principia MISSION

Maths in Space Pack 3

The speeds, distances and times involved in getting to the International Space Station (ISS)

A mathematics resource for primary and secondary school teachers

9 - 16

UK SPACE AGENCY

esero

STEM LEARNING

UK Space Agency

The UK Space Agency is at the heart of UK efforts to explore and benefit from space. The UK's thriving space sector contributes £11.8 billion a year to the UK economy and directly employs over 34,000 people with an average growth rate of almost 8.5%.

The UK Space Agency is responsible for ensuring that the UK retains and grows a strategic capability in space-based systems, technologies, science and applications

STEM Learning Ltd

STEM Learning Ltd operates the National STEM Learning Centre and Network; providing support locally, through Science Learning Partnerships across England, and partners in Scotland, Wales and Northern Ireland; alongside a range of other projects supporting STEM education. STEM Learning is an initiative of the White Rose University Consortium (comprising the Universities of Leeds, Sheffield and York) and Sheffield Hallam University.

ESERO

ESERO-UK, also known as the UK Space Education and Resource Office, aims to promote the use of space to enhance and support the teaching and learning of science, technology, engineering and mathematics (STEM) in schools and colleges throughout the UK.

Principia

Tim's mission to the International Space Station, called 'Principia', will use the unique environment of space to run experiments as well as try out new technologies for future human exploration missions. Tim will be the first British ESA astronaut to visit the Space Station where he will spend six months as part of the international crew.

Introduction

On December 15th 2015 European Space Agency astronaut Tim Peake launched on the six month Principia mission to the International Space Station. Principia was named after Isaac Newton's *Naturalis Principia Mathematica*, describing the principal laws of motion and gravity.

The education and inspiration of young people is a core element of the Principia mission. Tim is determined to make Principia an exciting adventure for the younger generation. This resource is part of an extensive education programme to inspire children to pursue STEM subjects.

This collection of mathematics resources is aimed at teachers of key stage 2, 3 and 4 students (age 7 to 16), and is closely linked to elements of the mathematics national curriculums of England, Northern Ireland, Scotland and Wales which can be taught in new and stimulating ways. Children can explore familiar and unfamiliar mathematical ideas relating to Tim's Principia mission, including estimation, measures, combinations, permutations and probability.

This teacher guide, and the resources that accompany it,can be used in a number of different ways:

1. Following the activities in sequence will cover the curriculum links listed within. This might be done as part of a themed week, or over a series of sessions.

2. Teachers can pick and choose which activities, resources and links to use and when – they can be used independently of each other. This might enhance the ways in which space and mathematical topics are currently taught. If teachers have specific challenges in mind that align with their interests and those of the children, learning activities might be selectively chosen.

3. Teachers may wish to present children, in class or as part of an extra-curricular activity, with the activities only.

Click here for more teaching resources and ideas linked to Tim's mission.

Curriculum Links

Subject content:

- use the four operations
- recognise and use relationships between operations including inverse operations
- use standard units of mass, length, time, money and other measures, including with decimal quantities
- round numbers and measures to an appropriate degree of accuracy [for example, to a number of decimal places or significant figures]
- use approximation through rounding to estimate answers and calculate possible resulting errors expressed using inequality notation $a<x\leq b$
- use a calculator and other technologies to calculate results accurately and then interpret them appropriately
- change freely between related standard units [for example time, length, area, volume/capacity, mass]
- use scale factors, scale diagrams and maps
- use compound units such as speed, unit pricing and density to solve problems.
- calculate and solve problems involving: perimeters of 2-D shapes (including circles), areas of circles and composite shapes

England:

Working Mathematically

- select and use appropriate calculation strategies to solve increasingly complex problems
- use algebra to generalise the structure of arithmetic, including to formulate mathematical relationships
- develop their mathematical knowledge, in part through solving problems and evaluating the outcomes, including multi-step problems
- make and test conjectures about patterns and relationships; look for proofs or counter-examples
- interpret when the structure of a numerical problem requires additive, multiplicative or proportional reasoning
- develop their mathematical knowledge, in part through solving problems and evaluating the outcomes, including multi-step problems
- select appropriate concepts, methods and techniques to apply to unfamiliar and non-routine problems

Wales:

- transfer mathematical skills across the curriculum in a variety of contexts and everyday situations
- select, trial and evaluate a variety of possible approaches and break complex problems into a series of tasks
- prioritise and organise the relevant steps needed to complete the task or reach a solution
- choose an appropriate mental or written strategy and know when it is appropriate to use a calculator
- explain results and procedures precisely using appropriate mathematical language
- interpret answers within the context of the problem and consider whether answers, including calculator, analogue and digital displays, are sensible

Scotland:

- I can use a variety of methods to solve number problems in familiar contexts, clearly communicating my processes and solutions
- I can solve problems by carrying out calculations with a wide range of fractions, decimal fractions and percentages, using my answers to make comparisons and informed choices for real-life situations.
- By applying my understanding of probability, I can determine how many times I expect an event to occur, and use this information to make predictions, risk assessment, informed choices and decisions.

Northern Ireland:

- Examine the role of mathematics as a "key" to entry for future education, training and employment. Explore how the skills developed through mathematics will be useful to a range of careers
- Decide on the appropriate method and equipment to solve problems–mental, written, calculator, mathematical instruments or a combination of these
- Show deeper mathematical understanding by thinking critically and flexibly, solving problems and making informed decisions
- Work effectively with others
- Demonstrate self-management by working systematically, persisting with tasks, evaluating and improving own performance

Learning Activities

The speeds, distances and times involved in getting to the International Space Station (ISS)

The activities and ideas below are designed to get students thinking about the measures involved in Tim Peake's mission to the International Space Station:

Activity 1

Order the following distances:

a) Earth to the ISS (info)

b) The radius of the Earth (info)

c) London to Edinburgh (info)

d) York to Edinburgh (info)

e) A quadruple Ultra-triathlon (info)

* A quadruple ultra-triathlon is a form of long-distance triathlon, of greater distance than the Ironman Triathlon (2.4 mile swim, 112 mile cycle, 26.2 mile run). The current fastest time for a quadruple ultra- triathlon is 53hrs, 41mins, 00 seconds, set in 1993 by Søren Højbjerre of Norway.

Approximate distances:

a) 240 miles (400km)

b) 4000 miles (6500km)

c) 400 miles (650km)

d) 200 miles (320km)

e) 565miles (900km) (9.4 mile swim, 112mile cycle, 26.2 mile run)

Correct ascending order: d, a, c, e, b.

Activity 2

How far from the Earth's surface is the International Space Station?

To demonstrate you will need 3 or more students (or plastic cups):

- 'A' to stand at one extreme of the classroom, representing the Earth.
- 'B' will represent the Moon. This activity works best if A and B are at a distance of 10 metres apart.
- Students can then suggest where in the model they think the ISS is in relation to the Earth and Moon.

The correct distance using this scale is 1 cm away from the Earth.
Earth to the ISS is approximately 240 miles.
Earth to the moon is approximately 240 000 miles.

When using different scales, the Moon should be approximately one thousand times further away from the Earth than the ISS.

(For more ideas and resources visit our 'Night Sky' and 'Earth and Space' resource lists)

Activity 3

"How many _____ are needed to reach the ISS?"

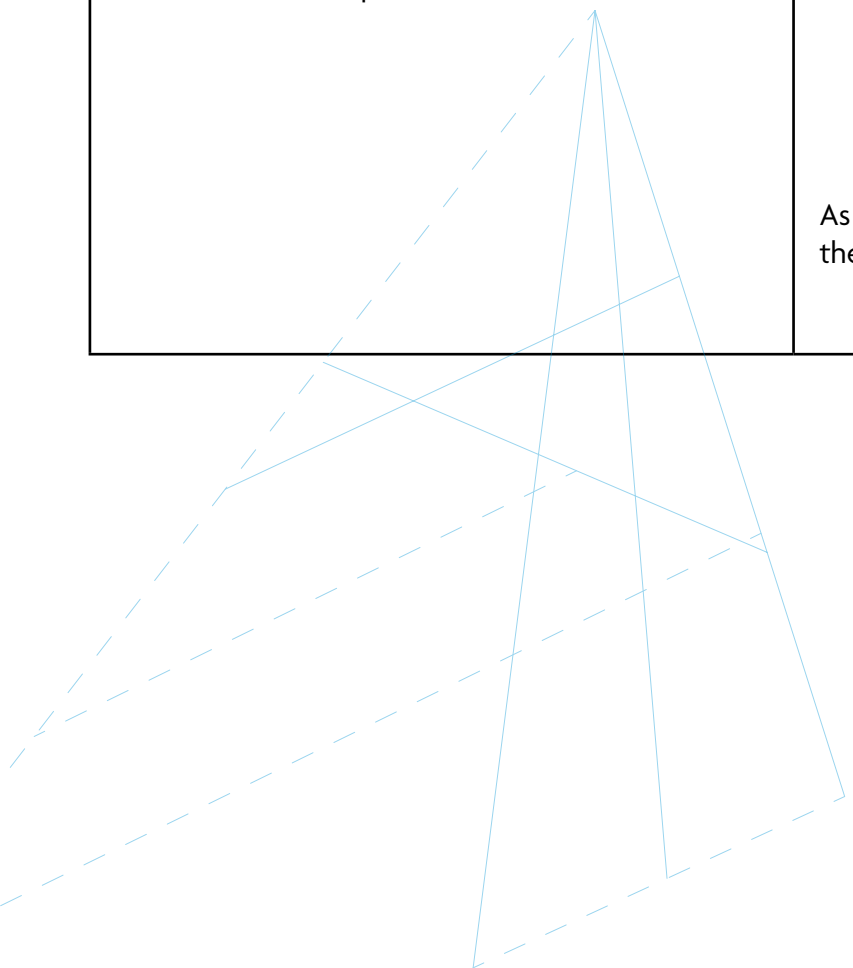
Invite students to investigate how many textbooks, people or pencil cases they would need to stand on top of each other to reach the International Space Station, a distance that varies between 205 and 255 miles from the surface of the Earth.

(For more ideas on teaching view the 'Accuracy of measures' video, part of our Teachers TV collection)

Activity 4

On Earth, in one rotation you travel approximately 25 000 miles, standing on the equator.

What extra distance will Tim have to travel on the ISS in order to complete one orbit?



If you need it, the radius of the Earth is 4 000 miles. (See the 'Circles' resource for additional teaching ideas, part of our Instant Maths Ideas collection).

The extra distance travelled for each rotation will be roughly:

$$2\pi (r+240)-2\pi r$$
$$= 2\pi r+480\pi-2\pi r$$
$$= 480\pi$$
$$\approx 1500 \text{ miles}$$

As a percentage, this is an additional 6.25% of the journey.

Activity 5

When aboard the ISS on his mission Tim will orbit the Earth 16 times each day.

- What is his average speed?
- How many orbits will Tim complete during the mission?
- How many miles do you think he will travel during his mission?

(For more ideas and resources visit our 'Compound Units' resource lists)

Emphasis should be on students clearly structuring the problem and justifying any of their estimates.

Students will have to have to calculate the distance the ISS travels in each rotation (see above), and the time this takes (roughly 16 orbits per day gives 90 minutes per rotation).

The International Space Station travels at around 17000 mph.

This will be roughly equivalent to 16 x 180 ≈ 3000 orbits.

A rough estimate is:
3 000 orbits x 26 500 miles
= 79.5 million miles

Activity 6

If there was a direct road to the ISS, how long would it take to reach it in a car?

It takes Tim 6 hours to get to the ISS. Why do you think it takes so long?

(For more teaching ideas see our lists 'Describing Motion' and 'Time')

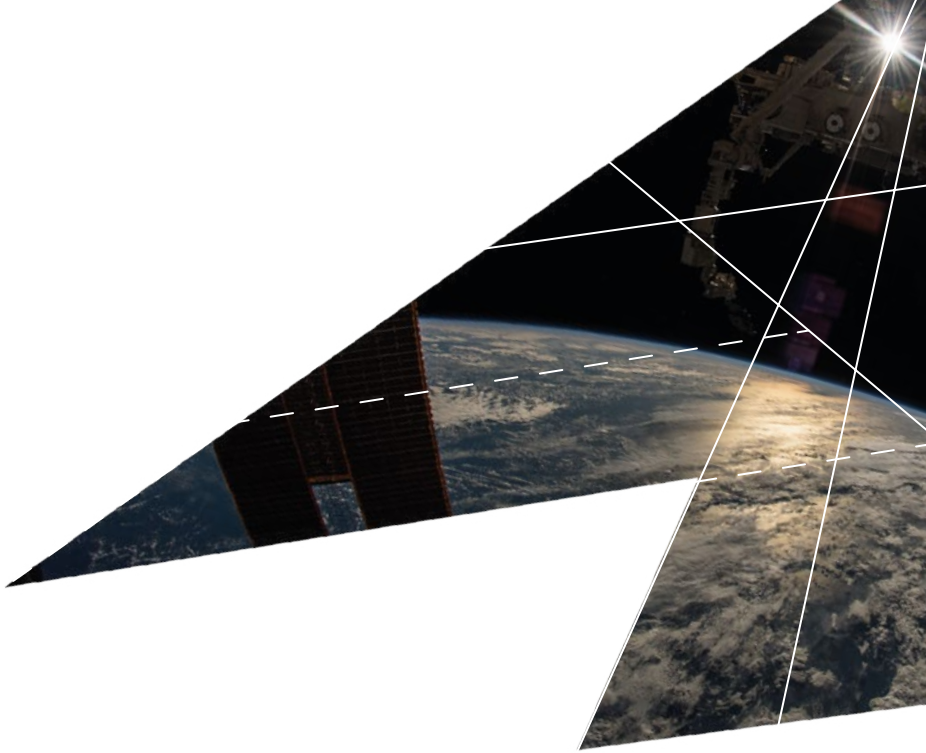
If we take the distance to be 240 miles, with an average speed of 30 mph, the journey would take eight hours.

The International Space Station travels at roughly ten times that of a speeding bullet, 17 000 mph

The Soyuz module must match this speed and align itself within millimetres to enable docking to take place.
What would happen if the Soyuz module travelled directly upwards to reach the ISS?
Instead, the module will follow a trajectory that orbits the Earth several times before docking with the ISS.

(Click here for more information on how Tim Peake gets into space and back)

Activity 1 — Distances



Order the following distances:

a) Earth to ISS

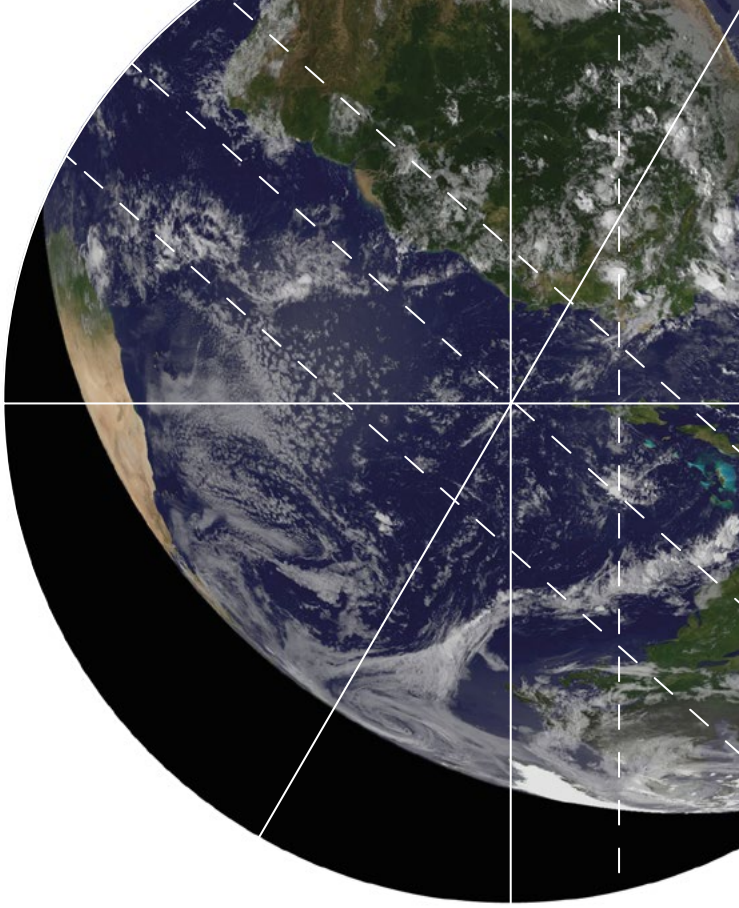
b) The radius of the Earth

c) London to Edinburgh

d) York to Edinburgh

e) A quadruple ultra-triathalon

Activity 4 | Orbital distance



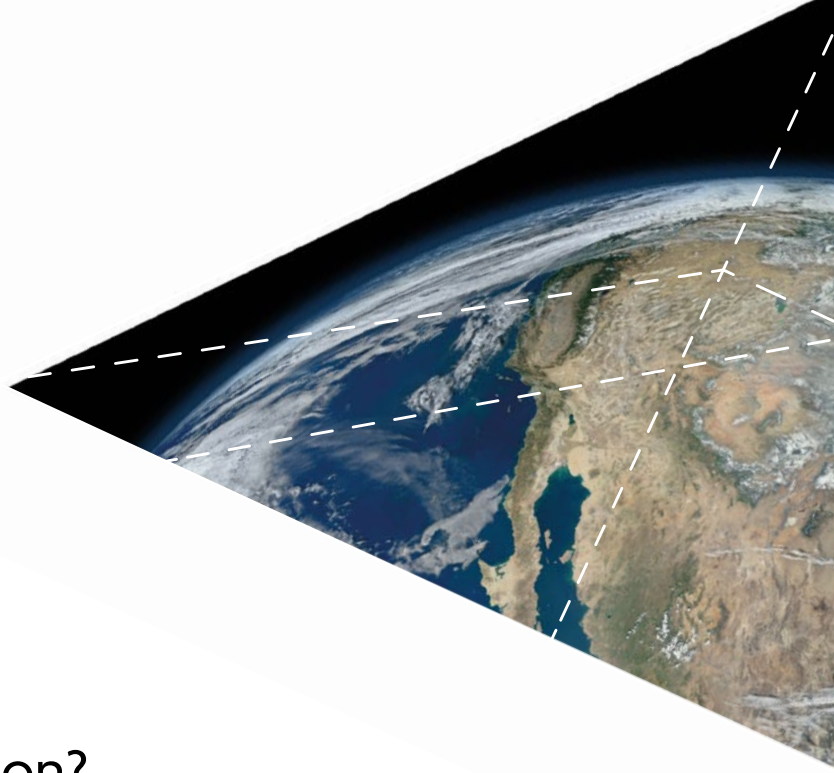
Orbiting the Earth:

On Earth, in one rotation you travel approximately 25 000 miles.

If you need it, the radius of the Earth is 4 000 miles.

What distance will Tim have to travel on the ISS in order to complete one orbit?

Activity 5 Orbital speed



Average speed:

When aboard the ISS on his mission Tim will orbit the Earth 16 times each day.

- How many orbits will Tim complete during the mission?
- How many miles do you think he will travel during his mission?
- What is his average speed?

Activity 6

The road to the ISS

Travelling to the ISS:

If there was a direct road to the ISS, how long would it take to reach it in a car?

It takes Tim 6 hours to get to the ISS. Why do you think it takes so long?

The Soyuz rocket must match this speed and align itself within millimetres to enable docking to take place.

What would happen if the Soyuz rocket travelled directly upwards to reach the ISS?

The International Space Station travels 17 000 mph, roughly ten times that of a spending bullet.

Find plausible estimations to the following questions:

Hair
If Tim didn't cut his hair during the mission, how long would it be on his return?

Face to face
How many astronauts are there currently living on Earth? What are your chances of meeting one in your day-to day life? What is the chance of meeting one tomorrow? This month? This year? Ever? How about someone that you know?

TV
Tim won't have a TV in space. How many episodes of Match of the Day will be on his series record when he arrives home? How many goals do you think this will be?

Heartbeats
Tim thinks his heartbeat might increase by an average of 10% during his mission. He thinks this could equate to one million extra heartbeats. Do you agree?

Oxygen
Tim will take around 6 hours to reach the International Space Station. How much oxygen do you think he will need?

Supplementary questions

Enrico Fermi

Enrico Fermi was an Italian physicist, born in 1901. He is primarily known for creating the world's first nuclear reactor and was awarded the Nobel Prize in Physics in 1938. For more information on his life, click here.

Fermi questions (also known as Fermi problems, or estimates) typically involve making good approximate calculations with little, or no actual information. The classic Fermi question asks "How many piano tuners are there in Chicago?" The problem can be solved in a series of steps using a set of plausible estimates to ensure a reasonable approximate solution.

Fermi-style questions

Hair

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Face to face

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