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Partner: Fourier, Joseph

Motion: Uniform and Non-Uniform

TA: Einstein, Albert (Section 1)

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I. OBJECTIVE

This experiment seeks to explore how position, speed, and acceleration are represented graphically. A motion sensor was used to record the position and velocity of a person. This data was analyzed to demonstrate zero and non-zero acceleration motion on position verses time and velocity verses time graphs. The motion sensor was also used to analyze the motion of a basketball under the influence of gravity and a linear fit was done of the free fall portions of the velocity graph. For any straight line drawn on a graph, the dependent variable (y) is related to the independent variable (x) by the equation

$$y=mx+b, \tag{Eq. 1}$$

where m represents the value of the slope of the line and b represents the value of y when $x = 0$.

II. EQUIPMENT AND PROCEDURE

An ultrasonic motion sensor was set on a table approximately 1 m off the ground and measured the horizontal motion of a person in front of it. Data was collected and graphed on a computer using Logger Pro 3 software. A prescribed pattern of motion was followed to demonstrate the motion on position versus time and velocity versus time graphs (see Fig. 1).

Next the motion sensor was repositioned so that it was pointing toward the floor and a basketball was dropped below it. Position and velocity data was collected from the vertical motion of the bouncing basketball which was then analyzed graphically verses time (see Figs. 2

and 3). Care was taken when dropping the ball to not spin it so that it remained under the sensor for at least three full bounces. The maximum velocity of the ball was dependant on the arbitrary height with which it was dropped.

<u>*Include a sketch diagram of the equipment setup here***</u>**

III. DATA AND ANALYSIS

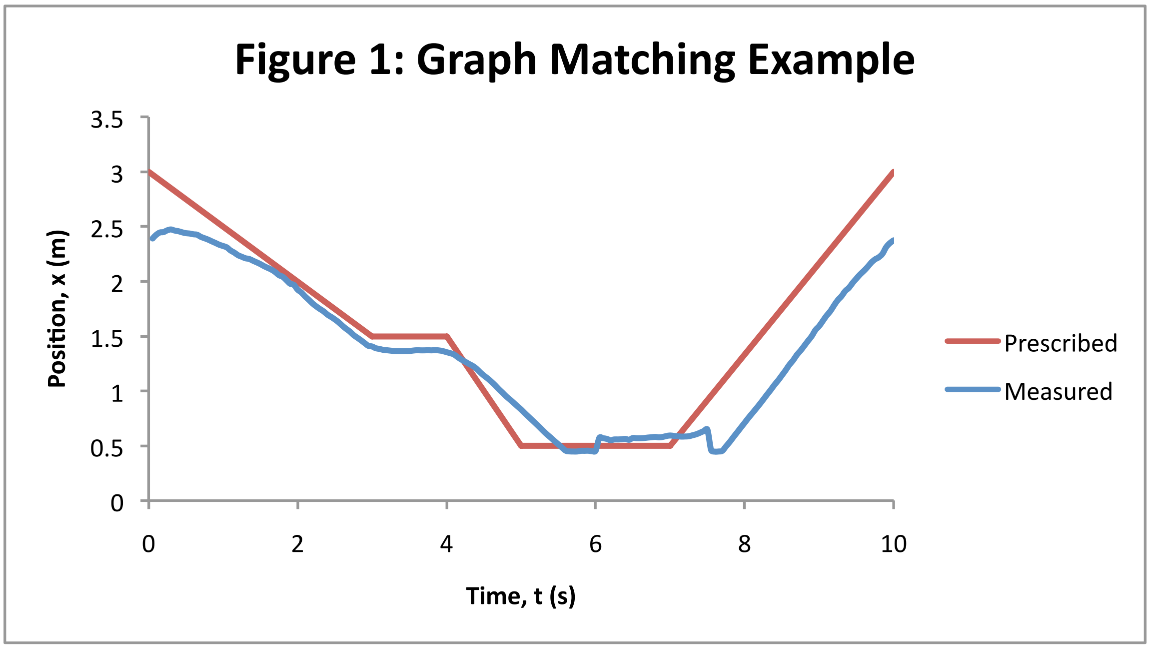


Table 1: Examining the Motion of a Bouncing Ball

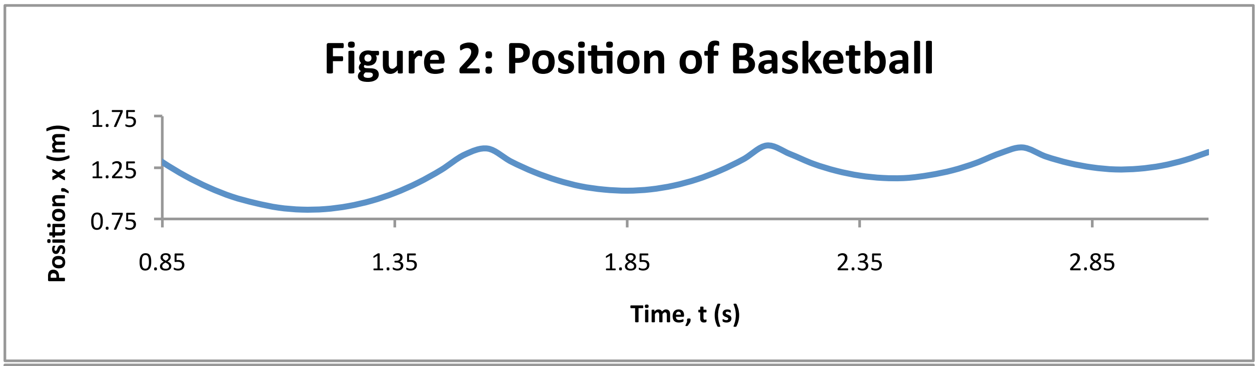
Location	Time (s)	Position (m)	Speed (m/s)	Acceleration (m/s^2)
Hitting ground	0.80	1.463	0.031	-33.516
Going up	1.00	0.967	-1.523	8.511
Near top	1.15	0.841	-0.140	9.486
Going down	1.30	0.927	1.283	9.193

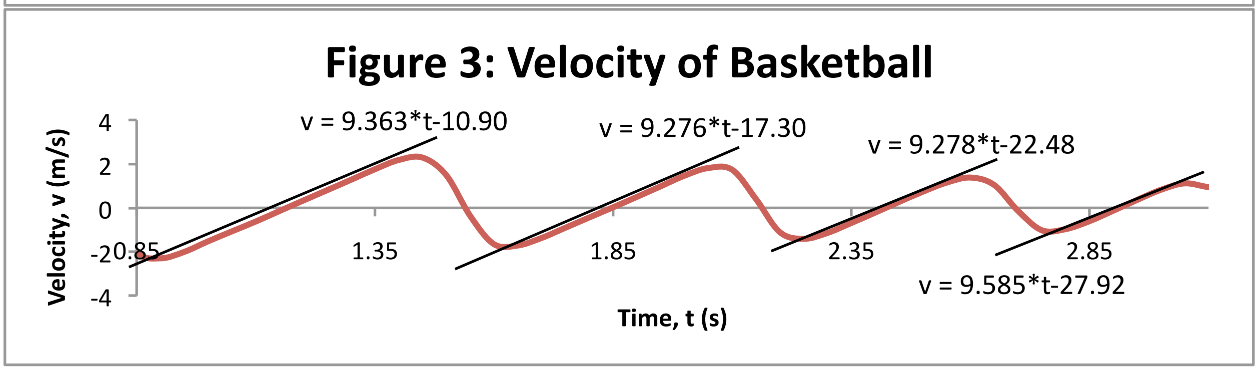
Table 2: Recorded Accelerations While Ball is in the Air

Bounce 1	Bounce 2	Bounce 3	Bounce 4
9.363 m/s^2	9.276 m/s^2	9.278 m/s^2	9.585 m/s^2
Average: 9.376 m/s^2	**Accel. of gravity:** 9.807 m/s^2		**% Error:** 4%

Average = (sum of all terms) / (number of terms)

% Error = |(accepted value) – (experimental value)| / (accepted value)





<u>*****Write in an example of your calculations if there are any here*****</u>

The slope of a line is defined as,

$$\text{slope}=\text{rise}/\text{run}=\Delta y/\Delta x. \qquad \text{(Eq. 2)}$$

It can be verified that the slope of a position versus time graph is equivalent to the velocity of the object being observed and that the slope of a velocity versus time graph is equivalent to the acceleration of the object being observed. This is made more clear by acknowledging the definition of speed (*v*) and acceleration (*a*)

$$v = \Delta x/\Delta t \qquad \text{(Eq. 3)}$$

and

$$a = \Delta v/\Delta t. \qquad \text{(Eq. 4)}$$

The intercepts of the graphs obtained did not have any physical significance because they depended on arbitrary events such as the relationship between when the data collection began and when the ball was dropped.

IV. CONCLUSION

Having observed how motion was plotted on position versus time and velocity versus time graphs, it was apparent the value of the slope of a position versus time graph is equal to the magnitude of the velocity of the object being observed. The value was positive or negative depending on which direction the object moved. Furthermore, the slope of a velocity versus time graph was shown to be equal to the magnitude of the acceleration of the object. According to how the test was set up, the slope was positive if the acceleration of the object is towards the ground or negative if the acceleration of the object was towards the ceiling.

Since velocity has been defined as a change in position over a change in time (see Eq. 3) with a specified direction and the slope as defined by Equation 2, it is clear that the slope of a position versus time graph gives velocity. This slope has a sign and a magnitude. This concept was observed experimentally when the prescribed motion pattern was replicated on a position versus time graph (see Fig. 1). For example, to create a line with a positive slope, the motion had to be at a constant rate away from the sensor. In a similar way, it was demonstrated that the slope of a velocity versus time graph gives acceleration (see Eq. 4). To acquire a positive slope on a velocity versus time graph, the motion had to be towards the sensor and slowing down at a constant rate or away from the sensor at an increasing rate.

The motion of a bouncing basketball was demonstrated in the same manner. Basic physics predicts that, while a bouncing ball is in the air, it experiences only the force of gravity accelerating it towards the ground. This is free fall motion. Since the motion sensor is placed above the basketball as it bounces and the motion sensor sees motion away from the sensor as positive, the peaks of the motion of the ball are the local minima on the position versus time graph and the points where the ball interacts with the ground are the local maxima. The time, position, velocity, and acceleration were thus determined at four specific locations of the motion of the ball (see Table 1). The velocity was obtained by analyzing the slope on the position versus time graph and by looking at the coordinate of the velocity versus time graph. The acceleration was obtained by looking at the slope of the velocity versus time graph.

A distinct positive slope was observed at periodic locations of the velocity versus time graph (see Fig. 3 and Table 2). These slopes imply a constant acceleration towards the ground that has an average value 4% away from the acceleration due to the gravity of earth. These accelerations occur in the region of the graph where the ball was in the air, so it is concluded that the acceleration due to earth's gravity was observed. The error in the result may come from the fact that there was actually more than simple physics at work in the experiment. That is, not only did the effect of gravity act on the ball, but also air added a slight resistance to the motion of the ball. Furthermore, the motion sensor had a non-negligible time-lag between data points collected which contributed to the uncertainty of the data.

V. QUESTIONS

DO THE QUESTIONS HERE