GEEN 3852 - Thermodynamics
Final Project: Candle-Powered Engine

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Background:

The objective of this project is to use a simple design with the application of thermodynamic cycles to transform the heat from a candle into mechanical work to lift 2 quarters a total of 10cm. The design of the system cannot contain other stored energy, such as a spring or a preloaded wheel.

Concept:

Our team determined that the most effective method would be using a simple piston-cylinder device. The candle would heat water to create steam, and the buildup of pressure would cause an increase of volume. This cycle would create boundary work.

Materials List:

2 22 cc syringes, 125ml beaker, rubber stopper, soda can, tin foil, 2 tea candles, room temperature tap water

Analysis:

Heat Output of the Candle:

The heat measurement of the candle was found experimentally.

Measurements:

Starting mass of candle	15g	Final mass of candle	12g	Change in mass	-3g
Start temp of water	20℃	Final temp of water	95℃	Change in temp	75℃
Mass of water	30g	Specific heat of water	4.18[J/g*C]	Time burning	10 min

Calculations:

- $\Delta Q = C_{P\_water} * \Delta T * m_{water}$
  - $\Delta Q = 30g * 4.18[J/g * C] * 75[K]$
  - $\Delta Q = 9.405 [kJ]$

- $1000 * \Delta Q/600 = Q_{dot}$
  - (9.405/600)=Q_{dot}
  - Q_{dot}=15.675 [kW]
- $Q_{dot}/\Delta m_{candle} = q_{dot\_candle}$
  - 15.675/0.003 = q_{dot_candle}
  - q_{dot_candle}= 5.225[kW/kg]
- $Q_{dot\_candle} = q_{dot\_candle} * m_{candle}$
  - $Q_{dot\_candle} = 5.225 [kW/kg] *.015$
  - $Q_{dot\_candle} = 0.0783 [kW]$

Energy Balance of System:

$$\Sigma Qin + \Sigma Qout + \Delta U = \Sigma Wout$$
$$\Delta U = 293.663\ [J/kg]$$

Theoretical Work of System:

- Mass of plunger & quarters: 0.018[kg] Weight: (9.8[m/s^2])*(0.18[kg])=.1764[N]
- Diameter of Syringe: 16cm Area = Πr^2=0.0201[m^2]
- Pressure in System = $(force)/(area)$ = $(.1764[N])/(.0201[m^2]) = 8.776\ kPa$
    - Pressure in the system stays constant because the weight of the plunger and quarters does not change and the atmospheric pressure surrounding the system stays constant. The internal energy of the system increases as heat is being added to the system. Ideally there is no heat lost, however due to lack of insulation there is a lot of heat loss.
- $W_{dot\_Ideal} = Q_{dot\_candle}$
    - $W_{dot\_Ideal} = 0.0783\ [kW]$
        - $W_{Ideal} = 0.0783\ [kW] * 600\ [s]$
        - $W_{Ideal} = 46.98\ [kJ]$

Actual Work of System:

The Boundary work can be calculated using initial volume, final volume, and pressure.

$Wout = P(V[2] - V[1])$

- V[1]=.00151[m^3] V[2]=.001711[m^3] P=83608.776[Pa] Wout_actual=130.4[J]
- $\eta = W_{out\_actual}/W_{out\_ideal}$
    - $\eta = (130.4/(46.98 * 1000) * 100$
    - $\eta = 0.28\%$

Non Ideal energy balance:

Assumptions

- Force of friction is zero
- KE, PE, ΔU are negligible
- Constant Pressure

$\Sigma Qin + \Sigma Qout = \Sigma Wout$

$\Sigma Qout = \Sigma Wout - \Sigma Qin$

$\Sigma Qout = (130.4/1000) - 46.98$

$\Sigma Qout = - 46.85\ [kJ]$

What we could have improved on:

- Factors that made this system not ideal include: friction in the plunger, heat loss in all stages of the system, human and instrument errors in the data collection

Property Plots: