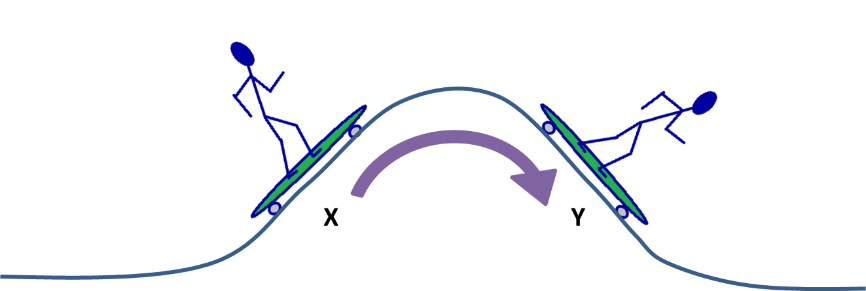
**Bumps and orbits**

**1. Skateboarder**

A skateboarder is going over a bump.



**To answer**

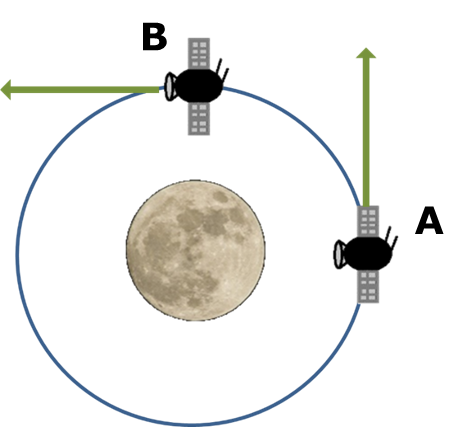
**a.** What is the direction of the velocity of the skateboarder at X?

**b.** What is the direction of the velocity of the skateboarder at Y?

**c.** What is the direction of the **change in the velocity** of the skateboarder between X and Y?

**2. Around the Moon**

A satellite is travelling around the Moon at constant speed.



**To answer**

What is the direction of the **change in the velocity** of the satellite between A and B?

Arrows that may be used to support thinking about **Bumps and orbits**.

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*Physics > Big idea PFM: Forces and motion > Topic PFM4: Measuring and calculating motion > Key concept PFM4.1: Velocity*

|  |
| --- |
| **Response activity** |
| **Bumps and orbits** |

**Overview**

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| Learning focus: | Velocity and displacement are vector quantities. Velocity measures by how much displacement changes in a given time interval. |
| Observable learning outcome: | Calculate differences in velocity for one-dimensional and two-dimensional motion. |
| Question type: | Application and practice |
| Key words: | Velocity, vector |

|  |  |
| --- | --- |
| **B** | **BRIDGING**  This response activity probes understanding of ideas that are usually taught at age 16-19, to build a bridge to later stages of learning. |

This activity can help develop students’ understanding by addressing the sticking-points revealed by the following diagnostic question:

* Diagnostic question: The difference matters
* Diagnostic question: Changing velocity

**What does the research say?**

Students may not differentiate clearly between the scalar quantity, speed, and the vector quantity, velocity. To be able to describe motion accurately, and to carry out calculations correctly, they need to be clear about the vector nature of quantities such as displacement, velocity and acceleration.

Research shows that despite being taught about vectors at school, very many students on undergraduate introductory physics courses in the USA have no *useful* knowledge of vectors (Aguirre, 1988; Knight, 1995).

Students’ misunderstandings of vector ideas may be compounded by the different approaches taken in school mathematics and physics teaching: although students may be able to add and subtract column vectors in mathematics, graphical addition and subtraction of vectors of the sort more likely to be encountered in physics proved more problematic (Tairab *et al.*, 2020). It is important, therefore, to establish a good understanding of displacement and velocity as vectors before studying accelerations and forces.

Reif and Allen (1992) note that acceleration is a vector that describes the rate of change of both the magnitude and the direction of a particle's velocity. In everyday life, acceleration typically means ‘speeding up’, so the fact that an object can accelerate whilst travelling at a constant speed when its direction is changing is a potential source of confusion for students. This activity prepares students for thinking about changes in velocity before explicitly developing ideas about acceleration.

**Ways to use this activity**

This task is intended for discussion in pairs or small groups. The activity can be made more concrete by allowing students to cut out the arrows to represent vectors and use these to add vectors tip to tail. As calculating a change in velocity requires that students need to think about the difference between two vectors, they need to be able to subtract vectors geometrically, which in turn means reversing the direction on the initial velocity vector.

As well as straight arrows, curved arrows are also provided. These cannot represent vectors as they do not have a unique direction, and if students attempt to use them in their discussions, this will give you feedback about fundamental misunderstandings about the nature of vector quantities.

Listening in to the conversations of each pair or group will 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 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**

**1. Skateboarder**

a. At 45o up and to the right

b. At 45o down and to the right

c. Vertically downwards

**2. Around the Moon**

The direction of the change in velocity is 45o down and to the left, towards the centre of the Moon.

The direction of the change in velocity in both cases is the same as the direction of the acceleration, and acceleration in the direction of the resultant force on the objects. For the skateboarder’s up and down movement, the resultant force is in the direction of the Earth’s gravitational pull; and the resultant force on the satellite is in the direction of the Moon’s gravitational pull.

**Acknowledgments**

Developed by Simon Carson (UYSEG), from ideas in the paper by Flores et. al. (2004).

Images: Simon Carson (UYSEG)

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