News Feature – The Third i4is Summer School at the Royal Institution

John I Davies

i4is has been delivering education outreach to both adults and young people since its birth, nearly 10 years ago. Just this year we have worked with schools in both UK and USA - and in earlier years we have also reached much further – examples include Nigeria and Viet Nam. Also this year we have briefed astronomical societies in the UK and in earlier years venerable institutions like the Bath Royal Literary and Scientific Institution. The jewel in our outreach crown is the Royal Institution, Faraday's workplace and the source of the famous Christmas lectures (www.rigb.org). This is an account of our latest work with them and where it originated. If you know an organisation, school or college which would like to know more about things from the maths of rockets to the challenges to interstellar travel and communication - and from the issues arising from the discovery of interstellar objects (ISOs) in our solar system to the challenges of reaching them – then get in touch via our ubiquitous email address, info@i4is.org. We are always listening on that frequency!

The Royal Institution Library with members of the i4is team 2022. Terry Regan and Khemare Chung in the foreground and Rob Swinney pointing to the i4is banner in the background.
Credit: Satinder Shergill

1 Introduction

On 25th and 26th August 2022, a team from i4is delivered the third i4is Summer School at the Royal Institution, London. We call it *Skateboards to Starships*. Our organisation has been delivering education and information about our objectives and technologies and the work of all who share the goal of reaching out to the stars. Back in 2016 (which feels like just after the Stone Age in these changing times) the i4is education team and STEM Learning Ltd (a UK government initiative - www.stem.org.uk) delivered an *Interstellar Challenge for London Schools* at Imperial College London [1]. Our primary partner at STEM Learning was Aasiya Hassan. Aasiya subsequently moved to the Royal Institution as Engineering Masterclasses Coordinator and, in the following year, put us in touch with her colleagues to discuss a possible session on the mathematics of rocketry. For various reasons this did not happen but later that year Aasiya [2] invited us to a Masterclass taster event and after some discussion we were asked to deliver our proposed *Skateboards to Starships* on 20 August 2018. This initial student group was to ages 13-15. This was successful enough for the RI to invite us back in 2019 to deliver two classes for ages 13-15 and 16-18 (the latter is often called Sixth Form in the UK and the stage just before university entrance). An unfortunate world biological problem made 2020 and 2021 quieter years for the Royal Institution but once things had calmed down a little, we were invited back this year, 2022. This is the story of what we have delivered to the Royal Institution, a pinnacle of science outreach in the UK and a world-renowned institution since the days of Michael Faraday. Its Royal Charter was granted in 1800 and a very brief history follows.

2 The Royal Institution

The Royal Institution of Great Britain (RIGB) dates back to a meeting at the Soho Square house of the President of the Royal Society of London (founded 1660), Joseph Banks, on 7 March 1799. Its Christmas lectures have been running since 1825 and it was the base for the science discoveries and engineering inventions of Michael Faraday from around the same time until 1860 just before his death in 1867. Today it operates by its motto "Science Lives Here". If you get the chance to visit, make sure you look into the beautiful main lecture theatre and the library (as on the opening page of this article), where our i4is Summer Schools were delivered this year.

3 The First Two Summer Schools

3.1 2018

In May 2017, Aasiya Hassan, Royal Institution (RI) Engineering Masterclasses Coordinator, contacted us to put us in touch with her colleague, Secondary Maths Masterclass Coordinator Dominique Sleet. We attended a briefing session at the RI and discussed a session based on Tsiolkovsky's Ideal Rocket Equation, why it matters and how to derive it from Newton's second law. However turning this from a one-hour school session to a full day proved too heavy a workload for i4is at the time. The following February 2018 we attended a Masterclass taster event and made contact with Peter Gallivan, RI Family Programme Manager. This led to our proposal for a whole day Summer School, Skateboards to Starships for school students age 13-15 for August of 2018. Aasiya continued to be our prime RI contact through to June that year [3].

Satinder Shergill, an old contact of ours at Space Studio West London (www.spacestudiowestlondon.org/) got involved in April and soon became an equal partner with John Davies. Having an experienced physics teacher from a space-oriented school who was also doing a space-based PhD at Cranfield University made an enormous difference to both the content and delivery of this, our first RI Summer School.

[1] See *Interstellar Inspiration for School Students: The i4is Interstellar Challenge*, Principium 19, November 2017, i4is.org/principium-19/

[2] Aasiya is now at BDSIP, bdsip.co.uk/, a UK educational support not-for-profit where she is Head of Careers, Higher Education and Work Experience.

[3] The RI listing for this at www.rigb.org/whats-on/events-2018/august/summer-schools-skateboards-to-starships-age-1315.

The i4is team included principal presenters Satinder Shergill and John Davies with Rob Matheson and Terry Regan provided practical support dealing with much of this highly interactive show [1].

The Summer School was well received and we were invited back the following year.

3.2 2019

In 2019 Peter Gallivan again asked us to run *Skateboards to Starships*, and we agreed an extra day to deliver to an older age group, ages 16-18. For this group Satinder added a major component covering orbital dynamics showing how patched conics and the Hohmann transfer defined the trajectory of a mission to Mars and more about fusion propulsion. We were again supported by Rob Swinney [2] and Rob Matheson– but Terry Regan could not make it due to work priorities.

After the Summer School the team adjourned to the local pub to celebrate.

Satinder explains a point at *Skateboards to Starships 2018*. Credit: Rob Matheson

The two 2019 Summer Schools were again well received and we were discussing delivery in the following year when the virus which afflicted us all came upon the world and the RI closed its in-person outreach activities.

The 2019 team, Satinder Shergill, Rob Matheson, John Davies and Rob Swinney

[1] Rob Matheson was at the UK Government Department of International Trade. He is now Head of Spaceflight Economics at the UK Space Agency. Terry is the i4is ace model builder. His "day job" is heavy freight vehicle maintenance – a true practical engineer

[2] Rob Swinney was and is Director of Education for i4is. He is a former engineering officer, Squadron Leader, in the Royal Air Force.

4 The Third i4is Summer School 2022

This year's Summer School followed a two-year gap as a result of that virus you may have heard of. Once

Skateboards to Starships 2019. John Davies explains how Freeman Dyson's team proposed a fast spacecraft powered by hydrogen bombs!

Credit: Rob Swinney

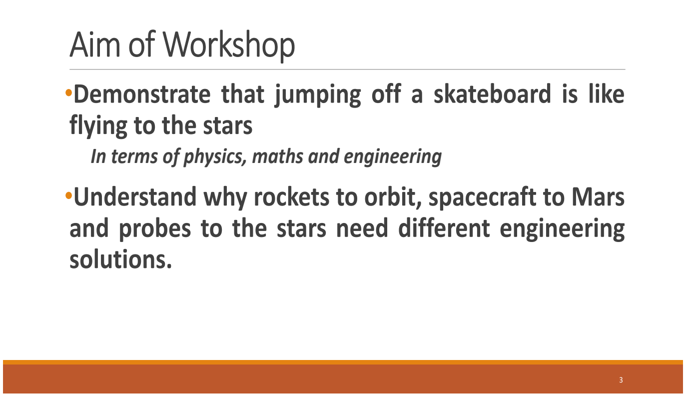
the Royal Institution returned to (more or less) normal they invited us again to deliver two consecutive days for a 13-15 age group and a 16-18 age group.

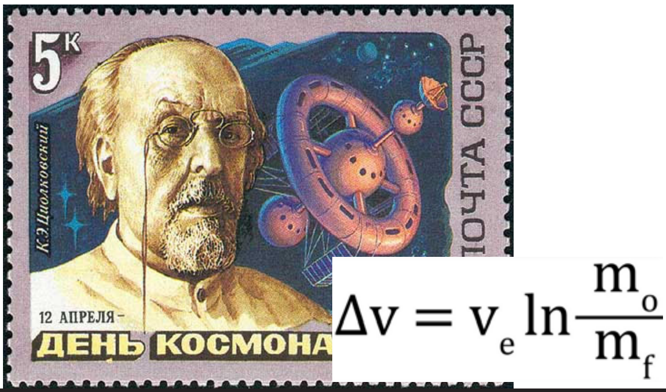
The team this year consisted of our two main presenters, Satinder Shergill and John Davies, Rob Swinney, who presented the fusion propulsion section [1] and, supporting the practical work, Terry Regan and Khemare Chung – a former school student of Satinder, now studying aerospace at Southampton University.

[1] Rob was Project Director of Project Icarus. This was an update of Project Daedalus supported by the BIS and the US Tau Zero Foundation. The most developed of several studies arising from that was Icarus Firefly, described in *Reaching the Stars in a Century using Fusion Propulsion*, by Patrick Mahon. This was in Principium 22 i4is.org/principium-22. The article can also be read online at i4is.org/reaching-the-stars-in-a-century-using-fusion-propulsion/

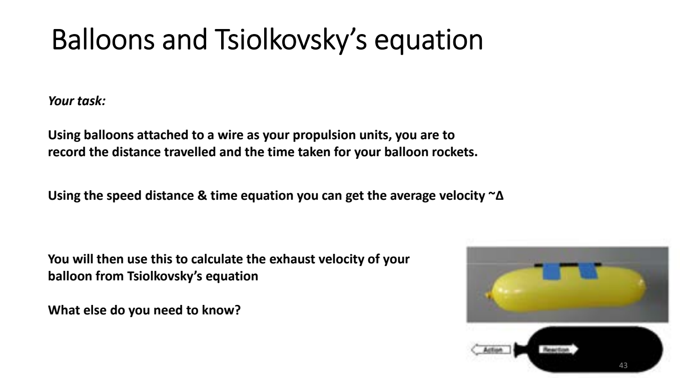
4.1 The Presentations

Here are some samples from this year's version of *Skateboards to Starships*

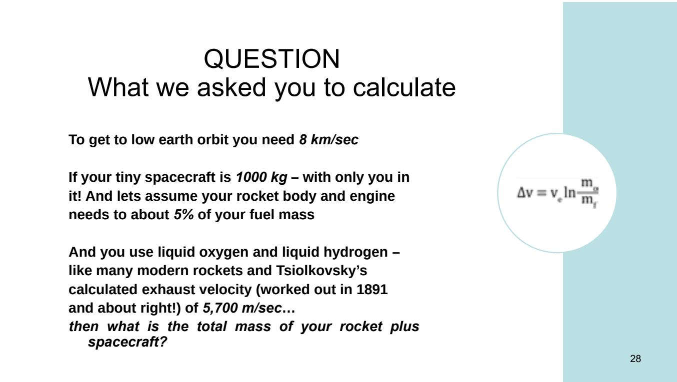




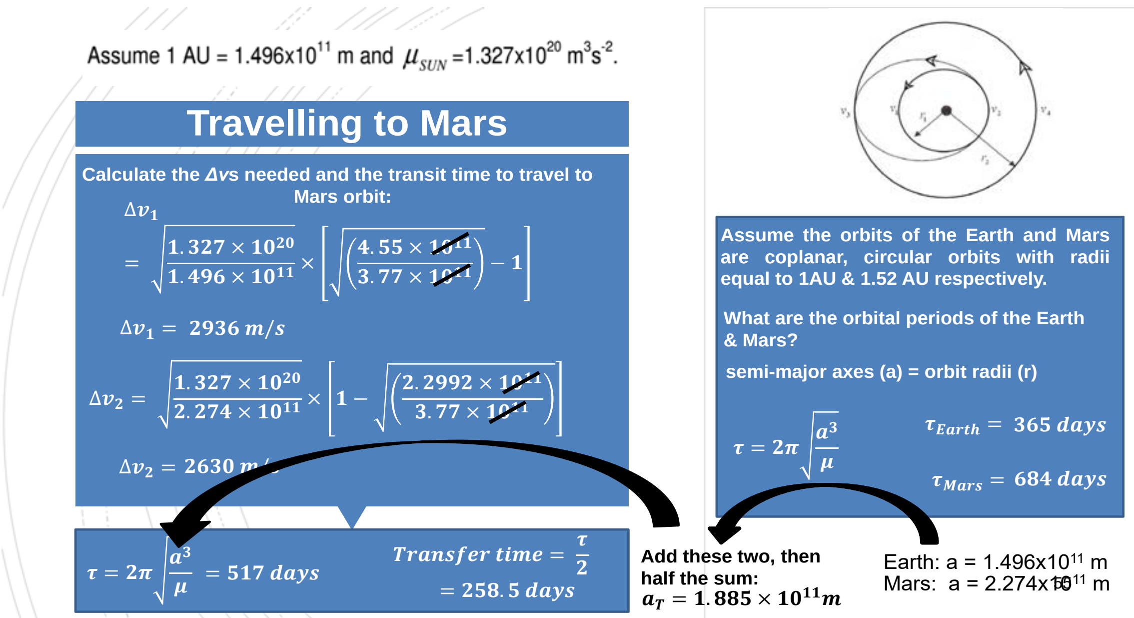
Konstantin Eduardovitch Tsiolkovsky and his Rocket Equation



the Balloon Rockets experiment – the problem to solve [1]

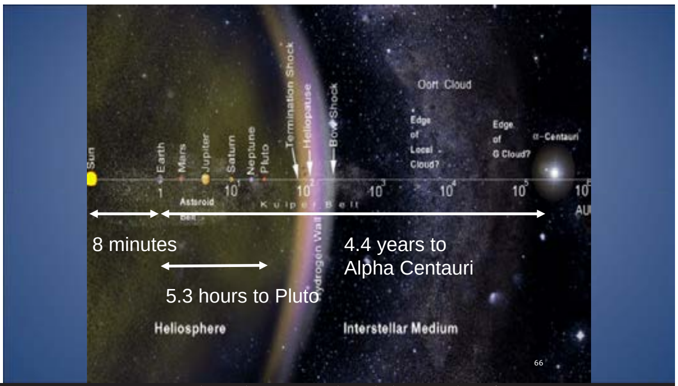


How much fuel do you need to get into orbit? This is a slightly trickier one since the rocket body and engine mass varies with the fuel mass. But we only asked for an approximation [2].

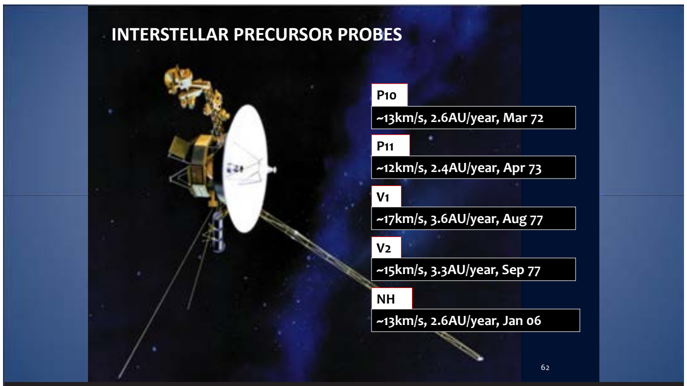


Travelling to Mars (16-18 Group). A challenging problem to take away…

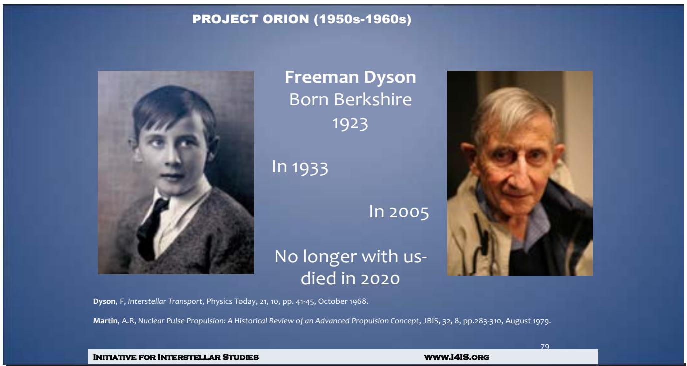
[1] To set up the balloon rocket experiment we used portable coat racks about 1.8 metres high and 3-4 metres apart. We attached 3 lines between them so that three teams at a time could do a few balloon runs each.
[2] The results obtained by the students were remarkable. See *4.2 The Balloon Exhaust Velocity Experiment* below



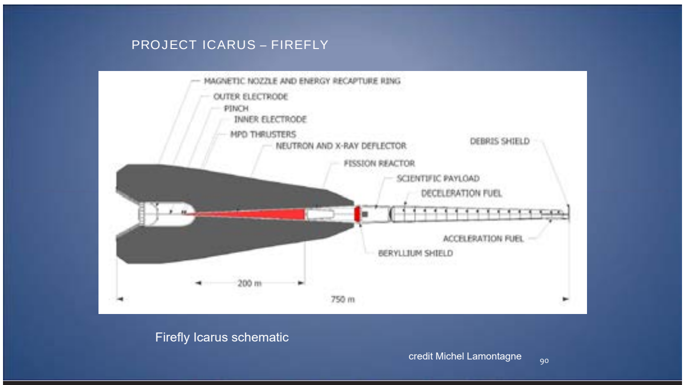
It's a long way to Alpha Centauri



How far and how fast have we gone so far?

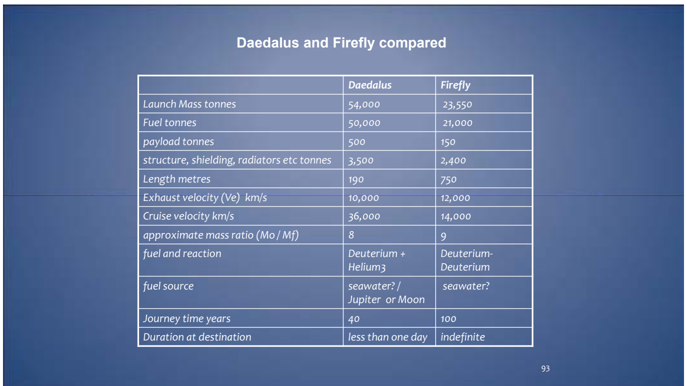


Freeman Dyson – hydrogen bomb propulsion, Dyson spheres – and lots of physics and pure maths [2]



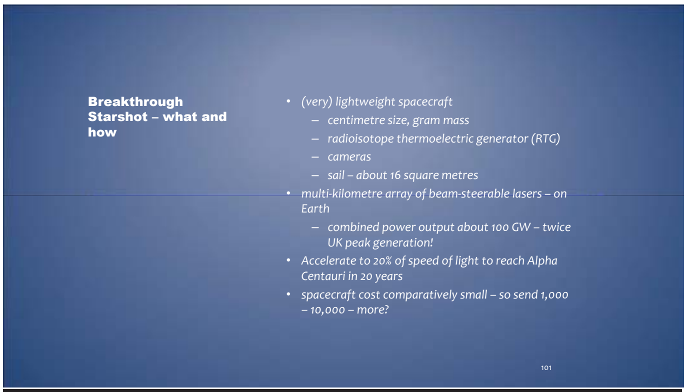
The Icarus Firefly fusion-propelled probe

Major components and dimensions



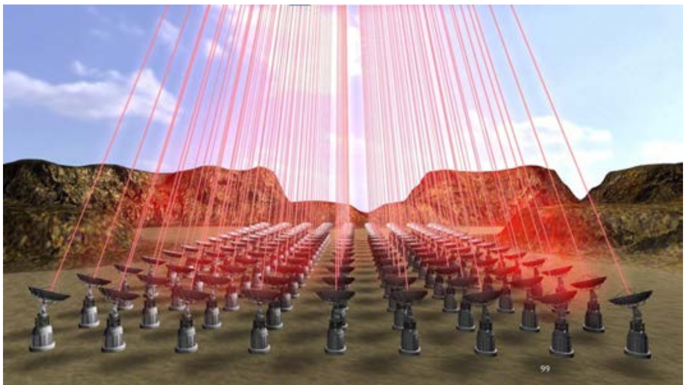
Fusion-propelled probes -

Daedalus vs Firefly What are the pros and cons?



Breakthrough Starshot – the numbers

[1]
[2] .
[3]



Breakthrough Starshot – the laser array visualised

Star Trek may take a lot longer!

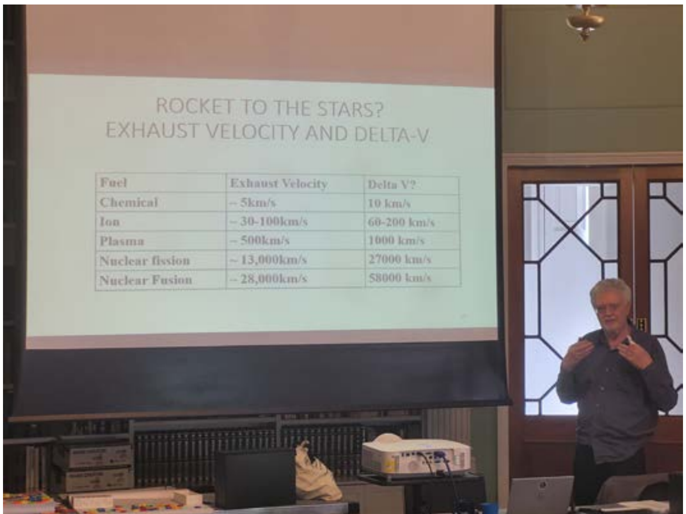
[1] *Freeman J. Dyson (1923–2020), Scientist and Writer, Who Dreamt Among the Stars, Dies at 96* https://www.ias.edu/press-releases/2020/freeman-j-dyson-1923%E2%80%932020

The slides were delivered to all the students in a PDF file after the workshop - via the Royal Institution.

4.2 Skateboards to Starships

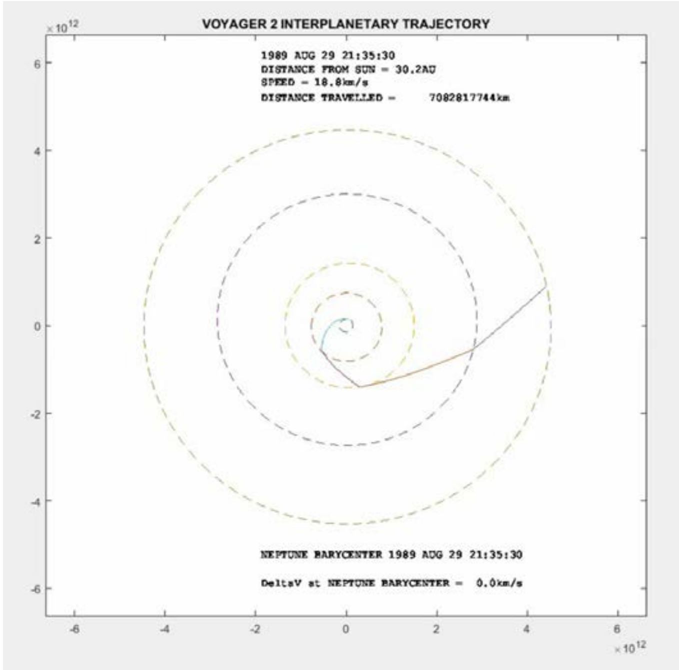
On the day -

John shows an animation of a Voyager trajectory. Illustrating the gravitational slingshot to the 16-18 group. Credit: Satinder

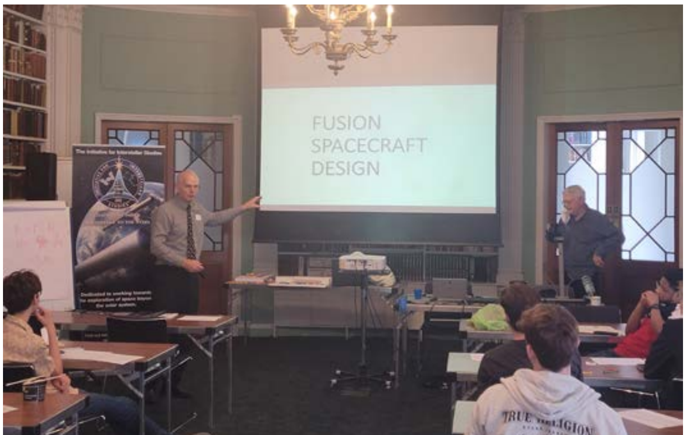


John explains how rocket fuels, chemical to fusion, deliver different exhaust velocities. Credit: Rob

John introduces the Breakthrough Starshot project for a laser sail interstellar probe. Credit: Rob

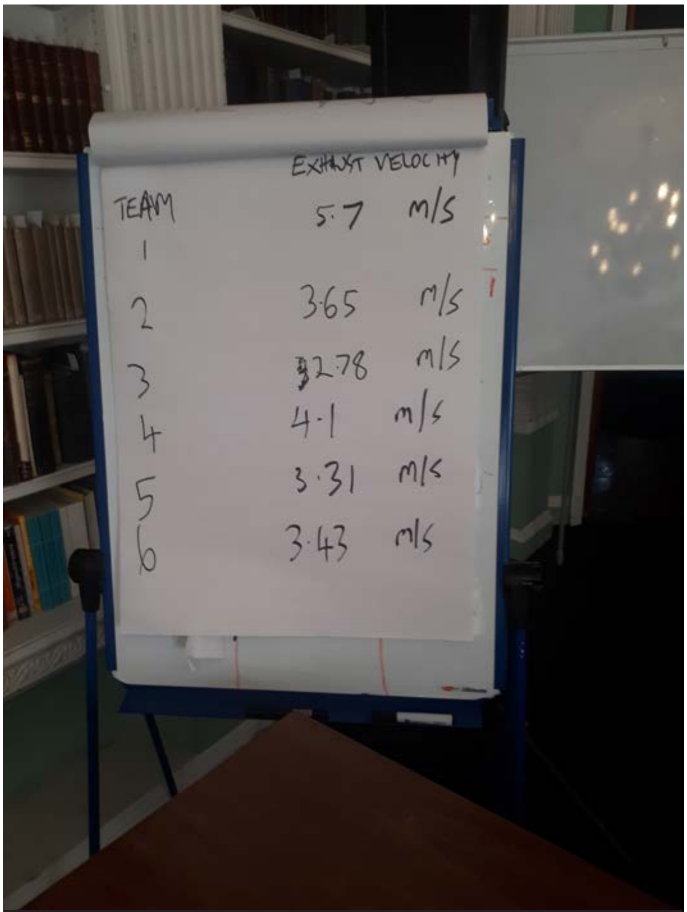


Voyager 2 interplanetary trajectory – animation illustrating the gravitational slingshot



Rob introduces fusion propulsion as the powerful way to fuel rockets

Satinder introduces the 16-18 age group to Keplerian orbits. Credit: Rob



Balloon Ve values calculated by the six teams of the 13-15 group. Credit: Rob

4.2 The Balloon Exhaust Velocity Experiment

We asked the teams to compute the exhaust velocity of balloon rockets using the mass of air, the volume of the balloon, the flight time and the distance – plumbing the values into a transposed Tsiolkovsky rocket equation. The equation is $\Delta V = Ve*\ln(Mo/Mf)$ where ΔV is velocity gained by the balloon, Ve is the exhaust velocity of the air coming out of the balloon, Mo is the mass of balloon+straw+air in the balloon and Mf is the balloon+straw as it finished its journey along the fishing line. We gave the teams the mass of balloon+straw and the density of air - so they could calculate the approximate mass of the expelled air by measuring the inflated balloon.

Teams had to transpose the equation to -

$Ve = \Delta V/\ln(Mo/Mf)$

- to work out Ve is the exhaust velocity of the air coming out of the balloon using the flight time of the balloon and the distance travelled to produce the ΔV, velocity gained by the balloon as a result of the expulsion of the air.

They came up with values 2.78, 3.31, 3.43, 3.65 and 5.7 metres per second. Inevitably differences in observation, the effect of friction between the straw (to which the balloons were taped) and the fishing line and, of course, air resistance - all are factors.

Not bad results for such a simple experiment!

As in previous years, the team adjourned to the pub after the second day's Summer School.

The team at the Royal Institution provided the usual RI excellent support. They were Sofi Tilahun, Richard Marshall and Peter Gallivan.

Get in touch (info@i4is.org)– we can deliver variants of both *Skateboards to Starships*, a highly interactive presentation and workshop with lots of physics, maths and engineering, or the *The i4is Interstellar Challenge for School Students*, a competitive team event covering not only physics, maths and engineering but also social issues, human biology, art and creative writing - the full STEAM package!

The building (top) and the people (below) about 1840. Credit: RIGB www.rigb.org/about-us