Questacon,
in partnership with Raytheon and
the Neutral Buoyancy Laboratory in the USA,
welcome you to

Mission Astronautica

An experimental journey
demonstrating some of the challenges
of working in zero-gravity.

Overview

The National Science and Technology Centre and the Neutral Buoyancy Laboratory in the USA will present a challenge to you and your students.

To answer this challenge, students will investigate the subject of neutral buoyancy by making an object that ‘hovers’ in water without any support. Along the way, they will cover topics such as buoyancy, forces and how a topic like neutral buoyancy is related to moving in zero-gravity.

What is neutral buoyancy?

If you place an object in a fluid and it sinks, it’s **negatively buoyant**. If it rises and floats up, it’s **positively buoyant**. An object is **neutrally buoyant** when it has an equal tendency to float and sink. It doesn’t go up or down.

Some examples of neutral buoyancy that you may have encountered:

- Fish can drift at the same level in water by inflating or deflating their swim bladders.
- Submarines fill and empty their ballasts so that they can sink or rise to various levels in the ocean, then remain neutrally buoyant to conserve energy.
- SCUBA divers wear weights on their belts to stop themselves floating back up to the water’s surface. This way, they can remain at the same level. SCUBA divers must also breathe carefully so that they don’t change their buoyancy too much by inflating or deflating their lungs.
- Our brains are neutrally buoyant! Though our brains weigh from 1.2-1.4 kg on average, they float in a fluid called cerebral spinal fluid. Neutral buoyancy ensures that our brains don’t float up to the top of our skulls (which could be a little jarring) or sink down and get squashed under their own weight.

For a more in-depth look at buoyancy, see appendix A.

What is the NBL and what happens there?

The Neutral Buoyancy Laboratory in Houston, Texas, is an enormous pool approximately 62 metres long, 31 metres wide and 12.34 metres deep. The pool is used to train astronauts to walk and move in space.

Astronauts are immersed in this pool in specially weighted suits that make them neutrally buoyant. They 'hover' in the water, which is the closest simulation they can get to the weightless feeling of being in space, while still remaining on the Earth.

Mock-ups of various areas of the international space station are used in the NBL pool. Astronauts use these to practice moving around as they would in space.

While the NBL is a cost-efficient way to train astronauts for space walks, there are two major differences between the experience in the pool and in space. Although astronauts can float at neutral buoyancy in the pool, within their suits they still experience the force of gravity, so they know when they aren't upright and still have a sense of up and down. The drag of water also slows down movement in the pool whereas there is no drag when moving in space.

Who is giving the challenge?

The challenge comes from scientists at the NBL in Houston, supported by Raytheon Australia and Questacon.

The challenge

➢ To create an object that is neutrally buoyant in water.

To meet the challenge:

- The object must stay at the same level in water.
- All parts of the object must remain at least 10 cm beneath the surface of the water.

You may choose to complete the challenge as a class project, or split your students into small teams. It is compulsory to attempt this challenge.

Students may use parts sourced from hardware stores, toy stores or aquariums, but they may not use a ready-made submarine toy or similar to meet the challenge.

Additional challenges

You may also choose to give your students as many of the following additional challenges as you wish, depending on their skills, enthusiasm and time available:

- The object stays neutrally buoyant when flipped upside down.
- The object stays neutrally buoyant when flipped on its side/s.
- Include a mechanism that allows you to control the ascent or descent of your object.
- Create a mechanism that moves your object from one side of the tank to the other using a remotely operated system.
- Make the object dock with another neutrally buoyant object.

All the additional challenges are optional, and any combination or number of additional challenges may be completed.

A summary table listing the parameters for completing the additional challenges is available in Appendix A

Resources

- The Neutral Buoyancy Lab
  http://dx12.jsc.nasa.gov/site/index.shtml
  http://arstechnica.com/science/2013/03/swimming-with-spacemen/

- Examples of previous Questacon video conference events
  A presentation by NASA Administrator Charles Bolden Jr.
  http://youtu.be/tqP_NwFtZTQ

  The Transit of Venus – a tale of discovery and science
  http://youtu.be/0lrSs7iMr8U

- The Accidental Maker (a good read about a Robot Submarine)
  http://www.make-digital.com/make/vol34#pg54

Appendices

Appendix A – Challenge summary table

COMPULSORY CHALLENGE		
Challenge	**Parameters for meeting challenge**	**Relevance of challenge**
Create an object that is neutrally buoyant.	- The object must stay at the same level in water. - All parts of the object must remain at least 10 cm beneath the surface of the water.	Astronauts are made neutrally buoyant in the NBL pool so that they can experience a sensation similar to feeling weightless in zero-gravity. The tools they use in the pool are also neutrally buoyant to simulate tools that float in zero-gravity.
ADDITIONAL CHALLENGES		
The object stays neutrally buoyant when flipped upside down.	- The object must stay at the same level in water. - All parts of the object must remain at least 10 cm beneath the surface of the water.	Astronauts training in the NBL pool are weighted so that they are neutrally buoyant on all axes. This simulates how they can ‘float’ upside down and sideways in space, so they can practice working at all angles.
The object stays neutrally buoyant when flipped on its side/s.	- The object must stay at the same level in water. - All parts of the object must remain at least 10 cm beneath the surface of the water.	Astronauts training in the NBL pool are weighted so that they are neutrally buoyant on all axes. This simulates how they can ‘float’ upside down and sideways in space, so they can practice working at all angles.
Include a mechanism that allows you to control the ascent or descent of your object.	- The mechanism must be part of the object (i.e. not an external object such as a crane) but may have parts that protrude from the water such as a pipe or hose.	Submarines and fish are able to control what level of water to which they rise or sink, then remain neutrally buoyant after they reach the desired level.
Create a mechanism that moves your object from one side of	- You may choose to make the object move using a system such as a series of lift bags within the tank	Astronauts in the NBL pool cannot move from place to place on their own as their suits restrict their motion. Teams of

the tank to the other using a remotely operated system.	(operated from outside the tank using syringes as pumps), or an external object such as a crane. - You may choose to make the object move by adding a motor that is operated by a battery-powered remote control.	divers move them around, and also use objects such as cranes and inflatable lift bags to help move items around the pool.
Make the object dock with another neutrally buoyant object.	- The unrestrained object may be floating on the surface of the water, or be neutrally buoyant itself. - Students cannot use the walls of the container of water as resistance when making the object dock.	One of the reasons astronauts must practice working in the NBL pool before working in space is because items behave differently when they are at neutral buoyancy or at zero-gravity. They do not have weight, so objects tend to offer little in the way of resistance.

Appendix B – Buoyancy explained

Buoyancy is caused by a difference in fluid pressure at different levels in the fluid. Particles that are lower down are pushed down by the weight of all the particles above them (it may help to visualise the particles as small balls). The particles at the upper levels have less weight above them. As a result, there is always greater pressure below an object than above it, so the fluid constantly pushes the object upward.

The force of buoyancy on an object is equal to the mass of the fluid **displaced**, or pushed aside, by that object. For example, if you submerge an empty 1 litre bottle in a bathtub, it displaces 1 litre of water. The water in the bathtub then pushes up on the bottle with 1 kilogram of force, the weight of 1 litre of water.

If you submerge an object with a greater volume, it will be pushed upwards with more force because it displaces a greater volume of water.

Floating, sinking and neutral buoyancy

Objects will float (be **positively buoyant**) when they displace an amount of water that weighs more than the object. An empty 1 litre bottle is lighter than the 1 litre of water that it displaces (equivalent to 1 kilogram of force), so it floats.

Objects will sink (be **negatively buoyant**) when they displace an amount of water that weighs less than the object. What happens if you put a 5 kilogram weight into the 1 litre bottle? You haven't changed the volume of the bottle, but it now becomes heavier than the 1 litre of water it displaces (equivalent to 1 kilogram of force), so it sinks.

Now imagine taking the 5 kilogram weight out of the 1 litre bottle and putting it in a 10 litre container. When you submerge the 10 litre container, it will displace 10 litres of water—the equivalent of 10 kilograms of force pushing the container upward. This is greater than the weight of the container, so the container will float.

When the density (the mass to volume ratio) of an object matches the density of the surrounding fluid, it will be **neutrally buoyant**, and remain where it is without rising or sinking.

Adapted from:
http://science.howstuffworks.com/environmental/life/zoology/marine-life/questions629.htm
http://www.howstuffworks.com/buoyancy-info.htm

Appendix C – National Curriculum Links

Year 7 – Science			
Strand	Sub-strand	Concept	Elaboration
Science Understanding	*Physical Sciences*	Change to an object's motion is caused by unbalanced forces acting on the object (ACSSU117)	- Investigating the effects of applying different forces to familiar objects - Investigating common situations where forces are balanced, such as stationary objects, and unbalanced, such as falling objects - Investigating a simple machine such as lever or pulley system
		Earth's gravity pulls objects towards the centre of the Earth (ACSSU118)	- Exploring how gravity affects objects on the surface of Earth
Science as a Human Endeavour	*Nature and Development of science*	Science knowledge can develop through collaboration and connecting ideas across the disciplines of science (ACSHE223)	
	Use and Influence of Science	Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations (ACSHE120)	
		People use understanding and skills from across	

		the disciplines of science in their occupations (ACSHE224)	
Science Inquiry Skills	*Questioning and Predicting*	Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS124)	- Working collaboratively to identify a problem to investigate - Using information and knowledge from previous investigations to predict the expected results from an investigation
	Planning and Conducting	Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS125)	- Working collaboratively to decide how to approach an investigation - Learning and applying specific skills and rules relating to the safe use of scientific equipment - Identifying whether the use of their own observations and experiments or the use of other research materials is appropriate for their investigation - Developing strategies and techniques for effective research using secondary sources, including use of the internet
		In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task (ACSIS126)	- Recognising the differences between controlled, dependent and independent variables - Using a digital camera to record observations and compare images using information technologies - Using specialised equipment to increase the accuracy of measurement within an investigation
	Processing and Analysing Data and Information	Summarise data, from students' own investigations and secondary sources,	- Using diagrammatic representations to convey abstract ideas and to simplify complex situations

		and use scientific understanding to identify relationships and draw conclusions (ACSIS130)	- Comparing and contrasting data from a number of sources in order to create a summary of collected data - Identifying data which provides evidence to support or negate the hypothesis under investigation - Referring to relevant evidence when presenting conclusions drawn from an investigation
	Evaluating	Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the method (ACSIS131)	- Discussing investigation methods with others to share ideas about the quality of the inquiry process - Identifying and considering indicators of the quality of the data when analysing results - Suggesting improvements to inquiry methods based on experience
		Use scientific knowledge and findings from investigations to evaluate claims (ACSIS132)	- Using the evidence provided by scientific investigations to evaluate the claims or conclusions of their peers
	Communicating	Communicate ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate (ACSIS133)	- Presenting the outcomes of research using effective forms of representation of data or ideas and scientific language that is appropriate for the target audience - Using digital technologies to access information and to communicate and collaborate with others on and off site
Year 8 – Science			
Science as a human	*Nature and Development of*	Science knowledge can develop	

Endeavour	*Science*	through collaboration and connecting ideas across the disciplines of science (ACSHE226)	
	Use and Influence of Science	Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations (ACSHE135)	
		People use understanding and skills from across the disciplines of science in their occupations (ACSHE227)	- Considering how engineers improve energy efficiency of a range of processes - Investigating how scientists have created new materials such as synthetic fibres, heat-resistant plastics and pharmaceuticals
Science Inquiry Skills	*Questioning and Predicting*	Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS139)	- Considering whether investigation using available resources is possible when identifying questions or problems to investigate - Using information and knowledge from their own investigations and secondary sources to predict the expected results from an investigation

	Planning and Conducting	Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS140)	- Working collaboratively to decide how to best approach an investigation - Identifying any ethical considerations that may apply to the investigation - Taking into consideration all aspects of fair testing, available equipment and safe investigation when planning investigations
		In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task (ACSIS141)	- Using specialised equipment to increase the accuracy of measurement within an investigation - Identifying and explaining the differences between controlled, dependent and independent variables
	Processing and analysing data and information	Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships, including using digital technologies as appropriate (ACSIS144)	- Describing measures of central tendency and identifying outliers for quantitative data - Explaining the strengths and limitations of representations such as physical models, diagrams and simulations in terms of the attributes of systems included or not included
		Summarise data, from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions (ACSIS145)	- Constructing tables, graphs, keys and models to represent relationships and trends in collected data - Drawing conclusions based on a range of evidence including primary and secondary sources
	Evaluating	Reflect on the	- Suggesting improvements

		method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the method (ACSIS146)	to investigation methods that would improve the accuracy of the data recorded - Discussing investigation methods with others to share ideas about the quality of the inquiry process
		Use scientific knowledge and findings from investigations to evaluate claims (ACSIS234)	- Identifying the scientific evidence available to evaluate claims - Deciding whether or not to accept claims based on scientific evidence - Identifying where science has been used to make claims relating to products and practices
	Communicating	Communicate ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate (ACSIS148)	- Using digital technologies to construct a range of text types to present science ideas - Selecting and using appropriate language and representations to communicate science ideas within a specified text type and for a specified audience

Years 7 and 8 – Technology		
	Design and Technologies	**Digital Technologies**
Knowledge and Understanding	Investigate and select from a range of materials, systems, tools and equipment	
	Consider the ways characteristics and properties or resources can be combined to create and produce solutions to problems for individual students and the community considering ethics, culture and social factors	

	Investigate design and technology professions and the contributions that each makes to society both locally and globally	
Processes and production skills	Use creativity, innovation and enterprise skills with increasing independence and collaboration	Collect and analyse relevant data with increasing independence and in collaboration with others
	Use production skills with increasing independence to design, plan, manage and safely produce quality solutions for increasingly complex problems	
	Evaluate design solutions using identified criteria taking account of users, resources, sustainability, ethics, and cultural and personal values.	

Appendix D – Classroom activities

These activities are intended to demonstrate some of the concepts involved in this challenge, as well as give your students ideas for how they can meet the challenge. All activities are optional.

Activity 1: Talking about buoyancy

This activity is best run as a teacher demonstration to stimulate discussions on what is buoyancy.

Materials
Three identical opaque watertight containers
Water trough large enough to hold all three

Method
Fill one container full of water, one a third/half full and leave the remaining container full of air without the students knowing.
Ask students what they think will happen when three apparently identical containers are placed in the water.
Once students have come to a consensus, place all three containers in the water, and lead a discussion about what the students observe, and what they believe to be happening.

Activity 2: Diving and rising pen lids

The students can work in small groups, and will need a few simple materials. The activity should take no longer than 20 minutes.

Materials (per group)
A clear cylindrical PET bottle of any size, full of water
A clear oval PET bottle of any size (e.g. an empty mouthwash bottle), full of water
Three pen lids or the tops of plastic pipettes
Plasticine or blu-tac

Method
For two of the lids: if the pen lid has a hole at the top, cover it with plasticine so air can be trapped.

Place some plasticine on the arm of the pen lid to act as a weight. Test the lid in both bottles of water. The lid should be able to float at the very top of the bottle, remaining upright with air inside it.
Add the remaining lid to the oval bottle after adding just enough weight to make it *sink* to the bottom.

Replace the lids of both bottles tightly and squeeze the sides. Release the pressure from the sides of the bottle. What happens to the pen lid? Does this change depending on where you squeeze the bottle?

What's happening?
Squeezing the cylindrical bottle causes the pen lid to sink because the increased pressure forces water into the lid. This compresses the air bubble that is in the pen lid and reduces the amount of water displaced so it sinks. The mass stays the same while the density changes, decreasing the buoyancy of the pen lid.

When you stop squeezing the bottle, the pressure on the air bubble decreases. Water moves back out of the pen lid so the 'submarine' regains its buoyancy and rises to the top again.

When squeezing the oval bottle from the "long" sides, the same thing happens. However, when you squeeze the "short/thin" sides together, you actually *increase* the volume inside the bottle. This reduces the pressure on the pen lid, allowing it to rise (if this doesn't occur, try reducing the amount of weight on the pen lid).

Activity 3: Neutral buoyancy with a balloon

The students can work in small groups, and will need a few simple materials. The activity should take no longer than 20 minutes.

Materials (per group)
Empty balloons with a small weight inside
A tub of water per group (a larger tub to be shared will also work)
One syringe and tube per group

Method
Challenge students to use a syringe and tube to slowly inflate the balloon until it reaches neutral buoyancy without letting in water.

Activity 4: Pushing and pulling in space

For the adventurous! Suggested to be run as a teacher led activity, with volunteers participating one at a time. Alternatively, this could be an interesting thought experiment for students.

Materials
Two skateboards or 2 pairs of rollerblades

Method
Have one student sit on a skateboard and try to push away a student of similar weight, sitting on a separate skateboard. If the students are similar in weight, it should be difficult for either student to move the other. Have one student swap

with a teacher and repeat the experiment. This demonstrates how astronauts in the NBL pool find it difficult to use their own mass to push/pull objects as they will simply float (or in this case, roll) away.

Activity 5: The smallest float

The students can work in small groups for this activity.

Materials (per group)
A stick of plasticine
Bucket of water

Method
Divide the plasticine into 5 pieces of equal size. Each piece must be moulded into different shapes, with the aim being to create a shape that will float with the smallest amount of submerged plasticine.

Appendix E – Questions for students to think through

The following questions may be used to create a worksheet, to engage students in discussion, or both!

Before they begin:

- Would the shape of the object affect how easy it is to make neutrally buoyant?
- What material will your object be made from, and how does this affect its buoyancy? Note that you may use parts sourced from hardware stores, toy stores or aquariums, but please do not use a ready-made submarine toy or similar to meet the challenge!
- How might your object be useful in space, or as a piece of practice/testing equipment in the NBL pool?

If attempting the additional challenge about an ascending/descending object:

- How do fish or submarines maintain neutral buoyancy? Can you use a similar mechanism for your object?

After completing their challenge:

- What was your favourite part of this project?
- What was your greatest challenge when trying to make your object neutrally buoyant?
- During your project, did you find out any information that might be useful for the people at the NBL to know?

If they have attempted the additional challenge about docking an object:

- How do you think the challenges involved in docking your object relate to manipulating objects in space?