# Freefalling Washers
## Measuring Freefall Distances

We know that an object in free fall accelerates at $g = 9.80$ m/s$^2$ in the absence of air resistance. Since the acceleration of the falling object is constant, we can use the kinematic equations to predict its speed $v$ and distance fallen $d$ at any time $t$:

$$v = v_i + gt \text{ and } d = v_i t + \tfrac{1}{2} gt^2$$

If the object is dropped from rest, $v_i = 0$ and the equations become $d = \tfrac{1}{2} gt^2$ and $v = gt$. These relationships indicate that the speed of a freely falling object is proportional to the time of fall and that the total distance fallen is proportional to the *square* of the time of fall.

### PURPOSE

Given up to 10 washers and 5 meters of string, you will tie the washers onto the string in such a way that when you hold the string vertically and release it the washers strike the ground at equal time intervals. For this activity, you will calculate the distances between the washers tied to the string so that when the string is held vertically and released, one washer strikes the ground every 0.1 s.

### MATERIALS

meter stick
5 meters of string
stairs, bleachers, or ladder
scissors
10 washers, approximately 1" diameter

### PROCEDURE

1. Using the free fall equations given in the introduction, calculate the distances you will need to tie each washer to the string so that when you hold the string vertically and release it the washers will strike the ground at 0.1-second time intervals. Record your distances in the table on your student answer page and mark the distances on the diagram of the string that follows the table.

2. Tie a washer to one end of the string; then tie a washer at each of the distances you calculated in step 1.

3. While standing on stairs, bleachers, or a ladder, hold the string and washers vertically with the washer on the end of the string (washer "zero") just touching the floor. Release the string and listen for the time intervals between the sounds of each washer striking the floor below.

4. Adjust the separation of the washers if necessary and drop the string again.

5. Answer the conclusion questions on your student answer page.

Name _____

Period _____

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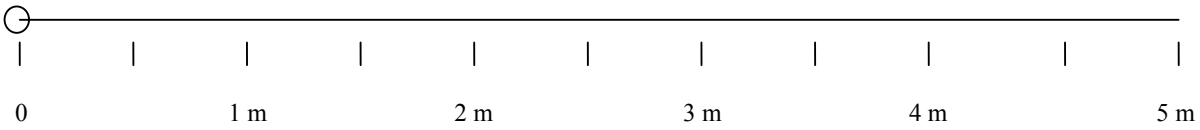
### DATA AND OBSERVATIONS

Determine the best way to arrange the washers on the string so that when the string is held vertically and dropped the washers will strike the ground at 0.1-second intervals. In the table below, show your work for your calculation of the distance between each washer or the total distance fallen by each washer. Be sure to indicate the time interval which is appropriate for each distance calculation.

On the diagram of the string that follows the table, mark the places you have determined the washers should be placed in order for them to strike the floor at 0.1-second intervals.

| Washer | Time (s) | Distance (m) |
|---|---|---|
| 1 | 0 | 0 |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |

Placement of washers along the string:




## CONCLUSION QUESTIONS

1. As the string and washers fall, each washer strikes the floor 0.1 second after the one before it. Does this mean all of the washers strike the floor with the same speed? Explain.

2. At the instant the first washer strikes the floor, the remaining washers are falling freely. Which washer is traveling at the greatest speed, the second washer or the last washer at the top of the string? Or, do all of the washers have the same speed at this instant? Explain your answer.

3. a. How much greater is the second interval distance (washer 1 to washer 2) than the first interval distance (washer 0 to washer 1)?

   b. How much greater is the third interval distance (washer 2 to washer 3) than the second interval distance (washer 1 to washer 2)?

   c. How much greater is the fourth interval distance (washer 3 to washer 4) than the first interval distance (washer 2 to washer 3)?

d. Make a prediction about the increase in interval distance for the remaining intervals. Why do you think the increase in interval distance follows this pattern?

4. Determine the speed of the fifth washer (at the top of the fourth distance interval)
   a. at the instant the third washer (at the top of the second interval) strikes the ground.

   b. at the instant the fifth washer strikes the ground.

5. If we wanted to have the washers strike the floor at 0.2-second intervals, should we double each interval distance between each washer in comparison to the 0.1-second intervals? Why or why not?