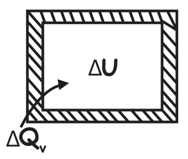
THERMODYNAMICS

Internal Energy(U)

(1) $\Delta U=\Delta Q_v=nC_v\Delta T=n\frac{f}{2}R\Delta T$

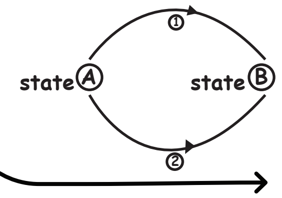
$=\frac{nR\Delta T}{\gamma-1}=\frac{\Delta(PV)}{\gamma-1}$

$=\frac{P_fV_f-P_iV_i}{\gamma-1}$



(Internal Energy is only the function of temperature of the gas)

- First law of T.D ⟹ $Q=\Delta U+W$
- Q, W ⟹ path functions
- ΔU ⟹ state function



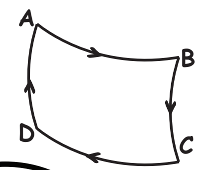
- $W_1 \neq W_2$
- $Q_1 \neq Q_2$
- $\Delta U_1=\Delta U_2=U_B-U_A$

Isothermal process ⟹ $\Delta T=0 \longrightarrow \Delta U=0$

Cyclic process

$A \rightarrow B \rightarrow C \rightarrow D \rightarrow A$

$\Delta U=U_A-U_A=0$



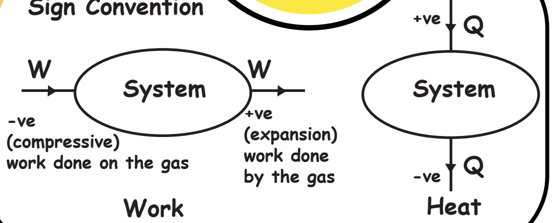
WORK

Work done: path function

$W=F.dx=\int Pdv$

- Unit: Joule(J)

Sign Convention



HEAT

Heat: path function

⟹ unit:calorie/Joule

For any process, $Q=nC\Delta T$

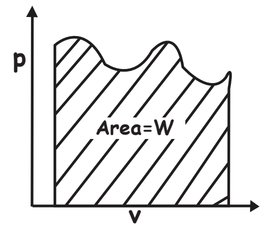
where, C= Specific heat capacity for the process

Adiabatic process ⟹ $\Delta Q=0$ [No heat transfer]

At constant volume ⟹ $Q_v=\Delta U=nC_v\Delta T$

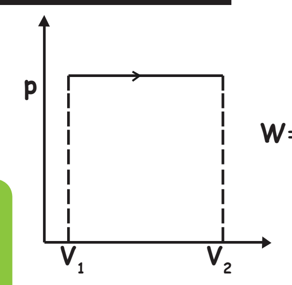
At constant pressure ⟹ $Q_p=\Delta U+W=nC_p\Delta T$

Work done from P-V Graph



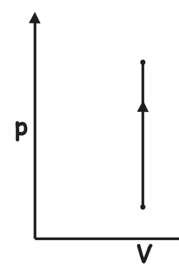
Area under P-V diagram gives work done by the gas

Isobaric process

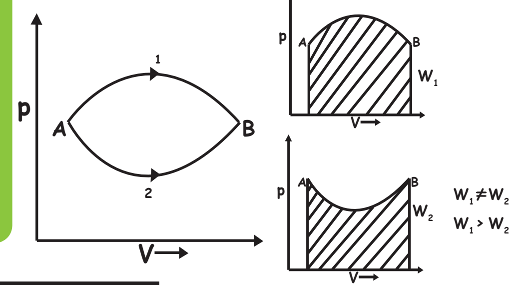


$W=P(V_2-V_1)$

Isochoric process



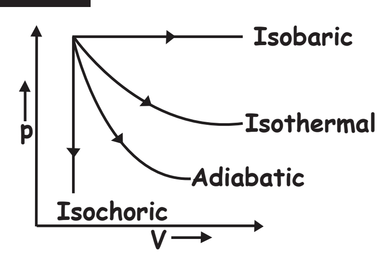
$W=P\Delta V=0$



$W_1 \neq W_2$

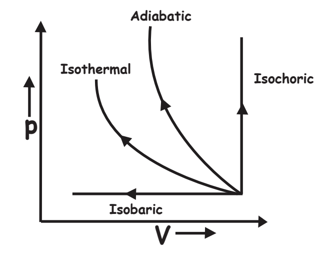
$W_1 > W_2$

Expansion



$W_{isobaric} > W_{isothermal} > W_{adiabatic} > W_{Isochoric}$

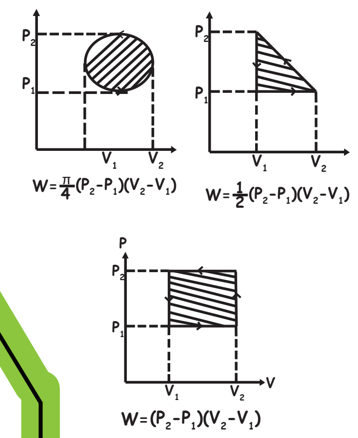
Compression



$|W_{adiabatic}|>|W_{isothermal}|>|W_{isobaric}|>|W_{isochoric}|$

Cyclic process

- W=are inside the graph
- For clockwise process, W=−ve
- For anti-clockwise process, W=+ve



$W=\frac{\pi}{4}(P_2-P_1)(V_2-V_1)$

$W=\frac{1}{2}(P_2-P_1)(V_2-V_1)$

$W=(P_2-P_1)(V_2-V_1)$

Thermodynamic processes

01 Adiabatic process

- $Q=0$ [no exchange of heat]
- Rapid or spontaneous process/insulated vessel

$Q=\Delta U+W$

$Q=0 \quad \Delta U=-W$

Compression

$W=-ve \quad \Delta U=+ve$

$\Delta U\uparrow$ ⟹ Temperature↑

⟹ Pressure↑

Expansion

$W=-ve \quad \Delta U=+ve$

$\Delta U\downarrow$ ⟹ Temperature↓

⟹ Pressure↓

Equation of state

$PV^{\gamma}=$ constant

$TV^{\gamma-1}=$ constant

$PT^{\left[\frac{\gamma-1}{\gamma}\right]}=$constant

Work done by the gas

$W=-\Delta U=nC_v(T_1-T_2)$

$=n\frac{f}{2}R(T_i-T_f)$

$W=\frac{nR}{\gamma-1}(T_i-T_f)$

$W=\frac{P_iV_i-P_fV_f}{\gamma-1}$

Slope of adiabatic process $=\gamma\times$ slope of isothermal process

specific heat of gas ⟹ $C=0$

$C=\frac{Q}{\Delta T} \rightarrow Q=0$

$C=0$

02 Isothermal process

⟹ $\Delta T=0$ ⟹ $\Delta U=0$

eg:- perfectly conducting slow process

$Q=\Delta U+W$

$Q=W$

equation of states ⟹ PV=Constant

$P_1V_1=P_2V_2$

Workdone by the gas

$W=2.303\ nRT\log\left(\frac{V_2}{V_1}\right)$

$W=2.303\ nRT\log\left(\frac{P_1}{P_2}\right)$

Slope:

Slope of adiabatic process $=\gamma\times$ slope of isothermal process

specific heat $C=\infty$

03 Isobaric process

$\Delta P=0$

$Q=\Delta U+W$

equation of state ⟹ $V\propto T$

$\frac{V_1}{V_2}=\frac{T_1}{T_2}$

Work done by the gas

$W=P\Delta V=P(V_2-V_1)=nR(T_2-T_1)$

specific heat

⟹ $C_p=\left(1+\frac{f}{2}\right)R$

$=\frac{\gamma R}{\gamma-1}$

04 Isochoric process

$\Delta V=0$ or V=constant

equation of state ⟹ $P\propto T$ ⟹ $\frac{P_1}{P_2}=\frac{T_1}{T_2}$

Work done by the gas

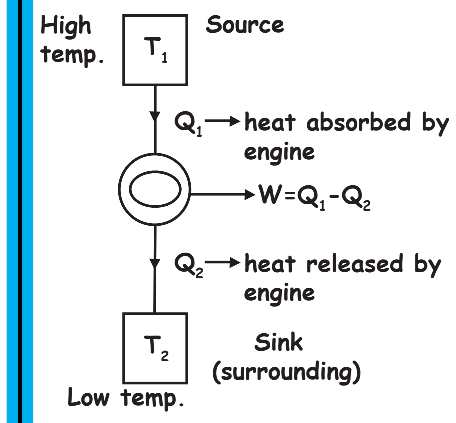
$\Delta V=0$ ⟹ $W=0$

specific heat ⟹ $C_v=\frac{f}{2}R$

$=\frac{R}{\gamma-1}$

Heat Engine

'Device that converts heat into work'



efficiency(η)

$\eta=\frac{W}{Q_1}=\frac{Q_1-Q_2}{Q_1}=1-\frac{Q_2}{Q_1}$

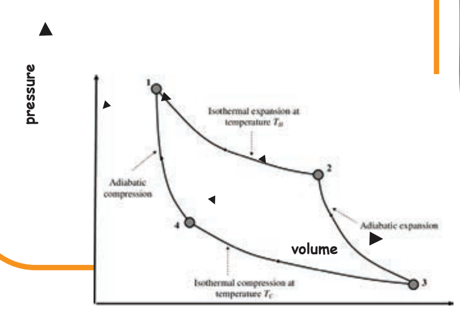
$\eta_{carnot}=\frac{T_1-T_2}{T_1}=1-\frac{T_2}{T_1}$

η_{max} ⟹ When $Q_2=0$ or T_2=0K (not possible)

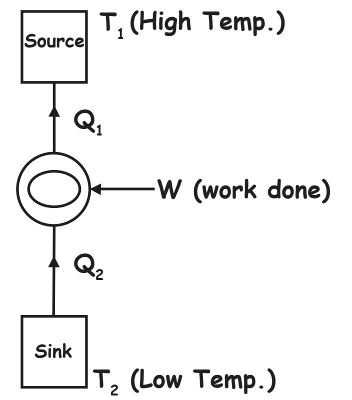
Carnot Engine

→ Ideal engine

→ $\eta=\frac{T_1-T_2}{T_1}=1-\frac{T_2}{T_1}$



Refrigerator and heat pump



Coefficient of performance of refgeration(β)

$\beta=\frac{Q_2}{W}=\frac{Q_2}{Q_1-Q_2}$ $\quad \beta=\frac{T_2}{T_1-T_2}$

Coefficient of performance of heat pump

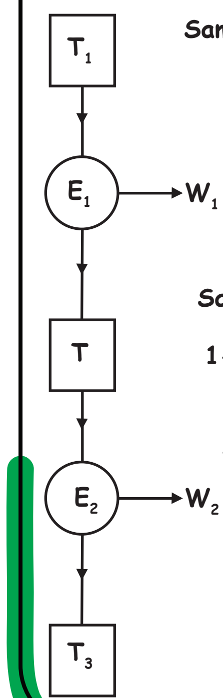
$=\frac{Q_1}{W}=\frac{Q_1}{Q_1-Q_2}=\frac{T_1}{T_1-T_2}$

Relationship between

$\beta=\frac{1-\eta}{\eta}$

$(COP)_{heat\ pump}=1+(COP)_{refrigerator}$

Cascaded engine



Same work output

$W_1=W_2$

$T_1-T=T-T_3$

$2T=T_1+T_3$

$T=\frac{T_1+T_3}{2}$

Same efficiency

$1-\frac{T}{T_1}=1-\frac{T_3}{T}$

$T^2=T_1T_3$

$T=\sqrt{T_1T_3}$