



Activity description

This is a practical activity in which students analyse and validate Galileo's model for the motion of a projectile. Students will need to be familiar with the uniform acceleration equations for motion in a straight line.

Suitability and time

Level 3 (Advanced); 2–3 hours

Resources and equipment

Student information sheet, worksheet

Optional: slideshow

Ball for demonstrating motion of a projectile, e.g. tennis ball,

For practical activity: track, small block, small ball, ruler, stopwatch, talcum powder or salt (optional), calculators, graph paper

Health & Safety

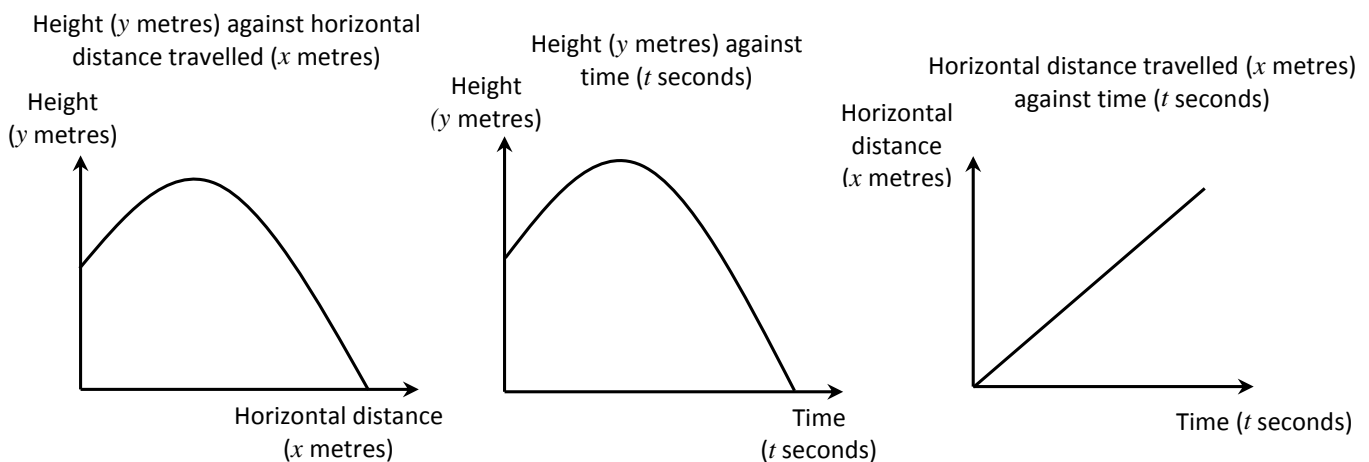
Carry out your own risk assessment and take suitable precautions before starting any practical work. Do not rely on what is said here.

Key mathematical language

Model, projectile, horizontal, vertical, velocity, acceleration, range, proportional, analyse, predict, validate, plot, compare

Notes on the activity

The first two slides can be used to introduce the activity before you use the graph-sketching activity (on page 1 of the student sheets) to provoke a class discussion of the motion of projectiles and the features of distance–time graphs. The graphs will depend on how the ball is thrown. Possible responses are given on slide 3 of the slideshow and shown below.



Some students might already know that the trajectory of a projectile is a parabola and that horizontal distance is proportional to time. However, they might not realise that the vertical distance is a quadratic in time, unless they recall the uniform acceleration equations or are already familiar with modelling projectiles.

Depending on the experience or interests of the students, the description of Galileo's work and the diagram of the parabolic trajectory could be touched on briefly, or more deeply as an extension activity.

During the activity

The analysis and practical parts of the activity can be done in either order, depending on availability of equipment.

Students do the practical activity (Tasks 1 and 2) in small groups.

Advise students to repeat their experiments a number of times and work with an average of their results. The analysis (Tasks 3–5) can be done by students working in pairs or small groups. Students who do the analysis first will need to be given the values of h and u to use in Task 5.

Points for discussion

If possible use the slideshow to aid class discussion about the graphs showing the motion of a projectile, then Galileo's approach. The aim of the student experiment is to validate his results.

Ask students what assumptions are being made by modelling a ball as a projectile.

The diagram accompanying the discussion of Galileo's experiment could be used to motivate a discussion about what we mean when we say that a body is 'moving with constant velocity'.

Discuss possible methods of checking that the vertical distances on Galileo's diagram are proportional to t^2 :

- check that the ratios of bg , bl , bn to bo are square numbers
- check that the differences in successive distances are odd multiples of bo
- plot vertical distance against t^2 to obtain a straight line graph through the origin.

Although the model has already been set up, it would be worth briefly discussing any modelling assumptions, and identifying constants and variables.

Modelling assumptions: the projected body is a particle, air resistance is negligible, speed along BC is constant, the path of the projectile lies in a plane.

Constants: the acceleration of the projectile throughout the motion is g downwards.

Variables: time from the instant of launch, speed of projection, height of the table, the range of the projectile.

If the height of the table is fixed during the experiment, the only factor affecting the range of the projectile is the launch velocity, which is in turn controlled by the release point on the slope AB. Discuss how the assumption that velocity is constant along BC allows the launch velocity to be estimated using the suggested method.

If you do not wish students to carry out the extension work, delete slides 11, 12 and 13 from the slideshow.

After the activity, help students to reflect on their work using the questions on the student sheets and the last slide in the slideshow, repeated below:

- What are the advantages of Galileo's projectile model?
- Do your experimental results validate Galileo's projectile model?
- Suggest examples of motion which could not be modelled well as projectiles.

Extensions

The extension generalizes the model to projection which is not horizontal. If appropriate, this could be related to work students have done on vectors. Slides 11, 12 and 13 introduce the extension and also give the answers.

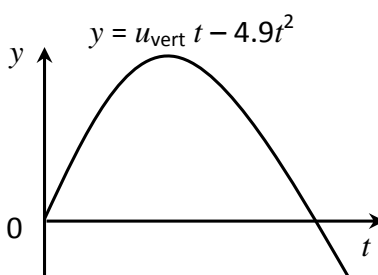
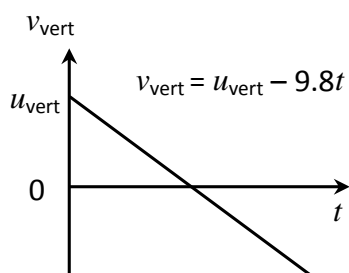
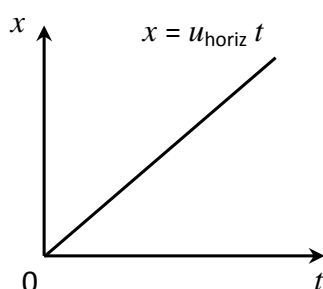
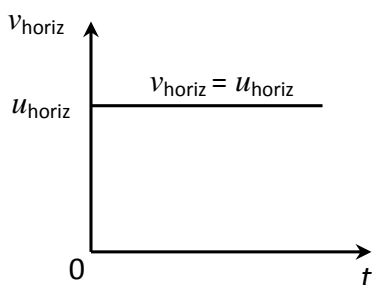
Answers

$$3a \ y = \frac{1}{2}gt^2, \quad 3b \ t = \sqrt{\frac{2h}{g}} \quad 4a \ x = ut, \quad 4b \ R = u\sqrt{\frac{2h}{g}}$$

4c A graph of R against u is a straight-line graph through O with gradient $\sqrt{\frac{2h}{g}}$.

Extension answers

- 1 $v_{\text{horiz}} = u_{\text{horiz}}, \ x = u_{\text{horiz}}t, \ v_{\text{vert}} = u_{\text{vert}} - 9.8t, \ y = u_{\text{vert}}t - 4.9t^2$.
- 2 The graphs below are given on slides 12 and 13 of the slideshow.



Acknowledgement

Adapted from Nuffield
Advanced Mathematics
Mechanics 1.
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