Physics > Big idea PFM: Forces and motion > Topic PFM1: Forces

Key concept (age 11-14)

PFM1.3: Balanced and unbalanced forces

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.

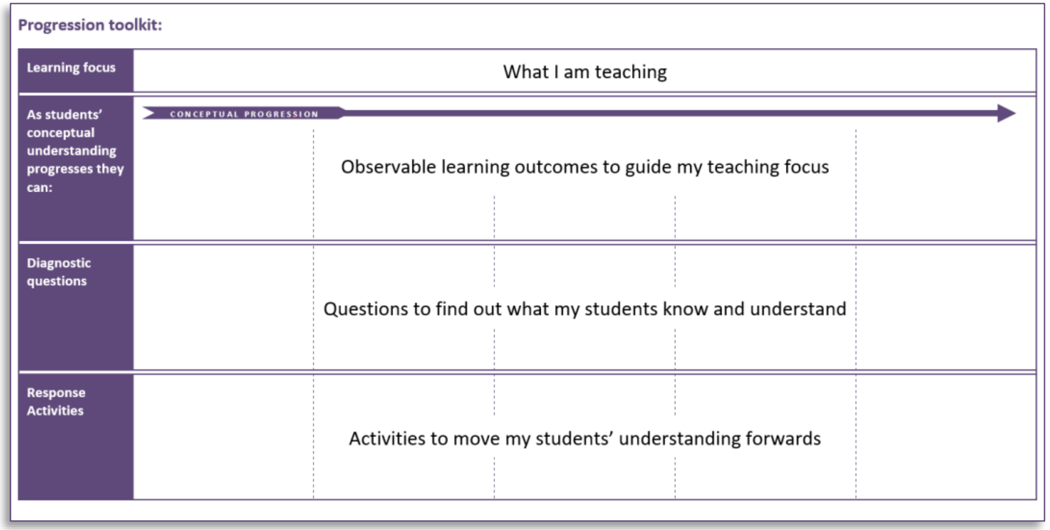
How does this key concept develop understanding of the big idea?

This key concept develops the big idea by building on the understanding that when more than one force acts on an object each one influences what happens, in order to help develop students' ability to predict the effect of two forces both acting on the same object.

The conceptual progression starts by checking understanding of balanced and unbalanced forces. It then develops the skill of calculating a resultant force in order to enable understanding of how two forces, acting along the same straight line, jointly affect an object.

How can you use 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: Balanced and unbalanced forces

Learning focus	The resultant force is the sum of the forces acting on the object, taking into account their direction. If there is no resultant force, the forces are balanced. Unbalanced forces change the speed, direction and/or shape of an object.				
As students' conceptual understanding progresses they can:	CONCEPTUAL PROGRESSION → Identify pairs of forces that are balanced or unbalanced	Deduce the relative size of resultant forces by comparing pairs of unbalanced forces	Calculate the size and direction of the resultant force of two forces acting along the same straight line	Describe what happens when two unbalanced forces act an object, both acting along the same straight line.	Describe what happens when two equal sized forces act on an object, both acting along the same straight line but in opposite directions.
Diagnostic questions	Balanced or unbalanced?	Resultant force	How much is left over?	What happens next?	What changes?
Response activities			Calculating the resultant force		Sitting on a chair

What's the science story?

Often more than one force acts on an object. The net effect of two forces acting in the same straight line (same direction, or exactly opposite directions) is found by adding them, taking account of their directions. 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 net force acting horizontally and/or vertically on the object.

Stationary objects: If an object is not moving (stationary), and the net force acting on it is zero, then there is not force left over to give it motion. It will remain at rest.

Changing motion: If a non-zero net 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 net force acts on a moving object in the same direction as its motion, the speed of the object will steadily increase. And if a non-zero net force acts on a moving object in the opposite direction to its motion, the speed of the object will steadily decrease.

In all cases, the bigger the net force, the greater the rate of change of motion (for a given object). And the bigger 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, and the net force acting on it is zero, then there is no force left over to change its motion. It will continue at the same steady speed.

What does the research say?

In a study of 32 Canadian students aged 6-14, Erikson and Hobbs (1978) found that when thinking about two forces acting on the same object, students appeared to think of the forces as being engaged in a struggle, with the bigger force dominating the smaller one. Osborne (1985) found similar thinking amongst students in New Zealand. Out of a group of 26 students in his study, ten students saw equilibrium as the end to this struggle, after which all the forces ceased to act. In fact, both forces continue to act, there is '*not force left over to make things change*'.

When forces are not in equilibrium, Driver *et al* (1994) identified several common misunderstandings that may confuse what students think will happen next:

- if there is motion, there is a force acting
- there cannot be a force without motion
- when moving the force is in the direction of the motion
- if there is no motion, then there is no force acting
- if there is no force, there is no motion
- constant speed results from a constant force

The first of these is very widely held because in everyday experience, when cycling or driving for example, we do need to apply a constant force in order to move at a steady speed in order to match friction and air resistance. This means that when an object is not moving it is wrongly perceived to have no force acting on it and the other misunderstandings tend to follow. Indeed, Driver et al (1994) point to a study of 1000 Norwegian upper secondary students, by Sjoberg and Lie (1981), which found just 50% of the young people recognised 'passive' forces acting when there was no movement.

Resultant force calculations can be a source of difficulty for some students. In *The language of mathematics in science* (2016), Boohan notes that a key difference between calculations in mathematics and science is that in science the numbers we calculate with most often have a *unit* as well as a number. Students need to pay attention to the manipulation of not just the numbers but the units as well. Addition and subtraction of values can only be done if they are expressed in the *same* units.

Students may be tempted to use number lines of positive and negative numbers to combine forces acting in opposite directions. This works, but when forces are in opposite directions it is simpler to take the smaller force from the larger and to consider the direction separately. This approach can help to clarify the idea that forces have *both* size and direction.

The progression toolkit for balanced and unbalanced forces reminds students that in everyday situations there are usually several forces acting on an object at the same time. Students begin by identifying situations in which pairs of forces may or may not be balanced. Where the forces are unbalanced students compare the difference between the two forces acting to determine the relative size of the resultant force. Calculating this force gives students opportunity to think analytically about how pairs of forces act, and by considering the effects of resultant forces, students have the chance to consolidate the idea of resultant forces with their understanding of what forces do. These ideas were covered in key concept PFM1.3: What forces do.

Guidance notes

In this key concept the units have been chosen to be the same. Some students may benefit from being stretched to convert between kilo-Newton and Newton.

References

Boohan, R. (2016) *The language of mathematics in science*, Association for Science Education, Hatfield, England.

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