

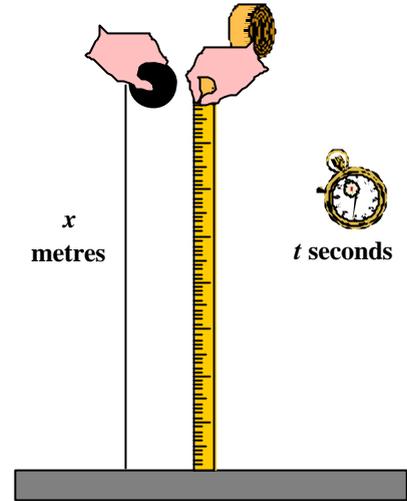
# Falling Ball

## Worksheet

Galileo claimed that all objects near the earth's surface fall with the same acceleration. In this activity you will attempt to validate Galileo's findings.

**Does a ball fall with constant acceleration,  $g = 9.8 \text{ ms}^{-2}$ ?**

From this claim you can make predictions about how displacement of a falling object varies with time. By using the ball, tape measure and stopwatch, you can measure how long the ball takes to fall through known distances. You can then compare these measurements with your predictions, thus checking Galileo's claim.



### Set up the model

When setting up a model you need to think carefully about the **assumptions** you make, the quantities that you keep **constant** and those you **vary**.

Here are some suggestions:

#### Assumptions:

- there is no air resistance
- the ball will always be released from rest
- the acceleration,  $a \text{ ms}^{-2}$  is constant with  $a = 9.8$

#### Constants

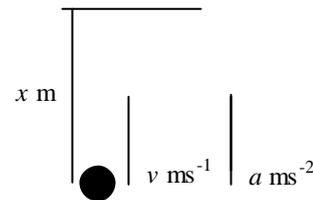
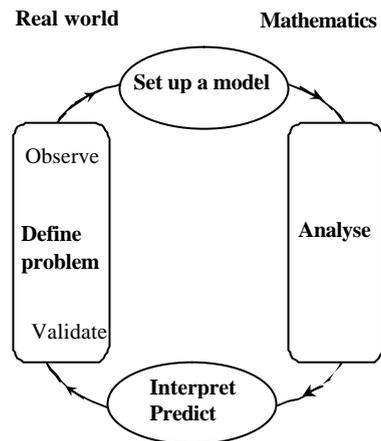
- the same ball will be used throughout

#### Variables

- the time  $t$  seconds
- the displacement,  $x$  metres, of the ball (i.e. the distance fallen by the ball) at time,  $t$
- the velocity,  $v \text{ ms}^{-1}$ , of the ball at time,  $t$

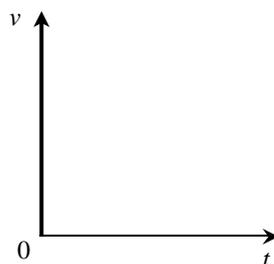
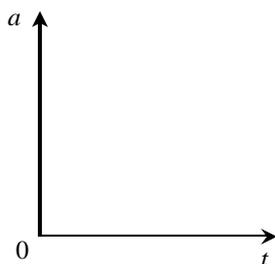
#### Draw a diagram

- this is a concise way of describing the features of the model and should show clearly the constants and variables that you use



### Analyse

Sketch graphs of  $a$  and  $v$  against  $t$  on the axes below.



Write down an expression for  $v$  in terms of  $t$ .

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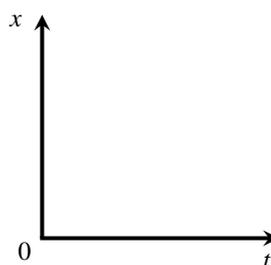
The displacement,  $x$ , is given by the area under the 2<sup>nd</sup> graph.

Use this to write down a function to model  $x$  in terms of  $t$ .

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On these axes sketch a graph of  $x$  against  $t$ .



**Predict**

Write a sentence or two describing how, if Galileo's model is true, both the velocity and the displacement of a falling ball vary with time.

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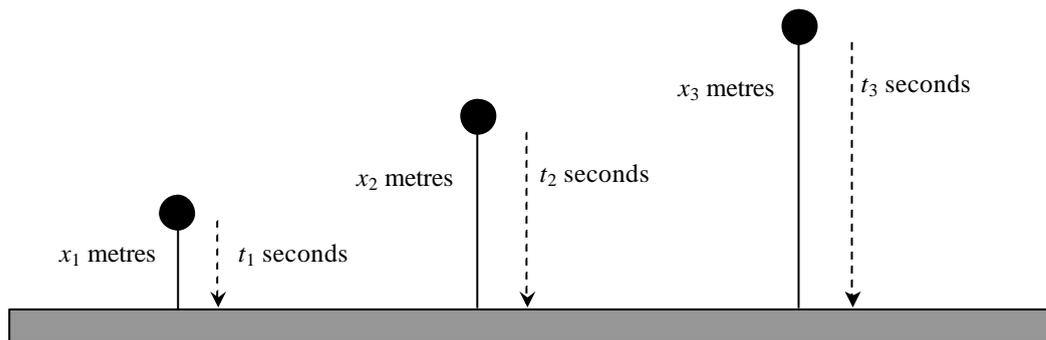
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**Validate**

You now have a theoretical model of what you expect a falling ball to do. Validate this model by timing the path of a real falling ball. It is difficult to measure directly the acceleration or velocity of a falling ball: collect data so that you can draw a graph plotting distance fallen,  $x$  metres, against time,  $t$  seconds.

Here is some practical advice:

- Instead of always releasing the ball from the same point and timing how long it takes to fall a measured distance from the release point, it is easier to release the ball from different heights above the floor and measure the time taken to reach the floor, as illustrated below. You then need to assume, for example, that in the first second of the ball's motion it will fall through the same distance no matter from where it is released.



- You may find a 'timer ball' useful in carrying out this practical work. This is a ball with a built-in stopwatch, which starts timing when the ball is released and stops when the ball first hits the ground. If you use an ordinary ball and a stopwatch, you may find it best to time the ball over longer distances perhaps by dropping it down a stair well.



- Whichever method you use, it is important to be consistent, and accurate. You need to ensure that the ball is always released from rest. If one person is releasing the ball and someone else is timing its fall, the person releasing the ball needs to count down to the release, perhaps saying, "Three, two, one, GO" or something similar.
- Time the ball a number of times over the same distance, and take an average value. A table is given below - you can enter up to 5 values of the time for each of 6 distances and the average values. Will it be better to use the mean or median?

$x$						
$t_1$						
$t_2$						
$t_3$						
$t_4$						
$t_5$						
Average $t$						

Use a graphic calculator or a spreadsheet to draw an accurate graph showing your readings of the distance fallen against time. On the same axes draw the graph of the function that you found for  $x$  in terms of  $t$  in your theoretical analysis (from the bottom of page 1). How well does the graph of your readings agree with that of the model?

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Find a function which fits your measured readings. ....

How does the function compare with the one you obtained from theoretical analysis?

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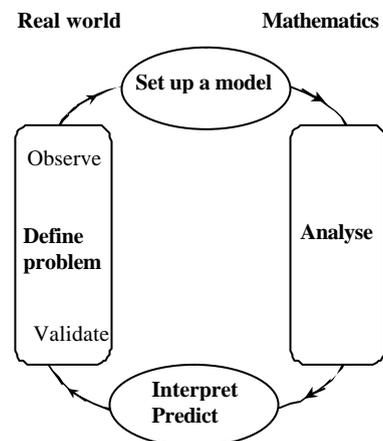
How does the value for the acceleration suggested by your readings compare with the value of  $a = g = 9.8 \text{ ms}^{-2}$ ?

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### Redefining the problem

If the value you have found for the acceleration differs significantly from  $9.8 \text{ ms}^{-2}$  you will need to think about how accurately you carried out your practical work or whether the value  $a = g = 9.8 \text{ ms}^{-2}$  is valid.

Think also about the assumptions that were made at the beginning. In cases where results in the real world do not validate the model, the problem must be tackled again using fewer or different assumptions and the modelling cycle starts again.



**Teacher Notes**

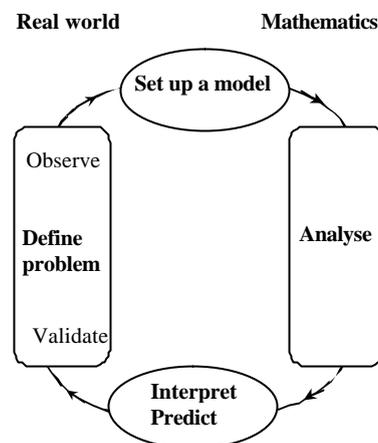
**Unit** Advanced Level, Dynamics

**Notes on Activity**

This activity was included in the book *Mechanics 1* which was funded by the Nuffield Foundation and published by Longman in 1994 (ISBN 0-582-09979-X).

The activity involves motion with constant acceleration in a context with which students will be familiar. You could start by discussing gravity with students to find out what they already know or by asking them to use the internet to find out what they can about gravity and Galileo's experiments. It is recommended that you discuss the idea of a modelling cycle and the main points given on page 1 before students try to analyse the situation and make predictions.

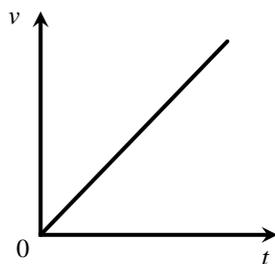
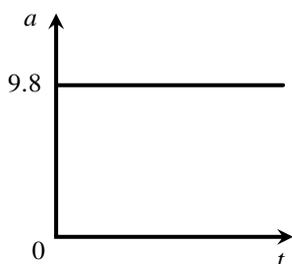
You may want to change some of the details in the practical advice given on pages 2 and 3 and go through this with students before they carry out the experiment.



Students can use either a graphic calculator or spreadsheet to find a function to model their data. If possible use both and ask students which they prefer and why.

**Answers**

**Page 1**



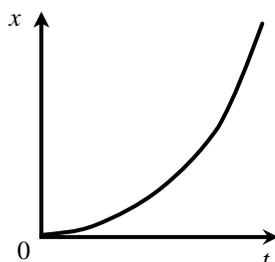
Expression for  $v$  in terms of  $t$ :

$$v = 9.8t$$

Function to model  $x$  in terms of  $t$ :

$$x = 4.9t^2$$

**Page 2**



**Predictions**

The velocity of the ball will increase steadily with time.

The displacement will initially increase slowly then more and more rapidly as time passes.

