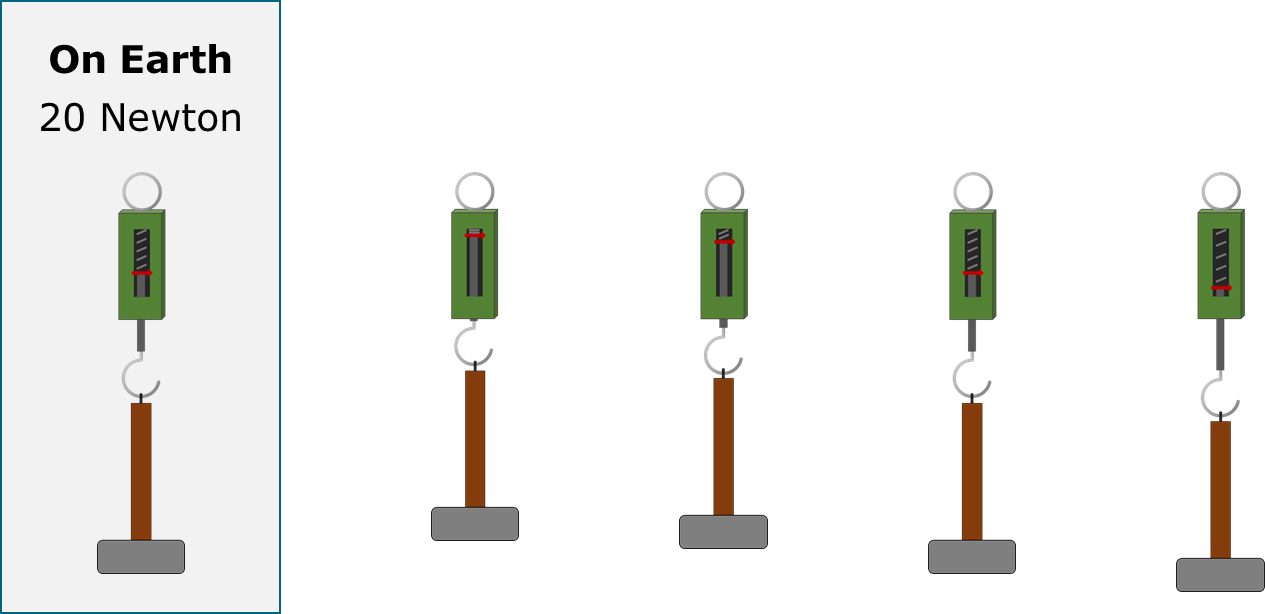
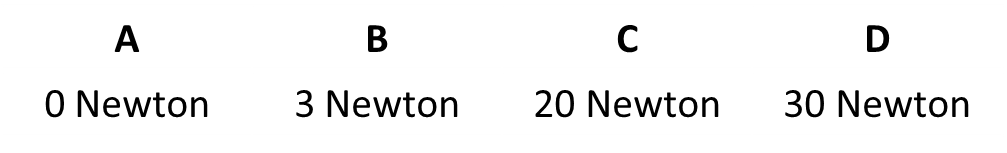
**Weight on the Moon**

An astronaut is on the Moon.

She is measuring the force needed to lift a hammer.

On Earth it takes 20 Newton to lift a hammer.

a. What force is needed to lift the hammer on the Moon?



**b.** What is the best reason for your last answer?

Put a tick (✓) in the box next to the best answer.

|  |  |  |
| --- | --- | --- |
| **A** | There is no gravity on the Moon. |  |
|  |  |  |
| **B** | The force of gravity is different on the Moon. |  |
|  |  |  |
| **C** | It is the same hammer. |  |
|  |  |  |
| **D** | There is no air on the Moon. |  |

*Physics > Big idea PFM: Forces and motion > Topic PFM3: More about force > Key concept PFM3.1: Mass and weight*

|  |
| --- |
| **Diagnostic question** |
| **Weight on the Moon** |

**Overview**

|  |  |
| --- | --- |
| 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 the relationship between the weight and mass of an object that is caused by a gravitational force. |
| Question type: | Two-tier multiple choice |
| Key words: | weight, mass, gravitational force |

**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.

What Newton did in defining weight was to (wrongly) equate the acceleration of freefall to the gravitational force (Galili, 2001; Stein et al., 2015). At the surface of the Earth these have almost exactly the same value, but they are not the same thing. For example, the acceleration of free fall of an object at the Equator is less than the gravitational force on the object - because the Earth is spinning.

Students aged 11-14 are typically taught that weight is a force and that a particular mass will weigh different amounts on different planets or moons because of changes in the gravitational force. This is true, but teaching that weight is caused by *just* the gravitational force (whether explicitly or implicitly) leads to misunderstandings that prevent students developing a good understanding of weightlessness, of how gravitational forces extend into space, and about other related ideas they encounter later in their studies (Gonen, 2008; Stein et al., 2015). For example, Sharma et al. (2004) found that half of physics undergraduates (n=200) wrongly defined weightlessness as an absence of gravity.

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).

**Ways to use this question**

Students should complete the questions individually. This could be a pencil and paper exercise, or you could use an electronic ‘voting system’ or mini white boards and the PowerPoint presentation. The follow on question will give you insights into how they are thinking and highlight specific misconceptions that some may hold.

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

*Differentiation*

You may choose to read the questions to the class, so that everyone can focus on the science. In some situations it may be more appropriate for a teaching assistant to read for one or two students.

**Expected answers**

**a.** B: 3 Newton (more precisely 3.3 Newton).

**b.** B: The force of gravity is different on the Moon.

**How to respond - what next?**

A significant proportion of students aged 13 believe there is no gravity on the Moon, often because it has no atmosphere and gravity is associated with the force of air pushing down.

Some students are likely to confuse weight with mass and consider weight to be unchanging.

If students have misunderstandings about how the weight of the hammer caused by a gravitational force is smaller on the Moon, it can help to discuss what the effect of having less gravity would have on how we move around. Student predictions can be compared to video footage of astronauts walking on the Moon. For example Buzz Aldrin on the Apollo 11 mission: <https://www.youtube.com/watch?v=qzYfwHr_62g> [accessed May 2019].

The following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Bathroom scales

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

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