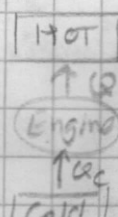
Refrigeration / Heat Pump: Opposite of engine!

COP = coeff of performance



$\Delta S = \frac{Q_H}{T_H} - \frac{Q_C}{T_C} \geq 0$ $\quad Q_H = W + Q_C$

Heat Pump: $COP \overset{def}{=} \frac{Q_H}{W_{on}} \leq \frac{1}{1 - \frac{T_C}{T_H}}$

Refrigerator: $COP = \frac{Q_C}{W_{on}} \leq \frac{1}{\frac{T_H}{T_C} - 1}$

Homework 7: Thermo Cycles

10/31/23

1) $n = 2.5$ mol $\quad V = 0.5\ m^3$
$T = 310$ K

1. $pV = NkT = nRT \qquad p = \frac{nRT}{V} \approx$ 12887 Pa

2. $P = 15464.04$
$V = \frac{NkT}{P} = \frac{nRT}{P} \approx$ 0.4167 m^3

3. $W_{on} = ?$
$W_{on} = -\int p\,dV = -\int \frac{nRT}{V}\,dV = -nRT \ln(V)\Big|_{0.5}^{0.4167} \approx$ 1174 J

2)

$T_H = 57°C$
$T_C = -23°C$
$t = 22$ min, engine absorbs 490 J from hot reservoir

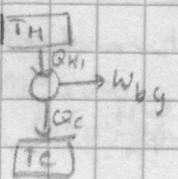
1. $\frac{dQ}{dt} = \frac{490}{1320} \approx 0.3712$ W

$\eta = 1 - \frac{T_C}{T_H} = 1 - \frac{Q_C}{Q_H} \qquad Q_C = \frac{T_C Q_H}{T_H} = \frac{(57+273.15)(490)}{(273.15-23)} \approx$ 371.25

2. $W = Q_H - Q_C \approx$ 118.75 J.

3. $\varepsilon = \frac{W}{Q_H} \leq 1 - \frac{T_C}{T_H} \qquad \varepsilon_{max} \approx 0.242$

3)



$T_H = 400°C$
$T_C = 30°C$
$\varepsilon = \eta = 0.25$ (including leak) : $\frac{Q_{H1}}{Q_{H1}} = ?$

$\varepsilon \leq 1 - \frac{T_C}{T_H} = 1 - \frac{Q_C}{Q_H}$

$\varepsilon_C = \frac{W}{Q_{H1}} \approx 0.55$

$\eta = \frac{W}{Q_H} = \frac{W}{Q_{H1} + Q_{H2}} = \frac{W/Q_{H1}}{1 + Q_{H2}/Q_{H1}}$

$0.25 = \frac{0.55}{1 + Q_{H2}/Q_{H1}}$

$1 + \frac{Q_{H2}}{Q_{H1}} = \frac{0.55}{0.25}$

$\frac{Q_{H2}}{Q_{H1}} \approx 1.1986$

$\frac{Q_{H1}}{Q_{H2}} \approx 0.8343$

4) 2nd reverse (fridge)

1. $W_{by} = -10^3$ J $\quad Q_C = ?$ $\quad P = 0.3712$ W $\quad \varepsilon = \frac{W_{by}}{Q_H} = 1 - \frac{T_C}{T_H}$ $\quad \frac{-10^3}{Q_H} = 1 - \frac{250.15}{330.15}$ $\quad Q_H = 4126.87$ J
$Q_C = Q_H - W_{on} \approx$ 3127 J

2. $Q_H \approx 4127$ J

3. $k = \frac{Q_{removed}}{W_{used}} = \frac{3127}{1000} \approx$ 3.127