[-PdV]

$$dE_{int} = dQ + dW$$

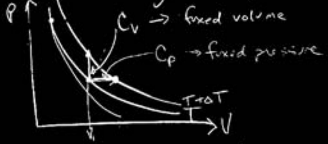
adiabatic expansion of ideal gas

$$dQ = 0 \Rightarrow dE_{int} = dW$$

recall specific heat measures amount of heat needed to change temp by ΔT

$$\Delta Q = nC\Delta T$$

specific heat depends on how you change T



look at C_V:

$$dE_{int} = dQ + dW \quad [v=0]$$

at constant V

$$\boxed{dE_{int} = nC_V dT}$$

So $nC_v\,dT = dE_{int}$

and

$$nC_v\,dT = -P\,dV$$

now eliminate dT in favor of P & V

$$PV = nRT$$

$$P\,dV + V\,dP = nR\,dT$$

$$\Rightarrow dT = \frac{1}{nR}\left(P\,dV + V\,dP\right)$$

$$\frac{nC_v}{nR}\left(P\,dV + V\,dP\right) = -P\,dV$$

$$V\,dP = -\left(1 + R/C_v\right)P\,dV$$

$$\frac{dP}{P} = -\left(1 + \frac{R}{C_v}\right)\frac{dV}{V}$$

$$\ln P = C_1 - \left(1 + R/C_v\right)\ln V$$

exponentiate:

$$P = C\,V^{-(1+R/C_v)}$$

$$\Rightarrow PV^{(1+R/C_v)} = \text{cst}$$

will show later that for an ideal gas,

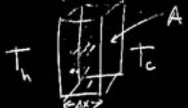
$$1 + R/C_v = C_P/C_V$$

define $\gamma = C_P/C_V$

along adiabat $PV^\gamma = C$

Energy transfer -

thermal conductivity



find empirically that heat Q transferred in a time Δt from hot side to cold side obeys

$$\frac{Q}{\Delta t} \propto A(T_h - T_c)/\Delta x$$

define $\mathcal{P} = \frac{Q}{\Delta t}$ = power transferred (watts if Q is in J and Δt is in s)

define thermal conductivity k by

$$\mathcal{P} = k A \left|\frac{dT}{dx}\right|$$

units of k are $\frac{W}{m \cdot {}^\circ K}$

for slabs, $\mathcal{P} = k A \frac{T_h - T_c}{\Delta x}$

high k – good thermal conductor

low k – poor thermal conductor

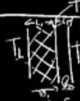
relate R value for insulation to thermal conductivity:

define $R = \frac{\Delta x}{K}$

bigger $R \Rightarrow$ better insulator

typical units for R are "English"

$ft^2 \cdot {}^\circ F \cdot h / Btu$



two slabs in "series"

heat cannot accumulate at interface, so

$$Q_1 = K_1 A\left(\frac{T_h - T_i}{L_1}\right) = Q_2 = K_2 A\left(\frac{T_i - T_c}{L_2}\right)$$

$$\frac{K_1}{L_1}(T_h - T_i) = \frac{K_2}{L_2}(T_i - T_c)$$

find T_i

$$T_i\,(K_1 L_2 + K_2 L_1) = K_2 L_1 T_c + K_1 L_2 T_h$$

$$T_i = \frac{K_2 L_1 T_c + K_1 L_2 T_h}{K_1 L_2 + K_2 L_1}$$

$$Q = \frac{K_1 A}{L_1}(T_h - T_i) = \frac{K_1 A}{L_1(K_1 L_2 + K_2 L_1)}\left(K_2 L_1 T_c + K_1 L_2 T_h - (K_1 L_2 + K_2 L_1) T_h\right)$$

$$Q = \frac{A(T_h - T_c)}{\left(L_1/K_1 + L_2/K_2\right)}$$

recall $Q = KA\frac{T_h - T_c}{L}$

K_{eff} (using L_{eff} of $L_1 + L_2$)

$$K_{eff} = \frac{L_1 + L_2}{\left(L_1/K_1 + L_2/K_2 \right)}$$

mechanisms for heat conductivity

- diffusion [random molecular motions]
- convection [concerted flows]
- radiation - emission of electromagnetic waves

Power emitted by a body is described by Stefan's law.

$$Q = \sigma A e T^4$$

Q: power radiated

e: emissivity

σ: Stefan-Boltzmann constant $= 5.6696 \times 10^{-8} \frac{W}{m^2 K^4}$

§21 Kinetic theory of gases.

relate macroscopic properties P, V, T to microscopic quantities

Here: low density gases.

1) # of molecules is large.
   separation is large.
2) molecules obey Newton's laws
   but as whole they move randomly
   "molecular randomness"