Monthly Maths

Issue 21 Nov 2012

Skyfall and M

Although there may well be maths in the latest James Bond film, we are referring to the recent record-breaking freefall jump, and to Mach numbers! In this edition we are looking at recent developments in travel across land, sea, air and space...and some fast driving stunts!

Spy scheme

The government is looking for apprentice spies! Students who enrol on a new apprenticeship scheme offered by the Foreign Office will study towards a foundation degree at De Montfort University while also working at GCHQ, MI5 or MI6.

Any school leaver over 18 with three A-levels, including at least a C in maths or a science, or a similar science or engineering vocational qualification can apply.

What is freefall?

When a body falls through air it is not in free fall because there is another force acting upon in. This is air resistance or drag, the result of collisions of the object's leading surface with air molecules. Increased speeds result in an increased amount of air resistance. Eventually, the force of air resistance becomes large enough to balance the force of gravity meaning the body will accelerate until reaching a terminal velocity. When a body falls through a liquid a similar thing happens.

Free fall is a special type of motion in which the only force acting upon an object is gravity. Objects that are said to be undergoing free fall are not encountering a significant force of air resistance; they are falling under the sole influence of gravity. Under such conditions, all objects will fall with the same rate of acceleration, regardless of their mass.

The standard acceleration for an object which is in free fall on earth is: 9.80665 m/s squared. This means that the velocity of the object changes by 9.8 meters per second every second.

- Why do objects that encounter air resistance ultimately reach a terminal velocity?
- In situations in which there is air resistance, why do more massive objects fall faster than less massive objects?

Click here for the MEI Maths Item of the Month

Mechanics Tutorial 7 - Free Fall and Terminal Speed is a useful resource from antonine-education.co.uk, with diagrams, explanations, questions and solutions.

Rollercoasters and Relativity resource pack has been designed by Alton Towers for KS3 and can be adapted for KS4 students.

It supports a visit to the site, but the resources could be used in the classroom to support teaching and learning of:

- Speed
- Energy
- Forces

Amusement park physics on the learner.org site covers why you feel almost weightless on a free-fall ride (as well as examining other fairground rides) - all supported by a commentary on the related physics. Suitable for KS4/5.

You might also find the Science in Focus: Forces and Motion video **'Making an impact'** useful for planning a practical activity for younger students.

The **Ballistics section of arachnoid.com** covers the dynamic motion of objects in free-fall. See also thephysicsclassroom.com tutorial: **Free Fall and the Acceleration of Gravity**.

A new MEI teaching resource is at the end of this bulletin. Click here to download it from our website.

Breaking the sound barrier

65 years since first supersonic flight – mission recreated

As Felix Baumgartner prepared to become the first man to break the speed of sound unaided, 700 miles away Chuck Yeager, the first man to ever go through the sound barrier, was recreating that feat 65 years later above California's Mohave Desert. On October 14, 1947 Yeager became the first human being to break the sound barrier when he flew past Mach 1 after being dropped from a B-29 bomber at 45,000 feet.

Read more about Chuck Yeager's life and achievements on his **website.**

October 14, 2012: Felix Baumgartner broke the speed of sound in freefall - did he make a sonic boom?

Last week Red Bull released a **video clip** of the stratospheric space jump by Felix Baumgartner in October, where experts had used the video footage and isolated the “wave form” that occurred as he sped faster than the speed of sound.

Austrian Felix Baumgartner and his team spent five years training and preparing for a mission designed to improve our scientific understanding of how the body copes with the extreme conditions near space. Prior to this mission, Baumgartner was best known for completing an unprecedented freefall flight across the English Channel using a carbon wing.

Previous records for the highest, farthest, and longest freefall were attained by retired US Air Force Col Joe Kittinger when he leapt from a helium envelope in 1960. His altitude was 102,800ft (31km). Kittinger was an integral part of Baumgartner's team and was Mission Control's primary point of radio contact with Felix during ascent.

On October 14 Baumgartner ascended to 128,100 feet in a stratospheric balloon and made a freefall jump rushing toward earth at supersonic speeds before parachuting to the ground. He reached an estimated speed of 833.9 mph (1,342.8 km/h) jumping from the stratosphere. Once these figures have been verified by the Federation Aeronautique Internationale (FAI), Baumgartner will hold the world record as the first skydiver to go faster than the speed of sound.

Felix broke two other world records during this mission: highest freefall and highest manned balloon flight. GPS data recorded on to a micro SD data card in the Austrian's chest pack will form the basis for the height and speed claims that are made. Kittinger’s record for the longest freefall remains intact (more than four and a half minutes before deploying his chute) as Baumgartner was in freefall for four minutes and twenty seconds.

The numbers

- Exit altitude: 128,100ft; 39,045m
- Total jump duration: 9’03″
- Freefall time: 4’20″
- Freefall distance 119,846ft; 36,529m
- Max velocity: 833.9mph; 1,342.8km/h; Mach 1.24

Read **examiner.com's article** for a mathematical analysis of this skydive.

Classroom resources

Stratosphere Space Dive. See MEI’s new KS4 teaching resource at the end of this issue.

Felix's Parachute Jump NRICH has published a challenge targeted at KS5. To answer these questions, your students will need to make certain modelling assumptions and they will need to do some research. Solutions can be submitted whole the problem is live - see **Felix's Parachute Jump**.

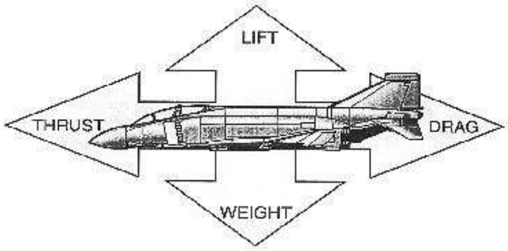
Aerodynamics and Mach numbers

Maths on a plane
This imaginatively written piece by Phil Trinh for Plus Magazine really brings to life the mathematical concepts in aerodynamics. **Read more here.**

Numerical Methods and Computational Fluid Dynamics
The development of numerical methods for fluid dynamics is described by the Thermofluids research group at Leicester University on their **web page** that includes useful animations of CFD flow geometries.

Sonic Boom
Physics Central **Physics Buzz blog** has a simple explanation with diagram of sonic boom, relating to Concorde.

Atmospheric Flight



This **NASA web page** has useful diagrams and explanations of the four forces on an aircraft in flight.

Mach numbers

The term Mach number was named after Ernst Mach, a late 19th century physicist who studied gas dynamics. Mach number, (or Mach or M), refers to the ratio of the speed of a body to the speed of sound in a particular medium, usually the Earth's atmosphere.

As an aircraft moves through the air, the air molecules near the aircraft are disturbed and move around the aircraft. If the aircraft travels at a low speed, typically less than 250 mph, the density of the air remains constant. But for higher speeds, some of the energy of the aircraft goes into compressing the air and locally changing the density of the air. This compressibility effect alters the amount of resulting force on the aircraft.

The Mach number of an aircraft travelling at a given velocity depends on the altitude of the aircraft and other atmospheric conditions that affect the speed of sound near the aircraft. The actual speed of sound varies depending on the altitude above sea level because sound travels at slightly different speeds at different temperatures, and the temperature varies according to altitude.

At sea level, the speed of sound is about 761 mph (1,225 km/h). At 20,000 feet (6,096 meters), the speed of sound is 660 mph (1,062 km/h). Because the speed of sound varies, a particular speed at sea level expressed as a Mach number would be faster than the same speed at 30,000 feet (9,144 meters), which would be faster than the same speed at 40,000 feet (12,192 meters).

Mach number 1 corresponds to the speed of sound, so when an aircraft reaches Mach 1, it is said to "break the sound barrier." As the flow velocity increases beyond Mach 1, it becomes supersonic and its characteristics change greatly. Very high velocity flows (usually above Mach 5 or 6) are called hypersonic. These types of flow are of great importance in the aerodynamics of rockets and re-entry vehicles, which achieve Mach numbers as high as 25.

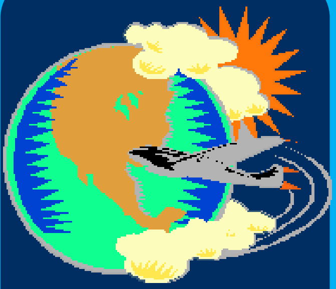
Subsonic to hypersonic speeds

Subsonic
$M < 0.8$

Transonic
$M = 0.8$ to 1.2

Supersonic
$M = 1.2$ to 5.0

Hypersonic
$M > 5.0$



To space and back…
the commute of the future?

Supersonic

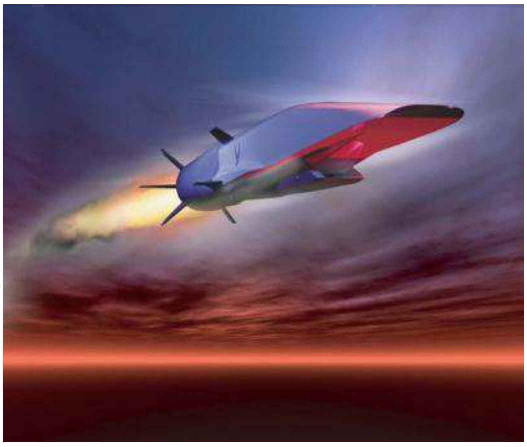
Just weeks after Baumgartner amazed the world with his stratospheric skydive, US firm XCOR Aerospace plans to send even more people to the edge of space with a supersonic aircraft capable of cruising at 3.5 times the speed of sound.

The Lynx takes off and lands on a runway like a conventional plane, but flies outside the atmosphere for a portion of its journeys, 62 miles above earth.

Test flights will start as early as the beginning of 2013, but it could be another 20 years before it hits the market ready to fly passengers.

Hypersonic

Meanwhile, the US Air Force is developing a free-flying vehicle that will fly longer hypersonically than all of its predecessors combined. The X-51A is called the Waverider because of an element of the plane's expected flight performance: once it hits the right velocity, it essentially surfs its own shockwave. **View video here**.



Hypersonic speeds are those in excess of Mach 5 (five times the speed of sound). At Mach 5, the vehicle travels at about a mile a second, or 3,600mph, so could also be a potential successor to Concorde with the ability to fly from London to New York in just one hour. The project has also been looking into the possibility of developing technologies allowing the US Air Force to launch ultrafast strikes on enemy targets.

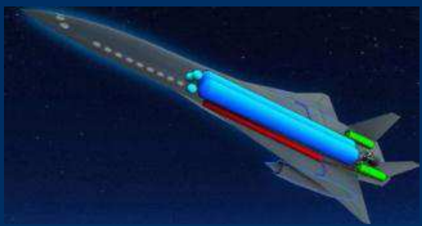
The vehicle uses scramjet technology that forces combustion to occur when airflow surpasses the speed of sound and hydrogen is injected into the flow, allowing for theoretical speeds of Mach 20. The Waverider vehicle is carried aloft by B-52 aircraft. The total assembly "stack," which is about 25 feet long and which weighs about 4,000 pounds, is dropped at 50,000 feet. After being released the vehicle uses solid-rocket boosters to achieve speeds approaching Mach 5. The solid-rocket motor is then jettisoned and the scramjet engine should then take over. That engine is made to burn oxygen from the atmosphere mixed with a small amount of jet fuel.

In August 2012 the third X-51A Waverider test vehicle was successfully launched from an Air Force B-52 bomber over Point Mugu Naval Air Warfare Centre Sea Range. However, after the rocket booster engaged and detached, a faulty control fin meant the prototype's scramjet engine was unable to start and the machine quickly lost control and disintegrated. Results from the investigation into the third aircraft's failed test flight are expected to be complete in mid-December. It has just been announced that the fourth and final test vehicle will fly

Fast, clean and silent

In 2011 French aircraft manufacturer EADS unveiled a high-speed intercontinental concept aircraft. The zero emission high supersonic transport concept – or ZEHST – would have a cruising speed of Mach 4 at an altitude of 32 km – meaning that it could fly from Paris to Tokyo in just 2.5 hours.

See video on the EADS website.



The Bloodhound Supersonic Car

Facts and figures

It can travel:

- Four and a half football pitches in 1 second
- 150 metres in the blink of an eye
- Faster than a bullet fired from a Magnum 357
- Its own car length in less than 3 hundredths of a second

Read more

Team members

Read datafiles of the team members, including their education and career backgrounds **here**.

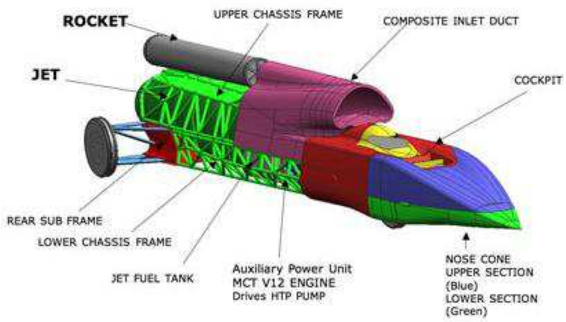
The international education initiative **Bloodhound Project** created the Bloodhound SSC, powered by a rocket bolted to a Eurofighter-Typhoon jet engine to attempt a 1,000 mph world land speed record.

Led by former land speed record holder Richard Noble OBE (Thrust 2, 633mph, 1983), and driven by Wing Commander Andy Green OBE, the current record holder (Thrust SSC, 763mph, 1997), the Bloodhound team also comprises experienced aerodynamicists, aerospace and automotive engineers, electronic experts and rocket scientists, as well as hundreds of volunteer ambassadors working within the 5,300 UK schools already engaged with the project.

Carbon Neutral

Following the recent successful **first test of Bloodhound SSC's full rocket system**, Carbon Neutral Investments (CNI) has been announced as sole environmental sponsor of the pioneering British team, to offset all emissions for the programme. Bloodhound SSC is now in build, and will roll out in Summer 2013 ready for a series of runway tests up to 250mph, before heading to South Africa ready to start the high speed campaign.

Andy Green is writing a blog on the BBC website. **Read it here**.



Register with the Bloodhound SSC Education Programme

If you haven't already done so, you can register your school on the Bloodhound SSC Education Programme. To join the programme, you first need to register your school, college, family or youth organisation. This will then enable you to download the education ideas and get started. You will be sent two free posters and a flyer, and you will be contacted to help you get the most out of the programme.

A range of curriculum resources covering the 5-19 curriculum for STEM subjects has been produced in parallel with the development of Bloodhound SSC. These are free for registered schools to download.

Click here to register.

View other ways in which you can engage with the project.

Suggested projects for students.

Supersonic Bloodhound

This article by Dr Ben Evans on the Plus Magazine website discusses the use of computational fluid dynamics in relation to the design and external shape of the Bloodhound SSC. **Read article here**.

Land and water speed records

Sustainability

Ecotricity says:

‘What will our transport look like, post oil and post carbon? In the UK we drive about 200 billion miles a year, and burn almost 25 million tons of oil to do it. This is simply unsustainable. Nearly a quarter of all the car trips we make are less than two miles, and 99.6% are less than 100 miles. So the problem was never the distance, it was the desirability.

The answer is electric cars, charged using renewable energy for the ultimate in sustainability - zero pollution, from a fuel source that will never, ever run out.’

2014 will mark the 50th anniversary of Donald Campbell's unique 'double' world records on land (Bluebird CN7) and water (Bluebird K7) in the same year.

It will also be the year in which world electric land and world electric water speed record attempts will be made by the present Bluebird team. In 2011 Sir Malcolm Campbell's great-grandson's attempt to smash the UK land speed record of 137mph for an electric car (set by his father Don Wales in 2000) was ended by a pothole on a beach. Sir Malcolm Campbell himself set a record in a combustion engine on the same Welsh beach, Pendine Sands, with a speed of 146mph in 1924. **View video here.**

The Bluebird team has built a new electric vehicle for a further world record attempt and are hoping to eventually hit 500mph and pass the 307mph record set by the American Buckeye Bullet 2.5 team last year. The first full working prototype of the Bluebird GTL electric race car was delivered in October this year, designed specifically for the inaugural Formula-E race series in 2014.

Meanwhile, the UK electric car land speed record has been broken this year by the electric super car ‘Nemesis’ (based on a modified Lotus Exige) topping 151 mph at Elvington airfield. To achieve this, the car had to complete two runs in opposite directions along the runway within one hour to account for prevailing winds – the average speed of the two runs provides the official time. **View video here**.

Ecotricity, the Stroud-based green energy company whose wind turbines produce the green electricity to power Nemesis, set out to destroy the myth that supercars cannot be sustainable or eco-friendly, by producing an ‘out-and-out desirable sports car, capable of combustion engine-beating speeds and able to do 100-150 miles on one ‘tank’. All with zero emissions.’

The company claims Nemesis to be ‘faster than a V12 Ferrari, 0-100mph in 8.5 seconds and a top speed of 170mph. All powered entirely from the wind. Or to be more precise by green electricity produced by Ecotricity’s windmills and delivered by the grid.’

Classroom activities

ATC²
An activity designed by Leicestershire Education Business Company with the support of King Edward VII School and staff at East Midlands Airport.

ATC² explores the mathematical subjects of bearings and scale as they apply to the real life activities of an airport. The project is aimed at Key Stage 4 students and is divided into four sessions. The scenarios presented in each session are real contexts approved by the Air Traffic Services staff at East Midlands Airport.

View the resource here

View all Manchester Airports Group KS4 resources here

Starters and activities in Mechanics

A PDF of activities from a session delivered by Emily Rae and David Holland at the 2012 MEI Conference at Keele University suggest types of things you can do for yourselves to meet the needs of your students. This includes the following as particularly relevant to this month's bulletin:

- The directions of displacement, velocity and acceleration
- The total surface force on an accelerating car

Mathematics Resources for Level 3 Engineering

Produced by MEI for The Royal Academy of Engineering and hosted on the **Integral site**, these resources use realistic engineering contexts to provide opportunities to learn how mathematics may be used to solve engineering problems.

Each resource includes two text documents, one of which is intended to be used only by teachers; the other is for students and contains a subset of the teacher material. Animations have been produced to support the text documents, which include information, activities, discussion points, links to multimedia, and answers and worked solutions (teacher's version only).

The resources have been designed to take advantage of web based demonstrations and activities, and we have included material of this type as appropriate.

The following resources are just a few of the many Mathematics Resources for Level 3 Engineering available on the **Integral site**, free of charge once you have completed this **simple registration form**.

Car Speedometers

This resource shows the method used to convert between miles per hour and kilometres per hour. 20-30 minute activity.

Simple Gears and Transmissions

This resource is about designing gears and transmissions to convert the speed of rotation and turning force from a motor into a new speed and turning force that match what is required for a particular piece of equipment. These resources include two animations and an interactive activity and have a longer target time of over an hour.

Regenerative braking

This resource is about designing a system for storing and reusing kinetic energy in a car. It includes one interactive activity and an animation. This resource is intended to be more challenging than those above. The mathematics involved is at the standard of Mathematics for Engineering and A level Mathematics.

Stunt secrets - myth or maths?

Skyfall stunt secrets revealed
If you missed the recent BBC TV screening of the behind the scenes look at the James Bond cars and stunt driving in **50 years of Bond Cars: a Top Gear Special**, the programme is available to view **on BBC iPlayer** until 21:59 5/11/12

The Man With The Golden Gun

The corkscrew jump, the first stunt ever to be calculated by computer modelling, was filmed in one take following months of computer calculations by aeronautical engineers in order to determine the exact specifications of the car and ramps.

View video clip.

The bus jump in *Speed*

Mythbusters tested the bus jump of the movie, *Speed*, in real life (**see video on Discovery channel**). In *Speed*, the bus had to cross a 50-foot gap in an overhead highway ramp, and it had to maintain a driving speed of at least 50mph. The *Mythbusters* **tested the physics at 1/12 scale**, writing an equation to find the scaled down ramp exit velocity, assuming that the small scale speed must be compensated downward because gravity does not scale down.

Running at a calculated speed of 20 miles per hour, the remote-controlled model bus plunged off the end of the road and crashed into the support posts at ground level on the other side. When the gap was halved, the bus still dropped far enough to hit the far end of the roadbed head-on. The team theorized that hidden ramps placed on either end of the gap may have helped the bus to make its jump safely.

A speed test was undertaken with a full size bus, which could travel up to 58mph, rather than the 70mph depicted in the film. With the 50-foot target distance scaled down to allow for the lower top speed, they jumped the bus off a ramp; it fell far short of the target, but remained relatively intact until it hit a concrete safety barricade. Since the bus could not make the jump, the team declared the myth busted.

View video of the filming of the bus jump in *Speed* **here**. The bus jump scene was done twice, as the bus landed too smoothly the first time. The bridge was actually there, but erased digitally. View a video clip of how the *Speed* bus jump scene was edited **here**.

The maths behind the movie

Decodedscience.com uses maths to drive through the calculations. Read the article **Math can Launch One Bus with Speed minus Gravity**.

Michael Richmond has created a useful page of teaching resources about the Speed bus jump. **Click here**.

In **David Colarusso's blog**, Phylm examines the bus jump from *Speed* using a video uploaded to YouTube, with transcript provided. Although the video takes a while to download and refers at the end to a 2007 competition, it is nonetheless an interesting mathematical analysis of the bus jump. **View video**.

Real life corkscrew record

Hot Wheels set a real-life record for a corkscrew jump in a car in September 2012 It was calculated that stunt driver Brent Fletcher had to rotate 230 degrees per second, hitting the ramp at exactly 54 mph to land wheels down. Maths involved: calculating approach speeds, departure angles and landing ramp position. **Read more and view video clip.**

Supporting women in STEM studies and careers

Girls in physics

The Institute of Physics (IOP) reports that: "For the last 20 years, only 20% of physics A-level students have been girls, despite about equal success between genders in GCSE physics and science."

Read the report: **It's Different for Girls: The influence of schools** and their briefing sheet: **How can senior leaders in schools support the take-up of A-level physics by girls?**

The website **Girl-friendly physics** "is intended for trainee teachers and newly qualified teachers to help them address the high proportion of girls who say they dislike physics and so drop it at age 16." **Visit the site.**

The UK Resource Centre (UKRC)

"is a leading organisation for the provision of organisational development services for businesses and organisations wanting to build gender equality and diversity in science, engineering, technology and the built environment (SET)." This includes working with organisations to help them provide training, mentoring and other support to women. **Read about the UKRC's current projects here**

The Royal Academy of Engineering

The Academy works closely with the UKRC . As part of the **Ingenious Grants** programme, the Academy funded the UKRC's **Ingenious Women project**.

WISE

Led by the UKRC, "WISE works to ensure that the UK has a skilled, committed and talented workforce in science, engineering and technology (STEM). This means helping schools, employers and other organisations to inspire girls and to enable women to progress in STEM careers." WISE offers classroom to boardroom information and services to inspire girls and support women in their science, technology, engineering and mathematics studies and careers. **View their A-Z of supporting organisations here**.

Royal Aeronautical Society's first female President

Jenny Body OBE, FRAeS, who recently retired as one the highest-ranking female engineers at Airbus UK, became the Royal Aeronautical Society's first female President Elect when she took up her new position in May 2012. In 2013 she will create history as the first female President of the world's oldest aeronautical society. The Royal Aeronautical Society was founded in 1866 to further the art, science and engineering of aeronautics, and is the world's only professional body dedicated to the entire aerospace community.

The Royal Aeronautical Society's Women in Aviation & Aerospace Committee was established in 2009 to encourage more young women to consider aviation and aerospace as a worthwhile and exciting career, as well as providing support for women already working in all sectors of aviation and aerospace.
Read more here.

ScienceGrrl

This is a network of (mainly) female scientists who are passing on their love of STEM to the next generation.

Launched in October 2012, the ScienceGrrl calendar 2013 is a project designed to raise the profile of the ScienceGrrl organisation and to raise funds to continue its work. **Read more**.

MEI

Innovators in Mathematics Education

Mathematics in Education and Industry

50 years at the forefront of Mathematics Education

STRATOSPHERE SPACE DIVE

Background

On the 14th October 2012, Felix Baumgartner made an historic jump from the edge of space, breaking 3 world records and collecting much scientific data.

In the following activities, we will explore his jump.

How high was that?

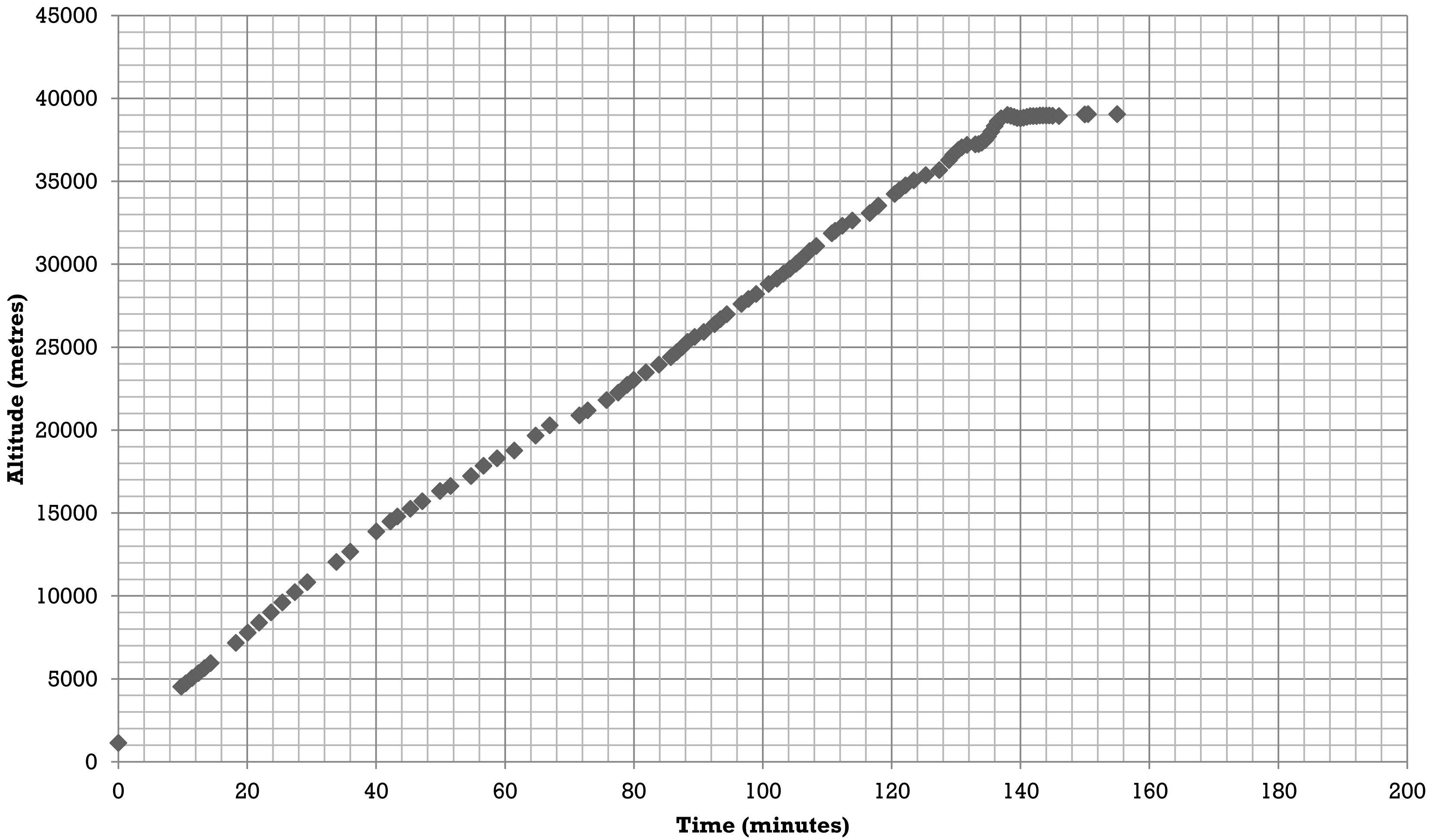
- To get a sense of the height he jumped from work out how many times higher he was than the given objects.

- The following information may help with some conversions:
  - 1 foot = 12 inches
  - 1 inch = 2.54 cm
  - 1 m = 100cm

Object	Approximate height	How many times higher Felix jumped from
A classroom	3 m	
A double decker bus	15 ft	
The London Olympic stadium	60 m	
Angel of the North	66 ft	
Altitude a large plane flies at	30,000 – 40,000 ft	
Mount Snowdon	1085 m	
Mount Everest	29000 ft	

How quickly did he fall?

- The next slide shows the time-distance graph of his ascent.
- He jumped from the capsule at 187 minutes
- He took just over 9 minutes to get back to solid ground…
- …if he had fallen at a constant speed, what would this look like on the graph?


45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Altitude (metres)
0
20
40
60
80
100
120
140
160
180
200
Time (minutes)

What happened?

For the first 42 seconds, Felix was accelerating in free fall.

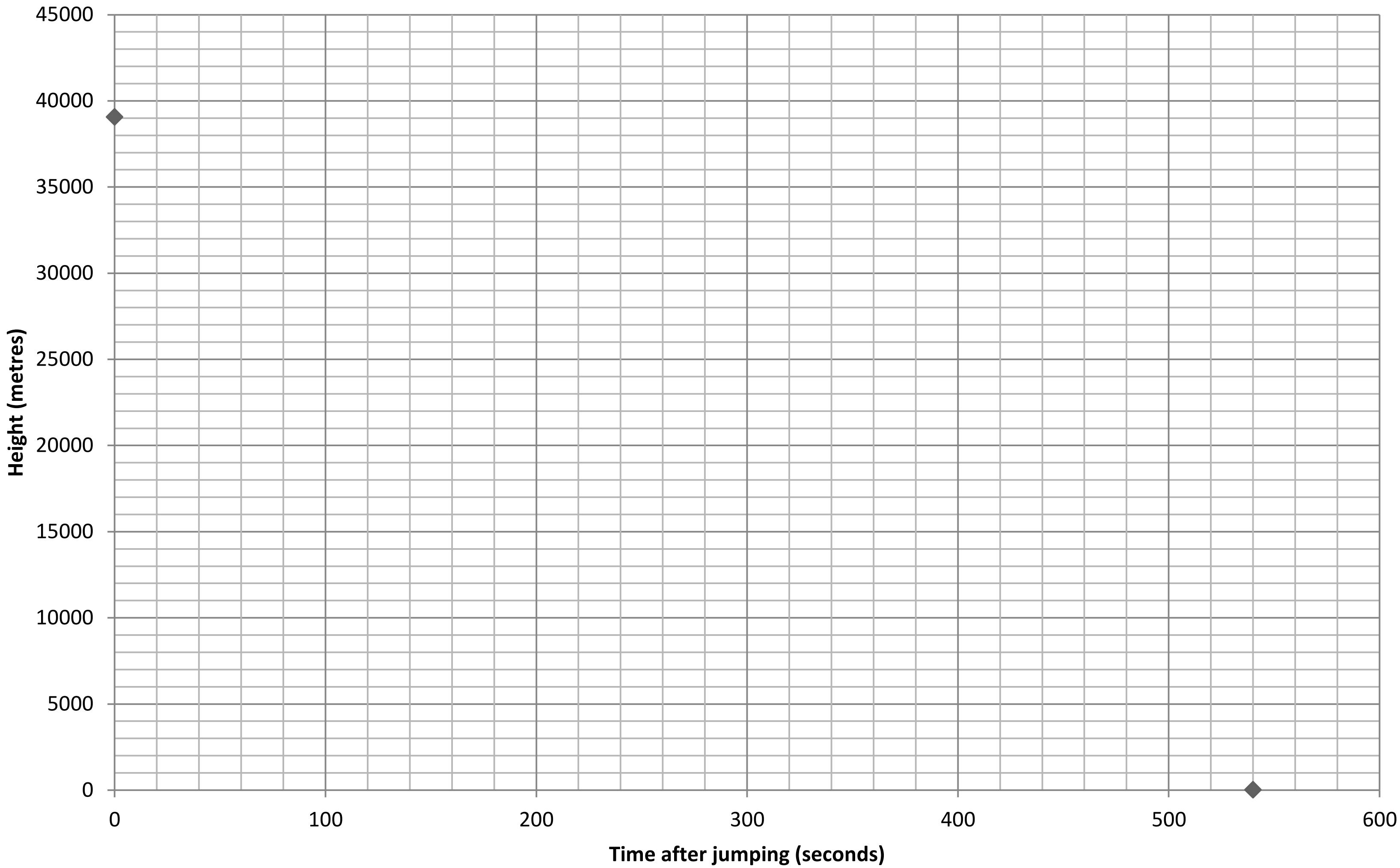
The following formula gives his approximate height:

$$\text{Height} = 30045 - 4.9t^2$$

Where t is the number of seconds after he jumped from the capsule.

What shape do you expect this part of the graph to be?

Choose several values for t, calculate and plot.


45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Height (metres)
0
100
200
300
400
500
600
Time after jumping (seconds)

What next?

- If Felix had continued at this rate of acceleration, how long would it be before he hit Earth?
- At 42 seconds, Felix reaches his maximum velocity.
- The next position we know for certain is that at 260 seconds, at a height of 2500m, he opened his parachute.
- He then descended to Earth, slowing at a steady rate.

The missing data…

Until the data are published, no-one knows exactly what the middle part of his descent looks like, but we can make some intelligent guesses.

- Falling objects eventually reach a ‘terminal velocity’ where the ‘strength’ of the air resistance counteracts the ‘pull’ of gravity, so the object continues at a steady speed. Felix’s maximum speed was reached at 42 seconds.
- At 210 seconds, Felix hit the denser part of the atmosphere, which slowed him.
- Use this information to make an educated guess at what the missing sections might look like.

Teacher Notes

This activity focuses on the following skills and content:

- Converting measures
- Using Formulae
- Constructing Distance-Time graphs
- Using Real data

The starter activity is designed to give pupils a sense of the height from which Felix jumped and requires them to convert measures. To personalise this activity, a few more local features could be included.

In the main activity, pupils explore a Distance-Time graph, using given information to plot Felix's descent.

Teacher Notes

Main activity:

Initially, consider what would happen if Felix had descended at a constant velocity; discuss the ascent and descent

Next focus in on what we know happened during those 9 minutes.

Pupils will need to use the formula to estimate Felix's height during the first 40 seconds, calculating for several chosen times within the interval to plot his progress.

From the time he opened his parachute and descended to Earth, he will have made a gradual descent.

Pupils then need to use the written information given to make an intelligent guess about the missing section of the graph.

Plenary: discussion of the different graphs pupils have produced.