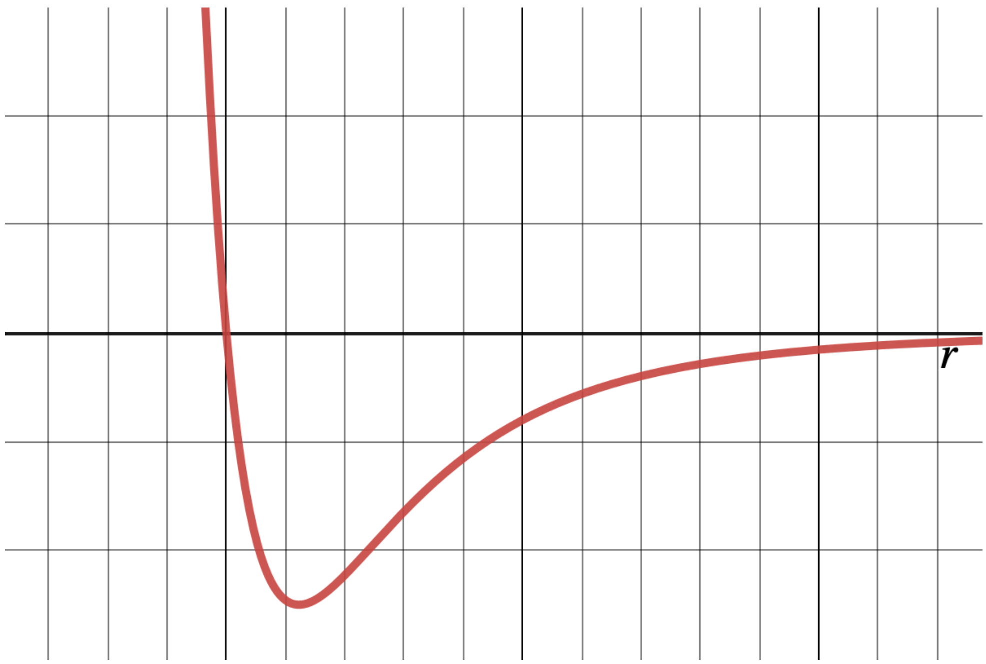
Practice 3; Phys 185 Name ______________

1. (0 points) The following graph gives the potential energy $U(r)$ due to the interaction between two particles, where r is the distance between the particles. Notice that U approaches 0 when r is very large, and that U becomes very large when r approaches 0.

The total energy of a pair of particles is $E_T = U + K$, where K is the kinetic energy due to the relative motion of the particles. There are no forces other than the interaction described by $U(r)$.

The two particles are said to be bound to each other if it is impossible for r to be larger than an upper limit, r_{max}. If there is no upper limit—if r can be arbitrarily large—the particles are unbound.

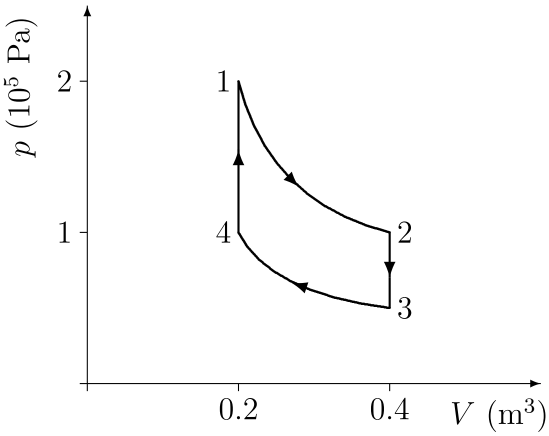


(a) Say $E_T > 0$. Are the particles bound or unbound? Provide an argument. (A visual argument where you draw on the graph above will be fine, if you prefer.)

(b) Say $E_T < 0$. Are the particles bound or unbound? Again, provide an argument.

(c) Say you put lots and lots of particles together, where the interaction of each pair of particles is described as above, and where the temperature is such that the *average* total energy $\bar{E}_T > 0$. Will this population of particles be in a gaseous state, or will it be in a more condensed state (liquid or solid)? Explain.

2. (0 points) You have a monatomic ideal gas that goes through the cycle $1 \to 2 \to 3 \to 4 \to 1$ shown in the diagram. No gas molecules are added or removed during the cycle.



(a) The $1 \to 2$ and $3 \to 4$ parts of the cycle takes place at *constant temperature*, so $T_1 = T_2$ and $T_3 = T_4$. Find p_3.

(b) The area under a constant temperature curve with temperature T on the p-V diagram, going from from an initial V_i to a final V_f, is

$$nRT \ln\left(\frac{V_f}{V_i}\right)$$

Find the work done by the gas for each step of this cycle: $W_{1\to2}$, $W_{2\to3}$, $W_{3\to4}$, $W_{4\to1}$.

(c) Find the change in thermal energy for each step: $\Delta E_{1\to 2}$, $\Delta E_{2\to 3}$, $\Delta E_{3\to 4}$, $\Delta E_{4\to 1}$.

(d) Find the heat added to the gas for each step of this cycle: $Q_{1\to 2}$, $Q_{2\to 3}$, $Q_{3\to 4}$, $Q_{4\to 1}$.

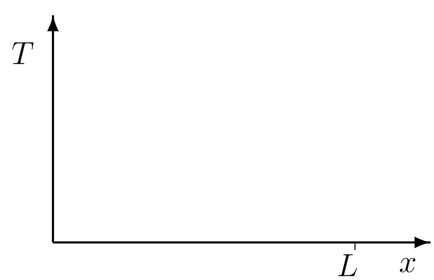
(e) Find the total heat input to this gas in one cycle, Q_{in}. Also find the total heat removed from the gas, Q_{out}, and the total work done, W.

(f) What is the efficiency of this heat engine? How does this compare to the maximum efficiency of a heat engine operating between heat reservoirs at T_1 and T_3?

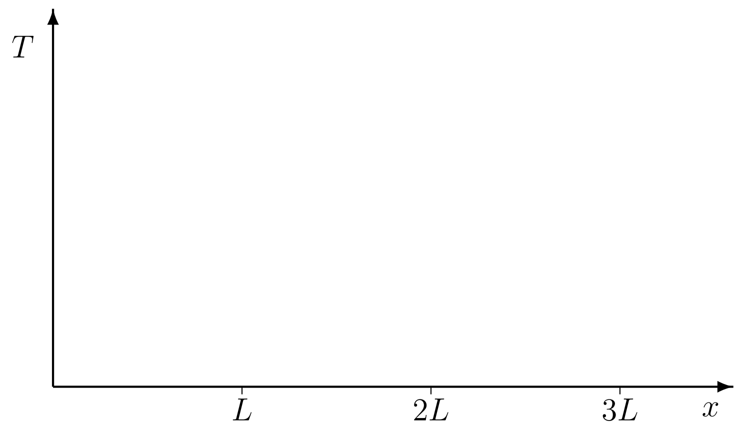
3. (0 points) You have a slab of material through which heat is being conducted at a rate of dQ/dt. The thickness of the material is L, the temperature on one side is T_1 and on the other side it's T_2.

(a) What is the temperature in the middle of the slab, a distance $L/2$ from either side? *Hint:* The same heat is going through at the same rate through both halves of the slab.

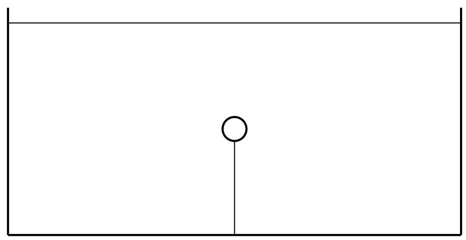
(b) Make a graph of $T(x)$, the temperature within the slab, with $x = 0$ one side of the slab and $x = L$ the other side. Give your reasoning for the shape you drew.



(c) You have a double-glazed window between the inside of a room at T_{in} and the outside at T_{out}. The thickness of the the two glass panes and the air trapped is all equal, L. The thermal conductivity of air is less than glass: $k_a < k_g$. Make a graph of $T(x)$, the temperature within the window, with $x = 0$ one side of the slab and $x = 3L$ the other side. Give your reasoning for what you drew.



4. (0 points) You take a table tennis ball with mass 0.0027 kg, and attach it to the bottom of a tub of water with a thread. The radius of the ball is 0.020 m, and the depth of the ball is 0.26 m. The density of water is 1000 kg/m^3. The volume of a sphere is $\frac{4}{3}\pi r^3$.



(a) Find the tension in the thread.

(b) You fail to use waterproof glue, and the thread comes unattached to the ball. How long does it take for the ball to rise to the surface, assuming there is no drag force on the ball?

(c) More realistically, the drag force in the water is large, and the ball will reach terminal speed almost instantly. With $D = \frac{1}{2}C_D \rho A v^2$, where $C_D = 0.52$ and A is the cross-sectional area of the ball, calculate how long it will take the ball to rise to the surface.