Announcements – 12 Nov 2009

1. Exam starts next Thursday
   a. (Thursday will be an in-class exam review)
2. Exam ends on the following Tuesday, not Wednesday
   a. Testing Center not open on Wed, due to Thanksgiving
3. Boltzmann 3D applet
   a. http://people.chem.byu.edu/rbshirts/research/boltzmann_3d

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Review

From kinetic theory: $\boxed{\text{(translational) } KE_{ave} = \frac{1}{2}mv_{ave}^{2} = \frac{3}{2}k_{B}T}$

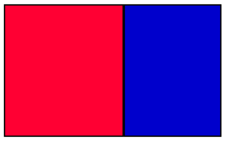
Specific heat: $\boxed{Q = mc\Delta T}$

Latent heat: $\boxed{Q = mL}$

Reference:
c_{water} = 4186 J/kg·°C
c_{ice} = 2090 J/kg·°C
$L_{melting} = 3.33 \times 10^{5}$ J/kg
$L_{boiling} = 2.26 \times 10^{6}$ J/kg

Clicker quiz: If you want to melt a cube of ice that's initially at -40° C, which part takes the most energy?
a. Raising the temperature to 0°
b. Converting from solid to liquid phase
c. Same

Calorimetry



Combining objects with diff. temps.

Conservation of energy:

$\boxed{Q_{\text{gained by cold objects}} = Q_{\text{lost by hot objects}}}$

(assuming no heat flow to outside)

→ Colton method: on both sides of equation use only *positive* quantities
→ Careful: May need to include melting and boiling: *mL* terms

Worked Problem: 0.2 kg of iron at 100° C is added to an insulated container with 0.2 kg of ice at -10° C. How much ice melts if they come to equilibrium at 0° C? (Ref: c_{iron} = 448 J/kg·°C)

Start with: $Q_{\text{gained by ice}} = Q_{\text{lost by iron}}$

Answer: 14.35 g

Worked Problem: (a) 5 g of hot iron at 300° C is added to 100 g of water at 30° C. What is the final temperature? (b) Repeat, but with 500 g iron

Set up for both: $Q_{\text{gained by water}} = Q_{\text{lost by iron}}$

(a)

(b)

Answers: 31.44° C; 124.1 (not real answer), -395.3° C (not real answer), 100° C

Blackbody Radiation
Hot objects glow!

"Glow" carries away energy

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

Power: watts = heat/time

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

e: "emissivity" between 0 and 1
Aluminum, highly polished: e ≈ 0.05
Aluminum, anodized (black): e ≈ 0.8
Depends on material, surface, shape, temperature, etc.

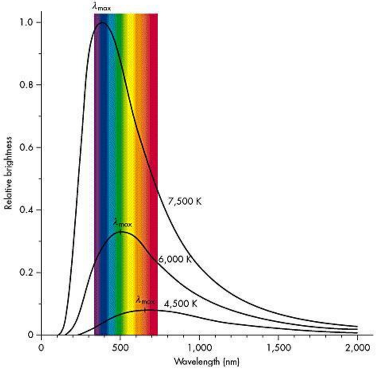
But wait! Surroundings are also glowing!

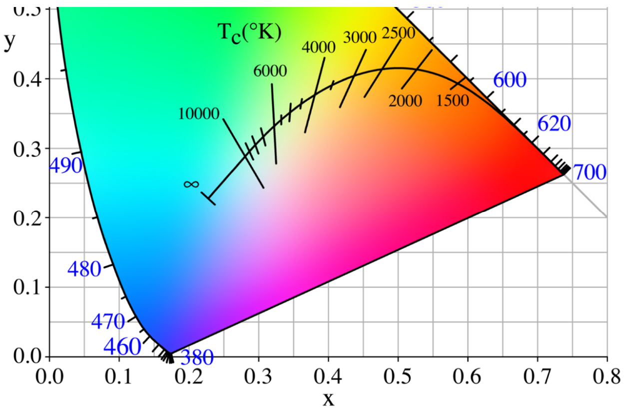
$\boxed{P_{in} = e\sigma A\,(T_{surroundings})^4}$ absorbed by the object

Net power lost = P_{out} - P_{in}

Demo: radiating heat and match

"Color" of emission, IR thermometers





Clicker quiz: A metal sphere is heated to 1200 K, and puts out 1000 W of radiation energy. If it is cooled to 600 K, it will put out ______ W of radiation energy. (Don't worry about heat absorbed by surroundings; assume emissivity is constant.)

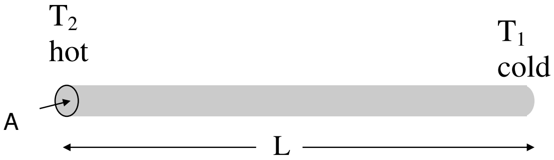
A. 31.25 B. 62.5 C. 125 D. 250 E. 500

Hint: use ratios

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

From warmup: Which of the following is not a way heat can be transferred:
a. conduction
b. convection
c. perpetuation
d. radiation

Thermal conduction:
heat transfer through materials



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

k = Thermal conductivity of the material (look it up)
L = length/thickness of heat flow
A = area of heat flow

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?

Clicker quiz: 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

Why do some things at **room temperature** feel cold?

"R-value" for a material

R = L/k (written in non-metric units)

$$\boxed{P = \frac{Q}{\Delta t} = A\left(\frac{T_2 - T_1}{R}\right)}$$

1 BTU = 1054 J

Some R-values
(from your textbook)

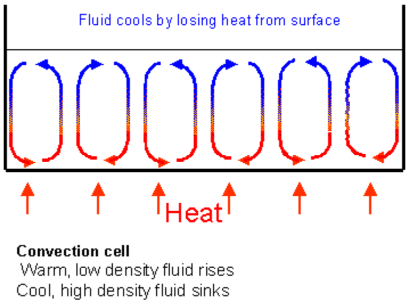
Material	R (ft^2·°F·hr/Btu)
Brick, 4" thick	4
Styrofoam, 1" thick	5
Fiberglass insulation, 3.5" thick	10.9
Drywall, 0.5" thick	0.45

Worked Problem: You foolishly decide to build the walls of your new house out of solid aluminum, 5 cm thick. As a result, in the wintertime heat leaks out like a sieve. How much money will this cost you each *day*? The inside temp is 70° F (21.1° C), the average outside temperature is 25° F (-3.9° C). The surface area is 280 m^2. The gas company charges you \$0.89 per "therm" (1.055×10^8 J). Only count heat loss through conduction.

Answer: \$24,286. Yikes!

Thermal convection

If air is a good thermal insulator why use fiberglass in attics?



Demo: dye in convection tube

From warmup: Ralph saw a sign while driving that said: "Caution: Bridge freezes before road." How can that be the case when the road and the bridge are in thermal contact with each other and in the same environment?

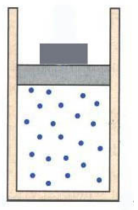
Answer from the class:

(end of chapter 11)

Work done by a gas

1 m^3 of an ideal gas at 300 K supports a weight in a piston such that the pressure in the gas is 200,000 Pa (about 2 atm). The gas is heated up. It expands to 3 m^3. How much work did the gas do as it expanded?

How do you know it did work? It exerted a force over a distance!



Result: $\boxed{W_{\text{by gas}} = P\Delta V}$ 5th edition

(for constant P)

$W_{\text{by gas}} > 0$ when…

Work done on a gas

$\boxed{W_{\text{on gas}} = -P\Delta V}$ 6th, 7th, 8th editions

(for constant P) $W_{\text{on gas}} > 0$ when…

Internal energy of an ideal gas: U

Return to Equipartition Theorem:

> The total kinetic energy of a system is shared equally among all of its independent parts, on the average, once the system has reached thermal equilibrium.
>
> Each "degree of freedom" of a molecule, has energy: $\frac{k_B T}{2}$
>
> independent parts: larger for molecules that can
> - rotate
> - vibrate
>
> (requires more than one atom)
>
> → **such molecules have more "internal energy"**

Monatomic ideal gas: only translational KE possible (3 directions)

KE_{ave} of each molecule = 3/2 $k_B T$

$KE_{tot} = N \times (3/2\ k_B T)$

→ $\boxed{U = 3/2\ Nk_BT = 3/2\ nRT}$ (monoatomic)

Other substances: U is more complicated, depends on temperature

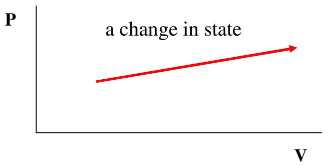
Diatomic: 2 rotational directions that take energy

(it takes no energy to rotate around long axis, since $I \approx 0$)

→ $\boxed{U = 5/2\ Nk_BT = 5/2\ nRT}$ (diatomic, around 300K)

P-V diagrams

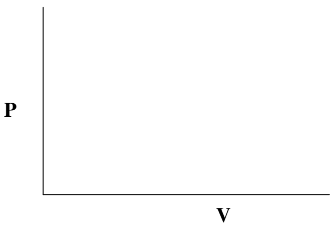
State postulate: any two (independent) variables determine the state: P, V, T, U, etc.



Work done: area under curve (but careful with sign)

→ warmup quiz answer!

How to tell at a glance if the temperature has increased or decreased: ***Isothermal curves***, contours of constant T



ΔU for an isothermal process is _____ because…

What is ΔU for the constant P process at top of page?

1st Law of Thermodynamics

$$\boxed{\Delta U = Q_{added} + W_{on\ system}}$$

(note: 5th edition uses $-W_{by\ system}$)

System: the object you are studying.

Environment: what it interacts with

What does it mean?? Use 5th edition version:

$\Delta U = Q_{added} - W_{by\ system} \;\rightarrow\; Q_{added} = \Delta U + W_{by\ system}$

Meaning of 1st Law:

Heat added can go either towards
- increasing internal energy (temperature), or
- doing work by the gas

→ Conservation of energy! (warmup quiz answer)

Final warning: Be careful with all the signs!!!

ΔU is positive if:

Q_{added} is positive if:

$W_{on\ system}$ is positive if:
