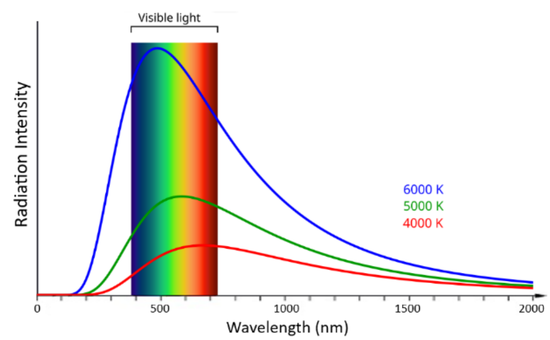
Observations with an Infrared Camera

Purpose

Investigate heat related physics with an infrared camera.

Introduction and Theory

Heat is a form of energy. Like height is a measure of gravitational potential energy, temperature is a measure of heat energy. One way to measure temperature is via thermal radiation, like infrared (IR) thermometers and infrared cameras. While IR cameras are not accurate in measuring the temperature of an object, they are good at showing the temperature difference of different objects and create so-called thermal images. We will use IR cameras to observe some heat related phenomena in this lab.



What is thermal radiation? All objects emit energy in the form of electromagnetic waves, and the wavelengths of this emission depend on the object's temperature. For example, the sun (surface temperature about 6000 K) emits electromagnetic waves with visible light with wavelengths peaked at about 500 nm. If you heat iron to around 600°C, it will emit visible red light. Red light has a wavelength from 620 nm to 750 nm, which is at the longer end of visible light. Most objects we see in our daily lives do not have such high temperatures, and the waves they emit have longer wavelengths, invisible to human's eyes, known as infrared light. The wavelength of infrared light ranges from about 700 nm to 1 mm, and the temperature of these objects typically ranges from 100°C to – 40°C.

You can read more about thermal radiation at https://en.wikipedia.org/wiki/Thermal_radiation.

Use of the IR camera: Turn on the power by holding the button for 2 seconds. You will see three markers on the screen: the central, stationary marker and jumping red and green markers. The big yellow reading is the temperature at the central marker's location. The red marker is at the highest temperature in the field of viewing, and the green marker at the lowest temperature. Their temperatures are shown with the small red and green readings.

Occasionally, the screen may freeze for a few seconds. This is normal, and all you need to do is to resume measurements afterwards.

Activity 1-3 will be done on your desk. The class will do Activity 4 together in the center of the room, then you will go around the room to finish Activity 5. Answer all numbered questions on this handout. You may use pen or pencil.

Apparatus A glass beaker with hot water in it, sitting on a hot plate (set to 3), a glass thermometer, two paper cups, a styrofoam cup, an IR camera, a stopwatch.

Note: the uncertainty and the sig. figs. are not the emphasis of this lab. To keep it simple, use uncertainty = ±0.5 °C for all temperature readings and you don't need to write them down. Record all temperatures to 1 decimal place.

Activity 1 First observations and get familiar with the IR camera

Observe the room with the IR camera for a minute. Then the instructor will turn off the light and let you observe the room in darkness. After about 2 minutes, the light will be back on.

1-1 Does the room appear to be the same with / without light?

1-2 What are the warm objects in the room?

After the room lights are back on, observe your hand with the IR camera, and take some temperature measurements. When reading a temperature, hold the IR camera about 10 to 15 cm from the hand and position the central marker at where you are measuring. If the big yellow reading jumps continuously, hold everything still to let the reading stabilize. If it still jumps, wait until the jump is back and forth and just take a reading. Don't take reading if the jump is always one way.

1-3 The temperature of the centre of my palm is _________, and the center of my partner's palm is _________.

1-4 The temperature of the centre of the back of my hand is _________, and the center of my partner's back of the hand is _________.

Activity 2 Measure temperatures with an IR camera; emissivity

First, we want to see if the angle affects the temperature measurement of the IR camera.

You can pick any object to test this, but your palm is a convenient choice. Aim the IR camera at the center of your palm, first directly into, then at about 45º angle, and then sideways. You may find it is easier to turn your palm rather than the camera.

2-1 Do you think the angle affects the temperature reading of the IR camera? ☐ Yes ☐ No

Next, we want to see if the distance affects the temperature measurement of the IR camera.

Again, your palm or your partner's palm is a convenient object. Aiming straight into your partner's palm and change the distance from ~10 cm to about a meter. Repeat if needed.

2-2 Does the distance to the object affect the temperature reading? ☐ Yes ☐ No

You may find that both the angle and the distance somewhat affect the temperature reading, but the effect is not very big if the variation of the angle or the distance is mild. However, there are other things that may affect the temperature reading. Next, we will test if the surface material affects the temperature readings of the IR camera.

Leave the glass beaker on the hot plate and keep the setting of the hot plate at 3. Check with the glass thermometer that the temperature of the hot water in the beaker is between 50 to 60 °C. Then take the temperature readings with the thermometer and the IR camera. To accommodate jumping readings, there are two columns for the IR camera: a low reading and a high reading. They can be the same if the reading is steady.

Table: Temperature of hot water in the glass beaker

	Low reading		High reading
Glass thermometer reading at the beginning			
IR camera aiming at water from the top		to	
IR camera aiming at glass from the side		to	
IR camera aiming at aluminum foil		to	
IR camera aiming at paper towel		to	
Glass thermometer reading at the end			

You will see that reading at the aluminum foil is much lower than other readings. In fact, through the IR camera, you can see the foil on the beaker – it shows up as a dark region. The reason for this is that aluminum foil, and metallic surfaces in general, have low emissivity and high reflectivity. IR camera measures the temperature by thermal radiation from the target, and that includes emitted, transmitted and reflected waves. The thermal radiation from the aluminum foil is mostly reflected waves from the surrounding, that is why it is close to room temperature (ambient temperature). To prove that, you can put your hand near the foil and read the foil temperature again: it will be close to the temperature of your hand. In fact, the reflection is so strong that you can see an image of your hand on the aluminum foil in the IR camera.

Emissivity and reflectivity: a surface that absorbs all thermal radiation and reflects none is a perfect emitter (emissivity = 1), called a blackbody. A surface that reflects all thermal radiation and absorbs none is a perfect reflector (emissivity = 0). Most objects we encounter in daily life, except metallic surfaces, have high emissivity, so the IR camera has a default setting of emissivity = 0.95. (You can check this in the settings.) The exact emissivity of an object maybe close to 0.95, but it is hard to say. Therefore, the temperature measurements by the IR camera are estimated only.

You can see that the angle, the distance, surface materials, and the ambient temperature all affect the temperature readings of an IR camera. Therefore, we should not rely on it to give us accurate temperature reading. But the IR camera has its advantages. It can observe temperatures of many objects at the same time and can spot anything that is unusual, even in darkness. Also, it is a touchless measurement which has its convenience.

Activity 3 Heat transfer

Turn off the hot plate and pour the hot water in the glass beaker equally into (1) a paper cup with lid, (2) a paper cup without lid, and (3) a Styrofoam cup. Using the IR camera to observe from the top and the side and then measure the temperatures at the center of the warm regions. When you measure the first cup, remove the lid temporarily. Fill in the first row of the table below. "Time" only needs to be recorded to the minute.

When waiting for the water to cool, we will do Activity 4 together with the instructor. After about 30 minutes, repeat the measurements and fill in the second row of the table.

Table: Compare temperatures of hot water in three Cups (in °C)

	Top view			Side view		
	Paper cup with lid	Paper cup no lid	Styrofoam cup	Paper cup with lid	Paper cup no lid	Styrofoam cup
Time:						
~ 30 min later Time:						

3-1 How do the temperatures in each cup compare before and after the 30 minutes?

3-2 The paper cup without lid lost heat via (choose all that apply)

☐ Conduction ☐ Convection ☐ Radiation

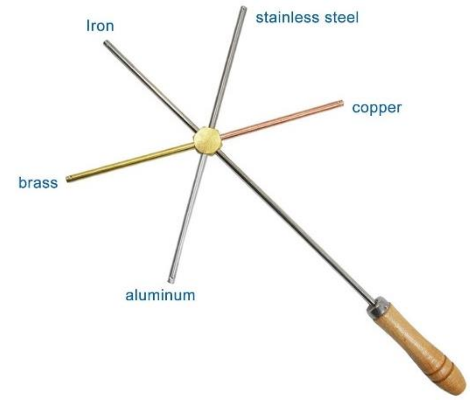
3-3 The paper cup with lid holds heat better because it has less

☐ Conduction ☐ Convection ☐ Radiation

3-4 The Styrofoam cup holds heat better because it has less

☐ Conduction ☐ Convection ☐ Radiation

Activity 4 Central station with the instructor, Conductivity of metal



This activity uses the apparatus shown in the picture. The instructor will stick a push pin under the end of each rod with petroleum jelly. He or she will then use a candle to heat the central peg. The heat will eventually melt the petroleum jelly and drop the pins.

Once the instructor moves the candle under the central peg, start your stopwatch. Record the time (minutes and seconds) when each pushpin drops. Do not stop the stopwatch until the last pin drops. While waiting, partners should take turns to watch the apparatus with the IR camera and each takes a screenshot. Later, you can press “Setting” then “Storage” to view the screenshots.

Table: How long is the central peg heated by candle flame before pushpins drop

Aluminum (Al)	
Brass (CuZn)	
Iron (Fe)	
Stainless steel (S.S.)	
Copper (Cu)	

4-1 List the metal in the order of conductivity from high to low based on your screenshots.

4-2 List again based on the time taken for the pushpins to drop. Is it the same as the previous answer?

4-3 There are many parameters like density, resistivity, specific heat, that are unique to the material, independent of its size and mass. Thermal conductivity is such a parameter: at a given temperature difference, it describes how much thermal energy passes through the material per unit time. What unit would you give to thermal conductivity? *(Hint: write down an equation to calculate the energy passed through the rod driven by the temperature difference.)*

Activity 5 Fun with the IR camera

Your group will go around the room to play the following (sequence does not matter):

Heat from friction View the countertop with your IR camera and select a dark region. Write something on the countertop with an eraser and then look at it through the IR camera. Try ways to make writing more visible. Which physical quantity(s) is related to the visibility?

Absorption Shine an incandescent light bulb on a piece of white paper with black writing on it. After removing the light, what do you see on the paper under the camera?

Cold water Observe the glass beaker with ice-water. Recall that the aluminum foil appears to be much colder than other parts of the beaker in Activity 2. Is it still true?

Transmitted thermal radiation Hold in front of your body different sheets of materials and let your partner look at you with the IR camera. If you wear eyeglasses, bring the sheet in front of your face: can your partner see that you are wearing glasses? (You can write notes below.)

1. A glass sheet:
2. A plastic bag:
3. A sheet of black garbage bag:
4. A sheet of aluminum foil:
   Aluminum foil again: look at the reflection:
5. A sheet of cardboard:

Pick one of the above that you find most interesting and write down your observations and explanations below.

End of lab short quiz

1. The thermal radiation detected by the IR camera consists of
   - ☐ emitted waves
   - ☐ transmitted waves
   - ☐ reflected waves

2. IR camaras can be used in the following:
   - ☐ Detecting heat loss in a house
   - ☐ Finding in a crowd who has a fever
   - ☐ Accurate temperature measurements
   - ☐ Wildlife monitoring

3. Comparing thermal radiation and the visible light, their transmission through materials:

   __________ is transmittable for both visible light and thermal radiation.

   __________ is transmittable for visible light, but not for thermal radiation.

   __________ is transmittable for thermal radiation, but not for visible light.

   __________ is not transmittable for both visible light and thermal radiation.

   a. Air
   b. Water
   c. Glass
   d. Transparent plastic bag
   e. Black garbage bag
   f. Cardboard

4. Order the following in their heat conductivities: ____________________.

   a. Copper
   b. Stainless steel
   c. Styrofoam
   d. Paper

After you finish this lab, empty water out of all cups to the sink. Leave all the apparatus on the desk and connect the IR camera to the charging cable.