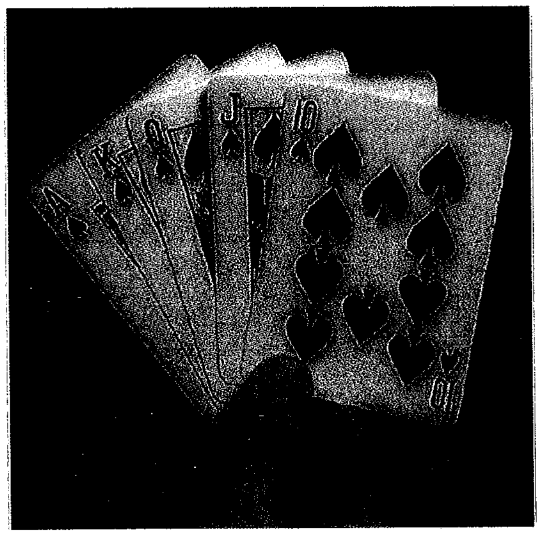
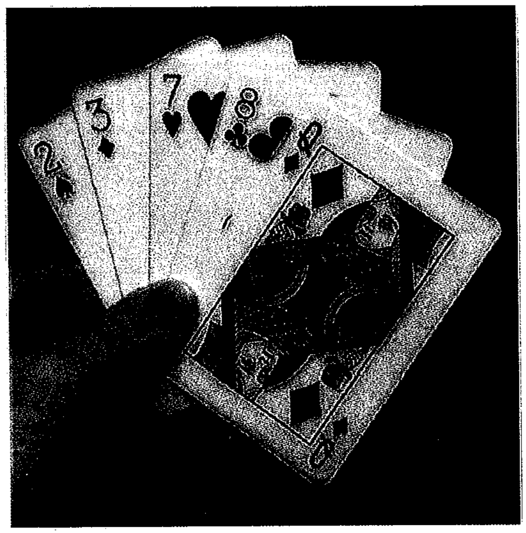
2nd Law of thermodynamics:

Heat spontaneously flows from hot to cold, not the other way around. "perfect refrigerator"

Why? **Order.** From textbook: which hand is more likely?





… but which is more likely, a straight flush or a garbage hand?

→ Boltzman 3D program revisited; increasing "entropy"

Another version of the law:

In an engine, you can't convert all the heat into usable work eff < 1 always

Why are they equivalent? "no perfect engine"

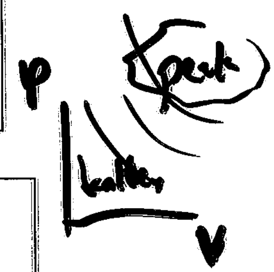
Review of Chapter 12

positive: $V_2 < V_1$
negative: $V_2 > V_1$

$W_{on\ gas}$ = area under curve in P-V diagram
(= $-P\Delta V$ for constant pressure process)

watch out for negative

U depends only on T; often it's strictly proportional
(= 3/2 nRT for monatomic ideal gas)



Visualizing isothermal contours in P-V diagrams helps understand changes in temperature—and hence U

1st Law: $\Delta U = Q_{added} + W_{on\ system}$

figure out last

Engines: transform heat to work
2nd Law: …but not *all* of the heat!

From fuel burned → $Q_h = |W_{net}| + Q_c$ ← Heat exhausted

efficiency = $|W_{net}|/Q_h$

Carnot Theorem: …often not even *most* of the heat!
max eff. = "e_c" = $1 - T_c/T_h$

lowest temp of your cycle
highest temp of cycle

Song:
http://www.uky.edu/~holler/CHE107/media/first_second_law.mp3

Formulas Review

Definitions and Fundamental Laws

Final exam: you will be expected to know these

Definition of density: $\rho = \frac{m}{V}$

Definition of pressure: $P = \frac{F}{A}$

Archimedes' Principle: $F_B = w_{displaced\ fluid}$

$= m_{displaced\ fluid} \times g = \rho_{fluid} V_{object} g$

Ideal Gas Law: $PV = nRT = Nk_B T$

First Law of Thermodynamics: $\Delta U = Q_{added} + W_{on\ system}$

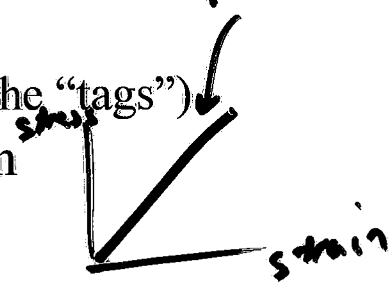
Definition: isothermal = no temperature change

Definition: adiabatic = no heat exchanged

New stuff, but not quite as basic

Final exam: I will give you these (but maybe without the "tags")

stress = F/A; strain = $\Delta L/L$; Y = stress/strain



$P = P_0 + \rho gh$ for static fluids

vol/time $VFR = A_1 v_1 = A_2 v_2$ "garden hose"

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$ for moving fluids

$\Delta L = \alpha L_0 \Delta T$ solids] thermal expansion

$\Delta V = \beta V_0 \Delta T$; $\beta = 3\alpha$

$KE_{ave} = \frac{1}{2} m v_{ave}^2 = \frac{3}{2} k_B T$ (from equipartition theorem)

Calorimetry: $Q = mc\Delta T$; $Q = mL$ latent heat

specific heat

Conduction: $\frac{\Delta Q}{\Delta t} = kA\frac{T_2 - T_1}{L}$ heat energy/time

Radiation: $P = e\sigma AT^4$ = heat energy/time

$W_{on\ gas} = -P\Delta V$ (constant pressure)

= area under curve in P-V diagram (general)

$U = \frac{3}{2}Nk_BT = \frac{3}{2}nRT$ (monatomic ideal gas)

Cycles: $Q_h = \|W_{net}\| + Q_c$ → $|W_{net}| = Q_h - Q_c$

$e = \frac{\|W_{net}\|}{Q_{added}} = 1 - \frac{Q_c}{Q_h}$ → $e = \frac{Q_h - Q_c}{Q_h}$

Carnot Theorem: $e_{max} = 1 - \frac{T_c}{T_h}$

Things which *you* might consider to be formulas

(but I don't really, so I won't give them to you on exam)

Constant volume: $W = 0$

Isothermal: $\Delta U = 0$ because $T_2 = T_1$

Adiabatic: $Q = 0$ definition

Cycles: $\Delta U = 0$ $T_f = T_i$

Exam 4 - Review of important concepts

1. Pressure (Force/area)
   a. Solids
      i. Stress (like 1D pressure) & Strain
      ii. Young's modulus
   b. Non-moving Liquids: + Gases
      i. Pressure increases with depth liquids: $P = P_0 + \rho g h$
      ii. Pascal's principle: pressure in fluid the same at same h
   c. Archimedes' Principle: F_B = weight of displaced fluid
      … = $\rho_{fl} V_{object}\, g$

2. Fluid dynamics
   a. Viscosity → friction
   b. "Garden hose equation" $A_1 v_1 = A_2 v_2 = VFR = \frac{\text{volume}}{\text{time}}$ $\frac{m^3}{s}$
      i. Why/when true
   c. Bernoulli effect: motion of fluid causes P to decrease
      i. wings: combination of air deflection and Bernoulli
   d. Bernoulli eqn: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

3. Temperature effects
   a. Thermal expansion:
      i. $\Delta L = \alpha L_o \Delta T$
      ii. $\Delta V = \beta V_o \Delta T$ ($\beta = 3\alpha$, for solids)
   b. Ideal gas law: $PV = Nk_BT$; $PV = nRT$
   c. Average kinetic energy of each molecule: $\frac{1}{2} m v_{ave}^2 = \frac{3}{2} k_B T$

$c_s = 2010$ $\quad L_{boiling} = 2.26 \cdot 10^6$

What mass of steam that is initially at 121.6° C is needed to warm 340 g of water and its 286-g aluminum container from 22.5° C to 48.5° C? $\quad c_w = 4186 \quad c_{Al} = 900$

$$|Q_{\text{lost by steam}}| = |Q_{\text{gained by Al+water}}|$$

121.6 to 100 $\quad$ 100 to 48.5

$$(mc\Delta T)_{steam} + (mL)_{steam \to water} + (mc\Delta T)_{\text{water that used to be steam}}$$

$$= (mc\Delta T)_{Al} + (mc\Delta T)_{water}$$

$$m(2010)(21.6) + m(2.26 \cdot 10^6) + m(4186)(51.5)$$

$$= (.286)(900)(26) + (.34)(4186)(26)$$

Solve for m

Answer: 17.4 g

Some clicker quizzes

Clicker quiz 1: Where fluid moves faster the pressure is…

a. greater
b. smaller
c. neither; pressure doesn't depend on speed.

Clicker quiz 2: When a spinning "curve ball" is thrown, it will tend to curve because of:

a. the Bernoulli effect
b. conservation of angular momentum
c. inertia
d. Newton's 3rd law
e. the torque applied

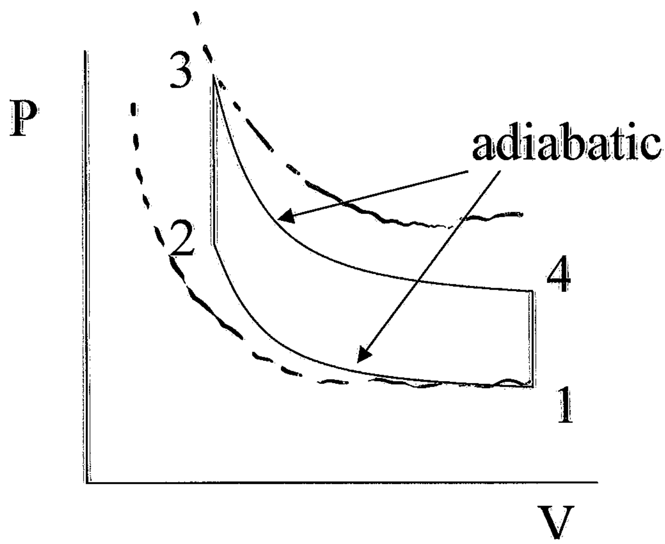
Clicker quiz 3: An ideal (Carnot) heat engine takes heat from water always at 100°C in a natural hot spring under the ground (geothermal energy), and generates useful work (electricity). It exhausts the waste heat to the air above the ground. The engine will be the most efficient in:

a. Summer
b. Winter
c. neither; always the same

$e_c = 1 - \frac{T_c}{T_h}$ ← outside temp

Clicker quiz 1: The *second* law of thermodynamics says for a heat engine:

a. you get more work energy out than you put in as heat
b. you get the same work energy out as you put in as heat
c. you get less work energy out than you put in as heat

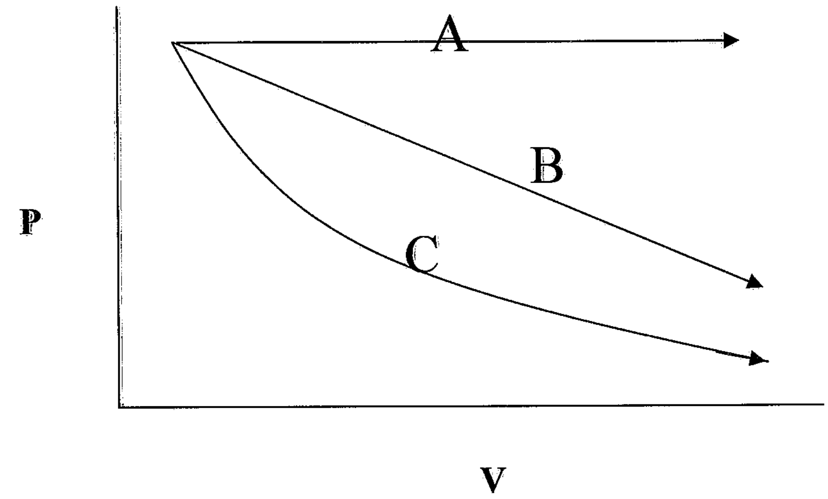


Clicker quiz 2: In this cycle, where is the lowest temperature?

a. 1
b. 2
c. 3
d. 4

Clicker quiz 3: Where is the highest temperature?

a. 1
b. 2
c. 3
d. 4



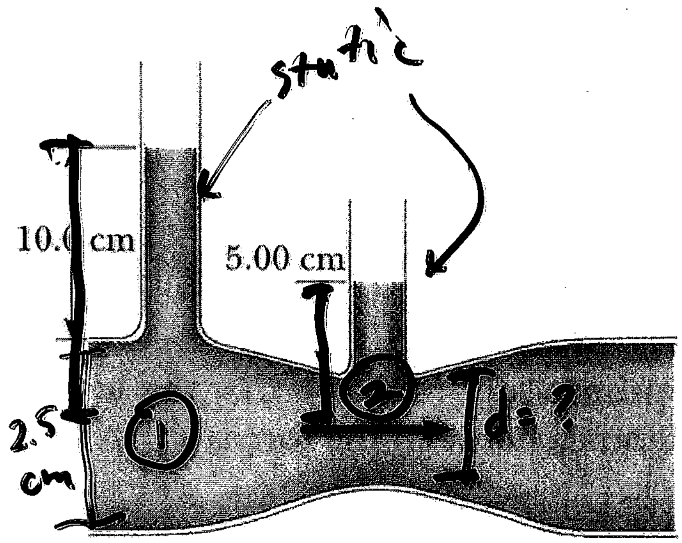
Clicker quiz 1: The process that does the **most work** (magnitude) is __A__

Clicker quiz 2: The process that is at **constant temperature** is __C__

Clicker quiz 3: The process that leaves the system at the **highest T** is:__A__

Clicker quiz 4: The process in which the **magnitudes** of W and Q are the **same** is: __C__ because $\Delta U = 0$

The inside diameters of the large portions of the horizontal pipe in the figure are 2.50 cm. Water flows to the right at a rate of 1.83E-04 m^3/s. Determine the inside diameter of the constriction.



$$VFR = A_1 \cdot v_1 = A_2 v_2$$

$$1.83 \cdot 10^{-4} = \pi \left(\frac{.025}{2}\right)^2 \cdot v_1$$

$$v_1 = \frac{1.83 \cdot 10^{-4}}{\pi \left(\frac{.025}{2}\right)^2} \qquad v_2 = \frac{1.83 \cdot 10^{-4}}{\pi \left(\frac{d}{2}\right)^2}$$

$$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$$

$$P_1 = 1\,atm + \rho g (.1) \qquad P_2 = 1\,atm + \rho g (.05)$$

Solve for d!

Answer: 0.0148 m