TEACHER'S GUIDE
SCIENCE KEY CONCEPTS SERIES:

HEAT ENERGY: TRANSFER AND PROPERTIES

20 minutes, Video

Chapters:

1. Heat Transfer 8 min
2.Thermal Expansion 6 min.
3. Specific Heat Capacity 6 min.

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FOR USE IN: Physics
LEVEL: Grades 9-12
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EDUCATIONAL OBJECTIVES:
To help the student understand these key concepts:

- **heat transfer by conduction convection and radiation**
- **thermal expansion in metal, liquids and gases**
- **specific heat capacity in liquids, and metal.**

CONTENT

Chapter 1. Heat Transfer 8 min.

A thermal imaging camera is used to show a saucepan being heated. We can see the hot plate and the heat spreading through the base into the pan. The pan is being heated by conduction. A hot and a cold block are placed in contact and we can see that the cold block warms up as the hot block cools. Eventually they will both be at room temperature. Metals are good conductors. Identical sized metal rods all have a rivet stuck to the end with petroleum jelly. They are simultaneously heated at their other end. The jelly melts soonest on the best conductor. The order from best to worst conductor is copper, aluminium, brass, steel.

Liquids are poor conductors as can be shown by holding ice at the bottom of a test tube of water and heating the water at the top until it boils. The ice does not melt. Gases are poor conductors as shown by a thermal image of a flame and by bringing a match very close to the side of a bunsen flame before it lights. Convection occurs in gases. A convection current is set up using a candle flame

to heat the air. Smoke is drawn in to show the convection current. Convection also occurs in liquids. A crystal of potassium permanganate is placed at the bottom of a beaker of water. When heated the purple dye from the dissolving crystal shows convection currents.

Energy from the Sun reaches us because of radiation. The part of the electromagnetic spectrum for heat transfer is infrared. A grill uses infrared radiation to cook food. All objects absorb and emit radiation which depends on their temperature. Some images using the thermal imaging camera are shown. An ice cream is cold and does not radiate as much as the human face. A dull can and a shiny can are compared. Although they are at the same temperature, but the dull can is radiating more as shown by the thermal image. So the dull can is radiating more heat and will cool more quickly.

Chapter 2. Thermal Expansion 6 min.

Bridge builders need to know that as solids get hotter they expand. The expanding bar experiment is shown. An iron bar is held tight between a nut and a cast iron pin. The bar is heated and the nut on the end turned so that the bar stays tightly held. When it is cooled it contracts again and the force is enough to snap the cast iron pin. A ball passes through a metal ring, but when the ring is cooled in liquid nitrogen the ball will no longer fit through the contracted metal ring. Railway tracks can buckle in hot weather so either sliding joints are used or expansion gaps are left.

Some bimetallic discs are shown. These are brass on one side and iron on the other. Can you explain what will happen when the discs are heated? When heated they will bend, as the brass expands more than the iron. This makes them jump upwards. A candle under a bimetallic strip works as a switch. The candle heats the strip so that it bends downwards, completing the electrical circuit which operates the fan. The fan cools the strip, which straightens again and the fan turns off. This shows how bimetallic strips are used as switches in thermostats.

Liquids expand more than solids. Three liquids are compared. They are: water, colored red; methylated spirits, colored blue; and paraffin which is clear. The flasks are placed in a water bath and as the temperature rises the liquid expands up the tube. Methylated spirits expands the most, a similar liquid is used in thermometers. Why is it so suitable? It gives a larger difference in liquid level for a degree change in temperature, which will be easier to read from the thermometer. Gases also expand when heated. When a flask of air has the exit tube placed under water and the air is heated with warm hands bubbles of air can be seen leaving the exit tube. Air is leaving the flask as it expands. If the flask is now

cooled it will contract and water is drawn into the flask. If a helium-filled balloon is put into liquid nitrogen the gas contracts. As it is taken out of the nitrogen the balloon starts to reinflate. Why does the balloon re-inflate?
Answer: Gas expands as it warms up to room temperature.

A flask of air is connected to a glass syringe so that as the gas expands the plunger will be pushed back and the change in volume can be measured. The flask is placed in ice and the plunger moves towards the flask as the gas contracts. The flask is heated and the readings of the temperature and the change in volume of the air in the syringe are noted:

Chapter 3. Specific Heat Capacity 6 min.

Identical pans containing 200g and 400g of water at the same temperature are heated on identical hobs. Which will boil first? The 200g will boil first. The heat capacity depends on the mass. Does it depend on the material? To find out, the same mass of oil and of water are placed in a pan and heated. When the water reaches 100°C the oil has reached 130°C. This shows that oil has a lower specific heat capacity than water.

If Q is the heat supplied then: $Q = mc\,(T_2 - T_1)$ where m is the mass (kg), c is the specific heat capacity (J kg-1 °C-1) and $T_2 - T_1$ is the change in temperature in °C.
Re-arranging gives: $c = Q \div m(T2 - T1)$ This equation can be used to calculate the specific heat capacity of a material.

An experiment to find the specific heat capacity of aluminium is demonstrated. A 1kg aluminium block has two holes in it, one for an immersion heater and one for a thermometer. The starting temperature is T_1 = 27°C and the final temperature after 20 minutes is T_2 = 37°C. The mass m = 1kg. If all the heat supplied is received by the aluminium then Q = VIt where V = 5.0V, I = 1.85A and t = 1200s.

Then Q = 11100J and c = 11100/10 = 1110 J kg-1°C-1. The actual value is 908 J kg-1°C-1.

Can you suggest causes of error and improvement?
(Answer: The main error will be heat lost from the aluminium block. This could be reduced by insulating the block.)

AFTER VIEWING THE VIDEO

Here are some suggested questons to stimulate student discussion:

Heat Transfer

1. Place these conductors in order, starting with the best: aluminium, brass, copper, steel
2. If ice is held at the bottom of a test tube it is possible to boil the water at the top of the test tube without the ice melting. What does this show? (Water is a poor conductor of heat)
3. Which method of heat transfer works well in liquids and gases but not in solids?
4. At the same temperature which will radiate more heat, a dull surfaced can or a shiny surfaced one?

Thermal Expansion

1. Metals expand when heated and contract when cooled. Describe a demonstration of one of these effects.
2. Complete this diagram of the circuit for the bimetallic strip operated fan by labeling the copper side of the strip and the steel side correctly to make the circuit work.
3. Which liquid expands more as the temperature increases: water, methylated spirits or paraffin?
4. Describe a demonstration which shows that air expands when heated and contracts when cooled.

Specific Heat Capacity

1. a) Which heats up more quickly, oil or water? b) Which has the lowest specific heat capacity, oil or water?
2. a) The experimental value of specific heat capacity for aluminium was:
b) The actual value of specific heat capacity for aluminium is:
c) Can you suggest causes of error in the experiment?
d) Can you suggest an improvement to the experiment?

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