Unit 18 *Homework Problems*

Learning Goals:

F.18 Define and distinguish in practice (with descriptions in words or with a Pressure-Volume diagram) the main types of thermodynamic processes: isothermal, isobaric, isovolumetric, and adiabatic.

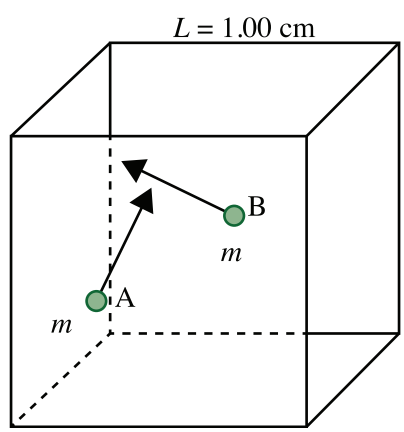
A.18 Analyze a simple heat engine cycle of an ideal gas to estimate thermal efficiency and work as a function of pressures and temperatures at various points in the cycle, including solving for unknown pressures and temperatures using previously derived relationships between quantities

18-1) According to kinetic theory a liquid has molecules moving at many speeds. The average kinetic energy of the molecules is proportional to the temperature of the liquid. When an individual molecule just happens to have enough kinetic energy to escape from the forces holding one molecule near its neighbors it evaporates. When the energetic molecule leaves the scene the remaining molecules have less energy on the average and the liquid cools a bit. This process is called *cooling by evaporation*. (There are two ways a liquid vaporizes: boiling and evaporation.)

(a) What effect does the evaporation of water from your skin have on how hot or cold you feel?

(b) During evaporation, thermal energy is transferred. What is it transferred from and what does it transfer to?

18-2) A cubical container of length $L = 1.00\ \mathrm{cm}$ on a side has two hydrogen atoms in it. Assume that the mass of each of these atoms is the same as that of a proton. Suppose these atoms behave like an ideal gas and collide with each other and the walls of the container elastically. The gas is at room temperature at $T = 298\ \mathrm{K}$.

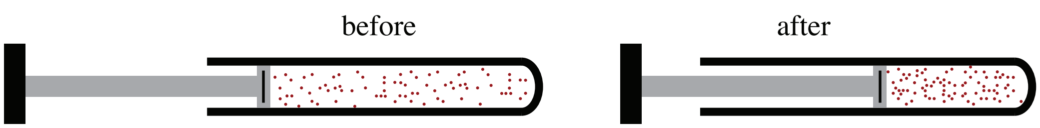


(a) Find the average (rms) speed of each hydrogen atom.

(b) Find the total internal energy of the gas in the cubical container in Joules.

(c) Suppose atom A is moving faster than atom B and then at a later time atom B is moving faster than atom A. Explain how this situation is possible.

18-3) Suppose the compression of 0.10 moles of an ideal monatomic gas shown in the diagram that follows is isothermal.



(a) What does it mean to say the compression is isothermal?

(b) How much does its internal energy change?

(c) If the system transfers 1.23×10^3 J of thermal energy to its surroundings during the compression, how much work is done on the system? (Be careful with the signs and the phrasing of the question – is the gas doing work or is work being done on it? What work are you trying to find?)

18-4) Consider a fire syringe similar to the one you used in Section 18.5. It was assumed that when the plunger is pushed in very quickly, the gas compression is adiabatic.

(a) What is an adiabatic compression?

(b) Is it reasonable to assume the compression is adiabatic? Why or why not?

(c) Is it reasonable to assume the compression is adiabatic when the plunger is moved into the glass tube very slowly? Why or why not?

(d) Do you think a significant proportion of the air molecules are leaking out of the tube when the air is being compressed? Why or why not.

18-5) Suppose the expansion of 0.10 moles of an ideal monatomic gas shown in the diagram that follows is isothermal and its initial temperature is 25°C. How much work is done by the gas if its final volume is 2.0 times its initial volume?

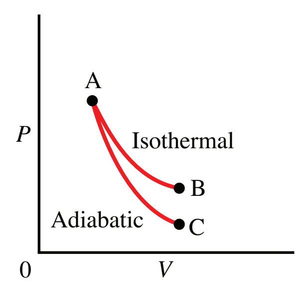
18-6) (a) What happens to the temperature of a gas when it is compressed suddenly?

(b) What happens to the temperature of a rubber band when it is allowed to compress suddenly?

(c) Do these two systems behave the same way under compression or differently? Can you think of any reasons why a container of gas or a rubber band might behave in a similar or different manner?

18-7) In an isothermal process, 3700 N•m of work is done by an ideal gas. Is this enough information to tell how much thermal energy has been added to the system? If not, why not (*i.e.*, what information is missing)? If so, how much has been added?

18-8) Consider the two processes shown in the diagram, in which there is an isothermal process (***AB***) and an adiabatic process (***AC***).

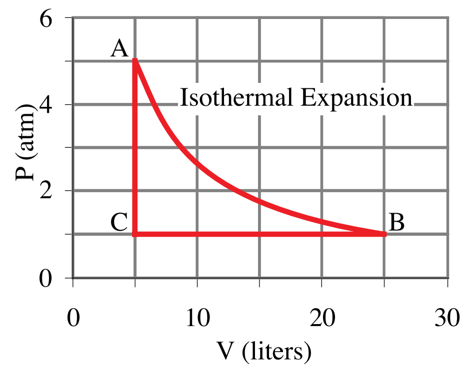


(a) Which process does more work? Explain.

(b) Which process has the greater change in internal energy? Explain.

(c) Which process has the greater transfer of thermal energy? Explain.

18-9) One mole of an ideal monatomic gas is taken through a cycle **ABCA** shown in the diagram. The process **AB** is a reversible isothermal expansion.



(a) Find the temperature of the gas at each of the points A, B and C. (*i.e.*, T_A, T_B, and T_C)

(b) Find the change in internal energy, ΔE^{int}, in Joules for each step in the cycle. Show your calculations and fill in your results in a table similar to the one shown on the next page.

(c) Calculate the work done, W, in N•m for each step in the cycle. Show your calculations and fill in your results in your table. In each case, indicate (in the table) whether work is done by the system or is done on the system.

(d) Find the amount of thermal energy transferred, Q, in Joules for each step in the cycle. Show your calculations and fill in your results in your table. In each case, indicate (in the table) whether thermal energy is absorbed from the surroundings or thermal energy is given off to the surroundings.

(e) Determine the efficiency, η, of the engine. (Remember! This is NOT a Carnot Cycle and that thermal energy is added in both the isothermal and isovolumetric transitions.) Compare this value to the efficiency of a Carnot cycle operating between the same two temperatures.

	A → B	**B → C**	**C → A**
ΔE^{int}			
W^{sys}			
Q			

Note: This particular cycle consists of an isothermal process, an isobaric process, and an isovolumetric process. You will want to be able to do this type of problem for any combination of processes that make up a cycle (including processes that are **not** isothermal, isobaric, isovolumetric, or adiabatic).