Visualising Conduction, Convection & Radiation using a thermal Imager and other fascinating applications

Roger Christiansz B.App.Sc, DipEd, Associate University of Melbourne

Kheang Khauv B.E. (Hons)

FLIR Systems Australia P/L

As a former maths and science teacher I am well aware of the impact scientific demonstrations and experiments have on students. It is an excellent way of teaching science and motivating students. Teaching heat and heat transfer in a purely theoretical fashion is not as stimulating as seeing the 3 modes of heat transfer. In this presentation we will demonstrate these modes of heat transfer visually. In addition we will present other fascinating uses for thermal imaging where heat is a source of problems in industry, veterinarian science, building, mining, oil and gas production, aviation etc.

What is a Thermal Imager?

A thermal imager is also referred to as an Infrared camera and is effectively a radiometer that receives IR energy in a certain wave band and converts this energy to a temperature and displays a thermal image or "temperature" picture in false colour. Most thermal imaging cameras on the market operate in the 3 to 5µ or 7.5 to 13µ wave bands. Those that operate in **the 3 to 5 µ band are referred to as mid-wave IR cameras** and those that operate in **the 7.5 to 13µ band are referred to as Long Wave IR cameras.**

Here's how the camera works:

The energy received by the detector in the IR camera is converted to a temperature using the **Stefan-Boltzmann's equation:**

$$E = \sigma \epsilon T^4$$

σ= The Stefan -Boltzmann's Constant 5.67x 10^{-8} W/m^2T^4

ϵ is the emissivity of the material or object and

T the absolute temperature in Kelvin

Then $T = 4\sqrt{E/\sigma\epsilon}$

The energy received by each detector is converted to a temperature and displayed as a thermal image.

So an IR camera with a detector array of 160 x 120 (HxV) has a total of 19,200 detectors (pixels) or measurement points

A 320 x 240 has 76,800 detectors (pixels) or measurement points

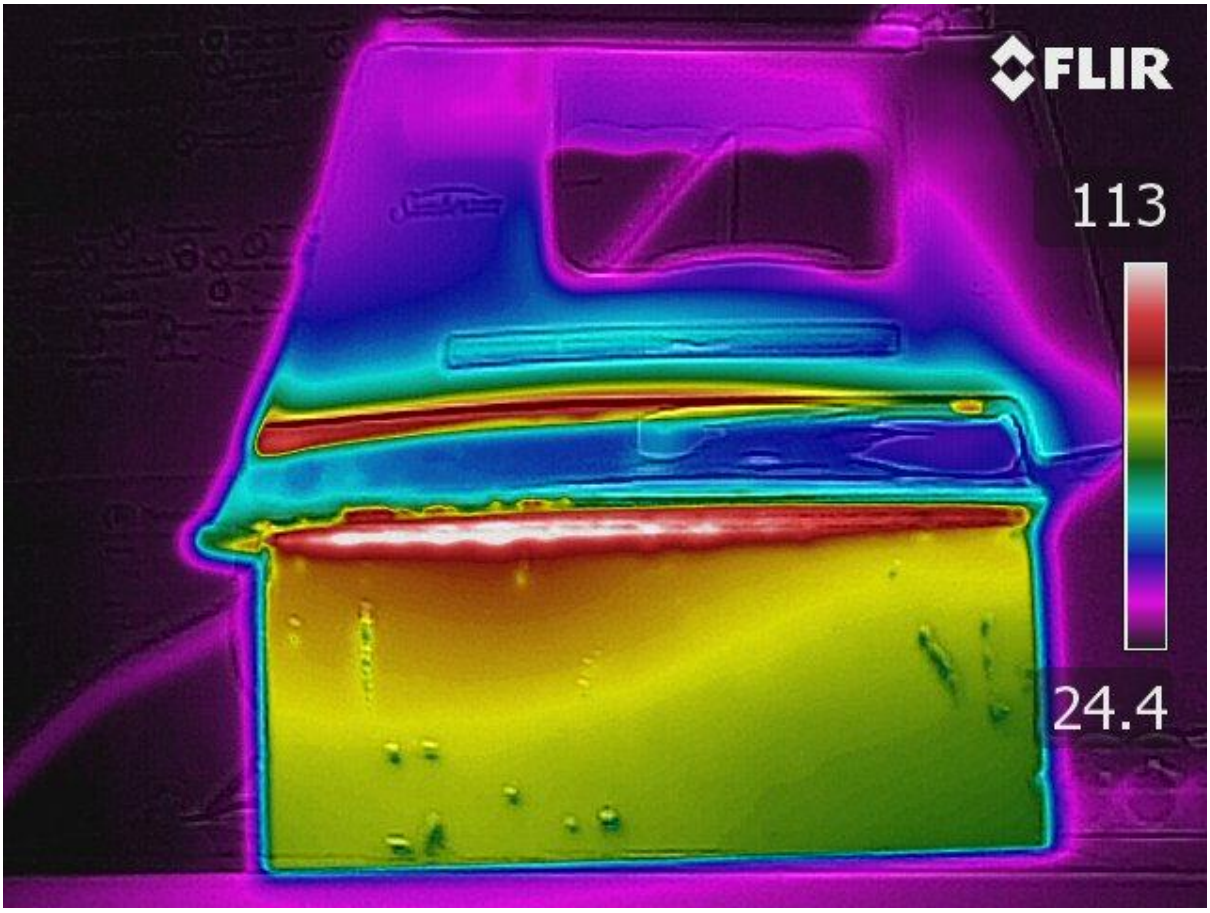
A 640 x 480 has 307,200 detectors (pixels) or measurement points.

The larger the array the better the spatial resolution

Conduction as we all know is the transfer of heat within a substance or between contacting substances without any exchange of mass.

In the demonstration we see that as the base plate of the clothes iron warms up some of the heat is then conducted to the Al block on which the iron sits.

Figure1 thermogram showing conduction



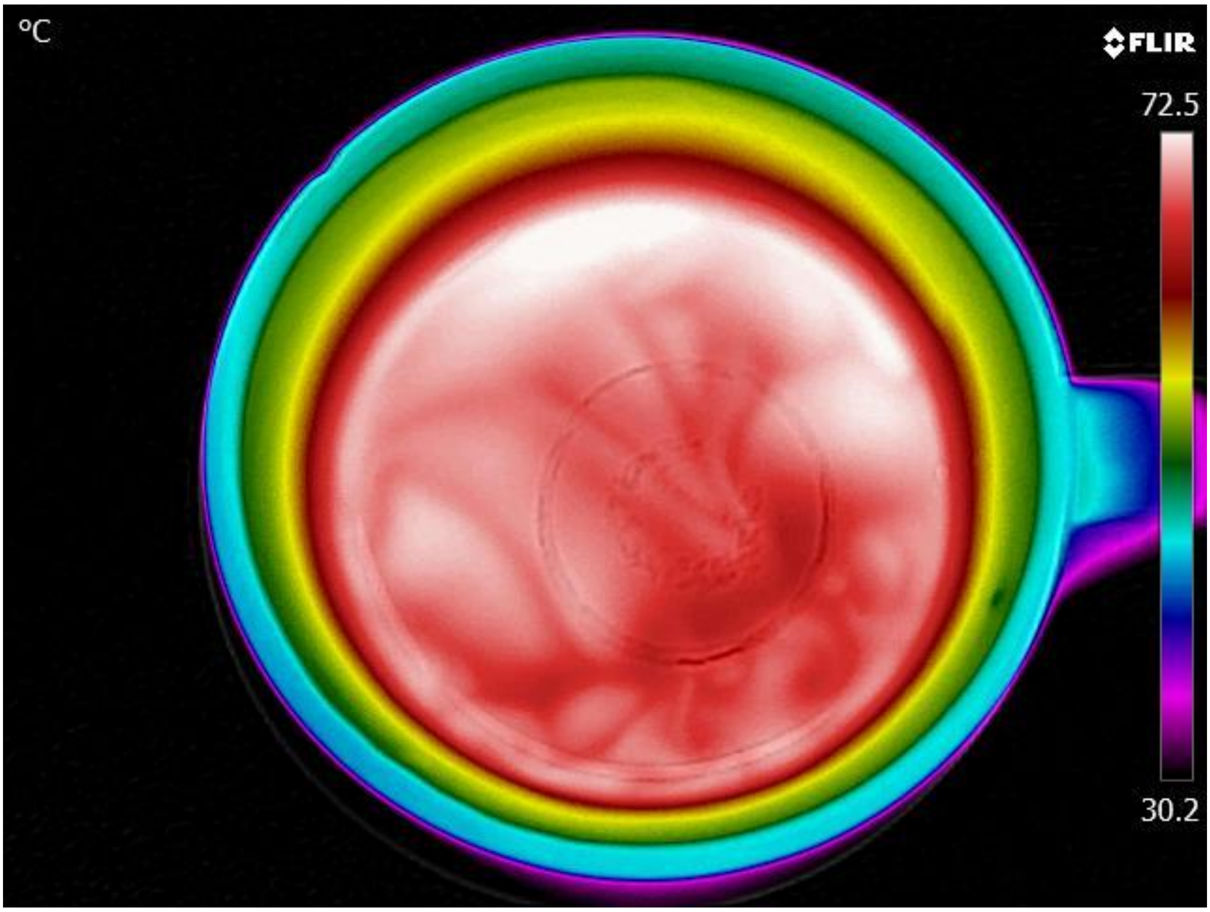
We can also see that the base plate of the iron is hotter towards the front.

Note the temperature gradients as the heat is conducted away from the base plate of the iron.

Convection: requires a moving medium to transfer energy. Convection is not possible in a solid. Free convection occurs when the only motion is due to the normal interaction of hot and cold molecules.

In the demonstration we see the convection currents on the surface of the hot water in the cup.

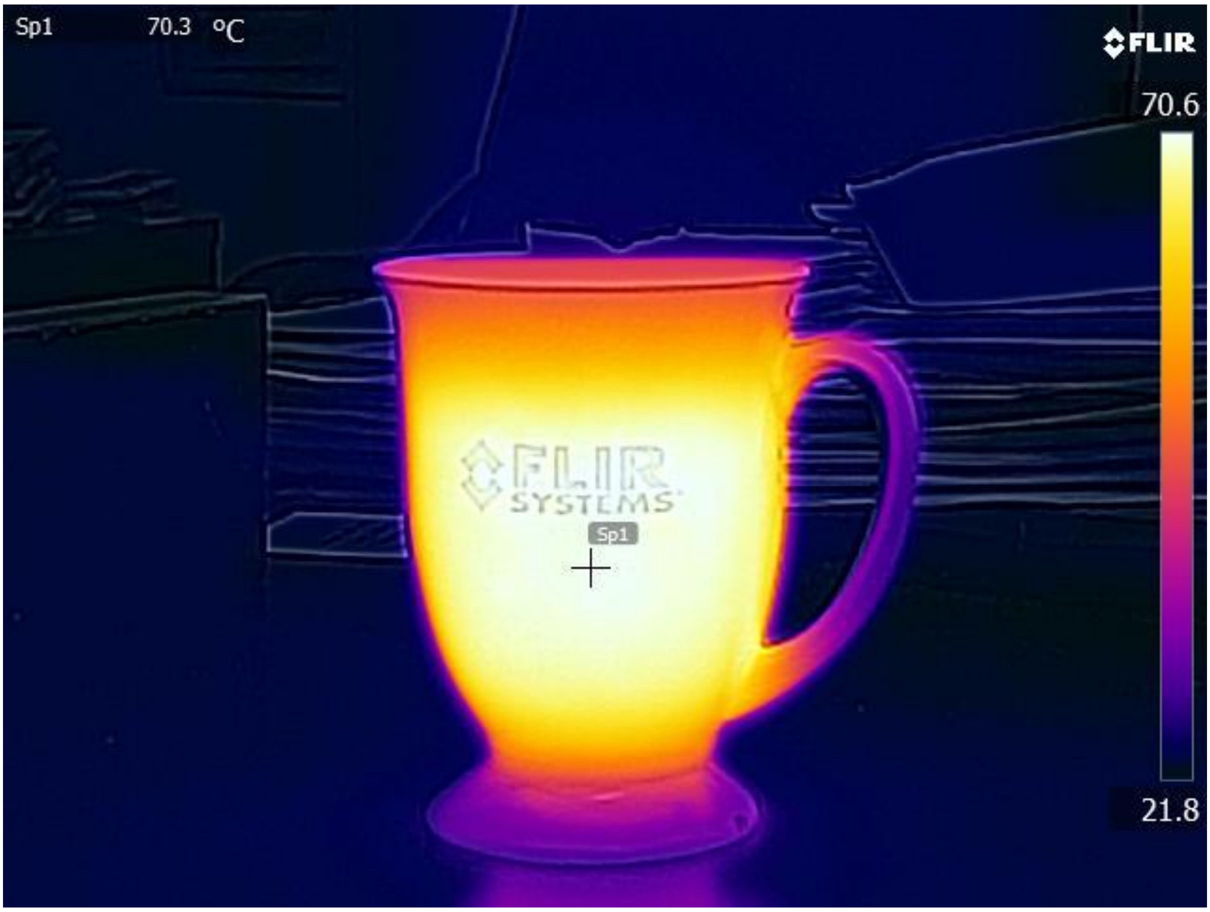
Figure 2 thermogram showing convection



In the live demonstration it can be seen that there is movement on the surface of the water (even though the surface appears perfectly still to the naked eye) due to the interaction of the hot and cold molecules.

Radiation: does not require a medium for the transfer of energy and therefore no direct contact between hot and cold substances. It involves “waves of energy” leaving one substance and being received by another.

Figure3 thermogram showing the energy radiated from the hot cup being received by the detector of the IR camera. Note! We can also see the water level in the cup.



For numerous other applications refer to the FLIR IR Primer Thermography booklet.