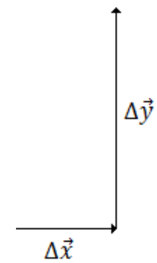
Projectile Motion Investigation

Name: **Date:**

The purpose of this investigation is to study the motion of projectiles. Galileo used horizontal and vertical components to analyze projectile motion, and so will we today. On page 3 of this investigation is a time-collapsed photograph of Mr. Haller bouncing a single ball off of the floor. The image was created by layering together 14 photographs that were taken 0.1 seconds apart from each other. The ball starts in the bottom left, goes up, and then goes to the bottom right.

Questions

1) On the photo on page 4, draw displacement vectors from each picture of the tennis ball to the next. Like Galileo, draw your vectors in component form (a horizontal, x, and a vertical, y, component), rather than diagonally from point to point. It should look like the figure to the right.



2) Use a ruler to measure the horizontal and vertical distances from each ball to the next, record your measurements in units of cm, and put them in the table on page 3 under $\Delta\vec{x}$ and $\Delta\vec{y}$.

3) What do you think the measurement uncertainty in those measurements was?

I think each of my measurements was accurate to $\pm$ 0.1 cm.

4) In the photo, you can see a copy of your textbook. This was included in the photo for scaling purposes. Measure the height of the textbook in the photograph, and measure it again in real-life. State the scale of the photo in the form of

height on paper : height in real-life

3.0 cm : 28.3 cm or 1 : 9.43

5) Adjust your measurements in part 2 so instead of the displacements being that of those on the page, we know the displacements in real-life. Record those values into the table, in units of metres.

6) Using the fact that each photo merged into the time-collapsed photo was taken 0.1 s apart, calculate the average velocity of the tennis ball during each interval and record those into the table. Recall $\vec{v} = \Delta\vec{d}/\Delta t$.

7) What do you notice about the x component of velocity, $\vec{v}_x$? Does it increase, decrease, or stay about the same?

The x component of the velocity doesn't change much, it hovers around 0.9 m/s.

8) What do you notice about the y component of velocity, $\vec{v}_y$? Does it increase, decrease, or stay the same?

The y component of the velocity decreases by about 1 m/s every 0.1 s.

9) Calculate the change between the consecutive $\vec{v}_y$ values you got, and then record them into the $\Delta\vec{v}_y$ $(\mathrm{m/s})$ column.

10) Acceleration is the change in velocity per unit time, $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$. Divide each of the $\Delta\vec{v}_y$ values in the previous question by the 0.1 s time interval. Record those values in the $\vec{a}_y$ $(\mathrm{m/s^2})$ column.

11) What do you notice about the y component of acceleration, $\vec{a}_y$? Does it increase, decrease, or stay the same?

The y component of the acceleration doesn't change much, it hovers around - 8.4 m/s.

12) Your answer from the previous question should have been that the vertical acceleration remains about the same. Calculate the average value you got for that acceleration, and estimate an uncertainty for that value. Explain how you estimated your uncertainty.

The average value of the y component of the acceleration is

$$\vec{a}_y = \frac{(-11.3 - 7.5 - 10.4 - 7.6 - 6.6 - 7.5 - 5.7 - 8.4 - 8.5 - 9.5 - 7.5 - 10.4)\ \mathrm{m/s^2}}{12} = -8.41\ \mathrm{m/s^2}$$

We could crudely measure the uncertainty by using $\pm$ the half width of the spread between the most extreme of values

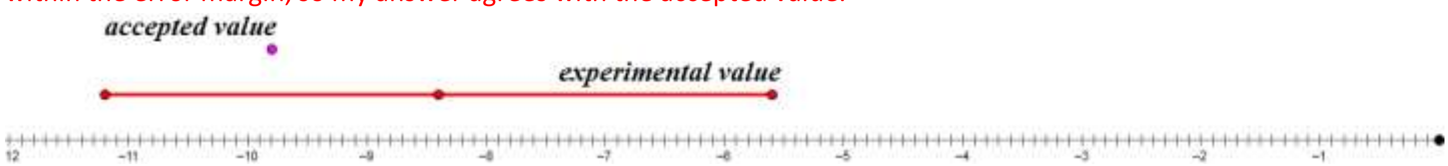
$$\sigma = \frac{(-5.7\ \mathrm{m/s^2}) - (-11.3\ \mathrm{m/s^2})}{2} = 2.8\ \mathrm{m/s^2}$$

Thus

$$\vec{a}_y = -8.4\ \mathrm{m/s^2} \pm 2.8\ \mathrm{m/s^2}$$

13) The accepted value of the vertical acceleration due to gravity is $-9.8\ \mathrm{m/s^2}$. Does your value from question 12 agree with the accepted value?

Below I sketched the acceleration I measured in this lab, with its uncertainty, on a number line. The accepted value lies within the error margin, so my answer agrees with the accepted value.

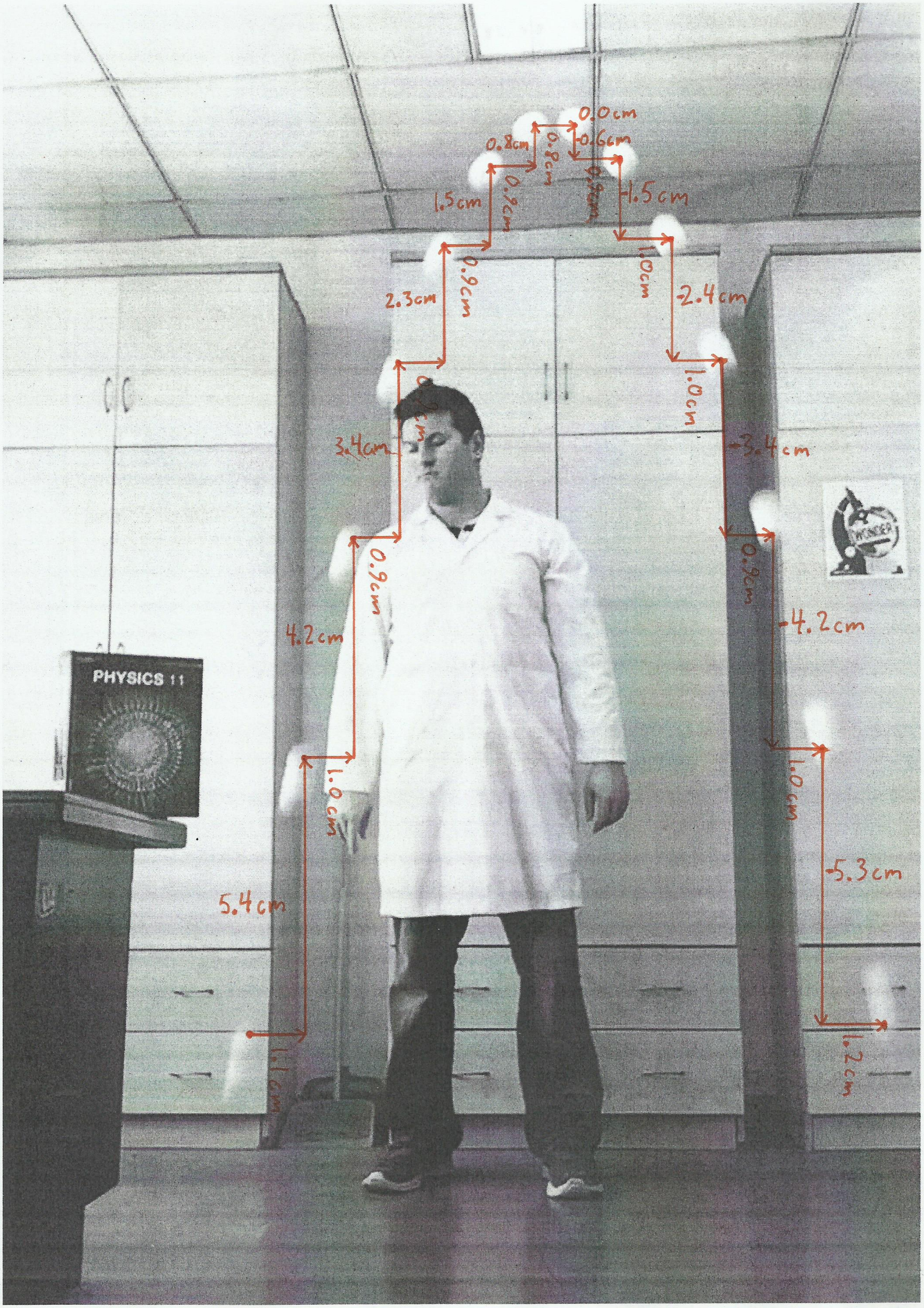


14) What are some of the sources of error in this investigation, what would be their effects, and how could you minimize them?

- It's hard to see the position of the tennis ball because of the motion blur in the photo. This affects the data randomly.
- The ball looks like it was behind the textbook which we used for scale. This would make our values for the acceleration and speeds smaller than they should have been.
- The camera was low, shooting upwards, and was a little of center. This could stretch the values when the ball was further away from the center of the photo.
- The ball appears to bounce slightly towards the camera, not exactly parallel to it. This skews the values on the right hand side more.
- We could improve these issues by placing the camera more in the middle, and parallel to the motion of the ball.
- We could use computer software to track the ball, zoom in on the video to find more accurate positions, and use a faster frame rate
- We could try to bounce the ball higher and faster so our measurements were larger, thus reducing our relative measurement uncertainty.
- We could use a heavier ball to reduce the effects of the air slowing the ball down.

Table of data

Interval	Δt (s)	On paper $\Delta\vec{x}$ (cm)	On paper $\Delta\vec{y}$ (cm)	In real-life $\Delta\vec{x}$ (m)	$\Delta\vec{y}$ (m)	$\vec{v}_x$ (m/s)	$\vec{v}_y$ (m/s)	$\Delta\vec{v}_y$ (m/s)	$\vec{a}_y$ (m/s^2)
$\vec{d}_1 \rightarrow \vec{d}_2$	0.1	1.1	5.4	0.104	0.509	1.04	5.09	-1.13	-11.3
$\vec{d}_2 \rightarrow \vec{d}_3$	0.1	1.0	4.2	0.094	0.396	0.94	3.96	-0.75	-7.5
$\vec{d}_3 \rightarrow \vec{d}_4$	0.1	0.9	3.4	0.085	0.321	0.85	3.21	-1.04	-10.4
$\vec{d}_4 \rightarrow \vec{d}_5$	0.1	0.9	2.3	0.085	0.217	0.85	2.17	-0.76	-7.6
$\vec{d}_5 \rightarrow \vec{d}_6$	0.1	0.9	1.5	0.085	0.141	0.85	1.41	-0.66	-6.6
$\vec{d}_6 \rightarrow \vec{d}_7$	0.1	0.9	0.8	0.085	0.075	0.85	0.75	-0.75	-7.5
$\vec{d}_7 \rightarrow \vec{d}_8$	0.1	0.8	0	0.075	0	0.75	0	-0.57	-5.7
$\vec{d}_8 \rightarrow \vec{d}_9$	0.1	0.9	-0.6	0.085	-0.057	0.85	-0.57	-0.84	-8.4
$\vec{d}_9 \rightarrow \vec{d}_{10}$	0.1	1.0	-1.5	0.094	-0.141	0.94	-1.41	-0.85	-8.5
$\vec{d}_{10} \rightarrow \vec{d}_{11}$	0.1	1.0	-2.4	0.094	-0.226	0.94	-2.26	-0.95	-9.5
$\vec{d}_{11} \rightarrow \vec{d}_{12}$	0.1	0.9	-3.4	0.085	-0.321	0.85	-3.21	-0.75	-7.5
$\vec{d}_{12} \rightarrow \vec{d}_{13}$	0.1	1.0	-4.2	0.094	-0.396	0.94	-3.96	-1.04	-10.4
$\vec{d}_{13} \rightarrow \vec{d}_{14}$	0.1	1.2	-5.3	0.113	-0.5	1.13	-5		



PHYSICS 11
0.0cm
0.6cm
0.8cm
1.5cm
0.9cm
1.5cm
2.3cm
0.9cm
1.0cm
2.4cm
1.0cm
3.4cm
3.4cm
0.9cm
0.9cm
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4.2cm
1.0cm
1.0cm
5.4cm
5.3cm
1.1cm
1.2cm