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ASEN 3113: Thermodynamics and Heat Transfer
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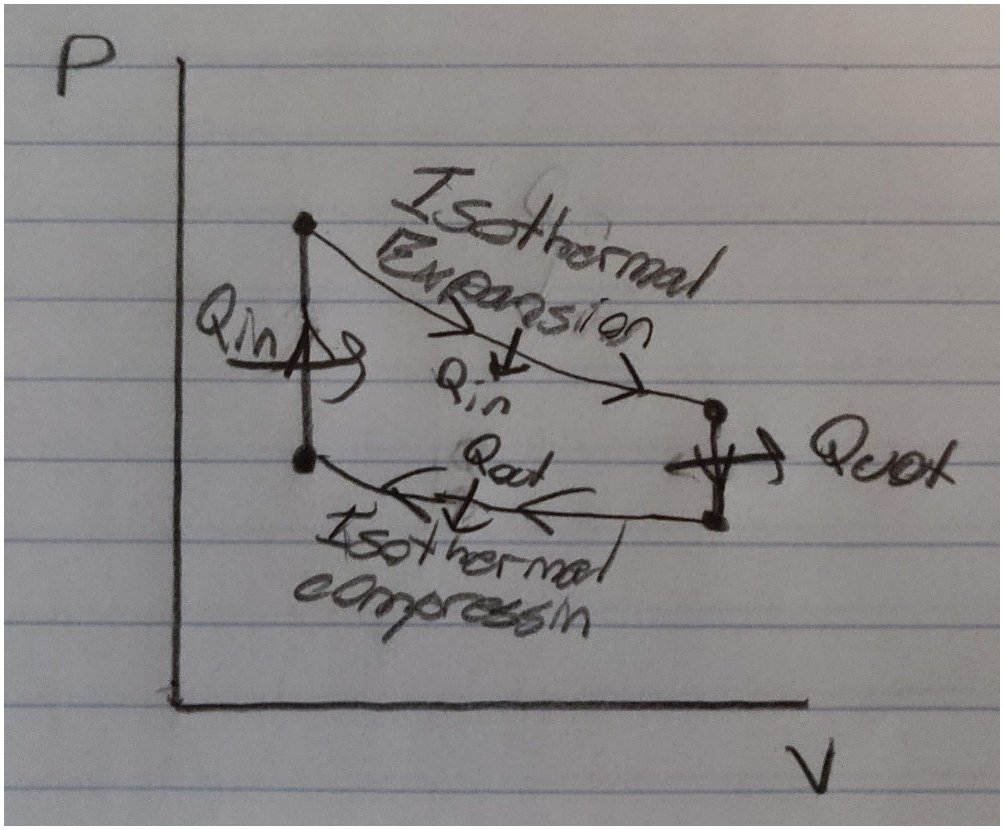
Lab 1 Pre-Lab

1. General Theory
    a. There are three types of Stirling engines all of which use pistons and a temperature difference to function. The first type is an alpha type. This type of Stirling engine uses two pistons, one hot piston, and one cold piston. One piston is placed in a high-temperature heat exchanger and the other is placed in a low-temperature heat exchanger. The second type of Stirling engine is the beta type. This type uses two pistons within the same chamber to move air between the hot and cold regions of the chamber. The final engine type is the gamma type. This engine is similar to the beta type as they both have pistons within the same chamber, but they differ on where the piston is placed. With the gamma type, the piston is offset from the displacer chamber and is generally smaller than the power piston.
    b. A gamma type Stirling engine works through a Carnot cycle, going through isothermal and adiabatic expansion and compression. To aid in creating this process a gamma type Stirling engine has two pistons, the displacement piston, and the power piston. The power piston is the piston that keeps the wheel spinning and is moved by the changing pressure within the displacement chamber. The displacement piston moves up and down within the displacement chamber moving the air within to the cold and hot plates. The power piston chamber sits on top of the displacement chamber, is smaller than the displacement chamber, and offset from the center of the circular displacement chamber. Centered on top of the displacement chamber is the flywheel that is connected to both pistons. The Carnot cycle starts with warm gas that has been heated through the bottom plate's heat source. This heated air pushes the power piston to the top of its chamber. While the power piston is moving up the displacer piston moves down and is moving the warm air to the cold plate. During this process, the heat source is transferring heat into the system to keep the temperature constant through this process. As the power piston moves up it creates a greater system volume and this increased volume decreases the pressure and as a result, a decline in temperature would normally be seen but the heat source provides the necessary heat transfer to keep the gas at the same temperature to counteract the temperature change due to the volume and pressure changes. Once the power piston hits the top of its chamber, the volume is held constant of a small amount of time as the power piston rod moves to the top of the flywheel's rotation and prepares to rotate

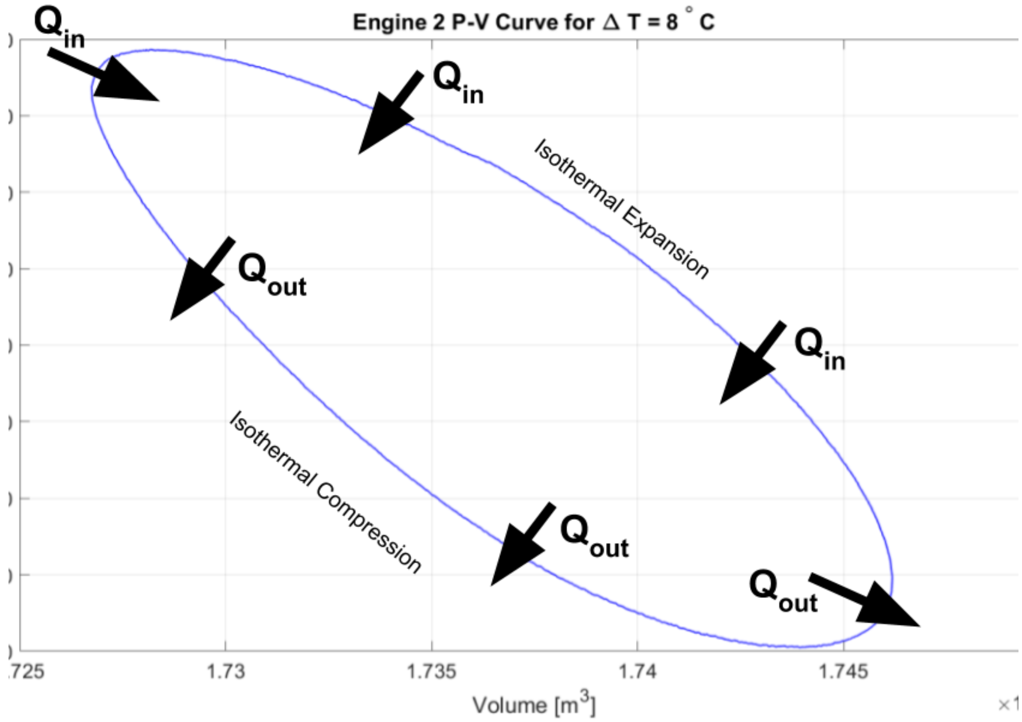
downwards. At this time, the displacement piston is half down its chamber and is continuing to move down. This creates a greater amount of air on the cooler plate side and thus the warm air is cooled by transferring heat to the cool plate. This causes the pressure to decrease, as the volume was constant, and the power piston moves down since it has lower pressure in the chamber than the outside atmosphere. Once the power piston begins to move down the isothermal compression begins as well. During this process, the volume in the chamber is decreasing because of the power piston falling. As a result, the pressure rises but the temperature remains constant since the cold plate is transferring heat out of the system at a rate that keeps the temperature constant. This allows this portion of the system to be called isothermal compression and this occurs until the power piston reaches the bottom of the chamber. At this point, the volume is constant again as the power piston rod is at the bottom of its cycle and is transitioning to go back to the top of the cycle. While this transition happens, the displacement piston is now halfway up the chamber and moves up past the halfway point. Now more of the air is at the warm heat source and as a result, the heat source transfers heat to the colder gas and this increases the temperature of the gas. This increased temperature increases the pressure in the chamber and drives the power piston to the top of the chamber and the cycle starts again. This cycle does resemble a Carnot cycle but unlike most Carnot cycles, this system does not have an adiabatic expansion or compression. This is because the volume, during those typical times, is constant, and as a result, heat must be removed or added to change the temperature of the gas within the engine. Without the heat transfer at these points, the power piston would not be displaced and the engine would not function.

   c. The internal volume of the Stirling engine moves between two values as time goes on. The internal volume increases as the power piston move up and is at a maximum when the power piston reaches the top of its chamber. The internal volume decreases as the power piston moves down and is at a minimum when the power piston is at the bottom of its chamber. Interestingly, the volume is constant at two points of this cycle for a brief period of time, as at those points the power piston rod is transitioning to a downward or upward path.

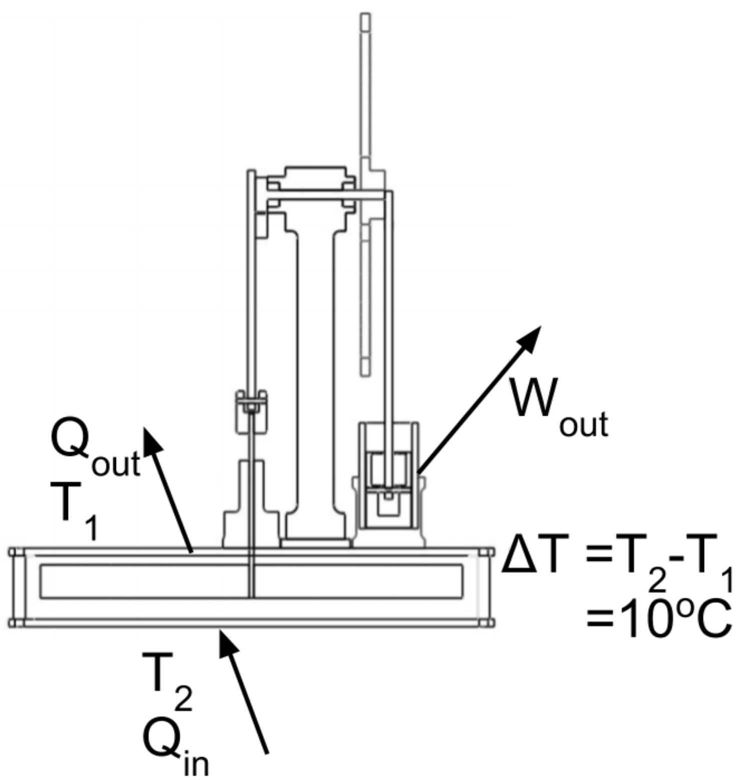
2. The Stirling Cycle
   a. Ideal Stirling cycle P-V diagram



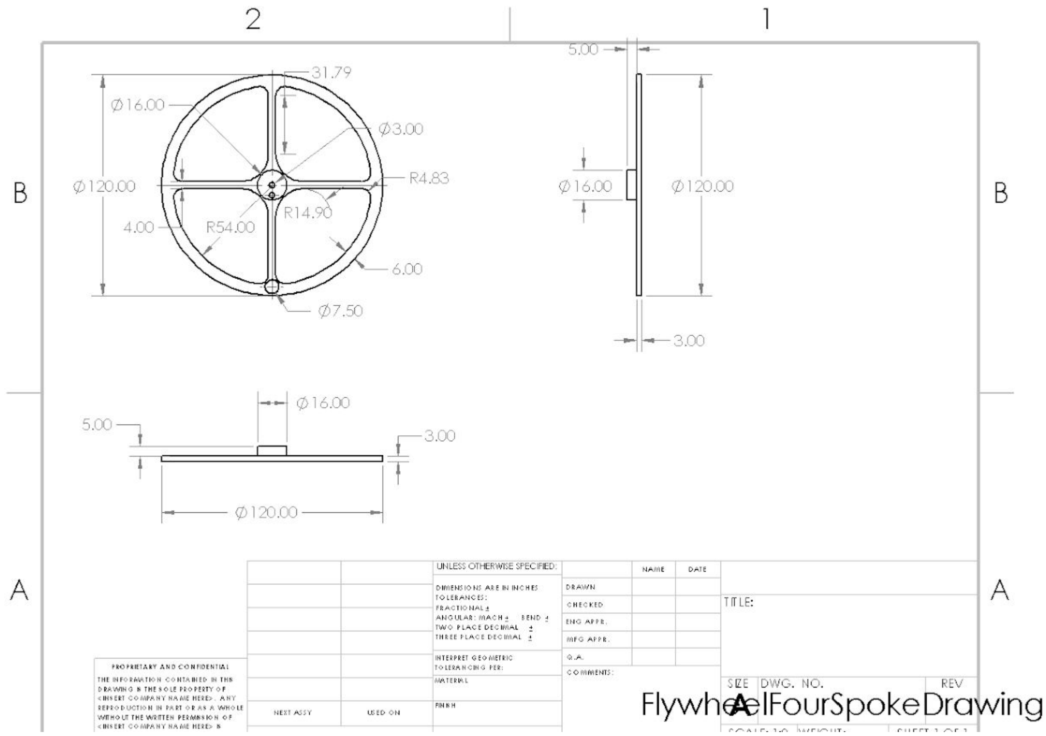
b. The ideal P-V diagram for the gamma type Stirling engine differs from the real data because the real P-V diagram does not have a part where volume is constant. Another difference is that the top line, isothermal expansion, is convex in the real diagram while the ideal diagram is concave. These differences can be attributed to assumptions made for the ideal P-V diagram. It is assumed that the efficiency of the heat pump is the highest attainable but in reality, it is not fully efficient. This drop in efficiency can be attributed to the thermal properties of the gas and the plates as they could potentially be poor at transferring heat.


Engine 2 P-V Curve for Δ T = 8 ° C
Q_in
Q_in
Q_in
Q_out
Q_out
Q_out
Isothermal Expansion
Isothermal Compression
.725
1.73
1.735
1.74
1.745
Volume [m^3]

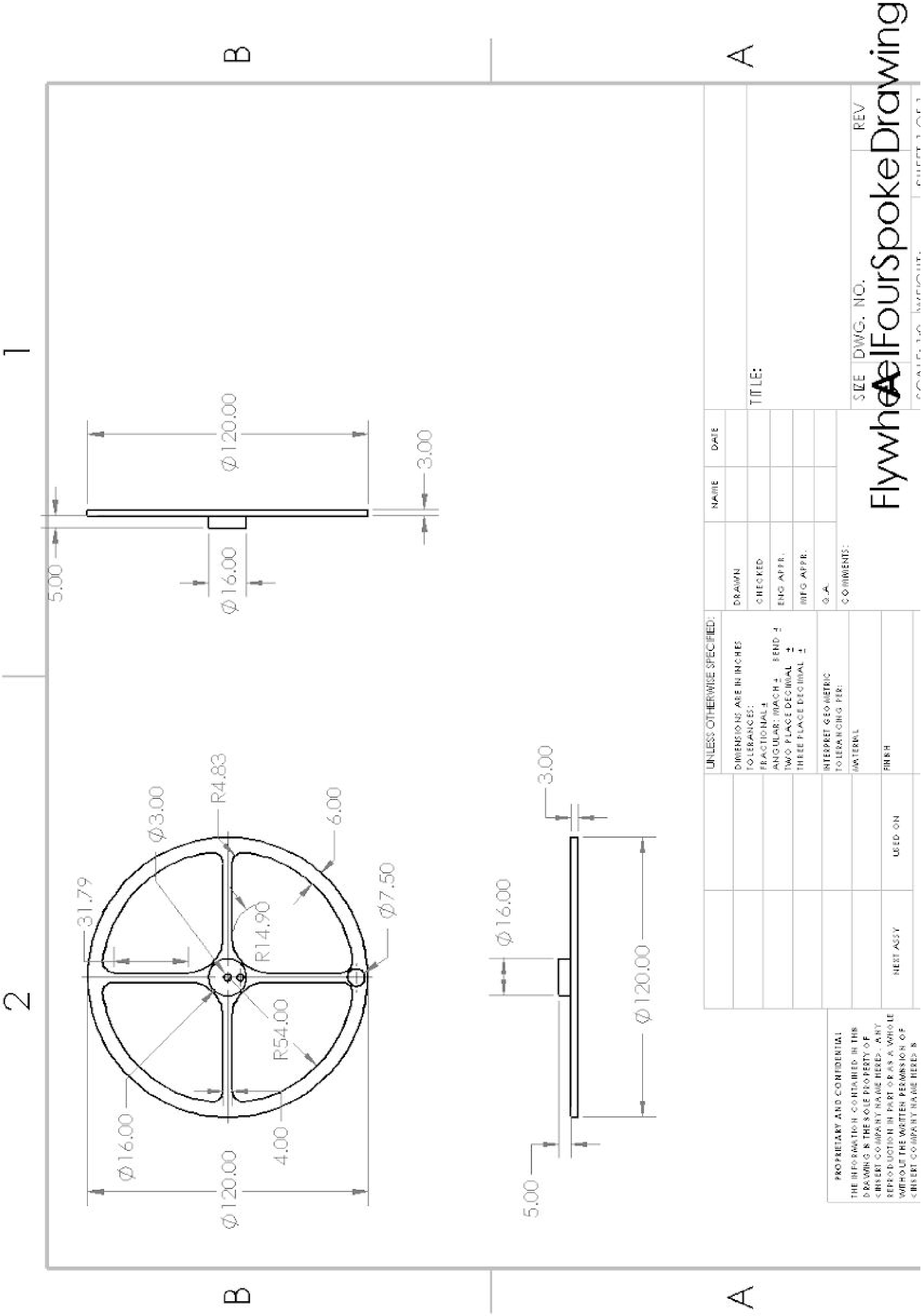
c.


W_out
Q_out
T_1
ΔT = T_2 - T_1
= 10°C
T_2
Q_in

3. CAD Model



A larger picture of the drawing is below so that the dimensions can be better seen!


Flywheel FourSpoke Drawing
1
2
A
B
Ø120.00
Ø16.00
5.00
3.00
31.79
Ø3.00
R4.83
6.00
Ø7.50
R14.90
R54.00
4.00
TITLE:
SIZE
A
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REV
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
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USED ON
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