Homework 3

Thermodynamics, gas processes and integration techniques

Due Friday Jan 26 at 5pm

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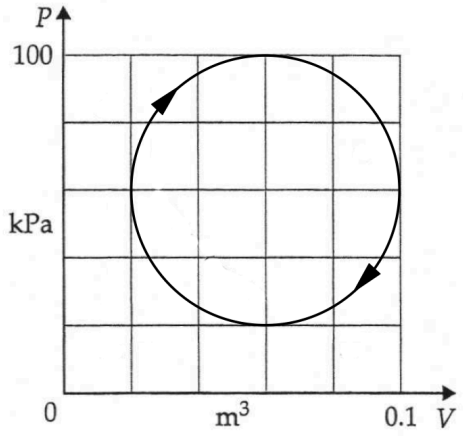
1. Integration techniques

You should be familiar with three techniques for calculating integrals

1. Equations and calculus
2. Geometric shapes (calculating a generalized area)
3. Simple numerical integration (a sum y-values appropriately weighted by Δx)

For the following three questions, pick the most appropriate integration technique

a) Find the net work for one cycle of the process shown below. Check the sign and units of your answer.



b) Consider compression of a gas where P = (constant)*$V^{5/3}$. The initial volume is 0.1 m^3 and the final volume is final volume is 0.05 m^3. The initial pressure is 100 kPa. Find the work done on the gas. Check the sign and units of your answer.

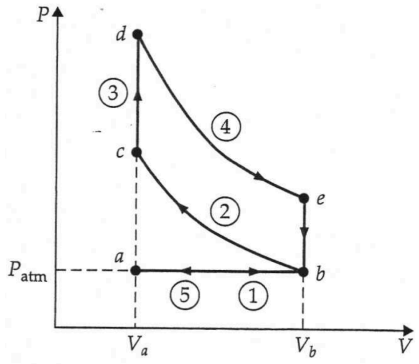
c) The following data is taken from one of the cylinder chambers of 1.6-liter 4-cylinder engine. The number of gas molecules inside the cylinder is fixed during this 8-ms time period. Calculate the work done by the gas during this 8-ms time period.

Time (ms)	P (kPa)	V (liters)
1	5000	0.05
2	3500	0.10
3	2500	0.15
4	1700	0.20
5	1100	0.25
6	600	0.30
7	400	0.35
8	300	0.40

2. Adiabatic expansion
T7M.9 *from Chpt 9 of Moore, 3rd Edition.*

Note: Adiabatic process means that no heat flows into or out of the gas. The textbook derives an expression for pressure as a function of volume for an adiabatic process.

3. Idealized automobile engine
T9D.5 *from Chpt 9 of Moore, 3rd Edition.*



4. Carnot Engine
T9D.3 *from Chpt 9 of Moore, 3rd Edition.*

5. Heat Pump
Imagine a Carnot engine working in reverse (the arrows on the PV diagram go counter clockwise instead of clockwise). Such a system is called a heat pump.

a) What is the temperature of the gas when heat is leaving the gas? (your choices are T_H or T_C)

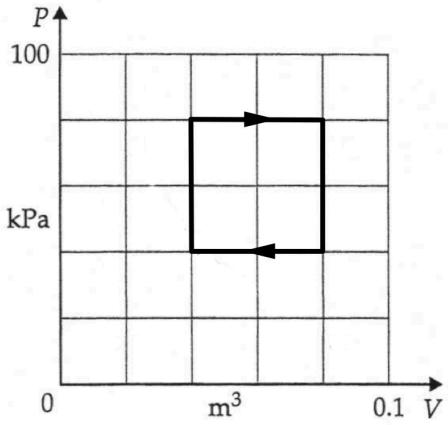
a) Find an expression for Q_{out} during one cycle.

b) Find an expression for the net work **done on the gas** during one cycle?

Sense making: Try applying your result to a real situation. Imagine that you can use this machine to pump heat into your house. The temperature outside is T_C = 273 K and the temperature inside is T_H = 293 K. You pump heat into the house at a rate of 4 kW. What rate would the machine use mechanical energy? (This mechanical energy is approximately equal to the electrical energy needed to run the heat pump).

Practice question for the mid-term (not graded)

Consider the following cyclic process that has heat as an energy input (Q_{in}) and work as an energy output. (There is also an energy output in the form of waste heat, Q_{out}).



a) Find the efficiency of this gas process by calculating the net work done by the gas, and dividing by Q_{in}.

b) How much could the efficiency be improved without changing the highest temperature and lowest temperature of the gas?