MARIANO MARCOS STATE UNIVERSITY
College of Teacher Education

Center of Excellence in Teacher Education

THERMODYNAMICS

Prepared by:

VIDA V. ANTONIO

Associate Professor IV

vidavantonio@yahoo.com

Heat Transfer

Objectives

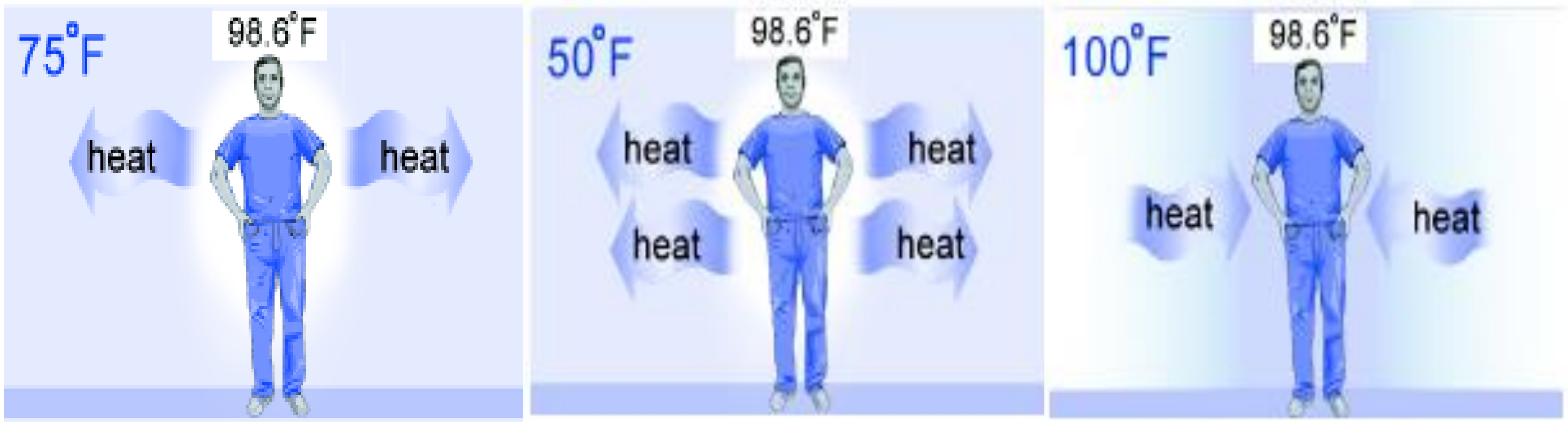
- To define heat transfer;
- To compare and contrast the three modes of heat transfer;
- To trace the path of energy when matter changes from one phase/state to another; and
- To apply the concept of heat transfer.

Heat Transfer

- The science of how heat flows is called heat transfer.
- There are three ways heat transfer works: conduction, convection, and radiation.

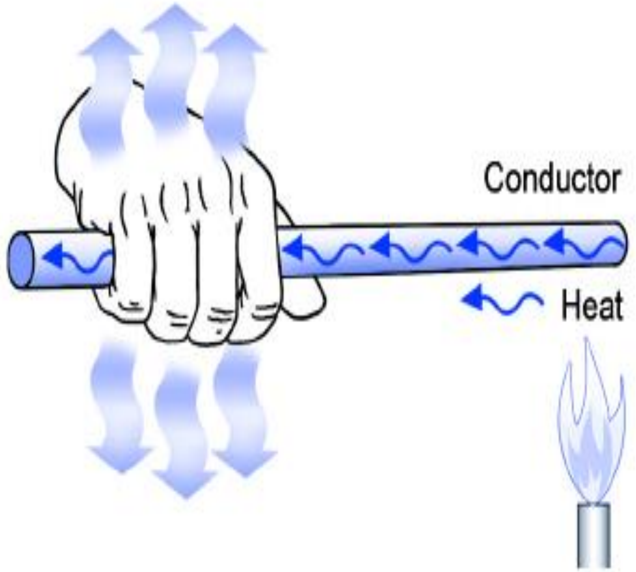
Heat Transfer

- Heat flow depends on the temperature difference.



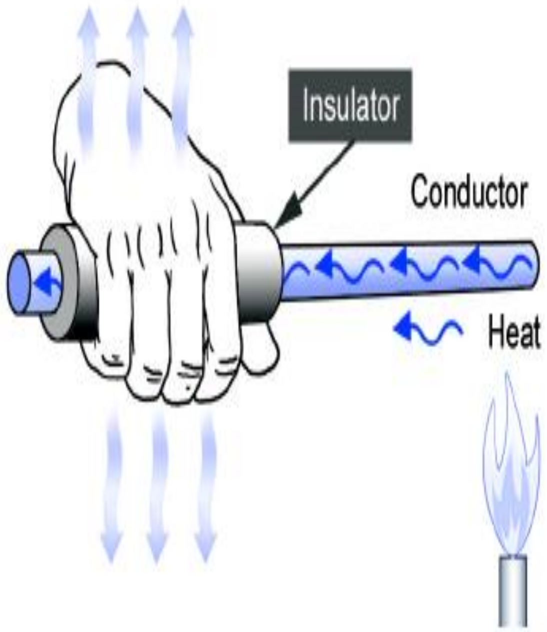
Heat Conduction

- Conduction is the transfer of heat <u>through</u> materials by the direct contact of matter.
- Dense metals like copper and aluminum are very good thermal conductors.



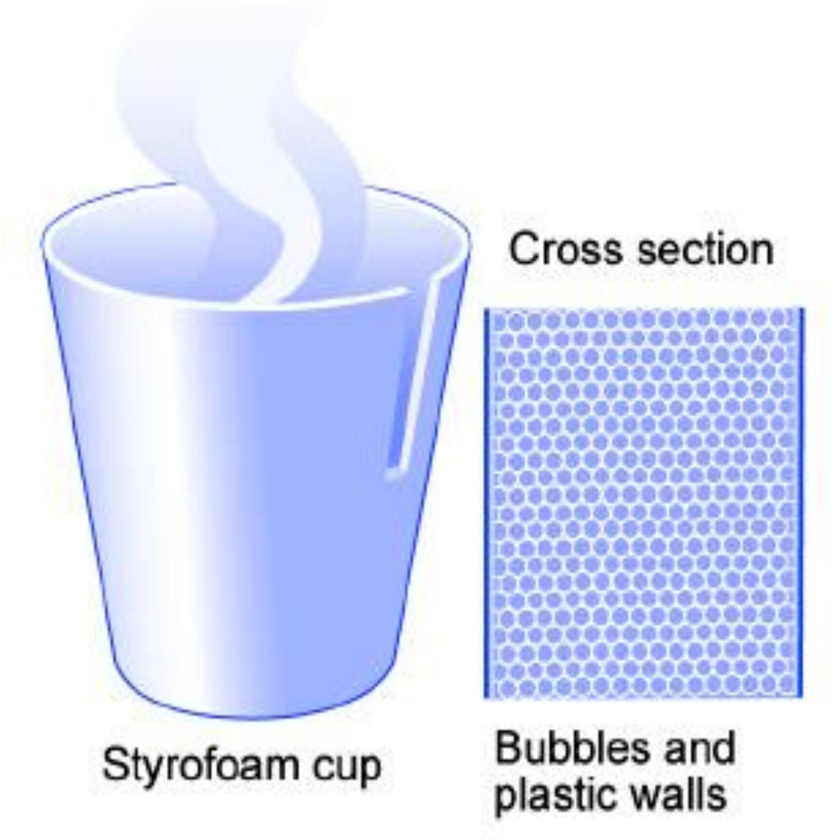
Heat Conduction

- A thermal insulator is a material that conducts heat poorly.
- Heat flows very slowly through the plastic so that the temperature of your hand does not rise very much.



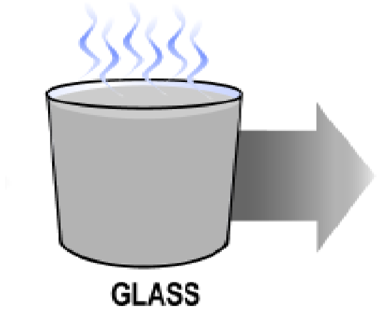
Heat Conduction

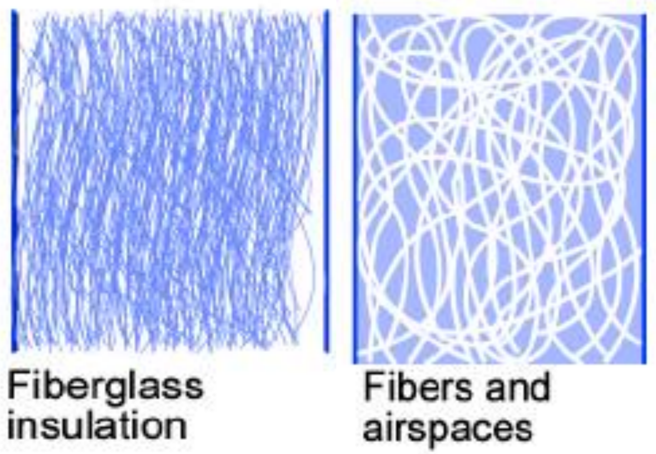
- Styrofoam gets its insulating ability by trapping spaces of air in bubbles.
- Solids usually are better heat conductors than liquids, and liquids are better conductors than gases.



Heat Conduction

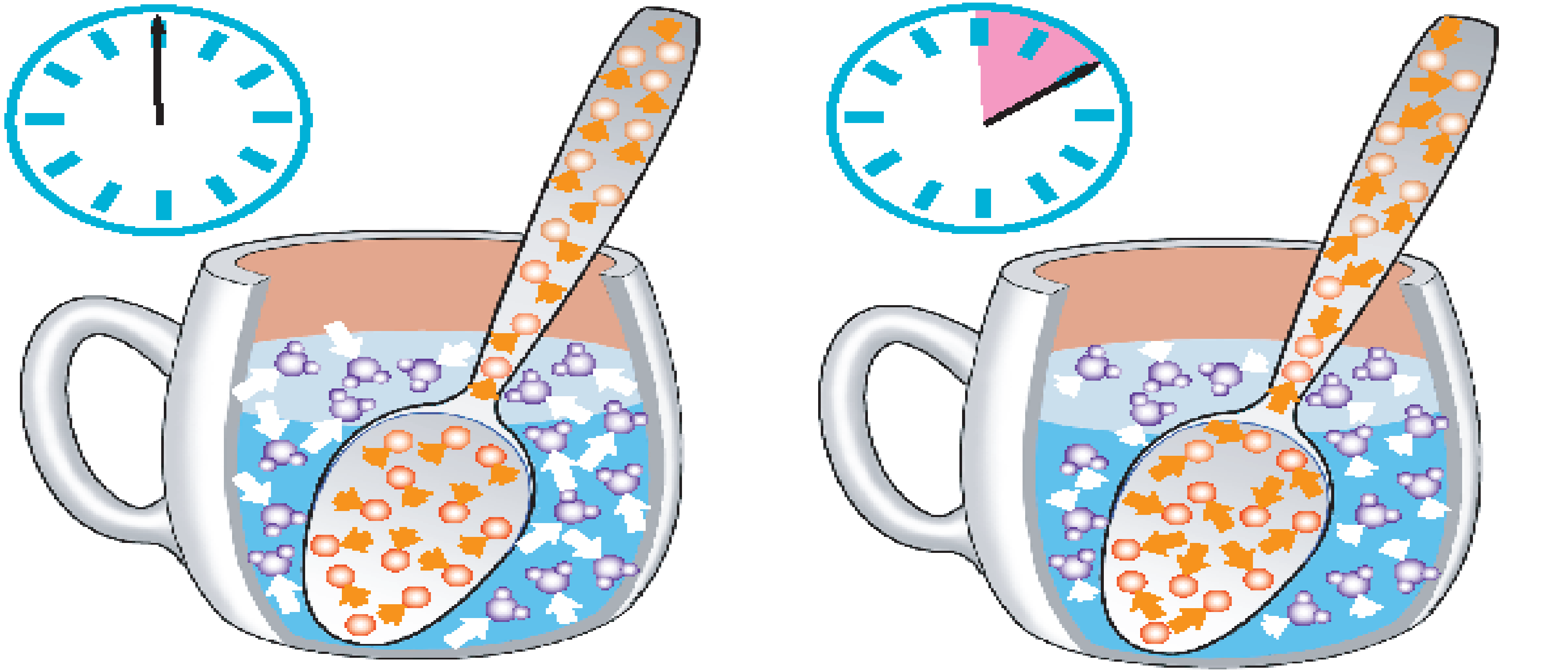
- The ability to conduct heat often depends more on the structure of a material than on the material itself.
  - Solid glass is a thermal conductor when it is formed into a beaker or cup.
  - When glass is spun into fine fibers, the trapped air makes a thermal insulator.





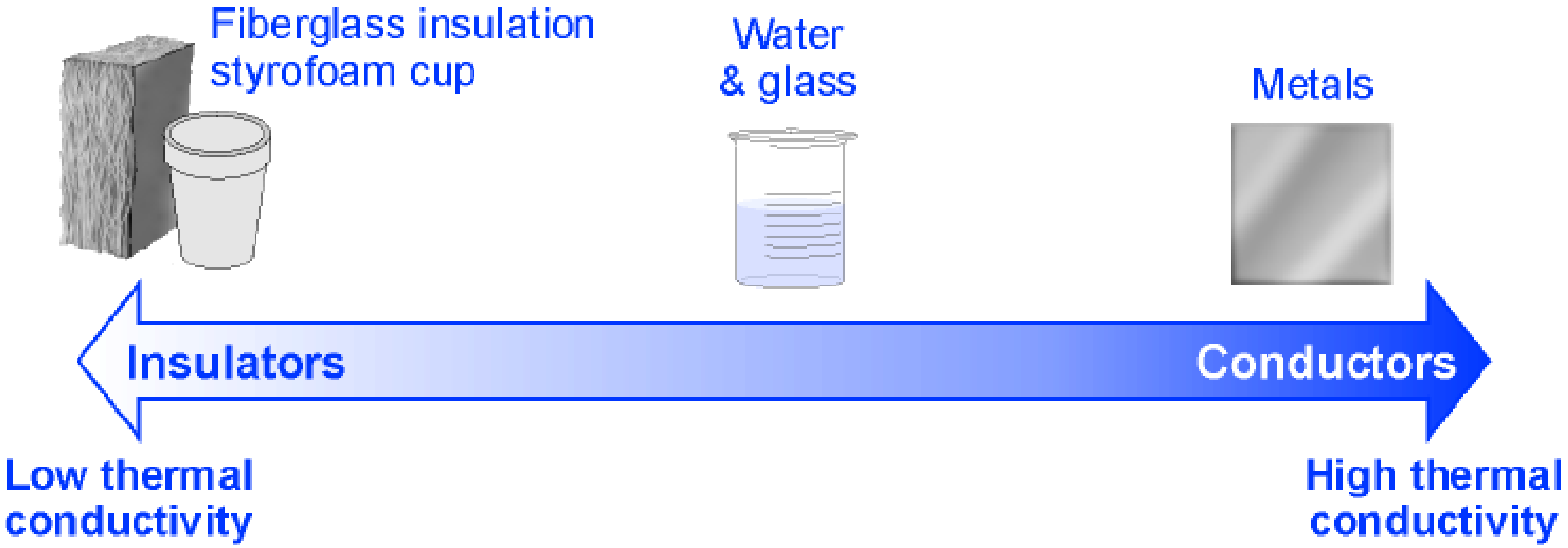
Conduction

Conduction is the transfer of heat by the direct contact of particles of matter. The molecules in the hot cup of liquid transfer their heat energy to the molecules in the cold spoon.



Thermal Conductivity

- The thermal conductivity of a material describes how well the material conducts heat.



Thermal Conductivity

Material	Thermal cond. (W/m°C)
IIa diamond	2,650
Copper	401
Aluminum	226
Steel	43
Rock	3
Glass	2.2
Ice	2.2
Liquid water	0.58
Wood	0.11
Wool fabric	0.038
Fiberglass insulation	0.038
Styrofoam	0.025
Air	0.026

- Heat conduction in solids and liquids works by transferring energy through bonds between atoms or molecules.

Heat Conduction Equation

Thermal conductivity (watts/m^{o}C)

Area of cross section (m^2)

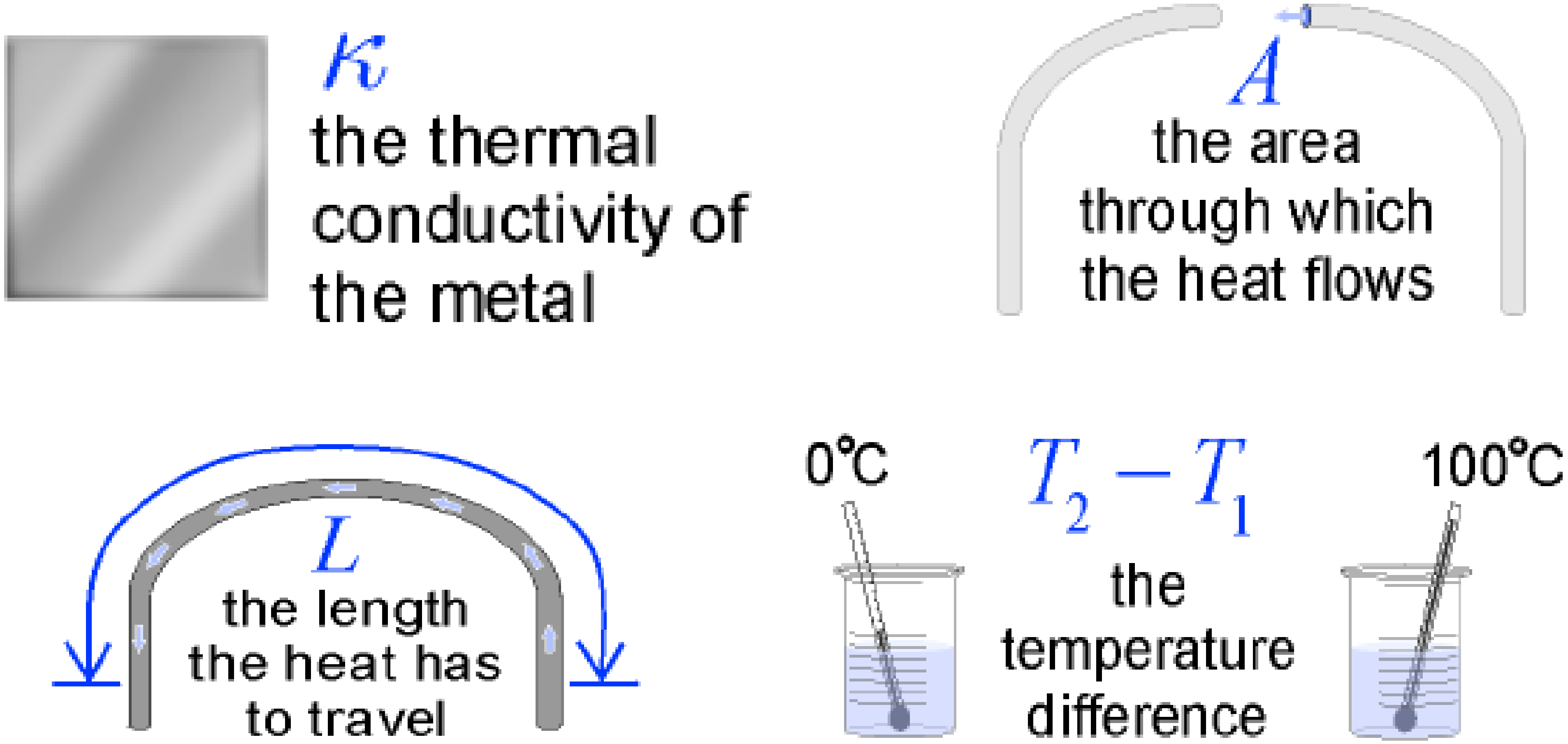
Heat flow (watts)

$$P_H = \kappa \frac{A}{L} (T_2 - T_1)$$

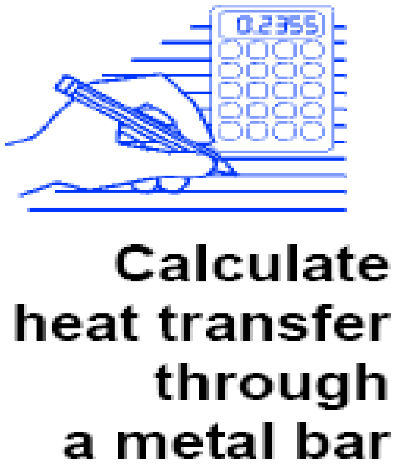
Temperature difference (^{o}C)

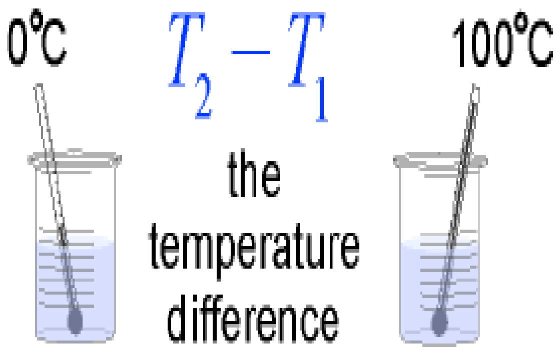
Length (m)

Variables for conduction



Calculate Heat Transfer





- A copper bar connects two beakers of water at different temperatures.
- One beaker is at 100°C and the other is at 0°C.
- The bar has a cross section area of 0.0004 m^2 and is one-half meter (0.5 m) long.
- How many watts of heat are conducted through the bar from the hot beaker to the cold beaker?
- The thermal conductivity of copper is 401 W/m°C.

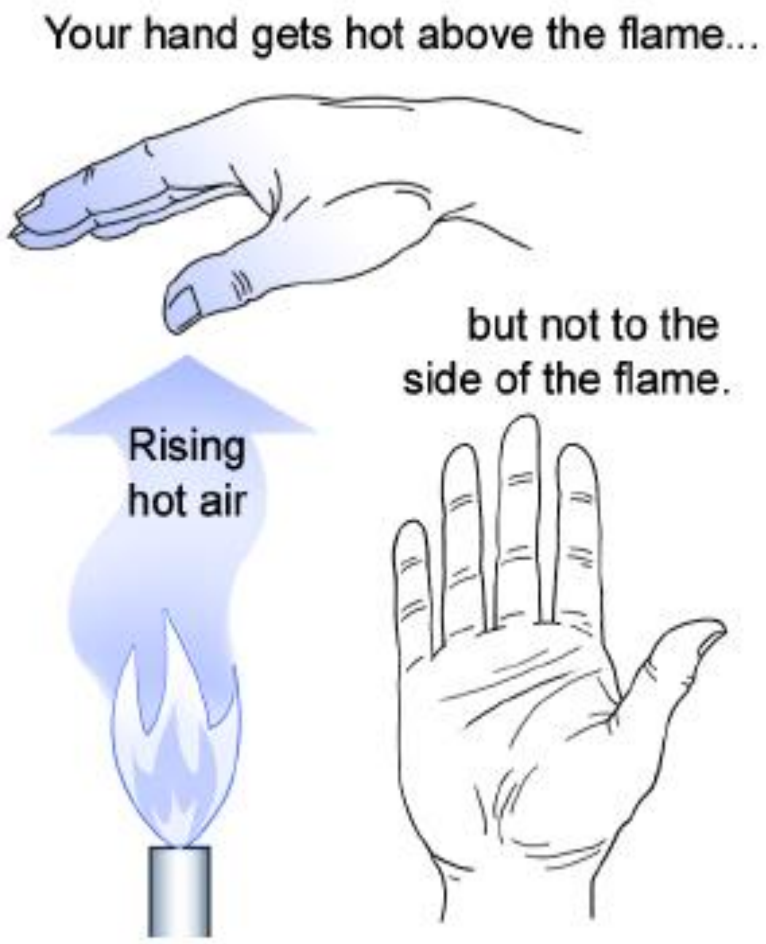
Convection

Key Question:

Can moving matter carry thermal energy?

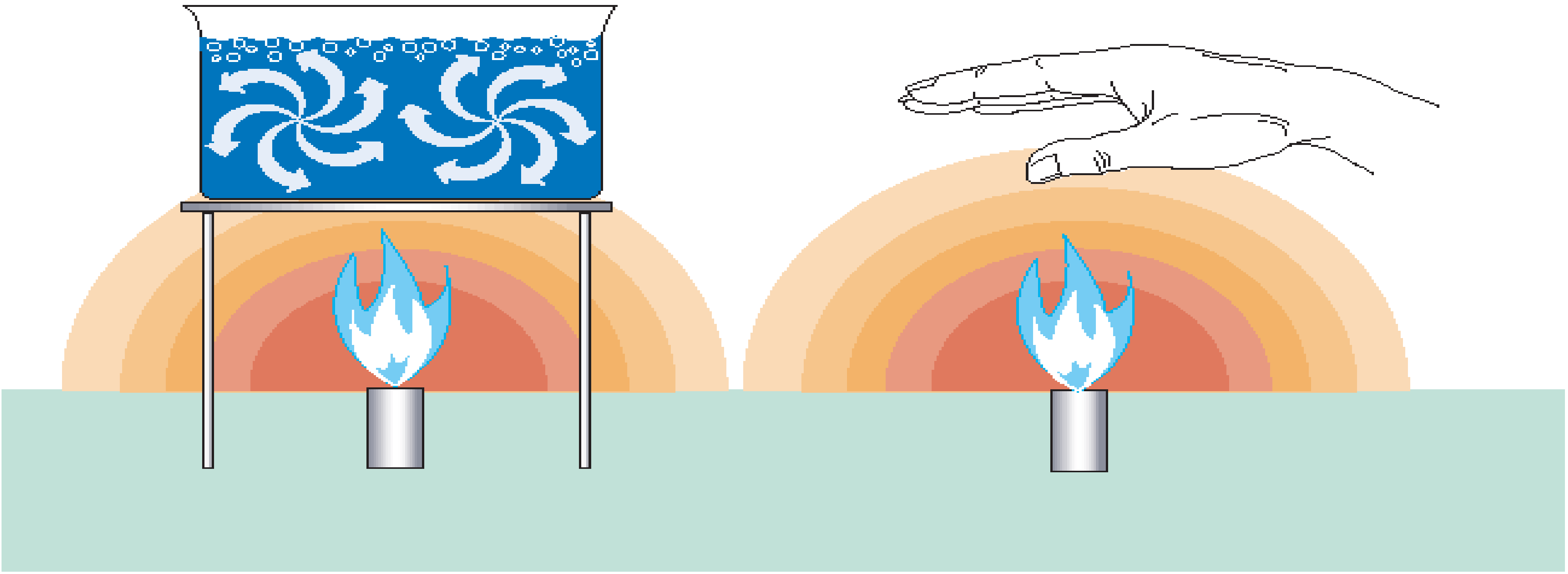
Convection

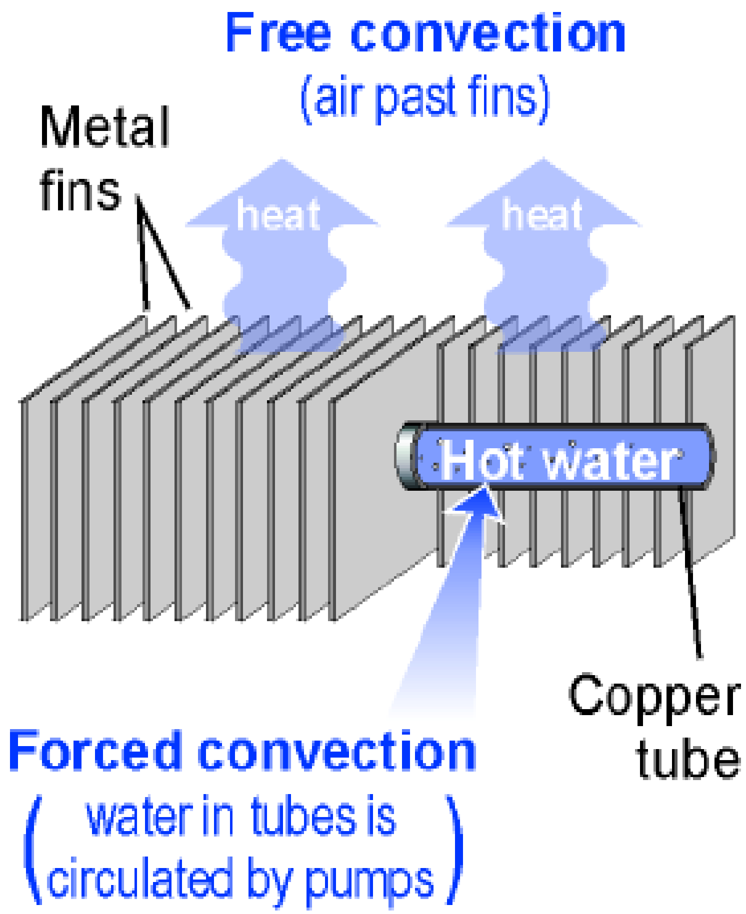
- Convection is the transfer of heat by the motion of liquids and gases.
  - Convection in a gas occurs because gas expands when heated.
  - Convection occurs because currents flow when hot gas rises and cool gas sink.
  - Convection in liquids also occurs because of differences in density.



Convection

Convection is the transfer of heat by the actual motion of a fluid (liquid or gas) in the form of currents.

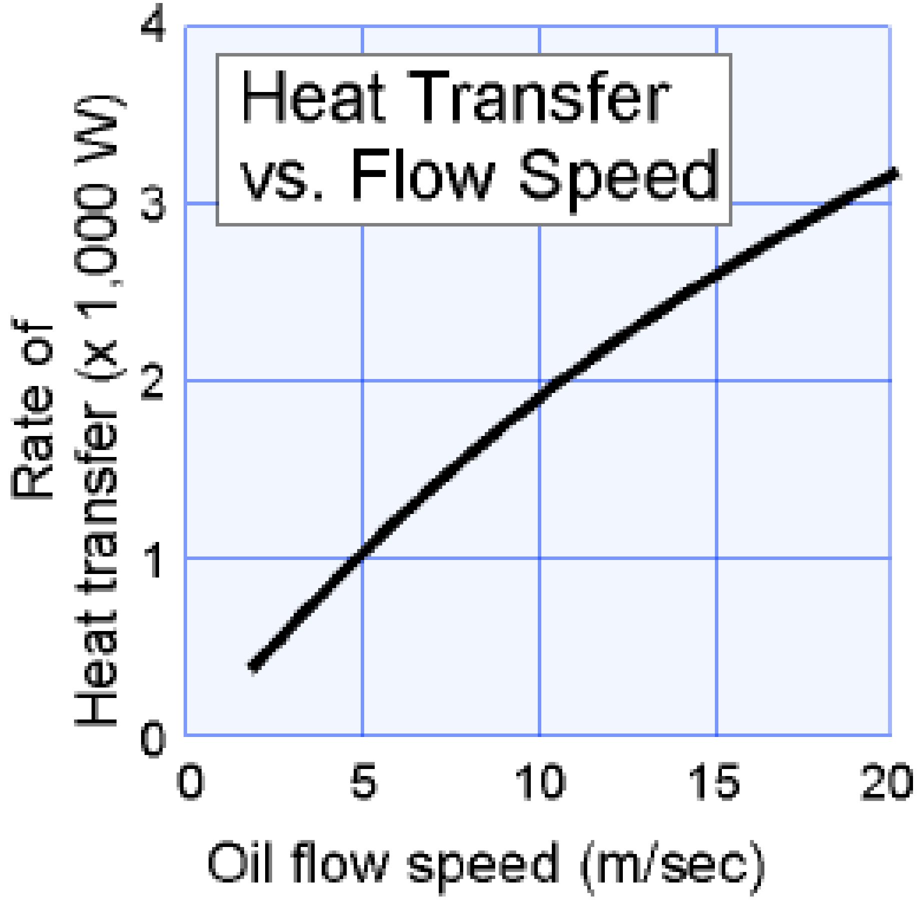




Convection

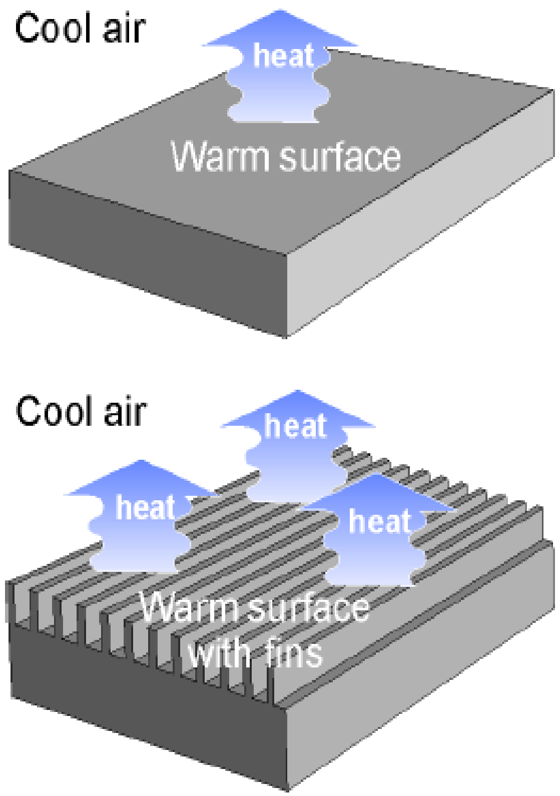
- When the flow of gas or liquid comes from differences in density and temperature, it is called free convection.
- When the flow of gas or liquid is circulated by pumps or fans it is called forced convection.

Convection



- Convection depends on speed.
- Motion increases heat transfer by convection in all fluids.

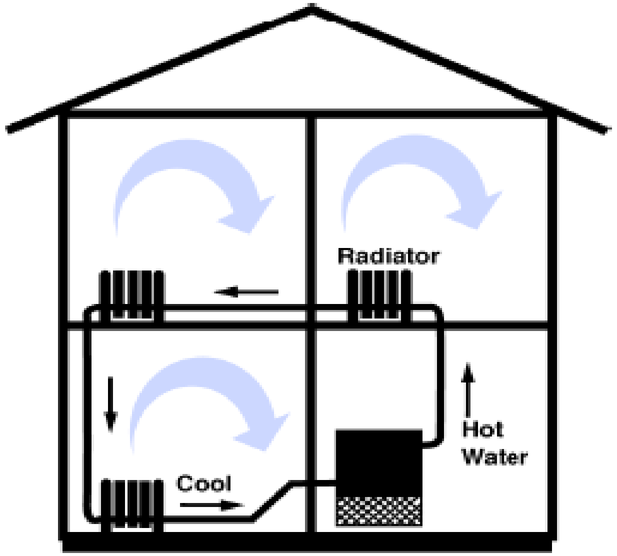
Convection

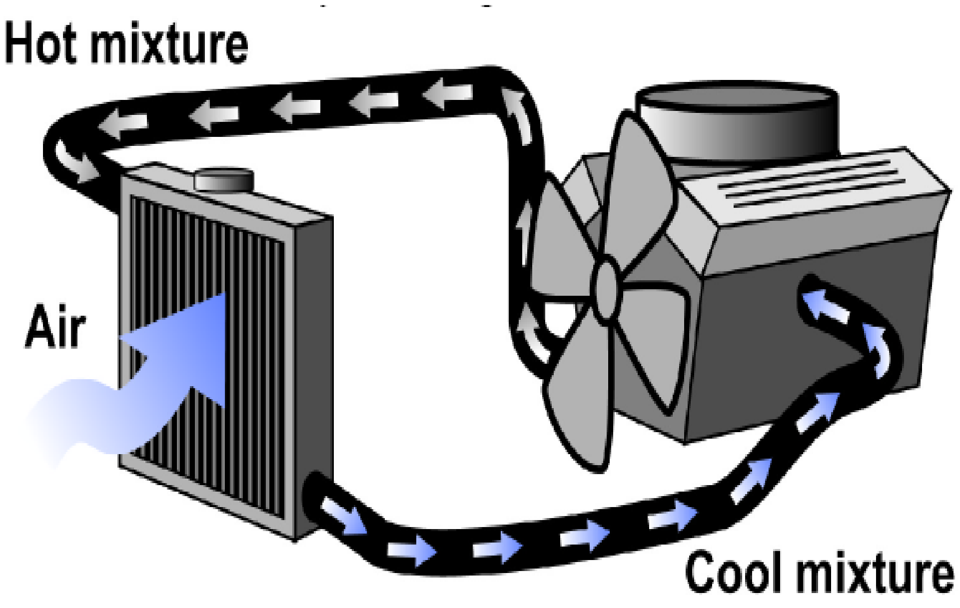


- Convection depends on surface area.
- If the surface contacting the fluid is increased, the rate of heat transfer also increases.
- Almost all devices made for convection have fins for this purpose.

Forced Convection

- Both free and forced convection help to heat houses and cool car engines.



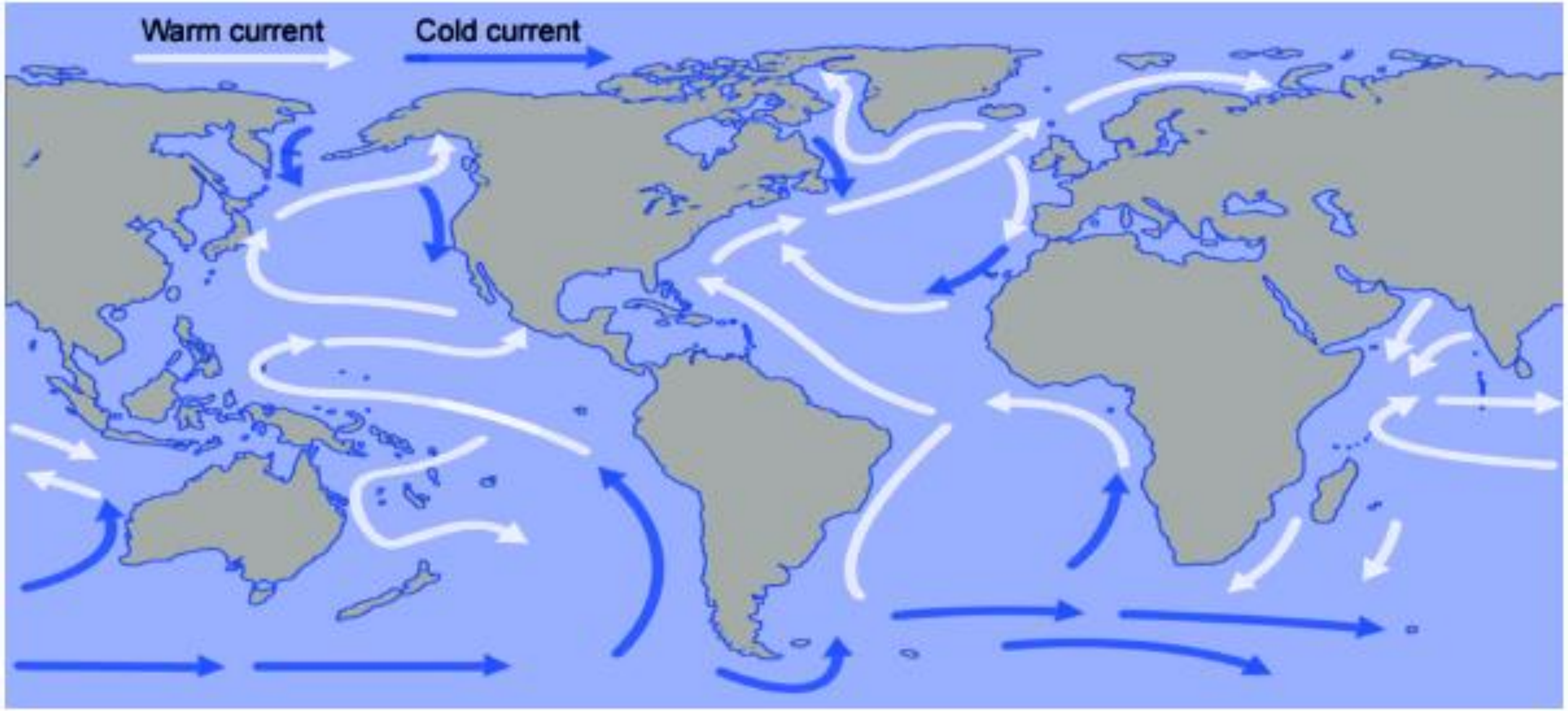


Convection and Sea Breezes

- On a smaller scale near coastlines, convection is responsible for sea breezes.
- During the daytime, land is much hotter than the ocean.
- A sea breeze is created when hot air over the land rises due to convection and is replaced by cooler air from the ocean.
- At night the temperature reverses so a land breeze occurs.

Convection Currents

- Much of the Earth's climate is regulated by giant convection currents in the ocean.



Heat Convection Equation

Heat transfer coefficient
(watts/m^2 °C)

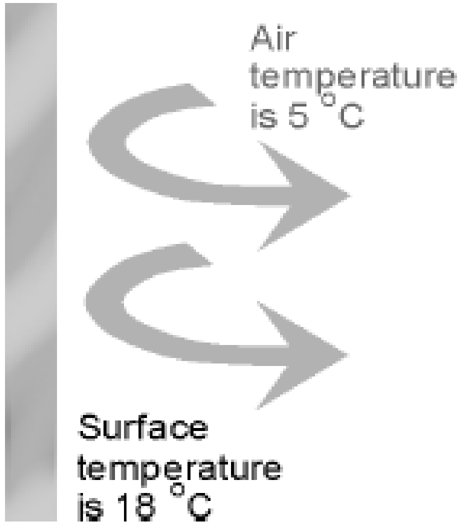
Area contacting fluids (m^2)

Heat flow
(watts)

$$P_H = h\,A\,(T_2 - T_1)$$

Temperature
difference (°C)

Calculate
the heat lost
through a glass
window



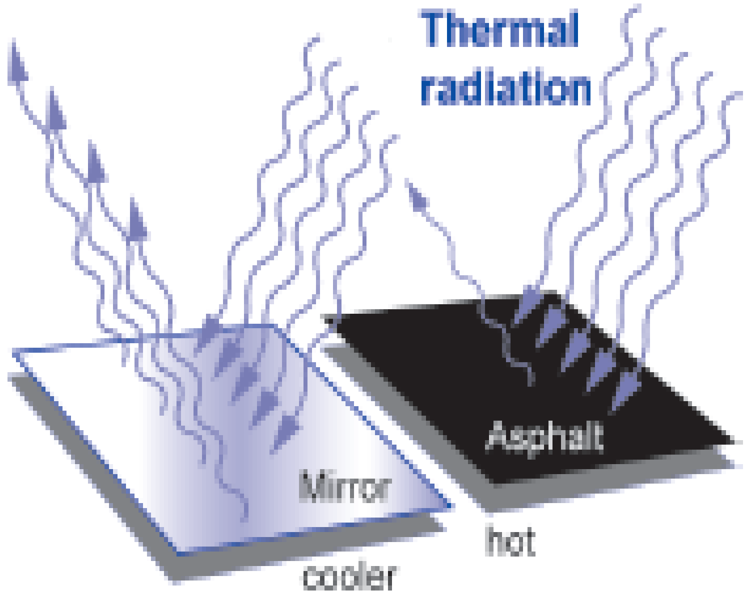
Calculating convection

- The surface of a window has a temperature of 18°C (64°F).
- A wind at 5°C (41°F) is blowing on the window fast enough to make the heat transfer coefficient 100 W/m^2°C.
- How much heat is transferred between the window and the air if the area of the window is 0.5 square meters?

Radiation

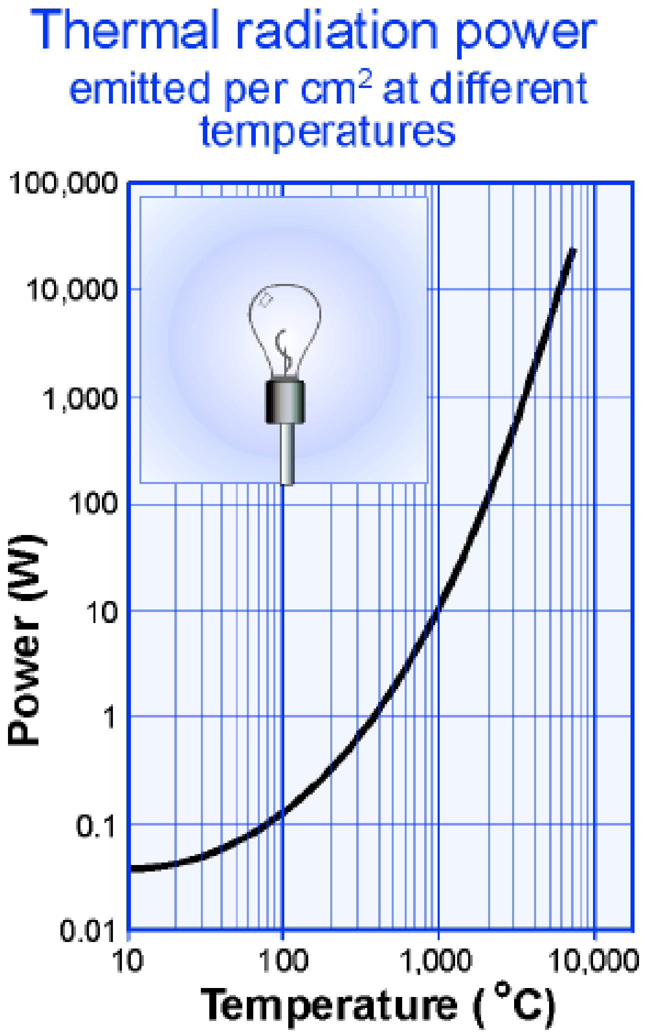
Key Question:

How does heat from the sun get to Earth?



Radiation

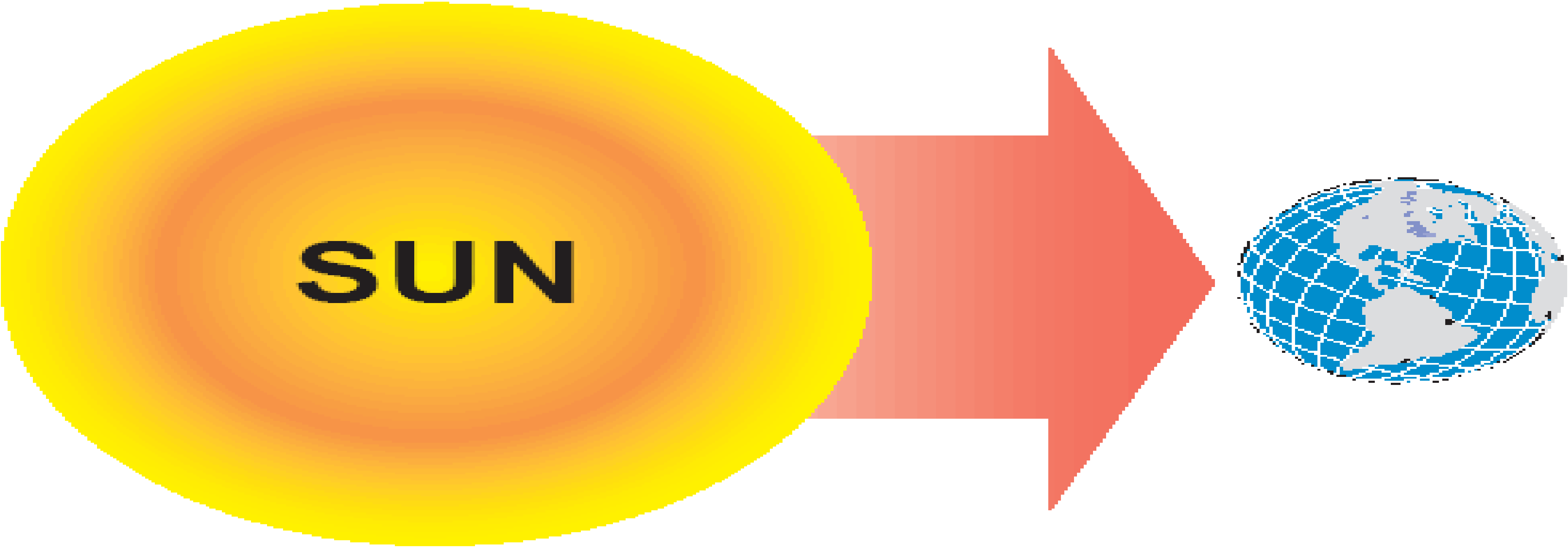
- Radiation is heat transfer by electromagnetic waves.
- Thermal radiation is electromagnetic waves (including light) produced by objects because of their temperature.
- The higher the temperature of an object, the more thermal radiation it gives off.



Radiation

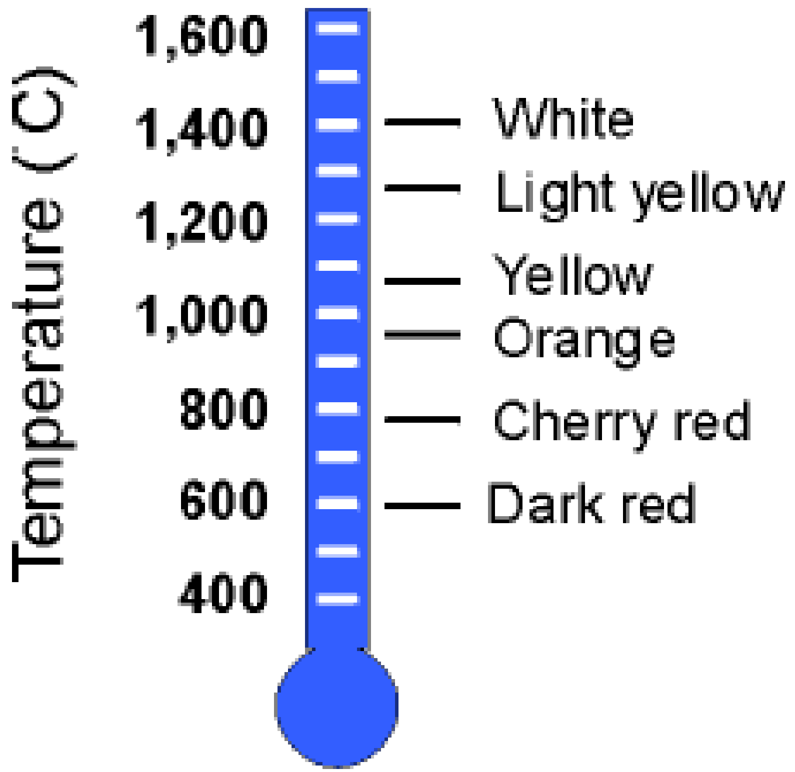
Radiation is heat transfer by electromagnetic waves.

Electromagnetic radiation from the sun heats Earth.



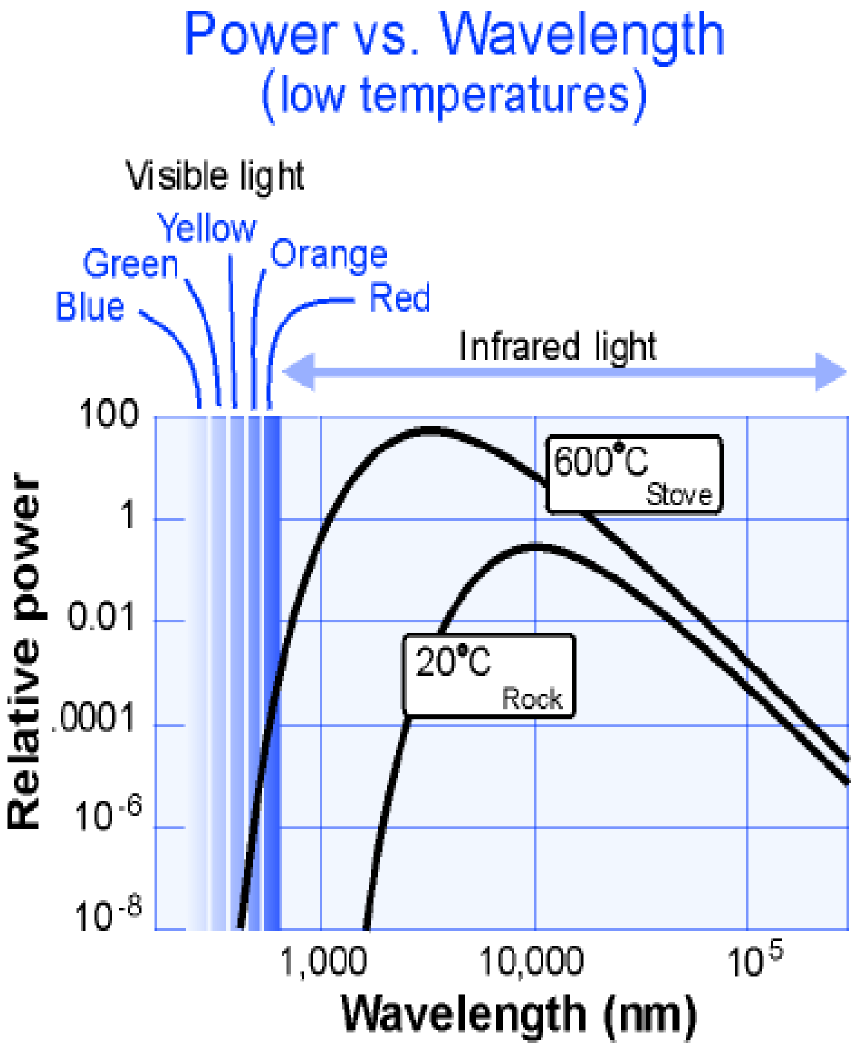
Radiant Heat

- We do not see the thermal radiation because it occurs at infrared wavelengths invisible to the human eye.
- Objects glow different colors at different temperatures.



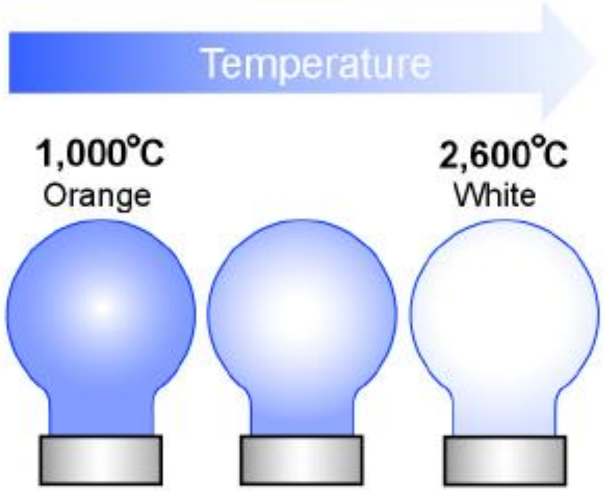
Radiant Heat

- A rock at room temperature does not “glow”.
- The curve for 20°C does not extend into visible wavelengths.
- As objects heat up they start to give off visible light, or glow.
- At 600°C objects glow dull red, like the burner on an electric stove.



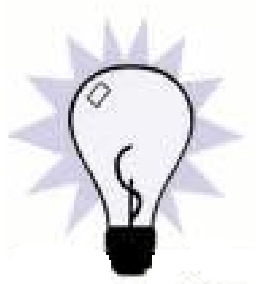
Radiant Heat

- As the temperature rises, thermal radiation produces shorter-wavelength, higher energy light.
- At 1,000°C the color is yellow-orange, turning to white at 1,500°C.
- If you carefully watch a bulb on a dimmer switch, you see its color change as the filament gets hotter.
- The bright white light from a bulb is thermal radiation from an extremely hot filament, near 2,600°C.



Radiant Heat

- A perfect **blackbody** is a surface that reflects nothing and emits pure thermal radiation.
  - The white-hot filament of a bulb is a good blackbody because all light from the filament is thermal radiation and almost none of it is reflected from other sources.
  - The curve for 2,600°C shows that radiation is emitted over the whole range of visible light.



Stefan-Boltzmann formula

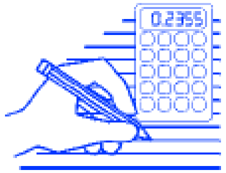
Surface area (m^2)

Power (watts) → $P = \sigma A T^4$

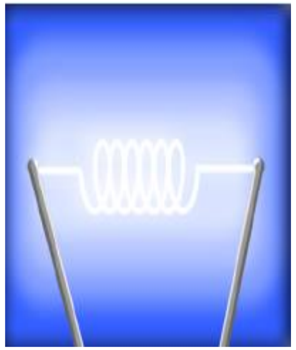
Stefan-Boltzmann constant
5.67×10^{-8} watts/m^2K^4)

Absolute temperature
(K)

Calculate Radiant Power

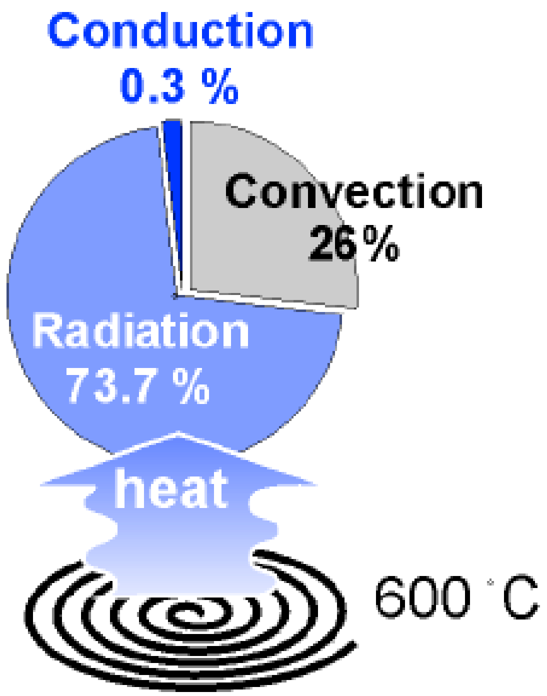


Calculate the radiation power from a small light bulb filament



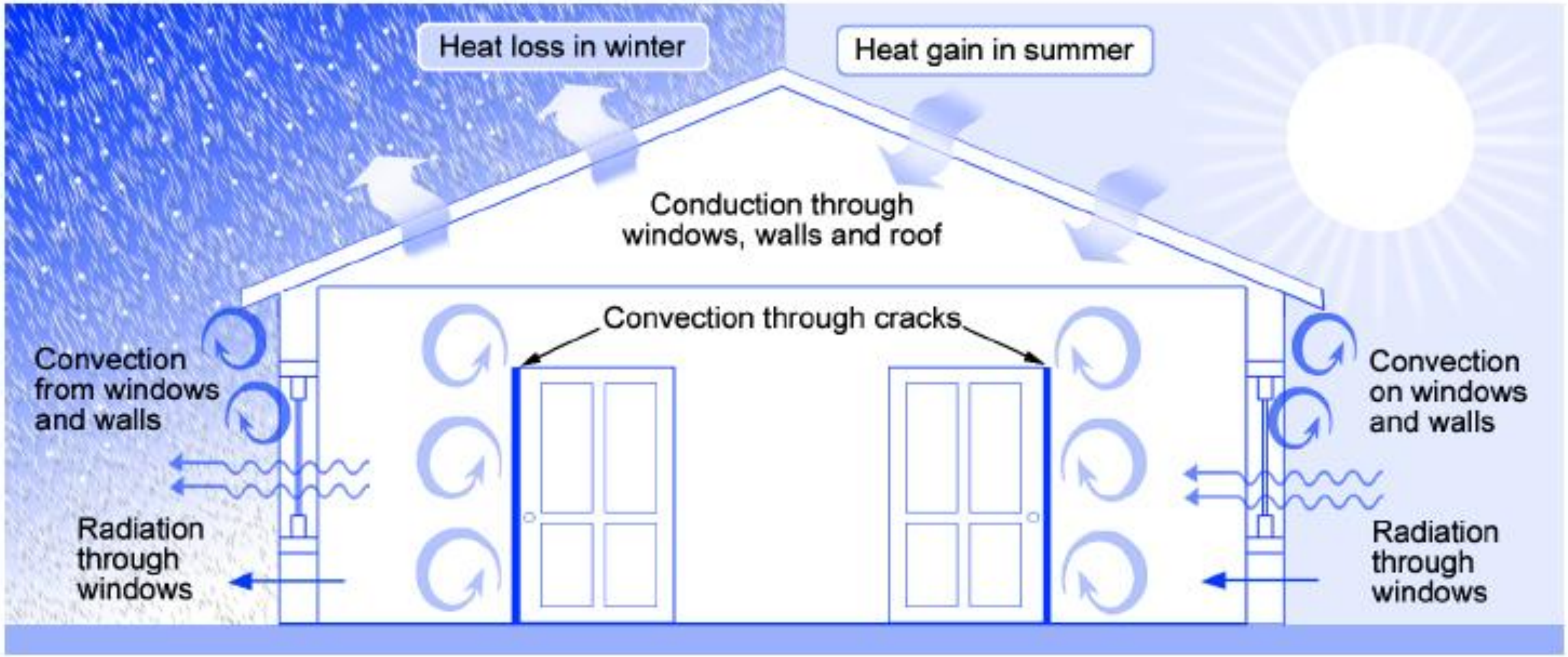
- The filament in a light bulb has a diameter of 0.5 millimeters and a length of 50 millimeters.
- The surface area of the filament is 4×10^{-8} m^2.
- If the temperature is 3,000 K, how much power does the filament radiate?

Radiant Heat



- When comparing heat transfer for a pot 10 cm above a heating element on a stove, radiant heat accounts for 74%
- How is heat transferred when the pot sits on the element?

Application: Energy-efficient Buildings



References

- Sootin, H. (1964). Experiments with heat. W.W. Norton and Company, Inc.
- Where is Heat coming from and where is it going? Retrieved online on March 10, 2012 from http://www.powersleuth.org/docs/EHM%20Lesson%204%20FT.pdf
- Conduction, Convection, Radiation: Investigating Heat Transfers. Retrieved online on March 10, 2012 from http://www.powersleuth.org/docs/EHM%20Lesson%205%20FT.pdf

Get in Touch With Us

Send us a message or visit us

Laoag City, Ilocos Norte, Philippines
(63) 77-600-2014
cte@mmsu.edu.ph

Follow us for updates

facebook.com/MMSUofficial
www.mmsu.edu.ph