

Chapters 10-12

Thermal Physics, Thermodynamics

Chapter 10

Thermal expansion-materials expand when heated and contract when cooled.

Linear expansion $\Delta L = \alpha L_0 \Delta T$ so delta L is change in length in m, α is linear thermal coefficient of expansion in $^{\circ}\text{C}^{-1}$, and delta T in change in temperature in Celsius.

There is also area expansion and volume expansion, just substitute A for L or V for L in formula.

$$\Delta A = \alpha A_0 \Delta T$$

$$\Delta V = \alpha V_0 \Delta T$$

TABLE 10.1 Average Coefficients of Expansion for Some Materials Near Room Temperature

Material	Average Coefficient of Linear Expansion $[(^{\circ}\text{C})^{-1}]$	Material	Average Coefficient of Volume Expansion $[(^{\circ}\text{C})^{-1}]$
Aluminum	24×10^{-6}	Ethyl alcohol	1.12×10^{-4}
Brass and bronze	19×10^{-6}	Benzene	1.24×10^{-4}
Copper	17×10^{-6}	Acetone	1.5×10^{-4}
Glass (ordinary)	9×10^{-6}	Glycerin	4.85×10^{-4}
Glass (Pyrex [®])	3.2×10^{-6}	Mercury	1.82×10^{-4}
Lead	29×10^{-6}	Turpentine	9.0×10^{-4}
Steel	11×10^{-6}	Gasoline	9.6×10^{-4}
Invar (Ni-Fe alloy)	0.9×10^{-6}	Air	3.67×10^{-3}
Concrete	12×10^{-6}	Helium	3.665×10^{-3}

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Water behaves oppositely by expanded when cooled and shrinking when heated.

Ideal Gases

$n = \#$ moles of substance $n = m / \text{molar mass}$ m is mass in g, molar mass in g/mol

Avogadro's number is the number of atoms or molecules in 1 mole

6.02×10^{23} particles/mole

Ideal Gas Law $PV=nRT$ P is pressure, V is volume, n is moles, R is universal gas constant, and T is temperature. The units of each depend on which R value used.

$$R=8.31 \text{ J}/(\text{mol}\cdot\text{K}) \quad \text{or} \quad R=0.0821 \text{ (L}\cdot\text{atm)} / (\text{mol}\cdot\text{K})$$

Kinetic Theory of Gases

1. many molecules far apart
2. obey Newton's motion laws
3. short-range collisions
4. elastic collisions
5. all molecules the same

$$KE=\frac{1}{2}mv^2=\frac{3}{2}k_B T \quad \text{units in Joules}$$

m is mass in kg, v is speed in m/s, k_B is **Boltzmann's constant** = $1.38 \times 10^{-23} \text{ J/K}$, and T in Kelvin degrees

Internal energy (U) energy of the molecules in a sample of gas in Joules

$$U=\frac{3}{2}nRT \quad n \text{ is moles, } R \text{ is universal gas constant, and } T \text{ is temperature; units depend on } R \text{ used.}$$

Root-mean-square speed of the molecules

$$v_{\text{rms}}=(3k_B T/m)^{1/2}=(3RT/M)^{1/2} \quad m \text{ is mass in grams, } M \text{ is molar mass in g/mole, } v \text{ is in m/s}$$

Chapter 11

Internal Energy (U)-energy of the microscopic particles (atoms, molecules). It includes KE and PE.

Heat (Q) is how energy is transferred; this is due to change in temperatures

$$1 \text{ calorie}=4.186 \text{ Joules}$$

Specific Heat $Q=mc\Delta T$ (learn in greater detail in a chemistry class)

Three types of heat transfer-----

Convection-heat currents due to heat rising. Ex. convection oven, lake "turning over" 2 times/year

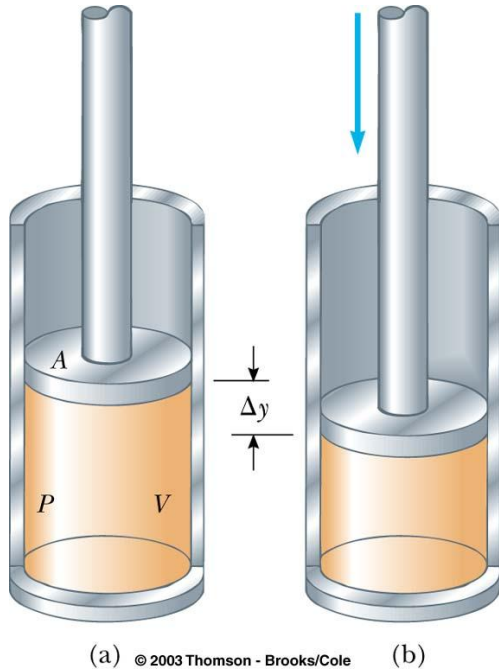
Conduction-particle to particle transfer of heat. Ex. heat moving up through handle of iron skillet.

Radiation-heat transfer by waves; does not need a medium. Ex. sun's heat reaching the earth.

Rate at which energy or work transfers is Power measured in Watts. $P=W/t$ in units Joule/second

Chapter 12-Thermodynamic Processes

Think of a system as a cylinder with a movable piston as shown below:



Work done by a gas

$$W=P\Delta V$$

P is pressure in atm, Pa

V is volume in L, m³

Sign convention

W+ when volume is decreases or system was being compressed.

W- when volume is increases or system was being expanded.

$\Delta U=Q+W$ internal energy equals heat energy plus work; all are in Joules

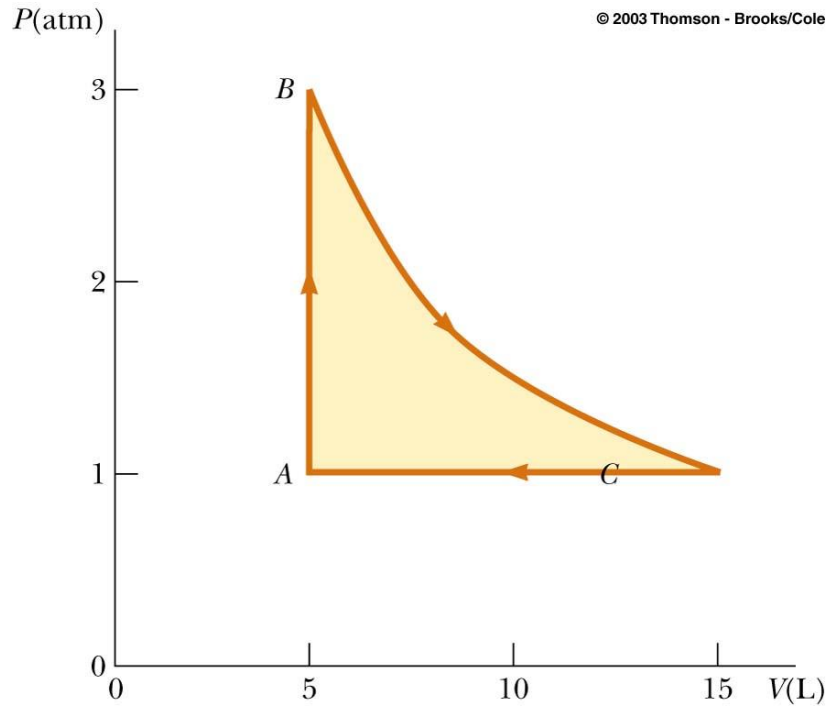
PV-diagrams

Isobaric-constant pressure during a segment of the process (from C to A)

Isovolumetric-constant volume, no Work occurs during this segment, $\Delta U=Q$ (from A to B)

Isothermic-constant temperature, no ΔU , so $Q=-W$ (from B to C)

Adiabatic-no time for Q exchange, so $Q=0$ and $\Delta U=W$



if W, Q, or U is added to system it is +

If W, Q, or U is taken out of a system it is -

common unit conversions

$$1 \text{ atm} = 1.013 \times 10^5 \text{ Pa} \quad 1 \text{ L} = 0.001 \text{ m}^3$$

$$1 \text{ Joule} = 1 \text{ Pa} \cdot \text{m}^3$$

Efficiency of engine

$$e = 1 - (Q_c / Q_h) \quad c\text{-cold temperature of system} \quad h\text{-hot temperature of system}$$

$$W_{\text{eng}} = Q_h - Q_c$$

$$e = 1 - (T_c - T_h) \quad \text{use temperatures in K, Q and W will be in Joules}$$

$$P = W_{\text{eng}} / t$$

$$W_{\text{eng}} = e Q_h$$