Problem 1:

The root-mean-square speed of molecules of mass m in an ideal gas at temperature T is

(A) 0

(B) $\sqrt{\frac{2kT}{m}}$

(C) $\sqrt{\frac{3kT}{m}}$

(D) $\sqrt{\frac{8kT}{\pi m}}$

(E) $\frac{kT}{m}$

Problem 2:

The surface of the Sun has a temperature close to 6,000 K and it emits a blackbody (Planck) spectrum that reaches a maximum near 500 nm. For a body with a surface temperature close to 300 K, at what wavelength would the thermal spectrum reach a maximum?

(A) 10 μm
(B) 100 μm
(C) 10 mm
(D) 100 mm
(E) 10 m

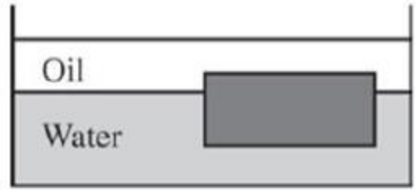
Problem 3:

For an adiabatic process involving an ideal gas having volume V and temperature T, which of the following is constant? ($\gamma = C_P/C_V$)

(A) TV
(B) TV^{γ}
(C) $TV^{\gamma-1}$
(D) $T^{\gamma}V$
(E) $T^{\gamma}V^{-1}$

Problem 4:

A layer of oil with density 800 kg/m^3 floats on top of a volume of water with density 1,000 kg/m^3. A block floats at the oil-water interface with 1/4 of its volume in oil and 3/4 of its volume in water, as shown in the figure. What is the density of the block?



(A) 200 kg/m^3
(B) 850 kg/m^3
(C) 950 kg/m^3
(D) 1,050 kg/m^3
(E) 1,800 kg/m^3

Problem 5:

A gas at temperature T is composed of molecules of mass m. Which of the following describes how the average time between intermolecular collisions varies with m?

(A) It is proportional to $\frac{1}{m}$.

(B) It is proportional to $\sqrt[4]{m}$.

(C) It is proportional to $\sqrt{m}$.

(D) It is proportional to m.

(E) It is proportional to m^2.

Problem 6:

An incompressible fluid of density ρ flows through a horizontal pipe of radius r and then passes through a constriction of radius $r/2$. If the fluid has pressure P_0 and velocity v_0 before the constriction, the pressure in the constriction is

(A) $P_0 - \frac{15}{2}\rho v_0^2$

(B) $P_0 - \frac{3}{2}\rho v_0^2$

(C) $\frac{P_0}{4}$

(D) $P_0 + \frac{3}{2}\rho v_0^2$

(E) $P_0 + \frac{15}{2}\rho v_0^2$

Problem 7:

Heat Q is added to a monatomic ideal gas under conditions of constant volume, resulting in a temperature change ΔT. How much heat will be required to produce the same temperature change, if it is added under conditions of constant pressure?

(A) $\frac{3}{5}Q$

(B) Q

(C) $\frac{5}{3}Q$

(D) $2Q$

(E) $\frac{10}{3}Q$

Problem 8:

A heat pump is to extract heat from an outdoor environment at 7°C and heat the environment indoors to 27°C. For each 15,000 J of heat delivered indoors, the smallest amount of work that must be supplied to the heat pump is approximately

(A) 500 J

(B) 1,000 J

(C) 1,100 J

(D) 2,000 J

(E) 2,200 J

Problem 9:

Consider 1 mole of a real gas that obeys the van der Waals equation of state shown.

$$\left(p + \frac{a}{V^2}\right)(V - b) = RT$$

If the gas undergoes an isothermal expansion at temperature T_0 from volume V_1 to volume V_2, which of the following gives the work done by the gas?

(A) 0

(B) $RT_0 \ln\left(\frac{V_2}{V_1}\right)$

(C) $RT_0 \ln\left(\frac{V_2 - b}{V_1 - b}\right)$

(D) $RT_0 \ln\left(\frac{V_2 - b}{V_1 - b}\right) + a\left(\frac{1}{V_2} - \frac{1}{V_1}\right)$

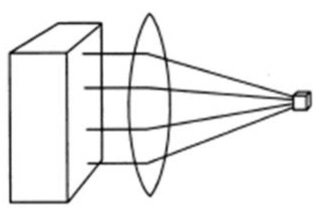
(E) $RT_0\left(\frac{1}{(V_2 - b)^2} - \frac{1}{(V_1 - b)^2}\right) + a\left(\frac{1}{V_2^3} - \frac{1}{V_1^3}\right)$

Problem 10:

A body of mass m with specific heat C at temperature 500 K is brought into contact with an identical body at temperature 100 K, and the two are isolated from their surroundings. The change in entropy of the system is equal to

(A) $(4/3)mC$
(B) $mC\ln(9/5)$
(C) $mC\ln(3)$
(D) $-mC\ln(5/3)$
(E) 0

Problem 11:



An experimenter needs to heat a small sample to 900 K, but the only available oven has a maximum temperature of 600 K. Could the experimenter heat the sample to 900 K by using a large lens to concentrate the radiation from the oven onto the sample, as shown above?

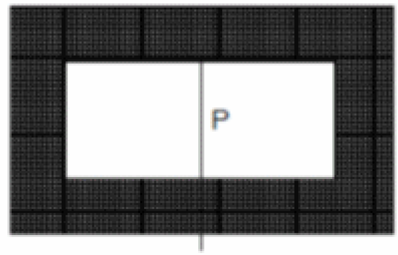
(A) Yes, if the volume of the oven is at least 3/2 the volume of the sample.
(B) Yes, if the area of the front of the oven is at least 3/2 the area of the front of the sample.
(C) Yes, if the sample is placed at the focal point of the lens.
(D) No, because it would violate conservation of energy.
(E) No, because it would violate the second law of thermodynamics.

Problem 12:

A mixture of one mole of helium (atomic weight = 4) and one mole of argon (atomic weight = 40) is in thermal equilibrium in a container at room temperature. The ratio of the rms speed of a helium atom to the rms speed of an argon atom, v_{He}/v_{Ar}, is most nearly equal to

(A) 1
(B) 0.3
(C) 1
(D) 3
(E) 10

Problem 13:



Gas at standard temperature and pressure is initially in the left-hand compartment of the device shown above. The right-hand compartment is initially evacuated. The volumes of the two compartments are the same, and the entire device is thermally insulated from its surroundings. If the partition P separating the two compartments is rapidly pulled out sideways, which of the following will be true?

(A) For an ideal gas, the temperature will be lower after the expansion.

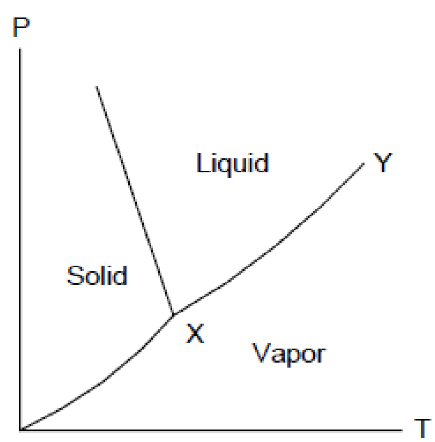
(B) For a real gas, the temperature will be the same after the expansion.

(C) The final temperature is determined solely by the specific heat ratio c_P/c_V.

(D) The final pressure must be known before the final temperature can be computed for an ideal gas.

(E) The internal energy will remain constant for any gas, real or ideal.

Problem 14:



For the substance represented by the diagram above of pressure P versus temperature T, which of the following statement is true?

(A) The substance expands when it freezes.

(B) In the vicinity of point X, the vapor is more dense than liquid.

(C) Point X represents the critical point for the substance.

(D) The segment of the graph from X to Y represents the fusion curve for the substance.

(E) At any temperature above that of the triple point, the distinction between liquid and gas disappears.

Problem 15:

A blackbody at temperature T_1 radiates energy at a power level of 10 milliwatts (mW). The same blackbody, when at a temperature $2T_1$, radiates energy at a power level of

(A) 10 mW

(B) 20 mW

(C) 40 mW

(D) 80 mW

(E) 160 mW