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 **Microwave Ovens Homework Due: Friday, Sept. 25th**

How our ancestors would have loved microwave ovens! Instead of sitting around smoky wood fires for hours on end, boiling up buffalo stew for their Stone-Age friends, they could have just tossed everything in the microwave, pressed a few buttons, and had a meal ready in a minute or two. Of course, they had no electricity, which might have been something of a problem…

When microwave ovens became popular in the 1970s, they lifted household convenience to a new level. A conventional oven heats food very slowly from the outside in, but a microwave oven uses high-powered [radio](http://www.explainthatstuff.com/radio.html) waves to cook food more evenly (loosely speaking, we sometimes say it cooks from the "inside out"—although that isn't quite correct). This is why a microwave can cook a pound of meat roughly six times faster than a conventional oven. Microwave ovens also save [energy](http://www.explainthatstuff.com/energy.html), because you can cook immediately without waiting for the oven to heat up to a high temperature first. Let's take a closer look at how they work!

**What is heat?** Microwave ovens are so quick and efficient because they channel [heat energy](http://www.explainthatstuff.com/heat.html) directly to the [molecules](http://www.explainthatstuff.com/atoms.html) (tiny particles) inside food. Microwaves heat food like the sun heats your face—by **radiation**.

A microwave is much like the electromagnetic waves that zap through the air from [TV](http://www.explainthatstuff.com/television.html) and [radio](http://www.explainthatstuff.com/radio.html) transmitters. It's an invisible up-and-down pattern of [electricity](http://www.explainthatstuff.com/electricity.html) and [magnetism](http://www.explainthatstuff.com/magnetism.html) that races through the air at the speed of light (300,000 km or 186,000 miles per second). While radio waves can be very long, microwaves have much shorter wavelengths and frequencies. The microwaves that cook food in your oven are just 12 cm (roughly 5 inches) long.

 Despite their small size, microwaves carry a huge amount of energy. One drawback of microwaves is that they can damage living cells and tissue. This is why microwaves can be harmful to people—and why microwave ovens are surrounded by strong metal boxes that do not allow the waves to escape. **Microwaves can be very dangerous, so never fool around with a microwave oven**. Microwaves are also used in [cellphones](http://www.explainthatstuff.com/cellphones.html) (mobile phones), where they carry your voice back and forth through the air, and [radar](http://www.explainthatstuff.com/radar.html).

How does a microwave turn electricity into heat? Like this!

1. Inside the strong metal box, there is a microwave generator called a [magnetron](http://www.explainthatstuff.com/how-magnetrons-work.html). When you start cooking, the magnetron takes [electricity](http://www.explainthatstuff.com/electricity.html) from the power outlet and converts it into high-powered, 12cm (4.7 inch) radio waves.
2. The magnetron blasts these waves into the food compartment through a channel called a wave guide.
3. The food sits on a turntable, spinning slowly round so the microwaves cook it evenly.
4. The microwaves bounce back and forth off the reflective metal walls of the food compartment, just like light bounces off a [mirror](http://www.explainthatstuff.com/howmirrorswork.html). When the microwaves reach the food itself, they don't simply bounce off. Just as radio waves can pass straight through the walls of your house, so microwaves penetrate inside the food. As they travel through it, they make the molecules inside it vibrate more quickly.
5. Vibrating molecules have heat so, the faster the molecules vibrate, the hotter the food becomes. Thus the microwaves pass their energy onto the molecules in the food, rapidly heating it up.

**Inside out?**

In a conventional oven, heat has pass from [electric heating elements](http://www.explainthatstuff.com/heating-elements.html) (or gas burners) positioned in the bottom and sides of the cooker into the food, which cooks mostly by [conduction](http://www.explainthatstuff.com/heat.html) from the outside in—from the outer layers to the inner ones. That's why a cake cooked in a conventional oven can be burned on the edges and not cooked at all in the middle. People sometimes say microwave ovens cook food from the "inside out," which is a bit of a gloss and isn't quite correct. When people say this, what they really mean is that the microwaves are simultaneously exciting molecules right through the food, so it's *generally* cooking more quickly and evenly than it would otherwise.

Exactly how the food cooks in a microwave depends mostly on what it's made from. Microwaves excite the liquids in foods more strongly, so something like a fruit pie (with a higher liquid content in the center) will indeed cook from the inside out, because the inside has the highest water content. You have to be very careful eating a microwaved apple pie because the inside may be boiling hot, while the outside crust is barely even warm. With other foods, where the water content is more evenly dispersed, you'll probably find they cook from the outside in, just like in a conventional oven.

Another important factor is the size and shape of what you're cooking. Microwaves can't penetrate more than a centimeter or two (perhaps an inch or so) into food. Like swimmers diving into water, they're losing energy from the moment they enter the food, and after that first centimeter or so they don't have enough energy left to penetrate any deeper. If you're cooking anything big (say a pound of meat in a large microwave oven), only the outer "skin" layer will be cooked by the waves themselves; the interior will be cooked from the outside in by conduction. Fortunately, most of the things people cook in small microwave ovens aren't much more than a couple of centimeters across (think about a microwaveable meat or fruit pie).

You'll notice that microwaveable dinners specify a "cooking time" of so many minutes, followed by a "standing time" that's often just as long (where you leave the cooked food alone before eating it). During this period, the food effectively keeps on cooking: the hotter parts of the food will pass heat by conduction to the cooler parts, hopefully giving uniform cooking throughout.

You might expect a microwave to be much more **efficient** than other forms of cooking: in other words, you'd expect more of the energy going in from the power cable to be converted into heat in your food and less to be wasted in other ways. Broadly speaking, that's correct: cooking in a microwave is cheaper and quicker than cooking with a conventional oven because you don't have to heat up the oven itself before you can cook.

But that's not the whole story. If you want to heat up only a small quantity of food (or a cup of hot water), a microwave oven is not necessarily the best thing to use. When you microwave something, apart from putting energy into the food, you're also powering an [electric motor](http://www.explainthatstuff.com/electricmotors.html) that spins a relatively heavy [glass](http://www.explainthatstuff.com/glass.html) turntable. Although you don't have to heat up the food compartment for the oven to cook, a microwave oven does, in fact, get fairly warm after it's been on for a while, so there are some heat losses. A magnetron is not perfectly efficient at converting electricity into microwaves: it will get hot. And you also have to power an electronic circuit, a timer display, and probably a cooling fan. Taken together, all these things make a microwave less efficient than it might be.

How much less efficient? Physicist Tom Murphy recently [compared the energy efficiency of different methods of boiling water](http://physics.ucsd.edu/do-the-math/2012/05/burning-desire-for-efficiency/%22%20%5Ct%20%22_blank) and found (perhaps surprisingly) that it was only about 40 percent efficient, which is about half as efficient as using an [electric kettle](http://www.explainthatstuff.com/how-electric-kettles-work.html).

Questions:

1. What makes microwaves useful? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. What type of thermal energy transfer is the main source of heating your food in a microwave? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. How is conduction a part of cooking microwaved foods? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. Mrs. Fleischmann thinks the best way to cook a turkey is in the microwave. Use evidence from the text to either agree or disagree with Mrs. Fleishmann’s claim? Would you want to eat Thanksgiving dinner at her house? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_