Portland State University
General Physics Workshop
Problem Set 8 **Universal gas law, Phase changes**

Equations and Relations:

Specific heat *c*: $Q = mc\Delta T$

Latent heat *L*: $Q = Lm$

Thermal conduction: $Q = k\dfrac{Area \cdot \Delta T \cdot t}{length}$

k, thermal conductivity

Stefan Boltzmann law: $P = \dfrac{Q}{t} = e\sigma AT^4$

Pressure: $p = \dfrac{F}{A}$

Pressure at a depth *h*:
$p = p_0 + \rho hg$

Universal gas law: $pV = nN_A kT = nRT$

Boltzmann's constant: $k = 1.381 * 10^{-23}\dfrac{J}{K}$

Avogadro's number: $N_A = 6.022 * 10^{23}\dfrac{1}{mol}$

Universal gas constant: $R = 8.314\dfrac{J}{molK}$

Kinetic Energy: $K = \dfrac{3}{2}nRT$

Velocity distribution: $v_{rms} = \sqrt{\dfrac{3RT}{M}}$

1. What is the net power that a dog with surface area of 0.075 m^2 radiates if his emissivity is 0.75, his skin temperature is 42 $^\circ$C, and he is in a room with a temperature of 22 $^\circ$C? The Stefan-Boltzmann constant is 5.67 x 10^{-8} W/(m^2K^4).

2. Radiant energy from the sun arrives at the earth at a rate of about 1.4 kW per meter squared of area perpendicular to the sun's rays. The average radius of the earth's orbit is 1.5 x 10^{11} m, and the radius of the sun is 7.0 x 10^8 m. From these figures find the surface temperature of the sun under the assumption that it radiates like a blackbody (which is approximately true). That is, take the emissivity *e* of the sun to be 1.0.

   - *How does the thermos bottle (consists of two glass vessel, each coated with a thin film of silver, one inside the other with the space between them evacuated) work? Can we use this for cold, as well as hot, drinks?*

3. Gas in a constant-volume gas thermometer registers a pressure of 95.0 kPa at 100ºC. Assuming ideal behavior, what is the temperature of this gas when the pressure is 190 kPa?

4. On a cold day, you take in 4.2 L of air into your lungs at a temperature of 0˚C. If you hold your breath until the temperature of the air in your lungs reaches 37˚C, what is the volume of the air in your lungs at that point, assuming the pressure does not change?

5. A vertical cylinder, closed at the bottom end, contains 0.0100 moles of gas. It is fitted at the top with a piston, which can move freely. The mass of the piston is 13.0 kg and the initial height of the piston above the bottom of the cylinder is 25 cm. What is the temperature of the gas?

6. Four closed tanks, A, B, C, and D, each contain identical numbers of moles of an ideal gas. The table gives the absolute pressure and volume of the gas in each tank.

	A	B	C	D
Absolute Pressure (kPa)	25.0	30.0	20.0	2.0
Volume (m^3)	4.0	5.0	5.0	75

a) Which tanks (if any) have the same temperature?

b) If each of the tanks contains 0.10 mol of gas, compute the temperature of each gas using this number and the data in the table.

7. The molecular weight of nitrogen is 28 g/mol. What is the rms speed of nitrogen molecules at 10.0 °C?

8. 2.5 mol of O_2 are placed in a portable container with a volume of 4.5×10^{-3} m^3
   (a) If the temperature of the gas is 280° C, find the pressure of the gas. (2.5 Points)
   (b) Find the average kinetic energy of an oxygen molecule.
   (c) Suppose the volume of the gas is doubled, while the temperature and number of moles are held constant. By what factor does your answer to part (a) change?
   (d) Suppose the volume of the gas is doubled, while the temperature and number of moles are held constant. By what factor does your answer to part (b) change?

9. A sealed steel canister is being used to store neon gas (atomic mass = 20.2 u). The mass of the steel canister alone is 19.3 kg, and it has an interior volume of 9.50 liters (= $9.50 \times 10^{-3} m^3$). There are 4.25 moles of neon gas in the canister, and the temperature of the entire system is 300 K.
   (a) Determine the pressure within the cylinder.
   (b) If the sealed cylinder were to be placed in a large tank containing a mixture of ice and water at 273 K, what is the pressure of the neon gas after the cylinder and its contents have reached thermal equilibrium?
   (c) Determine the mass of the ice that melts during the equilibration of the cylinder.

   Specific heat of steel = 448 J kg^{-1} K^{-1}

Specific heat of neon = 12.5 J mole^{-1} K^{-1}
Specific heat of water = 4186 J kg^{-1} K^{-1}
Heat of fusion of water = 3.33×10^5 J kg^{-1}
Density of water = 1.00×10^3 kg m^{-3}
Density of ice = 0.917×10^3 kg m^{-3}

Additional Questions:

1. Why do cooking directions on packages advise different timing for different elevations?

2. The volume of a gas is held constant while its temperature is raised. The pressure the gas exerts on the walls of its container increases because

_____ a) the masses of the molecules increase.
_____ b) each molecule loses more kinetic energy when it strikes the wall.
_____ c) the molecules are in contact with the wall for a shorter time.
_____ d) the molecules have higher average speeds and strike the wall more often.

3. The temperature of a gas is held constant while its volume is reduced. The pressure the gas exerts on the walls of its container increases because its molecules

_____ a) strike the container walls more often.
_____ b) strike the container walls with higher speeds.
_____ c) strike the container walls with greater force.
_____ d) have more energy.

4. Turning up the flame under a pan of boiling water causes

_____ a) the water to boil away faster.
_____ b) the temperature of the boiling water to increase.
_____ c) both the water to boil away faster and the temperature of the boiling water to increase.
_____ d) none of the above.

5. The pressure cooker cooks food more rapidly than an ordinary pot with a loose lid because

_____ a) the pressure forces heat into the food.
_____ b) the higher pressure lowers the boiling point of water.
_____ c) the higher pressure raises the boiling point of water.
_____ d) the higher pressure increases the specific heat capacity of water.