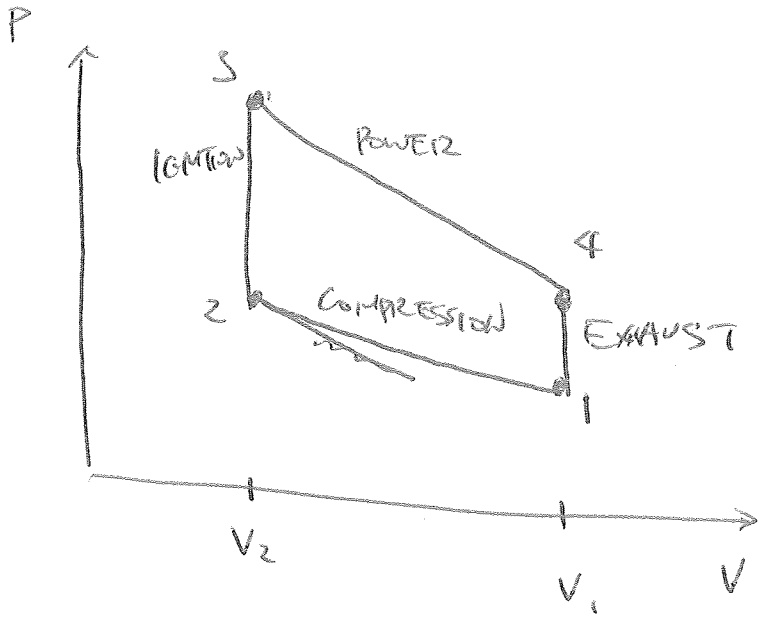
OTTO CYCLE 2



$$\varepsilon = \frac{|Q_{23}| - |Q_{41}|}{Q_{23}}$$

$$Q_{41} = C_v (T_4 - T_1)$$

$$Q_{23} = C_v (T_3 - T_2)$$

$$\varepsilon = 1 - \frac{T_4 - T_1}{T_3 - T_2} =$$

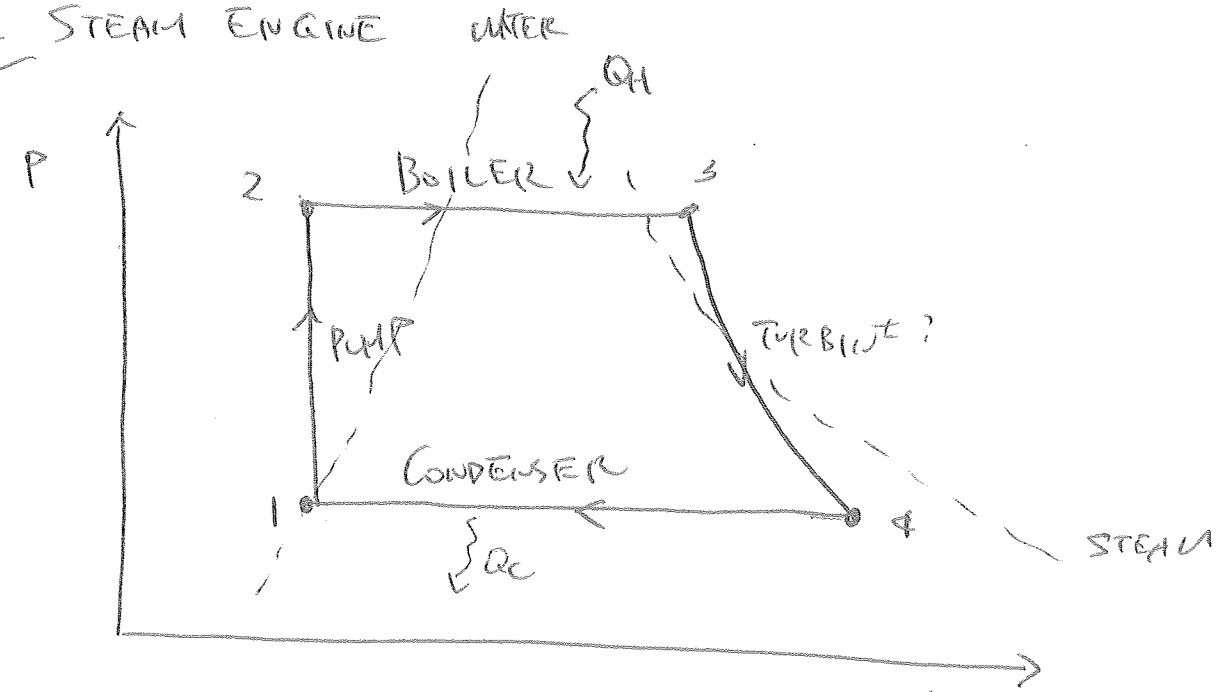
$$\boxed{\frac{T_4}{T_3} = \frac{T_1}{T_2}}$$ FROM PREVIOUS ANALYSIS $\frac{T_2}{T_3} = \frac{T_1}{T_4}$

$$\varepsilon = 1 - \frac{T_4\left(1 - \frac{T_1}{T_4}\right)}{T_3\left(1 - \frac{T_2}{T_3}\right)} = 1 - \frac{T_4}{T_3} = 1 - \frac{T_1}{T_2}$$

$$\varepsilon = 1 - \left(\frac{V_2}{V_1}\right)^{\gamma - 1}$$

OTTO CYCLE

#2 STEAM ENGINE

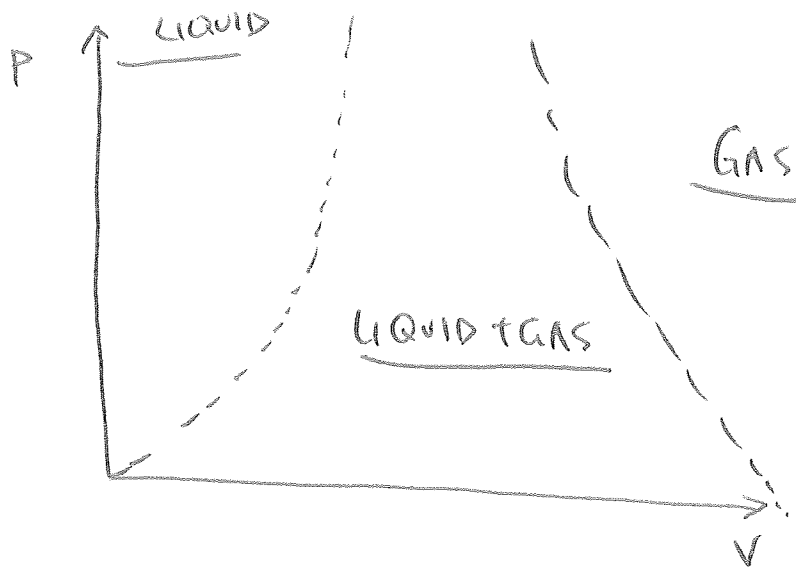


$$\varepsilon = 1 - \frac{Q_C}{Q_H} \Rightarrow 1 - \frac{H_4 - H_1}{H_3 - H_2}$$

$$Q_C = H_4 - H_1$$

$$Q_H = H_3 - H_2$$

STEAM ENGINE IN CLASS DO

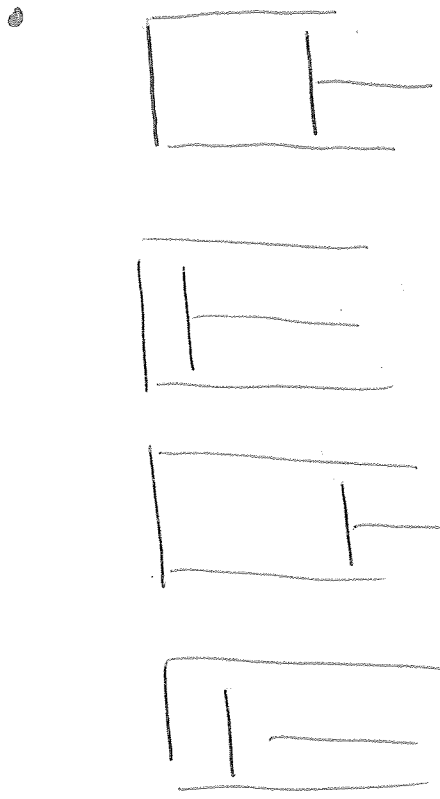


DRAW IT

5-10 MIN

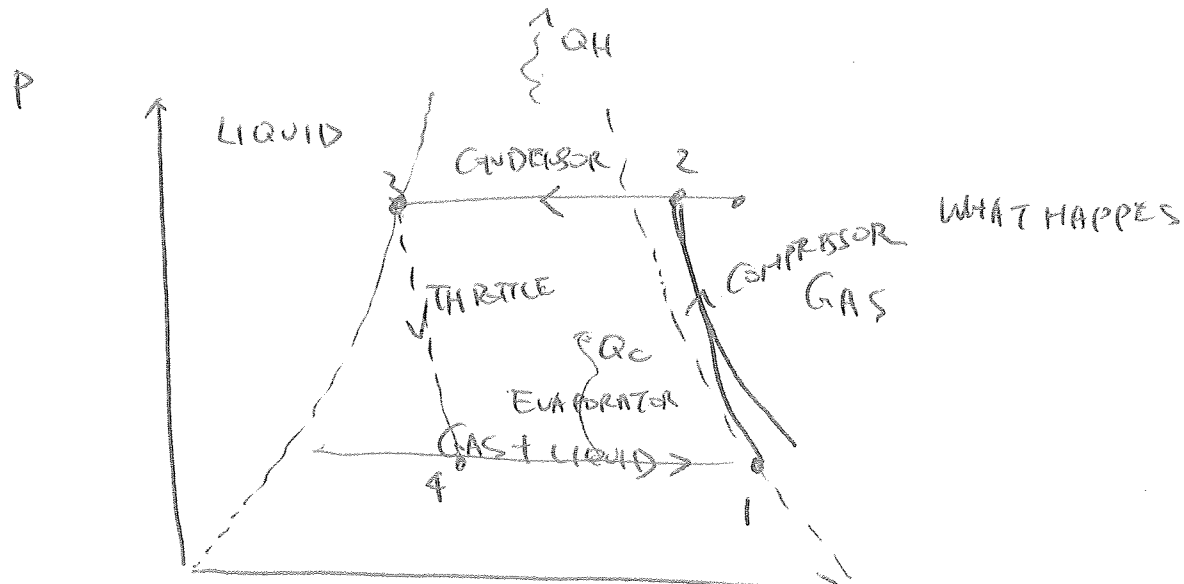
☆ 1

ENTHALPY H=U+PV LOOKS GOOD TO USE



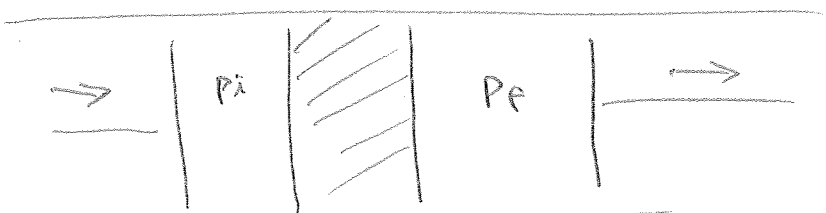
$$\varepsilon = 1 - \frac{Q_C}{Q_H}$$

REAL REFRIGERATORS



$$COP = \frac{Q_C}{Q_H - Q_C} = \frac{H_1 - H_4}{H_2 - H_3 - H_1 + H_4}$$

THROTTLE? BUT - THOMPROCESS



$$U_f - U_i = W_{LEFT} + W_{RIGHT} = P_i V_i - P_f V_f$$

$$U_f - U_i = P_i V_i - P_f V_f$$

i.e.

$$U_f + P_f V_f = U_i + P_i V_i \qquad H_f = H_i$$

ISO ENTHALPIC PROCESS

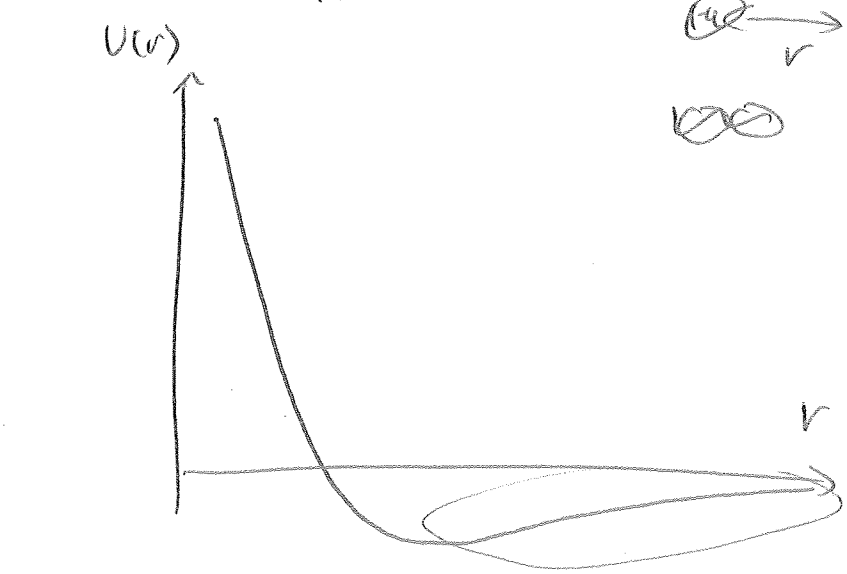
FOR IDEAL GAS

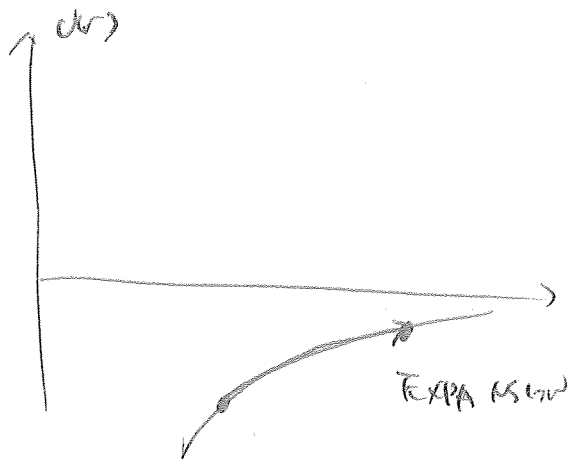
$$H = U + PV = \frac{f}{2} nRT + nRT = \frac{f+2}{2} nRT$$

T CONST ??? DOESN'T WORK

WORKS BECAUSE GAS NON-IDEAL

POTENTIAL ENERGY



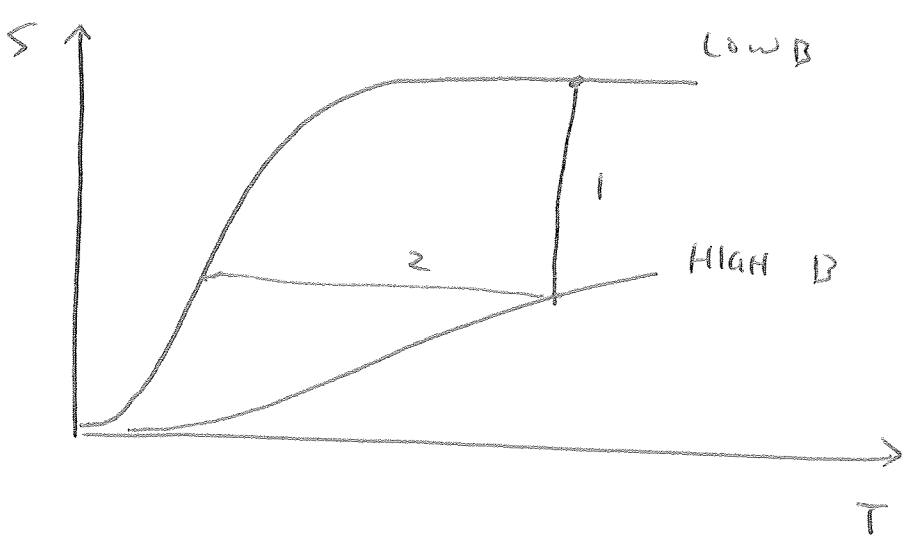


↑ P.E.

↓ K.E. ie. cools

HOW DO I GET LOWER IN TEMPERATURE?

- DILUTION REFRIGERATOR
- NUCLEAR DEMAGNETIZATION
- LASER COOLING



GO TO 2×10^{-10} K

^4He : 4.2K 1ATM

^3He : 0.3K 1ATM.

$H = U + PV$: ENTHALPY

$F = U - TS$: HELMHOLTZ FREE ENERGY

$G = U - TS + PV$ GIBBS FREE ENERGY

U : ENERGY

$dF = dU - TdS$ AT CONST T

$dF = Q + W - TdS$

IF $dS = 0$ THEN $Q = TdS$ SO

$\boxed{dF = W}$

IF $dS > 0$ THEN LET'S SAY $Q < TdS$ NOT QUASI STATIC

$dF < W$
