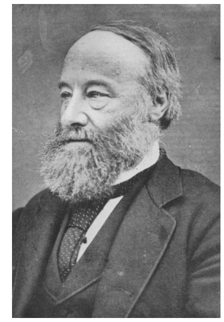
Announcements

1. No announcements yet

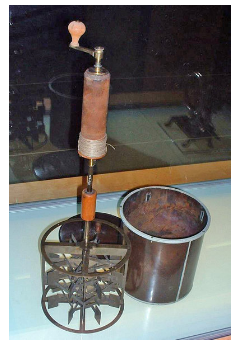
Heat

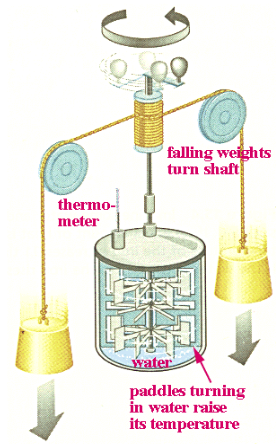
Heat is random kinetic energy!

Symbol: Q
Units: Joules



Mechanical equivalent of heat:
James Joule 1849





calories and Calories:

1 calorie = 4.186 J
Food calorie: 1 Cal = a *kilocalorie*

Specific heat

How much does T rise when heat energy is added?

- temperature rise is proportional to heat added
- the more mass… the less the temperature rises
- material dependent

$$Q = mc\Delta T$$

c = "specific heat"

mc sometimes called "thermal mass"

TABLE 11.1

Specific Heats of Some Materials at Atmospheric Pressure

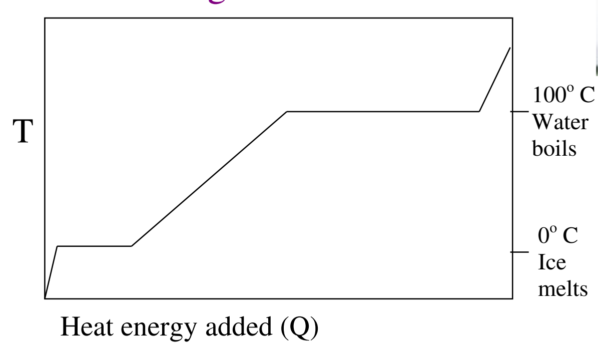
Substance	J/kg · °C	cal/g · °C
Aluminum	900	0.215
Beryllium	1 820	0.436
Cadmium	230	0.055
Copper	387	0.0924
Germanium	322	0.077
Glass	837	0.200
Gold	129	0.0308
Ice	2 090	0.500
Iron	448	0.107
Lead	128	0.0305
Mercury	138	0.033
Silicon	703	0.168
Silver	234	0.056
Steam	2 010	0.480
Water	4 186	1.00

Q4. If you add 5 J of heat to a mass of water, and 5 J of heat to the same mass of steel, which one increases the most in temperature?

a. Water
b. Steel
c. Same

a

Phase Changes



During phase change, no T increase
→ but heat still needed to complete the phase change

$$Q = mL$$

L depends on

- Material
- Type of phase change (i.e. solid-liquid, liquid-gas, or other)

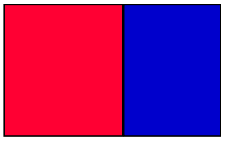
Water:

$L_{melting/freezing} = 3.33 \times 10^5$ J/kg
$L_{boiling/condensing} = 2.26 \times 10^6$ J/kg

Q5. If you want to melt ice at -40° C, which takes the most energy?

a. Raising the temperature
b. Converting from solid to liquid phase
c. Same

Calorimetry



Conservation of energy:

$Q_{\text{gained by cold objects}} = Q_{\text{lost by hot objects}}$ (if no heat flow to outside)

→ On both sides use *positive* quantities

Worked Problem: 5 g of hot steel at 300° C is added to 100 g of water at 20° C. What is the final temperature?

May also need to include melting and boiling: *mL* terms.

Blackbody Radiation

Hot objects glow!

$P_{out} = e\sigma A\,(T_{object})^4$

$P_{in} = e\sigma A\,(T_{surroundings})^4$

Power: watts = heat/time

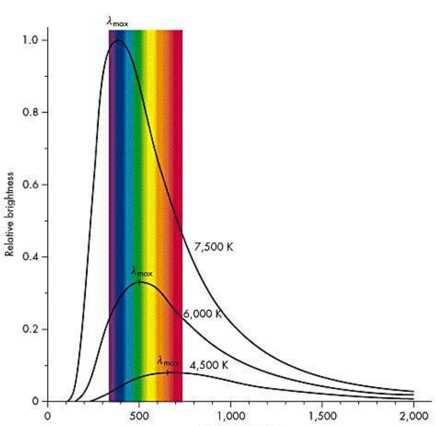
$\sigma = 5.67 \times 10^{-8}$ W/m^2 K^4
(a constant)

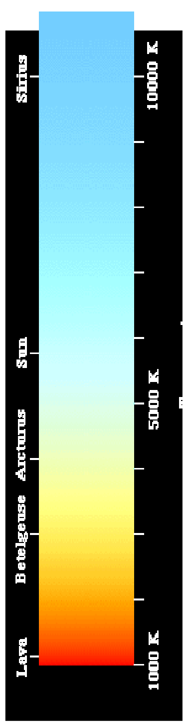
emissivity e

Aluminum - Highly Polished:
$e \approx 0.05$ (0.039-0.057)
Aluminum – anodized (black):
$e \approx 0.82$

Demo: radiating heat and match, running the "lightmill"

"Color" of emission, IR thermometers





Q6. A rough black metal sphere is heated white-hot to 3000 K, and puts out 1000 W of radiation energy. If it is cooled to 1500 K, it will put out ______ W of radiation energy.

A. 160 B. 250 C. 500 D. 750 E. 1000

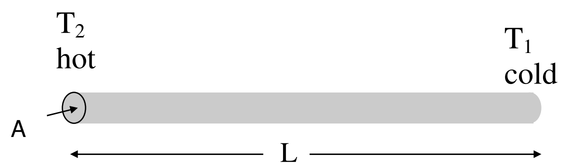
Hint: use ratios

$$\frac{P_2}{P_1} =$$

Q7. If instead the sphere is kept at 3000 K, but the radius of the sphere is doubled, it will put out ______ W of radiation energy.

A. 500 B. 1000 C. 2000 D. 4000 E. 8000

Thermal conduction:
energy transfer through materials



$$P = \frac{Q}{\Delta t} = kA\left(\frac{T_2 - T_1}{L}\right)$$

where k is the Thermal conductivity of the material and L is the length of the heat flow (or thickness)

Some Thermal Conductivities
(from your textbook)

Material	k (J/s·m·°C)
Copper	397
Aluminum	238
Iron	79.5
Glass	0.84
Wood	0.10
Air	0.0234

Vacuum?

Q8. You put the end of a rod in a fire and the other end in a tub of water. The rod that would heat the water fastest will be _______

a. short and fat
b. long and fat
c. short and thin
d. long and thin

Demo: conductivity spider

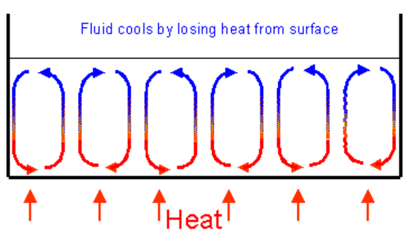
Why do things at **room temperature** feel cold or warm?

Worked Problem: Your house costs 200 cents/day to heat when you keep the temperature at 20° C and the average outside temperature is -10° C. How much will you save if you turn down the heat to 15° C?

R-value of house insulation:
R = L/k (written in British units)

Thermal convection

If air is a good insulator, why use fiberglass in houses, feathers in sleeping bags?



Convection cell
Warm, low density fluid rises
Cool, high density fluid sinks

Demo: dye in convection tube