Problem Set 6
Physics, summer 2020/21

1) **(2p.)** In a system undergoing adiabatic compression, what are the values of internal energy and heat if work done on the system is 500 J?

   Answer:
   This is an adiabatic process which means there is no heat transfer, $Q = 0$.
   According to the first law of thermodynamics, internal energy is equal to the sum of the heat within the system and the work done on the system. $\Delta U = q + w$.

   Following the first law of thermodynamics equation:
   $\boldsymbol{\Delta U = q + w}$
   $\boldsymbol{\Delta U = 0 + 500}$
   $\boldsymbol{\Delta U = 500\ J}$

2) **(2p.)** What is the change in internal energy of a system when a total of 150.00 J of heat transfer occurs out of (from) the system and 159.00 J of work is done on the system?

   Answer:
   The net heat transfer and total work are given directly to be
   $Q = -150.00$ J and $W = -159.00$ J , so that
   $\boldsymbol{\Delta U = Q - W = -150.00\ J - (-159.00\ J) = 9.00\ J.}$

3) **(3p.)** A coal-fired power station is a huge heat engine. It uses heat transfer from burning coal to do work to turn turbines, which are used to generate electricity. In a single day, a large coal power station has 2.50×10^{14}J of heat transfer from coal and 1.48×10^{14}J of heat transfer into the environment.
   a) What is the work done by the power station?
   b) What is the efficiency of the power station?

   <u>*Answer:*</u>
   a) We can use $W = Q_h - Q_c$ to find the work output W, assuming a cyclical process is used in the power station. In this process, water is boiled under pressure to form high-temperature steam, which is used to run steam turbine-generators, and then condensed back to water to start the cycle again.

   Work output is given by:
   $W=Q_h-Q_c$
   Substituting the given values:
   $W=2.50\times10^{14}J-1.48\times10^{14}J=1.02\times10^{14}J.$
   b) The efficiency can be calculated with $E_{ff}=W/Q_h$ since Q_h is given and work W was found in the first part of this example.
   Efficiency is given by: $Eff=W/Q_h$. The work W was just found to be 1.02×10^{14}J , and Q_h is given, so the efficiency is
   $E_{ff} =1.02\times10^{14}J/2.50\times10^{14}J = 0.408 = 40.8\%$

4) **(2p)** What is the heat energy required to completely vaporize 10 g of water beginning at 0°C? (The heat capacity of water is 4.2 J/g·K and the $\Delta H_{vaporization}$ of water is 2260 kJ/kg)

Answer:
When heat is causing an increase in temperature and then a subsequent phase change, it is necessary to determine the heat energy necessary for each part and then sum the components.
The first component is the raising of water's temperature to 100 °. We are increasing the temperature by 100 °C or 100 K. We can use $Q = mC\Delta T$ to get
Q = 10 * 4.2 * 100 = 4200 J.
The second component deals with the vaporization. Once the water has reached its boiling point it requires heat to vaporize into gas. This is equal to 2260 kJ for 1000g of water, or 22.60 kJ in our case with 10g of water.
*We can therefore add these two values together to get **26.8kJ = 4.2 kJ + 22.6kJ.***

5) **(1p.)** The temperature at the bottom of a high waterfall is higher than that at the top because:
   a) by itself the heat flows from higher to lower temperature.
   b) the difference in height causes the difference in pressure.
   c) thermal energy transforms into chemical energy.
   d) <u>mechanical energy transforms into thermal energy.</u>

   Answer: D

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6.04.2021r.