Announcements – 17 Nov 2009

1. **Exam starts Thursday**
   a. Thursday will be the in-class exam review
      i. No warmup due
   b. TA exam review(s): ________________
2. **Exam ends on Tuesday, not Wednesday**
   a. Testing Center is not open on Wed, due to Thanksgiving
3. Homework 20 due Thurs
   a. Next homework not due until Dec 5! You get 16 days off!
4. No class a week from today (Friday classes meet)
5. Table Tennis Tournament Results…

Review

From kinetic theory:

$U = 3/2\ Nk_BT = 3/2\ nRT$ (monoatomic)

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

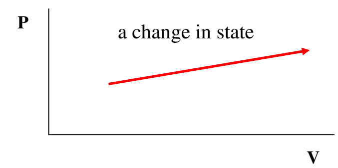
From force = pressure × area and work = force × Δx

$W_{by\ gas} = P\Delta V$

$W_{on\ gas} = -P\Delta V$

Only if P_________ is C__________

What if P_________ is not C_________?



Result: work done = area under curve (but careful with sign)

Isothermal Contours

Think of temperature as the "height" of the point

PV = nRT
→ if temperature is constant, this gives a curve like xy = 3
… or xy = 10 (for a higher temperature)

Contours of constant T: "isothermal"

Exam Question: Does temperature increase/decrease/stay the same for the change in state on the previous page?

→ How to tell?

If temp stays the same: isothermal process.
What is ΔU for an isothermal process? __________

1st Law of Thermodynamics

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

(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:

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

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!!!

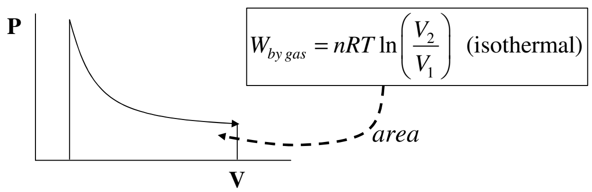
ΔU is positive if:

Q_{added} is positive if:

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

P-V diagram examples

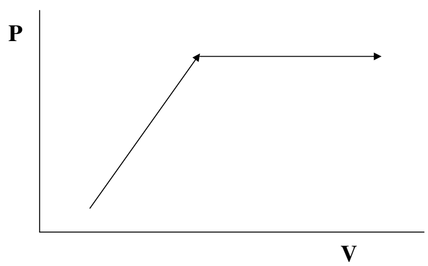
Isothermal process



$$W_{by\ gas} = nRT \ln\left(\frac{V_2}{V_1}\right) \quad \text{(isothermal)}$$

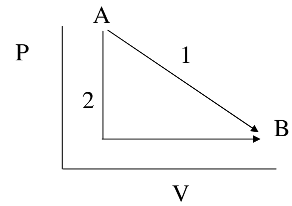
ΔU $\quad\quad$ $W_{on\ gas}$ $\quad\quad$ Q

Some random process



ΔU $\quad\quad$ $W_{on\ gas}$ $\quad\quad$ Q

A gas in a piston expands from point A to point B on the P-V plot, via either path 1 or path 2. Path 2 is a “combo path,” going down first then over.



Clicker quiz: The gas does the most work in:
- a. path 1
- b. path 2
- c. neither; it’s the same

Question: How much work is done in first half of path 2? What is this path physically?

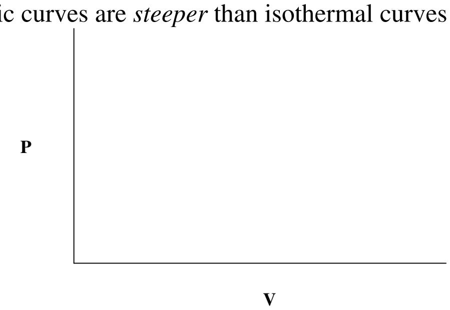
Clicker quiz: The process in which ΔU is the greatest (magnitude) is:
- a. path 1
- b. path 2
- c. neither; it’s the same

Adiabatic expansion or compression

Adiabatic: **“no heat added”**, either because…
- system is *insulated* , or
- ΔV is *fast,* so no time for much heat to go in/out of gas

Q $\quad\quad$ W $\quad\quad$ ΔU

Adiabatic curves are *steeper* than isothermal curves



→ “No heat added” does not mean “no temperature change”

Demos: adiabatic cotton burner
freeze spray

From warmup: Ralph is confused because he knows that when you compress gases, they tend to heat up. Think of bicycle pumps. So, how are isothermal processes possible? How can you compress a gas without its temperature increasing?

Answer from the class:

Summary: Four special types of state changes

Constant Pressure:

Constant Volume:

Isothermal:

Adiabatic:

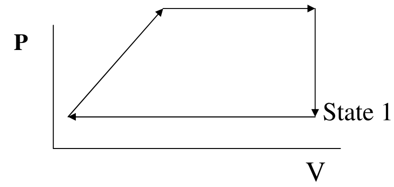
From warmup: A gas has its pressure reduced while its volume is kept constant. What does this look like on a PV diagram?

a. a horizontal line going to the right
b. a horizontal line going to the left
c. a vertical line going up
d. a vertical line going down

From warmup: Same situation. How did the temperature of the gas change during that process?

a. the temperature increased
b. the temperature decreased
c. the temperature stayed the same
d. the temperature change cannot be determined from the information given

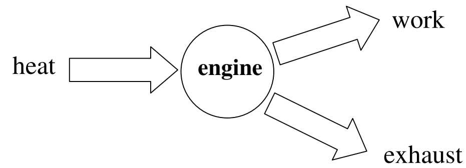
Cyclical Processes



ΔU $\qquad$ $W_{\text{on gas}}$ $\qquad$ Q

Engines

The basic idea: energy transformation



Notation: Q_h, Q_c, T_h, T_c, $|W_{net}|$

Demo: Stirling engine

Efficiency: how good is your engine at converting heat to work?

Definition: $\quad e =$

Engine Power: work per time (as usual)

Worked Problem: An engine produces power of 5000 W, at 20 cycles/second. Its efficiency is 20%. What are $|W_{net}|$, Q_h, and Q_c per cycle?

What do those quantities represent?

Answers: 250 J, 1250 J, 1000 J

Real engines modeled by PV-diagram cycles

Example: Gasoline engines

- Piston is compressed quickly
- Heat is then added quickly by igniting fuel
- Piston then expands quickly
- Heat is then expelled quickly (by getting rid of old air)
  → Same air is not re-used; the cycle is just an approximation

The "Otto cycle"

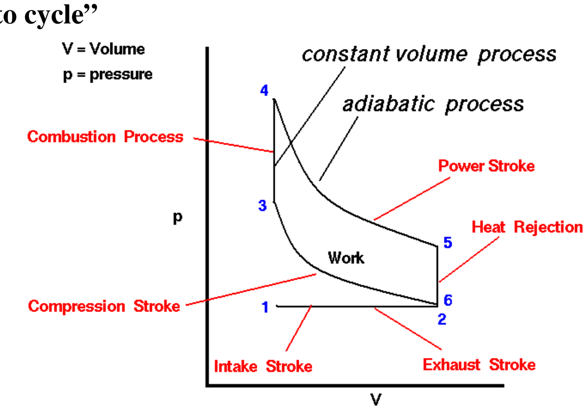


Image credit: http://www.grc.nasa.gov/WWW/K-12/airplane/otto.html

Difference between gas and diesel engines?

2^{nd} Law of thermodynamics:

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

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

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

Question: You separate a deck into two halves: one is 70% red, 30% black; the other is 30% red, 70% black. What will happen if you randomly exchange cards between the two?

Another version of the law:

In an engine, you can't convert all the heat into usable work (warmup quiz)

Why are they equivalent?

Carnot's Theorem:

You can't even convert *most* of the heat into work

$$e_{max} = "e_C" = 1 - \frac{T_c}{T_h}$$

C for Carnot

(Organized) Energy lost by "irreversibilities"

Irreversibilities occur when heat is added during a temperature change

Most efficient engine possible: Carnot engine

→ all heat added during constant temperature processes

Drawback: Isothermal = slow, typically

Review of Chapter 12

$W_{on/by\ gas}$ = area under curve in P-V diagram (watch the signs!)

U depends only on T; often it's strictly proportional
3/2 nRT for monatomic, 5/2 nRT for diatomic at ~300K

P-V diagrams: graph changes to state; visualize isothermal contours to understand changes in temperature—and hence U

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

Four specific changes
- constant pressure: $W = P\Delta V$
- constant volume: $W = 0$
- isothermal: $\Delta U = 0$, $W = nRT\ln(V_2/V_1)$
- adiabatic: $Q = 0$

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

From fuel burned / Heat exhausted

$Q_h = |W_{net}| + Q_c$

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

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

Song: (4 minutes)
http://www.uky.edu/~holler/CHE107/media/first_second_law.mp3