Announcements – 21 Nov 2013

1. **No class on Tuesday** (Friday instruction)

2. **You get two weeks off with no homework.** ☺
   a. HW 23 is due tonight
   b. HW 24 is "Good luck on the exam"
   c. HW 25 is due Dec 5

3. **Exam 4 starts today!**
   a. Exam ends Monday Dec 2, 3 pm. Late fee after Tues Nov 26, 2 pm
   b. 31 multiple choice questions
   c. Time estimate: 2 hrs 15 mins
   d. Covers all of Thermodynamics, i.e. Chapters 9-12, HW 18-24*
   e. **Read my chapter summaries in the syllabus**

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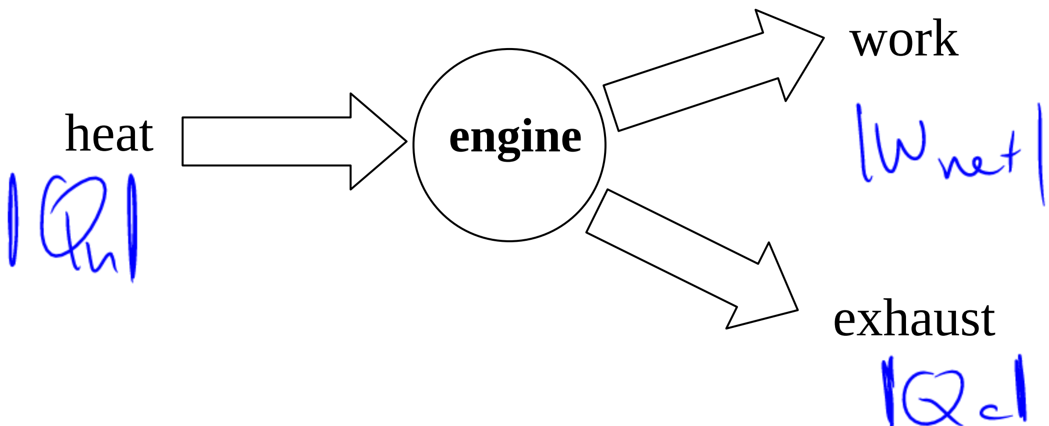
* There isn't really a HW 24

Engines (Review)

Picture



Equation

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

Efficiency: $e = \dfrac{|W_{net}|}{Q_h} = \dfrac{|Q_h| - |Q_c|}{|Q_h|} = 1 - \dfrac{|Q_c|}{|Q_h|}$

Power: $P = \dfrac{|W_{net}|}{t}$

Demo: Stirling Engine

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?

$$t = \frac{1\ \text{sec}}{20\ \text{cycles}} = .05\ \text{sec}$$

$$P = \frac{|W_{net}|}{t}$$

$$|W| = P \times t$$

$$= 5000\ \frac{J}{s} \times (.05)\ \text{sec}$$

$$= \boxed{250\ J}$$

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

$$e = \frac{|W|}{Q_h}$$

$$Q_h = \frac{|W|}{e} = \frac{250\ J}{.2}$$

$$= \boxed{1250\ J}$$

$$Q_c = Q_h - |W|$$

$$= 1250 - 250$$

$$= \boxed{1000\ J}$$

What do those quantities represent?

Answers: 250 J, 1250 J, 1000 J

Real engines
modeled by PV-diagram cycles

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"

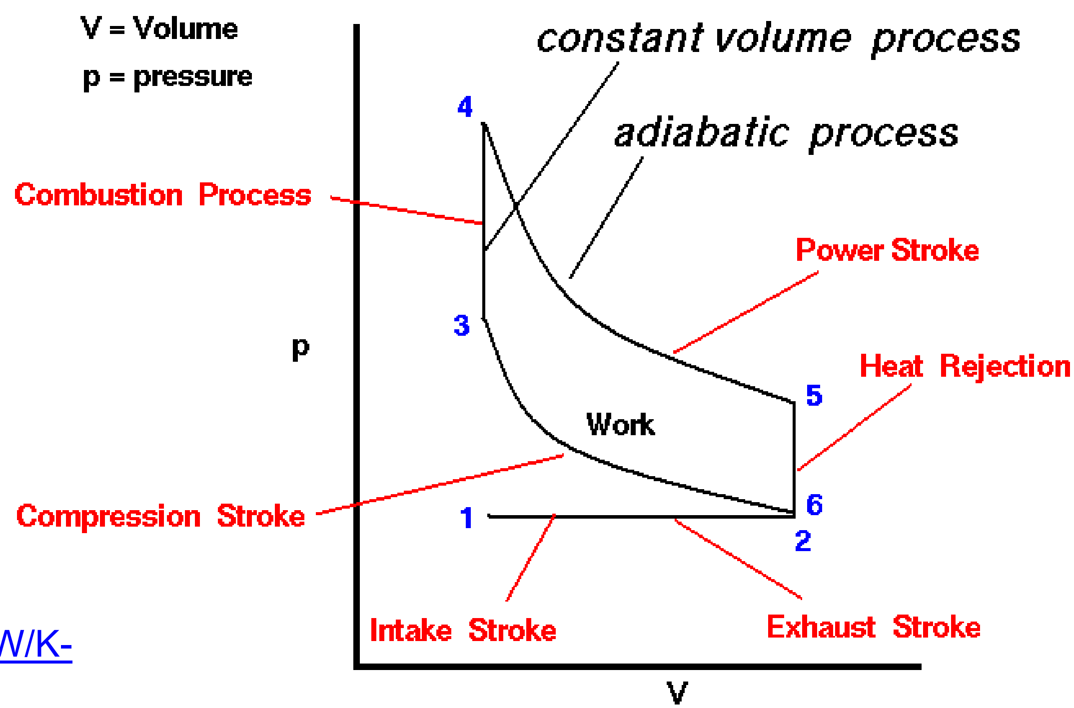
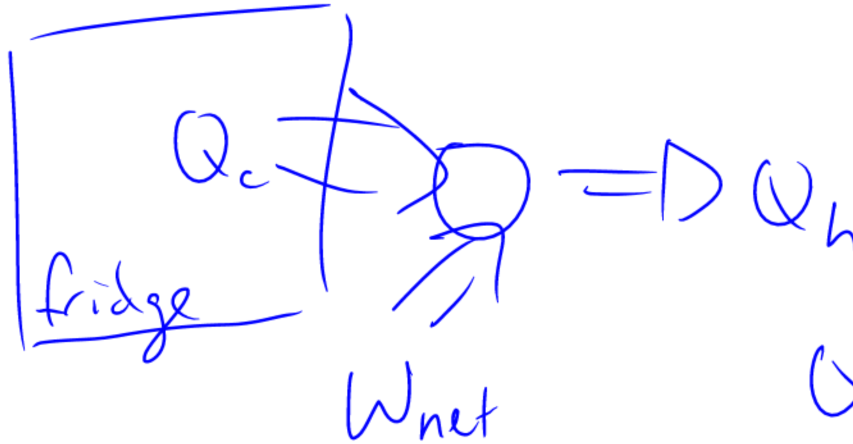


Image credit:
http://www.grc.nasa.gov/WWW/K-12/airplane/otto.html

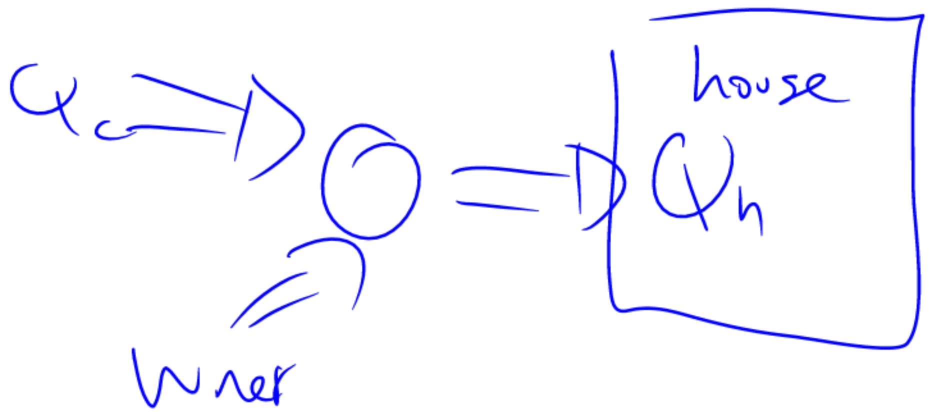
Refrigerators/Heat Pumps

Refrigerator picture:



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

Heat pump picture:



Admission:

You don't need this!

From warmup (last time)

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

2nd Law of thermodynamics (alternate)

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

Why? **<u>Order.</u>** From textbook: which hand is more likely?

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

Entropy concept

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?

Entropy equation: you don't need to know

Second Law, Two versions

In an engine, you can't convert all the heat into usable work

if **Heat doesn't flow from cold to hot** then

<u>Why are they equivalent?</u>

1. If you had a process whereby heat flows from cold to hot…

2. If you had an engine that completely converts heat to usable work…

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

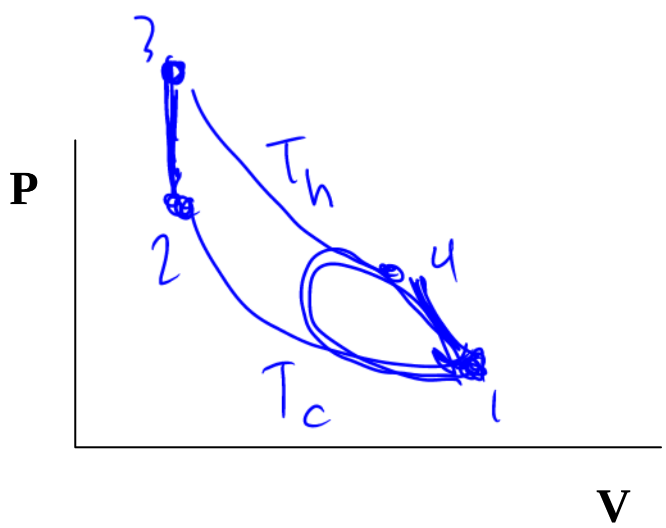
Carnot Engine

(Usable) Energy lost by "irreversibilities"

Irreversibilities occur when heat is added during a temperature change

Most efficient engine possible for given T_{max} and T_{min}: Carnot engine

→ all heat added during constant temperature processes



$$e = 1 - \frac{T_c}{T_h}$$

Drawback: Isothermal = slow, typically

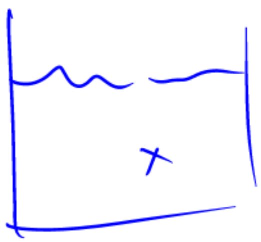
(end of chapter 12 !)

Song

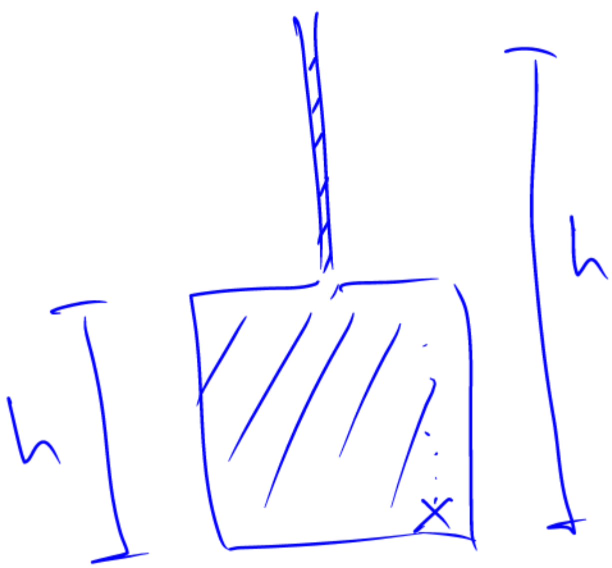
http://www.uky.edu/~holler/CHE107/media/first_second_law.mp3
(4 minutes)

Demo

Pascal's barrel



$$P = P_0 + \rho g h$$



Some details of the exam problems…

Requested Problems from Past Exams…

2007 #29, 30, 31, 32

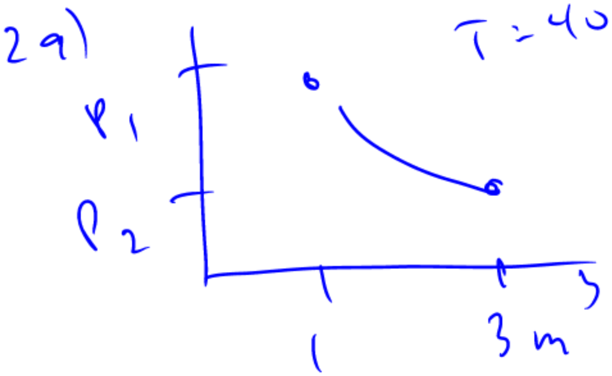
$\Delta U = Q + W_{on}$

$\uparrow$

0

$Q = -W_{on}$

29)



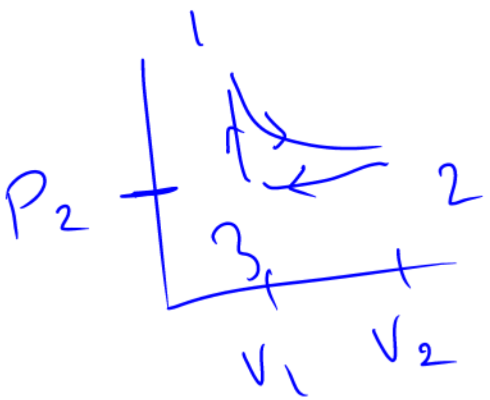
$T = 400\,K$

$n = 30$ moles

$|W| = 109554\,J$

$P_1V_1 = nRT_1 \rightarrow P_1 = \frac{nRT_1}{V_1} = \frac{(30)(8.31)(400)}{(1)}$

$P_2 = \frac{nRT}{V_2} = \frac{1}{3}$ of $\uparrow$



$W_{net} = (W_{12})_{by} - (W_{23})_{on}$

109554 J

$\uparrow$

?

$W = P_2 \Delta V$

$\uparrow$

$= (\text{answer to } P_2)(3-1)$

2008 #31

$$P_{left} + \cancel{\rho g h} + \cancel{\tfrac{1}{2}\rho v^2} = P_{right} + \cancel{\rho g h} + \tfrac{1}{2}\rho v^2$$

1atm

$$P_{right} = 1atm - \tfrac{1}{2}\rho_{air} v^2$$

$$P_A = P_B$$

1atm

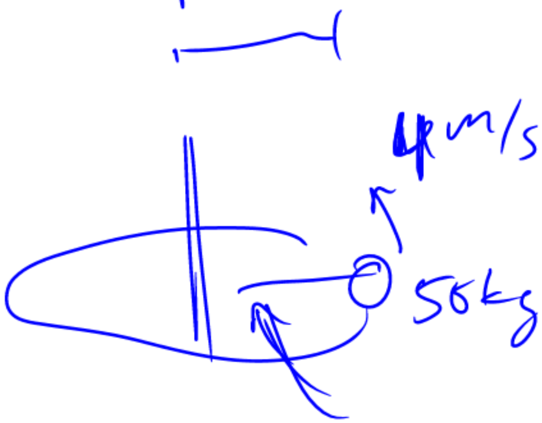
$$\boxed{P_{top} + \rho g h}$$

$$\cancel{1\,atm} = (\cancel{1\,atm} - \tfrac{1}{2}\rho_{air} v^2) + \rho_{water} \cdot g \cdot h$$

$$\tfrac{1}{2}\rho_{air} v^2 = \rho_{water}\, g\, h$$

$$v = \sqrt{\frac{2\rho_w}{\rho_a} g h}$$

2009 #31



Contact $A = 100\,cm^2$

$P = ?$

$\Sigma F = m a_c$

$T = \frac{mv^2}{r}$

$P = F/A$

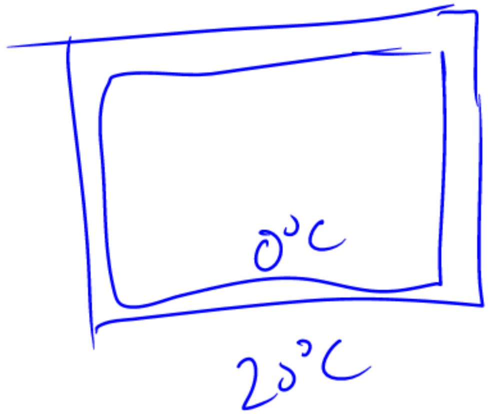
$$= \frac{mv^2}{r \cdot A} = \frac{(50kg)(4\frac{m}{s})^2}{(1.6m)\left(100cm^2 \cdot \left(\frac{1m}{100cm}\right)^2\right)}$$

$=$

Requested Problems from Past Exams…

2009 #33

cooler



$A = .5\,m^2$

thickness $= .04\,m$

$k = ?$

X melts: 10 hrs for 12 kg to melt

$L = 3\cdot10^5 \frac{J}{kg}$

$$mL = Q \qquad \frac{Q}{t} = \frac{kA}{\ell}\Delta T$$

$$\frac{(12\,kg)(3\cdot10^5\,\frac{J}{kg})}{10\cdot60\cdot60\,s} = \frac{k(.5\,m^2)}{(.04\,m)}(20-0)^\circ C$$

Solve!