Introduction: Thermodynamics

Unit: Thermodynamics

Topics covered in this chapter:

This chapter is about heat as a form of energy and the ways in which heat affects objects, including how it is stored and how it is transferred from one object to another.

- *Kinetic-Molecular Theory* explains the implications of the theory that gases are made of large numbers of independently-moving particles.
- *Gas Laws* and *The Ideal Gas Law* describe and explain relationships between pressure, volume, temperature and the number of particles in a sample of gas.
- *Energy Conversion* describes conversion between heat and other forms of energy.
- *Thermodynamics* describes the transfer of energy into or out of a sample of gas.
- *Pressure-Volume (PV) Diagrams* and *Heat Engines* describe the relationship between changes in pressure and volume, heat, and work done on or by a gas.
- *Efficiency* describes the relationship between the work obtained from changes to a sample of gas and the maximum amount of energy that is theoretically available.

New challenges specific to this chapter include looking up and working with constants that are different for different substances.

Use this space for summary and/or additional notes:

Standards addressed in this chapter:

Next Generation Science Standards (NGSS):

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles or energy stored in fields.

HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

AP® only

AP® Physics 2 Learning Objectives:

4.C.3.1: The student is able to make predictions about the direction of energy transfer due to temperature differences based on interactions at the microscopic level. [**SP 6.4**]

5.A.2.1: The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. [**SP 6.4, 7.2**]

5.B.4.1: The student is able to describe and make predictions about the internal energy of systems. [**SP 6.4, 7.2**]

5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. [**SP 1.4, 2.1, 2.2**]

5.B.5.4: The student is able to make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy). [**SP 6.4, 7.2**]

5.B.5.5: The student is able to predict and calculate the energy transfer to (*i.e.,* the work done on) an object or system from information about a force exerted on the object or system through a distance. [**SP 2.2, 6.4**]

Use this space for summary and/or additional notes:

AP® only

5.B.5.6: The student is able to design an experiment and analyze graphical data in which interpretations of the area under a pressure-volume curve are needed to determine the work done on or by the object or system. [**SP 4.2, 5.1**]

5.B.6.1: The student is able to describe the models that represent processes by which energy can be transferred between a system and its environment because of differences in temperature: conduction, convection, and radiation. [**SP 1.2**]

5.B.7.1: The student is able to predict qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles. [**SP 6.4, 7.2**]

5.B.7.2: The student is able to create a plot of pressure versus volume for a thermodynamic process from given data. [**SP 1.1**]

5.B.7.3: The student is able to use a plot of pressure versus volume for a thermodynamic process to make calculations of internal energy changes, heat, or work, based upon conservation of energy principles (*i.e.,* the first law of thermodynamics). [**SP 1.1**, **1.4**, **2.2**]

7.A.1.1: The student is able to make claims about how the pressure of an ideal gas is connected to the force exerted by molecules on the walls of the container, and how changes in pressure affect the thermal equilibrium of the system. [**SP 6.4**, **7.2**]

7.A.1.2: Treating a gas molecule as an object (*i.e.,* ignoring its internal structure), the student is able to analyze qualitatively the collisions with a container wall and determine the cause of pressure, and at thermal equilibrium, to quantitatively calculate the pressure, force, or area for a thermodynamic problem given two of the variables. [**SP 1.4**, **2.2**]

7.A.2.1: The student is able to qualitatively connect the average of all kinetic energies of molecules in a system to the temperature of the system. [**SP 7.1**]

7.A.2.2: The student is able to connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and to relate this to thermodynamic processes. [**SP 7.1**]

7.A.3.1: The student is able to extrapolate from pressure and temperature or volume and temperature data to make the prediction that there is a temperature at which the pressure or volume extrapolates to zero. [**SP 6.4**, **7.2**]

Use this space for summary and/or additional notes:

AP® only

7.A.3.2: The student is able to design a plan for collecting data to determine the relationships between pressure, volume, and temperature, and amount of an ideal gas, and to refine a scientific question concerning a proposed incorrect relationship between the variables. [**SP 3.2**, **4.2**]

7.A.3.3: The student is able to analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law $PV = nRT$. [**SP 5.1**]

7.B.1.1: The student is able to extrapolate from pressure and temperature or volume and temperature data to make the prediction that there is a temperature at which the pressure or volume extrapolates to zero. [**SP 6.4**, **7.2**]

7.B.2.1: The student is able to connect qualitatively the second law of thermodynamics in terms of the state function called entropy and how it (entropy) behaves in reversible and irreversible processes. [**SP 7.1**]

Topics from this chapter assessed on the SAT Physics Subject Test:

- **Laws of Thermodynamics**, such as first and second laws, internal energy, entropy, and heat engine efficiency.

1. Heat and Temperature
2. The Kinetic Theory of Gases & the Ideal Gas Law
3. The Laws of Thermodynamics
4. Heat Engines

Skills learned & applied in this chapter:

- Working with material-specific constants from a table.
- Working with more than one instance of the same quantity in a problem.
- Combining equations and graphs.

Use this space for summary and/or additional notes: