

Problem Set #3

In this problem set you will explore the response of the cardiovascular system to a sudden redistribution of blood as encountered during a rapid movement to the upright posture. You will analyze the system's response with the help of a mathematical model, called CVSIM, which can be accessed from any SUN workstation in the Athena clusters by clicking on **Coursework** and **HST** on the dash menu. Please familiarize yourself with CVSIM as soon as possible.

Question 1:

CVSIM simulates the hemodynamic state of a supine subject only, i.e. it lacks the capability of simulating changes in posture in an integrated fashion. We can, however, simulate the instantaneous translocation of blood within the circulation by changing the zero pressure filling volume (ZPFV) of the central venous capacitor.

To answer this question, set up a simulation window with arterial blood pressure and heart rate (at a paper speed of 0.1 cm/s). Click on *Set Parameters* and bring up the box for Venous ZPFV. While running the simulator, increase the venous ZPFV by 500 ml. When prompted, choose *Transient* to see the transient response of the system to your intervention.

Part 1: Do the above simulation in the uncontrolled state, i.e. with the baroreflex switched off. Explain the response of heart rate and blood pressure to your intervention.

Part 2: Repeat part 1 but this time with the baroreflex switched on. Explain the response of the system. Does the response make sense?

Compare your results to the attached data of an astronaut stand test 120 days before flight.

Part 3: Do you think that your crude simulation (instantaneous translocation of 500 ml of blood to the veins) is a good simulation of the data? Focus on the general dynamics of the responses rather than the magnitudes. Comment on major similarities and differences between simulation and data.

Question 2:

You have learned in lecture that the cardiovascular system adapts pretty well to the microgravity environment. Trouble begins when astronauts come back to earth. This question will focus on how to use the simulator to infer information about the adaptational processes. Bring up *Total Blood Volume* from the *Set Parameter* menu. Also bring up the parameters box of the baroreflex.

Part 1: Inspect the heart rate responses of the astronaut stand tests before and after space flight (Figures 1a and 2a). Comment on major differences.

Part 2: It is our goal to generate the post-flight heart rate response to standing by changing some of the simulators parameters. Reduce total blood volume by about 400 ml and simulate a rapid stand test like you did in question 1. (Astronauts in microgravity usually lose 10-15% of plasma volume.) Does this generate the desired heart rate dynamics? Justify your answer.

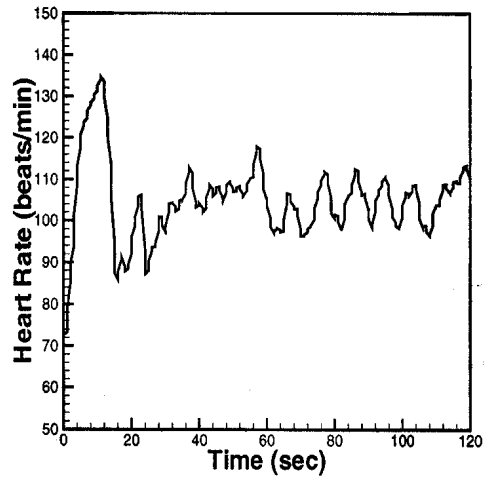
Part 3: Why do you think a decrease in plasma volume occurs in microgravity?

Part 4: In addition to a 400 ml reduction in blood volume, reduce the peripheral sympathetic gain in by 20%. Redo the simulation of the stand test. Does the heart rate response you generated this way match the dynamics of the data better?

P.S.: You might find it helpful to print out screendumps of the simulations you make when discussing some of the problems above.

Astronaut Stand Tests

(a)



(b)

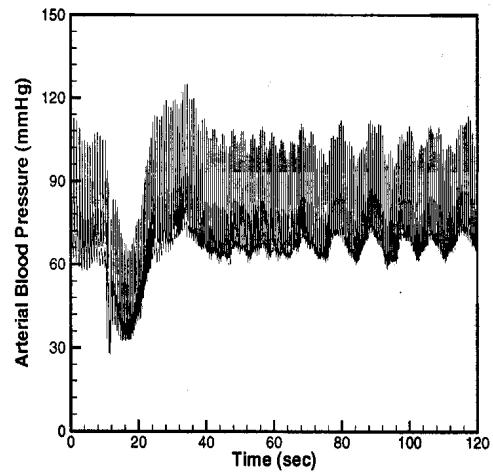
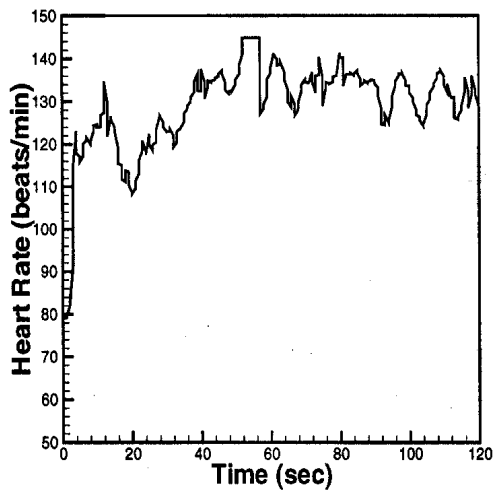


Figure 1: (a) Astronaut's heart rate and (b) arterial blood pressure before flight

(a)



(b)

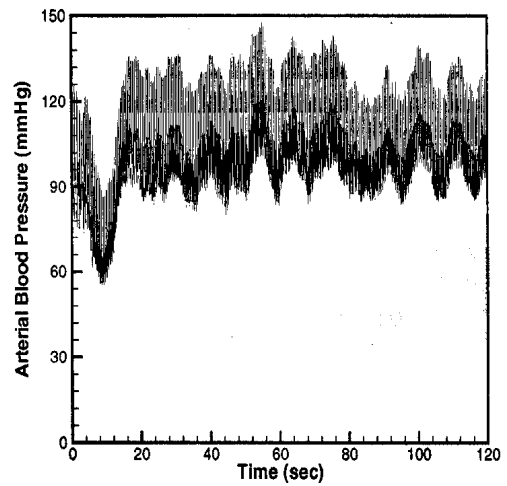


Figure 2: (a) Astronaut's heart rate and (b) arterial blood pressure after flight