greater the amount of energy gathered and focussed. If you look at the parabolic cooker in the picture above (on the right) you can see that solar energy from quite a large area (nearly a square metre in this case) is redirected onto the cooking pot in the centre.

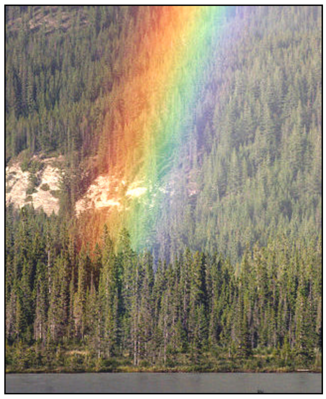
1 If you want more Physics, read our other article about increasing gains and reducing losses in solar cooker design

So the sunlight has now been directed towards the pot, or the cooking chamber, but you will have noticed from the pictures on the previous page that each cooker has some glass in the way so that the sunlight must pass through it to reach its target. As you already know, not all of that energy will pass through the glass. If you stand next to a car window on a sunny day, you can see a reflection of yourself in the window[2]. It's not a very bright one, but it makes it obvious that not all of the light travelling towards the window passes through it; a small proportion is always reflected. The same must be true of the glass used in solar cookers – they don't allow all of the solar energy to get through to the pot. How much they let through depends on the type of glass, and its thickness - some types of glass are just better than others at letting the light through.

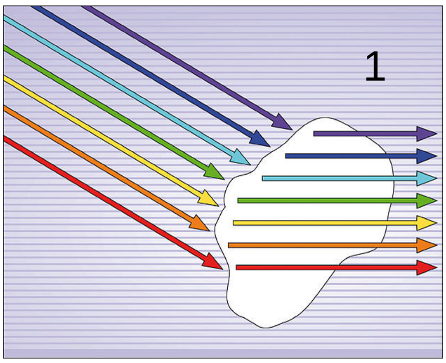
You already know that sunlight is composed of light of different colours, and that these can be revealed by shining the light through a prism[3] (left). Exactly the same process occurs when sunlight is reflected from the back of a raindrop[4] (centre), producing the characteristic colours of a rainbow[5] (right).

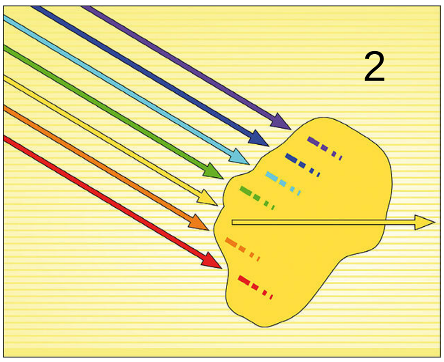


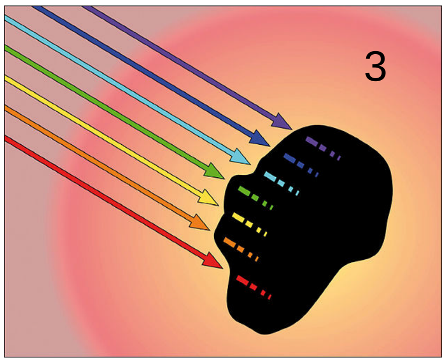




Once most of the sunlight has got through the glass, it strikes the pot or the walls of the cooking chamber. You can see from the pictures on the previous page that these pots and chamber walls are always black. There is a very good reason for this. Surfaces that appear white to us reflect all of the different colours of the rainbow[6] (1). Surfaces that absorb all of the colours *except* yellow light appear yellow to us[7] (2). Finally, surfaces that absorb *all* of the colours appear black because none of the light is reflected[8] (3). We can think of a black surface (e.g.- a blackboard) as one that absorbs all of the light.







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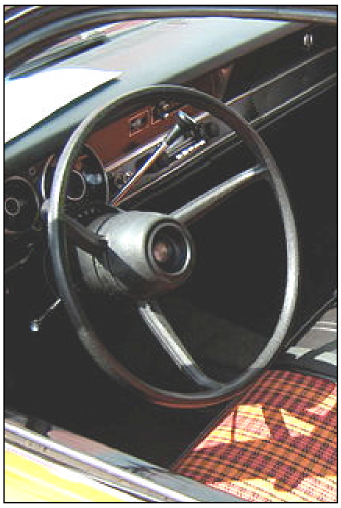
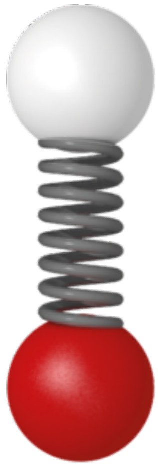


So black surfaces absorb the most light. If you have ever got into a car that has been standing in bright sunlight, you know that the dark surfaces on the top of the dashboard and the steering wheel, especially if they are matt black, can be too hot to touch. So you are already aware that black surfaces absorb light and heat up in the sun. But what does *absorb* mean exactly? How can light increase the temperature of a black surface. The answer is that when the sunlight strikes the surface, it sets some of the molecules on the surface vibrating and twisting. The bonds between atoms are capable of vibrating at set frequencies and in particular directions. If we pretend that the bonds between atoms are rather like springs, we can get an idea of how they can absorb energy when struck by sunlight and begin to vibrate. The model to the right illustrates this analogy. Imagine that you are holding the red 'atom' and that you flick the white 'atom'. You can see that it will wobble about, perhaps up and down, perhaps from side to side, like the balls on a deely-bopper. More complex molecules have more atoms, and therefore more bonds, all of which are capable of vibration and rotation in various directions. For an illustration of how a more complex molecule might vibrate and twist when it gets hot, take a look here[9]. This increased movement of molecules is what we know as heat. This is how the energy contained in sunlight is converted into heat in the cooking pot. Once the pot begins to heat up, that heat energy is transferred to the food, which begins to cook.



But we have not finished. Inevitably the temperature of the food and the pot will rise above the temperature of the surrounding air. You know from your own experience that objects that are hotter than their surroundings, like a hot cup of coffee, cool down over time. We must do our best to prevent that happening to the food in our solar cooker. If it does begin to lose heat to its surroundings, the food will heat more slowly, and may not even reach its proper cooking temperature. The more heat energy we can retain in the pot and the food, the more effective our cooker can be. In order to retain the heat energy, we need to find ways of *insulating* our cooking vessel.

We return now to the experience of getting into a car that has been parked in the sun for a while. You'll remember that the air inside the car can be uncomfortably hot. This is because the car is like a giant solar cooker, with sunlight entering through the windows and heating up the dark surfaces. Some of that heat is then transferred to the air inside the car. How often have you heard someone say, on opening a hot car door: "It's like an oven in there!" You know that if you keep the windows closed the air will remain hot, but that if you open the windows some of the cooler air outside will mix with the hot air in the car and make it more comfortable. The same principles apply in a solar cooker, except that you need to *retain* the heat, and *not* let it escape. The transparent layer(s) around the pot in a solar cooker are designed to *prevent* hot air from escaping from around the cooking vessel. If it is air-tight, like a car, it will retain the heat very well. The transparent layer in a solar cooker can be made of glass, or of plastic.

In a box cooker, the bottom and sides of the box are also very well insulated so that very little heat energy can escape through them. This insulating layer can be made of plastic foam, sheep's wool, or any other material with insulating properties. In the evacuated tube cookers, there is a vacuum between the two glass layers, and this completely blocks the heat that might be transferred by the motion of heated air from the hot inner tube to the cooler outer tube. The parabolic dish cookers, especially the larger ones, are capable of concentrating such a lot of solar power that there is no need to insulate the cooking vessel at all, and they can be used like a conventional gas or electric hob as they produce about the same amount of power.

We have seen how sunlight (visible and invisible) travels across space, then through the earth's atmosphere, losing about a quarter of its energy in the process. It strikes the reflector on our solar cooker, and 80 or 90% of it is redirected towards the cooking pot. Then it must get through the glass we have put in the way, losing some of its energy on the way. Finally, it strikes our black cooking pot, and vibrates the atoms and molecules that make up the surface of the pot. This vibration is what we know as heat. This heat is conducted through the pot and heats our food. Properly designed, so that the maximum amount of solar energy strikes the pot, and then the maximum amount of heat energy is retained, solar cookers are more effective than most people imagine.

[9] https://commons.wikimedia.org/wiki/File:Thermally_Agitated_Molecule.gif#/media/File:Thermally_Agitated_Molecule.gif