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

$W_{on/by\ gas}$ = 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: to graph changes to state; visualize isothermal contours to understand changes in temperature—and hence *U*

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

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
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" = $1 - T_c/T_h$

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 = 1.991×10^{30} kg
- Mass of Earth = 5.98×10^{24} kg
- Radius of Earth = 6.38×10^6 m
- Radius of Earth's orbit = 1.496×10^{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°) ≈ 0.866
- tan(30°) ≈ 0.577
- $\pi \approx 3.14$

Conversion factors
- 1 inch = 2.54 cm
- 1 m^3 = 1000 L
- 1 atm = 1.013×10^5 Pa = 14.7 psi
- $T_F = \frac{9}{5}T_C + 32$
- $T_K = T_C + 273.15$

Other equations
- $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
- Surface area of sphere = $4\pi r^2$
- Volume of sphere = $(4/3)\pi r^3$
- $v_{ave} = \frac{v_i + v_f}{2}$
- $v = v_o + at$
- $x = x_o + v_o t + \frac{1}{2}at^2$
- $v_f^2 = v_o^2 + 2a\Delta x$
- $w = mg$, $PE_g = mgy$
- $F = -kx$, $PE_s = ½ kx^2$
- $f = \mu_k N$ (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: $s = r\theta$
- $v = r\omega$
- $a_{tan} = r\alpha$
- $a_c = v^2/r$
- $F_g = \frac{GMm}{r^2}$, $PE_g = -\frac{GMm}{r}$
- $I_{pt\ mass} = mR^2$
- $I_{sphere} = (2/5)\ mR^2$
- $I_{hoop} = mR^2$
- $I_{disk} = (1/2)\ mR^2$
- I_{rod} (center) = $(1/12)\ mL^2$
- I_{rod} (end) = $(1/3)\ mL^2$
- $L = r_\perp p = rp_\perp = rp\sin\theta$
- $P = P_0 + \rho gh$
- $VFR = A_1v_1 = A_2v_2$
- $P_1 + \frac{1}{2}\rho v_1^2 + \rho gy_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho gy_2$
- $\Delta L = \alpha L_0 \Delta T$
- $\Delta V = \beta V_0 \Delta T$; $\beta = 3\alpha$
- $KE_{ave} = \frac{1}{2}mv_{ave}^2 = \frac{3}{2}k_B T$
- $Q = mc\Delta T$; $Q = mL$
- $\frac{\Delta Q}{\Delta T} = kA\frac{T_2 - T_1}{L}$
- $P = e\sigma AT^4$
- $|W_{on\ gas}|$ = area under P-V curve
  - $= |P\Delta V|$ (constant pressure)
  - $= |nRT\ln(V_2/V_1)|$ (isothermal)
  - $= |\Delta U|$ (adiabatic)
- $U = \frac{3}{2}Nk_BT = \frac{3}{2}nRT$ (monatomic)
- $U = \frac{5}{2}Nk_BT = \frac{5}{2}nRT$ (diatomic, 300K)
- $Q_h = |W_{net}| + Q_c$
- $e = \frac{|W_{net}|}{Q_{added}} = 1 - \frac{Q_c}{Q_h}$
- $e_{max} = 1 - \frac{T_c}{T_h}$
- $\omega = \sqrt{\frac{k}{m}}$, $T = 2\pi\sqrt{\frac{m}{k}}$
- $\omega = \sqrt{\frac{g}{L}}$, $T = 2\pi\sqrt{\frac{L}{g}}$
- $v = \sqrt{\frac{T}{\mu}}$, $\mu = m/L$
- $\beta = 10\log\left(\frac{I}{I_0}\right)$ $I_0 = 10^{-12}$ W/m^2
- $f' = f\frac{v \pm v_0}{v \pm v_S}$
- $f_n = n\frac{v}{2L}$ $n = 1,2,3,...$
- $f_n = n\frac{v}{4L}$ $n = 1,3,5,...$

Exam 4 - Review of important concepts

1. Pressure & Buoyancy in Static Fluids
   a. Definition of pressure, force/area: $P = \frac{F}{A}$
      not given on exam
   b. Definition of density: $\rho = \frac{m}{V}$ not given on exam
   c. Static liquids:
      i. Pressure increases with depth, $P = P_0 + \rho gh$
         is given on exam
      ii. Pressure in static fluid is the same at same *h*
   d. Archimedes' Principle: F_B = *weight of displaced fluid*
      $= m_{displaced\ fluid} \times g = \rho_{fluid}V_{object}g$
      not given on exam

2. Fluid dynamics: Pressure in Moving Fluids
   a. Viscosity
   b. "Garden hose equation", $VFR = A_1v_1 = A_2v_2$
      is 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: $P_1 + \frac{1}{2}\rho v_1^2 + \rho gy_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho gy_2$
      is given on exam

3. Temperature effects
   a. Thermal expansion:
      i. $\Delta L = \alpha L_o \Delta T$ — <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
   c. "Kinetic Theory Equation": transl. $KE_{ave} = \frac{1}{2}mv_{ave}^2 = \frac{3}{2}k_BT$ — <u>is</u> given on exam
      i. Use to get average speed or average KE
   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)

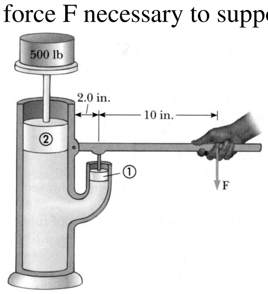
4. Heat
   a. Calorimetry: $Q_{gained\ by\ 1} = Q_{lost\ by\ 2}$ (Blueprint eqn)
      i. $Q = mc\Delta T$; $Q = mL$ — both <u>are</u> given on exam
      ii. Colton method: Make sure each term is positive
   b. Radiation: $P = \frac{heat}{time} = e\sigma AT^4$ — <u>is</u> given on exam
      i. Describes heat emitted and heat absorbed
   c. Conduction: $P = \frac{heat}{time} = kA\frac{T_2 - T_1}{L}$ — <u>is</u> given on exam
   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): ΔU=0 — <u>not</u> given on exam
      iv. adiabatic: Q=0 — <u>not</u> given on exam
      v. cycle: ΔU=0 — <u>not</u> given on exam

   This is what I give you on the exam for those changes:
   $|W_{on\ gas}|$ = area under P-V curve
   $= |P\Delta V|$ (constant pressure)
   $= |nRT\ln(V_2/V_1)|$ (isothermal)
   $= |\Delta U|$ (adiabatic)

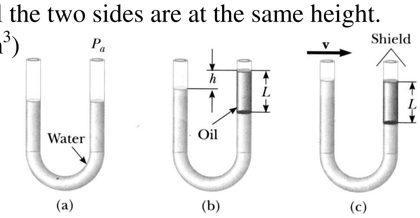
   d. Engines: general picture
      i. $Q_h = |W_{net}| + Q_c$ — <u>is</u> given on exam
      ii. Efficiency: $e = \frac{|W_{net}|}{Q_{added}} = \frac{Q_h - Q_c}{Q_h}$ — <u>is</u> given on exam
         1. Carnot Theorem: $e_{max} = 1 - \frac{T_c}{T_h}$ — <u>is</u> given on exam
      iii. Second Law: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

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.



Answer: 12.5 lbs

HW 16-5. Oil (ρ = 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? (ρ_{air} = 1.3 kg/m^3)



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.

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

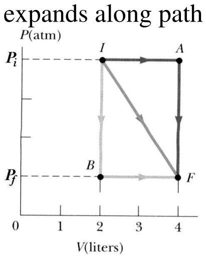
HW 19-3. Calculate the temperature at which a tungsten filament that has an emissivity of 0.25 and a surface area of 2.5×10^{-5} m^2 will radiate energy at the rate of 36 W in a room where the temperature is 22° C.

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?

Answers: 4550 J, 3640 J

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?

Answer: 0.26° C