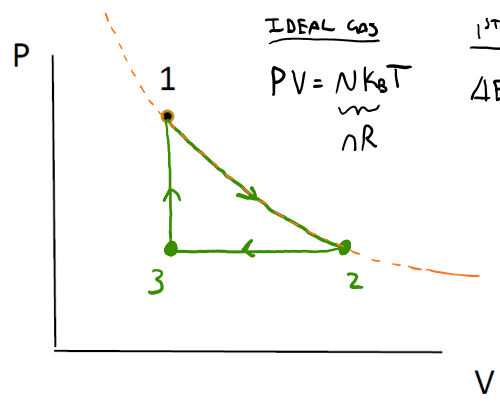


1



IDEAL GAS  
 $PV = Nk_B T$   
 $\underbrace{Nk_B T}_{nR}$

1<sup>st</sup> LAW  
 $\Delta E^{TH} = W + Q$

MONATOMIC GAS  
 $\Delta E^{TH} = \frac{3}{2} Nk_B \Delta T$   
 $\underbrace{Nk_B \Delta T}_{nR}$

WORK  
 $\pm \text{AREA}$   
 $\uparrow$   
 + FOR COMPRESSION  
 - FOR EXPANSION

	1 → 2	2 → 3	3 → 1	Complete cycle
$\Delta E^{TH}$	0 ISOTHERM $\Delta T = 0$	- $\Delta T (-)$	+ $\Delta T (+)$	0 $\Delta T = 0$
Q	+ 1 <sup>st</sup> LAW	- 1 <sup>st</sup> LAW	+ 1 <sup>st</sup> LAW	+ 1 <sup>st</sup> LAW
W	- EXPANSION	+ COMPRESSION	0 AREA = 0	- MORE (-) AREA

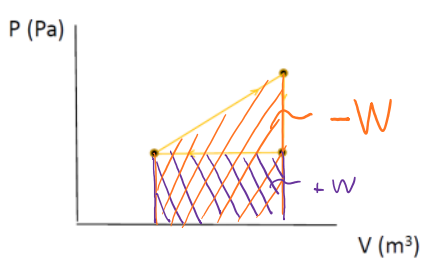
$\Delta E^{TH} = W + Q$   
 $0 = W + Q$

$V \propto T$   
 $V \downarrow T \downarrow$   
 $\Delta E^{TH} = W + Q$   
 $(-) = (+) + ?$

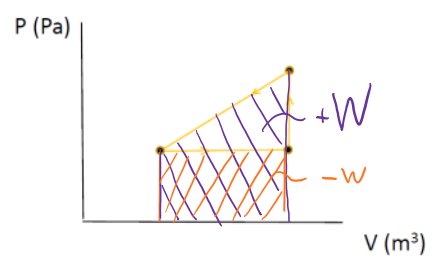
$P \propto T$   
 $P \uparrow T \uparrow$   
 $\Delta E^{TH} = W + Q$   
 $\Delta E^{TH} = Q$

$\Delta E^{TH} = W + Q$   
 $0 = W + Q$

2

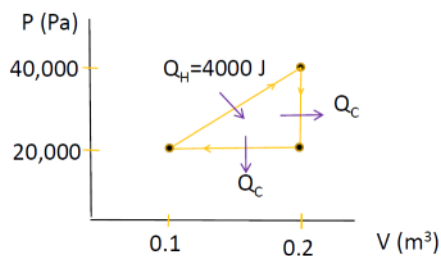


$\Sigma W = +W - W$   
 $\Sigma W (-)$   
 $\uparrow W_{out}$   
 SO ... ENGINE



$\Sigma W = +W - W$   
 $\Sigma W (+)$   
 $\uparrow W_{in}$   
 SO ... HEAT PUMP

3



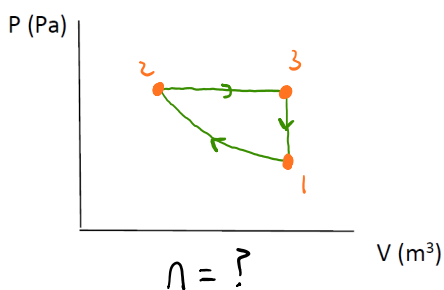
ENGINE

ALL work Both + & -  
 $\sum W$

$$e = \frac{Q_{ET}}{Q_{IN}} = \frac{|W_{OUT}|}{Q_{IN}} = \frac{\frac{1}{2} \cdot (0.2 - 0.1) \cdot (40000 - 20000) \text{ J}}{4000 \text{ J}} = 0.25$$

$\sum Q$  only + & -

4



$$PV = nRT$$

	1	2	3
P (kPa)	100	800	800
V (m³)	1.6	0.2	1.6
T (K)	$T_1$	$T_1$	$8T_1$

	1 → 2	2 → 3	3 → 1	Complete cycle
$\Delta E^{TH}$ (kJ)	0	+ 3549	-3549	0
Q (kJ)	-333	+ 4669	- 3549	787
W (kJ)	+ 333	- 1120	0	- 787

1 → 2

ISOTHERM

$$P \propto \frac{1}{V}$$

$$V \downarrow \uparrow$$

$$\Delta T = 0$$

so  $\Delta E^{TH} = 0$

$$W = -nRT_1 \ln\left(\frac{V_2}{V_1}\right)$$

$$= -P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$$

$$= 333 \text{ kJ}$$

$$\Delta E^{TH} = W + Q$$

$$0 = W + Q$$

2 → 3

ISOBAR

$$V \propto T$$

$$V \uparrow \uparrow$$

$$W = -P\Delta V$$

$$W = -1120 \text{ kJ}$$

$$\Delta E^{TH} = W + Q$$

$$Q = 4669 \text{ kJ}$$

3 → 1

ISOCORE

$$\text{AREA} = 0$$

so  $W = 0$

$$\Delta E^{TH} = \cancel{W} + Q$$

COMPLETE

$$\Delta T = 0$$

so  $\Delta E^{TH} = 0$

$$\Delta E^{TH}_{1 \rightarrow 2} + \Delta E^{TH}_{2 \rightarrow 3} + \Delta E^{TH}_{3 \rightarrow 1} = 0$$

$$\Delta E^{TH}_{2 \rightarrow 3} = -\Delta E^{TH}_{3 \rightarrow 1}$$

$$W_{1 \rightarrow 2} + W_{2 \rightarrow 3} + W_{3 \rightarrow 1} = W_{\text{cycle}}$$

$$W_{\text{cycle}} = -787 \text{ kJ}$$

$$\Delta E^{TH} = W + Q$$

$$0 = W + Q$$