Introduction: Thermal Physics (Heat)

Unit: Thermal Physics (Heat)

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.

- *Heat & Temperature* describes the concept of heat as a form of energy and how heat energy is different from temperature.
- *Heat Transfer* describes how to calculate the rate of the transfer of heat energy from one object to another.
- *Specific Heat Capacity & Calorimetry* describes different substances' and objects' abilities to store heat energy.
- *Phase Diagrams* describes how to use a phase diagram to determine the state of matter of a substance at a given temperature and pressure.
- *Phases & Phase Changes* and *Heating Curves* addresses the additional calculations that apply when a substance goes through a phase change (such as melting or boiling).
- *Thermal Expansion* describes the calculation of the change in size of an object caused by heating or cooling.

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

Standards addressed in this chapter:

NGSS Standards/MA Curriculum Frameworks (2016):

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).

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AP® Physics 2 Learning Objectives/Essential Knowledge (2024):

9.1.B: Describe the temperature of a system in terms of the atomic motion within that system.

9.1.B.1: The temperature of a system is characterized by the average kinetic energy of the atoms within that system.

9.1.B.1.i: The Maxwell–Boltzmann distribution provides a graphical representation of the energies and speeds of atoms at a given temperature.

9.1.B.1.ii: The root-mean-square speed corresponding to the average kinetic energy for a particle of an ideal gas is related to the temperature of the gas by $K_{avg} = \frac{3}{2}k_B T = \frac{1}{2}mv_{rms}^2$

9.3.A: Describe the transfer of energy between two systems in thermal contact due totemperature differences of those two systems.

9.3.A.1: Two systems are in thermal contact if the systems may transfer energy by thermal processes.

9.3.A.1.i: Heating is the transfer of energy into a system by thermal processes.

9.3.A.1.ii: Cooling is the transfer of energy out of a system by thermal processes.

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9.3.A.2: The thermal processes by which energy may be transferred between systems at different temperatures are conduction, convection, and radiation.

9.3.A.3: Energy is transferred through thermal processes spontaneously from a higher-temperature system to a lower-temperature system.

9.3.A.3.i: In collisions between atoms from different systems, energy is most likely to be transferred from higher-energy atoms to lower-energy atoms.

9.3.A.3.ii: After many collisions of atoms from different systems, the most probable state is one in which both systems have the same temperature.

9.3.A.4: Thermal equilibrium results when no net energy is transferred by thermal processes between two systems in thermal contact with each other.

9.5.A: Describe the energy required to change the temperature of an object by a certain amount.

9.5.A.1: The amount of energy required to change the temperature of a material is related to the material's specific heat capacity.

9.5.A.2: The specific heat capacity of a material is an intrinsic property of that material that depends on the arrangement and interactions of the atoms that make up the material.

9.5.B: Describe the rate at which energy is transferred by conduction through a given material.

9.5.B.1: The rate at which energy is transferred by conduction through a given material is related to the thermal conductivity, the physical dimensions of the material, and the temperature difference across the material.

9.5.B.2: The thermal conductivity of a material is an intrinsic property of that material that depends on the arrangement and interactions of the atoms that make up the material.

15.4.A: Describe the electromagnetic radiation emitted by an object due to its temperature.

15.4.A.1: Matter will spontaneously convert some of its internal thermal energy into electromagnetic energy.

15.4.A.2: A blackbody is an idealized model of matter that absorbs all radiation that falls on the body. If the body is in equilibrium at a constant temperature, then it must in turn emit energy.

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15.4.A.3: A blackbody will emit a continuous spectrum that only depends on the body's temperature. The radiation emitted by a blackbody is often modeled by plotting intensity per unit wavelength as a function of wavelength.

15.4.A.3.i: The distribution of the intensity of a blackbody's spectrum as a function of temperature cannot be modeled using only classical physics concepts. A blackbody's spectrum is described by Planck's law, which assumes that the energy of light is quantized.

15.4.A.3.ii: The peak wavelength emitted by a blackbody (the wavelength at which the blackbody emits the greatest amount of radiation per unit wavelength) decreases with increasing temperature, as described by Wien's law.

15.4.A.3.iii: The rate at which energy is emitted (power) by a blackbody is proportional to the surface area of the body and to the temperature of the body raised to the fourth power, as described by the Stefan-Boltzmann law.

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.