*Physics > Big idea PFM: Forces and motion > Topic PFM2: Moving by force*

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| **Key concept (age 11-14)** |
| **PFM2.4: Drag** |

**What’s the big idea?**

A big idea in physics is force, because it is the key to explaining changes in the motion or the shape of an object. The motion of an object can be explained or predicted if you know the sizes and directions of all the forces that act on it. Understanding forces helps us to predict and control the physical world around us.

**How does this key concept develop understanding of the big idea?**

This key concept helps to develop the big idea by building on students’ knowledge of how drag affects movement of an object through different fluids, in order to develop understanding of how an object’s shape and speed change the size of the drag force on it, and how this affects its motion in real situations.

****The conceptual progression starts by checking knowledge that it is harder to move through some fluids compared to others. It then supports the development of understanding the cause of drag and why the drag on an object increases with the object’s speed, in order to enable understanding of why a forward force is necessary to maintain a steady speed in a real-life situation.

**Using the progression toolkit to support student learning**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Drag**

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| **Learning focus** | The drag force on an object moving through a fluid increases with its speed and can be reduced by making the object more streamlined | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Identify in which fluid an object has the biggest drag force  **P** | Describe how streamlining reduces drag force | Explain why the drag force on an object increases with the object’s speed | Describe the forces acting on an object when it is moving at a constant speed through a fluid | Explain how using a parachute can make it safe to jump out of an aeroplane    **B** |
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| **Diagnostic questions** | Drag force | Drag on helmets | Speed is a drag | Top speed | Safe landing |
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| **Response**  **activities** |  | Ball pool drag | | |  |
|  |  |  | Parachutes | |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning | **B** | Bridge to later stages of learning |

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| **Drag force** | **Drag on helmets** | **Speed is a drag** | **Top speed** | **Safe landing** |
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| Simple multiple choice | Two-tier multiple choice | Confidence grid | Simple multiple choice | Explanation story |
| **Ball pool drag** | **Parachutes** | |  |  |
|  |  | |  |  |
| Critiquing a representation | Predict, explain; observe, explain - practical | |  |  |

**What’s the science story?**

The drag force on an object moving through a fluid increases with its speed. The size of the drag force can be reduced by giving the moving object a streamlined shape.

If a non-zero resultant force acts on a moving object in the same direction as its motion, the speed of the object will steadily increase.

If a non-zero resultant force acts on a moving object in the opposite direction to its motion, the speed of the object will steadily decrease.

If an object is moving at a steady speed in a straight line, the resultant force acting on it is zero. A resultant force is needed to change the motion of an object, but not to maintain motion at a uniform speed.

**What does the research say?**

Drag (often called air resistance in air) is a force acting opposite to the relative motion of any object moving with respect to a surrounding fluid. Drag is the force of the fluid on the moving object. The energy needed to push fluid particles out of its way transfers energy from the kinetic properties of the object to the fluid particles, and correspondingly reduces the potential speed of the object.

When the speed of an object is being increased, students tend to focus on the applied force that appears to be needed to get it going, and keep it going. They often think that a moving object *has* force that keeps it moving, and which runs out when it comes to rest (Gunstone, R and Watts, 1985; Driver et al., 1994a). Osborne (1985) found that as students get older they *increasingly* hold the view that a force, pushing in the direction of motion, is needed to keep an object moving. In a study of 200 students he found 46% of 13 year olds believed this, increasing to 53% of 14 year olds and 66% of 15 year olds.

Instead of concentrating on the applied force students need to think about all the forces acting and how they combine to produce the resultant force. They need to identify when the resultant force acts, when it changes and when it ceases. This involves understanding drag and the direction it acts in in order to recognise how it contributes to the resultant force (Driver et al., 1994b).

For most students the idea that a bigger resultant force produce a bigger effect is intuitive, but it is important to emphasise that resultant force does not produce speed, but a change in speed (Driver et al., 1994b). In other words: any moving object will continue to accelerate whilst a resultant force is acting on it.

The effect of drag on falling objects can be very confusing because although drag can significantly affect the motion of an object falling in the real world, students often do not take it into account. In a study, Lee and Kwok (2009) found that when 11- to 12-year-olds (n=204) were asked to label the forces on a falling ball, 90% were able to label the gravitational force, but none of them included any drag force.

When two balls are dropped together Newton’s Laws of Motion teach us that they both speed up at the same rate and each should fall an equal distance in an identical time. This contradicts what young children predict will happen: that the heavier object will hit the ground first (Hise, 1988). But it turns out that when drag is taken into account, the young children are usually right!

If two balls are exactly the same except for their weight, then when falling through the air at any particular speed the drag on each will be identical. As they speed up the drag on each ball will increase and the resultant force will decrease because resultant force equals weight (gravitational force) minus the drag force. As the resultant downward force decreases, the balls’ speed increases less and less quickly. When the size of the drag force becomes as big as the force of gravity, there is no resultant downward force and each ball falls at a steady top speed. What is often forgotten in this analysis is that the heavier ball needs to be going faster than the lighter one for drag to be equal in size to its weight. In other words, it needs to speed up for longer to reach a higher top speed in order for the drag on it to equal its weight. More complex analysis of how drag affects each ball\* also shows that at any particular speed, the heavier ball will have greater acceleration and will speed up more quickly than the lighter one.

A study of college students (n=50) aged 17-23 Oberle *et al* (2005) found the majority persistently held onto the misunderstanding that all objects *in the real world* fall at exactly the same rate, and that this belief was stronger in those with a physics background! This is a view that is consistent with Newton’s Laws of Motion in situations with no air resistance. Indeed, in their later studies physics students often, for simplicity, learn how to apply Newton’s Laws to situations with *negligible* drag.

*\*The resultant force on a falling ball = weight of the ball minus drag. Newton’s second law tells us the resulting force equals mass x acceleration; and the weight of a ball equals mass x gravitational field strength, g. So for a falling ball: ma = mg – drag. Dividing both sides by the mass gives the acceleration of the ball: a = g - . Because the balls in the example are identical apart from their mass, for any particular speed the drag force on each will be the same. So when the mass of the ball is bigger, is smaller and this means that drag reduces the ball’s acceleration by a smaller amount than it would if the ball weighed less.*

In the progression toolkit ‘drag’, knowledge that moving objects experience more drag in some fluids compared to others is checked, along with understanding that a streamlined shape reduces drag and moving more quickly increases drag. A model is used develop students’ understanding of the causes of drag. It also gives them opportunity to develop clear explanations of what drag is, leading to explanations of why a forwards force is necessary to maintain steady motion in real world situations (when drag is acting). Practical work consolidates this understanding and allows students to apply their learning to a new situation.

**Guidance notes**

*Air resistance* is a specific example of the force of drag, experienced by an object moving relative to air.

**References**

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