Making moves and staying still: Connecting forces and motion

An overview of forces and motion in the Victorian Curriculum F–10

Learning how to observe and how to describe observations is key in the practice of science. Students build skills in how to observe and describe forces and motion experienced by objects. Students then explore how forces can affect shape and motion.

Describing how things move is the first step towards explaining why they move as they do. The second step is describing the interaction of the ‘thing’, or object, with the elements of its environment. Some of these interactions involve contact: pushing, pulling, rubbing, sticking. Some do not, such as the attractive force that exists between objects because they have mass and that causes unsupported objects to fall – that is, the force known as gravity.

For major links between the concepts of forces and motion and the Victorian Curriculum F–10, see [Links to the Victorian Curriculum F–10: Science](#Links) in this document.

Initially, students at Foundation to Level 2 describe forces using the language of ‘pushes’ and ‘pulls’. They link changes in the motion and/or shape of objects to forces applied to the objects. At Levels 3 and 4, their concept of forces is expanded to include forces that do not require objects to be touching each other, such as gravitational and magnetic forces. At Levels 5 and 6, students model the motion of the planets in the Solar System and interpret this motion in terms of an attractive force that is causing a change in the direction of motion of the planets. At Levels 7 and 8, students consider all of the forces acting on an object and explain whether they balance each other out or are unbalanced. At Levels 9 and 10, students explore relationships between forces and motion quantitatively as well as qualitatively. They are also introduced to energy transfer as an alternative way of explaining observed changes in motion.

**Sample learning activities:**

For sample learning activities that cover a conceptual development of the understanding of forces and motion from Foundation to Level 10, please see the following resources on the VCAA’s Science teaching resources webpage:

* How do we stop and start? Foundation to Level 2
* How do forces affect our everyday lives? Levels 3 and 4
* How do the planets go around the Sun? Levels 5 and 6
* How can forces cause change? Levels 7 and 8 *(coming in 2022)*
* How can the laws of physics predict our moves? Levels 9 and 10 *(coming in 2022)*

These learning activities link to the Science Understanding curriculum content below and also link to the Science as a Human Endeavour sub-strand of the Science Understanding strand, and all sub-strands of the Science Inquiry Skills strand.

Links to the Victorian Curriculum F–10: Science

The major curriculum links related to the concepts of forces and motion, as part of the Science Understanding strand of the Victorian Curriculum F–10: Science, are listed in the table below.

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| **Levels** | **Content description** | **Relevant achievement standard extracts** |
| Foundation to 2 | The way objects move depends on a variety of factors including their size and shape: a push or a pull affects how an object moves or changes shape [(VCSSU048)](https://victoriancurriculum.vcaa.vic.edu.au/Curriculum/ContentDescription/VCSSU048) | [Students] describe the properties, behaviour, uses and the effects of interacting with familiar materials and objects… identify and describe the changes to objects … and things in their local environment |
| 3 and 4 | Forces can be exerted by one object on another through direct contact or from a distance  [(VCSSU064)](https://victoriancurriculum.vcaa.vic.edu.au/Curriculum/ContentDescription/VCSSU064) | … link the physical properties of materials to their use… use contact and non-contact forces to describe interactions between objects |
| 5 and 6 | Earth is part of a system of planets orbiting around a star (the Sun) [(VCSSU078)](https://victoriancurriculum.vcaa.vic.edu.au/Curriculum/ContentDescription/VCSSU078) | … use models to describe the key features of our Solar System |
| 7 and 8 | Change to an object’s motion is caused by unbalanced forces acting on the object; Earth’s gravity pulls objects towards the centre of Earth [(VCSSU103)](https://victoriancurriculum.vcaa.vic.edu.au/Curriculum/ContentDescription/VCSSU103) | … predict, represent and analyse the effects of unbalanced forces, including Earth’s gravity, on motion |
| 9 and 10 | The description and explanation of the motion of objects involves the interaction of forces and the exchange of energy and can be described and predicted using the laws of physics [(VCSSU133)](https://victoriancurriculum.vcaa.vic.edu.au/Curriculum/ContentDescription/VCSSU133) | … give both qualitative and quantitative explanations of the relationships between distance, speed, acceleration, mass and force to predict and explain motion |

The forces and motion story

The forces and motion story begins in Foundation to Level 2 with students observing actions resulting in change in shape and motion. The actions involve touch and are pushes and pulls, establishing a connection between contact interactions and change. Differentiating between changing and staying the same is a foundational skill that underpins all subsequent learning about forces and motion.

At Foundation to Level 2, students can identify that pushes and pulls have a direction. They can begin to use diagrams incorporating arrows as a tool to represent the concept of direction. The arrow condenses the push or pull of a larger object such as a hand, arm or foot into a single straight line with an arrowhead pointing in the direction of the push or pull. At Foundation to Level 2, students can use their senses to find that as they push on an object they can feel a push back on themselves by the object. This is a key concept, namely that forces exist as pairs between objects: one object pushes on a second object and the second object pushes back equally on the first object.

Learning at Levels 3 and 4 builds on learning at Foundation to Level 2, first by extending the force concept to non-contact interactions, such as gravity and magnetism, and second by demonstrating that multiple forces can act on objects at the same time. It is very helpful to always refer to forces as ‘the force on … by …’ because it reminds students that the force is due to an interaction. Terms such as ‘friction’, ‘tension’ and ‘gravity’ need to be unpacked so that the interaction is clearly described. For example, the friction experienced by a box pushed across carpet is the sticking force on the box by the carpet.

A force arrow is a helpful simplified representation of the direction and size of a force. Imagine placing the palm of your hand on a box and pushing on the box. Every part of your hand that is touching the box is involved in the push. Your hand is connected to your body, which is also involved in the push. The entire contact between your hand/body and the box is summarised by a single arrow. If someone else is pushing on the other side of the box, then the relative size of the two forces arrows will reflect the relative size of the two pushes.

pushing force on a box by one hand

pushing force on a box by another hand

pushing force on a box by one hand

The force due to gravity pulls downward on the whole of an object. This is usually summarised by drawing a single arrow with the base at the centre of the mass of the object and the arrow pointing towards the centre of Earth.

force of gravity on box by Earth

Force arrows are helpful for describing the direction and relative size of different forces. It is very important not to confuse force arrows with motion arrows. Force arrows do not describe motion: they simply describe the direction of pushes and pulls. Some force arrows will be in the same direction as motion, but motion is the result of the overall force on an object.

Learning at Levels 5 and 6 presents an opportunity for reinforcing the idea that the force on an object does not have to be in the direction of motion. A simple model of the Solar System depicts the planets travelling in circular orbits around the Sun. The force on the planets points in towards the centre of the circle, while their motion continually changes direction.

At Levels 7 and 8 the concept of overall force on an object is developed. The overall force on an object takes into account all of the forces experienced by the object. A force on the object from one direction might be balanced out by a force from another direction. At Levels 7 and 8 students are only expected to quantitatively compare forces that are in the same or opposing directions. The essential learning here is that where the forces do not balance each other out, there is a change in the speed, shape and/or direction of motion of the object. A highly prevalent misconception is that speed and force are directly related, for example a doubling in speed is due to a doubling in force. Force can cause a change in speed, but it does not cause speed itself. The larger the overall force, the greater the change in speed and/or shape and direction of motion.

At Levels 9 and 10 the above concepts are formalised as the application of Newton’s laws of motion, and students are able to quantitatively connect change in motion to the direction and magnitude of the overall force. Newton’s first law states that an object that is moving with a constant speed in a constant direction will continue to do so. Overall force is **not** needed to maintain motion. Newton’s second law explicitly connects the effect of overall force on an object to change in motion, stating that the overall force on an object is equal to the change in speed and/or direction over time of the object multiplied by the mass of the object. In other words, the larger the overall force on an object, the greater the change in motion; however, for the same overall force, lighter objects will experience a greater change than heavier objects. Newton’s third law specifies that forces are interactions, that if there is a force on one object by a second object then there is a force of equal size but in the opposite direction on the second object by the first. In addition, students are introduced to the idea of energy of motion – that is, kinetic energy – and energy due to interactions such as gravitational potential energy. They can show that, because the overall energy of any system remains the same, energy is transferred from one form to another when objects move and they can quantitatively connect energy transfer to change in position and speed.

Misconceptions about forces and motion

A naive concept of force as pushes and pulls applied by humans that always result in motion is at the root of much student thinking about motion and force. The ‘push’ or ‘pull’ language to describe forces has some unfortunate side effects. It sounds as if forces always involve some kind of muscular effort. It makes it seem that an object has to be active – moving or trying to move – in order to be experiencing force. It also sounds as if forces can only occur where there is contact. None of these ideas are correct. Yet such ‘common sense beliefs’ persist into tertiary study and hold students back from being able to properly apply mechanical principles.

Some typical misconceptions are unpacked in the following paragraphs. These widely held misconceptions highlight the need for students to be clear about the effect of interactions and their nature. The sample learning activities for Foundation to Level 10 that accompany this resource on the VCAA website aim to enable students to clearly differentiate between motion and change in motion and/or shape and force.

**Misconception 1: Forces are associated only with living things**

This misconception follows logically from associating forces with applying effort using muscles and not understanding the interactive nature of force. Ask students to close their eyes and describe what they feel when they pull on the hand of another student. Do they feel that they are pulling on the other student? Do they feel that the other student is pulling on them? Now replace the other student’s hand with a piece of elastic or a resistance band. What has changed? What is the same? The resistance band does not have muscles but is applying a force on the student. This activity both combats the concept that forces have be associated with living bodies and explicitly demonstrates that the existence of force requires two or more objects to be interacting.

**Misconception 2: If something is not moving, there are no forces acting on it**

Following on from the previous activity, the same logic can now be applied to a student pushing on a wall. The student can be quite certain that they are pushing on the wall; however, the wall is not moving. The wall does not move because the foundations of the wall push back on the wall in response to the push by the student on the wall. The force on the wall by the student is balanced out by the force on the wall by its foundations or fixings. There are forces acting on the wall but there is no overall force on the wall.

**Misconception 3: If something is moving, there is a force acting on it in the direction of motion**

This idea comes from the highly prevalent belief that there is a direct connection between force and motion. It is good to explicitly set up scenarios where the motion of an object is not in the direction of the overall force on the object to try to separate these two concepts. For example, if an object on a tabletop is given an initial push and starts to move, there is an overall force in the direction of the push. However, once the push ceases, there is no longer a push but there is still friction between the object and tabletop opposing the motion, so the overall force is opposite to the direction of motion and the object slows down.

**Misconception 4: The amount of motion is proportional to the amount of force**

This misconception is also due to a belief in a direct connection between force and motion. For example, when we give a box a push, we expect that if we push harder, the box will move faster; however, we need to observe that what we have done is change the motion of the box. The box was originally not moving, and our push has changed the speed of the box. The harder we push, the greater the change in speed of the box.

**Misconception 5: Force is the property of a moving object, rather than something acting on it from outside**

This is similar to misconception 3 and follows from a belief that motion occurs only when there is a push or a pull. Motion that occurs when contact ceases can then only be understood as the force persisting with the object. That kind of thinking tends to associate slowing down with running out of force. When a cricketer hits a ball, while the ball is in contact with the bat a force is applied that changes the motion of the ball to a high speed in a forward direction. As soon as the ball is no longer in contact with the bat, the ball starts to slow down due to its interaction with the air and the ground. The change in motion comes from the interaction, not because the ball is somehow carrying force with it that is gradually wearing off.

Reference

Tytler, R & Hubber, P 2005, ‘Force and motion’, Ideas for Teaching Science: Years P–8, Resources for Teaching Science, Deakin University, <https://blogs.deakin.edu.au/sci-enviro-ed/early-years/force-and-motion>