Cardiac Output

During a normal heartbeat the left ventricle undergoes 4 phases: I) isovolumetric contraction; II) ejection; III) isovolumetric relaxation; IV) filling. During phase I), the valves are closed and no blood can get in or out of the ventricle. During this phase the ventricular muscle starts to contract rapidly increasing the ventricular pressure. When the ventricular pressure exceeds the aortic valve pressure, we enter in phase II) where the valve opens and the blood flows out of the ventricle reducing its volume. As blood is ejected, the ventricular pressure starts to decrease until the aortic valve closes again. At this point, we are in phase III) in which the ventricle is relaxing with both valves closed once again keeping the blood volume constant. As the ventricle relaxes, the pressure decreases. When the ventricular pressure becomes smaller the the atrial pressure, we enter in phase IV) where the mitral valve opens and blood fills the ventricle again increasing its volume. As the blood fills the ventricle again pressure increases and we return back to phase I). For more detail on this process, you can check these videos (youtube_video1 and youtube_video2).

The following data for pressure and volume was recorded during the four phases together with the time (starting from a initial time $t_0 = 0$)

Phase I						Phase II				
t_I[ms]	0.	11	22	34	-	t_{II}[ms]	68	119	170	221	255
p_I[mmHg]	8.1	32.2	56.2	79.9	-	p_{II}[mmHg]	95.3	115.0	125.1	126.3	112.9
v_I[ml]	120.0	119.8	119.6	119.4	-	v_{II}[ml]	115.1	105.3	85.4	70.7	55.8
Phase III						Phase IV				
t_{III}[ms]	272	280	289	297	-	t_{IV}[ms]	331	425	510	578	646
p_{III}[mmHg]	90.6	70.0	50.1	30.6	-	p_{IV}[mmHg]	13.5	8.4	6.2	5.1	7.5
v_{III}[ml]	50.7	49.7	49.5	49.2	-	v_{IV}[ml]	50	64.3	79.7	94.1	109.0

We want to generate a model for this set of data to get some of the missing information.

1. What are the values of the pressure when the ventricular volume is 90ml? Hint: Interpolate the values of the pressure.

2. What are the values of the volume when the pressure is 110 mmHg? Hint: Use the interpolating polynomial of the previous point.

3. We also want to assess the ventricular function using the stroke work. The stroke work refers to the work done by the ventricle to eject a volume of blood. The force that is applied to the volume of blood is the intraventricular pressure. Stroke work is best depicted by the use of a pressure-volume diagrams, in which stroke work is the area within the pressure-volume loop. What is the stroke work for this set of data? Hint: Plot the pressure over volume data. The plot defines a closed region. Compute the area of such region.