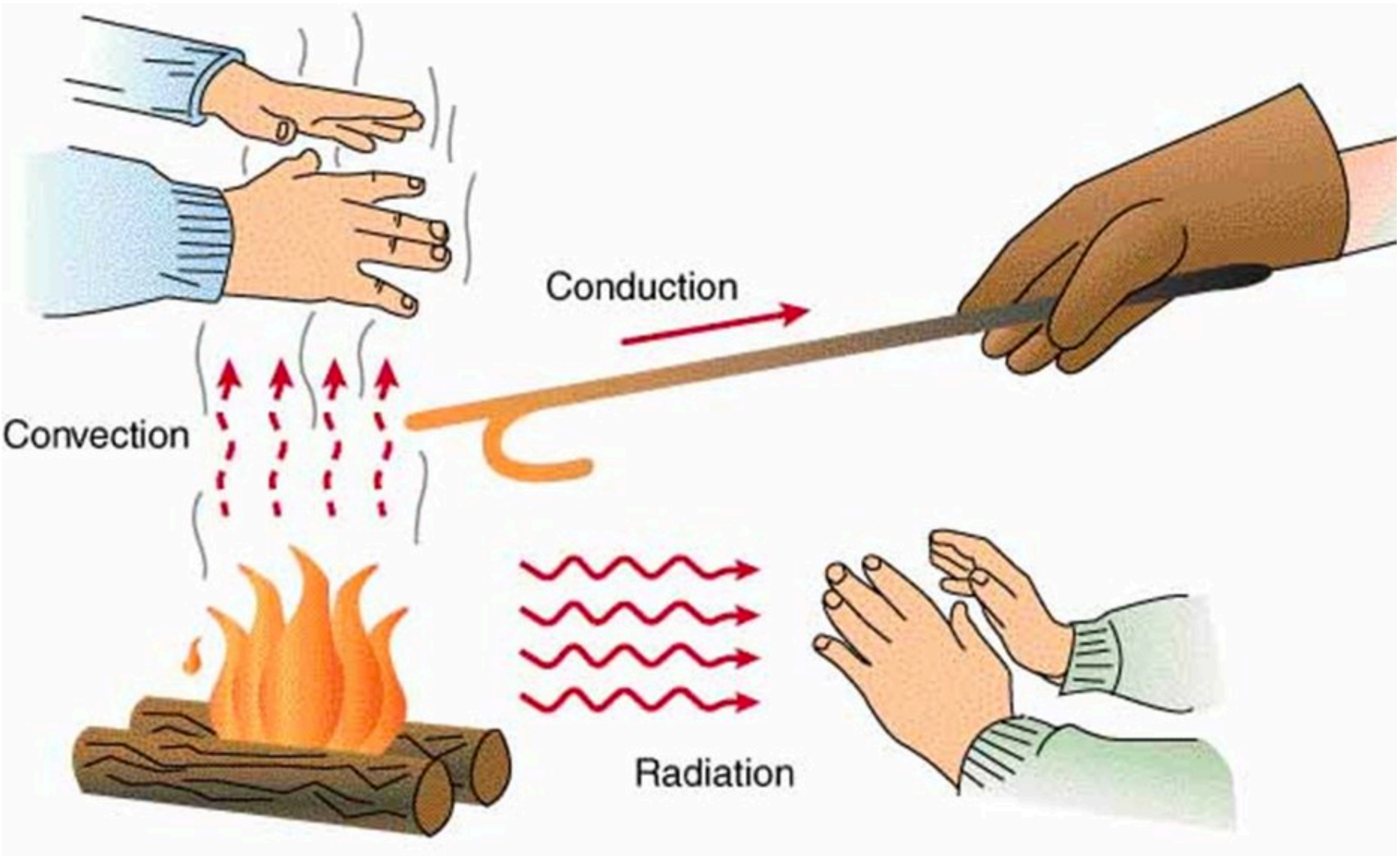
College Physics I: 1511 Mechanics & Thermodynamics

Professor Jasper Halekas
Van Allen Lecture Room 1
MWF 8:30-9:20 Lecture

Announcements

- I will be absent Monday-Wednesday [11/14-16]
  - All labs and discussions as usual
  - Prof. Kletzing will sub Monday and Wednesday
  - Office hours canceled Tuesday and Wednesday
  - Available by e-mail if questions arise
- Back on Thursday
  - Office hours on Thursday 11/17 as usual
  - Homework due Thursday night as usual
  - Lecture Friday 11/18 as usual

How is Heat Transferred?



Thermal Equilibrium

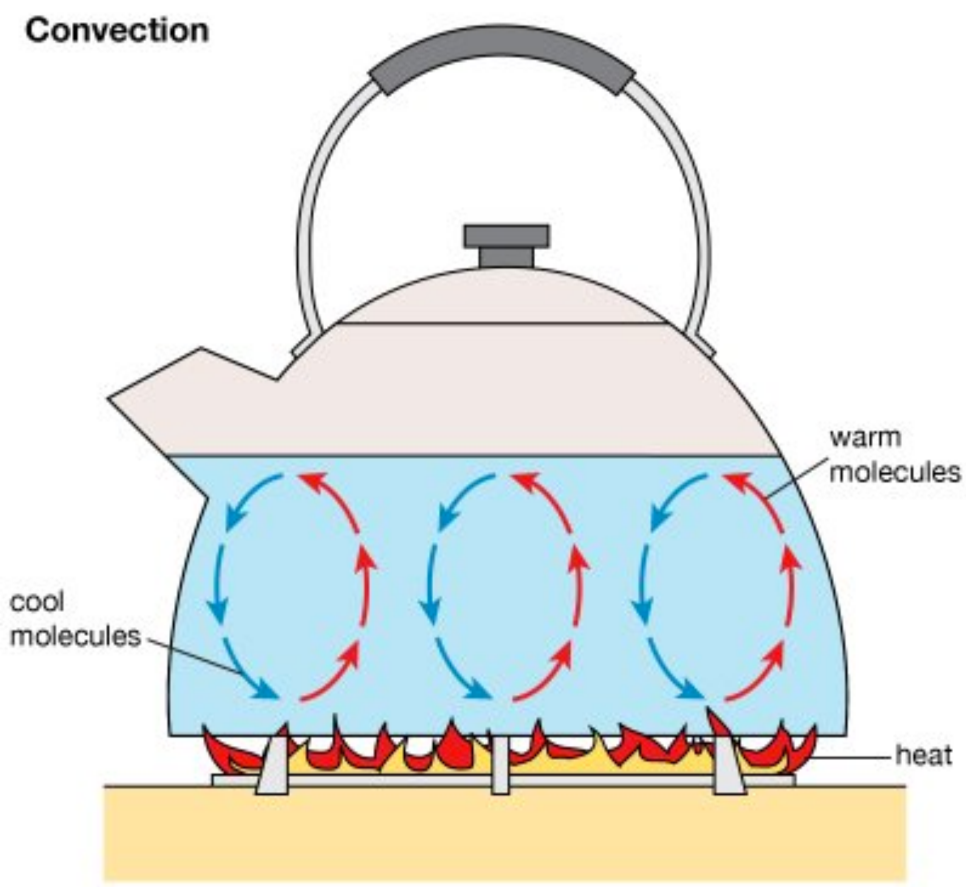
- Objects are in thermal equilibrium if they have the same temperature
- Bodies that are at different temperatures exchange heat to try to reach thermal equilibrium
- In different scenarios with different materials, different modes of heat transfer are more or less efficient
  - Heat uses whatever means it can to flow and try to reach thermal equilibrium

Convection

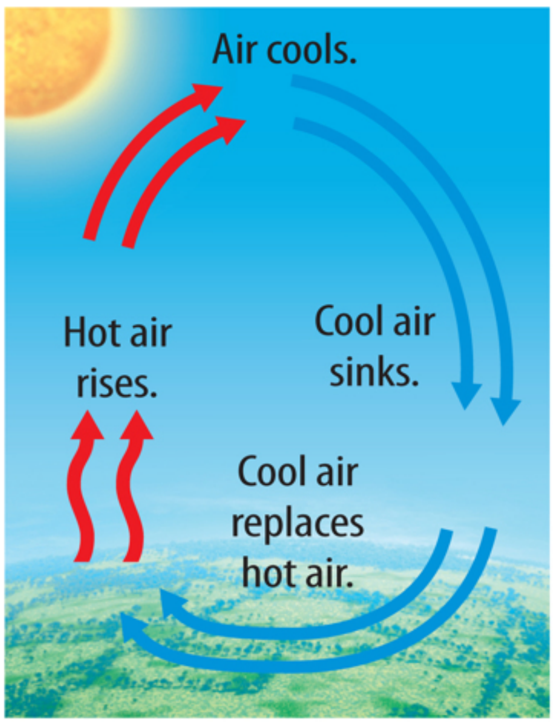
- Convection is a process by which warm fluid/ gas expands (becoming less dense) and rises while cold fluid/gas contracts and sinks

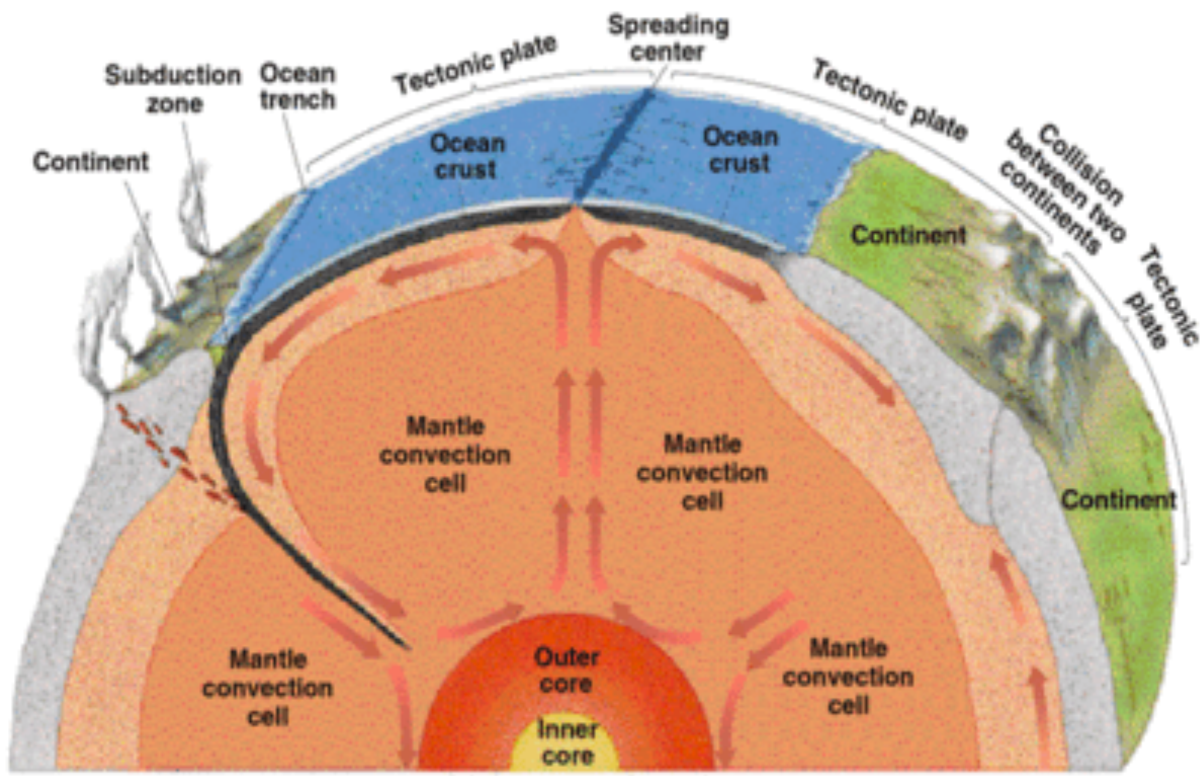
- This process can be explained by Archimedes' principle
  - Warm substance is less dense than surrounding, so buoyant force exceeds weight
  - Cold substance is more dense than surrounding, so weight exceeds buoyant force

Small-Scale Convection

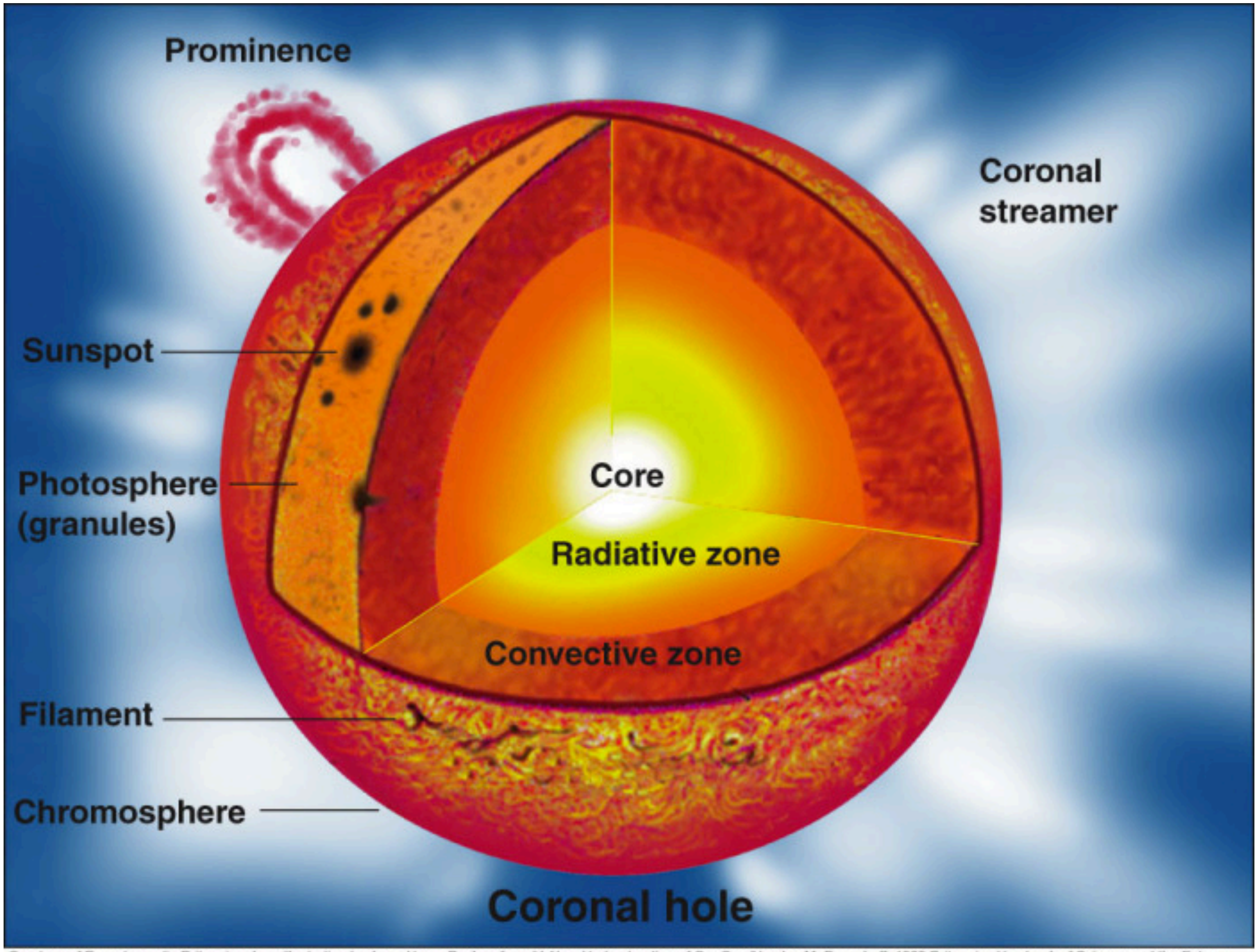


Large-Scale Convection





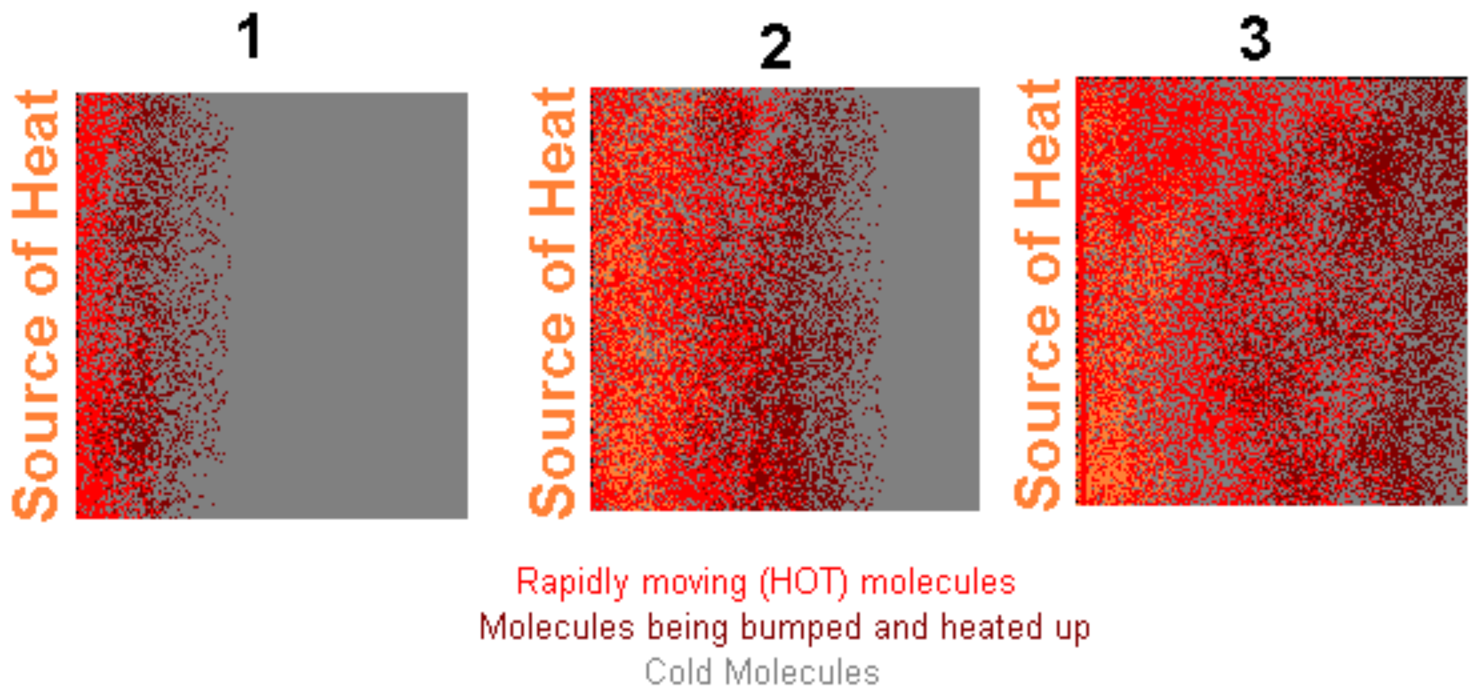
Really Large-Scale Convection



Courtesy of Encyclopaedia Britannica, Inc.; illustration by Anne Hoyer Becker; from "A New Understanding of Our Sun," by Jay M. Pasachoff, 1989 Britannica Yearbook of Science and the Future

Conduction

- Conduction is the process of transfer of heat directly through a material (often by collisions between atoms/molecules)



Concept Check

- Which heat transfer process would be most efficient in a solid?

A. Convection
B. Conduction
C. Both equal
D. Neither operates in a solid

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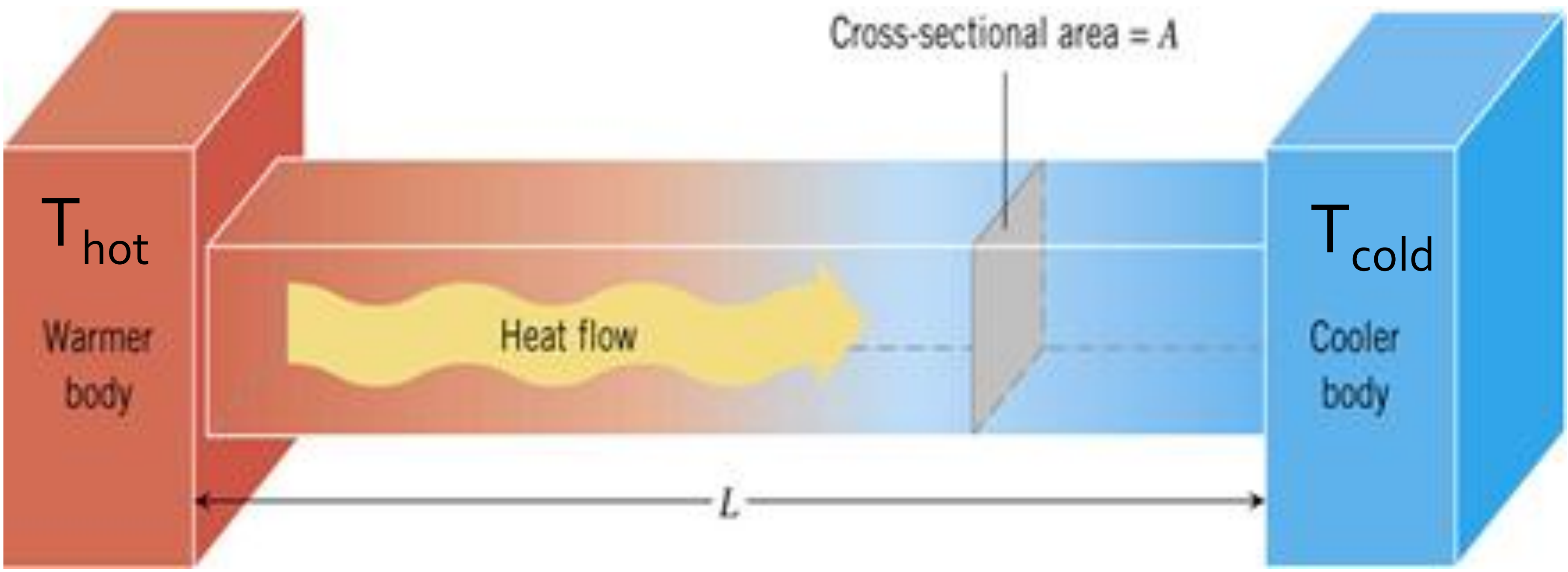
Conduction Vs. Convection

- Convection involves large-scale motions of fluid/gas
  - Doesn’t work in solids
- Conduction involves only microscopic motions
  - Most efficient in solids

Conduction Equation

- $Q/t = (kA\,\Delta T)/L = kA\,(T_{hot} - T_{cold})/L$



k = thermal conductivity = J/(s m °C)

Material Conductivity

Heat Conductivity* of Various Substances

SUBSTANCE	HEAT CONDUCTIVITY (Watts† per meter per °C)
Still air	0.023 (at 20°C)
Wood	0.08
Dry soil	0.25
Water	0.60 (at 20°C)
Snow	0.63
Wet soil	2.1
Ice	2.1
Sandstone	2.6
Granite	2.7
Iron	80
Silver	427

Don’t use these values in homework problems – only use values given in book!

Sample question

- How much heat can be transferred across a 1m x 1m x 1m iron cube in 20 seconds, if you hold two opposite faces at temperatures 10 degrees apart?

$$Q/t = kA\Delta T/L$$

$$= k \cdot 1^2 \cdot 10/1$$

$$= k \cdot 10$$

$$= 80 \cdot 10$$

$$= 800 \text{ J/s}$$

$$Q = 800 \cdot 20$$

$$= \boxed{16000 \text{ J}}$$

Concept Check

- Imagine you hold two ends of a rectangular bar of length L and cross-sectional area A at two different (constant) temperatures.
- If you double the scale of the object (in other words, double all linear dimensions), what happens to the rate of heat conduction through the bar?

A. Q/t goes up
B. Q/t goes down
C. Q/t stays the same

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$$Q/t = kA\,\Delta T/L$$

double scale

$$A \to 4A$$
$$L \to 2L$$

$$A/L \to \frac{4A}{2L} = 2\,A/L$$

Q/t goes up!

Specific Heat Vs. Conductivity

- $Q = m\,c\,\Delta T$ (specific heat)
- $Q/t = kA\,\Delta T/L$ (conduction)

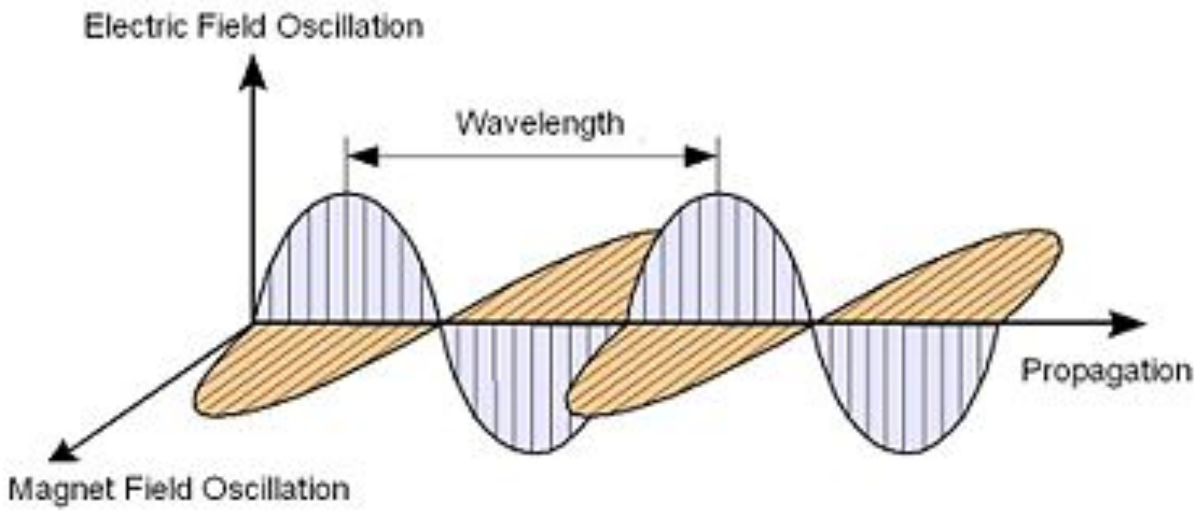
- These equations are superficially similar in appearance, but very different in nature
  - Specific heat describes how much heat must be transferred to change a material's temperature
  - Conductivity describes how fast heat is transferred between materials of different temperatures

Specific Heat Vs. Conductivity

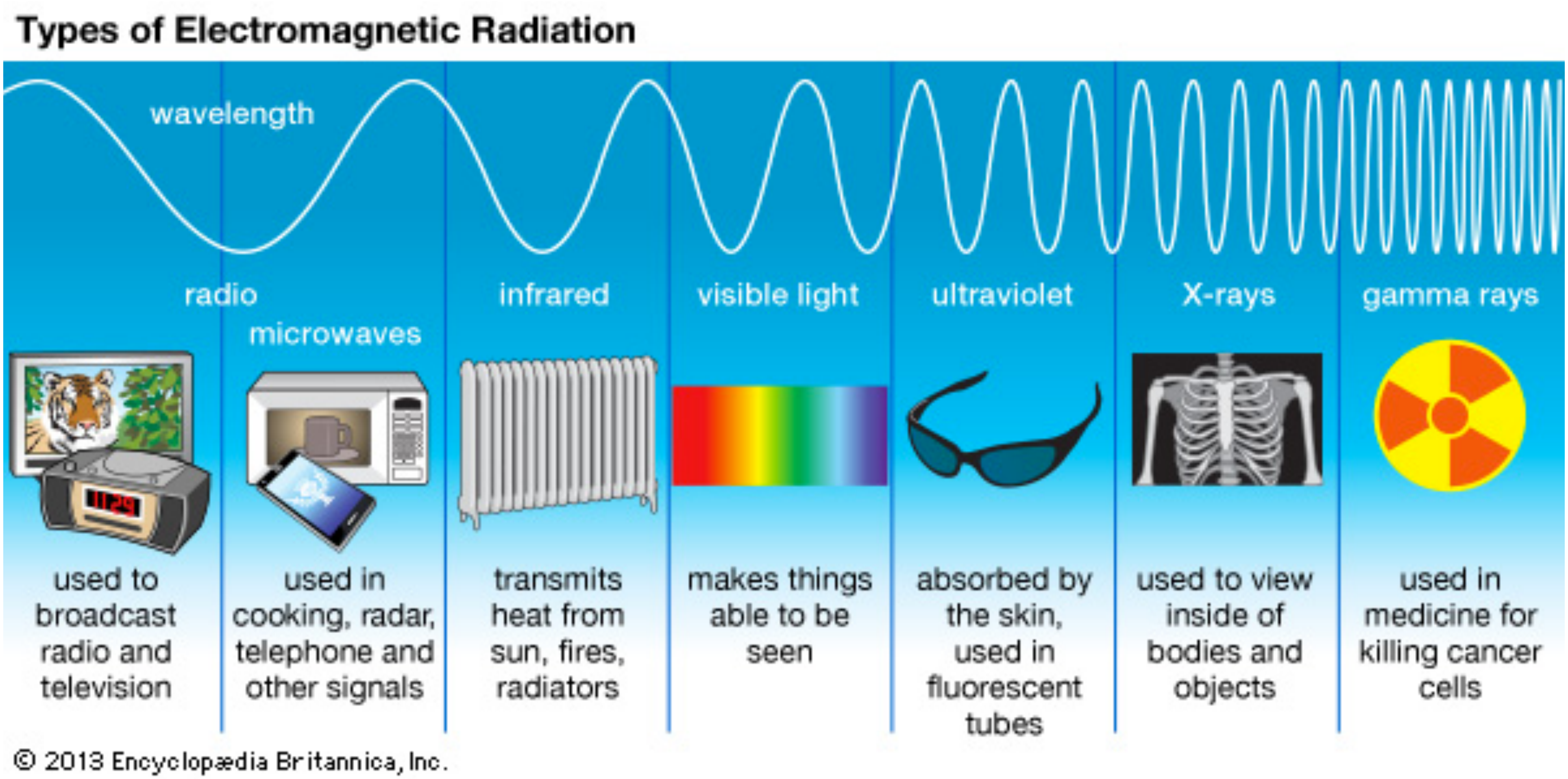
- Objects with high conductivity tend to have low specific heat capacity
- In general, the more conductive an object is, the easier it is to change its temperature (takes less heat for a given temperature change)
- Materials with high “k” tend to have low “c”

Radiation

- Heat can be transferred not just by large-scale and small-scale motion of materials
- It can also be transferred by electromagnetic waves (light)

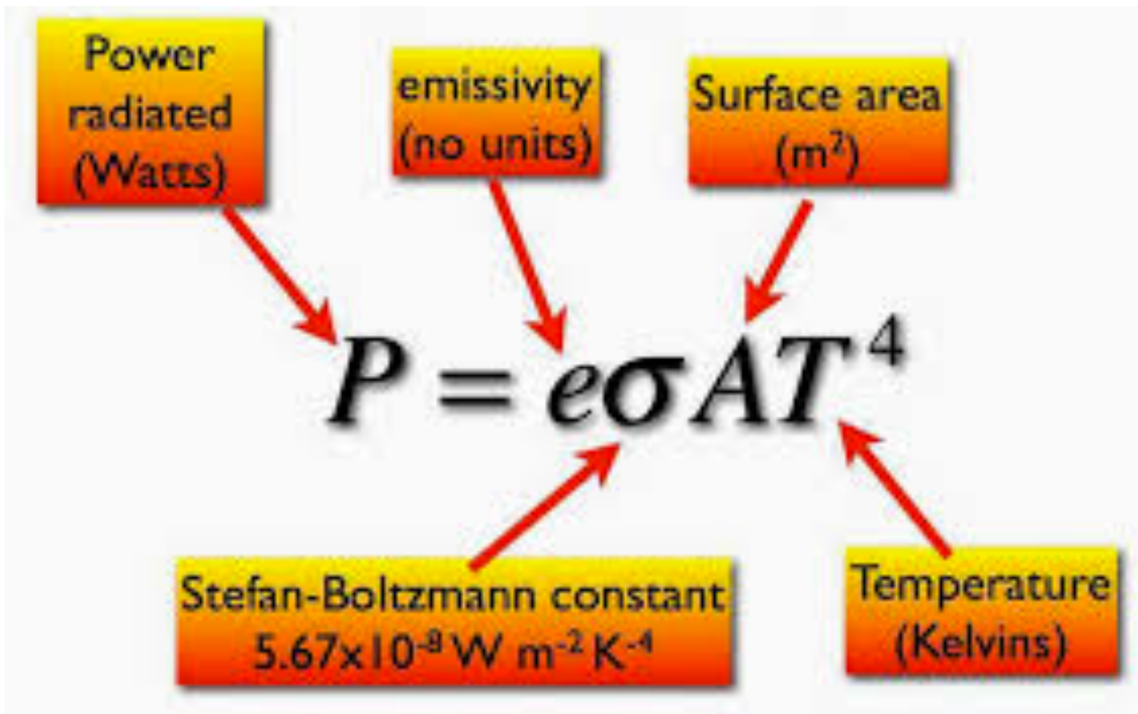


Electromagnetic Radiation



Radiation Equation

- $Q/t = A\ e\ \sigma\ T^4$
  - e = efficiency (for perfect black body emitter e = 1)
  - σ = Stefan-Boltzmann const. = $5.67 \times 10^{-8}\ J/(s\ m^2\ K^4)$



Energy on Earth