E³E Homework #5

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① a) Power From the Ocean

Efficiency is $\frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$

22°C (295.15 K) @ Surface
4°C (277.15 K) @ Floor

For heat engines, the maximum possible efficiency is called the Carnot Efficiency and is given by

$$\text{Carnot Efficiency} = 1 - \frac{T_C}{T_H}$$

Using this, we can determine that the highest efficiency possible for our engine is

$$\text{Carnot Efficiency} = 1 - \frac{(277.15\,K)}{(295.15\,K)} \rightarrow \boxed{0.061}$$

① Power from the Ocean Cont.

b) We are producing 1×10^9 W of power. We can turn this into Heat (Q) with the equation $\eta Q = 10^9 \frac{J}{s}$, where η is the efficiency we just calculated.

$$\eta Q = 1\times10^9 \frac{J}{s} \rightarrow Q = \frac{(1\times10^9 \frac{J}{s})}{(0.061)} \rightarrow Q = 1.64\times10^{10} \frac{J}{s}$$

Since we have heat, we can plug in our Q into $Q = mC\Delta T$ along with our temperatures to get mass (m).

$$T_i = 295.15K \; ; \; T_f = 277.15K \; ; \; C_p = 4.2 \frac{J}{g\cdot K}$$

$$\Delta T = T_f - T_i = (277.15K) - (295.15K) = -18\ K$$

$$Q = mC\Delta T \rightarrow (1.64\times10^{10} \frac{J}{s}) = m(4.2 \frac{J}{g\cdot K})(-18K)$$

$$m = \frac{(1.64\times10^{10} \frac{\cancel{J}}{s})}{(4.2 \frac{\cancel{J}}{g\cdot \cancel{K}})(-18\cancel{K})} \rightarrow m = 2.16\times10^8 \frac{g}{s}$$

Now we are in the home stretch, because we can convert mass to volume mad easy.

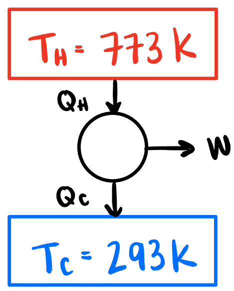
① Power From the Ocean Cont.

From like physics preschool we know $m = \rho V$ and, in turn, $V = m/\rho$. So, all we need to do is plug in our mass and density ($\rho_w = 1 \frac{g}{m^3}$).

$$V = \frac{m}{\rho} = \frac{m_w}{\rho_w} = \frac{(2.16 \times 10^8 \ \cancel{g}/s)}{(1 \ \cancel{g}/m^3)} \rightarrow \boxed{V = 216.9 \ \frac{m^3}{s}}$$

② Power Plant on a River

a)



Using the same formula as before, we can solve for efficiency by plugging in temperature.

$$\eta = 1 - \frac{T_C}{T_H} = 1 - \frac{(293K)}{(773K)} \rightarrow 0.621$$

$$\boxed{\text{Thus, our max efficiency is } 62.1\%}$$

b) We are given a new value for T_c which is 288K. Using this new value, we can re-find max efficiency using the equation from before.

$$\eta_{river} = 1 - \frac{T_c}{T_H} = 1 - \frac{(288K)}{(773K)} = 0.627 \rightarrow 62.7\%$$

Knowing this, we can then multiply our power term by it and the number of seconds in a year to find the rate in joules.

$$\eta\left(P\,\tfrac{J}{s}\right)t \rightarrow \left[(\eta_{river} - \eta)(3.154\times10^{7}\cancel{s})\left(10^{9}\tfrac{J}{\cancel{s}}\right)\right]$$

② Power Plant on a River Cont.

$$[(0.6274)-(0.6210)](3.154\times10^{16}\,J)$$

$$(0.0064)(3.154\times10^{16}\,J) \rightarrow 2.019\times10^{14}\,J$$

Now, we just use some unit conversion to get an answer in terms of \$.

$$1\,kWh = 3.6\times10^{6}\,J \;;\; \frac{10¢}{1\,kWh} \;;\; 1\$ = 100¢$$

$$(2.019\times10^{14}\,J)\left(\frac{1\,kwh}{3.6\times10^{6}\,J}\right)\left(\frac{10¢}{1\,kWh}\right)\left(\frac{1\$}{100¢}\right)$$

$$\boxed{\text{You would make } \$\,5{,}612{,}444.44}$$

c) using our diagram as reference, we can see that rate can be expressed as

$$W = Q_H - Q_c \rightarrow Q_c = Q_H - W$$

where Q_c is the heat dumped into the river

② Power Plant on a River Cont.

Assuming the same efficiency from part a, we can rearrange the equation $\eta_{max} Q_H = W$ and plug into our before expression to solve.

$$\eta_{max} Q_H = W \rightarrow Q_H = \frac{W}{\eta_{max}}$$

$$Q_C = Q_H - W \rightarrow Q_C = \left(\frac{W}{\eta_{max}}\right) - W \rightarrow Q_C = W\left(\frac{1}{\eta_{max}} - 1\right)$$

Numbers Time!

$$Q_C = \left(10^9 \tfrac{J}{s}\right)\left[\frac{1}{(0.621)} - 1\right] \rightarrow \boxed{Q_C = 6.10 \times 10^8 \tfrac{J}{s}}$$

d) We are given that the river's flow rate is $V_{river} = 100 \, m^3/s$. To find the change in temperature we can use $Q = mC\Delta T$.

$$Q = mC\Delta T \rightarrow \Delta T = \frac{Q}{(\rho V)\, C} \quad \text{where} \quad C = 4182 \frac{J}{(kg \cdot K)}$$

Using the values of Q_c from before along with book values for ρ and C, we can solve.

② Power Plant on a River Cont.

$$\Delta T = \frac{Q}{(\rho V)\,C} \rightarrow \Delta T = \frac{(Q_c)}{\left(1000\frac{kg}{m^3}\right)\left(100\frac{m^3}{s}\right)\left(4182\frac{J}{kg\cdot k}\right)} \rightarrow \Delta T = \frac{\left(6.10\times10^{8}\frac{J}{s}\right)}{\left(4.182\times10^{8}\frac{J}{s\cdot k}\right)}$$

The river's temperature will increase by $\boxed{\Delta T = 1.46\,K}$

e) The Latent Heat of vaporization for water is $L_f = 2260\ kJ/kg$ at 100°C. So, to evaporate 1g of water at 500°C we can use

$$Q = mC_s\Delta T + mL_f \rightarrow Q = (1g)\left(4.2\frac{J}{g\cdot k}\right)(100-500°c) + (1g)L_f$$

$$Q = -1680\,J + 2260\,J \rightarrow Q = 580\,J \text{ for 1 gram}$$

using Q_c, we can divide by L_f to get the rate

$$\frac{Q_c}{L_F} \rightarrow \frac{\left(6.10\times10^{8}\frac{J}{s}\right)}{\left(2.617\times10^{3}\frac{J}{g}\right)} \rightarrow 2.332\times10^{5}\ \frac{g}{s}$$

Now we change kg to m^3 with $\left(\frac{1m^3}{1000\,kg}\right)$

② Power Plant on a River Cont.

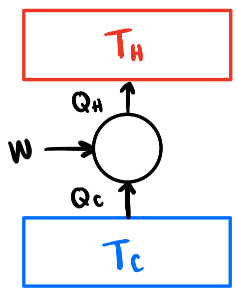
$$2.33\times10^{5}\ \frac{\cancel{kg}}{s}\left(\frac{1\,m^3}{1\times10^{6}\,\cancel{kg}}\right) \rightarrow \boxed{0.233\ \frac{m^3}{s}}$$ water evaporated

Since the river's flow rate is $100\,\frac{m^3}{s}$ we can divide our value by this to get a ratio.

$$\frac{0.233\ \cancel{\frac{m^3}{s}}}{100\ \cancel{\frac{m^3}{s}}} \rightarrow 2.33\times10^{-3} \rightarrow \boxed{0.233\%\text{ of river}}$$

③ Heat Pump

a)



Using our diagram as a guide, what we put in is Q_C and what we get out is Q_H.

$$\frac{(\text{out})}{(\text{in})} = \frac{Q_H}{W} = \boxed{\frac{Q_H}{Q_H - Q_C}}$$

b) From the second law, the maximum efficiency can be written as

$$\Delta S_H + \Delta S_C = 0 \quad \text{where} \quad \Delta S_C = \frac{Q_C}{T_C} \text{ and } \Delta S_H = \frac{Q_H}{T_H}$$

Since Q_H is leaving the system, Q_H will be negative.

$$\frac{Q_C}{T_C} - \frac{Q_H}{T_H} = 0 \rightarrow \frac{Q_C}{T_C} = \frac{Q_H}{T_H} \rightarrow Q_H = \frac{T_H Q_C}{T_C}$$

Using our efficiency γ, we can plug in

$$\gamma = \frac{Q_H}{Q_H - Q_C} \rightarrow \gamma = \left(\frac{T_H \cancel{Q_C}}{T_C}\right)\left(\frac{1}{\left(\frac{T_H \cancel{Q_C}}{T_C}\right) - \cancel{Q_C}}\right) \rightarrow \gamma = \frac{\left(\frac{T_H}{T_C}\right)}{\left(\frac{T_H}{T_C}\right) - 1}$$

③ Heat Pump Continued.

$$\gamma = \frac{\left(\frac{T_H}{T_c}\right)}{\frac{1}{T_c}\left(T_H - T_c\right)} \rightarrow \gamma = \frac{T_H(1)}{T_H - T_c} \rightarrow \boxed{\gamma = \frac{T_H}{T_H - T_c}}$$

If $T_c \ll T_H$ then,

$$\gamma = \frac{T_H}{T_H - (0)} \rightarrow \gamma = \frac{T_H}{T_H} \rightarrow \gamma = (1) \rightarrow \boxed{\gamma = 1}$$

c) If $T_H - T_c \ll T_c$, then $T_H \ll 2T_c$ and our efficiency becomes

$$\gamma = \frac{T_H}{T_H - T_c} \rightarrow \gamma = \frac{(0)}{(0) - T_c} \rightarrow \gamma = (0) \rightarrow \gamma = 0$$

This makes sense, because if $T_c \gg T_H$ we are putting work in to heat up the water but are getting no heat change in return. Therefore, the efficiency is $\emptyset$.

③ Heat Pump Cont.

d) $T_{in} = 70°F$ (294.3 K) $\rightarrow$ $T_{out} = 50°F$ (283.15)

$$\gamma = \frac{T_H}{T_H - T_C} \rightarrow \gamma = \frac{(294.3K)}{(294.3K)-(283.15K)} \rightarrow \boxed{\gamma = 26.39}$$

If we let $T_c = 30°F$ (272.04 K) we get

$$\gamma = \frac{T_H}{T_H - T_C} \rightarrow \gamma = \frac{(294.3K)}{(294.3K)-(272.04K)} \rightarrow \boxed{\gamma = 13.22}$$

④ Violating the Second Law

claim:

According to Kumar, the graphene and circuit share a symbiotic relationship. Though the thermal environment is performing work on the load resistor, the graphene and circuit are at the same temperature and heat does not flow between the two.

Violation:

They say that the graphine and the circuit are are the same temperature and heat does not flow between the the two. This means that the system is in themoequilibrium and ΔQ is 0. So far it's fine, but, from the Second Law of Thermo dynamics, we know that to get work out of the system There needs to be an internal energy ($\Delta U \neq 0$).

$$\Delta U = Q + W \rightarrow \Delta U = (\emptyset) + W \rightarrow \Delta U = W \neq 0$$

So there better be a changing internal energy for physics to be happy. However, they say that they are getting energy out of the system without the system changing $-\Delta U = 0-$ which is impossible from what was previously established. Hence, 1st Law is violated.

④ Violating the Second Law

I realized most the way through writing the above explanation that it only violated the first Law. I can't bring myself to erase it. Please use the write up below for assessment. Thanks.

Claim:

"Although the violation is only on the local scale, the implications are far-reaching," Vinokur said. "This provides us a platform for the practical realization of a quantum Maxwell's demon, which could make possible a local quantum perpetual motion machine."

Violation:

They are saying that the principles behind Maxwell's demon can be utilized on a local scale for cooling. This cannot happen for the same reason Maxwell's demon cannot exist — because any attempt to sort particles introduces energy to both systems. Any attempt to decrease entropy (sort particles) without using any energy violates the second law. Hence, the 2nd Law is violated.

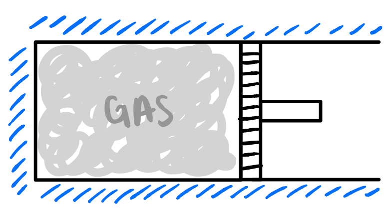
5) Name the Experiment.

The First Law of Thermodynamics gives us

$$du = Tds - PdV \rightarrow \left(\frac{\partial u}{\partial P}\right)_s = -P\left(\frac{\partial V}{\partial P}\right)_s$$

Since entropy is constant for an adiabatic process, our derivative can be found using one.

<u>My Experiment</u>



The system would consist of a gas sealed in an insulated piston chamber, such that no heat is exchanged. Then, we could vary the volume of the chamber using a piston and record the resulting change in pressure. Finally, upon graphing V vs P, we can determine $(\partial V/\partial P)_s$.