Year 12 Science: Motion, vectors and projectiles

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A cyclist speeds up uniformly from 2.0 m s^{-1} to 8.0 m s^{-1} in 4.0 s. What is her acceleration?

2. How far does she travel in those 4.0 s?

3. A ball is thrown straight up at 14.7 m s^{-1}. How high does it rise?

4. A rock rolls horizontally off a cliff 44.1 m high at 5.00 m s^{-1}. How far from the foot of the cliff does it land?

5. A plane heads north at 70.0 m s^{-1} through air that is moving east at 24.0 m s^{-1}. What is its velocity over the ground?

Exam-style question: the driving range

At a golf driving range, Tama hits a ball from the ground at 30.0 m s^{-1} at 25.0° above the horizontal. A safety fence 3.00 m high stands 60.0 m away on level ground. Ignore air resistance and use g = 9.8 m s^{-2}.

6. Describe the force on the ball during its flight and what it does to the horizontal and vertical parts of its velocity.

7. Calculate the horizontal and vertical components of the ball's initial velocity.

8. By calculating, decide whether the ball clears the fence.

9. Explain why the ball's speed is smallest at the top of its path, but not zero.

Fix the mistake

10. Correct this statement: "At the top of its path the ball has stopped, so its acceleration is zero there."

11. Correct this statement: "Time to reach the posts = 45.0 m ÷ 25.0 m s^{-1}, using the launch speed."

12. Correct this statement: "A ball thrown up at 14.7 m s^{-1}: $v_f^2 = 14.7^2 + 2 \times 9.8 \times d$, so d comes out negative."

13. Correct this statement: "The heavier ball has more weight, so it falls faster and lands sooner."

Answer key (for parents and tutors)

1. A cyclist speeds up uniformly from 2.0 m s^{-1} to 8.0 m s^{-1} in 4.0 s. What is her acceleration?
   $a = (v_f - v_i) \div t = (8.0 - 2.0) \div 4.0 = 1.5$ m s^{-2}.

2. How far does she travel in those 4.0 s?
   $d = \frac{1}{2}(v_i + v_f)t = \frac{1}{2} \times (2.0 + 8.0) \times 4.0 = 20$ m.

3. A ball is thrown straight up at 14.7 m s^{-1}. How high does it rise?
   Up is positive: $0 = 14.7^2 + 2 \times (-9.8) \times d$, so $d = 216.09 \div 19.6 = 11.0$ m.

4. A rock rolls horizontally off a cliff 44.1 m high at 5.00 m s^{-1}. How far from the foot of the cliff does it land?
   Vertically $44.1 = \frac{1}{2} \times 9.8 \times t^2$, so $t^2 = 9.00$ s^2 and $t = 3.00$ s; horizontally $d = 5.00 \times 3.00 = 15.0$ m.

5. A plane heads north at 70.0 m s^{-1} through air that is moving east at 24.0 m s^{-1}. What is its velocity over the ground?
   $v = \sqrt{(70.0^2 + 24.0^2)} = \sqrt{5476} = 74.0$ m s^{-1}; $\tan\theta = 24.0 \div 70.0$, $\theta = 18.9°$, so 74.0 m s^{-1} at 18.9° east of north.

6. Describe the force on the ball during its flight and what it does to the horizontal and vertical parts of its velocity.
   Only the weight acts, straight down. There is no horizontal force, so the horizontal velocity stays the same; the vertical velocity decreases on the way up, is zero at the top and increases on the way down, changing at 9.8 m s^{-2} (Achieved for one correct statement, Merit for linking the force to each component).

7. Calculate the horizontal and vertical components of the ball's initial velocity.
   $v_x = 30.0 \cos 25.0° = 27.19$ m s^{-1}, about 27.2 m s^{-1}; $v_y = 30.0 \sin 25.0° = 12.68$ m s^{-1}, about 12.7 m s^{-1} (Achieved for either).

8. By calculating, decide whether the ball clears the fence.
   Time to travel 60.0 m across: $t = 60.0 \div 27.19 = 2.2068$ s (keep the unrounded value in the calculator). Height then: $d = v_i t + \frac{1}{2}at^2 = 12.68 \times 2.2068 - 4.9 \times 2.2068^2 = 27.98 - 23.86 = 4.12$ m. Check it is still in the air: time of flight $= 2 \times 12.68 \div 9.8 = 2.59$ s, longer than 2.21 s. So the ball is 4.12 m up when it reaches the fence and clears the 3.00 m fence (Merit for the method with one slip, Excellence for the correct height and a concluding sentence).

9. Explain why the ball's speed is smallest at the top of its path, but not zero.
   The speed combines both components. At the top the vertical component has fallen to zero, so the speed is just the horizontal component, its smallest value; that component stays at 27.2 m s^{-1} because no horizontal force acts, so the speed is never zero (Excellence links both components to the forces).

10. Correct this statement: "At the top of its path the ball has stopped, so its acceleration is zero there."
    Only the vertical velocity is zero at the top; the weight still acts, so the acceleration is 9.8 m s^{-2} downwards all the way.

11. Correct this statement: "Time to reach the posts = 45.0 m ÷ 25.0 m s^{-1}, using the launch speed."
    Horizontal distance uses the horizontal component: $t = 45.0 \div (25.0 \cos\theta)$.

12. Correct this statement: "A ball thrown up at 14.7 m s^{-1}: $v_f^2 = 14.7^2 + 2 \times 9.8 \times d$, so d comes out negative."
    With up as positive, $a = -9.8$ m s^{-2}, so $0 = 14.7^2 - 2 \times 9.8 \times d$ and $d = 11.0$ m.

13. Correct this statement: "The heavier ball has more weight, so it falls faster and lands sooner."
    Without air resistance every object accelerates at 9.8 m s^{-2}, because the bigger weight has a bigger mass to move.