2023 Solar System Orbits

Welcome to the **British Physics Olympiad Computational Challenge 2023.** The goal is to build *computer models* based upon the instructions in the **Challenge Presentation document.** These can mostly be achieved using a *spreadsheet* such as Microsoft Excel, although you are very much encouraged to use a *programming language* of your choice*.

The challenge runs from **Easter 2023 till August 2023.** To submit an entry you will need to fill in a web form. There may be a small administration charge of, payable online as per other BPhO competition entries.

The deliverable of the challenge is to produce a **screencast** of ***maximum length two minutes*** which describes your response to the challenge, i.e. the graphs and the code & spreadsheets and your explanation of these. Your video should make it really clear *how you* have arrived at your solutions to the tasks set. This is what we need evidence for in your video. All credit is for 'show your working' !

The videos must be uploaded to **YouTube**, and we recommend you set these as *Unlisted* with *Comments disabled*. **Your entry will comprise a YouTube link.** To produce the screencast, we recommend the Google Chrome add-on **Screencastify.**

You can enter the challenge **individually** or in **pairs**. If you opt for the latter, *both* of you must make equal contributions to the screencast.

Gold, **Silver** or **Bronze** e-certificates will be emailed to each complete entry, and the **top five** Golds will be invited to present their work at a special ceremony. You should receive a result by December 2023. Note no additional feedback will be provided, and the decision of the judges is final.

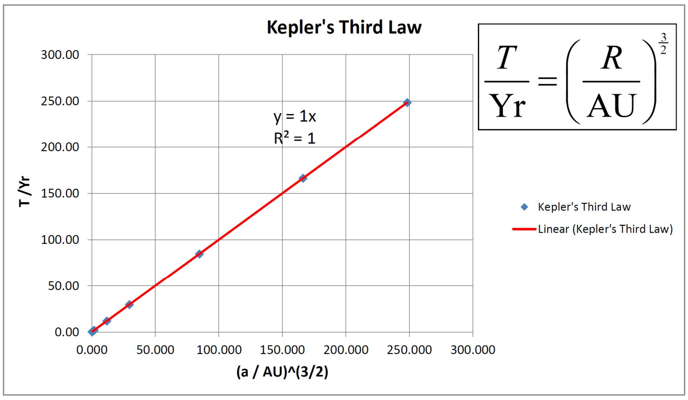
Bronze: Initial spreadsheet-based challenge elements attempted, some basic coding.

Silver: All the spreadsheet-based elements completed, and a commendable attempt at the programming-based elements. Most tasks completed to a reasonable standard.

Gold: All tasks completed to a high standard, with possible extension work such as the construction of apps (i.e. programs with graphical user interfaces), significant development of the models, attempt at extension work, short research papers etc.

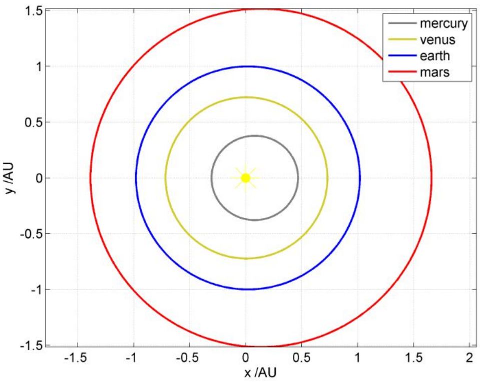
*MATLAB or Python is recommended, although any system that can easily execute code in loops and plot graphs will do. e.g. Octave, Java, Javascript, C#, C++, Mathematica... Use what you can access and feel comfortable with. These Programming resources might be a helpful start.

INSTRUCTIONS *** First download the Challenge Presentation from the BPhO website ***

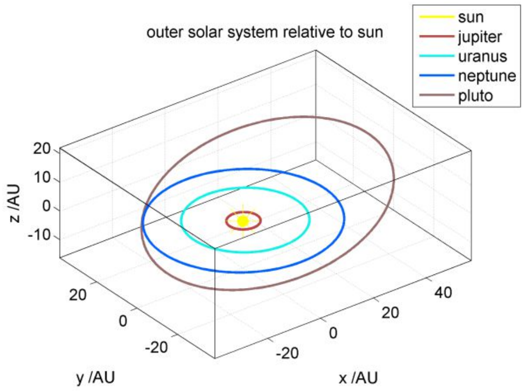


Summary of tasks (each will have Bronze, Silver and Gold aspects - although each task is more involved than the previous).

TASK 1: Using Solar System parameters, verify that the *square of orbital period is proportional to the cube of the orbital semi-major axis.* If units of years for time and Astronomical Units (AU) for distance are used, show that the constant of proportionality is very close to unity for the Solar System.

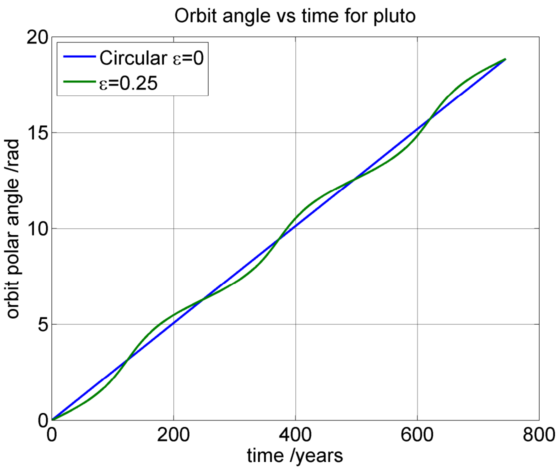


TASK 2: Compute and accurately plot elliptical orbits of the five inner planets. Then (using a larger scale), plot the outer planet orbits.

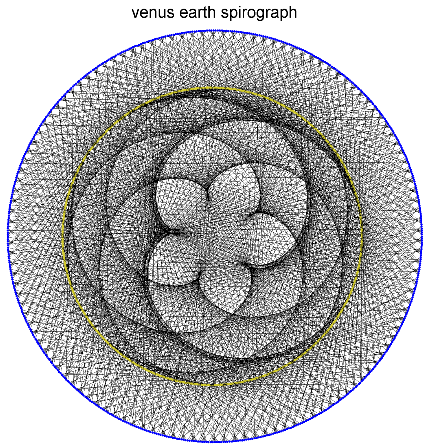


TASK 3: Create a 2D *animation* of the orbits of the planets.

TASK 4: Use the inclination angle value β and hence plot 3D orbit animations of the planets. Do include the dwarf planet Pluto, as it is off the *plane of the ecliptic* much more than the other planets.

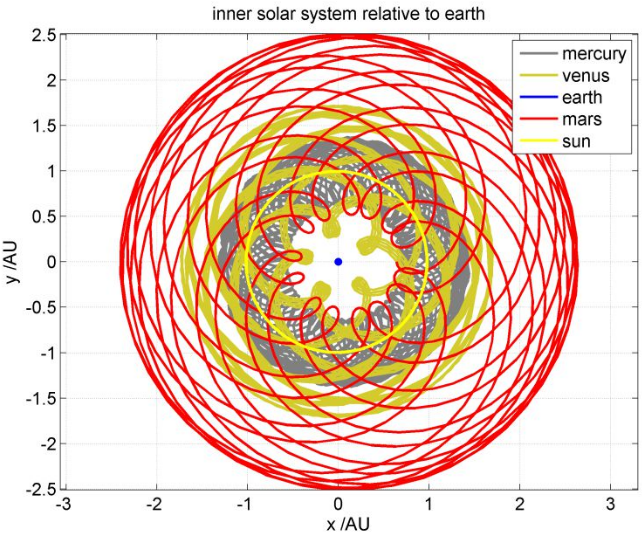


TASK5: Use Simpson's numeric integration method to determine how orbital time varies with polar angle. Hence code-up a function which outputs orbit polar angle from orbit time. Update your models with this function, and contrast how polar angle varies with time for Pluto, compared to a circular motion example with the same 248.348 year period.



TASK6: Solar System spirograph! Choose a pair of planets and determine their orbits vs time. At fixed time intervals, draw a line between the planets and plot their positions. Keep going for 10 orbits of the outermost planet.

RESEARCH



TASK7: Be like Ptolemy! Use your orbital models to plot the orbits of the other bodies in the solar system, with a chosen object (e.g. Earth) at a fixed position at the origin of a Cartesian coordinate system. i.e. choose a coordinate system where your chosen object is at (0,0,0).

POSSIBLE EXTENSION OPPORTUNITIES:

- Find data about *exoplanets* around stars other than the Sun. Stick to single-star systems rather than binaries, as planetary orbits may not be elliptical in more-than-two body systems. Simulations of many-body systems will be discussed in the online course that precedes this challenge. Recordings of the seminars are available on the BPhO website.

- Write a graphical user interface (GUI) for the orbital model and encode this as an ‘app’. Coding up an iOS/Android smartphone app will particularly impress the judges!

- Write up your model as a short paper. (Aim for about 10 sides of A4, two columns).

AF 22/8/2022

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