Thermodynamics and Statistical Mechanics

Problem 1:

. Consider the quasi-static adiabatic expansion of an ideal gas from an initial state i to a final state f. Which of the following statements is NOT true?

(A) No heat flows into or out of the gas.
(B) The entropy of state i equals the entropy of state f.
(C) The change of internal energy of the gas is $-\int PdV$.
(D) The mechanical work done by the gas is $\int PdV$.
(E) The temperature of the gas remains constant.

Problem 2:

If the absolute temperature of a blackbody is increased by a factor of 3, the energy radiated per second per unit area does which of the following?

(A) Decreases by a factor of 81.
(B) Decreases by a factor of 9.
(C) Increases by a factor of 9.
(D) Increases by a factor of 27.
(E) Increases by a factor of 81.

Problem 3:

An engine absorbs heat at a temperature of 727° C and exhausts heat at a temperature of 527° C. If the engine operates at maximum possible efficiency, for 2000 joules of heat input the amount of work the engine performs is most nearly

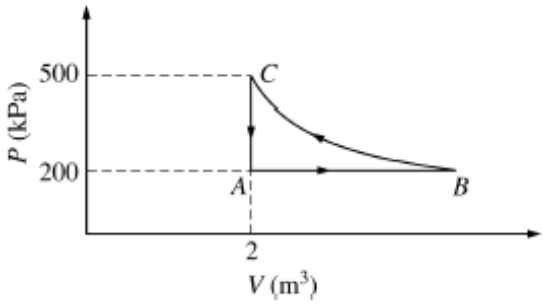
(A) 400 J
(B) 1450 J
(C) 1600 J
(D) 2000 J
(E) 2760 J

Problem 4:

The speed of sound in an ideal gas is related to the temperature T of the gas. This speed is proportional to

(A) $T^{1/4}$
(B) $T^{1/2}$
(C) T
(D) $T^{4/3}$
(E) T^2

Problem 5:



A constant amount of an ideal gas undergoes the cyclic process $ABCA$ in the PV diagram shown above. The path BC is isothermal. The work done by the gas during one complete cycle, beginning and ending at A, is most nearly

(A) 600 kJ
(B) 300 kJ
(C) 0
(D) −300 kJ
(E) −600 kJ

Problem 6:

An ideal monatomic gas expands quasi-statically to twice its volume. If the process is isothermal, the work done by the gas is W_i. If the process is adiabatic, the work done by the gas is W_a. Which of the following is true?

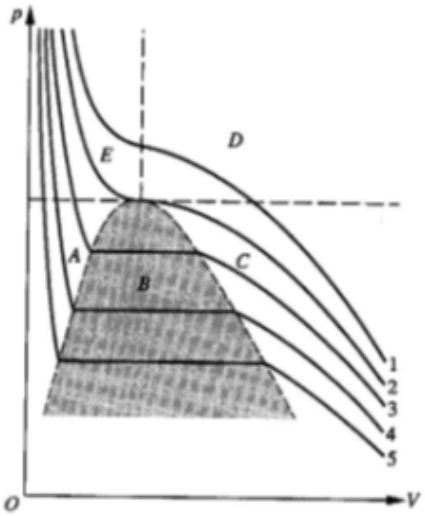
(A) $W_i = W_a$
(B) $0 = W_i < W_a$
(C) $0 < W_i < W_a$
(D) $0 = W_a < W_i$
(E) $0 < W_a < W_i$

Problem 7:

A Carnot engine converts $1/5^{th}$ of the heat, which it absorbs from the source, into work. When the temperature of the sink is reduced by 100° C, its efficiency is doubled. The temperature of the source is

(A) 400 K
(B) 450 K
(C) 500 K
(D) 600 K
(E) 700 K

Problem 8:



Isotherms and coexistence curves are shown in the pV diagram for a liquid-gas system. The dashed lines are the boundaries of the labeled regions.

Which numbered curve is the critical isotherm?

(A) 1
(B) 2
(C) 3
(D) 4
(E) 5

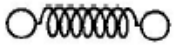
Problem 9:

Refer to the previous problem:

In which region are the liquid and the vapor in equilibrium with each other?

(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *E*

Problem 10:



A classical model of a diatomic molecule is a springy dumbbell, as shown above, where the dumbbell is free to rotate about axes perpendicular to the spring. In the limit of high temperature, what is the specific heat per mole at constant volume?

(A) $\frac{3}{2}R$
(B) $\frac{5}{2}R$
(C) $\frac{7}{2}R$
(D) $\frac{9}{2}R$
(E) $\frac{11}{2}R$

Problem 11:

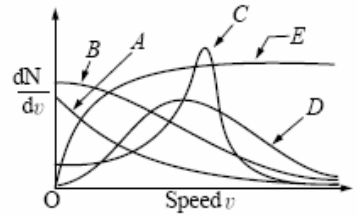
The total energy of a Blackbody radiation source is collected for one minute and used to heat water. The temperature of the water increases from 20.0 ^{o}C to 20.5 ^{o}C. If the absolute temperature of the Blackbody were doubled and the experiment repeated, which of the following statements would be most nearly correct?

(A) The temperature of the water would increase from 20 °C to a final temperature of 21 °C.
(B) The temperature of the water would increase from 20 °C to a final temperature of 24 °C.
(C) The temperature of the water would increase from 20 °C to a final temperature of 28 °C.
(D) The temperature of the water would increase from 20 °C to a final temperature of 36 °C.
(E) The water would boil within the one-minute time period.

Problem 12:
An ideal diatomic gas is initially at temperature *T* and volume *V*. The gas is taken through three reversible processes in the following cycle: adiabatic expansion to the volume 2*V*, constant volume process to the temperature *T*, isothermal compression to the original volume *V*.
For the complete cycle described above, which of the following is true?
(A) Net thermal energy is transferred from the gas to the surroundings.
(B) The net work done by the gas on the surroundings is positive.
(C) The net work done by the gas on the surroundings is zero.
(D) The internal energy of the gas increases.
(E) The internal energy of the gas decreases.

Problem 13:
Refer to the previous problem.
Which of the following statements about entropy changes in this cycle is true?
(A) The entropy of the gas remains constant during each of the three processes.
(B) The entropy of the surroundings remains constant during each of the three processes.
(C) The combined entropy of the gas and surroundings remains constant during each of the three processes.
(D) For the complete cycle, the combined entropy of the gas and surroundings increases.
(E) For the complete cycle, the entropy of the gas increases.

Problem 14:



Which of the curves in the graph above best represents the distribution of speeds of the molecules in an ideal gas at thermal equilibrium?
(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *E*

Problem 15:

For an ideal gas, the specific heat at constant pressure C_p is greater than the specific heat at constant volume C_v because the
(A) gas does work on its environment when its pressure remains constant while its temperature is increased
(B) heat input per degree increase in temperature is the same in processes for which either the pressure or the volume is kept constant
(C) pressure of the gas remains constant when its temperature remains constant
(D) increase in the gas's internal energy is greater when the pressure remains constant than when the volume remains constant
(E) heat needed is greater when the volume remains constant than when the pressure remains constant