

Here is data for nine states, taken from a take-home version of the PDM:

David R. started putting a table in here.

	$F_L:$	$F_L:$	$F_L:$
$x_R:$	$F_R:$	$F_R:$	$F_R:$
	$x_L:$	$x_L:$	$x_L:$
$x_R:$	$F_R:$	$F_R:$	$F_R:$
	$x_L:$	$x_L:$	$x_L:$
$x_R:$	$F_R:$	$F_R:$	$F_R:$
	$x_L:$	$x_L:$	$x_L:$

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1. What does each cell represent? Each row or column?
2. It takes TWO graphs to plot all this data. Why?  
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3. Notice that the graphs are correlated. How?
4. Draw/label the processes State 1 to State 2 to State 3 to State 4 on each graph.
5. For the PDM, the analogue of the First Law and the thermodynamic identity are:

$$\Delta U = W_L + W_R \tag{1}$$

$$dU = \bar{d}W_L + \bar{d}W_R \tag{2}$$

$$dU = F_L dx_L + F_R dx_R \tag{3}$$

$$dU = F_L dx_L + F_R dx_R \tag{4}$$

$$dU = F_L dx_L + F_R dx_R \tag{5}$$

$$\Delta U = \int F_L dx_L + \int F_R dx_R \tag{6}$$

Find  $\Delta U$  from state 1 to state 3 along (at least) two different paths. What can you say about the values of  $\Delta U$ ,  $W_L$ , and  $W_R$  along the different paths.

You may wonder why the thermodynamic identity treats the four variables asymmetrically? Let's explore this asymmetry.

6. Pull on the right-hand side of your PDM. You are doing work. Where does the energy go?  
 A Legendre transformation is a mathematical manipulation of the state variables. Define a new state variable  $B$  by:

$$B = U - F_L x_L$$

7. Find  $dB$

8. If we do a Legendre transformation to the new state variable  $B$ , we have:

$$dB = -x_L dF_L + F_R dx_R \quad (7)$$

(8)

$$\Delta B = \int -x_L dF_L + \int F_R dx_R \quad (9)$$

9. How do you calculate  $\Delta B$  on your graphs?

10. Suppose your experimental set-up has no tape on the left-hand side. (Right-hand measuring tapes have not yet been developed.) For what process can you find  $\Delta B$  but NOT  $\Delta U$ ?