I. Objectives

1. Investigate the principle of energy transfer through radiation and the concept of emissivity.
2. Examine the physical characteristics of an object that influence its emissivity.
3. Determine how reflectivity and color affect temperature changes.

II. Introduction

The surface of an object plays a significant role in determining how much radiant energy an object will emit or absorb. Surface features can include color, reflectivity, degree of roughness, as well as others. Objects emit and absorb electromagnetic waves simultaneously. When an object has the same constant temperature as its surroundings, the amount of radiant energy absorbed must balance the amount emitted. If absorption exceeds emission, then the energy of the object would increase; if emission exceeds absorption, then the energy of the object would decrease.

The amount of radiant energy emitted by an object is proportional to its emissivity, fourth power of the Kelvin temperature, surface area, and emission time. These relationships are expressed mathematically as the Stefan-Boltzmann Law of Radiation:

$$Q = e\sigma T^4 At$$

where

Q = radiant energy

e = emissivity

$\sigma = 5.67\ x\,10^{-8}\ J/s\ m^2\ K^4$

T = temperature in Kelvins

A = surface area

t = time

Emissivity e depends on the surface conditions of the object.

III. Calculations

The amount of heat that must be supplied or removed to change the temperature of a substance is:

$$Q = mc\Delta T$$

where

m = mass of the substance

c = specific heat of the substance

ΔT = temperature change

IV. Equipment and Materials

Infrared thermometer, objects on campus, black, silver and white radiation cans with stoppers and thermometers, 250 mL graduated cylinder, calculator

V. Procedure

Part 1 Temperatures of Common Objects

1. In Table 1 record the temperature of 25 different objects taken at right angles to the objects under different lighting conditions and situations. Be sure to select a variety of metallic, non-metallic, highly reflective, non-reflective, dark, light, rough, and smooth objects.

2. Find the emissivity of as many of the objects as possible using the Internet or other sources and enter the values in column H. If you leave the last column blank you will receive no credit for Table 1.

Part 2 Radiation Cans

3. Fill black, silver, and white radiation cans each with 325 mL of tap water and allow the water to sit in the **uncorked** cans for approximately 10 minutes.

4. After 10 minutes, put the corks with the thermometers in the radiation cans.

5. After 5 additional minutes, with the corks and thermometers in the cans, record the initial water temperature in Table 2 below for time $t = 0$ seconds.

6. Place all three cans outside in the same lighting conditions, preferably in direct sunlight.

7. Record the water temperature in each can every 3 minutes, until you have 10 data points for each can or until the temperature in **all three can**s remains the same for three consecutive temperature readings.

8. On the same graph, graph the temperature *T* versus time *t*, using *t* as the x-coordinate and temperature *T* as the y-coordinate for each one of the cans. There will be three separate lines on the graph, one for each of the cans. You must include the three separate exponential best fit lines generated by the spreadsheet program, not a hand drawn line, to connect the points for each radiation can on the graph. Staple the graph to the lab.

VII. Data

Table 1 Temperatures and Characteristics of Campus Objects

A	B	C	D	E	F	G	H
Object	Temper-ature	Color	Lighting conditions: indoor, sunlight, shade	Reflectivity: high, medium, low	Surface: rough, smooth	Metallic or non-metallic	Emissivity

Table 2 Radiation Can Water Temperatures

A	B	C	D
Time *t* in *s*	Black can water temperature in ^{0}C	Silver can water temperature in ^{0}C	White can water temperature in ^{0}C
0			

VIII. Discussion Questions

Part 1 Temperatures of Common Objects

1. What physical characteristics affect the emissivity of an object? List at least 3.

2. What is the physics related definition of a black body?

3. What kind of radiation do black bodies emit at room temperature?

4. The surface area of an adult human is about 2.0 m^2. If the ambient temperature T_0 = 24^{0}C and the surface temperature of the adult human is T = 28^{0}C, calculate the radiated power $P = e\sigma(T^4 - T_0^4)A$. Hints: what temperature scale must be used? http://hyperphysics.phy-astr.gsu.edu/Hbase/thermo/bodrad.html

5. How many joules per day is this?

Part 2 Radiation Cans

6. Does reflectivity and color affect the rate at which the water in the cans changes temperature? If so, how?

7. How would the outside temperature affect the rate at which the temperature inside the cans changes?

8. How would the sun angle affect the rate at which the temperature inside the cans changes?

9. How much heat was required to change each of the three cans from the initial to the final water temperature? Hint: you need the mass and specific heat of the water. You must show your calculations to receive credit for this question.

   white can:

   silver can:

   black can: