MIT Course 3.00 Fall 2002

Solutions to the problems discussed in Recitation #2
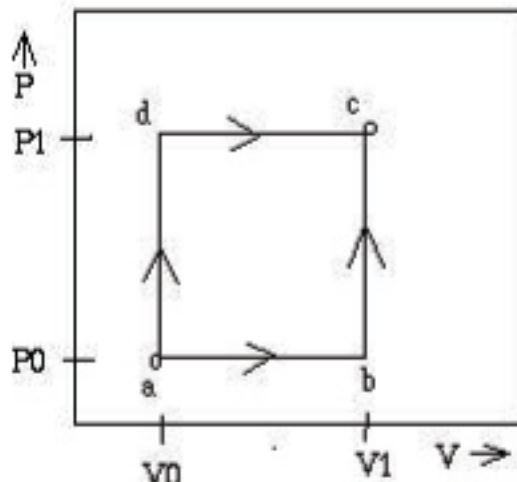
1. Is workdone a state function?

   Generally no. Workdone depends on the path taken to go from one thermodynamic state to another.

   An example would be work done in changing the thermodynamic state from (V0, P0) to (V1,P1) as illustrated in the figure.

   Change in work, $\qquad\qquad dW = \int_{V_0}^{V_1} PdV$

   Assuming a constant pressure, $\Delta W = P(V_1 - V_0)$

For the path $a \rightarrow b \rightarrow c$, work done W1 = P0 * (V1 − V0) + 0.0

For the path $a \rightarrow d \rightarrow c$, work done W2 = 0.0 + P1 * (V1 − V0)

since P1 > P2, W2 > W1.

2. What is the average power production (in watts) of a person who burns 2500 kcal of food a day? Estimate the average additional power production of 75kg person who is climbing a mountain at a rate of 20m/min.

 Essential thing to know is the definition of power.

$$\text{power} = \text{(work done by the system)}/\text{(time taken to do the work)}$$

Unit of power is watts which is one joule of energy spent in one second.

Converting to SI system of units: 2500 kcal = 4.1868 * 2500 * 1000 Joules

$$= 10467 \times 10^3 \text{ Joules}$$

Average power production $= 10467 \times 10^3 / (24*60*60)$ watts

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$$= 121.14 \text{ watts}$$

Since climbing a mounting increases the potential energy of the body,

Additional work done	=	increase in potential energy (in one minute)
	=	mgh = 75 * 9.8* 20 kg. ms^{-2}.m
	=	14700 Nm (as 1Newton = kg.ms^{-2})
Additional average power production	=	14700 / 60 watts
	=	245 watts.

3. What is the amount of work that must be done on 1 cubic cm of water to convert into uniform spray having spherical droplets which are 5 μm in radius. (surface tension of water 0.073 N/m).

Number of droplets with $5\mu m$	=	(total volume)/(volume of the droplets) = V/((4/3)πr^3)
	=	1.0 * 10^{-6} / ((4/3)*π *(5*10^{-6})^3)
	=	6 * 10^{15}
Total surface area of these droplets	=	6 * 10^{15} * (4 *π *25*10^{-12}) m^2
	=	1884.95 * 10^3 m^2

Since the initial shape of the 1ccm volume of water of water is not given, we can assume it has a spherical shape.

Radius of spherical waterdrop   R = ((3 * 1*10^{-6})/(4 *π))$^{1/3}$ = 0.6203 *10^{-2} m

Surface area (assuming spherical shape) = 4 * π* 0.6203* 0.6203* 10^{-4} m^2

$$= 4.835*10^{-4} \text{ m}^2$$

(Compare the surface area with the total surface area of the droplets - we could have dropped the above calculation and take the surface area to be negligle. shape doesnt matter here !)

Change in surface area $\Delta A = (1884.95*10^3$ - 4.835*10^{-4}) $\simeq$ 1884.95*10^3 m^2

Amount of work that must be done is $\Delta W = -\Gamma * \Delta A$

(with the assumption that surface tension doesnt change with the area itself)

$$= -0.073 * 1884.95 * 10^3 \text{ Nm}^{-1}\text{m}^2 = -137.60 * 10^3 \text{ Nm}$$

4. Is academic pressure in MIT an intensive quantity or extensive quantity? what is its conjugate variable?

Overall consensus seems to be it is an Intensive variable (it is a 'Force' to be reckon with!)

For the conjugate extensive variable, the candidates include

Problem sets,

Time spent on reading,

Time spent on sleeping,

number of people in your group, ...

we can safely eliminate *time spent on reading* and *time spent on sleeping*, which pretty much remain constant, irrespective of which course, throughout the students stay here - one is large and the other small (i will let you guess which one is which.)

Some of the criteria for conjugate variables are

1. work done = intensive variable * extensive variable

2. intensive variable takes on equilibrium values when extensive variable is allowed to exchange.

3. with every pair of conjugate variables an equilibrium can be associated (for example, pressure with mechanical equilibrium, Temperature with thermal equilibrium etc...)

Applying the above criteria:

1. Work done in completing the course successfully = *academic pressure* * (*number of problem sets* or *interval of time spent working* or *inverse of sleeping time* or *number of people in your group*)

2. If *number of problem sets* is the extensive variable:

when number of unsolved problem sets are doubled, the *pressure* increases indefinitely! So *number of problem sets* can be dropped out safely.

If *number of students in the group* is the extensive variable:

when your group is added to another working group, though number of students in a group increased, academic pressure is still uniform for the entire group and changes to equilibrium value for all.

The winner - *number of students in a group* as the extensive variable.

Take home moral of the story : work in groups to get work done fast and you get 5% bonus marks too!!!

If you cant get sleep, try figuring out the variables, and equation of state!!!

What are the thermodynamic variables for thermodynamic academics @ MIT (for a single class)?

academic pressure = function of (self imposed pressures + peer pressures)

groups = function of (friendliness, frequency of baths, ...)