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TUTORIAL - HEAT ENGINE

1 Cyclic Heat engine

T_1 (source) = $800°C$ = $1073 K$

T_2 (sink) = $30°C$ = $303 K$

$\eta = \frac{W}{Q_1}$; $\eta = 1 - \frac{T_2}{T_1} = \frac{1073 - 303}{1073} = 0.717$

$\therefore \frac{W}{Q_1} = \eta = 0.717$

$W = 1KW$

$Q_1 = 1.39KW$

Q_1 is the amount of heat absorbed from the source.

$W = Q_1 + Q_2$

Q_2 (heat rejected) = $1.39 KW - 1 KW = 0.39W$.

least rate of heat rejection per kw is $0.39W$.

2 $T_1 = 90^\circ C = 363 K$

$T_2 = 20^\circ C = 293 K$

1880 kJ/m^2h of energy can be collected when plate is operating at 363 K

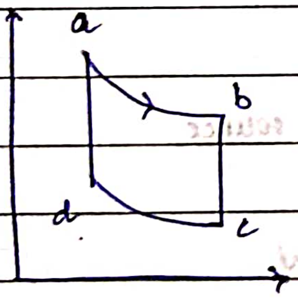
$$\eta_{max} = \frac{W}{Q_{min}} = 1 - \frac{T_2}{T_1} = 1 - \frac{363}{293} = \frac{293-363}{293} = \frac{-70}{293} = 0.238$$

$$= Q_{min} = \frac{1}{0.192} \; kJ/s$$

$$Q_{min} = 5.208 \; kJ/s = \frac{5.208 \times 10^3}{60 \times 60} \; J/h = 18750 \; kJ/h$$

minimum area required $\Rightarrow \frac{18750}{1880} = 9.97 \, m^2$

3



$T_1 = 800 K$

$T_2 = 400 K$

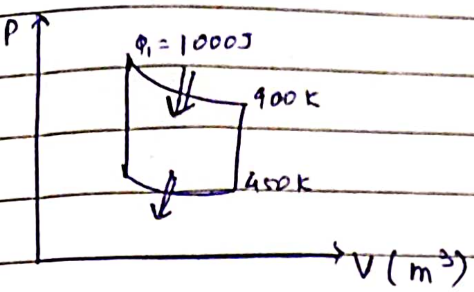
$Q_1 = 10{,}000 J$

W is ?

$$\eta = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1} = 1 - \frac{400}{800} = \frac{400}{800} = \frac{1}{2}$$

$$W = \frac{1}{2} \times 10000 = 5000 J = \text{Work done}$$

4



$Q_1 = 600J$

$T_1 = 600K$

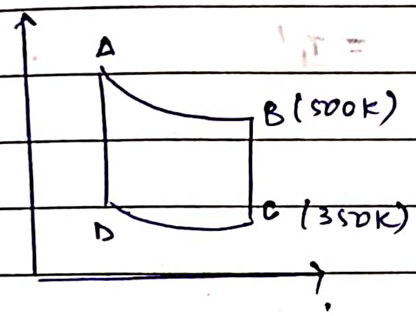
$T_2 = 400K$

$W = ?$

$$\eta = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1} = 1 - \frac{400}{600} = \frac{1}{3}$$

$$W = \frac{1}{3} \times 600 = 200J$$

5 .



$T_1 = 500K$

$T_2 = 350K$

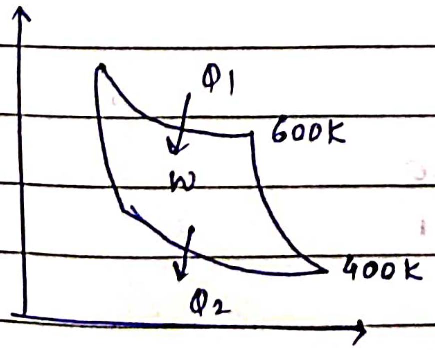
$e = ?$

$$\eta = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1} = 1 - \frac{\cancel{350}^{7}}{\cancel{500}_{10}}$$

$$= 1 - \frac{7}{10} = \frac{3}{10} = 0.3$$

$$\text{efficiency} = \frac{3}{10} \times 100 = 30\%$$

6



$T_1 = 600K$

$T_2 = 400K$

$$\eta = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1} = 1 - \frac{400}{600} = \frac{200}{600} = \frac{1}{3}$$

$Q_1 = 3W\ J$.

Heat output $= Q_2 = Q_1 - W$

$= 3W - W$

$= 2W\ J$

7 $T_1 = 800K$; $\eta = 50\%$

$T_1' = ?$; $\eta = 80\%$

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

$$0.5 = 1 - \frac{T_2}{800} \quad ; \quad T_2 = 0.5 \times 800$$

$$T_2 = 400K.$$

$$\Rightarrow \quad 0.80 = 1 - \left(\frac{T_1'}{400}\right)^{-1} = 1 - \frac{400}{T_1'}$$

$$T_1' = (0.20)^{-1} \times 400$$

$$= \frac{\cancel{400}^{200}}{\cancel{200}} \times 100 = 2000\ K = T_1'$$

8 $T_1 = 600K$

$\eta = 40\%$

$T_2 \rightarrow$ constant

$$0.4 = 1 - \frac{T_2}{600}$$

$$\frac{T_2}{600} = 0.6$$

$$T_2 = 360.0\ K$$

$T_1' = ?$, $\eta = 75\%$ $\Rightarrow$ $0.75 = 1 - \frac{360}{T_1}$

$$\Rightarrow \frac{360}{T_1'} = \frac{25}{100}$$

$$T_1' = \frac{360}{0.25} = 1440K$$

— x —— x —— x —— x ——