Work of Thermal Systems
\[ W = \int p\, dV \]

- Isobaric (constant pressure)
  \[ \Delta Q = n c_p \Delta T \]

- Isochoric (constant volume)
  \[ \Delta Q = W = \int V' \, dV' \]

- Isothermal (constant temp)
  \[ \Delta Q = W = n c_v \Delta T = n c_p \Delta T \]

- Adiabatic \((\Delta Q = 0)\)
  \[ V_{\text{initial}}^{\gamma-1} = V_{\text{final}}^{\gamma-1} \]

Heat
\[ Q = mc \cdot \Delta T \]
\[ \kappa = \text{thermal conductivity} \]
\[ R = \text{thermal resistance} \]

Heat Capacity
\[ Q = mc \cdot \Delta T \]

Thermal Conductivity
\[ \Delta Q = -A \frac{T_1 - T_2}{L} \]
\[ R = \frac{L}{K} \]

Thermal Resistance
\[ R_{\text{series}} = R_1 + R_2 \]
\[ R_{\text{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} \]

Refrigerators
- Carnot
\[ \eta_{\text{Carnot}} = \frac{T_2}{T_1 - T_2} \]

Efficiency
\[ \eta = \frac{W}{Q} = 1 - \frac{Q_2}{Q_1} \]

Otto Cycle
- Compression ratio
\[ r = \frac{1}{\gamma - 1} \]

Carnot Cycle
- \( T = T_1 \frac{Q}{Q_2} = T_2 \frac{Q}{Q_1} \)

Conversions
- 1 cal = 4.186 J
- 1 L = 1000 cm³
- 1 m³ = 1000 L

Molecular Thermal Physics
- \( m \) – mass of a molecule
- \( M \) – molecular mass
- \( n \) – number of moles
- \( N \) – number of molecules
- \( k \) – Boltzmann constant = \( 1.38054 \times 10^{-23} \) J/K

Efficiency
\[ \eta = \frac{W}{Q} = 1 - \frac{Q_2}{Q_1} \]

Otto Cycle
- Compression ratio
\[ r = \frac{1}{\gamma - 1} \]

Carnot Cycle
- \( T = T_1 \frac{Q}{Q_2} = T_2 \frac{Q}{Q_1} \)

Heat
- \( Q \) – heat
- \( c \) – specific heat
- \( \kappa \) – thermal conductivity
- \( R \) – thermal resistance

Heat Capacity
\[ Q = mc \cdot \Delta T \]

Thermal Conductivity
\[ \Delta Q = -A \frac{T_1 - T_2}{L} \]
\[ R = \frac{L}{K} \]

Thermal Resistance
\[ R_{\text{series}} = R_1 + R_2 \]
\[ R_{\text{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} \]

Refrigerators
- General
\[ K = \text{coefficient of performance} \]
\[ H = \text{heat current} \]
\[ P = \text{power input} \]
\[ Q_1 = W + [Q] \]
\[ K = \frac{[Q]}{W} \]
\[ EER = 3.413 K \]

Carnot
\[ K_{\text{Carnot}} = \frac{T_2}{T_1 - T_2} \]

Entropy
\[ \Delta S = \int \frac{dQ}{T} \]
\[ \Delta S = m c_p \ln \frac{T_2}{T_1} \]

Ideal Gas
\[ \Delta S = C_v \ln \frac{T_2}{T_1} + n R \ln \frac{V_2}{V_1} \]
1. (2 pts) Given your experience of what feels colder when you walk on it, which of the surfaces would have the lowest thermal conductivity?
   a.) a rug
   b.) a steel surface
   c.) a concrete floor
   d.) has nothing to do with thermal conductivity

2. (2 pts) Van der Waals equation is a better approximation to the:
   a.) first law of thermodynamics
   b.) second law of thermodynamics
   c.) ideal gas law
   d.) Newton’s third law
   e.) Maxwell-Boltzmann’s law

3. (2 pts) Which has a greater internal energy?
   a.) 2 moles of oxygen at 10°C and 300 kPa absolute pressure
   b.) 2 moles of oxygen at 40°C and 100 kPa absolute pressure
   c.) 1 mole of oxygen at 10°C and 300 kPa absolute pressure
   d.) 1 mole of oxygen at 40°C and 100 kPa absolute pressure

4. (2 pts) A process that happens very fast is typically considered to be:
   a.) constant volume
   b.) constant pressure
   c.) constant temperature
   d.) adiabatic

5. (8 pts) The root mean squared velocity (v_{rms}) of carbon dioxide molecules (molecular mass is equal to 44.0 g/mol) in a flame is found to be 1.05×10^5 m/s. What temperature does this represent?

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6. (14 pts) A 0.3 kg block of aluminum (c = 0.215 cal/g·°C) at 28°C is brought into contact with a 0.2 kg block of unknown material at 6°C. The equilibrium temperature is 23°C. Determine the specific heat of the second material.

7. (14 pts) A Styrofoam cooler has a total surface area of 0.9 m² and an average wall thickness of 0.02 m. The inside of the cooler is kept at 0°C by melting ice. How much ice melts in one day if the ice box is kept in the trunk of a car at 35°C? The thermal conductivity of Styrofoam is 0.01 J/m·s·°C.
8. (14 pts) Bicycle tires are filled with air to a gauge pressure of 400 kPa at a temperature of 28°C. Determine the mass density of the air in the tires. ($M_{\text{air}}=29$ g/mol)

9. (14 pts) 0.3 m$^3$ of air initially at 140 kPa absolute pressure is compressed isothermally. 46 kJ of work is done to compress the air. Determine the final volume of the air.

10. (14 pts) A Carnot air conditioner transfers heat from a 20°C environment to a 35°C environment. How much work must be done if 4000 kJ of heat are to be removed from the cool environment?

11. (14 pts) Water initially at 60°C is heated until it is all converted to steam at 100°C. The increase in entropy is 15000 J/K. Determine the mass of the water.