Midterm 1 Solutions

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- 200 MW fuel plant (steam cycle)
- boiler @ 400°C ⟶ condenser @ 100°C

a) $\eta = 1 - \frac{T_C}{T_H}$ (convert to °K)

$\eta = 1 - \frac{373}{67} = 0.446$

* but this is only 60% efficient

$\eta_{actual} = 60\% \, \eta$

$\eta_{actual} = 0.268 = \frac{|W|}{Q_H}$

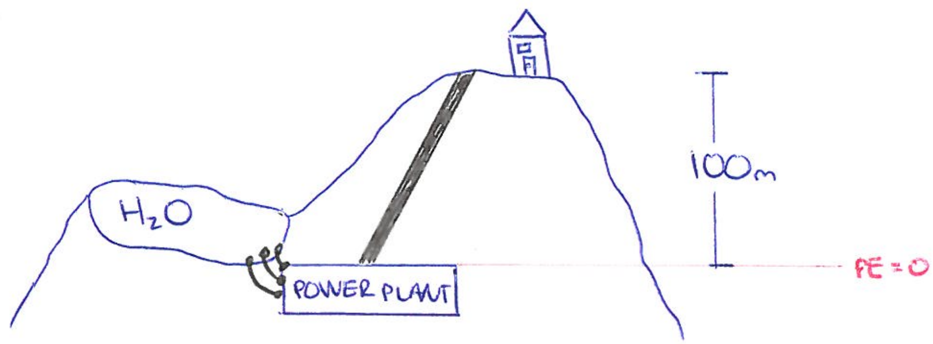
3 $\therefore \boxed{Q_H} = \frac{200 MW}{0.0268 \times 10^1} \boxed{= 746 MW}$

b) $Q_{OUT} = Q_{IN} - W$

$= 746 MW - 200$

1 $\boxed{Q_{OUT} = 546 MJ/s}$

$\boxed{2}$



① $\frac{\text{energy}}{s} = 500 \times 10^6\,W \times 70\% = 350\ MJ/s$

$PE_g = mg\Delta h$

① $\boxed{m} = \frac{PE_g}{g\Delta h} = \frac{350\ [MJ/s]}{9.81\ [m/s^2] \cdot 100\ [m]}$ $\boxed{= 3.6 \times 10^5\ kg/s}$

$\boxed{3}$ Entropy Question:

(a) Al $m = 10\ kg$ @ $60^\circ C$

lake   m = large! $\xrightarrow{\text{later}}$ Al lake

After some time, Al has given off heat Q to the lake

$Q_{Al} = mC_{Al}\Delta T = (10\ kg)(895\ J/kg/K)(-50\ K) = -4.5 \times 10^{-5}\ J$

$\Delta S_{lake} = \frac{Q_{lake}}{T_{lake}} = -\frac{Q_{Al}}{T_{lake}} = +\frac{4.5 \times 10^{-5}\ J}{283\ K} = \boxed{1.58 \times 10^{3}\ \frac{J}{K}}$

(b) Case (b): In this case, the Al receives heat from lake

$Q_{Al} = m\,C_{Al}\,\Delta T = (10\ kg)(895\ J/kg/K)(+5) = 44750\ J$

$\Delta S_{lake} = \frac{Q_{lake}}{T_{lake}} = -\frac{Q_{Al}}{T_{lake}} = -\frac{44750\ J}{283\ K} = 158\ \frac{J}{K}$ ②

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a) False. The rule is that, in a closed system the change in entropy of the system is zero. If there are two objects in a system, one can decrease in entropy; but the other object will increase such that $\Delta S_{total} \geq 0$

b) false. A heat pump uses warm air to heat objects (room) that are already hot. It takes work (W) to achieve this, but it is possible.

The correct statements says: No process is possible whose sole result is the removal of heat from one object and the transfer of an equal amount of heat to a hotter object.

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(a) $COP_{max} = \dfrac{T_H}{T_H - T_C} = \dfrac{293}{293 - 263} = 9.8$

$W_{min} = \dfrac{Q_H}{COP_{max}} = \dfrac{20\,kW}{9.8} = \underline{\underline{2.0\,kW}}$

(b) Actual $COP = 0.4\,COP_{max} = (0.4)(9.8) = \underline{\underline{3.9}}$

$\therefore\ W = \dfrac{Q_H}{COP} = \dfrac{20\,kW}{3.9} = \underline{\underline{5.1\,kW}}$

(c) Advantages: Ground based have smaller difference between T_H + T_C since the ground is warmer than the air in winter. This means higher COP

Disadvantage: Increase cost associated with burial of evaporator lines.

$\boxed{6}$ $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

molar mass	
C	= 12g/mol
H	= 1 g/mol
O	= 16 g/mol

$CH_4 = 12 g/mol + 4(1) g/mol$

$CH_4 = 16 g/mol$

$\text{mol } CH_4 = 1000g \cdot \frac{mol}{16g} = 62.5 \text{ mol}$

$CO_2 = 12 g/mol + 2 \cdot 16 g/mol$

$CO_2 = 44 g/mol$

$\text{Amount } CO_2 = \frac{62.5 \text{ mol}}{CH_4} \cdot \left[\frac{1 \text{mol } CH_4}{1 \text{mol } CO_2}\right] \cdot \frac{44 g}{1 \text{ mol } CO_2} = 2750 g$

2 $\boxed{= 2.75 \text{ kg}}$

b) $Q = mc\Delta T + mL_v$

$= (1)(2\times10^3)(-161 - 20 °C.) + (1)(-59\times10^3)$

2 $\boxed{Q = 4.21 \times 10^5 J}$ "removed"

c) ratio is 2:1, so it takes 8.42×10^5 J of electrical energy for the same job.

But only 40% efficient that means actual energy needed was $Q_{IN} = \frac{8.42\times10^5}{0.4} = 2.1 \times 10^6 J$

2

$\text{amount natural gas} = 2.1\times10^6 J \times \frac{1 kg}{55\times10^6 J} = \boxed{0.038 \text{ kg}}$

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- world natural oil resources 1.38×10^{12} bbl
- consumption rate is 3.2×10^{10} bbl/year

a) " constant rate "

$$\boxed{\text{time}} = \frac{1.38 \times 10^{12}\,[\text{bbl}]}{3.2 \times 10^{10}\,[\text{bbl}/\text{year}]} \boxed{= 43 \text{ years}}$$ 1

b) " exponential rate "

- know it takes 23 years to double

$$\boxed{N = N_0 e^{kt}}$$ exponental growth eqn.

$$N/N_0 = 2 \longrightarrow 2 = e^{kt} \longrightarrow \ln(2) = \ln(e^{kt})$$

$$\ln(2) = kt\ln(e) \longrightarrow K = \frac{\ln(2)}{t}$$

$$\boxed{K = \frac{\ln(2)}{23} = 0.030 \text{ years}^{-1}}$$ 1

* asks for lifetime

$$t = \frac{1}{K} \ln\left(\frac{K Q_T}{N_0} + 1\right)$$

$Q_T = 1.38 \times 10^{12}$ [bbl]
$N_0 = 3.2 \times 10^{10}$ [bbl/year]

$$= \frac{1}{0.030} \ln\left(\frac{0.03 \cdot 1.38 \times 10^{12}}{3.2 \times 10^{10}} + 1\right)$$

$$\boxed{t = 28 \text{ years}}$$ 1

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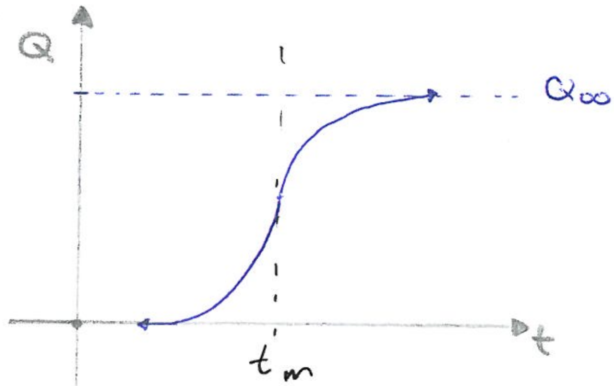
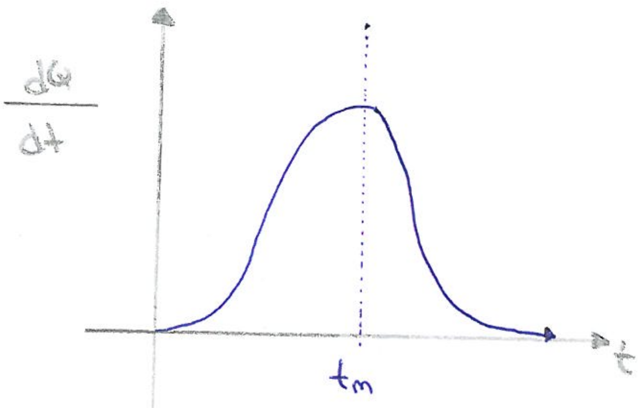
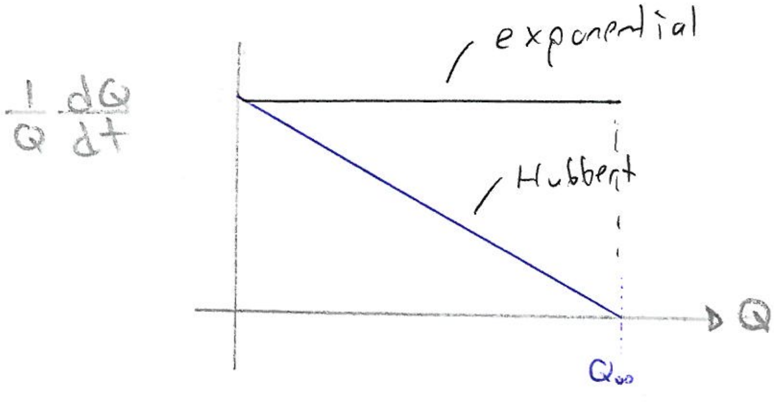
a)





b)



Note: x axis is $Q(t)$, not t

c) takes into account : rate of discovery, rate of production and the size of resources at any time. The resource (assuming fixed amount) is first utilized slowly, then more rapidly as technologies are developed to better use resources potential. The production rate eventually declines because there are less and less of the resource to produce.