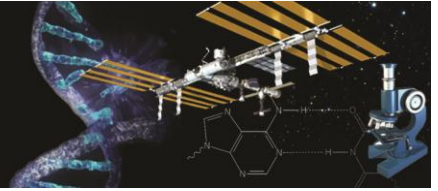




# MATH AND SCIENCE @ WORK

AP\* CALCULUS Student Edition



\*AP is a trademark owned by the College Board, which was not involved in the production of, and does not endorse, this product.

## TAKING A WALK IN THE NEUROSCIENCE LABORATORIES

### Background

Over the duration of their mission, astronauts can go through many physical, psychological, and neurological changes. Exposure to reduced gravity during spaceflight can lead to adaptive changes in all systems of the human body, including the human nervous system.

The Neuroscience Laboratories at NASA Johnson Space Center investigate the effects of spaceflight on the human nervous system, with particular emphasis on posture and gait (manner of walking), eye-head coordination, perception, space motion sickness, and the involuntary sensory function of the inner ear.

The central focus for these laboratories is the development of countermeasures (ways to lessen or prevent spaceflight-related changes) in the nervous system, particularly the function associated with adapting to the reduced gravity environment of space, and then re-adapting to gravitational environments.

Within the Neuroscience Laboratories, many different functions are tested. For example, researchers in the Motion Laboratory focus on the post-flight disturbances in balance and gait control—areas with which many astronauts struggle. This laboratory develops training programs that will facilitate recovery of normal mobility after long-duration spaceflight.

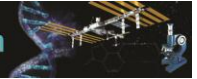


Figure 1: An instrumented test subject walks on a treadmill while viewing a rotating visual flow



Figure 2: Test subject on the motion base treadmill

Through a series of flight and ground-based studies, the Motion Laboratory is developing countermeasures built around treadmill exercise activities. The sensory conditions astronauts experience in space are simulated on Earth by varying the visual flow patterns, body load, and walking surface of the treadmill. When walking on the treadmill, a test subject's body weight can be "unloaded" by physically raising him or her off the treadmill surface using a body harness. The stability of the



walking surface can also be manipulated in any combination of six degrees of freedom by changing the orientation of the motion base platform on which the treadmill is mounted (see Figure 2). Research shows that this training regimen promotes adaptive change in walking performance, therefore improving the ability of the astronaut to adapt to a new gravity environment.

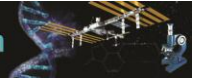
Watch *Vestibular Research in the Neuroscience Laboratory* at <http://youtu.be/oAoHYFZz5U4> for more information.

**Problem**

The data in Table 1 comes from a test subject who walked on a treadmill in one of the Neuroscience Laboratories. A measurement sensor was attached to the test subject’s torso near the neck. Table 1 shows part of the data collected from the sensor. The first column is time (sec) and the second column is vertical acceleration (m/sec<sup>2</sup>).

Table 1: Vertical acceleration of a test subject walking at a normal pace on a treadmill in the Neuroscience Laboratories

Time (sec)	Acceleration (m/sec <sup>2</sup> )	Time (sec)	Acceleration (m/sec <sup>2</sup> )	Time (sec)	Acceleration (m/sec <sup>2</sup> )
0.00	-4.305020916	0.68	-0.002515208	1.36	7.559980507
0.02	-6.364482106	0.70	-1.599918134	1.38	5.093448023
0.04	-6.32596376	0.72	-3.619421353	1.40	3.895199996
0.06	-6.500910727	0.74	-5.961877413	1.42	2.97402008
0.08	-1.501415973	0.76	-7.679560356	1.44	1.397794943
0.10	23.10789083	0.78	-9.401999874	1.46	-1.546336189
0.12	10.02004670	0.80	-10.96935964	1.48	-3.487565684
0.14	2.945086430	0.82	-10.05849293	1.50	-5.29653065
0.16	12.91133145	0.84	-7.956654692	1.52	-6.844008628
0.18	8.133487355	0.86	-0.261320539	1.54	-8.010422071
0.20	9.127715358	0.88	15.57593726	1.56	-8.730919794
0.22	8.955759236	0.90	0.999822617	1.58	-9.22676161
0.24	6.259131273	0.92	6.126813152	1.60	-9.780502436
0.26	4.717210286	0.94	8.368961568	1.62	-9.557058181
0.28	3.708324781	0.96	5.977433249	1.64	-5.497351597
0.30	2.046347978	0.98	6.842496904	1.66	12.91056347
0.32	-0.624171481	1.00	4.309617979	1.68	6.884465739
0.34	-2.6311823	1.02	4.404795652	1.70	0.410255819
0.36	-4.385754433	1.04	1.679738457	1.72	11.02674725
0.38	-5.664348618	1.06	-0.074290732	1.74	7.200456072
0.40	-7.524490023	1.08	-1.194951937	1.76	5.726827097
0.42	-8.825604387	1.10	-3.896116275	1.78	4.589098954
0.44	-7.051679576	1.12	-6.193762972	1.80	2.604763805
0.46	-1.02600842	1.14	-7.776284353	1.82	2.090026913
0.48	6.884695354	1.16	-9.032151946	1.84	0.649630821
0.50	7.485673859	1.18	-10.04421953	1.86	-0.199668585
0.52	3.843485811	1.20	-9.990987964	1.88	-1.865004983
0.54	9.729917039	1.22	-9.9416564	1.90	-3.914575793
0.56	8.676480809	1.24	-7.876564619	1.92	-5.613636372
0.58	6.835736946	1.26	1.726172226	1.94	-6.429382243
0.60	6.038568746	1.28	10.15765401	1.96	-8.388814882
0.62	4.208792058	1.30	3.604958809	1.98	-9.363141599
0.64	4.80875954	1.32	8.662195794		
0.66	2.128342368	1.34	9.380231592		



On the TI-Nspire™ handheld, open the document, *TakingAWalk*, complete the instructions and questions embedded within the document. Space is also provided on this handout to record your answers to the questions.

A. Analyze the vertical acceleration data of the test subject found in Table 1.

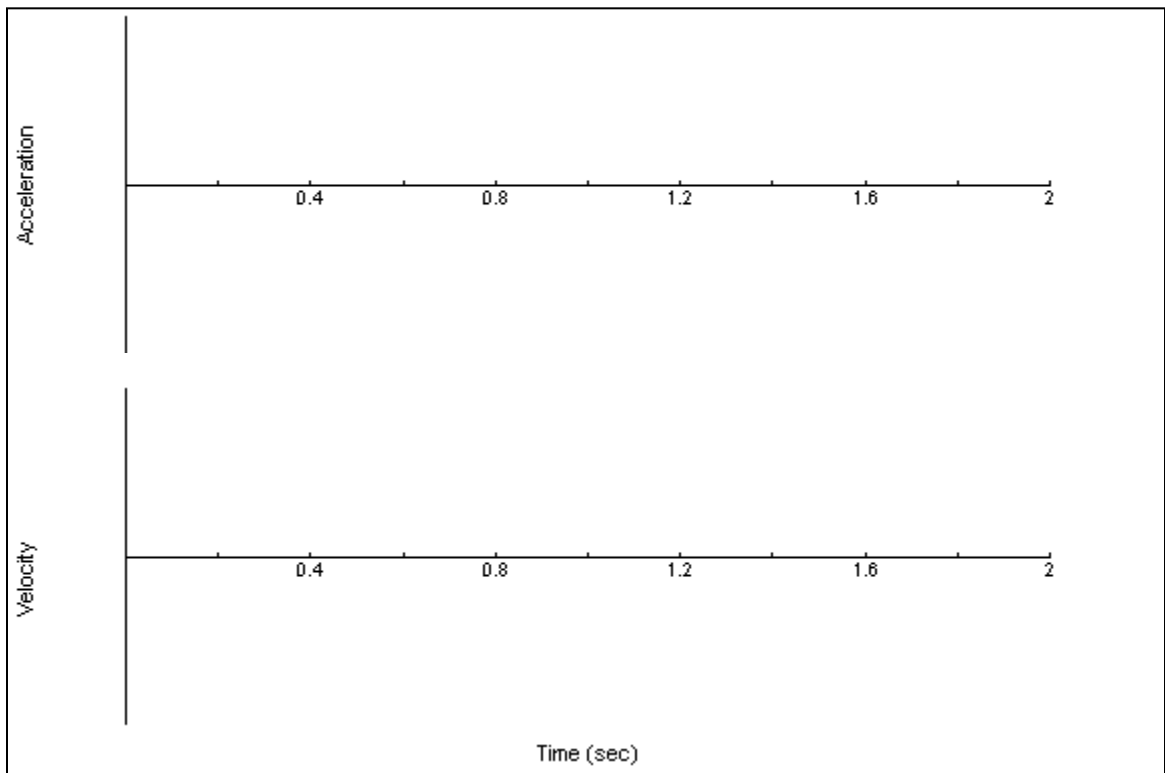
I. What patterns do you see in the data?

II. Create a scatter plot of acceleration vs. time. What patterns do you see in the scatter plot?

III. How would you explain the pattern found in context of the given situation?

B. Analyze the velocity.

I. Sketch the graph of acceleration that you found in question A part III. Then sketch a prediction of the velocity and show how it corresponds to the acceleration graph.





When an acceleration function is given for a situation, one can use definite integrals to find velocities at specified times. In this situation there is no acceleration function to integrate; however, numerical methods can be used to find velocities. For example, we could compute a left Riemann sum of acceleration directly from the data in the table.

- II. The **sum** command can be used to find the sum of a list. Use this command to find the left Riemann sum that approximates the velocity at two seconds. For this question, assume an initial velocity of -1 m/sec. Show your work in the calculator page provided.
  - III. In the spreadsheet on page 1.12, enter the following command in the formula cell for the column labeled vel\_z, then go on to page 1.13: **vel\_z:=cumulativesum(accel\_z) • 0.02+v0**.  
*Note: v0 represents the initial velocity of the test subject.*
  - IV. Why did the command: **vel\_z:=cumulativesum(accel\_z) • 0.02+v0** calculate velocities?
  - V. Plot velocity vs. time. Adjust the graph with the v0 slider to represent what the vertical velocity should look like when a subject is walking on a treadmill. Explain your selection of v0.
- C. Analyze the position.
- I. Use numerical methods to find positions. On page 1.17, enter the following command in the formula cell for the column labeled pos\_z, then go on to page 1.18:  
**pos\_z:=cumulativesum(vel\_z)• 0.02+z0**.  
*Note: z0 represents the initial position of the test subject.*
  - II. Plot position vs. time. Adjust the graph with the z0 slider to represent the movement of the sensor when a subject is walking on a treadmill. Explain your selection of z0.
- D. The reduced gravity experienced during spaceflight can lead to a loss of balance when an astronaut first returns to Earth. How might the graphs change if the test subject has just returned from an extended stay on the International Space Station?