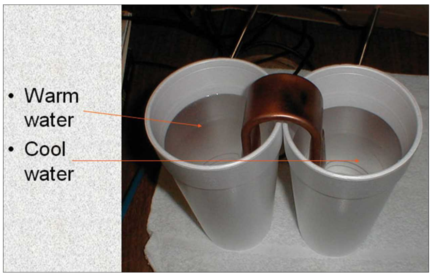
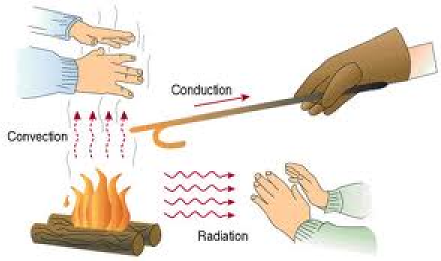
2.B.4 - Heat Transfer



Three Ways of Transferring Heat

What are they?
Conduction: direct contact between objects
Convection: movement of fluids
Radiation: electromagnetic waves



Conduction

Thermal conductors transfer heat well.

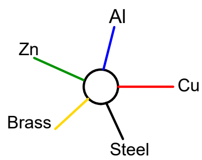
Thermal insulators transfer heat poorly.

1. Physics Democracy A

Metallic Heat Race Part one!

Which wax melts first?

They have the same diameter.



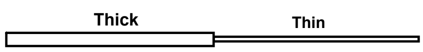
Zinc	Brass	Steel	Copper	Aluminum

2. Physics Democracy B

Metallic Heat Race Part Two!

These rods are both brass with the same length, but different diameters.

Which diameter's wax melts off first?



Conduction

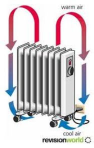
Thermal conduction is rate of heat flow: $\Delta Q/\Delta t$.

$P = \dfrac{\Delta Q}{\Delta t} = \dfrac{k \cdot A \cdot \Delta T}{L}$ AP Equation	P = power (W) k = conductivity constant (Table 2.B.3) Units = J/(m · s · °C) or W/(m · °C) A = area of contact (m^2) ΔT = temperature difference (°C) L = thickness of object (m)

Convection

Heat movement by mass transfer.

Natural Convection happens when the density of a fluid becomes less than its surroundings and rises, or if its density is greater than its surroundings it will sink.



Forced Convection involves mechanical movement to propel fluids.

Radiation

Heat movement requires no medium for transfer.

Radiant energy is all forms of electromagnetic waves.

Infrared radiation is the radiative mechanism of heat transfer in human life processes.

Radiation

When an object and its surroundings are in thermal equilibrium, rate of emission equals rate of absorption.

When there are temperature differences though, there will be a net transfer of energy.

Stefan's Law

Calculates rate of energy emission of an object:

Case 1: Thermal Equilibrium $P_{net} = \frac{\Delta Q}{\Delta t} = \sigma A e T^4$	P_{net} = power (W) σ = Stefan-Boltzmann constant = 5.67 E-8 W/(m^2·K^4) A = area (m^2) e = material's emissivity constant. (0 – 1) T = temperature of object (K)
Case 2: Out of Equilibrium: $P_{net} = \frac{\Delta Q}{\Delta t} = \sigma A e (T_s^4 - T^4)$	T_s = Surrounding Temp. (K)

Note: in Case 2, object loses or gains energy.

A Note on Emissivity

Emissivity of a material is its effiency in emitting energy as thermal radiation: depends on material and roughness of the surface.

Emissivity is the ratio of the thermal radiation from a surface vs. the radiation from an ideal black surface (perfect radiator) at same temperature.

Items with high emissivity radiate well (asphalt (e = 0.88) rough, dark), those with low don't (polished silver (e = 0.2)).

Low emissivity windows (Glass' e = 0.95) are coated with a material that makes them lose energy at a reduced rate.

3. Heat Loss Example

How fast will a naked body lose heat at 20.0°C?
Skin emissivity = 0.700, A = 1.50 m^2, body = 34.0°C.

T_s = 20.0 + 273 = 293.0 K
T = 34.0 + 273 = 307.0 K

$$P_{net} = \sigma A e (T_s^4 - T^4)$$

$$= 5.67E-8 \frac{W}{(m^2 \cdot K^4)} \cdot 1.5 m^2 \cdot 0.70 \cdot \left((293K)^4 - (307K)^4\right)$$

$$= -90.1 W$$

Homework

2.B.4 Booklet Problems.
Due next class.

Study for Heat Quiz (Thursday)

Finish Unit 2.B Review Problems
Due: Friday

Review!

Preparation for Quiz (open resource).

How much energy is lost when 2.0 kg of water cools from 45 ºC to solid ice at 0.0 ºC?

Two phases of cooling require two calculations:
1. water cooling from 45 ºC to 0 ºC,
2. water freezing to ice at 0 ºC.

Review Answer

Data: mass = 2.0 kg

Notes

Two phases:
1. water cooling from 45 ºC to 0 ºC

$Q = c_{H_2O} \cdot m \cdot \Delta T = 4186\, J/kg \cdot {}^\circ C \cdot 2.0\, kg \cdot (-45\, {}^\circ C) = -3.78\, E\, 5\, J$

2. water freezing to ice at 0 ºC.

$Q = -L_f \cdot m = -3.33\, E\, 5\, J/kg \cdot 2.0\, kg = -6.66\, E\, 5\, J$

Energy lost:
-3.78 E 5 J + (-6.66 E 5 J)
= 1.04 E 6 J of heat lost.