Thermo 2
Quiz 1 grading sheet (March 24, 2004)

<u>Short answer</u>

1. Regeneration is implemented by bleeding some fraction of the turbine steam to heat the water entering the boiler, using a feedwater heater. (1 pt) It raises the efficiency of the cycle by increasing the average temperature at which external heat is added (2 pt).
2. A diesel engine can be operated at a higher compression ratio because only air is compressed in the compression stroke and therefore there is no risk of autoignition, whereas the gasoline engine compresses a fuel-air mixture which can auto-ignite.
3. The main argument of Robert Manning is that agriculture is an unsustainable practice. Planted fields, unlike wild prairies, always require more energy than they receive from the sun. They must satisfy this energy deficit by mining the energy "bank" which accumulated in the earth over the past millennia. This was true *even before* modern industrial farming, but has been accelerated with its advent.

<u>Problem</u>

Part a) 20 points total

- **8** power = force x velocity
- **8** Fe = Fd + mgsin(theta)
- **4** Final answer is correct (55 kW)

Part b) 20 points total

- **6** efficiency = W/Q
- **4** W = wdot x time
- **2** time = D/V
- **4** Nengine = ½ Notto = ½ * $(1 - 1/r^{(k-1)})$
- **3** mf = Q/HV
- **1** Vf = mf/rho
- **0** final answer (

Part c) 25 points total

- **5** $W_{A/C} = W_{engine,A/C}$ = (mf)(HV)(Nengine)
- **4** $W_{A/C} = Q_L/COP_{A/C}$
- **3** QL = (1000W)*t_{trip}
- **2** $COP_{A/C}$ = (h1-h4)/(h2-h1)
- **2** (h2-h1) = 1/Nc * (h2s-h1)
- **1** h1 = hg(12C)
- **2** h4 = h3 = h(48C,1.4MPa) = hf(48C) since subcooled
- **1** h2s = h(1.4MPa, s1)
- **5** final answer

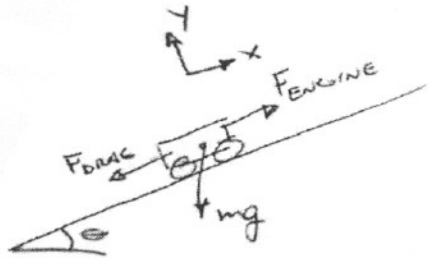
Part d) 15 points total

- **5** Qsun = Qremoved by AC ideally
- **2** Qsun = 1000W * t_{trip}
- **2** $Q_{A/C} = Q_L * t_{on}$

- **2** Q_L = mdot(h1-h4)
- **4** correct interpretation of answer based on calculated numbers (whether the numbers themselves are correct or not)

Part e) 9 points total

- **3** 2nd law with valve as CV
- **2** ds/dt = 0 since its steady state
- **2** Q/T = 0 since valve is adiabatic
- **2** s4 = s(h3,12 C)
- **0** final answer



a) $\dot{W}_E = \frac{d}{dt}(F_E \cdot D) = F_E \frac{dD}{dt} = F_E V$

where D = distance
V = velocity
F_E = force due to engine
$\dot{W}_E$ = power of engine

Find F_E: $\Sigma F_x = 0 = F_E - F_D - mg(\sin\theta)$

$F_E = F_D + mg(\sin\theta)$

$= 1980\ N$

$\dot{W}_E = 1980\ N \times 100 \frac{km}{h} \times \frac{h}{3600s} = \underline{\underline{55\ kw}}$

b) $\eta_E = \frac{1}{2}\eta_{otto} = \frac{1}{2}\left[1 - \frac{1}{r^{k-1}}\right] = \frac{W_{net}}{Q_{in}} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = 0.288$

$\dot{W}_{net} = 55\ kw$ from a)

$\dot{Q}_{in} = \frac{55}{0.288} = 191\ kw = \dot{m}_f HV$

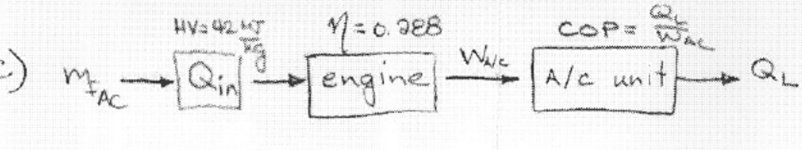
$\dot{m}_f = 4.55\ g/s$ $\quad m_f = \int \dot{m}_f dt = \dot{m}_f \Delta t$

where $\Delta t = \frac{D}{V} = 720s$

$m_f = 3.27\ kg$

$V_f = \frac{m_f}{\rho_f} = \underline{\underline{3.76\ l}}$

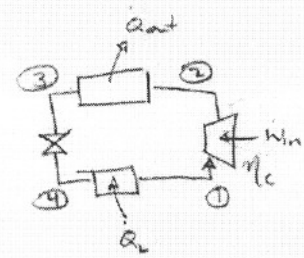
c)



$$W_{AC} = \frac{Q_L}{COP_{AC}} = Q_{in}\eta_E = m_f HV \eta_E$$

$$\Rightarrow m_f = \frac{Q_L}{COP_{AC}} \cdot \frac{1}{HV\eta_E} \quad \text{where } Q_L = \int \dot{Q}_{sun}\,dt = (1000W)\Delta t$$

find COP_{AC}:



$$COP_{AC} = \frac{\dot{Q}_L}{\dot{W}_{AC}} = \frac{\dot{m}(h_1 - h_4)}{\dot{m}(h_2 - h_1)}$$

$$= \frac{h_1 - h_4}{(h_{2s} - h_1)\frac{1}{\eta_c}}$$

$h_1 = h_g(12°C)$ (assume sat vapor enters compressor) $= 192.56\ \frac{kJ}{kg}$

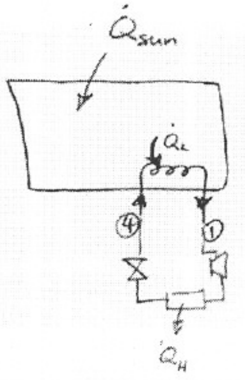
$h_4 = h_3 = h(48°C, 1.4MPa) \approx h_f(48°C)$ since subcooled $= 82.83$ kJ/kg

$h_{2s} = h(1.4MPa, \overset{0.6913}{S_1}) = 212.71$ kJ/KG

$\Rightarrow COP_{AC} = 4.36$

$\Rightarrow m_f = 0.0137$ kg $\quad V_{f_{AC}} = 0.0157\,l = \underline{15.7\ ml}$

d)



we need to remove $\dot{Q}_{sun}$ with the A/c to keep the temperature constant in the passenger compartment

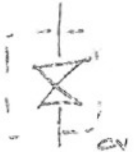
$$\int \dot{Q}_{sun}\,dt = E_{in} = \int \dot{Q}_L\,dt = \dot{Q}_L \sum_i t_{on}$$

$$\dot{Q}_{sun}\Delta t_{trip} = \dot{Q}_L \sum t_{on}$$

$$\frac{\sum t_{on}}{\Delta t_{trip}} = \frac{\dot{Q}_{sun}}{\dot{Q}_L} = \frac{\dot{Q}_{sun}}{\dot{m}(h_1 - h_4)} = \frac{(1000)}{(0.008)(192.56 - 82.83)}$$

$= 1.14 \rightarrow$ A/C needs to be on 114% of the time!!

A/C unit is not capable of removing all the incoming heat. need a bigger unit e)



2nd law: $\frac{dS_{cv}}{dt} = \sum \frac{\dot{Q}}{T} + \dot{m}_{in} s_{in} - \dot{m}_{out} s_{out} + \dot{S}_{gen}$

(SS; adiabatic)

$\Rightarrow \dot{S}_{gen} = \dot{m}(s_4 - s_3)$

$s_3 = s(h_3, 12°C)$

$= 0.3064$

$= (0.008)(0.3064 - 0.2973)$

$= 0.073 \ J/K$