Royal Academy of Engineering

THIS IS ENGINEERING

Student guide

MISSION TO MARS

How will engineers make it possible to live on other planets?

This resource aims to give students the opportunity to investigate the science, technology, engineering and mathematics (STEM) of space exploration.

CONTENTS

INTRODUCTION

THE SPACE INDUSTRY HAS LED TO MANY INNOVATIONS THAT HAVE HAD A POSITIVE IMPACT ON LIFE ON EARTH.

In medicine, there have been many technological advancements that have origins in space, from CAT scans and robotic surgery, to more functional prosthetic limbs. Foam material developed by NASA to be used as a shock absorber has been adapted to create natural looking flesh for prosthetics as well as to help reduce friction between the prosthesis and the skin of the user. This foam has also been used in memory foam mattresses.

Another NASA invention is used every day in mobile phones. While at NASA, Eric Fossum wanted to miniaturise cameras for an interplanetary mission, so he invented the complementary metal-oxide-semiconductor (CMOS) active pixel image sensor and the so-called 'camera-on-a-chip' CMOS image sensor.

This image sensor technology, along with the charge-coupled device (CCD) and the pinned photodiode (PPD), has transformed medical treatments, science, personal communication and entertainment. It saves lives, by using non-surgical pill cameras and endoscopes inside our bodies to diagnose medical problems, as well as helping to reduce X-ray doses to patients and improving dental care.

For this advancement in image sensor technology, Eric Fossum, George Smith, Nobukazu Teranishi and Michael Tompsett won the Queen Elizabeth Prize for Engineering (QEPrize) in 2017. Awarded every two years, the QEPrize celebrates the greatest achievements of modern engineering. The Create the Trophy competition to design the next trophy for the QEPrize is open to 14 to 24 year olds.

For more information about the QEPrize, and the Create the Trophy competition visit **http://qeprize.org/**

LAUNCH

CREW

Boeing's new CST-100 module has been designed to fit up to seven crew members comfortably, or any number of crew less than seven plus cargo. To reduce the fuel that is needed for launch, the crew and cargo need to be configured in a way that balances the forces.

TIME TO THINK

How many people could you accommodate in different spacecraft and does that leave enough space for cargo?

METHOD 1

Calculate the areas of each spacecraft to estimate the maximum number of seats you can fit in the following space craft:

Apollo

The diameter of the Apollo module 3.90 m

CST-100

The diameter of the CST-100 module 4.56 m

Soyuz

The diameter of the Soyuz module 2.72 m

A seat needs a space with a height of 1.18 m and a width 0.52 m

? Why is the real maximum number of seats lower than this?

METHOD 2

1. Draw a scale plan of the spacecraft on A3 sheets of paper.
2. Create an outline shape for the seat on paper and card. These outlines are your basic repeat units. Use them to work out the maximum number of seats that can fit in each craft.

AERODYNAMICS

All moving objects experience a drag force, which slows the moving objects down.

It occurs because objects moving through gas or liquids push their way through particles.

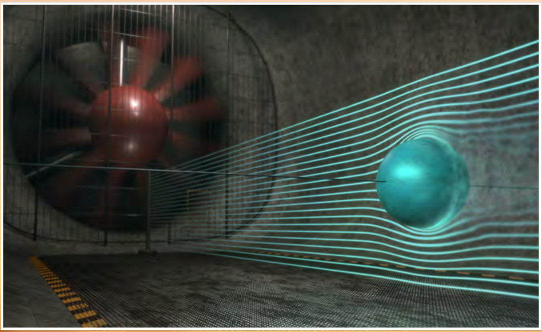
Launch vehicles are designed to be aerodynamic, making it easier to push past the particles and therefor reducing the drag forces on launch. This means less thrust is needed to launch a rocket into space.

TIME TO INVESTIGATE

Part 1

Investigate how different shapes move through fluids.

- Shape the same mass of plasticine into the following shapes: sphere, cube, disc, cone.
- Ensure each shape has string attached, so that you can easily remove the shapes from the oil.
- Pour 450ml of oil into a 500ml measuring cylinder
- Drop the shapes, one at a time, into the measuring cylinder of oil. Time how long it takes each one to fall through the measuring cylinder.



Shape	Time taken to drop to bottom of cylinder(s)

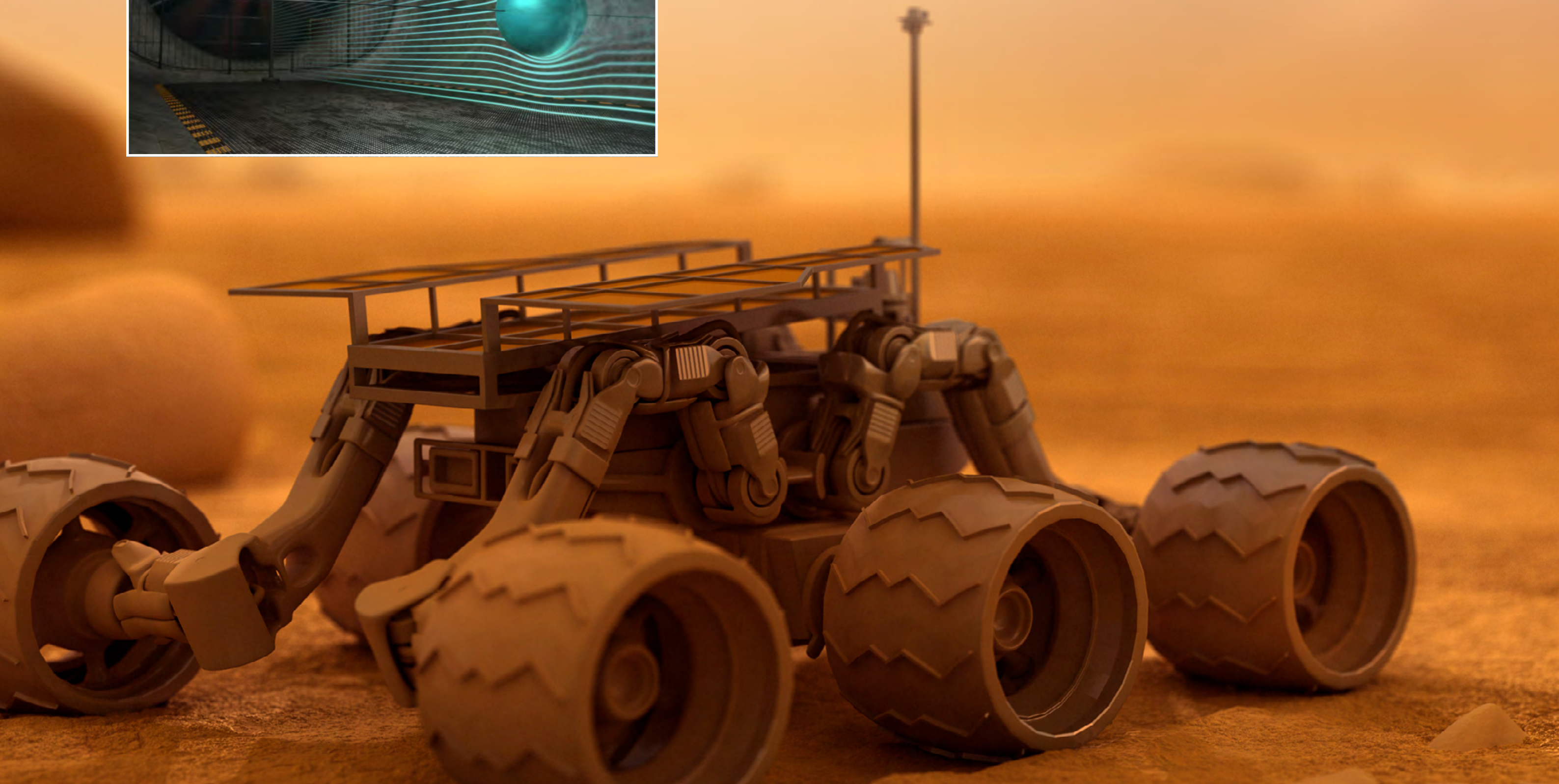
The most aerodynamic shape is

____

1. What has been done to ensure the experiment is reproducible?
2. Identify the independent, dependent and control variables.

Part 2

Use what you have learnt to design the nose cone for a balloon rocket.



LANDING

GRAVITY

Gravity is a force that attracts objects towards each other. The gravitational force felt by an object depends on the mass of the objects and the distance between the objects.

The gravitational force felt by objects is different on different planets.

Weight is a force measured in Newtons, caused by gravity. Therefore, objects have different weights on different planets or moons. This can be observed when watching astronauts walking on the Moon.

TIME TO CALCULATE

Weight can be calculated using the equation:

$W = m \times g$

Where

W = weight, m = mass and g = gravity.

The gravitational force on the Earth is $9.81 m/s^2$

The gravitational force on the Moon is $1.62 m/s^2$

1. Calculate the weight of a 15kg object on Earth
2. Calculate the weight of a 15kg object on the Moon
3. What is the gravity on Mars if an object with a mass of 15kg weighs 55.65N?

HEAT SHIELD

When spacecraft enter an atmosphere of a planet at high speed, it must be able to withstand high temperatures. For example, the outside of the Soyuz capsule can reach temperatures of 3000°C upon re-entry to the Earth's atmosphere.

The melting point of steel, a commonly used material in transport and infrastructure, is between 1425°C and 1540°C. Engineers must make sure that the spacecraft they design can withstand high temperatures without melting or burning the people inside.

DESIGN CHALLENGE

Part 1

Investigation into the temperature change of water in a beaker when heat is applied to a beaker covered in different insulating materials.

Pour water into a beaker and cover the outside of the beaker with insulating materials.

Use a thermometer to find the temperature of the water before and after heating the beaker.

Heat the beaker with a hairdryer for 5 minutes.

Part 2

Use your observations to design a heatshield for a spacecraft. Make a container for a small square of chocolate to protect the chocolate from heat.

To test the heat shield, place the covered box a warm oven set at 45°C for two minutes to see if it protects the chocolate. Chocolate melts at body temperature so the oven does not need to be too hot.

- How would layers effect the heat shield?
- How would adding a gap between layers effect the heat shield?

Insulating material	Temperature of water before heating (°C)	Temperature of water after 5 minutes (°C)	Temperature change (°C)

LIFE ON MARS

TASTE IN SPACE

Astronauts have found that food tastes different in space. On Earth, fluids in the body are pulled down due to gravity. In the first few days' astronauts spend in space the fluids are distributed equally around the body due to the reduced gravity, which is called fluid shift.

This causes astronauts to have a puffy face and the fluid blocks the nasal passages. The puffy face feels like a heavy cold and can reduce their ability to smell.

TIME TO INVESTIGATE

Investigate how food tastes different in space.

Taste each of the foods, first with your nose covered, then with your nose uncovered.

Write your observations in the table.

Food	Taste with no smell	Taste with smell

FOOD ON MARS

The journey to Mars will take approximately six months, so it is essential to be able to grow food on Mars to be able to sustain human life. For plants to grow on the surface of Mars the conditions of the atmosphere and soil need to be right.

The atmosphere on Mars is almost 95% carbon dioxide. Plants use carbon dioxide to produce energy in a process called photosynthesis. Photosynthesis is a chemical process used by plants and algae to make glucose and oxygen from carbon dioxide and water, using light energy.

carbon dioxide + water → glucose + oxygen

Almost all life on Earth depends upon this process. Plants provide energy for animals when they are eaten, and photosynthesis also maintains the levels of oxygen and carbon dioxide in the atmosphere.

Theoretically Mars would be a great environment to grow crops for food, however plants also need oxygen for respiration.

Soil on Mars contains all the nutrients need to grow plants; such as potassium, phosphorus and nitrogen. Nitrogen is an essential constituent of chlorophyll, the green chemical in chloroplast that enables photosynthesis to take place.

TIME TO INVESTIGATE

Investigate the effects of acids and alkalis on plant growth.

- Set up three petri dishes, one labelled “acid”, one labelled “alkali” and the final labelled “neutral”
- Insert cotton around the edges and bottom of Petri dish.
- Add 10 ml of diluted sulphuric acid to the petri dish labelled “acid”.
- Add 10 ml of tap water to the “neutral” petri dish.
- Add 10 ml of limewater to the “alkali” petri dish.
- Test and record the pH of each of the petri dishes in the table below.
- Place 5 cress seeds in each of the petri dishes and observe the growth over 5 days.

	Observations		
Day	**Acid pH__**	**Neutral pH__**	**Alkali pH__**
1			
2			
3			
4			
5			

PRESENTATION ACTIVITY

HOW WILL ENGINEERS MAKE IT POSSIBLE TO LIVE ON OTHER PLANETS?

Use the information and ideas that you have gathered from these activities to present your answer to the big question: How will engineers make it possible to live on other planets?

PRESENTATION SPECIFICATION

The presentation must:

- include a supported answer to the 'big question', 'How will engineers make it possible to live on other planets?'
- include examples of problems faced during the launch and landing of a mission as well as living in space and on other planets.

The presentation could:

- refer to previous space missions, including the missions to the moon.
- include relevant information about life on the International Space Station
- include relevant information from internet-based research, identifying the source of the information
- identify specific examples of the contributions made by one or more types of engineer
- explain the relevant science, technology or mathematics knowledge you used for a problem-solving activity.

The presentation could take a number of forms and could include:

- text
- photographs
- diagrams
- charts
- data

The Royal Academy of Engineering is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

In collaboration with our Fellows and partners, we're growing talent and developing skills for the future, driving innovation and building global partnerships, and influencing policy and engaging the public.

Together we're working to tackle the greatest challenges of our age.

What we do

Talent & diversity

We're growing talent by training, supporting, mentoring and funding the most talented and creative researchers, innovators and leaders from across the engineering profession.

We're developing skills for the future by identifying the challenges of an ever-changing world and developing the skills and approaches we need to build a resilient and diverse engineering profession.

Innovation

We're driving innovation by investing in some of the country's most creative and exciting engineering ideas and businesses.

We're building global partnerships that bring the world's best engineers from industry, entrepreneurship and academia together to collaborate on creative innovations that address the greatest global challenges of our age.

Policy & engagement

We're influencing policy through the National Engineering Policy Centre – providing independent expert support to policymakers on issues of importance.

We're engaging the public by opening their eyes to the wonders of engineering and inspiring young people to become the next generation of engineers.

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