

Progression toolkit: Force, mass and acceleration

	The acceleration of an object is proportional to the resultant force acting on it and inversely proportional to its mass. An object accelerates in the direction of the resultant force acting on it.				
As students' conceptual understanding progresses they can:	<div>CONCEPTUAL PROGRESSION</div>				
	Describe the effect of a resultant force on objects of different mass. <div>P</div>	Describe the relationship between the resultant force on an object and its acceleration.	Explain the equation $F = m \times a$ and use it to make calculations.	Use the equation $F = m \times a$ to determine and explain the motion of falling objects.	Apply an understanding of $F = m \times a$ for a changing mass. <div>B</div>
Diagnostic questions	Loaded lorry	Drag race II	Spaceships	Accelerating ball	
			Rearranging the equation	Stopping in mid-air	
Response activities	Trolley pull			Free-fall	Rocketing up!
	Dropping forces				

Key:

P Prior understanding from earlier stages of learning

B Bridge to later stages of learning

Loaded lorry	Drag race II	Spaceships	Rearranging equations	Accelerating ball																																																																										
<p>BEST STUDENT WORKSHEET</p> <p>Loaded lorry</p> <p>You control some acceleration from a steering wheel. One lorry is carrying a load. They both start at the same time.</p> <p>After 5 seconds, the blue lorry is travelling faster.</p> <p>What can you say about the resultant force on each lorry? Put a tick (✓) in the box next to the best answer:</p> <p>A The resultant force on each lorry is the same. <input type="checkbox"/></p> <p>B The resultant force on the blue lorry is bigger. <input type="checkbox"/></p> <p>C The resultant force on the yellow lorry is bigger. <input type="checkbox"/></p> <p>(ignore the effect of air resistance)</p> <p>Downloaded by the University of York Science Education Group, the Salters' Institute and the Institute of Physics. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</p>	<p>BEST STUDENT WORKSHEET</p> <p>Drag race II</p> <p>Two cars race from the same start and finish, but different engines. The red car is pushed with a force two times bigger than the green car starting at the same time. Both cars accelerate from rest.</p> <p>The red car is pushed with twice the force as the green car. What do you think about each statement? Put a tick (✓) in the box next to the best answer.</p> <table border="1"> <thead> <tr> <th></th> <th>I am sure this is right</th> <th>I think this is right</th> <th>I think this is wrong</th> <th>I am sure this is wrong</th> </tr> </thead> <tbody> <tr> <td>A The red car has twice the top speed.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>B After 1 s, the red car accelerates at twice the rate.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>C After 1 s, the red car has twice the force on it.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>D As the red car speeds up, its acceleration goes down.</td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p>Downloaded by the University of York Science Education Group, the Salters' Institute and the Institute of Physics. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. 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If the mass of the object is doubled, acceleration is halved.</p> <p>acceleration = $\frac{\text{force}}{\text{mass}}$</p> <p>This relationship is usually written as:</p> <p>Force = mass × acceleration $F = m \times a$</p> <p>Force, F, in newtons (N) mass, m, in kilograms (kg) acceleration, a, in metres per second squared (m/s²)</p> <p>One newton is the force needed to accelerate a mass of 1 kg at a rate of 1 m/s².</p> <p>Which of these equations have been re-arranged correctly? 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<p>BEST STUDENT WORKSHEET</p> <p>Stopping in mid-air</p> <p>Albert throws a ball straight up in the air. At the top of the flight it stops for a short moment.</p> <p>What do you think about each statement? 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Put a tick (✓) in the box next to the best answer.</p> <table border="1"> <thead> <tr> <th></th> <th>I am sure this is right</th> <th>I think this is right</th> <th>I think this is wrong</th> <th>I am sure this is wrong</th> </tr> </thead> <tbody> <tr> <td>A The trolley will stop.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>B The trolley will move at a constant speed.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>C The trolley will accelerate.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>D The trolley will stop.</td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p>Downloaded by the University of York Science Education Group, the Salters' Institute and the Institute of Physics. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. 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Put one statement in each row to explain how.</p> <table border="1"> <thead> <tr> <th></th> <th>The force of gravity on the red ball is twice as big as it is on the green ball.</th> <th>The force of gravity is the same on both balls.</th> </tr> </thead> <tbody> <tr> <td>1</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>2</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>3</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>4</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>5</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> </tbody> </table> <p>Downloaded by the University of York Science Education Group, the Salters' Institute and the Institute of Physics. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. 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(She is wearing a parachute.)</p> <p>Some students are discussing why Eve reaches a top speed.</p> <p>Julia: There are no forces on Eve when she stops accelerating because Frima.</p> <p>Leo: She is weightless because all the forces cancel out.</p> <p>Nadia: The faster Eve gets, the more the air resistance pushes up on her.</p> <p>Umar: She stops accelerating when her weight is equal to the drag and Frim.</p> <p>Peggy: She stops accelerating because the air pushes equally on her in all directions.</p> <p>To answer:</p> <ol style="list-style-type: none"> Who is right about why Eve reaches a top speed? → Explain your answer. Who is wrong about why Eve reaches a top speed? → What would you say to help them understand? <p>Downloaded by the University of York Science Education Group, the Salters' Institute and the Institute of Physics. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</p>	<p>BEST STUDENT WORKSHEET</p> <p>Rocketing up</p> <p>A fireworks is shot up into the sky. The gunpowder burns to produce a steady force. As the gunpowder burns, the fireworks loses mass.</p> <p>Some students are discussing what happens to the fireworks.</p> <p>Mama: The steady forward force makes it accelerate at a steady rate.</p> <p>Nadia: The resultant force increases its acceleration as it loses mass.</p> <p>Umar: The force of gravity on the fireworks stays the same.</p> <p>Oliver: The force pushing it forward gets bigger as it loses mass.</p> <p>Peggy: Air resistance increases as it speeds up.</p> <p>To answer:</p> <ol style="list-style-type: none"> Who is definitely right about the fireworks? Who is definitely wrong about the fireworks? How would you describe what happens to the fireworks and why? <p>Downloaded by the University of York Science Education Group, the Salters' Institute and the Institute of Physics. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</p>						
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