1) (a)

Soln Tutorial 4

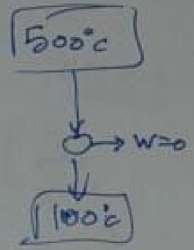
$Q_H = 1.944\ kWh = 1.944 \times 3600 \times 10^3\ J \approx \underline{\underline{7\ MJ}}$

$W_{out} = 7\ MJ$

this devices does not reject any heat to T_c

violates II law, so this device is not a possible device

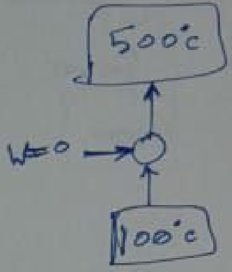
(b)



possible! all heat is wasted & no useful work! $\eta = 0$.!!

heat goes from hot to cold → increases S of universe!

(c)

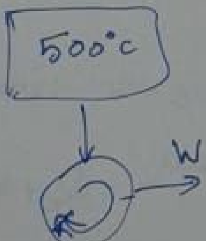


$COP = \frac{Q_H}{W} \to \infty$

not possible.

violates Claussius 2nd law.

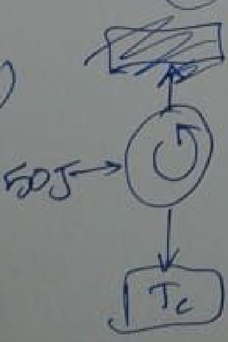
(d)



not possible

violates Kelvin-Planck statement of 2nd law.

(e)



this is a possible device taking work, converting to heat and giving to cold reservoir will increase entropy of surroundings (reservoir)

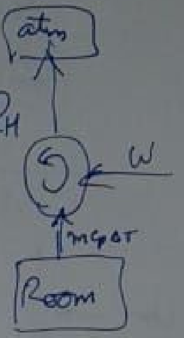
Tut 4 soln

f) 1A 200V ⇒ 200W energy for 20 sec = 4000J

$\Delta E = mc\Delta T = 1\,\text{kg} \times 4.186\,\text{J/kg/K} \times 20 = \underline{83.72\ \text{J}}$

It is possible. rest of electrical energy is used up to increase T of surroundings, entropy increases

g) 500kW for 10 min = $500 \times 10^3 \times 600 = \underline{300\text{MJ}}$



$m_{air} = 27\,m^3 \times 1.22\,\text{kg/m}^3 = 32.94\ \text{kg}$

$c_p = 1010\ \text{J/kg/K}$

$\Delta T = 10^\circ C$

$Q_C = m c_p \Delta T = \underline{3.33 \times 10^5\ \text{J}} = 332.7\ \text{kJ}$

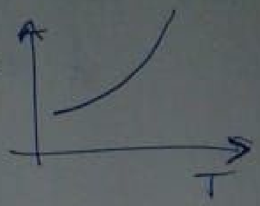
$Q_H = 332.7\ \text{kJ}$

$Q_C = Q_H$! not possible! violation of Classius statement!

there is also violation of First law! $Q_C + W \neq Q_H$

Tut 4 soln

2) (a) V & T for $\Delta S = 0$



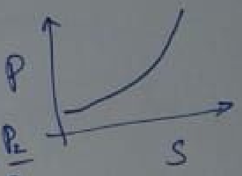
$$\Delta S = C_V \ln \frac{T_2}{T_1} + R \ln \frac{V_2}{V_1} = 0$$

$$\left(\frac{T_2}{T_1}\right)^{C_V/R} = \frac{V_2}{V_1} = \cancel{\left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}}} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}}$$

(b) P & S for $\Delta V = 0$

$$V_2 = V_1 \Rightarrow \frac{P_2}{T_2} = \frac{P_1}{T_1} \Rightarrow \frac{P_2}{P_1} = \frac{T_2}{T_1}$$

$$\Delta S = C_V \ln \frac{T_2}{T_1} + R \ln \cancel{\frac{V_2}{V_1}}^{\,0}$$

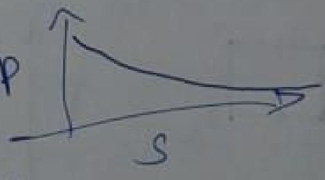


$$\therefore S_2 = S_1 + C_V \ln \frac{T_2}{T_1} = S_1 + C_V \ln \frac{P_2}{P_1}$$

$$\frac{P_2}{P_1} = \exp\left(\frac{\Delta S}{C_V}\right)$$

(c) P & S for $\Delta T = 0$ $\quad \Delta S = C_p \ln \cancel{\frac{T_2}{T_1}}^{\,0} - R \ln \frac{P_2}{P_1}$

$$\therefore \exp\left(-\frac{\Delta S}{R}\right) = \frac{P_2}{P_1}$$



(d) H & S ; $\Delta P = 0$ $\quad \Delta S = C_p \ln \frac{T_2}{T_1} - R \ln \cancel{\frac{P_2}{P_1}}^{\,0}$

$$\frac{T_2}{T_1} = \exp\left(\frac{\Delta S}{C_p}\right) = \frac{H_2 - \Delta H_f}{H_1 - \Delta H_f}$$

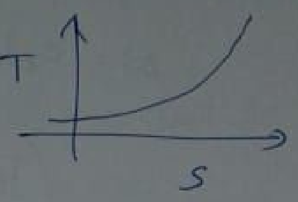
2 (e)

Tut 4 – soln

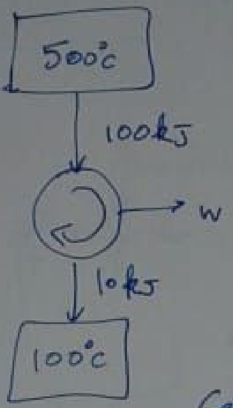
$T \propto S$; $\Delta V = 0$

$\therefore \; \Delta S = c_v \ln \frac{T_2}{T_1} + R \ln \frac{V_2}{V_1}^{\nearrow 0}$

$$\frac{T_2}{T_1} = \exp\left(\frac{\Delta S}{c_v}\right)$$



3)



$W = 100\text{kJ} - 10\text{kJ} = 90\text{kJ}$

$\eta = \frac{W}{Q_H} = \frac{90}{100} = 90\%$

Carnot eff. $= 1 - \frac{T_C}{T_H} = 1 - \frac{373}{773} = 1 - 0.483$

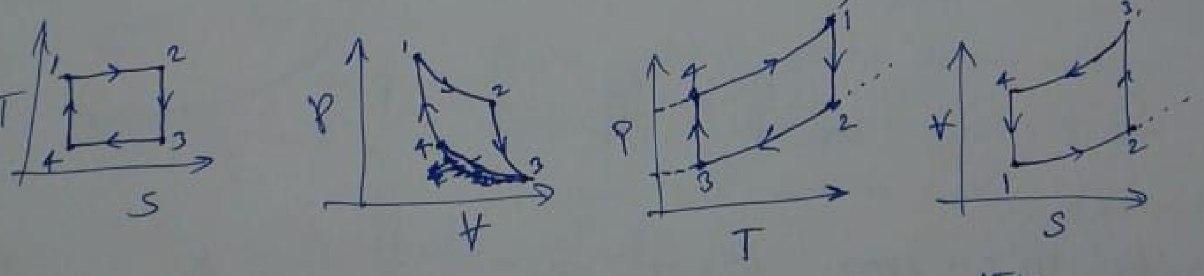
$= 0.517$

$= 51.7\%$

$\therefore$ this engine has $\eta > \eta_{carnot}$, so not a possible engine!

4)

CARNOT cycle : rev. isothermal heating, isentropic exp., rev. isothermal cooling, isentropic compression.



$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^{\gamma/\gamma-1}$ for $\Delta S = 0$

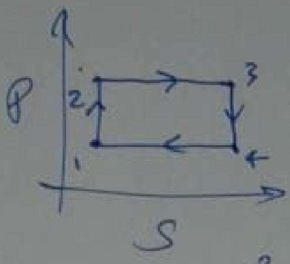
$P_2 < P_1$ for isothermal heat.

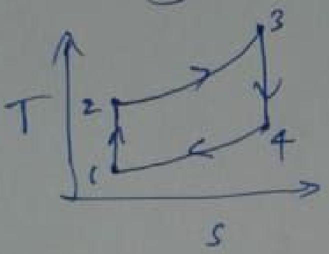
$\Delta T = 0$

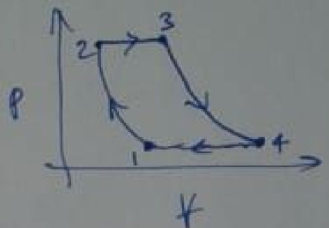
$\exp\left(\frac{\Delta S}{R}\right) = \frac{V_2}{V_1}$ & $V_3 > V_2$

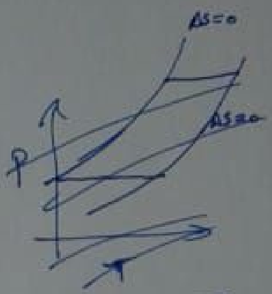
5) Tut 4 – Soln.

Brayton cycle: isentropic compression, constant P heating, isentropic expansion, constant P cooling.







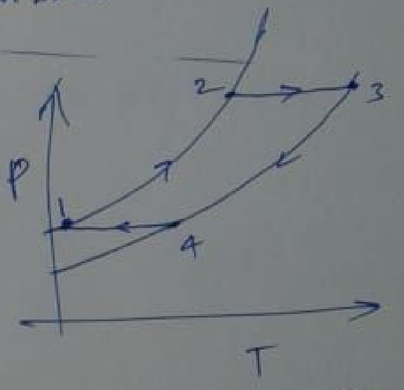


$\Delta P = 0 \Rightarrow \exp\left(\frac{\Delta S}{c_P}\right) = \frac{T_2}{T_1}$

$P V^{\gamma} = \text{const}$ for $\Delta S = 0$

$\Delta S = 0 \Rightarrow \frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^{\gamma/\gamma-1}$

$\Delta S = 0 \Rightarrow \frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^{\gamma/\gamma-1}$



for $\Delta P = 0$, $\Delta S = c_p \ln \frac{T_2}{T_1} - R \ln \cancel{\left(\frac{P_2}{P_1}\right)}^{0}$

$P = \text{const} \Rightarrow \frac{T_2}{T_1} = \frac{V_2}{V_1}$

$\therefore \frac{V_2}{V_1} = \exp\left(\frac{\Delta S}{c_P}\right)$