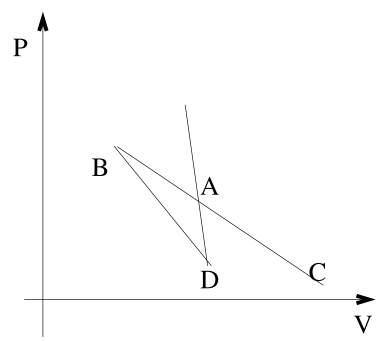
1. A water cooled electric power plant generates 50 MW of power. Its efficiency is 38%. What must the flow rate of the cooling water be if the water may not warm more than 9°C in the process?

Answer:
The work it produces per cycle is .38 times the heat in per cycle.
The heat out, the 'waste' heat that must be absorbed by the cooling water, is the heat in minus the work done, $= Q_{\text{in}} - .38 \times Q_{\text{in}} = .62 * Q_{\text{in}}$
or $\dfrac{.62 \times 50 \times 10^6 \text{joules/sec}}{.38} = 82. \times 10^3$ kJ/sec.
That is the heat the water absorbs, which is the mass used per second times its specific heat times its temperature increase: $mc\Delta T$. That gives $m = \dfrac{Q_{\text{out}}}{c\Delta T}$.

2. If adiabates could intersect the second law would be violated. Use this cycle to demonstrate that. Suppose DA and DB are adiabates and AB is an isotherm. Hint: How much work is done in a cycle? How much heat is taken in during one cycle?



Answer: The work done during the cycle BADB is the area inside the triangle. There is no heat in or out during AD or BD so it all must come in during BA. That is a machine using this cycle takes in heat from a hot reservoir and converts it all to work. and has no other effect. That contradicts the 'heat engine' statement of the second law (p. 632 of the text).

3. An ideal heat pump uses cold outside air, temp T_1, that is warmed to temp T_2 and discharged into a house. How much work must be used to operate the device for every 1.0×10^3J of heat sent to the house?

	A	B	C	D
T_1(°C)	-5.0	-10.0	0.0	10
T_2(°C)	30.0	20.0	20.0	25

Answer:

The heat pump takes Q_C from the air, and W from its power source, and discharges Q_H into the house.
'Ideal' means it's the best possible. That is it uses a Carnot cycle, for which $|fdQ + HT_H = Q_C T_C$, so $Q_C = \dfrac{T_C}{T_H} Q_H$.
The first law says $W + Q_C = Q_H$ or
$W = Q_H - Q_C = Q_H - \dfrac{T_C}{T_H} Q_H = Q_H(1 - \dfrac{T_C}{T_H} = ((1 - \dfrac{T_C}{T_H} \times 1.0 \times 10^3$ J/sec.
There were several sets of temperatures given.

4. A refrigerator runs using a reversible cycle. Its coefficient of performance is 5.0. It removes 5J of heat from its interior in one cycle. If it is run backward, as engine, what would the efficiency of that engine be? hint: sketch the appropriate cartoons for the engine and the refrigerator.

It takes in Q_C from the inside of the fridge, uses work W during each cycle and dumps it all, $Q_C + W$, into the (hot, temp T_H) kitchen.
The first law requires $Q_H = Q_C + W$.
The coefficient of performance is $\frac{\text{good stuff}}{\text{stuff you pay for}}$. That's $\frac{Q_C}{W}$ for this example.
That gives $W = \frac{Q_C}{5.0} = \frac{5\text{J}}{5.0} = 1.0$ J per cycle.
The engine's efficiency would be $\frac{W}{Q_H} = \frac{1\text{J}}{5\text{J} + 1\text{J}} = 17\%$.

5. An ideal heat engine uses 2.00 moles of gas and operates between a hot reservoir at $T_H = 450$ K and cold reservoir at $T_L = 310$ K, in a cycle from $a \rightarrow b \rightarrow c \rightarrow d \rightarrow a$. From $a \rightarrow b$ the gas undergoes an isothermal expansion, changing its volume from V_a to $4.00V_a$. From $b \rightarrow c$, the pressure is reduced at a constant volume. From $c \rightarrow d$, the gas undergoes an isothermal compression, and from $d \rightarrow a$, the pressure is increased at a constant volume until the gas is back at the original condition a.
How much work is obtained from the engine in each cycle?
Answer:

Work is only done during ab and cd. During the expansion ab the gas does work and during the compression it has work done on it. The work done by the engine in one cycle is the algebraic sum of the two.
In ab the work is $nRT_{\text{ab}} \ln \frac{V_b}{V_a}$ and in cd it is $nRT_{\text{cd}} \ln \frac{V_d}{V_c}$.
Since $V_d < V_c$ the second logarithm, thus the second term, is negative, as expected.
$T_{\text{ab}} = 450$ K and $T_{\text{ab}} = 310$ K.

6. A steam power plant with an efficiency of 65% of the maximum thermodynamic efficiency operates between 250°C and 40°C. How much heat is rejected to the cold reservoir in doing 340.kj of work?
Answer: The maximum efficiency is $1 - \frac{T_C}{T_H}$ so this plant's efficiency is $.65 \times (1 - \frac{313}{523}) = .26$. Efficiency is $\frac{W}{Q_H}$ so $W = \frac{W}{.26}$. The first law is $Q_C = Q_H - W = \frac{W}{.26} = 2.8W$ so if $W = 340$ kJ then $Q_C = 970$ kJ.

7. Suppose it takes (on average) 3000 Joules/sec to maintain the inside temperature of a particular house at 22°C while the outside temperature is -5°C. That could be provided by an electric heat pump or by direct electric heating. What would be the savings in the monthly (30 day) electric bill if the heat pump is used instead of direct electrical heating? Assume that 1 kW hr costs \$0.15 and the heat pump is the best allowed by the second law.
Answer:

If run as a heat pump the first law says $Q_C = W + Q_H$. The most efficient engine operating between T_C and T_H has efficiency=$1 - \frac{T_C}{T_H}$. That is .092 in this problem.
The work done if 3000 J were taken from the hot reservoir would be .092*3000=275 J. So if run as a heat pump it would require 275 J to discharge 3000 J into the hot reservoir (that is into the house).
That's (3000-275=2725) J less than if the heat were all coming from the wall