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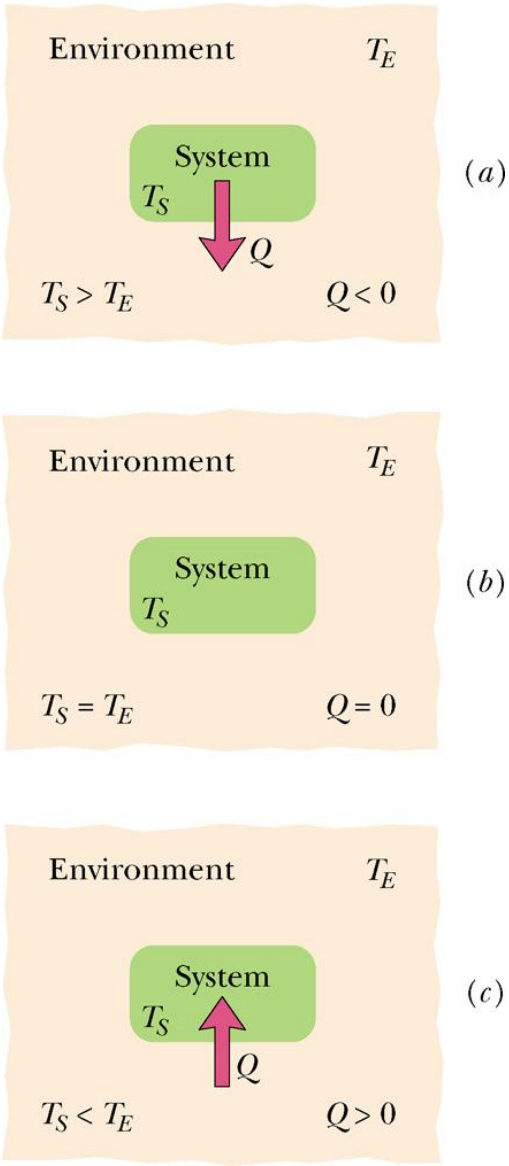
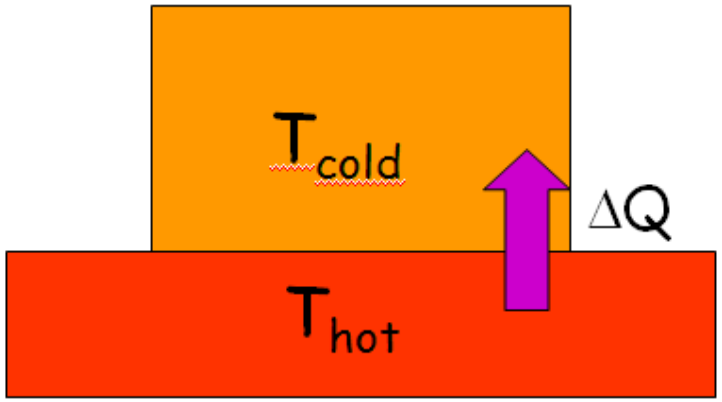
  1. University Physics, Bauer and Westfall, McGraw-Hill, 2011.
  2. Principles of Physics, Halliday, Resnick, and Walker, Wiley, 8^{th} and 9^{th} Ed.
- The rest is made by me.

Chap 18. Heat and the 1st law of Thermodynamics

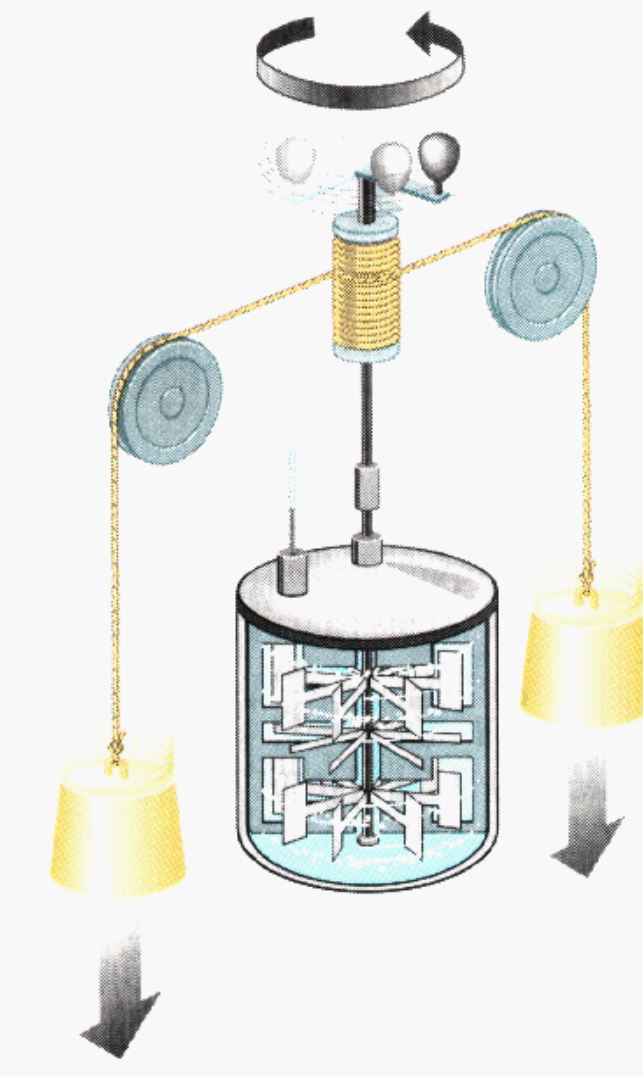
Temperature and heat





열 (heat): 온도가 높은 물체에서 온도가 낮은 물체로 전달되는 에너지

Joule's experiment



ΔE : 추의 역학적 에너지 변화

ΔW : 추가 해준 일

$\Delta E(int)$: 데워진 물이 얻은 에너지

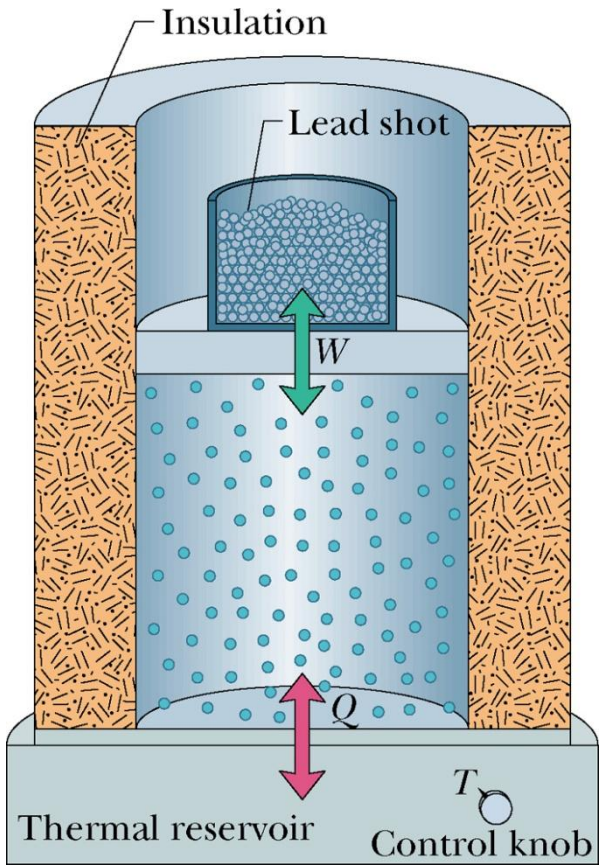
1 cal = 4.186 Joule

ΔQ : 데워진 물이 다시 주위의 온도로 식으면서 내준 에너지

Heat and work

extensive
intensive

quasistatic process

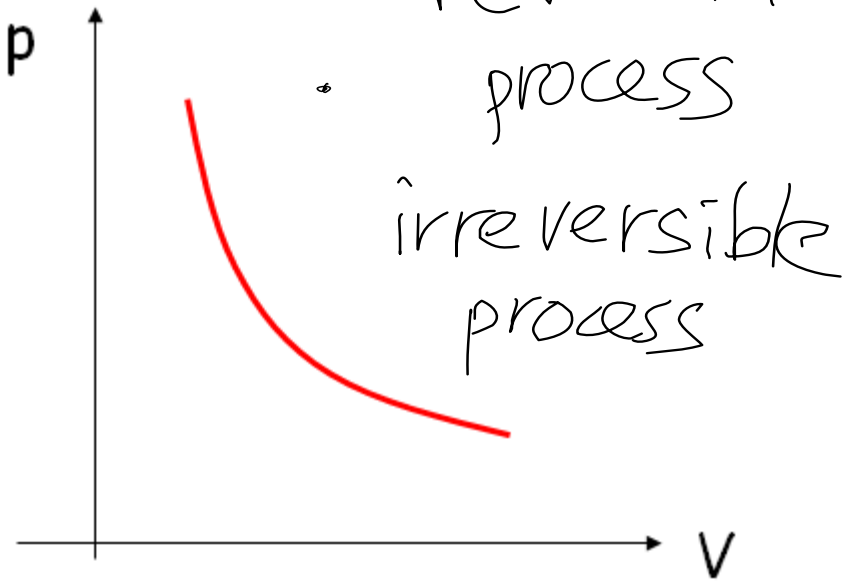


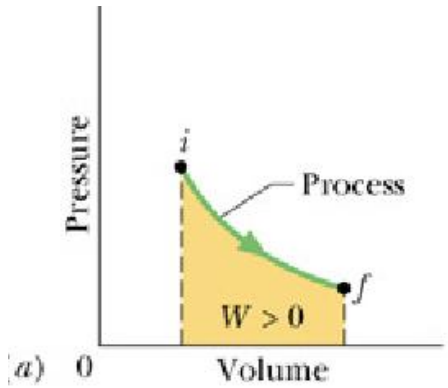
열역학적 변수: p, V, T, N

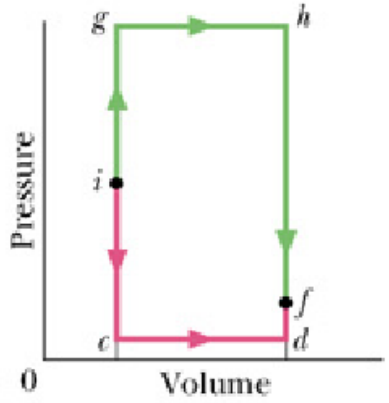
열역학적 과정: $\Delta W, \Delta E, \Delta Q$

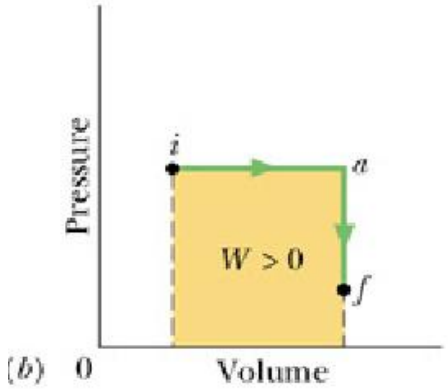
reversible process

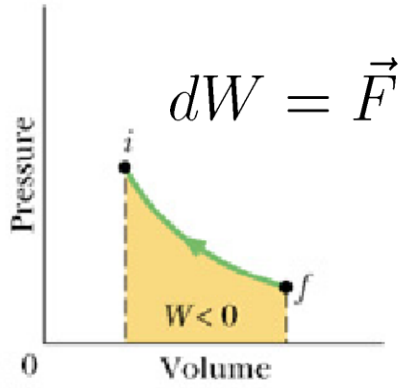
irreversible process





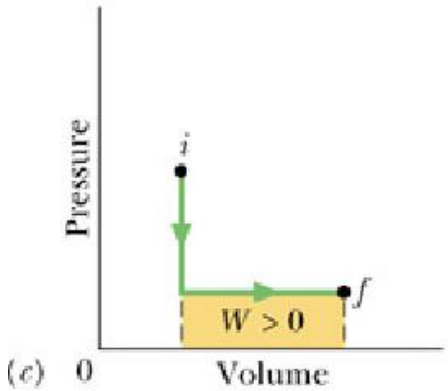


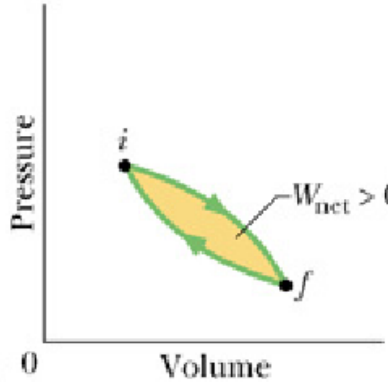




$$dW = \vec{F} \cdot d\vec{s} = (pA)ds = p(Ads) = pdV$$

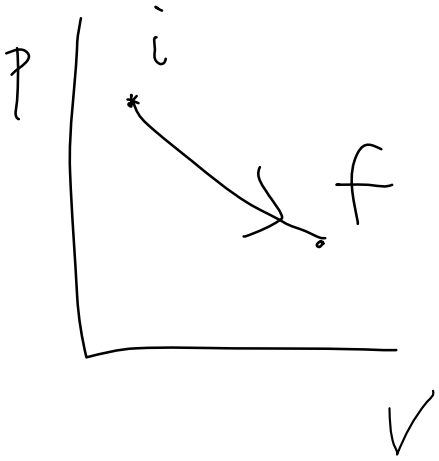
$$W = \int dW = \int_{V_i}^{V_f} pdV$$





The 1st law of thermodynamics

계의 내부에너지는 계에 도달할 때 교환한 열과 일의 차이에만 의존하고, 경로에 무관하다.



$$\Delta E_{\text{int}} = E_{\text{int},f} - E_{\text{int},i} = Q - W$$

$$dE_{\text{int}} = đQ - đW$$

고체와 액체의 열흡수

heat capacity

어떤 물체를 단위 온도만큼 올리는데 필요한 (열) 에너지

$$Q = C\Delta T = C(T_f - T_i)$$

specific heat

단위질량, 또는 몰의 어떤 물체를 단위온도만큼 올리는데 필요한 (열) 에너지

$$Q = cm\Delta T = cm(T_f - T_i)$$

latent heat

상의 변화를 일으킬 때 열로 전달되는 단위질량당 에너지

$$Q = Lm$$

물의 증발열

$$L_V = 539 \text{ cal/g} = 40.7 \text{ kJ/mol} = 2256 \text{ kJ/kg}$$

물의 융해열

$$L_F = 79.5 \text{ cal/g} = 6.01 \text{ kJ/mol} = 333 \text{ kJ/kg}$$

보기문제 18-3: 질량 720인 섭씨 영하 10도의 얼음을 섭씨 15도로 올리는데 필요한 열은?

(1) 얼음 데우기: $Q_1 = c_{\text{ice}} m(T_f - T_i) = 15.98 \text{ kJ}$

(2) 얼음 녹이기: $Q_2 = L_F m = 239.8 \text{ kJ}$

(3) 물 데우기: $Q_3 = c_{\text{water}} m(T_f - T_i) = 45.25 \text{ kJ}$

$$Q = Q_1 + Q_2 + Q_3$$

Sample prob.

구리 75g, 섭씨 312도, 물 220 g, 섭씨 12도 $C_b = 45 \text{ cal/K}$

나중 온도는?

$$Q_w = c_w m_w (T_f - T_i)$$

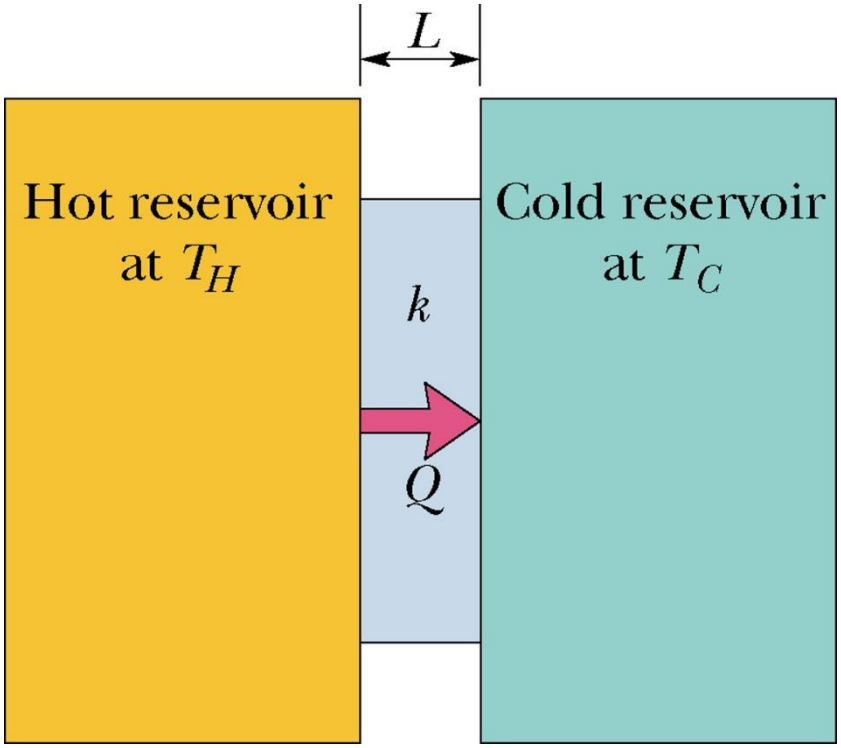
$$Q_b = C_b (T_f - T_i)$$

$$Q_c = c_c m_c (T_f - T)$$

$$c_w m_w (T_f - T_i) + C_b (T_f - T_i) + c_c m_c (T_f - T) = 0$$

$$T_f = \frac{c_c m_c T + C_b T_i + c_w m_w T_i}{c_w m_w + C_b + c_c m_c}$$

Heat transfer

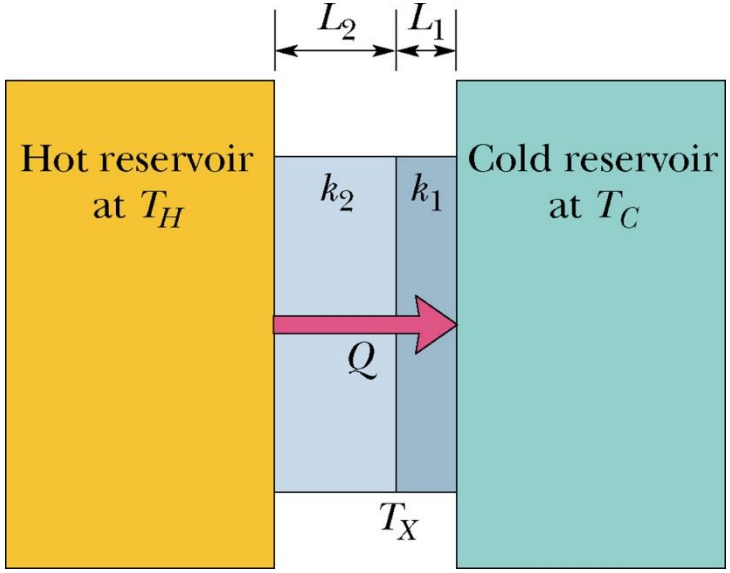


전도율: 단위시간당
전달된 열에너지

$$P_{\text{cond}} = \frac{Q}{t} = kA\frac{T_H - T_C}{L}$$

k: 열전도도

열저항 $R = \frac{L}{k}$



$$P_{\text{cond}} = \frac{k_2 A(T_H - T_X)}{L_2} = \frac{k_1 A(T_X - T_C)}{L_1}$$

$$T_X = \frac{k_1 L_2 T_C + k_2 L_1 T_H}{k_1 L_2 + k_2 L_1}$$

$$P_{\text{cond}} = \frac{A(T_H - T_C)}{L_1/k_1 + L_2/k_2} \rightarrow \frac{A(T_H - T_C)}{\sum L_i/k_i}$$

$$\frac{k_2 A}{L_2}\left(T_H - \frac{k_1 L_2 T_C + k_2 L_1 T_H}{k_1 L_2 + k_2 L_1}\right)$$

$$= \frac{k_2 A}{L_2(k_1 L_2 + k_2 L_1)}$$

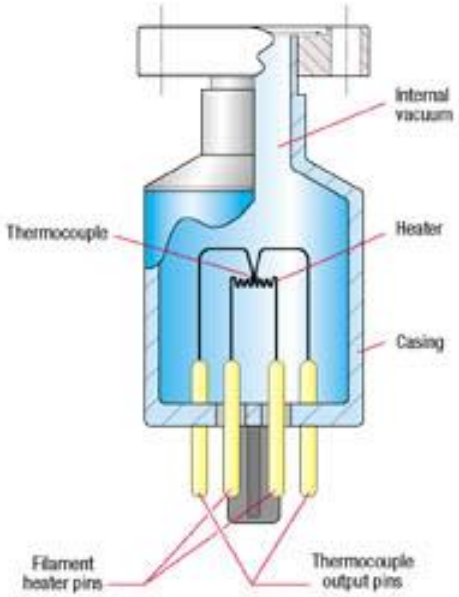
$$\times\left(k_1 L_2 T_H + k_2 L_1 T_H - k_1 L_2 T_C - k_2 L_1 T_H\right)$$

$$= \frac{k_2 A(k_1 T_H - k_1 T_C)}{k_1 L_2 + k_2 L_1}$$

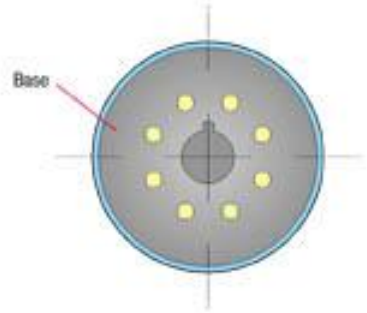
$$= \frac{k_1 k_2 A(T_H - T_C)}{k_1 L_2 + k_2 L_1}$$

$$= \frac{A(T_H - T_C)}{L_1/k_1 + L_2/k_2}$$

convection



Thermocouple gauge tube



thermocouple vacuum gauge

열전달 ; radiation

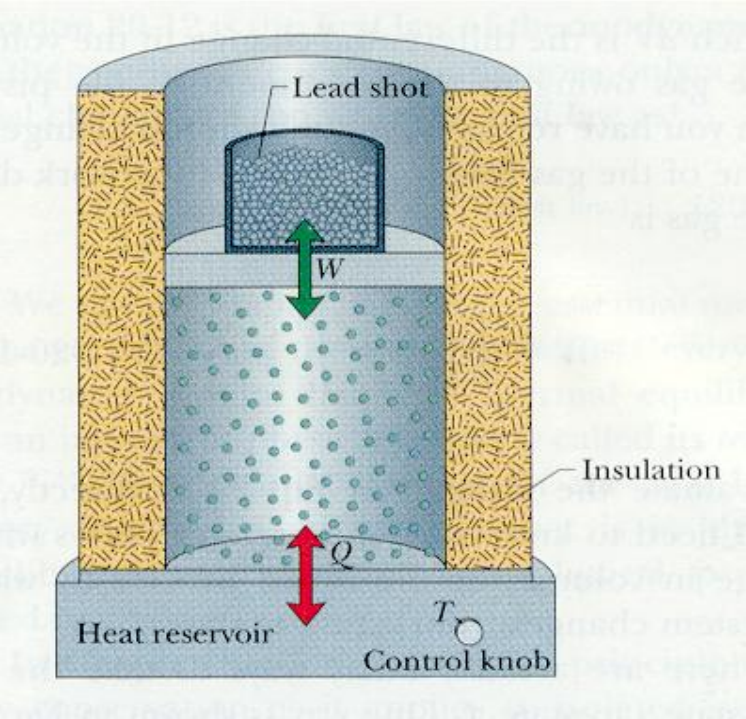
$$E^* = \sigma T^4$$

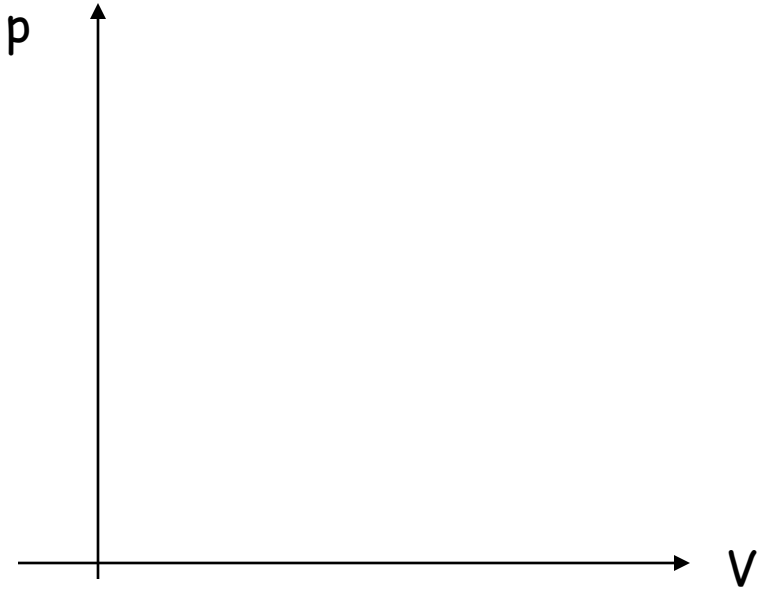
where σ (sigma) = 5.67×10^{-8} Wm^{-2} K^{-4}

and T is the temperature in Kelvin

isothermal process

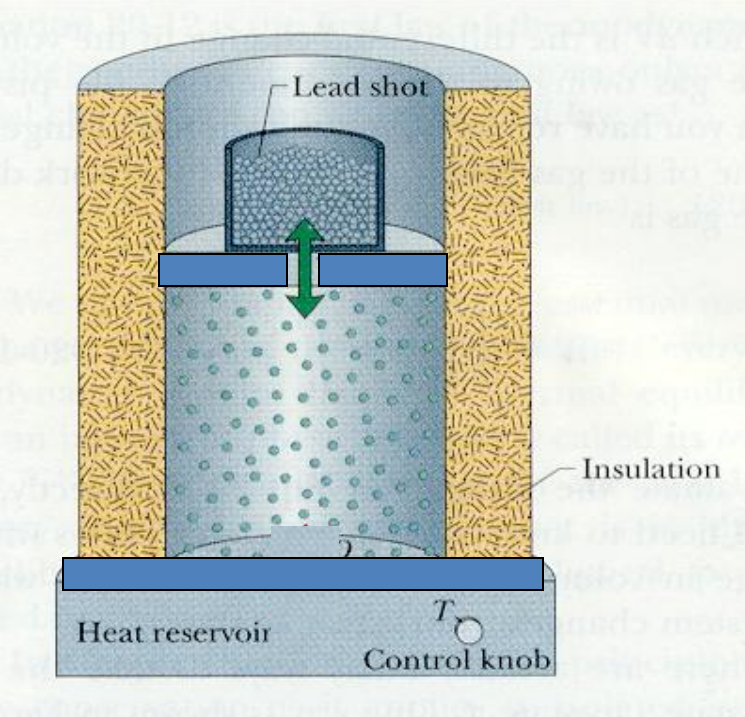
T= constant ($\Delta E = 0$) ; $\Delta Q = \Delta E + \Delta W$

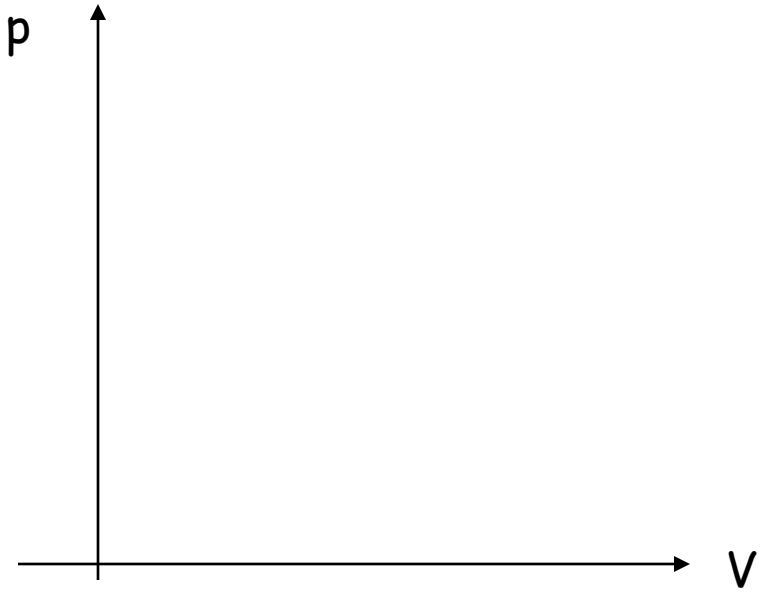




adiabatic process

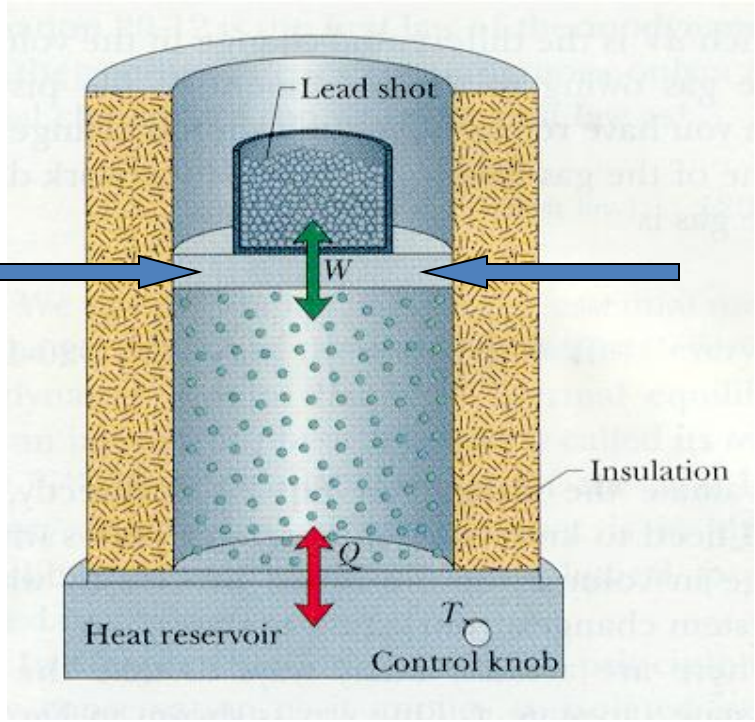
$\Delta Q = 0$; $\Delta Q = \Delta E + \Delta W$

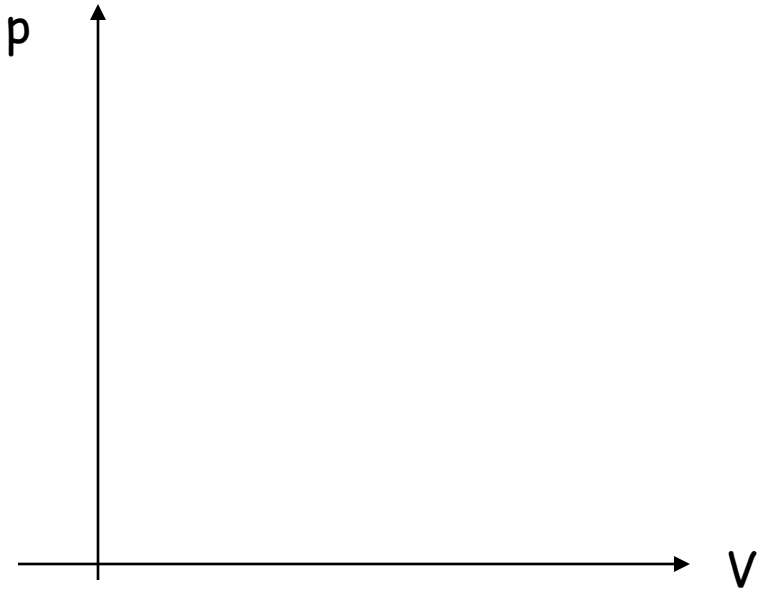




constant-volume process

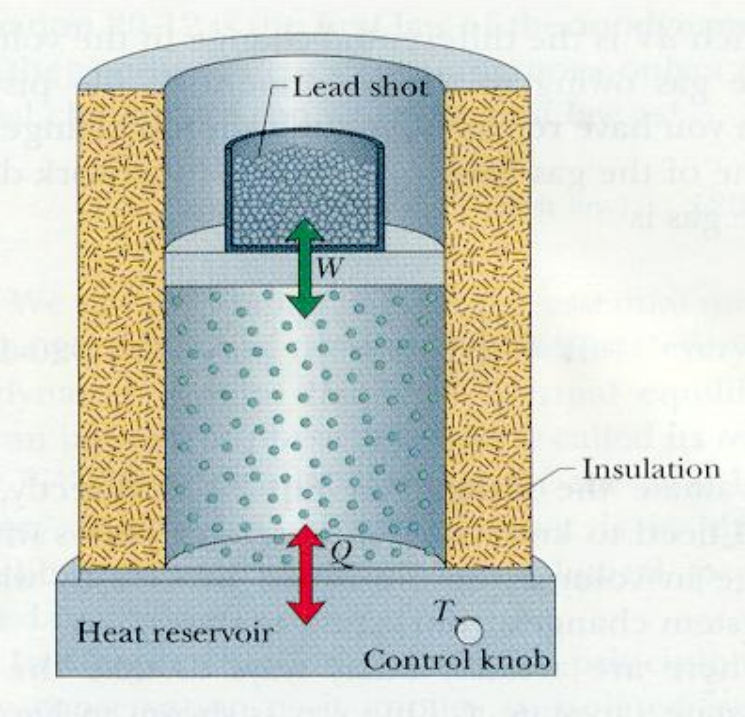
$\Delta W = 0$; $\Delta Q = \Delta E + \Delta W$

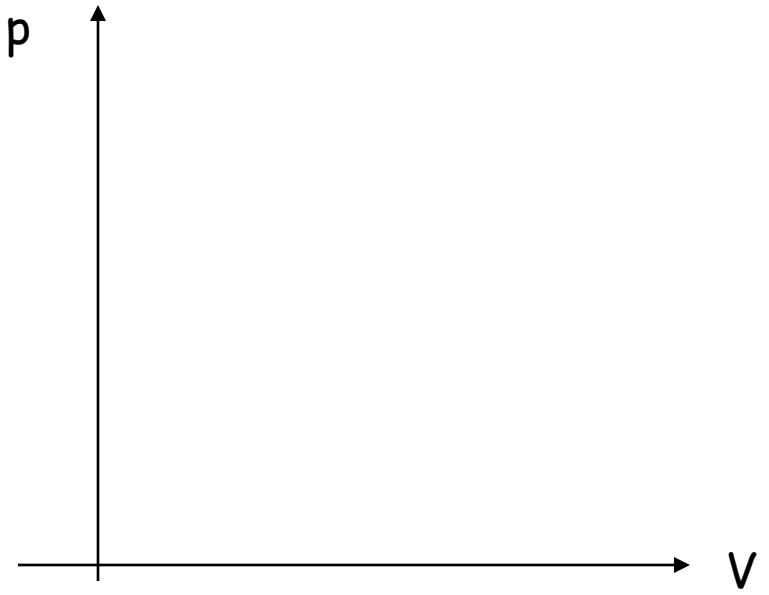




cyclic process

$\Delta E = 0$; $\Delta Q = \Delta E + \Delta W$





free expansion

$\Delta Q = 0, \Delta W = 0$; $\Delta Q = \Delta E + \Delta W$