A Guide to Projectile Motion

Teaching Approach

Projectile motion refers to the free fall motion of an object after it has been projected (launched). It is therefore important to help learners to understand clearly what is meant by free fall, especially since falling has a different meaning in common language than in scientific language. This is explained in Lessons 1 and 2. During free fall, an object accelerates at the acceleration due to gravity, g, 9,8 $m \cdot s^{-2}$ downward. We confirm this value through practical measurement in the laboratory in Lesson 3.

The projectile motion section offers an opportunity to consolidate the learners' understanding of motion, developed during earlier grades. This includes application of the equations of motion, and use of graphs of motion, which the learners were introduced to in grade 10. This is focussed on in Lessons 4 and 5 respectively. Lesson 6 gives learners a detailed description of how to do these calculations and will be valuable practice.

The task lesson is provided either as additional practice for the learners, or as an assessment tool to evaluate learning of this section of work.

Video Summaries

Some videos have a 'PAUSE' moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day's lesson; if desired, learners can be given specific questions to answer in preparation for the next day's lesson

1. Downward Free Fall

We focus on the basic concepts and sample data for an object moving downward while in free fall. An object is in free fall when its weight is the only significant vertical force acting on it. It is then called a projectile.

2. Upward and Downward Free Fall

This is a lesson on free fall. In scientific language an object can be falling when it is moving upward, downward, or stationary for an instant at the top of its motion.

3. Practical Confirmation of the Value of 'g', the Acceleration Due to Gravity

This lesson confirms the value of the acceleration due to gravity, g, as 9,8 $m \cdot s^{-2}$. A ball is dropped past a motion detector which measures its initial and final velocities as it falls a distance of 0,5 m.

4. Equations of Motion and Free Fall

In this lesson we practice using the equations of motion to solve projectile motion problems.

5. Graphing Free Fall I

In this lesson we draw position-time, velocity-time and acceleration-time graphs for projectile motion.

6. Graphing Free Fall II

We've drawn graphs for a projectile moving downward. In this lesson we draw graphs of a projectile moving both up and down.

7. **Calculations**

   In this lesson we work through some calculations about 1-dimensional projectile motion.

8. **Calculations with Graphs**

   In this lesson we will look at some questions related to two graphs of motion.

Resource Material

1. Downward Free Fall	http://www.youtube.com/watch?v=ndFXXasM6ZE	A ball and a feather fall together in a vacuum tube.
	http://www.slideshare.net/AngelaStott/projectile-motion-down	A PowerPoint on SlideShare, with many of the graphics and text used in the video.
	http://www.youtube.com/watch?v=b3Cv2WTwZak	Footage from the moon. An astronaut drops a feather and a hammer at the same moment. They hit the moon's surface at the same time because they are both in free fall, since there is no atmosphere to provide air resistance on the moon.
2. Upward and Downward Free Fall	http://www.physicsclassroom.com/Class/1DKin/	This link leads to the contents page for 1-D kinematics for The Physics Classroom. This contains many links, each of which leads to clear, concise explanations of an aspect of 1-D kinematics. These explanations are clearly and attractively illustrated, include worked examples, and have links to other useful resources for learners and teachers.
	http://www.physicsclassroom.com/mmedia/vectors/mzi.cfm	A simulation of what would happen if a person threw a banana at a monkey: In a gravity-free environment, on Earth, and on planets with stronger or weaker forces of gravity than Earth.
	http://www.slideshare.net/AngelaStott/projectile-motion-upanddown	A PowerPoint on SlideShare, with many of the graphics and text used in the video.
3. Practical Confirmation of the Value of 'g', the Acceleration Due to Gravity	http://video.mit.edu/watch/blossoms-finding-acceleration-of-gravity-g-using-pendulum-english-voiceover-7716/	A video showing an alternative way of measuring acceleration due to gravity, g, using a pendulum.
	http://gilesc.pbworks.com/f/PendulumLab.pdf	A worksheet with instructions on how to measure acceleration due to gravity, g, using a pendulum, and questions to guide teachers and learners through this practical.
	https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCwQFjAA&url=http%3A	A Word document containing instructions on how to measure the value of the acceleration due to

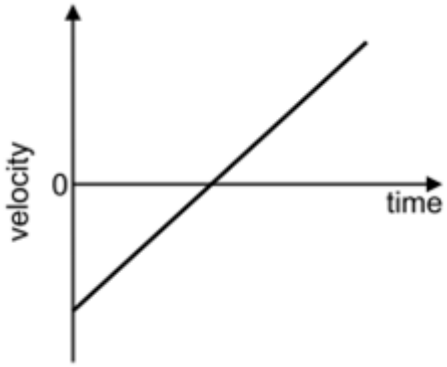
	%2F%2Fwww.schoolphysics.co.uk%2Fage11-14%2FMechanics%2FMotion%2Fexperiments%2Fgravity_ticker_timer.doc&ei=JO1nUs3GJ-6A7QblzYGgAQ&usg=AFQjCNH0FLFyvL0XXBvpczmIdQY-jZQUIA&sig2=y-ztWBgeJ9E3ZbCnl56BhQ&bvm=bv.55123115,d.ZGU	gravity, g, using a ticker-timer.
4. Calculations for Photoelectric Effect	https://www.khanacademy.org/science/physics/one-dimensional-motion/old-projectile-motion/v/projectile-motion--part-1	A video showing a worked example for 1-D vertical projectile motion from the Khan Academy. There are 5 parts to this series, so learners can click on the links to the next parts for more.
	https://www.khanacademy.org/science/physics/one-dimensional-motion/kinematic_formulas/v/projectile-height-given-time	A video showing a worked example for 1-D vertical projectile motion from the Khan Academy. The height a projectile reaches is calculated from information about the time of the projectile's motion. There are two other relevant videos ('Deriving Max Projectile Displacement Given Time' and 'Impact Velocity From Given Height') which can also be accessed from this link.
	http://phet.colorado.edu/en/simulation/projectile-motion	A Phet simulation of projectile motion.
5. Graphing Free Fall I	https://everythingscience.co.za/grade-12/06-motion-in-two-dimensions/06-motion-in-two-dimensions-02.cnxmlplus	Text from Siyavula's free grade 12 physical science textbook. Includes a number of worked examples using equations and graphs of motion for 1-D vertical projectile motion.
6. Graphing Free Fall II	https://www.khanacademy.org/science/physics/one-dimensional-motion/kinematic_formulas/v/plotting-projectile-displacement--acceleration--and-velocity	A video from the Khan Academy in which position-time, velocity-time and acceleration-time graphs are drawn for 1-D vertical projectile motion.
7. Calculations	http://www.slideshare.net/AngelaStott/projectile-motion-equationsofmotion	A slideshare PowerPoint containing most of the questions and graphics used in this video.

8. Calculations with Graphs	http://www.slideshare.net/AngelaStott/projectile-motion-graphs http://www.slideshare.net/AngelaStott/projectile-motion-graphs	A slideshare PowerPoint containing most of the questions and graphics used in this video.

Task

Question 1

Refer to the following velocity-time graph of a projectile to answer these questions:



1.1 State whether each of the following statements is true or false. If false, correct the statement:

1.1.1 This projectile's velocity is constant.

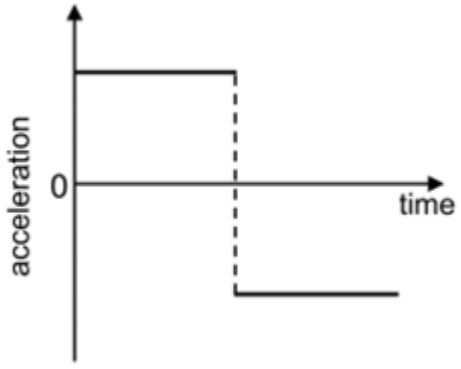
1.1.2 This projectile's acceleration is positive.

1.1.3 This projectile's acceleration is constant.

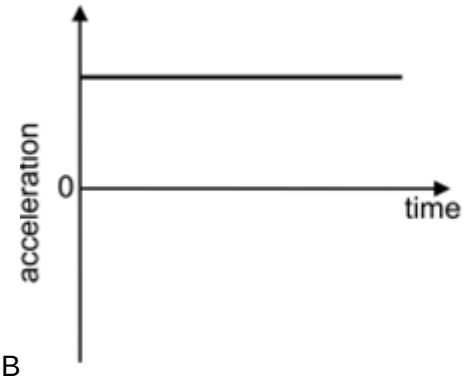
1.1.4 The downward direction is taken as positive for this graph.

1.1.5 This graph shows that the projectile moves downward, hits the ground and bounces up.

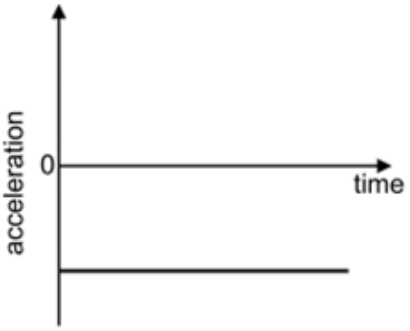
1.2 Which one of these graphs represents the acceleration-time graph which corresponds to the motion of this projectile?



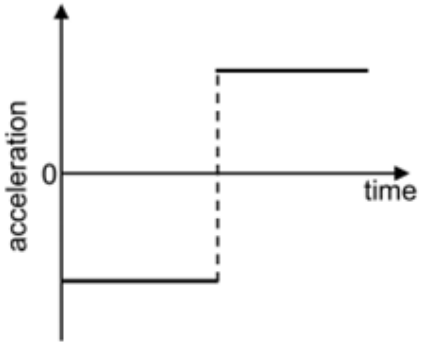
A



B



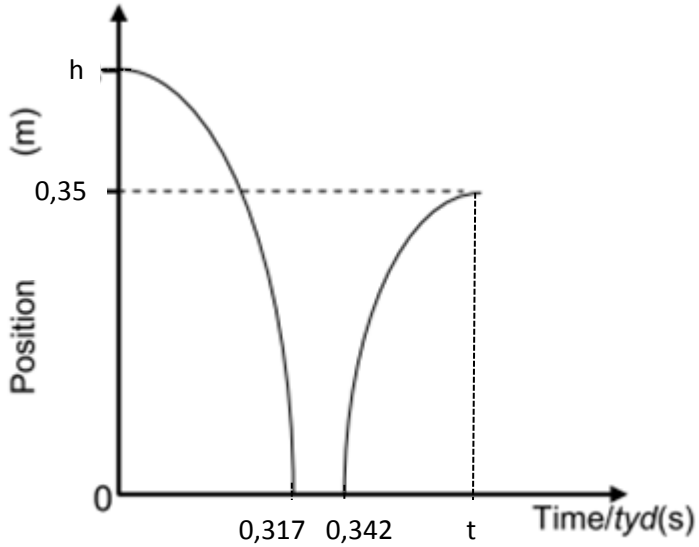
C



D

Question 2

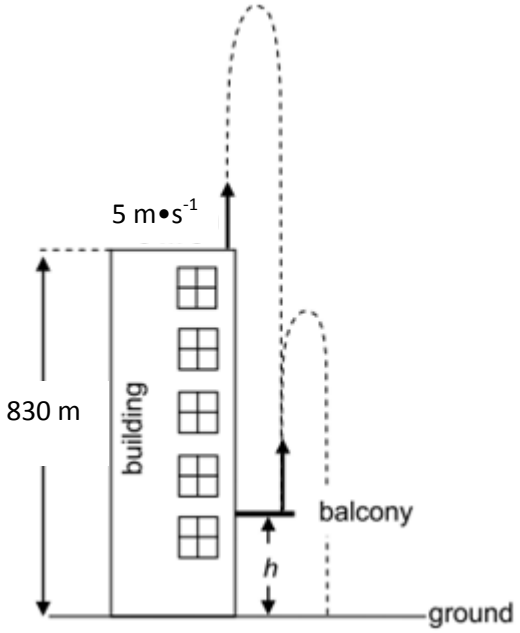
Refer to the following position-time graph of a bouncing ball to answer these questions. Ignore air resistance.



2.1 Calculate the height (h) the ball was dropped from.
2.2 What was the velocity of the ball the moment before it hit the ground (time 0,317 s)?
2.3 What was the velocity of the ball the moment after it left the ground (time 0,342 s)?
2.4 What was the velocity of the ball at time t?
2.5 When the ball is at maximum height (times 0 and t), is its acceleration upward, downward or zero?

Question 3

An object is projected vertically upwards at 5 m•s^{-1} from the roof of a building which is 830 m high. It strikes a balcony below after 8 s. The object then bounces off the balcony and strikes the ground as illustrated below. Ignore the effects of friction.



3.1 Calculate the:

3.1.1 Velocity at which the object strikes the balcony

3.1.2 Height, h, of the balcony above the ground.

3.2 The object bounces off the balcony at a velocity of 60 $m \cdot s^{-1}$ and strikes the ground 18,4 s after it leaves the balcony.

Sketch a velocity-time graph to represent the motion of the object from the moment it is projected from the ROOF of the building until it strikes the GROUND. (Note: The sketch does not need to be to scale). Indicate the following velocity and time values on the graph:

- The initial velocity at which the object was projected from the roof of the building
- The velocity at which the object strikes the balcony
- The time when the object strikes the balcony
- The velocity at which the object bounces off the balcony
- The time when the object strikes the ground

Task Answers

Question 1

1.1

1.1.1 False. The projectile's velocity increased constantly.

1.1.2 True.

1.1.3 True.

1.1.4 True.

1.1.5 False. The graph shows the projectile moving upward, reaching maximum height and zero velocity, and then moving downward.

1.2 B

Question 2

Let upward be positive

2.1 $\Delta y = v_i \Delta t + \frac{1}{2} a\Delta t^2$

$\Delta y = 0(0,317) + \frac{1}{2} (-9,8) 0,317)^2$

$\Delta y = 0 - 0,49$

$\Delta y = -0,49$ m

The ball moves 0,49 m downward during the first 0,317 s. Therefore, the height, h, is 0,49 m above the ground.

2.2 $v_f = v_i + a\Delta t$

$v_f = 0 + (-9,8) (0,317)$

$v_f = -3,1$ m•s^{-1}

$v_f = 3,1$ m•s^{-1} downward

2.3 $v_f^2 = v_i^2 + 2a\Delta y$

$0 = v_i^2 + 2(-9,8)(0,35)$

$-v_i^2 = - 6,86$

$v_i^2 = 6,86$

$v_i = \sqrt{6,86}$

$v_i = 2,62$ m•s^{-1} upward

2.4 0 m•s^{-1}

2.5 Downward

Question 3

Let upward be positive

3.1

3.1.1 $v_f = v_i + a\Delta t$

$v_f = 5 + (-9,8)(8)$

$v_f = 5 - 78,4$ m•s^{-1}

$v_f = -73,4$ m•s^{-1} downward

3.1.2 $\Delta y = v_i \Delta t + \frac{1}{2} a\Delta t^2$

$\Delta y = 5(8) + \frac{1}{2} (-9,8)(8)^2$

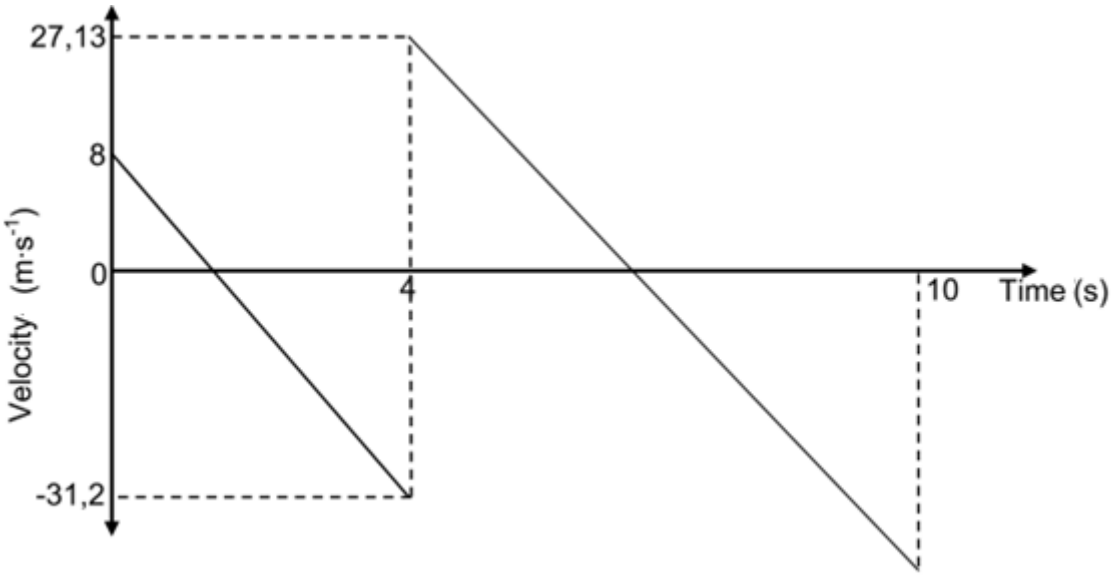
$\Delta y = 40 - 313,6$

$\Delta y = - 273,6$ m

So the ball hits the balcony 273,6 m below its starting point, which was 830 m above the ground, therefore the balcony is (830 – 273,6) m above the ground.

So the balcony is 556,4 m above the ground.

3.2



Acknowledgements

Mindset Learn Executive Head	Dylan Busa
Content Manager Classroom Resources	Jenny Lamont
Content Coordinator Classroom Resources	Helen Robertson
Content Administrator	Agness Munthali
Content Developer	Angela Stott
Content Reviewers	Liz Harris
	Dawn Clark

Produced for Mindset Learn by Traffic

Facilities Coordinator	Cezanne Scheepers
Production Manager	Belinda Renney
Director	Alriette Gibbs
Editor	Nonhlanhla Nxumalo
Presenter	Patrick Shabangu
Studio Crew	Abram Tjale
	James Tselapedi
	Wilson Mthembu
Graphics	Wayne Sanderson

Credits