Physics 06-07 Convection and Radiation	***Name:*** ______________________

Convection

- Flow of heat due to the ______________ of matter
- Artificial
  - ______________ system pumps blood
  - ______________ pumps antifreeze
- Natural
  - Difference in ______________ of fluids with different temperatures
  - Warm air rises, cold air falls

When you are working out, your sweat evaporates to cool you. How much sweat must evaporate to lower the body temperature of a 80-kg man by 1°C?

One winter day, the climate control system of a large university classroom building malfunctions. As a result, 250 m^3 of excess cold air is brought in each minute. At what rate in kilowatts must heat transfer occur to warm this air by 10.0°C (that is, to bring the air to room temperature)?

Wind chill

- Air feels colder when wind is blowing because heat is removed by ______________ as well as ______________.

At what temperature does still air cause the same chill factor as 2°C air moving at 5 m/s?

Table 14.4 Wind-Chill Factors

Moving air temperature	Wind speed (m/s)				
(°C)	**2**	**5**	**10**	**15**	**20**
5	3	−1	−8	−10	−12
2	0	−7	−12	−16	−18
0	−2	−9	−15	−18	−20
−5	−7	−15	−22	−26	−29
−10	−12	−21	−29	−34	−36
−20	−23	−34	−44	−50	−52
−10	−12	−21	−29	−34	−36
−20	−23	−34	−44	−50	−52
−40	−44	−59	−73	−82	−84

Radiation

- Transfer of energy via ____________________ waves (radio waves, microwaves, x-rays, infrared, and visible light)
- All bodies (objects) ______________ emit radiation
  - Bodies like ice cubes emit ______________ radiation
  - Warm bodies, like human bodies, emit ______________ radiation
  - When the temperature of a body reaches ______________, it starts to emit visible dull red light
  - When the temperature of a body reaches ______________, it emits white-hot light
- Different objects react differently to radiation
  - Black box ______________ most of radiation
  - Silver box ______________ little radiation
    - The rest of the radiation is reflected
- Blackbody is an object that ______________ ______________ radiation that hits it
  - All objects ______________ and ______________ radiation continually—Good absorbers are also good emitters

Stefan-Boltzmann Law of Radiation

$$\frac{Q}{t} = \sigma e A T^4$$

- $\frac{Q}{t}$ = rate of heat transfer, σ = 5.67x10^{-8} J/(s m^2 K^4), e = emissivity (% of radiation emitted as compared to a perfect emitter), A = surface area, T = temperature in Kelvin

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Because heat is both ________________ and ________________ at the same time, the ________________ of heat transfer by radiation is

$$\frac{Q}{t} = \sigma e A(T_2^4 - T_1^4)$$

- T_1 = temperature of object, T_2 = temperature of surrounding, e = emissivity of object, A = surface are of object

Find the rate that heat is radiated by the sun if the surface temperature is 6000K and emissivity = 1.

Find rate that heat is radiated from a bald head if we estimate that it is a sphere with radius 120 mm and emissivity of 0.97. (Body temperature is 37.0°C and the surrounding room is at 20°C)

Homework

1. One often hears about heat transfer by convection in gases and liquids, but not in solids. Why?
2. One way that heat is transferred from place to place inside the human body is by the flow of blood. Which one of the three heat transfer processes best describes this action of the blood? Justify your answer.
3. A pot of water is being heated on an electric stove. The diameter of the pot is smaller than the diameter of the heating element on which the pot rests. The exposed outer edges of the heating element are glowing cherry red. When you lift the pot, you see that the part of the heating element beneath it is not glowing cherry red, indicating that it is cooler than the outer edges. Why are the outer edges hotter?
4. If you were stranded in the mountains in cold weather, it would help to minimize energy losses from your body by curling up into the tightest ball possible. Which of the factors in Stefan-Boltzmann Law of Radiation are you using to the best advantage by curling into a ball? Why?
5. Why are cloudy nights generally warmer than clear ones?
6. Why are thermometers that are used in weather stations shielded from the sunshine? What does a thermometer measure if it is shielded from the sunshine and also if it is not?
7. At what wind speed does −10°C air cause the same chill factor as still air at −29°C? (OpenStax 14.45) **10 m/s**
8. The “steam” above a freshly made cup of instant coffee is really water vapor droplets condensing after evaporating from the hot coffee. What is the final temperature of 250 g of hot coffee initially at 90.0°C if 2.00 g evaporates from it? The coffee is in a Styrofoam cup, so other methods of heat transfer can be neglected. (OpenStax 14.47) **85.7°C**
9. (a) How many kilograms of water must evaporate from a 60.0-kg woman to lower her body temperature by 0.750°C? (b) Is this a reasonable amount of water to evaporate in the form of perspiration, assuming the relative humidity of the surrounding air is low? (OpenStax 14.48) $\mathbf{6.44 \times 10^{-2}}$ **kg, Yes**
10. The Kilauea volcano in Hawaii is the world’s most active, disgorging about 5×10^5 m^3 of 1200°C lava per day. What is the rate of heat transfer out of Earth by convection if this lava has a density of 2700 kg/m^3 and eventually cools to 30°C? Assume that the specific heat of lava is the same as that of granite. (OpenStax 14.51) $\mathbf{2 \times 10^4}$ **MW**
11. During heavy exercise, the body pumps 2.00 L of blood per minute to the surface, where it is cooled by 2.00°C. What is the rate of heat transfer from this forced convection alone, assuming blood has the same specific heat as water and its density is 1050 kg/m^3? (OpenStax 14.52) **293 W**
12. At what net rate does heat radiate from a 275-m^2 black roof on a night when the roof’s temperature is 30.0°C and the surrounding temperature is 15.0°C? The emissivity of the roof is 0.900. (OpenStax 14.55) **−21.7 kW**
13. (a) Cherry-red embers in a fireplace are at 850°C and have an exposed area of 0.200 m^2 and an emissivity of 0.980. The surrounding room has a temperature of 18.0°C. If 50% of the radiant energy enters the room, what is the net rate of radiant heat transfer in kilowatts? (b) Does your answer support the contention that most of the heat transfer into a room by a fireplace comes from infrared radiation? (OpenStax 14.56) **−8.80 kW, yes**
14. Find the net rate of heat transfer by radiation from a skier standing in the shade, given the following. She is completely clothed in white (head to foot, including a ski mask), the clothes have an emissivity of 0.200 and a surface temperature of 10.0°C, the surroundings are at −15.0°C , and her surface area is 1.60 m^2. (OpenStax 14.59) **−36.0 W**
15. The Sun radiates like a perfect black body with an emissivity of exactly 1. (a) Calculate the surface temperature of the Sun, given that it is a sphere with a 7.00×10^8-m radius that radiates 3.80×10^{26} W into 3-K space. (b) How much power does the Sun radiate per square meter of its surface? (c) How much power in watts per square meter is that value at the distance of Earth, 1.50×10^{11} m away? (This number is called the solar constant.) (OpenStax 14.62) $\mathbf{5.74 \times 10^3}$ **K,** $\mathbf{6.17 \times 10^7}$ **W/m²,** $\mathbf{1.34 \times 10^3}$ **W/m²**