**Physics 1408/1420**

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Hello Fellow Physicists

I am Aman Patel, the Master Tutor for Physics this semester. I have created this resource document to help you review some of the topics you have been introduced to this semester to better prepare for your Final in physics.

**Keywords:** Temperature, Thermal Expansion, Ideal Gas Law, Kinetic Theory

| Important Notes |
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| Important Conventions |

**Temperature:**

The temperature of a system is the quantification of the how hot or cold something is. In reality, the temperature of something is the quantification of the thermal energy of the system. Cold is a system with a comparatively low amount of heat. Truly, cold is just less hot. The most common scales used to measure temperature today are Fahrenheit and Celsius. The conversion between the two is as follows.

$$T(^{\circ}\mathrm{C}) = \tfrac{5}{9}[T(^{\circ}\mathrm{F}) - 32]$$

$$T(^{\circ}\mathrm{F}) = \tfrac{9}{5}T(^{\circ}\mathrm{C}) + 32.$$

**Zeroth Law of Thermodynamics:**

"If two systems are in thermal equilibrium with a third system, then they are in thermal equilibrium with each other."

When two systems are in thermal equilibrium, their temperatures are equal, and no thermal energy is exchanged between the two systems.

**Thermal Expansion:**

When the temperature of an object is changed, it can contract or expand based on the change of temperature and the type of material.

The length and volume of objects can contract or expand due to the change in temperature. The type of material affects how much the length can change. This is accounted for by the coefficient of linear expansion (α) and coefficient of volume expansion (β) for materials.

The change in volume and length of the material is determined by the following equations.

$$\Delta \ell = \alpha \ell_0 \, \Delta T,$$

$$\Delta V = \beta V_0 \, \Delta T,$$

**Example:**

An iron ring is to fit snugly on a cylindrical iron rod. At to 20°C, the diameter of the rod is 6.445 cm and the inside diameter of the ring is 6.420 cm. to slip over the rod, the ring must be slightly larger than the rod diameter by about 0.008 cm. To what temperature must the ring be brought if its hole is to be large enough so it will slip over the rod?

**Solution**

New Diameter = 6.445 + 0.008 = 6.453 cm

$$\Delta T = \frac{\Delta \ell}{\alpha \ell_0} = \frac{6.453\text{ cm} - 6.420\text{ cm}}{(12 \times 10^{-6}/\text{C}^\circ)(6.420\text{ cm})} = 430\text{ C}^\circ. \qquad T = (20^\circ\text{C} + 430\text{ C}^\circ) = 450^\circ\text{C}.$$

**Ideal Gas Law**

The ideal gas law is a congregation of three other laws that consider three different thermal states.

Boyles Law: $V \propto \frac{1}{P}$, $PV = \text{constant}$ [constant $T$]

Charles's Law: $V \propto T$. [constant $P$]

Gay-Lussac's Law: $P \propto T$. [constant $V$]

Combing all of these relations, we get

$$PV = nRT$$

P = Pressure, V = Volume, n = number of moles, R = Universal Gas Constant, T = Temperature

This relation can also be seen in terms of molecules

$$PV = NkT$$

P = Pressure, V = Volume, k = Boltzmann constant, N = no. of molecules, T = Temperature

**Example:**

Determine the volume of 1 mole of any gas, assuming it behaves like an ideal gas at STP.

**Solution**

At STP, the temperature is assumed to be 0°C and the pressure is 1 atm = 101300 Pa. You must memorize this condition as it will be very common.

$$V = \frac{nRT}{P} = \frac{(1.00\ \text{mol})(8.314\ \text{J/mol}\cdot\text{K})(273\ \text{K})}{(1.013 \times 10^5\ \text{N/m}^2)} = 22.4 \times 10^{-3}\ \text{m}^3.$$

**Kinetic Theory**

In kinetic theory, matter is analyzed in terms of atoms in random motion. When we apply it to ideal gases, we make several assumptions

1. There are a large number of molecules present in the system, each moving in random directions with different speeds.

2. There is assumed to be a large amount of distance between the molecules to allow room for movement
3. The molecules can collide with one another and have kinetic energy. Any weak force between them is assumed to be negligible
4. Collisions between the molecules and the surfaces are assumed to be perfectly elastic collisions.

Based on these assumptions, the following relationship between the kinetic energy and the temperature of the system.

$$KE = 3/2\ kT = ½\ mv^2$$

From this equation, we can see that the average translational kinetic energy of molecules in random motion in an ideal gas is directly proportional to the absolute temperature of the gas.

The average velocity of the molecules is estimated by the root-mean-square velocity.

$$v_{rms} = \sqrt{\overline{v^2}} = \sqrt{\frac{3kT}{m}}$$

**<u>PV Diagram</u>**

The last thing to understand in this chapter is the PV diagram and the essential points in the graph.

Each region describes the state of matter at that pressure and temperature for the system. Changes in either can lead to change in state of matter, which can be observed by tracking it in the graph.