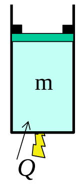
CM Energy and Enthalpy Examples: #1



- **Given:** Piston-cylinder but piston is locked in place, fluid inside being heated. No other work being done (only pdV work possible)
- **Find:**

  How much heat (transfer) required to change temperature of fluid by some given amount

- **Assume:** (eventually) ideal gas

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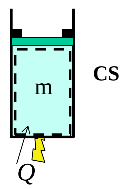
CM Energy and Enthalpy Examples: #1



- **Analysis:**

1st Law $dE = \delta Q + \delta W$ ($dE \to dU$, $\delta W \to 0$)

only internal energy: dU — with piston locked: $pdV = 0$ so $\delta W = 0$

$$\boxed{dU = \delta Q}$$

ideal gas (or incomp. subst.) $\quad \delta Q = mc_v dT$

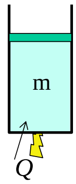
finite change $\quad Q_{12} = m\int_{T_1}^{T_2} c_v dT$

*this is why c_v is known as **specific heat** at **constant volume** – heat (transfer) required to raise temperature of given mass by 1 deg. if volume not changing*

on a rate basis $\quad \boxed{\dot{Q} = \frac{dU}{dt}} = mc_v \frac{dT}{dt}$

CM Energy and Enthalpy Examples: #2

- **Given:** Piston-cylinder being heated again, but now let piston move slowly and make process isobaric



- **Find:**

  How much heat (transfer) required to change temperature of fluid by some given amount

- **Assume:** ideal gas

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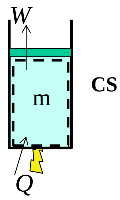
CM Energy and Enthalpy Examples: #2

- **Analysis:** **1st Law** $dE = \delta Q - \delta W$ ($dE \to dU$, $\delta W \to pdV$)



adding 0 because dp=0 here

$$\delta Q = dU + pdV = dU + \left(pdV + Vdp\right)$$
$$= dU + d\left(pV\right)$$

$$\boxed{\delta Q = dH}$$

ideal gas $\quad \delta Q = mc_p dT$

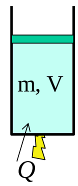
finite change $\quad Q_{12} = m\int_{T_1}^{T_2} c_p dT$

on a rate basis $\quad \boxed{\dot{Q} = m\frac{dh}{dt}} = mc_p\frac{dT}{dt}$

*why c_p is known as **specific heat** at **constant pressure** – heat (transfer) required to raise temperature of given mass by 1 deg. if pressure not changing*

CM Energy and Enthalpy Examples: #3

- **Given:** Piston-cylinder being heated again, moving slowly, constant pressure in cylinder BUT what happens if the piston has friction as it moves?



- **Find:**

  Compare how much heat (transfer) required to make the gas go from V_1 to V_2 for piston:
  1) with friction, and
  2) without friction

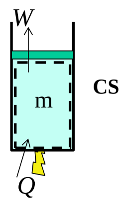
- **Assume:** ideal gas

CM Energy and Enthalpy Examples: #3

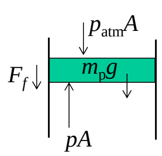
- **Analysis:** **1st Law** still isobaric process

$$\delta Q = dH$$

$$Q_{12} = H_2 - H_1$$



- If Q different, it is because there is some change in initial and/or final states
- Let's look at force required to move piston



$$p = p_{atm} + \frac{m_p g + F_f}{A} \Rightarrow p_{w/\ friction} > p_{w/o}$$

Need T

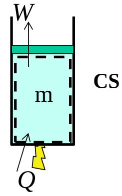
Use conserv. of mass and Ideal Gas EOS

$$m_{w/} = m_{w/o}$$

$$\frac{p_{w/}V_1}{RT_{1,w/}} = \frac{p_{w/o}V_1}{RT_{1,w/o}} \Rightarrow \frac{T_{1,w/o}}{T_{1,w/}} = \frac{p_{w/o}}{p_{w/}} < 1$$

CM Energy and Enthalpy Examples: #3

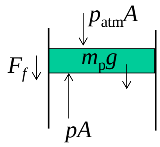
- **Analysis:** initial state $\frac{T_{1,w/o}}{T_{1,w/}} < 1$



final state $m_1 = m_2 \Rightarrow \frac{pV_1}{T_1} = \frac{pV_2}{T_2} \Rightarrow \frac{T_2}{T_1} = \frac{V_2}{V_1}$

Ideal Gas

$$\frac{T_{2,w/o}}{T_{1,w/o}} = \frac{T_{2,w}}{T_{1,w}}$$



assume cpg

$$\frac{Q_{w/o}}{Q_w} = \frac{c_p\left(T_{2,w/o} - T_{1,w/o}\right)}{c_p\left(T_{2,w/} - T_{1,w}\right)}$$

$$= \frac{T_{1,w/o}\left(T_{2,w/o}/T_{1,w/o} - 1\right)}{T_{1,w}\left(T_{2,w/}/T_{1,w} - 1\right)} < 1$$

less Q required for frictionless case – BUT INITIAL conditions not the same