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

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| **Key concept (age 11-14)** |
| **PFM2.3: Changing motion** |

**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 existing understanding of how resultant forces change the speed of objects, the detail of which can be analysed in order to develop understanding of how continually acting forces affect motion of objects in real situations.

****The conceptual progression starts by checking understanding of calculating a resultant force along a straight line and the force’s effect on motion. It then supports the development of describing how speed changes throughout the time a resultant force acts, in order to enable understanding of why a presence of friction determines that a maintained forwards force is necessary to keep an object in uniform motion.

**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: Changing motion**

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| **Learning focus** | A resultant force on an object can cause it to speed up or slow down, depending on the direction of the force. | | | | |
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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** | | | | |
| Calculate the size and direction of the resultant force of two forces acting along the same straight line.  **P** | Describe how quickly the speed of an object can be changed if acted on by resultant forces of different size.  **P** | Describe how the speed of an object changes throughout the time that a resultant force is acting on it. | Explain how friction and other resistive forces can act to continually reduce the speed an un-propelled object. | Explain why friction and other resistive forces make it necessary to exert a constant force to keep an object moving at a steady speed.    **B** |
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| **Diagnostic questions** | How much is left over? (2) | Drag race | Skydiving | Shopping trolley disaster! | Supermarket dash |
| Rolling stone |
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| **Response**  **activities** | Calculating resultant force (2) | Steady force | | Counter force | Trolley racing |

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

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| **How much is left over? (2)** | **Drag race** | **Skydiving** | **Rolling stone** | **Shopping trolley disaster!** |
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| Linking ideas | Simple multiple choice | Two-tier multiple choice | Confidence grid | Two-tier multiple choice |
| **Supermarket dash** | **Calculating resultant force (2)** | **Steady force** | **Counter force** | **Trolley racing** |
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| Simple multiple choice | Application and practice - calculations | Predict, explain, observe, explain - practical/demonstration | Predict, explain, observe, explain - practical/demonstration | Talking heads |

**What’s the science story?**

To explain the motion of an object, it is essential first to identify all the forces acting on that object. From this, we can then work out the resultant force acting horizontally and/or vertically on the object.

*Changing motion:* If a non-zero resultant force acts on a stationary object, the object will start to move in the direction of the force and its speed will steadily increase.

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 its speed falls to zero, and the force continues to act, the object will then start to move in the direction of the force, with a steadily increasing speed.

In all cases, the bigger the resultant force, the greater the rate of change of motion (for a given object). And the more massive the object, the smaller the rate of change of motion.

*Uniform motion:* 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?**

When students think about a resultant force acting on a moving object they often apply the misunderstanding that if there is motion, there is a force acting. This can lead to the further misunderstandings that a constant speed results from a constant force; and when moving, the force is in the direction of the motion *(Driver et al., 1994a).* In fact an object will continue to move at a constant speed in a straight line if there is *no resultant force* acting; a resultant force that acts along the line of motion of an object will change its speed.

Students tend to equate getting faster with ‘catching-up’ and when one object catches up with another it is common for them to think that at the point of overtaking both objects are moving at the same speed. This may fit with a student’s experience: of accelerating when they set off in pursuit; of running at a steady (albeit faster) speed as they catch up; and then often falling into pace with the person they have chased. What is missing from this experience is an account of time, which students often do not consider when thinking about motion. (Driver et al., 1994b)

Children below the age of about 11 tend to think of speed change as a short intensive effort, followed by constant speed. In a study (Hast and Howe, 2013), children observed a ball falling in free fall, accelerating down a ramp and rolling along a flat surface. In each case they were asked to predict whether the ball was speeding up, slowing down or travelling at a steady speed through the second half of each motion. For the accelerating balls the thirty-six 11-year-olds involved in the study made correct predictions only a little more often than they would have done by chance. They were significantly worse at predicting that the ball rolling along a horizontal surface was slowing down throughout the whole of the motion.

In a study by Dykstra and Sweet (2009) of 9- to 13-year-olds in the United States (n=103), it was found that the majority of students (aged 11-12) described the motion of an object as a snapshot of its direction and speed (moving *quickly this way* or *slowly that way*). Just 11% of this group gave a dynamic description of an accelerating object, in free fall or rolling down a ramp, in terms of a *changing* speed.

Dykstra and Sweet (2009) also found that many students had difficulty in modelling acceleration. Asked to ‘start from rest and walk across the room whilst speeding up’; the majority of students either walked at a steady pace, or walked slowly at first with a sudden speed-up at a point somewhere before the end. These students were then given the opportunity in class to use real time graphing with a motion sensor to examine graphs of their own motion. Following this intervention it was found that more than 50% of the sample described the *changing* speed of accelerating objects without prompting.

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 a resultant force acts, when it changes and when it ceases. This involves understanding friction and the direction in which it acts in order to recognise how it contributes to the resultant force (Driver et al., 1994b).

For most students the idea that a bigger force produces a bigger effect is intuitive, but it is important to emphasise that 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.

**Guidance notes**

In this progression toolkit, the ability to calculate resultant forces in a straight line is checked along with the understanding that bigger resultant forces change speed more quickly. Diagnostic questions investigate students’ understanding of how gravity continually speeds up objects throughout the time it is acting, and motion sensors are used to plot real-time graphs of motion to challenge any misunderstanding. Practical work also helps students to develop clear explanations of how friction continually reduces the speed of an un-propelled object. This will enable some students to explain why a continual forwards force is necessary to maintain steady motion in real world situations (when friction is acting).

Clear and accurate descriptions of motion are needed to understand dynamic systems described by Newton’s Laws of Motion. Research suggests that real time graphing of motion is a useful way of helping students to recognise how motion changes over time in order to understand the nature of acceleration. The BEST response activity *Speedy graphs* from key concept PFM2.2 *Motion graphs* could be used to do this.

In the diagnostic question *Supermarket dash*, the counter forces have been described as ‘friction’ to include all the different types of friction, including drag (air-resistance) and rolling friction.

**References**

Driver, R., et al. (1994a). *Making Sense of Secondary Science: Research into Children's Ideas,* London, UK: Routledge.

Driver, R., et al. (1994b). *Making Sense of Secondary Science: Support Materials for Teachers,* London: Routledge.

Dykstra, D. and Sweet, D. (2009). Conceptual development about motion and force in elementary and middle school students. *American Journal of Physics,* 77:5**,** 468-476.

Gunstone, R and Watts, M. (1985). Force and Motion. In Driver, R, Guesne, E. & Tiberghien, A. (eds.) *Children's Ideas in Science.* Milton Keynes, England: Open University Press.

Hast, M. and Howe, C. (2013). The Development of Children's Understanding of Speed Change: A Contributing Factor Towards Commonsense Theories of Motion. *Journal of Science Education and Technology,* 22**,** 337-350.

Osborne, R. (1985). Building on children's intuitive ideas. In Osborne, R & Freyberg, P. (eds.) *Learning in Science* Aukland, New Zealand: Heinemann.