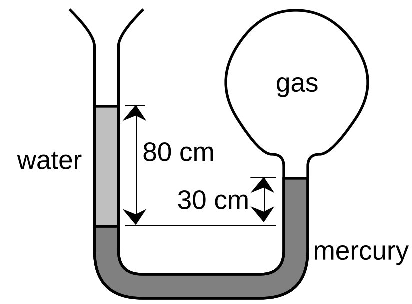
Name ____

PLEASE READ THIS FIRST: Work the problems on separate sheets of paper and staple this sheet to the front. Read each problem carefully. Show your work and/or give explanations for *all* answers. Make sure that all numerical answers are given with a reasonable number of sig figs and that you have included appropriate units. Check your answers for physical *reasonableness* whenever possible. I do give partial credit, but *only* if I can follow your work, so be as clear as possible about what you are doing.

Note: You may consider *any* 10 pts worth of stuff on this exam to be "Extra Credit"! (That is to say neither more nor less than that the points add up to 110!)

1. [15 pts] The open tube manometer at right is filled with mercury and water as shown and being used as a gauge for the pressure in the gas. What *is* the "gauge pressure" of the gas—*i.e.*, the *difference* between P_{gas} and P_{atm}? (The density of mercury is 13.6 g/cm^3.)

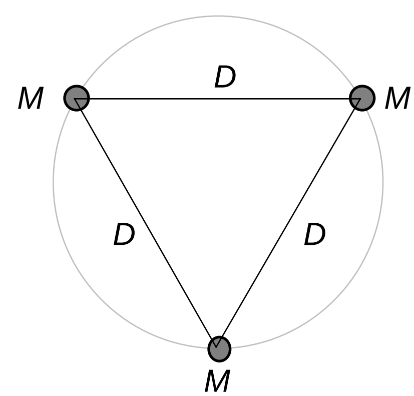


2. A sinusoidal wave on a string makes pieces of the string move transversely with an amplitude of 2.0 mm at a frequency of 500 Hz. When one piece is at its maximum positive transverse displacement, the pieces 30 cm to either side are at their equilibrium positions. The tension in the string is 400 N.

a) [10 pts] What is the maximum speed *and* the maximum acceleration of a piece of the string? Comment on your results. (Hint: Each piece just executes "simple harmonic motion.")

b) [10 pts] What is the linear mass density of the string? (Hint: First find the wave speed.)

3. Three identical stars of mass M are located at the corners of an equilateral triangle with sides of length D. Express your answers in terms of M and D and, possibly, other physical constants ...
[**OPTIONAL: For 2/3 credit** you may use the following numerical values: $M = 2.0 \times 10^{30}$ kg (Sun mass), $D = 1.50 \times 10^{11}$ m (Earth to Sun distance)]



a) [8 pts] Find the *magnitude* of the net gravitational force acting on each individual star. (This *will* require vector considerations.)

Now suppose that all three stars move in the *same* circular orbit about their center of mass.

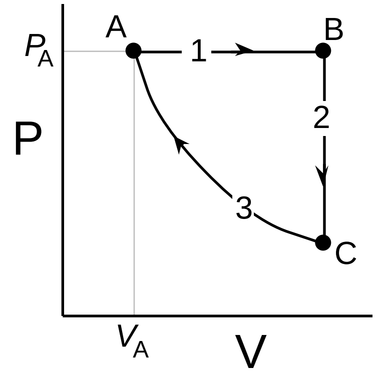
b) [4 pts] Find the radius of this orbit. (No physics here, just some geometry and trig.)

c) [8 pts] Find the period of this orbit. (Hint: Apply F = ma and use what you know about uniform circular motion.)

(Over for problems 4 and 5)

Score ________/100

4. A diatomic ideal gas undergoes the quasistatic cyclical process shown in the PV diagram at right. Along leg 1 the volume increases by a factor of *r*. (That is, $V_B = rV_A$.) Leg 3 of the cycle is isothermal. Express your answers to parts c through e in terms of P_A, V_A, *r*, and *n*, the amount of gas in moles.
[**OPTIONAL: For 2/3 credit** on parts c through e you may use the following numerical values: $P_A = 2.0$ atm, $V_A = 3.0$ liters, $r = 5.0$ and $n = 0.10$ mol]



a) [4 pts] What is the algebraic sign (+, –, or 0) of the "thermodynamic heat" (that is, the energy *added* in the form of heat) along each of the three legs? (As *always*, don't forget to support your answers!)

b) [3 pts] Which states (A, B, or C) have the highest *and* lowest entropy?

c) [10 pts] Find the values of Q_{in}, Q_{out}, and W for one cycle of a heat engine based on this process.

d) [3 pts] Find the efficiency of this heat engine and evaluate your answer for $r = 5.0$.

e) [5 pts] Find the efficiency of a *Carnot* engine operating between the same two temperature *extremes* encountered by the gas in this cycle and evaluate your answer for $r = 5.0$.

5. 1.00 kg of water at 100°C is mixed with 1.00 kg of water at 0°C in a well insulated container of negligible heat capacity.

a) [12 pts] What is the change in entropy of this system during the *irreversible* process by which it reaches thermal equilibrium? (Hint: Obviously the final temperature is 50°C. Imagine a process where heat is added slowly to the low temperature subsystem and removed slowly from the high temperature subsystem and integrate dS = dQ/T for both subsystems to find an expression for ΔS.)

If, instead, we operated a reversible heat engine between the two subsystems (now considered as thermal "reservoirs" with a slowly decreasing temperature difference), we would be able to extract useful work in the process. We would also deliver less heat to the low temperature reservoir than we remove from the high temperature reservoir. As a result, the ultimate equilibrium temperature would be less than 50°C. Because the process is reversible and because no heat is added to or removed from the environment, the total entropy of the water does not change.

b) [5 pts] What *is* the final temperature of the system in this *reversible* process? (Hint: Use your previous expression for ΔS but with an *unknown* T_{final} and set ΔS = 0!)

c) [5 pts] Evidently, then, how much energy was removed from the system in the form of work done on the environment?

d) [3 pts] How high could the 2.00 kg system be lifted using the work that it is capable of generating?