

Heat Transfer: Reducing Energy Losses in Design

Companion to the video: Script and Illustrations

One of the most common ways to lose energy is heat transfer, but good design can solve this.

Efficient refrigerators today use 75% less energy than an average fridge from thirty years ago. You can get results like this too.



Heat's transferred in three ways — through conduction, convection, and radiation.

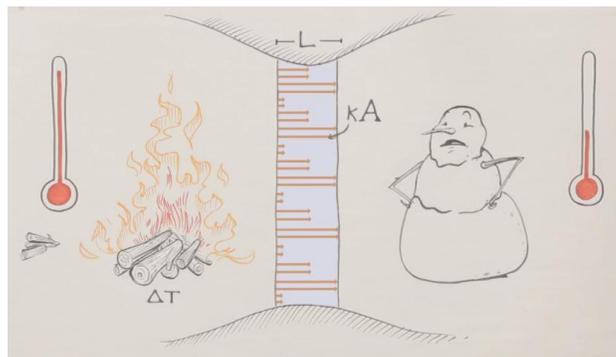
When we control these transfers, we can get huge energy savings.

Let's start with conduction. That's heat flowing through a material, like the wall of a refrigerator.

More heat flows as the material gets more conductive...

...the surface area gets larger...

and the temperature difference gets bigger.



That temperature difference is why the freezer will always lose more energy than the fridge.

And the thicker the material, the LESS heat is transferred.

A material's thermal conductivity per unit area at a given thickness is called its U-value.

$$q = \frac{kA\Delta T}{L}$$

But to insulate, you want high thermal RESISTANCE.

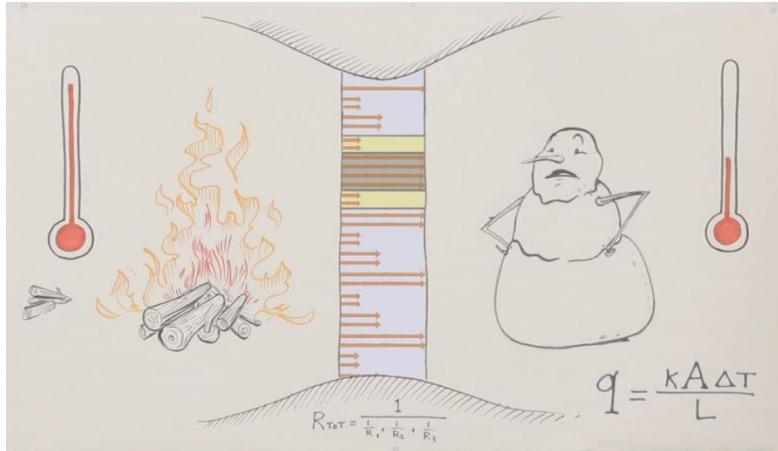
That's the material's R-value, which is one over its U-value.

Thermal resistance behaves similarly to electrical resistance. Adding layers of materials in series adds their R-values linearly.



But if the materials are in PARALLEL, one with low resistance can conduct heat right around high-resistance materials. These resistances add as one over the sum of their reciprocals.

So, super-insulating your refrigerator won't do much good if its metal skin wraps around from inside to outside. The metal will create a thermal bridge across the insulation, quickly conducting heat in.

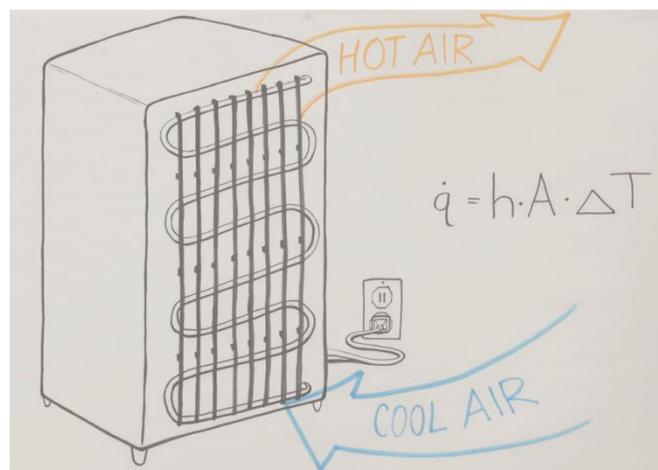


When heat is transferred by conduction, the material absorbs and STORES some heat energy. It's called thermal inertia.

Water has a much higher thermal inertia than air; so a fridge full of cold drinks will keep cool longer than an empty fridge if the power goes out.

Convection is when heat is carried by a moving fluid, like air or water. That's why you lose energy every time you open your fridge.

But convection can also help your fridge use energy efficiently. It takes waste heat away, so the refrigerator can pump new heat from inside to outside.



This is natural convection, caused by the different densities of hot and cold fluids.

You can also force convection with a fan, like in your computer.

Similar to conduction, the rate at which heat is lost is equal to a heat transfer coefficient times the area of the surface exposed to the fluid times the temperature difference between the surface and the fluid.

Heat sinks have fins to maximize that surface area.

Finally, radiation is when heat travels as light. When you warm your hands beside a fire, you're using the electromagnetic radiation given off by the fire.

If you look through an infrared camera, you'll see heat radiating off of people, buildings, cars, all sorts of things.

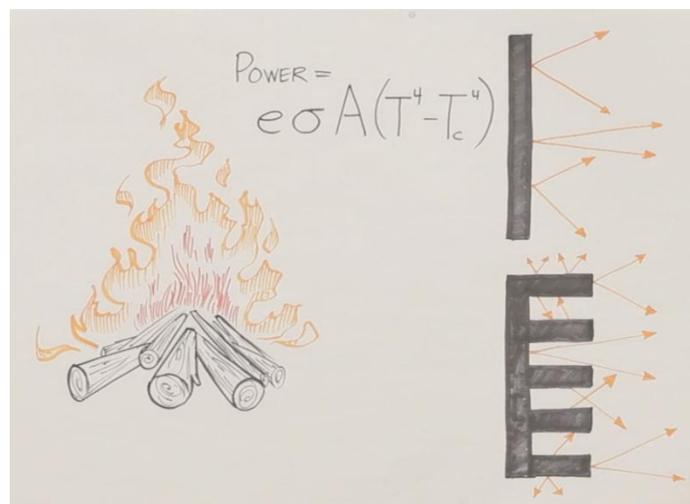
You can control radiation heat transfer in three ways:

First, some materials radiate heat more than others; we measure this as emissivity.

Reflective surfaces have low emissivity, while dull black materials radiate more heat, so a matte black coating on a metal heat sink can improve its radiative cooling.

Then there's area. Not ALL surface area, just the area exposed to the outside world. See, radiated heat that doesn't escape to the outside just gets re-absorbed.

The third variable for radiation heat transfer is the temperature difference between the object and its surroundings. And temperature is raised to the 4th POWER!



That's huge -- that's why you can't warm yourself from a person's radiation, but you can from a fire's radiation.

By understanding heat transfer, designers can cut energy demands in all kinds of products—not just refrigerators, but electronics, vehicles, even buildings.

In fact, wherever you find something that produces heat or cooling, you can find chances to save energy.