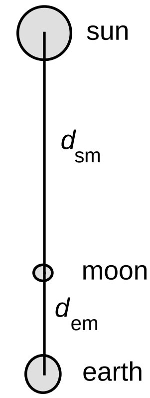
Name ____

Please work the problems on separate sheets of paper and staple this sheet to the front. Read each problem carefully. *Show* your work and make sure that your answers are *clearly marked*, physically *reasonable*, and expressed with an appropriate number of *sig figs* and proper *units*. I give partial credit, but *only* if I can follow your work, so be as clear as possible about what you are doing.

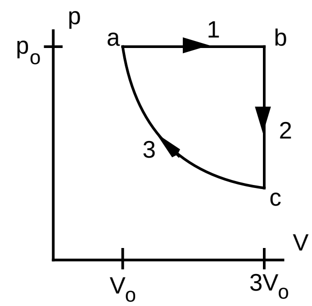
1. a) [14 pts] Find the *acceleration* (magnitude *and* direction) of the moon when it and the sun and the earth are in the positions shown at right. (Note that the drawing is not to scale and ignore any forces on the moon other than those due to the sun and the earth. Make sure that your answer is not ambiguous about the direction of the acceleration.)
   Some data:
   $m_{sun} = 2.0 \times 10^{30}$ kg $m_{earth} = 6.0 \times 10^{24}$ kg $m_{moon} = 7.4 \times 10^{22}$ kg
   $d_{sm} = 1.49 \times 10^{8}$ km $d_{em} = 3.8 \times 10^{5}$ km



   b) [3 pts] Would you call this a large, moderate, or small acceleration? Compare it with something to support your answer.
   c) [3 pts] How would your answer to part a change if the mass of the moon were just 1 kg? Explain.

2. A system absorbs 700 J of heat and in the process it does 300 J of work.
   a) [8 pts] If the initial internal energy of the system was 1100 J, what is the final internal energy?
   b) [8 pts] The system follows a different thermodynamic path to the same final state and absorbs 200 J of heat in the process, how much work does it do?
   c) [4 pts] If you were to take the system along the thermodynamic path of part a and then return it to its *initial* state by taking it *backwards* along the thermodynamic path of part b, would you have in effect constructed a heat engine or a refrigerator? Explain.

3. A monatomic ideal gas ($\gamma = 5/3$) is taken around the cycle shown at right.



   a) [16 pts] Find the work done *and* the heat absorbed by the gas in *each* of the three processes that form the cycle. (Process 3 is isothermal.) Express all six of your answers in terms of p_o and V_o.
   b) [4 pts] What is the efficiency of a heat engine based on this cycle?

4. Give *brief* but *complete* and *clearly* explained answers to the following questions:
   a) [5 pts] Why does the temperature of a gas decrease in a quasistatic adiabatic expansion?
   b) [5 pts] Why is the specific heat of a gas at constant pressure always greater than its specific heat at constant volume?
   c) [5 pts] What is the primary advantage of using a heat pump for heating a house?
   d) [5 pts] When you make ice cubes from liquid water, the entropy of the water decreases. Explain whether this *does* or does *not* violate the second law of thermodynamics and why.

5. A normally inflated beach ball has an internal pressure equal to that of the atmosphere (which we will take to be 1.0×10^{5} Pa) and a radius of 20 cm. The total mass of the beach ball, including all of the air inside, is 200 g.
   a) [2 pts] What is the volume of the beach ball? (You can take this to be the volume of the air itself; assume that the "skin" of the ball has negligible volume.)
   b) [4 pts] What is its volume 10 m under the surface of a large body of water? (Take the temperature of the water at *all* depths to be the same as it is at the surface. The density of water is 1.00 g/cm^3.)
   c) [3 pts] What is the buoyant force acting on the beach ball when it is in the position of part b?
   d) [6 pts] At what depth would the buoyant force equal the weight of the beach ball?
   e) [5 pts] What would the beach ball do if we released it at this depth and *then* cooled the surrounding water? Explain.