Phys 201
no office hour today (11/30)

last time: heat
ΔQ

heat added depends on process.

transfer variables: depends on process ΔQ

state variables. volume V, pressure P, temperature T } do not depend on procedure

§20.4 Work.

transfer variable

ex:

work done by piston on gas when piston moves by $-dx\,\hat{i}$

is $dW = \vec{F}\cdot d\vec{r}$

$= -F_x\,dx$

$= -PA\,dx$ (P: pressure)

$dW = -P\,dV$ ← volume change

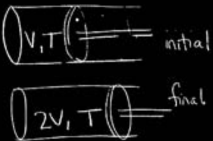
$$dW = -P\,dV$$

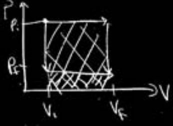
if change V by a lot,

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

if you know P(V), then can calculate work

Work is transfer variable





path 1
pull piston out slowly
piston does negative work on gas

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path 2
punch hole in piston
piston does no work on gas

How to describe relationship between state variables and transfer variables

— laws of thermodynamics

1^{st} law of thermodynamics

$$\Delta E_{int} = Q + W$$

↑ internal energy

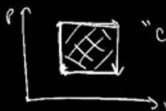
↑ heat added

↑ work done on system

Q, W transfer variables but Q+W is state variable

for infinitesimal changes of state,

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



"cyclic process"

end in same thermo state in which you started

E_{int} is state variable

$\Rightarrow$ for cyclic process $\Delta Q = -\Delta W$

§20.6 Examples of 1st law

$$[\, dE_{int} = dQ + dW \,]$$

1) adiabatic process ($\Delta Q \overset{def}{=} 0$)

$$\Delta E_{int} = \underset{\uparrow}{W} \left(\int_{V_i}^{V_f} P\,dV \right)$$

work done on system

2) isobaric constant pressure

work done $W = -P(V_f - V_i)$

3) Isovolumetric process (constant volume)

$$\Delta W = 0$$

$$\Rightarrow \Delta E_{int} = Q$$

4) Isothermal process (constant T)

for ideal gas

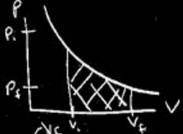
calculate work done when expand isothermally.

T fixed
start at V_i end at V_f

for ideal gas

$$PV = nRT$$

$$P = \frac{nRT}{V}$$



work done on gas

$$W = -\int_{V_i}^{V_f} P\,dV = -\int_{V_i}^{V_f}\left(\frac{nRT}{V}\right)dV = nRT\int_{V_i}^{V_f}\frac{dV}{V} = nRT\ln\left(\frac{V_f}{V_i}\right)$$