

## The Big Ideas—Chapter 19

(Serway and Beichner, Physics for Scientists and Engineers, 5<sup>th</sup> Edition)

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| <p><i>Sections 1&amp;2</i></p> <p><b>Objects in “thermal contact” exchange energy via “heat.” They cease this process when they reach “thermal equilibrium.” We find experimentally—and give as the so-called “zeroth law of thermodynamics”—that two objects that are <i>separately</i> in thermal equilibrium with a third object, are also in thermal equilibrium with <i>each other</i>.</b></p> <p>We can tell when heat is being exchanged by monitoring a so-called “thermometric property” of the objects. A “thermometric property” is one that depends on the total internal energy of the objects, like density, length, resistivity, color, etc. It can be used to make a “thermometer.” For instance, mercury thermometers exploit thermal variations in the density of mercury.</p> <p>The Celsius temperature scale is defined in terms of two so-called “fixed points”: One is a mixture of ice and water at atmospheric pressure (the “freezing point” of water) which is defined to have a temperature of 0°C. The other is a mixture of steam and water at atmospheric pressure (the “boiling point” of water) which is defined to have a temperature of 100°C. How one uses those fixed points to determine the size of 1 Celsius degree is not obvious. (See the next section.)</p> |  |
| <p><i>Section 3</i></p> <p><b>A constant volume gas thermometer has the remarkable twin properties of 1) predicting the <i>same size</i> for one degree regardless of what gas is used <i>and</i> 2) predicting a “lowest possible temperature.” These at first surprising facts are used in conjunction with the fixed points to determine the size of each Celsius degree and to define the Kelvin or “absolute” temperature scale.</b></p> <p>Other temperature scales are defined in similar manners and three—Celsius, Kelvin, and Fahrenheit—are in common use.</p> <p>Absolute zero, the freezing point of water, and the boiling point of water are given in each scale at right.</p>  | $\frac{T_K}{K} = \frac{T_C}{^\circ C} + 273.15$ $\frac{T_F}{^\circ F} = \frac{9}{5} \frac{T_C}{^\circ C} + 32$ <p>0K = -273.15°C = -459.7F<br/>                 273.15K = 0°C = 32F<br/>                 373.15K = 100°C = 212°F</p> |

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| <p><i>Section 4</i></p> <p><b>The thermal expansion properties of materials can be given in terms of a thermal coefficient of expansion which is an <i>intensive</i> property—that is, a property of the <i>material</i>.</b></p> <p>The coefficient is defined as the <i>fractional</i> change in length (or volume) per unit change in temperature. Thus, <i>long</i> things <i>change</i> their length proportionally more than <i>short</i> things given the <i>same</i> change in temperature.</p> <p>It is easy to show from geometric considerations that the volume coefficient of expansion is necessarily three times the linear coefficient of expansion.</p>   | $L = L_i T$ $V = V_i T$ <p>where</p> $= 3$   |
| <p><i>Section 5</i></p> <p><b>At low enough pressures all gases approach the behavior of an “ideal gas.” Ideal gases in thermal equilibrium obey a simple law relating their pressure, volume, temperature, and number of molecules.</b></p> <p>The ideal gas law is sometimes expressed in terms of the number of moles of gas particles (preferred by chemists) and sometimes in terms of the number of molecules (preferred by physicists.)</p> <p>Note that <math>N/V</math>—the number of molecules per unit volume is called the “number density.” It is the mass density divided by the mass of a single molecule.</p> <p>Relationships between pressure, density, and temperature are called “equations of state.”</p> | $PV = Nk_B T$ $PV = nRT$ <p>where</p> $n = N / N_A$ $N_A = 6.022 \times 10^{23} / \text{mol}$ $k_B = 1.38 \times 10^{-23} \text{ J/K}$ $R = N_A k_B = 8.315 \text{ J/mol K}$ $= 0.08214 \text{ L atm/mol K}$ |