Announcements – 19 Nov 2009

1. **No class on Tuesday** (Friday instruction)
2. **Exam 4 starts today!**
   a. Exam ends **Tues Nov 24** (late fee after 3 pm)
   b. Covers Chapters 9-12, HW 15-20 (but cumulative)
   c. Anticipated average time: 2 hours
   d. Anticipated average score: 75-80%
   e. No problems where you turn in work
   f. Look over the first page of exam on class website
   g. No outside calculators (you can check one out if you like)
   h. Things to study, roughly in order of importance:
      i. HW problems
      ii. Conceptual stuff, especially:
         1. Clicker quizzes
         2. Warmup questions
         3. Demos
         4. Questions from old exams
      iii. Problems from old exams
      iv. Worked problems from class
      v. Textbook problems

Summary of Chapter 12

W on gas positive : volume decreasing
W on gas negative : volume increasing

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

internal energy

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

ΔU positive: temp increase
ΔU negative: temp decreases

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

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

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

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: $Q = 0$

$\Delta U = 0$

Engines: transform heat to work
2nd 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" = $1 - T_c/T_h$

in kelvin!

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

First page of the Exam

yellow = stuff specifically for this exam

Constants:

$g = 9.8$ m/s^2 → **but you may use 10 m/s^2 in nearly all cases**

$G = 6.67 \times 10^{-11}$ N·m^2/kg^2

$k_B = 1.381 \times 10^{-23}$ J/K

$N_A = 6.022 \times 10^{23}$

$R = k_B \cdot N_A = 8.314$ J/mol·K

$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4

Mass of Sun $= 1.991 \times 10^{30}$ kg

Mass of Earth $= 5.98 \times 10^{24}$ kg

Radius of Earth $= 6.38 \times 10^6$ m

Radius of Earth's orbit $= 1.496 \times 10^{11}$ m

Density of water: 1000 kg/m^3

Density of air: 1.29 kg/m^3

Linear exp. coeff. of copper: 17×10^{-6} /°C

Linear exp. coeff. of steel: 11×10^{-6} /°C

Specific heat of water: 4186 J/kg·°C

Specific heat of ice: 2090 J/kg·°C

Specific heat of steam: 2010 J/kg·°C

Specific heat of aluminum: 900 J/kg·°C

Latent heat of melting (water): 3.3×10^5 J/kg

Latent heat of boiling (water): 2.26×10^6 J/kg

Thermal conduct. of aluminum: 238 J/s·m·°C

$v_{air} = 343$ m/s at 20° C

$\sin(30°) = 0.5$

$\cos(30°) \approx 0.866$

$\tan(30°) \approx 0.577$

$\pi \approx 3.14$

Conversion factors

1 inch = 2.54 cm

1 m^3 = 1000 L

1 atm $= 1.013 \times 10^5$ Pa = 14.7 psi

$T_F = \frac{9}{5} T_C + 32$

$T_K = T_C + 273.15$

Other equations

$x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Surface area of sphere = $4\pi r^2$

Volume of sphere = $(4/3)\pi r^3$

$v_{ave} = \dfrac{v_i + v_f}{2}$

$v = v_o + at$

$x = x_o + v_o t + \frac{1}{2} a t^2$

$v_f^2 = v_o^2 + 2a\Delta x$

$w = mg$, $PE_g = mgy$

$F = -kx$, $PE_s = \frac{1}{2} kx^2$

$f = \mu_k N$ (or $f \le \mu_s N$)

$P = F_{//} v = Fv\cos\theta$

$\vec{F}\Delta t = \Delta\vec{p}$

Elastic: $(v_1 - v_2)_{bef} = (v_2 - v_1)_{after}$

arc length: $s = r\theta$

$v = r\omega$

$a_{tan} = r\alpha$

$a_c = v^2/r$

$F_g = \dfrac{GMm}{r^2}$, $PE_g = -\dfrac{GMm}{r}$

$I_{pt\ mass} = mR^2$

$I_{sphere} = (2/5)\ mR^2$

$I_{hoop} = mR^2$

$I_{disk} = (1/2)\ mR^2$

I_{rod} (center) $= (1/12)\ mL^2$

I_{rod} (end) $= (1/3)\ mL^2$

$L = r_\perp p = r p_\perp = rp\sin\theta$

$P = P_0 + \rho g h$

$VFR = A_1 v_1 = A_2 v_2$

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

$\Delta L = \alpha L_0 \Delta T$

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

$KE_{ave} = \frac{1}{2} m v_{ave}^2 = \frac{3}{2} k_B T$

$Q = mc\Delta T$; $Q = mL$

$\dfrac{\Delta Q}{\Delta T} = kA\dfrac{T_2 - T_1}{L}$

$P = e\sigma A T^4$

$|W_{on\ gas}|$ = area under P-V curve

$= |P\Delta V|$ (constant pressure)

$= |nRT\ln(V_2/V_1)|$ (isothermal)

$= |\Delta U|$ (adiabatic)

$U = \frac{3}{2} N k_B T = \frac{3}{2} nRT$ (monatomic)

$U = \frac{5}{2} N k_B T = \frac{5}{2} nRT$ (diatomic, 300K)

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

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

$e_{max} = 1 - \dfrac{T_c}{T_h}$

$\omega = \sqrt{\dfrac{k}{m}}$, $T = 2\pi\sqrt{\dfrac{m}{k}}$

$\omega = \sqrt{\dfrac{g}{L}}$, $T = 2\pi\sqrt{\dfrac{L}{g}}$

$v = \sqrt{\dfrac{T}{\mu}}$, $\mu = m/L$

$\beta = 10\log\left(\dfrac{I}{I_0}\right)$ $\quad I_0 = 10^{-12}$ W/m^2

$f' = f\dfrac{v \pm v_0}{v \pm v_S}$

$f_n = n\dfrac{v}{2L}$ $\quad n = 1,2,3,\ldots$

$f_n = n\dfrac{v}{4L}$ $\quad n = 1,3,5,\ldots$

Exam 4 - Review of important concepts

1. Pressure & Buoyancy in Static Fluids

   a. Definition of pressure, force/area: $P = \frac{F}{A}$

   <u>not</u> given on exam

   b. Definition of density: $\rho = \frac{m}{V}$ <u>not</u> given on exam

   c. Static liquids:

      i. Pressure increases with depth, $P = \overset{P_{top}}{P_0} + \overset{\text{density}}{\rho} g \underset{}{h}$ depth

      <u>is</u> given on exam

      ii. Pressure in static fluid is the same at same h

   d. Archimedes' Principle: F_B = *weight of displaced fluid*

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

   <u>not</u> given on exam

2. Fluid dynamics: Pressure in Moving Fluids

   a. Viscosity friction in fluid

   b. "Garden hose equation", $\overset{m^3/s}{VFR} = \underset{\text{cross section area}}{A_1} \overset{\text{speed}}{v_1} = A_2 v_2$

   <u>is</u> given on exam

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

   <u>is</u> given on exam

linear expansion coefficient

volume " "

$nR = Nk_B$

3. Temperature effects

a. Thermal expansion:

i. $\Delta L = \alpha L_o \Delta T$ solids — <u>is</u> given on exam

ii. $\Delta V = \beta V_o \Delta T$ ($\beta = 3\alpha$, for solids) — <u>is</u> given on exam

b. Ideal gas law: $PV = nRT$, $PV = Nk_BT$ — <u>not</u> given on exam

(P: Pa; V: m^3; n: moles; R: 8.31; T: kelvin; N: #molecules; k_B: $1.38\cdot10^{-23}$)

c. "Kinetic Theory Equation": transl. $KE_{ave} = \frac{1}{2}mv_{ave}^2 = \frac{3}{2}k_BT$ — <u>is</u> given on exam

$n = \frac{N}{6.022\cdot10^{23}}$

i. Use to get average speed or average KE

$n = \frac{m}{MM}$

d. Internal energy — both <u>are</u> given on exam

1. $U = \frac{3}{2}Nk_BT = \frac{3}{2}nRT$ (monatomic)

2. $U = \frac{5}{2}Nk_BT = \frac{5}{2}nRT$ (diatomic, ~300K)

4. Heat

a. Calorimetry: $Q_{gained\ by\ 1} = Q_{lost\ by\ 2}$ (Blueprint eqn)

i. $Q = mc\Delta T$; $Q = mL$ — both <u>are</u> given on exam

(c: specific heat; L: latent heat)

ii. Colton method: Make sure each term is positive

b. Radiation: $P = \frac{heat}{time} = e\sigma AT^4$ — <u>is</u> given on exam

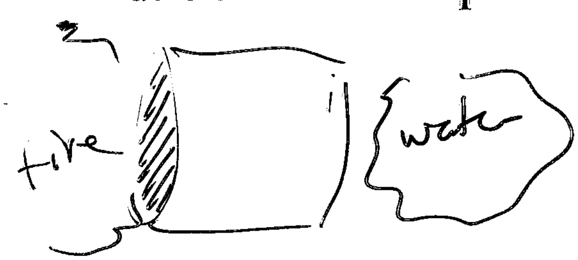
(P: power; e: emissivity; A: surface area; T: in kelvin; σ: $5.67\cdot10^{-8}$)

i. Describes heat emitted and heat absorbed

c. Conduction: $P = \frac{heat}{time} = kA\frac{T_2 - T_1}{L}$ — <u>is</u> given on exam

(P: power; A: cross section area; L: length/thickness; k: thermal conductivity)

d. Convection: qualitative only



5. Thermodynamics
   a. P-V diagrams
      i. Isothermal contours to visualize temperature changes
      ii. Work done on/by a gas: area under curve on P-V
         1. Positive vs. negative
   b. First Law: $\Delta U = Q_{added} + W_{on\ system}$ — <u>not</u> given on exam
   c. Five special state changes:
      i. constant P
      ii. constant V: $W=0$ — <u>not</u> given on exam
      iii. isothermal (constant T): $\Delta U=0$ — <u>not</u> given on exam
      iv. adiabatic: $Q=0$ — <u>not</u> given on exam
      v. cycle: $\Delta U=0$ — <u>not</u> given on exam

   This is what I give you on the exam for those changes:

$$\left|W_{on\ gas}\right| = \text{area under P-V curve}$$
$$= \left|P\Delta V\right| \quad \text{(constant pressure)}$$
$$= \left|nRT\ln\left(V_2/V_1\right)\right| \quad \text{(isothermal)}$$
$$= \left|\Delta U\right| \quad \text{(adiabatic)}$$

   d. Engines: general picture
      i. $Q_h = \left|W_{net}\right| + Q_c$ — <u>is</u> given on exam

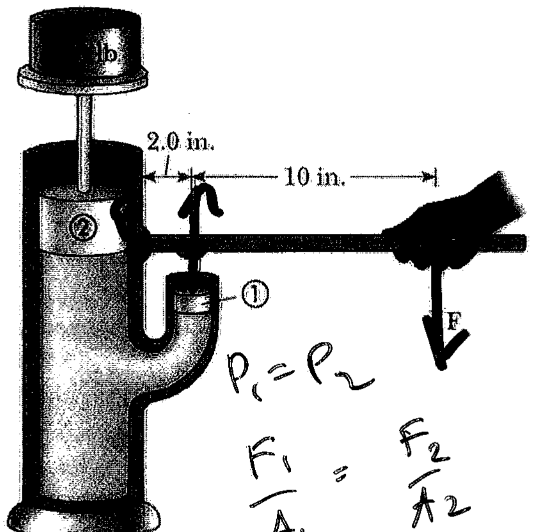
      from burning exhaust

      ii. Efficiency: $e = \dfrac{\left|W_{net}\right|}{Q_{added}} = \dfrac{Q_h - Q_c}{Q_h}$ — <u>is</u> given on exam
         1. Carnot Theorem: $e_{\max} = 1 - \dfrac{T_c}{T_h}$ — <u>is</u> given on exam
      iii. Second Law: Two versions, qualitative reason

a = work
b = don't work

$A = \pi r^2 = \frac{\pi d^2}{4}$

HW 15-2. Piston 1 in the figure has a diameter of 0.58 in.; piston 2 has a diameter of 1.5 in. In the absence of friction, determine the force F necessary to support the 500-lb weight.



$\Sigma \tau_p = 0$

$+F_1(2\text{ inch}) - F(12\text{ inch}) = 0$

solve for $\boxed{F = 12.5\text{lbs}}$

$P_1 = P_2$

$\frac{F_1}{A_1} = \frac{F_2}{A_2}$

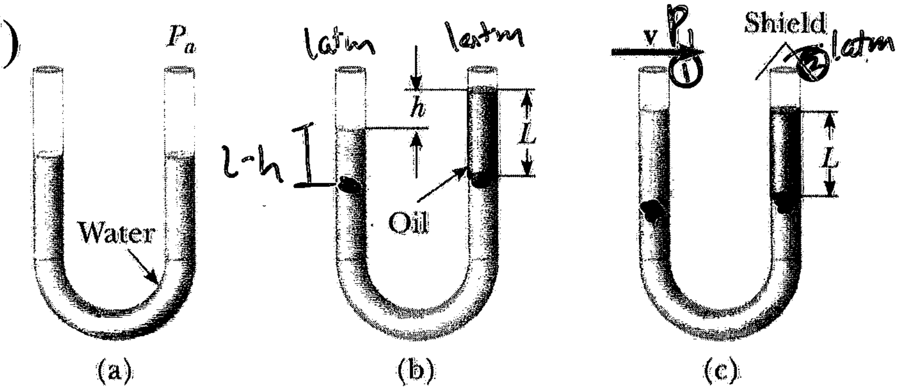
$F_1 = \left(\frac{A_1}{A_2}\right) F_2$

$= \left(\frac{\pi d_1^2/4}{\pi d_2^2/4}\right) F_2$

$= \left(\frac{.58\text{ inch}}{1.5\text{ inch}}\right)^2 500\text{lbs} =$

Answer: 12.5 lbs

HW 16-5. Oil ($\rho = 700\ kg/m^3$) is poured into the right arm of a U-tube and forms a column L = 3 cm high. (a) What is h? (b) Air is blown across the left arm while the right arm is shielded; the left side gets "sucked" up until the two sides are at the same height. What is v? ($\rho_{air} = 1.3\ kg/m^3$)



pressure at a depth

$$P = P_{top} + \rho g h$$

(a) $\cancel{1\ atm} + \rho_w g(L-h) = \cancel{1\ atm} + \rho_{oil} g L$

$$\rho_w \cancel{g}(L-h) = \rho_{oil}\cancel{g} L$$

$$1000\,(.03-h) = 700\,(.03)$$

solve for $\boxed{h_1 = .009\ m}$

(b) $P_1 + \rho_w g L = 1\,atm + \rho_{oil} g L$

applied to air!

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

$$P_1 + \tfrac{1}{2}\rho_{air} v_1^2 = 1\,atm$$

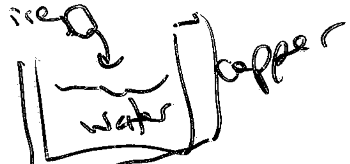
$$\cancel{P_1} + \rho_w g L = (\cancel{P_1} + \tfrac{1}{2}\rho_{air} v_1^2) + \rho_{oil} g L$$

solve for v_1, $= \boxed{11.6\ \frac{m}{s}}$

Answers: 0.9 cm, 11.6 m/s

HW 17.3. An underground gasoline tank at 54° F can hold 930 gallons of gasoline. If the driver of a tanker truck fills the underground tank on a day when the temperature is 90° F, how many gallons, according to his measure on the truck, can he pour in? Assume that the temperature of the gasoline cools to 54° F upon entering the tank. Use the coefficient of **volume** expansion for gasoline given in the textbook, $\beta = 9.6 \times 10^{-4}$ /°C

Answer: 948 gallons



HW 18-5. A 45.1-g block of ice is cooled to –78.3° C. It is added to 567 g of water in an 85-g copper calorimeter at a temperature of 25.3° C. Determine the final temperature. Remember that the ice must first warm to 0° C, melt, and then continue warming as water. The specific heat of ice is 2090 J/kg·°C.

$$Q_{\text{gained by ice}} = Q_{\text{lost by water + copper}}$$

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

$$(.0451)(2090)(78.3) + (.0451)(3.33\cdot 10^5) + (.0451)(4186)(T_f - 0)$$
$$= (.567)(4186)(25.3 - T_f) + (.085)(387)(25.3 - T_f)$$

$$\boxed{T_f = 14.8^\circ C}$$

Answer. 14.8° C

HW 18-6. 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?

Answer: 17.4 g

HW 19.1. A Styrofoam box has a surface area of 0.832 m^2 and a wall thickness of 2.09 cm. The temperature of the inner surface is 4.8° C, and that outside is 25.5° C. If it takes 9.79 hours for 5.54 kg of ice to melt in the container, determine the thermal conductivity of the Styrofoam.

Answer: 0.0635 W/m·°C

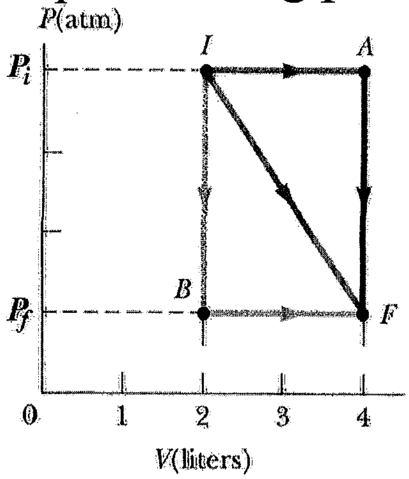
HW 19-3. Calculate the temperature at which a tungsten filament that has an emissivity of 0.25 and a surface area of 2.5×10^{-5} m^2 will radiate energy at the rate of 36 W in a room where the temperature is 22° C.

Answer: 2900° C

HW 19-4. A sample of helium behaves as an ideal gas as it is heated at constant pressure from 273 K to 369 K. If 34 J of work is done by the gas during this process, what is the mass of helium present?

Answer: 0.170 g

HW 19-5 (b). Calculate the work done on the gas as the gas expands along path IF. $P_i = 3.05$ atm and $P_f = 1.07$ atm.



Answer: -417 J

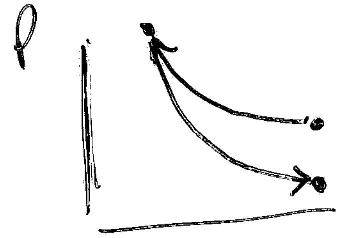
HW 20-3. 2.23 moles of a monatomic ideal gas have a volume of 1.00 m^3, and are initially at 354 K. (a) Heat is carefully removed from the gas as it is compressed to 0.50 m^3, causing the temperature to remain constant. How much work was done on the gas in the process? (b) Now the gas is expanded again to its original volume, but so quickly that no heat has time to enter the gas. This cools the gas to 223 K. How much work was done by the gas in this process?

isothermal: $|W| = |nRT \ln V_2/V_1|$

$= (2.23)(8.31)(354)\ln\left(\frac{1}{.5}\right)$

$= +(2.23)(8.31)(354)\ln 2$

$= \boxed{4550\ J}$



adiabatic $\Delta U = \overset{=0}{\cancel{Q_{added}}} + W_{on}$

$W_{on} = \Delta U$

$= \frac{3}{2} nR\Delta T$

$= \frac{3}{2}(2.23)(8.31)(-131)$

$W_{by} = \frac{3}{2}(2.23)(8.31)(+131)$

$= \boxed{3640\ J}$

Answers: 4550 J, 3640 J

$\frac{|W_{net}|}{time}$

HW 20-6. A nuclear power plant has an electrical power output of 1000 MW and operates with an efficiency of 33%. If the excess energy is carried away from the plant by a river with a mass flow rate of 1.9E6 kg/s, what is the rise in temperature of the flowing water?

$$\frac{Q_h}{time} = \frac{|W_{net}|}{time} + \frac{Q_c}{time}$$

$|W_{net}|/time = 1000 \cdot 10^6$

solve for $\frac{Q_c}{time}$

$$e = \frac{|W_{net}|/time}{Q_h/time}$$

$e = .33$, $|W_{net}|/time = 1000 \cdot 10^6$

solve for $Q_h/time$

$$\frac{Q_c}{time} = \frac{m}{time} c \Delta T$$

$\frac{m}{time}$: $\frac{kg}{s}$

Answer: 0.26° C