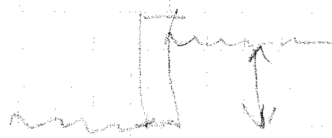
Termodynamik FYP014 FMN 400 2004-08-28

Förslag till lösningar:

1)



$h = 100$ m

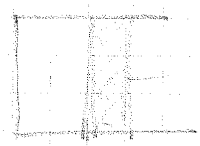
Potentiell energi $= mgh$

$\therefore \; mgh = m C_p \cdot \Delta T$

$$\Delta T = \frac{mgh}{m C_p} = \frac{g \cdot h}{C_p} = \frac{9{,}8 \cdot 100}{4{,}19 \cdot 10^3} = 0{,}23 \text{ K}$$

Svar: 0,2 K

2)



Adiabatisk kompression

$m = 4{,}5$ kg $\quad W = ?$

$p_1 = 1{,}0 \cdot 10^5$ Pa $\quad p_2 = 4{,}0 \cdot 10^5$ Pa

$T_1 = 19°C = 292 K \quad T_2 = ?$

Ideal gas: $pV = nRT$ $\quad \gamma = 1{,}40$

Adiabat: $Q = 0$ $\quad pV^\gamma = \text{konst} \Rightarrow p_1 V_1^\gamma = p_2 V_2^\gamma$

$$\begin{aligned} p_1 V_1 &= nRT_1 \\ p_2 V_2 &= nRT_2 \end{aligned} \Rightarrow p_1 \left(\frac{nRT_1}{p_1}\right)^\gamma = p_2 \left(\frac{nRT_2}{p_2}\right)^\gamma$$

$$\Rightarrow T_1^\gamma / p_1^{\gamma-1} = T_2^\gamma / p_2^{\gamma-1}$$

$$\Rightarrow T_2^\gamma = T_1^\gamma p_2^{\gamma-1} / p_1^{\gamma-1}$$

$$\Rightarrow T_2 = T_1 \left(\frac{p_2}{p_1}\right)^{(\gamma-1)/\gamma} = 434 \text{ K} = 161°C$$

Svar: 161°C

(3) 5,0 g H_2O vid 0,0°C värms till 100°C och förångas, $\Delta S = ?$

Värm 0° → 100°C:

$$\Delta S = \int \frac{\delta Q}{T} = \int_{T_1}^{T_2} \frac{m c_p dT}{T} = m c_p \int_{T_1}^{T_2} \frac{dT}{T} =$$

$$= m c_p \ln(T_2/T_1) = 5 \cdot 10^{-3} \cdot 4{,}19 \cdot 10^{3} \ln\left(\frac{100+273}{273}\right)$$

$$= 6{,}5 \text{ J/K}$$

Förångning: $m \cdot 2{,}26 \cdot 10^{6} = 1{,}13 \cdot 10^{4}$ J (ångbildningsvärme)

$$\Delta S = \frac{Q}{T} = \frac{1{,}13 \cdot 10^{4}}{100+273} = 30{,}3 \text{ J/K}$$

totalt: 36,8 J/K

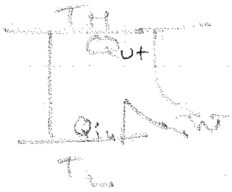
Svar 36,8 J/K

(4) Ideal värmepump → Carnot värmepump

$T_L = 8°C = 281$ K

$T_H = 20°C = 293$ K

$W = 1{,}0$ Ws $Q_{ut} = ?$



Kylmaskin: $K_K = \frac{Q_{in}}{W} = \frac{T_L}{T_H - T_L}$

men för värmepump $K_V = \frac{Q_{ut}}{W}$

men: $Q_{in} + W = Q_{ut}$

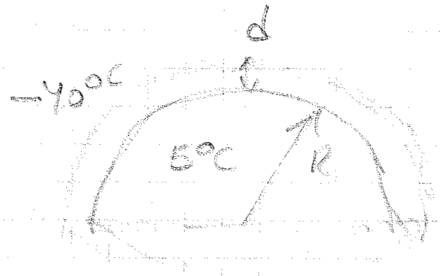
$$\Rightarrow K_V = \frac{Q_{in} + W}{W} = \frac{Q_{in}}{W} + 1 = \frac{T_L}{T_H - T_L} + 1 =$$

$$= \frac{T_L + T_H - T_L}{T_H - T_L} = \frac{T_H}{T_H - T_L} = 24{,}4$$

$\therefore Q = 24$ J

Svar 24 J

(5)



$R = 2{,}5$ m

$d = 0{,}30$ m

$k = 1{,}67$ W/mK

$R_{med} = 2{,}65$ (halvt inuti väggen)

Värmeledningsekv:

$$\frac{dQ}{dt} = kA\frac{\Delta T}{\Delta x} = k \cdot 2\pi R_{med}^2 \frac{T_2 - T_1}{d} =$$

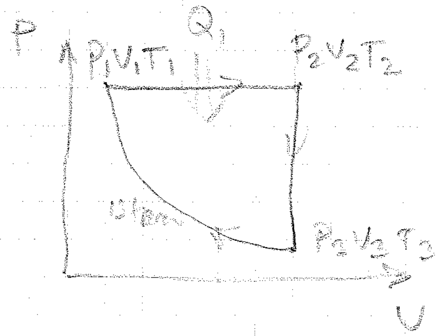
$$= 1{,}67 \cdot 2\pi \cdot (2{,}65)^2 \cdot \frac{45}{0{,}3} =$$

$$= 1{,}1 \cdot 10^4 \text{ J/s} = 11 \text{ kW} \quad (!)$$

Svar: 11 kW

Där vi bortsett från isolerande luftlager på isytorna som ger isolerande effekt i verkligheten

(6)



$P_1 = P_2 = \quad V_2 = V_3$

$T_1 = T_3 = 100°C = 373K$

$T_2 = 275°C = 548K$

$\eta = ?$

$\eta = \frac{W}{Q_{in}}$

Arbete:

Isobaren: $W_1 = \int p\,dV = p_1(V_2 - V_1)$

Isokoren: $W_2 = 0$

Isotermen: $W_3 = \int p\,dV = \int_{V_2}^{V_1} \frac{nRT}{V}\,dV = nRT \ln(V_3/V_1)$

↑ $pV = nRT$

$W_{tot} = p_1(V_2 - V_1) - nRT_1 \ln(V_3/V_1)$

$= p_1\left(\frac{nRT_2}{p_2} - \frac{nRT_1}{p_1}\right) - nRT_1 \ln(T_2/T_1)$

(lika) ↑ $p_2V_2 = nRT_2$ ↑ $p_1V_1 = nRT_1$ ↑ ty $\frac{V_3}{V_1} = \frac{V_2}{V_1} = \frac{nRT_2\, p_1}{p_2\, nRT_1} = \frac{T_2}{T_1}$

$\therefore W = nR(T_2 - T_1) - T_1 \ln(T_2/T_1)\,nR$

tillförd värme: $Q_1 = n \cdot c_p (T_2 - T_1)$

$\eta = \frac{W}{Q_1} = \frac{nR(T_2 - T_1 - T_1 \ln(T_2/T_1))}{n c_p (T_2 - T_1)}$

där $c_p = \frac{7}{2}R$ (ideal tvåatomig gas)

$\eta = \frac{T_2 - T_1 - T_1 \ln(T_2/T_1)}{\frac{7}{2}(T_2 - T_1)} = [\ldots] = 0{,}051$

Svar: $\eta = 5,1\%$