**Spaceships**

A force acting on an object can make it accelerate.

Doubling the resultant force doubles the acceleration.

If the mass of the object is doubled, acceleration is halved.

acceleration

=

force

mass

This relationship is usually written as:

force, F, in newton (N)

mass, m, in kilogram (kg)

acceleration, a, in metres per second squared (m/s2)

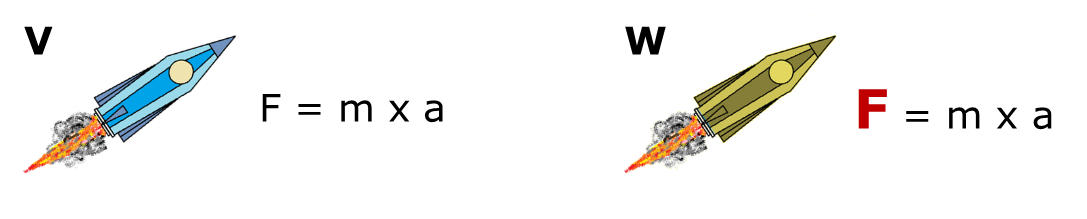
Force = mass x acceleration

F = m x a

***One newton*** *is the force needed to accelerate a mass of 1 kg at a rate of 1 m/s2.*

1. Spaceship W has the same mass as spaceship V.

It has twice the resultant force acting on it.



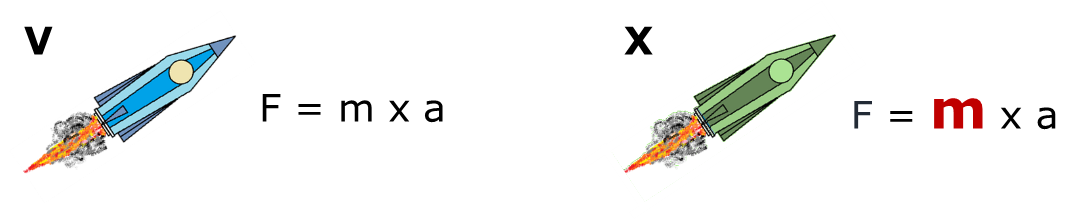
What is the acceleration of spaceship W?

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

|  |  |  |
| --- | --- | --- |
| **A** | Two times smaller than V. |  |
|  |  |  |
| **B** | The same as V. |  |
|  |  |  |
| **C** | Two times bigger than V. |  |

1. Spaceship X has twice the mass of spaceship V.

The resultant force acting on it is the same.



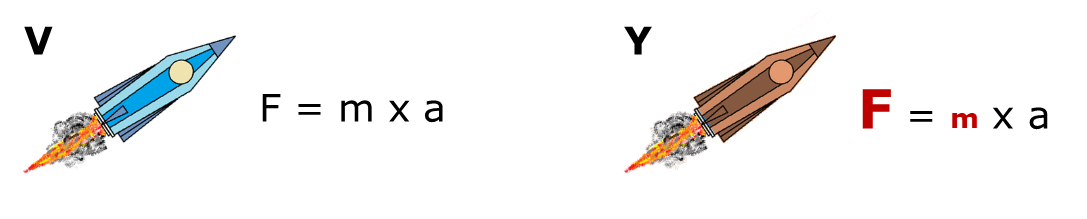
What is the acceleration of spaceship X?

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

|  |  |  |
| --- | --- | --- |
| **A** | Two times smaller than V. |  |
|  |  |  |
| **B** | The same as V. |  |
|  |  |  |
| **C** | Two times bigger than V. |  |

1. Spaceship Y has half the mass of spaceship V.

The resultant force acting on it is two times as big.



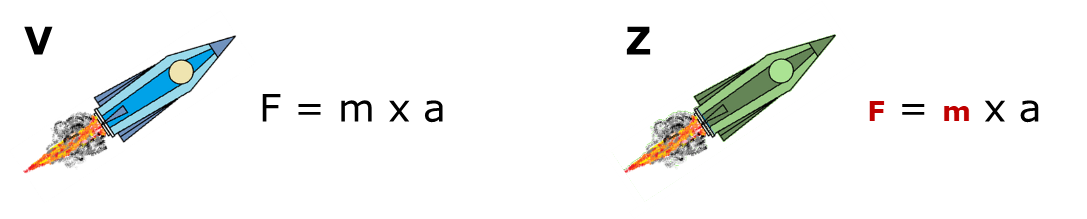
What is the acceleration of spaceship Y?

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

|  |  |  |
| --- | --- | --- |
| **A** | The same as V. |  |
|  |  |  |
| **B** | Two times bigger than V. |  |
|  |  |  |
| **C** | Four times bigger than V. |  |

1. Spaceship Z has the same mass as spaceship V.

It has twice the resultant force acting on it.



What is the acceleration of spaceship Z?

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

|  |  |  |
| --- | --- | --- |
| **A** | Four times smaller than V. |  |
|  |  |  |
| **B** | The same as V. |  |
|  |  |  |
| **C** | Four times bigger than V. |  |

*Physics > Big idea PFM: Forces and motion > Topic PFM6: Forces make things change > Key concept PFM6.2: Force, mass and acceleration*

|  |
| --- |
| **Diagnostic question** |
| **Spaceships** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | The acceleration of an object is proportional to the resultant force acting on it and inversely proportional to its mass. An object accelerates in the direction of the resultant force acting on it. |
| Observable learning outcome: | Explain the equation F = m x a and use it to make calculations. |
| Question type: | Simple multiple choice |
| Key words: | Force, mass, acceleration |

**What does the research say?**

Students may be able to use Newton’s second law when performing calculations, but a superficial knowledge of the use of formulae may mask qualitative misunderstandings and misconceptions (Viennot, 1979; Clement, 1982). They may demonstrate rote learning of Newton’s laws without an understanding of how to apply them and may focus on superficial features of physical situations rather than applying general principles (Lemmer, 2013).

Whilst carrying out calculations is an important part of students’ learning, success in using equations is not the same thing as developing conceptual understanding and misconceptions may remain (Kim and Pak, 2002). To expert physicists, symbols stand for physical quantities, and the results of the mathematical manipulations must be interpreted in terms of their meaning for a given physical system. Experts draw on their experience and (often tacit) knowledge of physical systems in order to make meaning from the mathematics (Carson, 1999; Redish and Kuo, 2015). To novices, the manipulation of the symbols, and the substitution of numbers into formulae may be ends in themselves, devoid of physical meaning. It is therefore important to ask students to think qualitatively and quantitatively about mathematical formulae as well as substituting in numbers in order to carry out calculations.

**Ways to use this question**

Students should complete the question 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 answers to the question will show you whether students understood the concept sufficiently well to apply it correctly.

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**

1. B 2. A 3. C 4. B

**How to respond - what next?**

These questions are designed to help students to reason quantitatively about the relationship between the variables without doing any calculations with numbers. Students should be encouraged to develop their physical intuition by thinking about the effect on one variable in the equation when one or both of the others changes. They can be encouraged to use familiar contexts – pushing a bus and a car, for example – to support their quantitative reasoning.

1. Some students may think wrongly that acceleration needs to half in order to ‘balance’ the doubling of force.

2. A few students may think wrongly that acceleration doubles to give consistency to the right-hand side of the equation.

3. Some students may wrongly consider that a halving of mass and a doubling of force cancel out and the acceleration is the same.

4. Here, it is relatively common for students to think that the acceleration is either four times bigger or four times smaller.

If students have misunderstandings about predicting how one quantity in the equation F = m x a is affected by other quantities, a useful strategy is to give them the opportunity to consider the equation as a balance. A change on one side requires a change on the other side to increase or decrease its value in the same way.

Giving students the opportunity to work in pairs or in small groups to explain each example in terms of what is happening physically, can help develop a better understanding by encouraging the social construction of new ideas through dialogue.

**Acknowledgments**

Developed by Simon Carson (UYSEG).

Images: Simon Carson (UYSEG).

**References**

Carson, S. (1999). Physics in mathematical mood. *Physics World,* 12(4)**,** 48-48.

Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics,* 50(1)**,** 66-71.

Kim, E. and Pak, S.-J. (2002). Students do not overcome conceptual difficulties after solving 1000 traditional problems. *American Journal of Physics,* 70(7)**,** 759-765.

Lemmer, M. (2013). Nature, Cause and Effect of Students' Intuitive Conceptions Regarding Changes in Velocity. *International Journal of Science Education,* 35(2)**,** 239-261.

Redish, E. F. and Kuo, E. (2015). Language of physics, language of math: Disciplinary culture and dynamic epistemology. *Science and Education,* 24**,** 561-590.

Viennot, L. (1979). Spontaneous Reasoning in Elementary Dynamics. *European Journal of Science Education,* 1(2)**,** 205-221.