SP211 Lab 2
Two Dimensional Kinematics

Equipment

You will need the following equipment to complete this lab. Quantities needed are listed inside of the parenthesis.

Spark Table (2 per room)
Regular "Butcher" Paper (1 stack per spark table; 2 per room)
Carbon Paper (1 per spark table; 2 per room)
Wooden Blocks (2 blocks per spark table; 4 per room)
Meter Stick (1)
Small Ruler (1)
Level (1 per spark table; 2 per room)

You may wish to also make use of your rolling/parallel ruler from navigation to aid in vector translation.

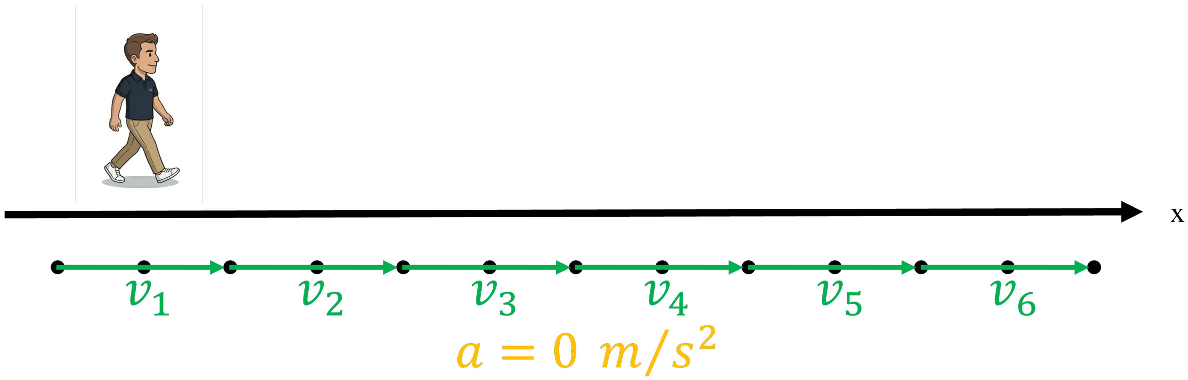
Motion Diagrams

A motion diagram consists of three parts: (1) points that represent the position of an object spaced at *equal time intervals*, (2) velocity vectors at each position point, and (3) an acceleration vector at each point. For motion with constant acceleration, sometimes just one acceleration vector is drawn.

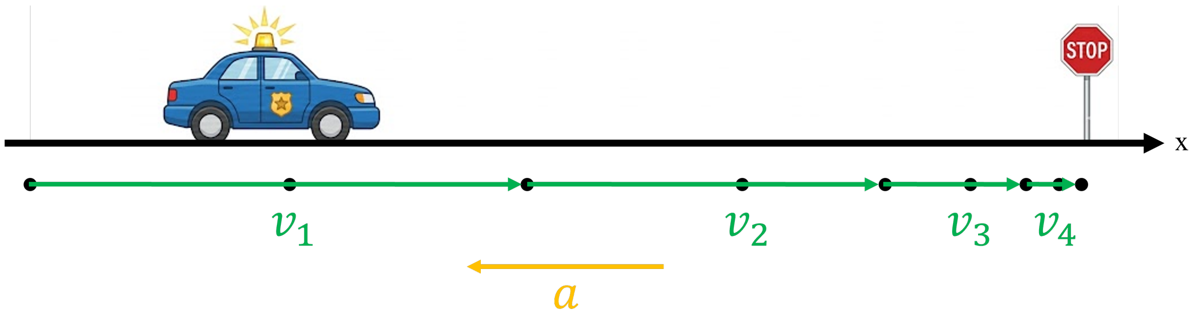
Consider a person walking at a constant speed in one direction. The correct motion diagram for this scenario is shown in Figure 1a. The person constantly travels the same distance in the same amount of time. Therefore, the person's motion diagram has equally spaced points with equally sized velocity vectors. A car coming to a stop has an acceleration in the opposite direction of its motion. Therefore, its motion diagram (Figure 1b) has points that get closer together with time and velocity vectors that get smaller with time.

Motion diagrams can also be drawn for motion in two dimensions. Figure 1c shows a motion diagram for a skydiver. When the skydiver leaves the plane, they have a constant velocity in the x-direction and an acceleration in the y-direction. Therefore, the distance between their points is equally spaced in the x-direction, but gets larger and larger in the y-direction the farther they fall.

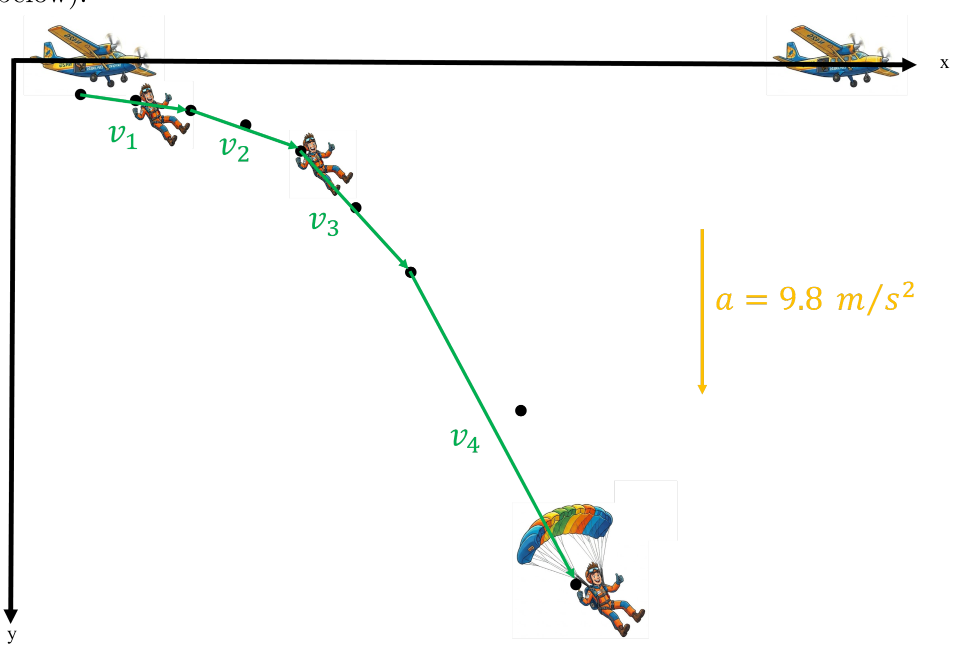
Updated August 20, 2026



(a) A person walking in a straight line with no acceleration (top) and their associated motion diagram (below).



(b) A car coming to a stop with a constant acceleration (top) and the car's associated motion diagram (below).



(c) A skydiver with a constant acceleration due to gravity and their associated motion diagram drawn overtop of them.

Figure 1: Examples motion diagrams for different scenarios.

Now that you've familiarized yourself with a few motion diagrams, try qualitatively drawing one yourself on the attached worksheet (Question 1).

Data Collection

1) Level the spark table and then shim the back of the table up using the provided wooden blocks. For the best data, use two or three blocks.

2) Place carbon paper on the spark table carbon side up. Place a piece of plain paper on top of the carbon paper such that it fits tight to the left bottom corner of the table. In that same corner, mark what direction is toward the right of the paper.

3) *Carefully and slowly* turn on the air without bursting the air lines. You need just enough for the pucks to float freely on the paper.

4) Practice launching one puck so that it makes a smooth arc over the paper.

5) Once you are proficient at launching the puck, set the spark generator to 10 Hz. At almost the same time, press and hold the pad to produce sparks while launching the puck. Stop holding the pad down once the arc is complete. ***Do not move or flip the paper yet!*** The sparks will mark the *backside* of the paper.

WARNING: DO NOT SIMULTANEOUSLY PUSH ON THE PAD AND TOUCH A METAL PART OF THE TABLE OR A METAL PART OF THE PUCKS. YOU WILL GET AN ELECTRICAL SHOCK IF YOU DO SO.

6) Without moving the paper, allow the puck to start from rest and travel straight down the incline while producing sparks. Attempt to make it avoid crossing over your previous arc. Your data should look like something similar to Figure 2, where it is easy to tell which dots are part of the arc and which are part of the straight line.

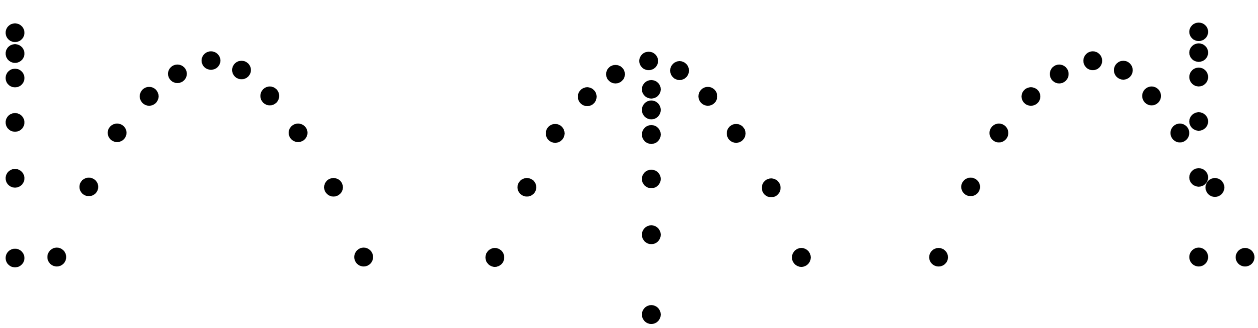


Figure 2: Examples of what acceptable data looks like.

7) Using your knowledge of trigonometry and some measurements of the length and heights of the table (Figure 3), determine the angle at which the table was shimmed up. Record your measurements, work, and answer on the attached worksheet (Question 2).

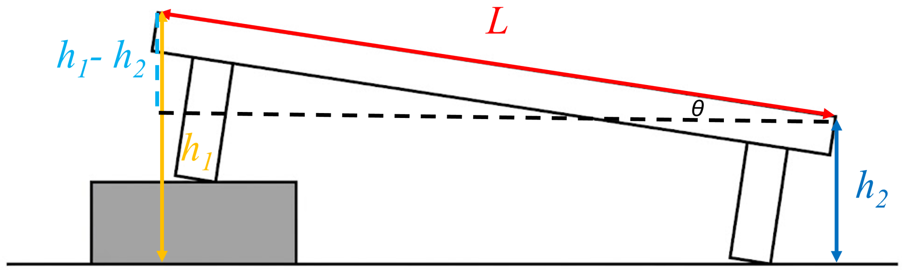


Figure 3: Measurements needed to determine the angle at which the table is shimmed.

CHECK POINT:

Data Analysis

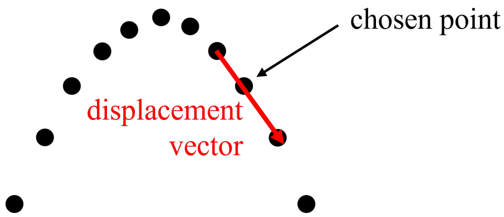
1) You set the spark table to produce sparks at a frequency of 10 Hz. A Hz (Hertz) is a unit equivalent to $\frac{1}{s}$. How many seconds of time passed between each spark? Record your answer on the the attached worksheet (Question 3).

2) Pick 6 widely space points from your arc to analyze and number them. They cannot be from when you were pushing the puck. Make sure that when you flipped the paper over you can identify if those points are from when the puck was going up or down the arc.

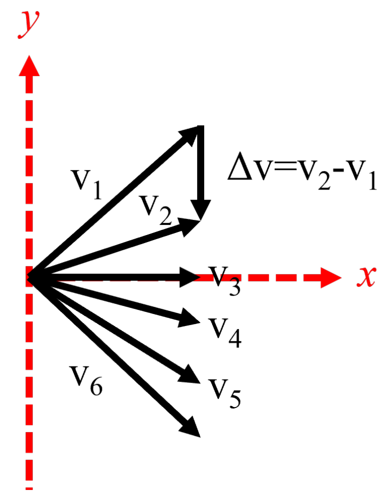
3) For each point, draw in its displacement vector using the points immediately adjacent to your chosen point (see Figure 4a). For each of your chosen data points calculate the velocity of the puck on your spark sheet. To do this, measure the length of the displacement vector you drew and divide by twice the time you found step 1 of your data analysis. (It takes the time you calculated for the puck to go from the closest point on the left to your chosen point *and* that time *again* to go from your chose point to the closest point on the right.) Record your measurements and the resulting velocities on the attached worksheet (Question 4).

4) Translate the velocity/displacement vectors you just drew such that their 'tails' are all together at one point. It is helpful to draw this near the points for the puck that was allowed to travel in a straight line. In the next step, we will use these to calculate a Δv for the puck, as shown in Figure 4b. Answer Question 5 and 6 on the attached worksheet.

5) Now you are going to calculate the acceleration for the puck using our translated velocity vectors. To do this, you need to first calculate the vertical and horizontal components of the velocity vectors. This can be done the same way as when you calculated the total velocity (step 3), except now you calculate the horizontal component of the velocity with



(a) Example of how to draw a displacement vector.



(b) Example of how to draw a vector for Δv.

Figure 4: Steps towards determining our acceleration vectors.

just the horizontal component of the displacement vector and the vertical component of the velocity with just the vertical component of the displacement vector. The points recorded from when you let the puck drop straight down can help you determine exactly which way the vertical direction is on your spark sheet and help you create a coordinate system. Take your rolling ruler and line it up with the points where the puck went straight down. Translate this vertical line to the place where you have all of the tails of the velocity vectors. This vertical line is your y-axis, as shown in Figure 4b. Use your rolling ruler to draw a line perpendicular to the y-axis, which is now your x-axis. With these axes defined, you should be able to determine the x and y components of the displacement and velocity vectors and record them in the table on the worksheet (Question 7).

6) Now that you have the components of the velocity, calculate the components of the Δv for each adjacent pair of translated velocity vectors. Use the components of Δv to calculate the magnitude of Δv. Record these in the table on the attached worksheet (Question 8).

Determine the number of seconds that occurred between the two velocities you are using to calculate each Δv (i.e. How many seconds passed between point 1 and point 2? 2 and 3? etc.) Note: This is *not* the same amount of time you calculated in Question 3. It is also *not* the same amount of time for each pair of points. Record those times in the table (Question 8).

Finally calculate the acceleration and record it in the table. (Question 8; Make sure your answers have the correct units!)

7) Answer Questions 9 and 10 on the attached worksheet.

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5-day section break point ____________________

Further Work

1) Think more about the motion of the puck that traveled on the arc. Does the velocity or acceleration of the puck change with time? Where was the velocity and acceleration of the puck the largest? Where was the velocity and acceleration of the puck the smallest? Place your answers on the attached worksheet (Questions 11 and 12).

2) We used displacement vectors (Δr) to do our analysis in this lab, which is the difference between two vectors. Therefore, the initial displacement vectors we used to calculate velocity were the difference in two *position* vectors. Does a displacement vector depend upon the choice of the origin? Does a position vector depend on the choice of an origin? What does the motion of this puck look like? Write your answers on the attached worksheet (Questions 13 through 15).

3) Using the same procedure as above, construct a motion diagram for the puck that traveled in a straight line. Compare the acceleration for this puck with the acceleration you found for the puck that traveled on an arc (Questions 16 and 17 on the attached worksheet.)

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Clean Up

Please return your lab station and the drawer of equipment to a clean and organized form. Follow any directions your instructor gives you about where to return equipment to when you are finished with the lab.

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LAB 2 Worksheet

Name(s) and Alpha(s) Date

Motion Diagrams

Question 1: On the graph paper below, qualitatively sketch what a motion diagram would look like for the Blue Angel taking off in Figure 5.

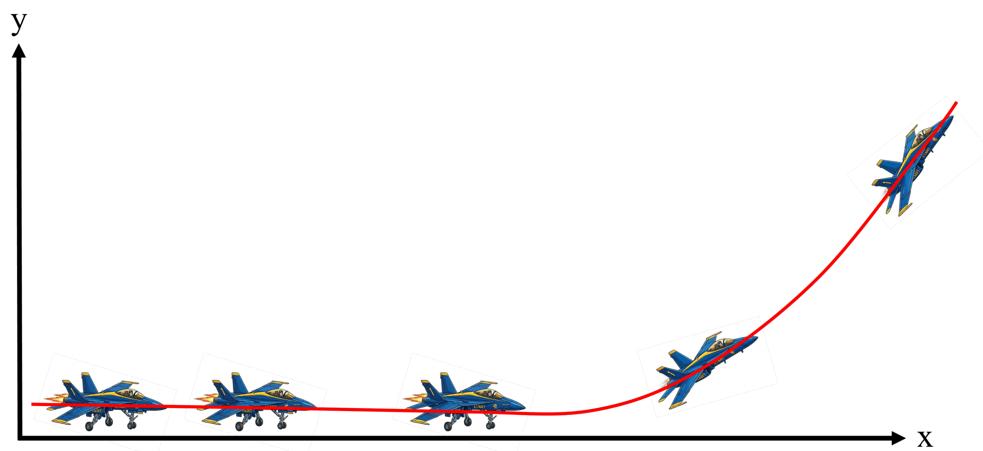

Figure 5: A Blue Angel's airplane taking off from a runway.

Data Collection

Question 2: What is the angle that the table is shimmed up at? Show your work.

Data Analysis

Question 3: How many seconds of time passed between each spark? Show your work.

Question 4: Record the length of your displacement vectors and their velocities below.

Point #	Displacement Vector Length (m)	Velocity (m/s)
1		
2		
3		
4		
5		
6		

Question 5: What do you notice about the horizontal component of the velocity vectors?

Question 6: Based on your translated velocity vectors, what direction must the acceleration of the puck be in?

Question 7: Calculate the vertical and horizontal components of the velocity vectors and record the results here.

Point Number	Horizontal Displacement Vector Length (m)	Horizontal Velocity (m/s)	Vertical Displacement Vector Length (m)	Vertical Velocity (m/s)
1				
2				
3				
4				
5				
6				

Question 8: Calculate the components and magnitude of Δv for each adjacent pair of translated velocity vectors. Determine the time between the points used to determine each Δv and calculate the acceleration of the puck for each Δv. Record your results here.

	Horizontal Δv	Vertical Δv	Magnitude of Δv	Time Between Points	Acceleration
$v_2 - v_1$					
$v_3 - v_2$					
$v_4 - v_3$					
$v_5 - v_4$					
$v_6 - v_5$					

Question 9: Calculate the average acceleration from your data (Question 8). Show your work. How does this average acceleration mathematically relate to the acceleration due to gravity ($g = 9.8\frac{m}{s^2}$)?

Question 10: Using the acceleration due to gravity and the angle you shimmed the spark table at (Question 2), what is the theoretical value for the acceleration of the puck? What is the percent difference between this and the experimental value you found? Show your work.

Further Work

Question 11: Based on the motion diagram for the arc, does the velocity of the puck change with time? Where is magnitude of the velocity of the puck the largest? Where is the velocity the smallest?

Question 12: Based on the motion diagram for the arc, does the acceleration of the puck change with time? Where is magnitude of the acceleration of the puck the largest? Where is the acceleration the smallest?

Question 13: Does a displacement vector depend upon the choice of the origin?

Question 14: Does a position vector depend on the choice of an origin?

Question 15: If you chose an origin and axes (a reference frame), what equations on our equations sheet predict the location and velocity of the puck everywhere on the arc on which it travels?

Question 16: What was the acceleration of the puck that only moved in one dimension?

Question 17: How does the acceleration of the puck that traveled on the arc compare to the one that traveled in a straight line?