Physics 1408/1420 – General Physics 1

Week of November 7th, 2022

Jorge Martinez-Ortiz

Hello Fellow Physicists,

I am Jorge Martinez, the Master Tutor for Physics this semester. To help you on your journey to learn about this wonderful branch of science and the understanding it gives us of the world around us, I will be preparing this resource every week to give you an additional tool to better prepare for your week. I will also be conducting Group Tutoring sessions every week, the information for which will be given below. If you are unable to attend group tutoring, the tutoring center also offers one-on-one tutoring sessions, so be sure to visit the tutoring center or visit https://baylor.edu/tutoring.

PHY 1408/1420 General Physics 1 Group Tutoring sessions will be held every Wednesday from 6:30-7:30 pm in the Sid Richardson building basement, Room 75. See you there!

In the past two weeks, your professors will have covered sound. This week, you will finish studying temperature and ideal gas law.

Keywords: Temperature, Thermal Expansion, Ideal Gas Law

Important Notes
Important Conventions

Temperature:

The temperature of a system is the quantification of 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."

All Images are from Physics: Principles with Applications (7th Edition) by Douglas C. Giancoli

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 fact is accounted by the coefficient of linear expansion (α) and coefficient of volume expansion (β) of 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 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

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

All Images are from Physics: Principles with Applications (7^{th} Edition) by Douglas C. Giancoli

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.

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

All Images are from Physics: Principles with Applications (7th Edition) by Douglas C. Giancoli

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 many 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.

$$KE = 3/2\ kT = \frac{1}{2} mv^2$$

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.

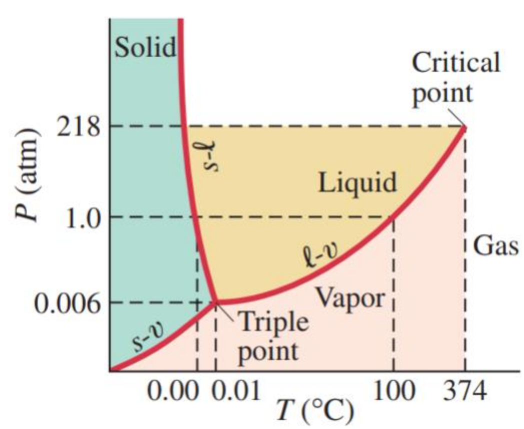
The average velocity of the molecules is estimated by the root-mean-square velocity.

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

PV Diagram

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.



All Images are from Physics: Principles with Applications (7th Edition) by Douglas C. Giancoli

CHECK YOUR LEARNING

1. A thermometer tells you that you have fever of 25 C. What is this in Fahrenheit?
2. A concrete highway built of slabs 5 m long (20°C). How wide should the expansion cracks between the slabs be (at 20°C) to prevent buckling if the range of temperature is -10°C to 45°C? ($\alpha=12*10^{-6}$)
3. If 30 L of oxygen at 10°C and an absolute pressure of 1.5 atm are compressed to 60 L at the same time the temperature is raised to 100 C, what will the new pressure be?
4. A gas is at 40°C. To what temperature must it be raised to double the rms speed of its molecules?

THINGS YOU MAY STRUGGLE WITH

1. Remember the thermal expansion and contraction of materials. You need to keep track of 2 things. First is whether its regarding a change in length or volume and second is the direction of change in length of the material. The second is much easier. Make sure that when you find the change in temperature, its in the direction as stated in the problem, then the sign attached to the final value for the change in length or volume will be correct.
2. Make sure you understand the ideal gas law and how the variables relate to each other. It is important to remember Boyle's law, Charles' law, and Gay-Lussac's Law. Their relationships are important to understand for analyzing the changes in pressure, volume, and temperature.
3. Keep in mind the basic principles of the kinetic theory of gases. You should memorize the 4 characteristics for the ideal gas systems.

I hope you have a wonderful week! Please feel free to reach out to me if you have any questions and check out all the resources the Tutoring Center has to offer at: https://baylor.edu/tutoring.

Answers: 1) 77 F, 2) 0.0015 m, 3) 0.989 atm, 4) 979 °C

All Images are from Physics: Principles with Applications (7th Edition) by Douglas C. Giancoli