Activity description

In this activity students use the equations for motion in a straight line with constant acceleration, and the projectile model, to solve problems involving the motion of projectiles in real contexts.

Suitability

Level 3 (Advanced)

Time

2 hours

Resources

Student information sheet, worksheet.

Equipment

Calculators
Optional: graph paper, spreadsheet (for extension activity)

Key mathematical language

Projectile, force, component, acceleration, velocity, displacement, angle, sine, cosine, model, assumptions, underestimate, overestimate.

Notes on the activity

This activity could be used to introduce students to the projectile model, or as a revision activity. If you use it as an introduction, you may prefer to split it into two or more sections.

Students will need to be familiar with the equations for motion in a straight line with constant acceleration, and how to use these to solve problems involving motion in a straight line, including vertical motion.

During the activity

Students could work individually or in pairs. If this activity is used for revision, students could work in small group and discuss how to solve the worked examples, rather than working through the details on the information sheet.

Points for discussion

Discuss how the equations of motion in a straight line with constant acceleration can be applied separately in the horizontal and vertical directions. Emphasise the assumptions that need to be made to allow problems to be solved and discuss whether these are realistic in practice.

At the end of the activity you can discuss the questions given in the 'Reflect on your work' section of the student sheets. These are repeated below.

- How does separating the vertical and horizontal motion help you to solve the problems?
- What affects the time of flight of a body if it is projected at an angle to the horizontal?
- What affects the time of flight of a body if it projected horizontally?
- How have your modelling assumptions affected your solutions?
  (It might be necessary to remind students that they should make a note of any modelling assumptions they make when solving the projectile problems, and decide how these have affected their answers.)

Extensions

Students are asked to investigate how the time of flight and range are affected by the velocity of projection. Some students may work algebraically with the projectile model, while others may use one of the problems on the worksheet (such as problems 1, 2 or 3) and investigate how different values of initial velocity affect their answers. These students might choose to plot their results on a graph or use a spreadsheet.

It might be worth prompting students to think about whether the same relationship between velocity and range holds whether the body is projected horizontally or at an angle to the horizontal.

Many A-level Mechanics textbooks and websites provide exercises which can be used for further practice. Projectile problems may also be solved using vector methods. A separate activity covers this method.

Answers

1a x = 24.6 metres, y = 10.2 metres (to 3 sf)

b 10.5 metres (to 3 sf)

c 59.9 metres (to 3 sf) from the point at which it was kicked

Assumptions – no air resistance, wind or other forces (except weight) act upon the ball.

Air resistance would slow down the ball and decrease the values given in the answers. Wind could increase or decrease them. Any spin given to the ball in the kick or any intervention by other players would also affect the results.

2a x = 89.1 metres, y = 14.8 metres (to 3 sf)

b 16.8 metres (to 3 sf)

c 132 metres (to 3 sf) from the point at which it was hit.

Assumptions – no air resistance, wind or other forces (except weight) act upon the ball.

Air resistance would slow down the ball and decrease the values given in the answers. Wind could act to increase or decrease them. Any spin given when the ball was hit or any obstacles in the path of the ball would also affect the results.

3a 1.28 seconds (to 3 sf) **b** 12.8 metres (to 3 sf) **c** 12.5 m s^{-1} (to 3 sf)

Assumptions – no air resistance, wind or other forces (except weight) act upon the stone.

Air resistance would slow down the stone. This means the time taken to reach the sea would be more than the answer given in (**a**), but the distance from the cliff and the velocity of the stone when it enters the sea would be less than the answers given in (**b**) and (**c**). Wind and any spin given when the stone was thrown would also affect the results.

4a The ball will be at a height of 0.911 metres (to 3 sf) when it reaches the net.

b The ball hits the ground 0.684 seconds after it was hit, with a horizontal distance of 5.20 metres (to 3 sf) from where it was hit (that is 3.20 metres behind the net).

Assumptions – no air resistance, wind or other forces (except weight) act upon the ball.

Any of these forces could affect the results sufficiently to mean that the ball does not pass over the net (0.911 m is not much more than 0.9 m). This means that the answers to the questions could be significantly different from those given above.

5a 3.19 seconds (to 3sf)

b 63.9 metres (to 3sf)

c 31.3 m s^{-1} (to 3sf)

Assumptions – no air resistance, wind or other forces (except weight) act upon the package.

Air resistance would slow down the package. This means the time taken to reach the ground is likely to be more than the answer given in (**a**), whilst the distance from P and the velocity of the package when it reaches the ground are likely to be less than the answers given in (**b**) and (**c**). Wind could also affect the results.

6 No – the height of the ball as it passes over the net is 4.41 metres (to 3 sf).

Assumptions – no air resistance, wind or other forces (except weight) act upon the ball.

The player's opponent can only reach a height of 2.7 metres – air resistance and wind are unlikely to affect the ball sufficiently to bring it within his reach.

7 Ball will be at a height of 2.53 metres (to 3 sf) when it reaches the net. The highest height reached by the ball is 3.06 metres (to 3 sf), but this is reached before it gets to the net.

Assumptions – no air resistance, wind or other forces (except weight) act upon the ball.

Air resistance is unlikely to affect the ball much, but a strong wind may affect the result. Any spin given to the ball when it was thrown could also affect the result.

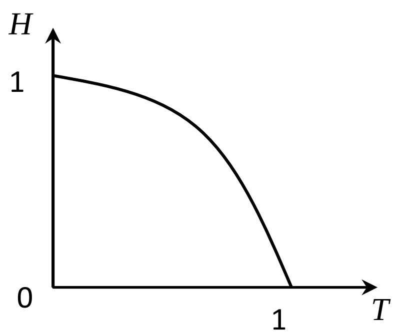
8a 0.0766 metres or 7.66 cm (to 3 sf)

b 0.306 metres or 30.6 cm (to 3 sf)

Assumptions – no air resistance, wind or other forces (except weight) act upon the ball.

These could affect the results significantly over a long distance.

9a See below. **b i** The graph would be the same. **b ii** 5.25 metres (to 3 sf)



Assumptions – no air resistance, wind or other forces (except weight) act upon the diver.

Air resistance would slow her down so the time taken to reach the water would increase slightly. The distance across the pool would be less.

Acknowledgement

A few of the problems used in this activity originally appeared in Nuffield Advanced Mathematics *Mechanics 1* Longman 1994. ISBN 0 582 09979 X.