



Bringing science to life with the incredible, ERASABLE FriXion pens, markers and highlighters.

High School

# HEAT IT UP: CONDUCTION, CONVECTION & RADIATION



Through a teacher demonstration using water, heat and food coloring, students see how convection moves the energy of the Sun from its core outwards. Students learn about the three different modes of heat transfer—convection, conduction, radiation—and how they are related to the Sun and life on our planet. Students will then demonstrate conduction, convection, and radiation on their own using FriXion pens.



## LEARNING OBJECTIVES

After this activity, students should be able to:

- Define the three different modes of heat transfer
- Explain how heat gets from the Sun to Earth
- Give one example of why engineers need to understand heat transfer
- Explain why FriXion ink is a useful tool for demonstrating the effects of heat transfer methods

Developed by





## MATERIALS

### To share with the entire class (teacher demonstration):

- FriXion pens
- Clear baking dish
- 6 or more dictionaries or thick text books
- Portable heat source, such as a small burner, can of Sterno, propane or small warming candle in a fireproof holder
- Fireproof surface
- Water
- Food coloring (orange works well)
- Glitter
- Thermometer

## INTRODUCTION/MOTIVATION

Can heat move? Yes! Heat (energy) travels in three ways: convection, conduction and radiation. Conduction works by direct contact of two materials. This is what happens when a pot is placed on the stove. First the stove material is heated. Then the heat is transferred by conduction to the pot, which is in direct contact with the hot stove. Convection works through the interaction of fluid molecules such as air or water. Convection typically occurs when a hot fluid or gas moves upward. Radiation works through the movement of heat waves. This is similar to light and radio waves.

So, how does heat get from the Sun to Earth? Conduction and convection require a material (either solid, liquid or gas) to be present. Inside the Sun is matter, and therefore other forms of heat transfer are at work. The Sun uses two methods to transport energy out from the interior. The first is radiation. Radiation begins in the Sun's core. In the Sun's radiation zone, heat from the core travels as electromagnetic waves (radiation) outwards to the Sun's convective zone. Convection currents are currents created when there are differences in temperature and density. Warmer liquids and gasses are less dense and therefore float (or rise) when in cooler liquids and gasses. As this warmer gas (or liquid) rises, cooler gas (or liquid) moves to take its place where it is heated. This is called a convection current. Convection currents swirl the energy until it passes through to the Sun's photosphere.

When the Sun's energy (in the form of radiation) hits our planet's atmosphere, some of it reflects off while some of it heats up the air, water and land. Once the material that makes up the Earth and its atmosphere is heated, it can move around the globe through convection and conduction. Heat loss through a wall is an example of conduction. Insulation limits conduction and keeps the heat inside your house. Cooling yourself with a fan is an example of convection. Convection is the reason it feels colder on a windy day.

Engineers must understand how heat moves so that the devices they build do not get too hot or too cold. What would happen if an engineer did not make sure there was insulation in the walls of your house? It would be very cold inside on a winter day because the heat could escape through conduction. What would happen if the cord to an appliance did not



have an insulated covering on it? The wire would be exposed and the electricity running through it could hurt someone or start a fire. What would happen if an engineer wrapped an engine in insulation? The heat generated by the engine would not be able to get out and the engine would overheat.

## PROCEDURE

### Before the Activity

- Gather materials for the teacher demonstration

### With the Students

1. Explain to students the three different modes of heat transfer (radiation, conduction and convection).
2. Have students write their heat transfer definitions in their science notebook, with an example of each that they have experienced or seen in their own lives.
3. Tell students you will share FriXion pens.

By design, FriXion erasable pens, markers and highlighters incorporate science, technology, and engineering. The unique, thermo-sensitive ink formula utilizes covalent bonding and PH to allow the ink to:

- **Write smoothly** and vividly in a variety of colors
- **Be 'erased' completely** by becoming invisible with erasing friction or when heated to temperatures higher than 140°F (65°C)
- **Be made to reappear** when cooled to extremely low temperatures of less than 14°F (-20°C)

The thermochromic chemistry in FriXion uses three types of chemical compounds that rely on acid-base interactions, temperature sensitivity, and covalent bonding. When you rub the ink with the hard rubber eraser, heat from the resulting friction causes the temperature-sensing compound to activate the acid compound, thus neutralizing the dye.

### The 3 compounds are:

- A. The Color Pigment (which is stable at room temperature but changes color upon reaction with acids).
- B. A Color-Activating/Developer that acts as an acid to produce the color change that bonds.
- C. A Transparency/Color Change Regulator that controls the temperature at which the color transition takes place.

When A & B covalently bond you can see the ink color, when that bond is broken with heat, B & C bond and the ink becomes invisible. If the bond between A & B is reformed with cooling, the ink color will reappear. Students can control both methods and rates of heat transfer in class using FriXion ink to test and demonstrate conduction, convection and radiation.



4. Using a piece of paper draw out a scribbled box using a FriXion pen. Then demonstrate to students how FriXion pens erase. You can draw a design through the box or a simple line.
  - a. Conduction is heat transfer through stationary matter by physical contact. Heat transferred by an iron being placed on the paper to demonstrate conduction.
  - b. Convection is the heat transfer by the macroscopic movement of a fluid. This type of transfer can be demonstrated by using a blow dryer to make the FriXion ink disappear.
  - c. Radiation is heat transfer from microwaves, infrared radiation, visible light, or another form of electromagnetic radiation, being emitted or absorbed.
5. Tell students that they will be recording observations from a new demonstration.
6. Make sure all students can see the demonstration and that, for safety, no student is too close to the flame.
7. Place the baking dish on two piles of dictionaries that are high enough and far enough apart to place a fireproof plate and sterno can (or warming candle) under the baking dish.
8. Pour cool water into the baking dish.
9. Make sure the table is very still so that the water does not move. Take the temperature of the water. Have students record the temperature. Repeat the temperature several times so all students have time to record the temperature on their worksheets (a volunteer may want to keep track on the board).
10. Carefully light the heat source. Drop a few drops of food coloring and some glitter into the water. It works best to drop the glitter and food coloring into the water directly above the heat source.
11. Take the temperature of the water at two-minute intervals. Be sure to take the temperature in roughly the same location in the dish every time. What is happening to the glitter as the water gets hotter? Have students record the temperatures.
12. The heat source should slowly heat the water in the middle of the baking dish. The food coloring helps students observe the movement of the water.
13. The glitter flows from the high heat in the center to the outsides where it is cooler. Convection transfers heat (energy) by currents of gas or liquid. (It may help to have students get up and walk past the demonstration so that they can get a closer look.)
14. Have students record their observations. Have students make a bar graph of the temperature. What do they notice about the temperature? (The water temperature should show an increase.)
15. Conclude by reviewing the learning objectives. Review the ways that heat moves.
  - Conduction = by direct contact of two materials
  - Convection = by the interaction of fluid molecules (such as air or water)
  - Radiation = by the movement of heat waves



### DISCUSSION QUESTION

- How is the effect of heat on the ink in FriXion pens similar the heat transfer from the sun?
- How is it similar or dissimilar to the heat transfer in the water dish demonstration?