# Lesson Plan

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| **Title:** Kepler’s Laws of Planetary Motion  | **Date:** |
| **Learning objective/s:*** To understand the basic concepts of each of Kepler’s Laws.
* To use Kepler’s Third Law to investigate the properties of stellar systems.
* To develop an understanding of basic EXCEL functions such as manipulating graphs, inputting data and formulae.
 | **Curriculum links:** |
| **Learning outcomes****I want evidence students can:*** Use initiative concerning switching between standard units and units used in astronomy.
* Manipulate equations to acquire the correct variables.
* Analyse data using basic EXCEL functions.
* Discuss the implications of their findings and think about their applications to other scenarios in the Universe.
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| **Notes on children who have exceeded the performance expected:** | **Action to be taken:** |
| **Notes on children who did not achieve the performance expected:** | **Action to be taken:** |
| **Essential vocabulary:**Orbit, eccentricity, gravity, mass, parabolic, period, semi-major axis, exoplanet. | **Possible misconceptions:**Although we treat planets as if they have an eccentricity of 0 in the mathematics they do not have a value of exactly 0 but, for the purpose of this exercise, it does not matter. The orbiting bodies actually orbit the ‘centre of mass’ of a system but, in the case of the planets and the Sun, the centre of mass is actually a point within the Sun so again does not affect this exercise (if the Sun were gravitationally interacting with another replica of the Sun, and that alone, the centre of mass would be directly in the middle).  |
| **Cross curricular links:** Physics, ICT, Mathematics. |
| **Teacher resources including ICT:** * Introductory PowerPoint Presentation.
* Teacher Lesson Plan
 | **Children’s resources including ICT:** * Access to a computer and the NSO website/internet
* EXCEL spreadsheet
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| **Organisation and class management:** | **Teaching points:** | **Notes:** |
| **Introduction:** Whole class discussion | * Introduce the task and the learning objectives.
* Use the Powerpoint presentation to briefly introduce the concepts of Kepler’s laws of planetary motion.
* The activity will focus on Kepler’s third law; The Law of Periods. At this point students may open their EXCEL spreadsheets.
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| **Main phase:**Independent work  | **Part 1:*** Students will use planetary data on the NSO website, found by typing in ‘Planets’ in the search bar (or elsewhere online) and manipulate Kepler’s Third Law equation to fill in the missing variables in the EXCEL spreadsheet (the spreadsheet should look mostly blank!) and plot a graph of $T^{2}$ against $r^{3}$. They should produce a straight line going through each point – this proves the relationship between the orbital period and semi-major axis (distance).
* Students will use the data they have produced to calculate the mass of the Sun using each planet. Are the values different? Why? Discuss this before moving on the next part.

**Part 2:*** Students will now move onto the next part to investigate a different stellar system; TRAPPIST-1. There is a separate EXCEL tab where students will fill in the blanks, much like before but this time to find out the distances between each TRAPPIST-1 planet and the host star.
* Students should convert the units from meters to AU (1 Astronomical Unit = $1.496×10^{11}m$; the distance between the Earth and the Sun).
 | *Students may need to be reminded to keep track of their units.* *The values for the mass of the Sun should be different for each planet, especially compared to that which Mercury produces. Students may need reminding (and it would be helpful to go back to the slide with planetary eccentricities) that not all Solar System planets have eccentricities extremely close to 0. Mercury’s is relatively high – as we have not taken these into account and assumed circular orbits for all, the values of mass for the Sun will vary.* *The TRAPPIST-1 plot will fill out itself as an aid (it should produce another straight line if done correctly).*  |
| **Plenary/Conclusion:**Whole class discussion  | * As a class, look up the TRAPPIST-1 planetary data and discuss how close the measurements are to the accepted values.
* Were there any sources of error when carrying out the calculations?
* As you have proven, Kepler’s laws can be applied to objects outside of our own Solar System. Can the students think of any other scenarios where the laws will apply?
 | *Students may need reminding again that we have not taken eccentricity into account and have assumed* $ε=0.$ |

**EXCEL Notes:**

Typing in an equation:

* Click on a cell and, starting with ‘=’, manually **type in the equation.**
* You can type in cell numbers manually or select them with the mouse, this will insert them into your equation.
* To multiply a number by another in EXCEL, use ‘ \* ’ (not ‘x’ or ‘X’)

Dragging cell data (to avoid manually inputting everything):

* By clicking on the small box in the bottom-right corner of a cell (after selecting the cell) and dragging it down, you can copy the equation into all of the relevant cells. This saves typing in the equation each time manually.
* In doing this, the cells you selected to go in the equation will move to the next row. But this **will not work when using constants.**

Using constant efficiently

* When typing in an equation and using a constant in a cell, we wish for that cell to be part of the equation **even when dragged down**. To keep this cell as part of the equation, simply insert a $ symbol before and after the cell letter. For example: =$D$25\*F5, where ‘D25’ is a constant and ‘F5’ is a cell we wish to change as it is dragged down.