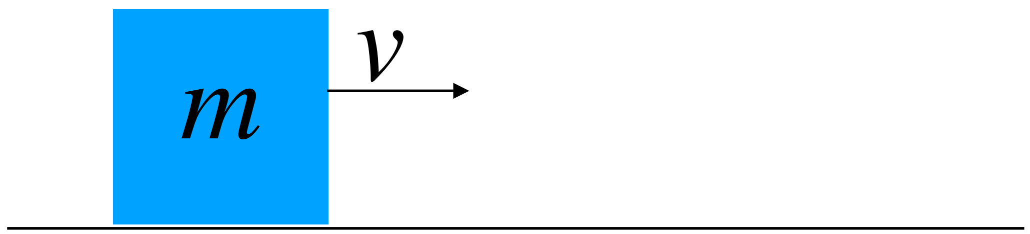


$$U = \frac{1}{2}mv^2$$

$$v_f = 0$$

$$U = 0 + heat$$

work: ΔU due to macroscopic force or field

heat: ΔU due to random microscopic motion

heat into system

change in system's total energy $\Delta U = Q + W$ **1st law of thermodynamics**

work on system

$$1\ \mathrm{J} = 1\ \frac{\mathrm{kg\ m^2}}{\mathrm{s^2}}$$

$$1\ \mathrm{cal} = 1^\circ\mathrm{C\ change\ for\ 1\ g\ H_2O} \equiv 4.186\ \mathrm{J}$$

- **conduction: contact, random motions**
- **convection: transport of material**
- **radiation: electromagnetic radiation**

Estimate how long a 600 W microwave oven takes to boil 200 g of water.

$$200\ \text{g}\ H_2O\ \text{at}\ 20^\circ\text{C} \rightarrow 100^\circ\text{C}$$

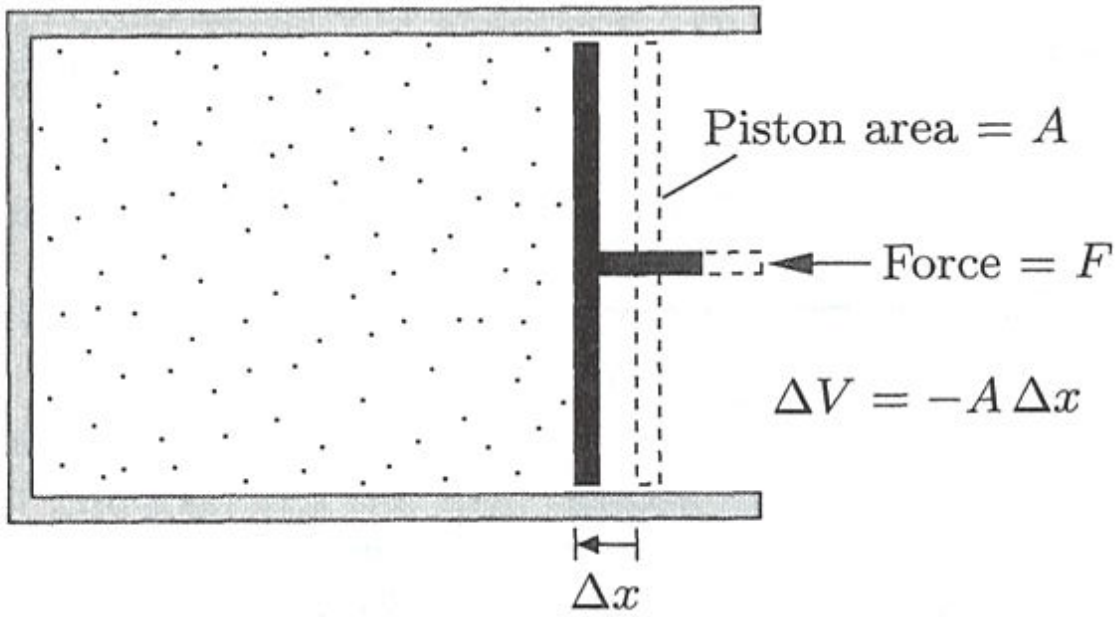
$$\left(200\ \text{g}\ H_2O\right)\ \frac{1\ \text{cal}}{1^\circ\text{C g}\ H_2O}\ 80^\circ\text{C}\ \frac{4.186\ \text{J}}{1\ \text{cal}} = 67\ \text{kJ}$$

$$\frac{67\ \text{kJ}}{600\ \text{J/s}} = 110\ \text{sec}$$

compression/expansion

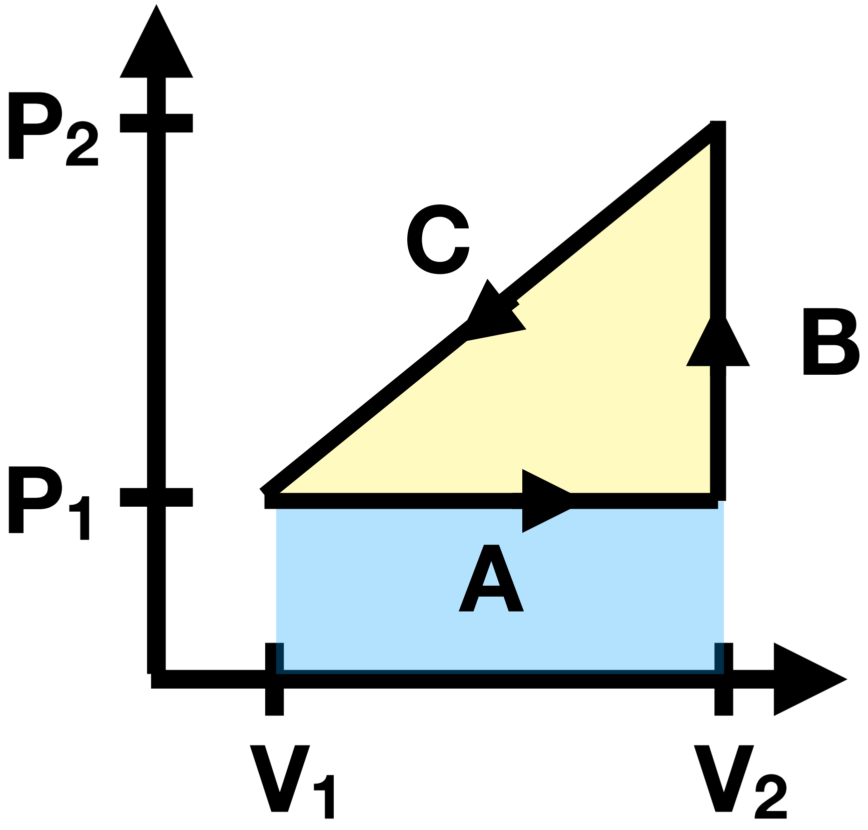
$$\begin{aligned} W &= (F)\;\Delta x \\ &= (PA)\,\Delta x \\ &= P(A\,\Delta x) \\ &= P\,(-\Delta V) \end{aligned}$$

$$W = -P\,\Delta V$$



quasistatic, finite

$$W = -\int_{V_i}^{V_f} P(V)\,dV$$



P2
P1
C
B
A
V1
V2

isothermal compression/expansion
T = constant

$$W = -\int_{V_i}^{V_f} P(V)\, dV$$

$$= -\int_{V_i}^{V_f} \left(\frac{NkT}{V}\right) dV$$

$$= -NkT \int_{V_i}^{V_f} \left(\frac{1}{V}\right) dV$$

$$= -NkT \left[\ln V_f - \ln V_i\right]$$

$$= NkT \ln \frac{V_i}{V_f}$$

adiabatic compression/expansion
Q=0

$$dU = \frac{f}{2} Nk\, dT = -P(V) dV$$

$$\frac{f}{2} Nk\, dT = -\frac{NkT}{V} dV$$

$$\int_{T_i}^{T_f} \frac{f}{2} \frac{dT}{T} = -\int_{V_i}^{V_f} \frac{dV}{V}$$

$$\frac{f}{2} \ln \frac{T_f}{T_i} = -\ln \frac{V_f}{V_i}$$

$$V_f {T_f}^{f/2} = V_i {T_i}^{f/2}$$

$$V_f \left(\frac{P_f V_f}{Nk} \right)^{f/2} = V_i \left(\frac{P_i V_i}{Nk} \right)^{f/2}$$

$$PV^{\frac{2+f}{f}} = PV^{\gamma} = constant$$

adiabatic exponent