The First Law of Thermodynamics

- The First Law of Thermodynamics is a special case of the **Law of Conservation of Energy**
  - It takes into account changes in internal energy and energy transfers by heat and work
- Although *Q* and *W* each are dependent on the path,

  ***Q* - *W* is independent of the path**
- The First Law of Thermodynamics states that

$$\Delta \boldsymbol{E}_{\mathbf{int}} = \boldsymbol{Q} - \boldsymbol{W}$$

  - All quantities must have the same units of measure of energy

NOTE: Only CHANGE in internal energy matters

The First Law of Thermodynamics

- For infinitesimal changes in a system

$$\boldsymbol{dE_{\mathrm{int}} = dQ - dW}$$

- The first law is an energy conservation statement specifying that the only type of energy that changes in a system is internal energy

Isolated Systems

- An isolated system is one that does not interact with its surroundings
  - No energy transfer by heat takes place
  - The work done on the system is zero
  - $Q = W = 0$, so $\Delta E_{\text{int}} = 0$
- **The internal energy of an isolated system remains constant**

Cyclic Processes

- A cyclic process is one that starts and ends in the same state
  - This process would not be isolated
  - On a *PV* diagram, a cyclic process appears as a closed curve
- The change of internal energy must be zero since it is a state variable (does not depend on path)
- If $\Delta E_{\text{int}} = 0$, $Q = W$
- In a cyclic process, the net work done on the system per cycle equals the area enclosed by the path representing the process on a *PV* diagram

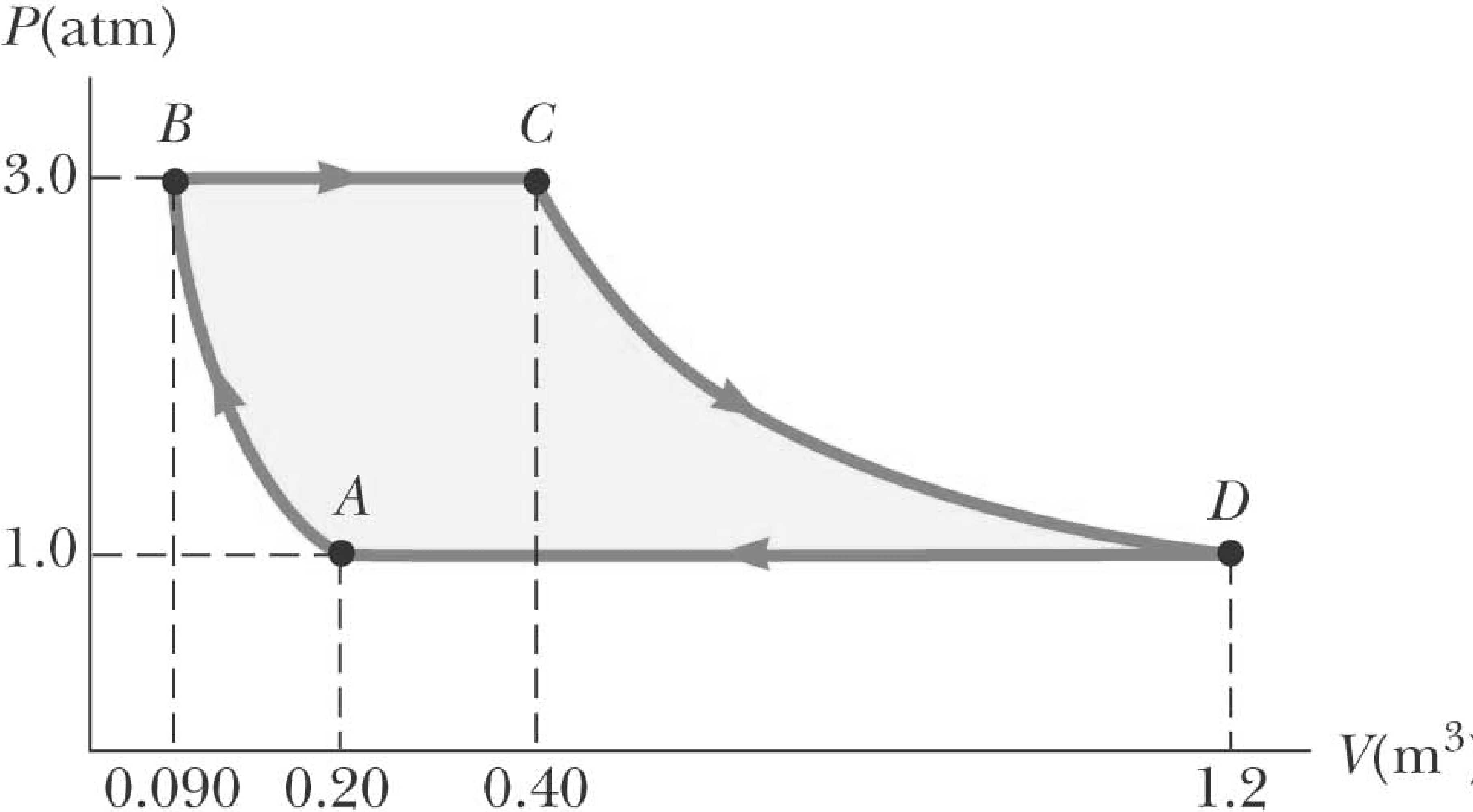
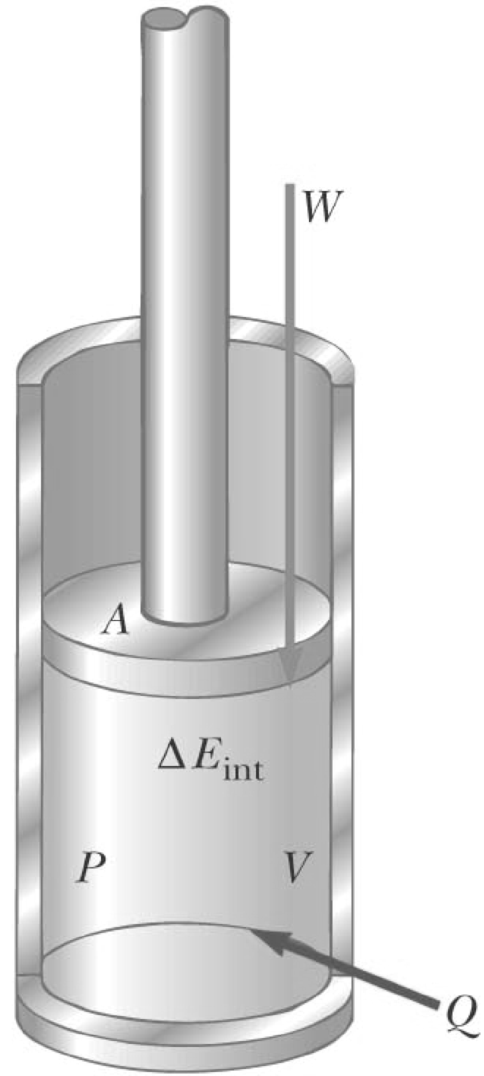


Fig. P20.32, p.634

Adiabatic Process

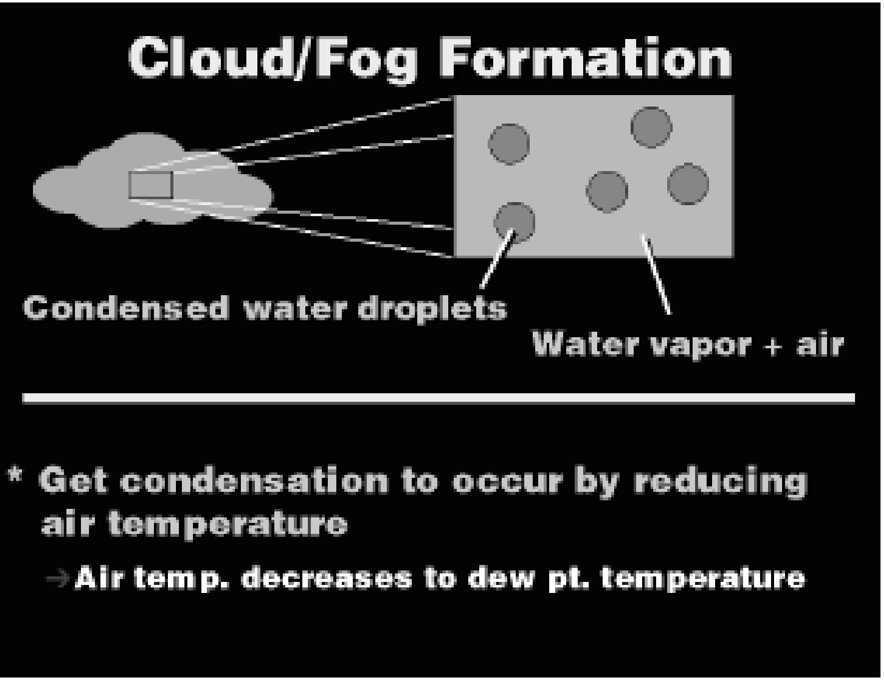
- An adiabatic process is one during which no energy enters or leaves the system by heat
  - ***Q* = 0**
  - This is achieved by:
    - Thermally insulating the walls of the system
    - Having the process proceed so quickly that no heat can be exchanged

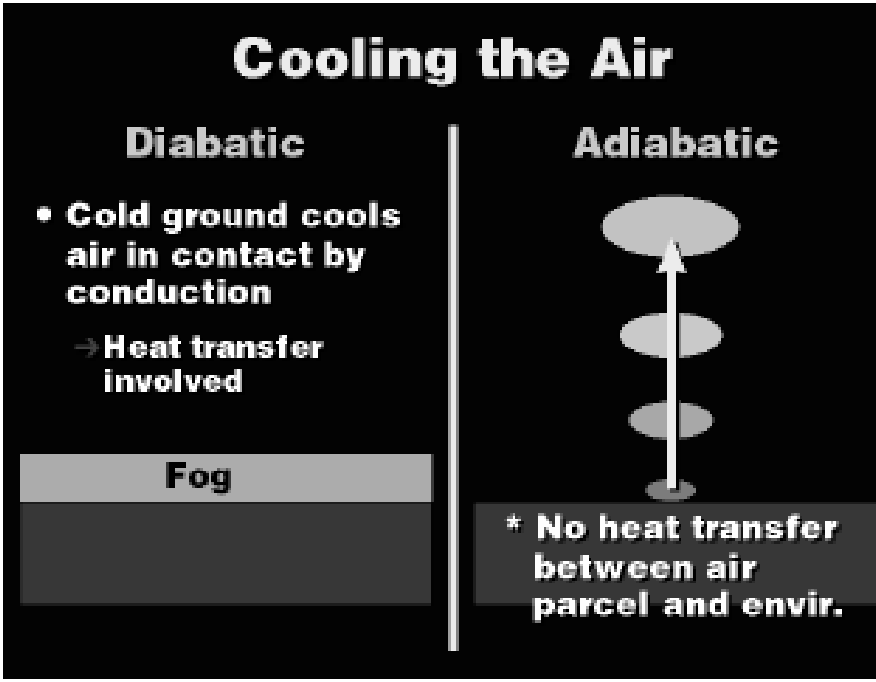


Adiabatic Process

- Since $Q = 0$, $\Delta E_{int} = - W$
- If the gas is compressed adiabatically, W is negative so ΔE_{int} is positive and the temperature of the gas increases
- If the gas expands adiabatically, the temperature of the gas decreases
- For adiabatically isolated system, the work done on the system by external forces does not depend on the path and is determined only by initial and final state

Adiabatic Process and clouds





Adiabatic expansion during ascent causes air parcel temperature to decrease; adiabatic compression during descent causes air parcel temperature to increase

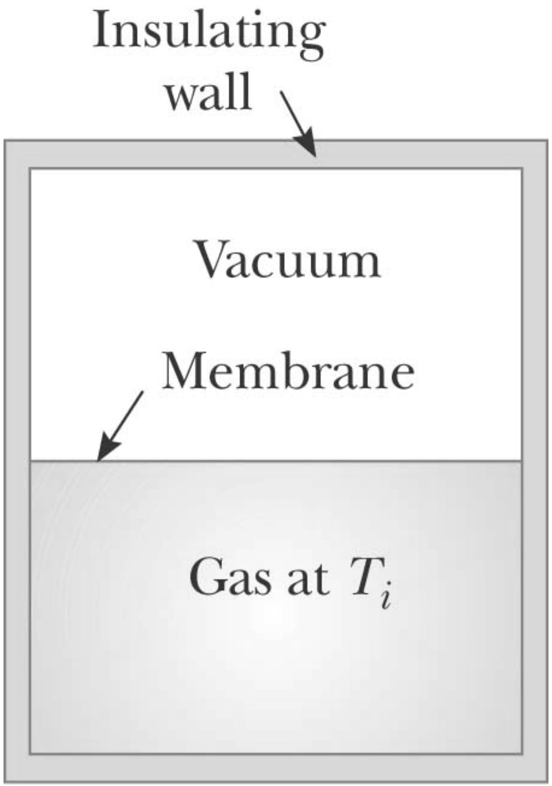
http://www.atmos.ucla.edu/ugrads/classes/win99/win99_3/scrns/top10/Note01.html

Adiabatic Processes, Examples

- Some important examples of adiabatic processes related to engineering are:
  - The expansion of hot gases in an internal combustion engine
  - The liquefaction of gases in a cooling system
  - The compression stroke in a diesel engine

Adiabatic Free Expansion

- This is an example of adiabatic free expansion
- The process is adiabatic because it takes place in an insulated container
- Because the gas expands into a vacuum, it does not apply a force on a piston and $W = 0$
- Since $Q = 0$ and $W = 0$, $\Delta E_{int} = 0$ and the initial and final states are the same
  - No change in temperature is expected



(b)

Isobaric Processes

- An isobaric process is one that occurs at a constant pressure
- The values of the heat and the work are generally both nonzero
- The work done is $W = P\,(V_f - V_i)$ where P is the constant pressure

Isovolumetric Processes

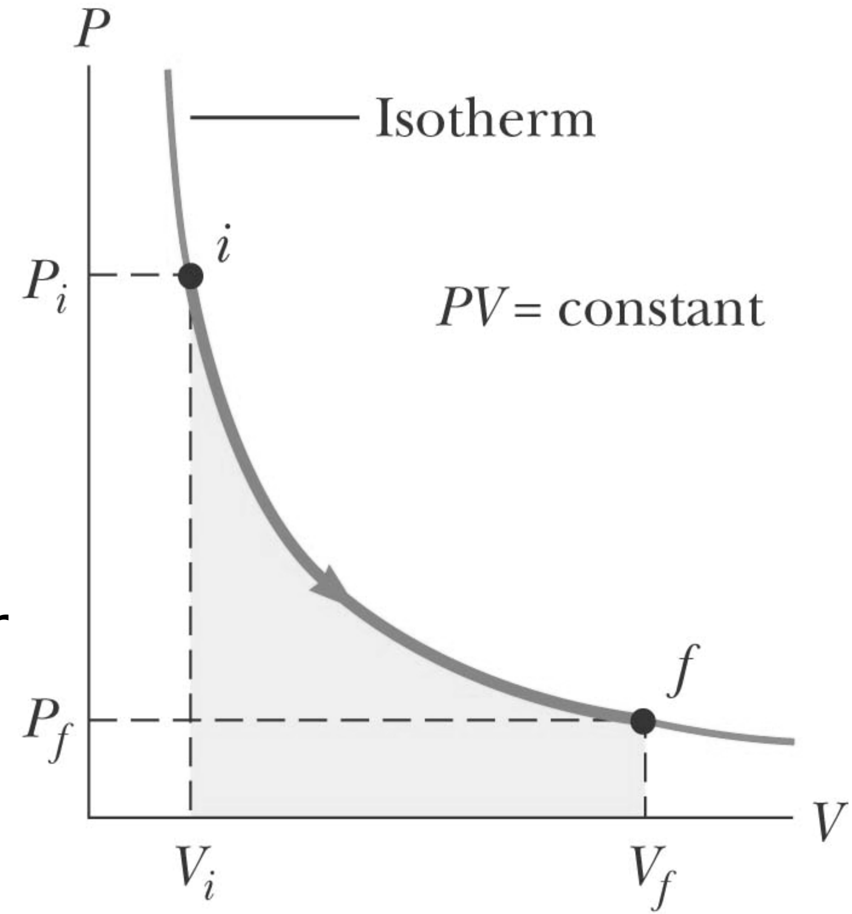
- An isovolumetric process is one in which there is no change in the volume
- Since the volume does not change, $W = 0$
- From the first law, $\Delta E_{int} = Q$
- If energy is added by heat to a system kept at constant volume, all of the transferred energy remains in the system as an increase in its internal energy

Isothermal Process

- An isothermal process is one that occurs at a constant temperature
- Since there is no change in temperature, $\Delta E_{\text{int}} = 0$
- Therefore, $Q = W$
- Any energy that enters the system by heat must leave the system by work

Isothermal Process

- At right is a *PV* diagram of an isothermal expansion
- The curve is a hyperbola
- The curve is called an **isotherm**



Isothermal Expansion:Work

- The curve of the *PV* diagram indicates *PV* = constant
  - The equation of a hyperbola
- Because it is an ideal gas and the process is quasi-static, *PV* = *nRT* and

$$\mathbf{W} = \int_{Vi}^{Vf} P dV = \int_{Vi}^{Vf} \frac{nRT}{V} dV = nRT \int_{Vi}^{Vf} \frac{dV}{V} = nRT \ln V \Big|_{Vi}^{Vf} = nRT \ln\left(\frac{V_f}{V_i}\right.$$

Isothermal Expansion, final

- Numerically, the work equals the area under the *PV* curve
  - The shaded area in the diagram
- If the gas expands, $V_f > V_i$ and the work done on the gas is positive
- If the gas is compressed, $V_f < V_i$ and the work done on the gas is negative

Special Processes: Summary

- **Adiabatic**
  - No heat exchanged
  - $Q = 0$ and $\Delta E_{\text{int}} = -W$
- **Isobaric**
  - Constant pressure
  - $W = P\,(V_f - V_i)$ and $\Delta E_{\text{int}} = Q - W$
- **Isothermal**
  - Constant temperature

    $\Delta E_{\text{int}} = 0$ and $Q = W$