**A very tall tower**

The International Space Station is 408 km above the Earth.

A very tall tower is built to put satellites into space.

It is 400 km tall.



Some boys are talking about what it would be like on top of the tower.

**Albert:** You would float because you are in space.

**Brandon:** You weigh the same as you do on the ground.

**Declan:** There is no air to breathe.

**Cameron:** The force of gravity is less than it is on the ground.

Talk about your answers to these questions:

1. Who do you think is right about what it is like on top of the very high tower?

*Explain your answer.*

1. What mistakes do you think the others made?

*What would you say to them to help them to understand?*

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| Cards for  **A very tall tower** |  |
| **Albert:** You would float because you are in space. | **Brandon:** You weigh the same as you do on the ground. |
| **Cameron:** The force of gravity is less than it is on the ground. | **Declan:** There is no air to breathe. |

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| Cards for  **A very tall tower** |  |
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*Physics > Big idea PFM: Forces and motion > Topic PFM3: More about force > Key concept PFM3.1: Mass and weight*

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| **Diagnostic question** |
| **A very tall tower** |

**Overview**

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| Learning focus: | Mass is a measure of the amount of matter an object or substance is comprised of and weight is the force needed to support the object or substance. |
| Observable learning outcome: | Explain why an astronaut orbiting the Earth is weightless. |
| Question type: | Talking heads |
| Key words: | mass, weight, gravitational force |

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| **B** | **BRIDGING**  This diagnostic question probes understanding of ideas that are usually taught at age 14-16, to build a bridge to later stages of learning. |

**What does the research say?**

In most text books (Galili and Kaplan, 1996; Tural, Akdeniz and Alev, 2010; Stein, Galili and Schur, 2015) and in many syllabuses and curricula (Department for Education, 2013; Department for Education, 2014) weight is defined as the gravitational force acting on a mass. The equation weight = mass x gravitational field strength (w = mg) clearly shows that an object with more mass feels heavier and has more weight. This is logically correct because ‘bigger mass’ describes an object which contains more matter which requires more force to lift.

There is however a problem with this definition in that it also suggests that an astronaut will be weightless only when there is zero gravity; and this is not the case. On the International Space Station (ISS) astronauts clearly experience weightlessness, yet the ISS orbits so close to the surface of Earth (about 400 km) that the gravitational force on it and on the astronauts inside is still 89% of what it is on the Earth’s surface.

Defining weight as the gravitational force on an object does not work in all situations and reinforces the misunderstanding that there is no gravity in space (Stein et al., 2015). An alternative definition of weight that is often used by teachers is: weight is the force needed to pick up an object; or alternatively weight is the force which an object pushes down on a surface. This definition works well to explain what is happening to the astronaut in the ISS. The ISS and the astronaut are orbiting at the same speed and are following the same path, so as the astronaut falls - the ‘floor’ of the space station falls away from her at exactly the same speed. The experience of the astronaut is explained, but the equation w=mg does not work.

Driver et al. (1994) note several studies that show students do not generally think of weight as a force of gravity (Stead and Osborne, 1980; Ruggiero et al., 1985; Watts, 1982) instead this is a concept that is introduced through teaching. Watts (1982) found secondary students do not use the concept of gravity consistently, applying gravity differently to different objects and not always in the same way at all times to a particular object. When weight is defined as equal to mass multiplied by gravitational field strength and students understand that mass is unchanging, then it becomes necessary for them to apply a non-scientific and flexible approach in order to make sense of situations such as the weightlessness of an astronaut in Earth orbit.

Stead and Osborne (1980) found in a study of 11- to 14-year-olds that it is common for eleven-year-olds to think that gravity only relates to the Earth. At age thirteen (n=258) 44% do not think there is gravity on the Moon, and they commonly think that not all planets have gravity. 81% of 13-year-olds and 75% of 14-year-olds in the study did not think that there is gravity in space (Driver et al., 1994). Similarly, Galili (1995) found that the majority of students aged 14-15 (n=34) understood weightlessness to depend solely on an object’s location (a place with little or no gravity).

This question investigates students’ understanding of gravity at the height of the International Space Station whilst they are connected to the ground. This can help develop an understanding of how motion can explain why astronauts can be weightless in a moving apace-craft that is in the same location as a place with lots of gravitational force.

**Ways to use this question**

This task is intended for discussion in pairs or small groups. It can be done as a pencil and paper exercise or projected onto a screen.

Students should read the statements and follow the instructions on either the worksheet or the PowerPoint. Listening in to the conversations of each group will often give you insights into how your students are thinking. Each member of a group should be able to report back to the class.

Feedback from each group can be used, with careful teacher questioning, to bring out a clear description or explanation of the science.

*Differentiation*

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in the each group. For example, you may choose to select a student with strong prior knowledge as the scribe, and forbid them from contributing any of their own answers. They may question the others and only write down what they have been told. This strategy encourages contributions from more members of each group.

NB in any class, small group discussions typically improve over time and a persistence with this strategy is often very successful in the medium to long term.

**Expected answers**

Cameron and Declan are correct about what it is like at the top of the tower.

Albert imagines there is no weight because he probably associates weightlessness with the absence of gravity.

Brandon is applying the understanding described by the equation w=mg to a situation in which g (gravitational field strength) has changed because it is dependent on both mass and distance of separation of centres of mass.

**How to respond - what next?**

In a study of 34 students aged 14-15, Galili and Kaplan (1996) found that 21% agreed with Albert, 21% agreed with Brandon, and a further 21% ‘did not know’ what would happen to weight.

In fact, the force of gravity at the top of the tower would be about 90% as strong as the force of gravity on the ground, so a person would experience pretty much the same weight in both locations. It is likely that wrong answers may relate to a misunderstanding of why astronauts experience weightlessness in the International Space Station (ISS).

If students have misunderstandings about why a person does not experience weightlessness on the very tall tower, it can help to compare the experience of being on the tower with being on the ISS. The diagnostic question: *Falling weight* investigates students understanding of measuring weight in freefall. The following BEST ‘response activity’, that investigates the effect of movement on measured weight, could be used in follow-up this diagnostic question:

* Response activity: Moving weight

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