

Homework 6

Score _____ / 30

- (3 pts) The ground temperature for coastal cities varies less than the ground temperature of inland cities. Why?
- (3 pts) (a) If two objects are at the same temperature, do they contain the same amount of thermal energy? Why or why not? (b) If two objects have the same mass and are at the same temperature, do they contain the same amount of thermal energy? Why or why not?
- (4 pts) I have two solid bars with a square cross section. Both have a cross section of 1 cm^2 , and both are 30 cm long, but one is made of copper and one of iron. I place the two side by side and braze them together, making a composite bar which is 30 cm long with a cross section of 2 cm^2 . I then place one end of this rod in boiling water and one end in ice water. How much power will be conducted through the rod when it reaches steady state?
- (7 pts) Hot water from my water heater passes through a section of insulated pipe. The pipe is made of iron with an inner diameter of 1 cm and an outer diameter of 1.3 cm. The pipe is then surrounded by a thin layer of rubber out to a diameter of 1.4 cm. Assuming that the water is flowing quickly enough that the temperature of the water is always 40°C and that the outer surface of the rubber is always at 25°C , (a) what is the difference in the temperature of the water and the temperature at the iron/rubber interface, and (b) how much power flows out of a section of pipe which is 2 meters long? Hint: you have to integrate.
- (4 pts) A typical 100 Watt incandescent bulb has a filament which is at a temperature of 3000 K. Typically, of the 100 W that goes into the bulb, 98 W is conducted or convected away and only about 2 W is radiated as light (and most of that is invisible infrared light — now you see why incandescent lights are so inefficient). (a) If we assume the emissivity of the tungsten filament in such a bulb is 0.5, what is the surface area of the filament in a typical 100 W bulb? (b) If we could raise the temperature we would expect that the losses due to conduction and convection to go up by about the same factor as the temperature increase. But blackbody radiation scales as T^4 . If we increase the temperature of the filament by 50% to 4500 K, by what factor will the light output increase? Unfortunately, if the filament gets too hot, it will melt or vaporize. This is why almost all incandescent bulbs run at about the same temperature - as hot as possible without quickly destroying the tungsten filament. This is also the secret to Halogen bulbs — the halogen gas in the bulb reduces the rate at which the tungsten evaporates from the filament, allowing them to operate at higher temperatures for more brightness and efficiency.
- (5 pts) The intensity of the light from the sun at the radius of the Earth's orbit is 1340 W/m^2 . Assuming that the emissivity of the Earth is the same for all wavelengths of light, calculate the temperature of the Earth in steady state. You should get something very cold. The reason that the Earth is not this cold is due to the fact that the emissivity of the Earth depends strongly on wavelength due to the so-called "greenhouse effect." Because of the atmosphere, the Earth absorbs and emits visible radiation better than infrared radiation. Since the sun is very hot, it emits a lot of visible light which is absorbed by the Earth. Since the Earth is much colder it emits mostly infrared light. The clouds are very reflective in the infrared, so the emissivity is small right where the Earth would be radiating most of its blackbody radiation otherwise. On the moon, however...
- (4 pts) The wall of a house is 10 feet tall by 25 feet wide. It is made of a 4 inch layer of brick followed by a 3.5 inch layer of fiberglass batting which is covered by a 0.5 inch sheet of drywall. (a) What is the R value for the wall (in $\text{ft}^2 \cdot ^\circ\text{F} \cdot \text{h/Btu}$)? Don't forget about the stagnant air layer on both sides of the wall. (b) How much power (in Btu/hr) will be flowing through the wall if the inside air is at a temperature of 62°F and the outside air is at a temperature of 0°F . (c) How many Watts is that? (One Btu = 1054 J).

Extra problems I recommend you work (not to be turned in)

- Imagine a copper rod which is 1 cm in diameter and 10 cm long. One end of the rod is kept at 0°C and the other is heated with a torch. How hot do we have to get the end of the rod before the power radiated by the rod is 0.1% of the power conducted through the rod?

- I have two solid round bars which are 1 cm in diameter. One, made of copper, is 20 cm long. The other, made of iron, is 10 cm long. I braze one end of the copper bar to one end of the iron bar to make a bar with a combined length of 30 cm. I then place the very tip of the copper end of the bar in a pot of ice water and the very tip of the iron end in a pot of boiling water. (a) When the bar has reached “steady state,” what will the temperature be at the junction between the iron and the copper? (b) How much power will be conducted through the rod?
- Now consider many rods made of different materials brazed end to end. Prove that we can solve this problem by adding R values.
- Imagine a spherical ball with emissivity ϵ_1 suspended at the center of a spherical vacuum chamber with emissivity ϵ_2 . Show that if and only if the ball is at the same temperature as the chamber, the rate at which it emits blackbody radiation will be equal to the rate at which it absorbs radiation.
- Put something plastic and something metal somewhere where they will get significantly hotter or colder than room temperature. Let them come into thermal equilibrium. (a) What did you choose and where did you put them? (b) Which one will *feel* “hottest”/”coolest” if you pick it up? (c) Why? (d) Try it. Were you correct? Note: on a day which is very sunny (or cold) you simply find a metal and plastic object which has been outside for a long time (like a plastic sign on a metal sign post).
- A cylindrical insulating bucket is filled with water at 0°C . The air above the water has a temperature of -12°C . If the air remains at this temperature, how long will it take for a 1 cm layer of ice to form on the surface of the water?