Launch Window

Background Story:

A MASSIVE meteorite is coming, you are in great DANGER and you need to leave planet "**" as soon as you can. Your scientists spotted a safer place "not too far", planet "%%" should be a great place for your colony.
When is your next launch window? Your fuel is limited and you need to be very very conservative with it, so be sure to find the optimal solution!

Scientific Background about launch window:

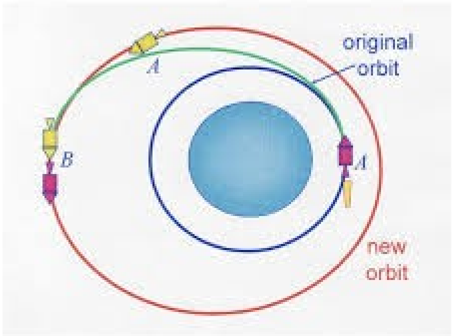
When a spacecraft is launched from "**", its forward velocity combined with the gravitational pull of "**" cause it to travel in a curved path. As the spacecraft heads toward another planet, the gravitational pull of that planet factors in to the path the spacecraft takes. The more a spacecraft can "coast" with engines off, the lower the cost of the mission (rocket fuel is not cheap!).

The path called the **Hohmann transfer orbit** uses the least energy and is thereby considered to be the most efficient.

The Hohmann transfer is an elliptical orbit with the sun at one focus of the ellipse that intersects the orbit of the target planet. Launch occurs when "**" is at Hohmann perihelion (the point of the Hohmann orbit that is closest to the sun). Arrival occurs when "%%" is at Hohmann aphelion (the point of the Hohmann orbit that is farthest from the sun).

To make sure the spacecraft and "%%" arrive at the same place at the same time, the spacecraft must launch within a particular window of time. This window is called the "launch window" and, depending on the target, can be a few minutes or as much as a few weeks in length.

If a spacecraft is launched too early or too late, it will arrive in the planet's orbit when the planet is not there. And you might get lost in space **forever**!!!!



Data and Physics laws :

Scientist have been working on this escape plan for a while now, they have been collecting some data. Here is all the information at your disposition:

- Both planets “**” and planet “$$” have a circular orbit around their sun.

- The orbit radius of planet “**” is 1AU (Astronomical Unit) and the orbit radius of planet “%%” is 1.52 AU.

- The Period of revolution of planet “**” is similar to ours : 1year=365 days.

- Kepler’s Third Law states that the square of the period (P) in years, of any planet is proportional to the cube of the semi-major axis (a) of its orbit in astronautical units(AU). An equation can represent this relationship:

$P^2=ka^3$ with k being the constant of proportionality

Procedure:

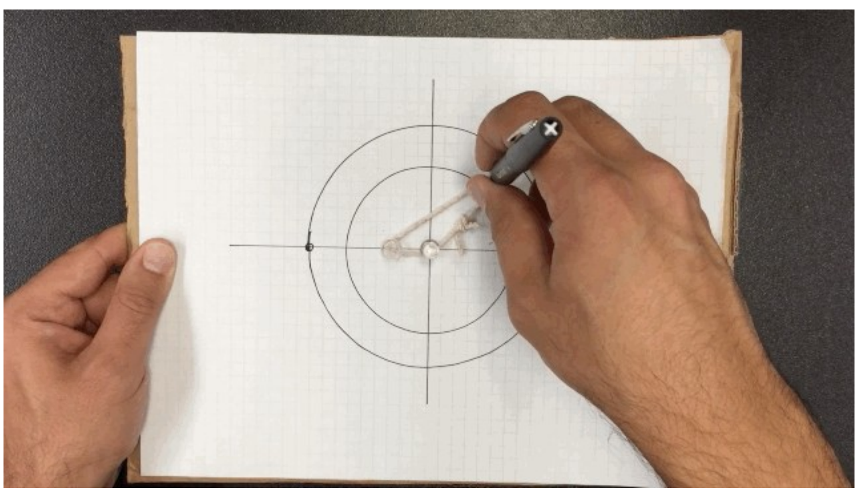
We are going to use the following scale : 1AU → 10 cm
Each step will earn you 2 points.

1) Plot planet “**” orbit on the provided paper using a push pin and a piece of sting cut at the proper dimension. (you really only need the upper half of the orbit)

2) Plot planet “%%” orbit on the provided paper using a push pin and a piece of sting cut at the proper dimension. (you really only need the upper half of the orbit)

3) Evaluate the length of the semi-major axis of the transfer orbit and mark it on the paper.
This is the midpoint on the vernal equinox (or x-axis) between the left x-intercept of the orbit of planet “%%” and the right x-intercept of planet “**”. Write down the length on your graph and put a push pin at the corresponding point.

4) Draw the Hohmann orbit by cutting a piece of string of appropriate length (twice the semi-major length) and using 2 push pins placed respectively on the sun and at the semi-major axis)



5) Use Kepler’s Third Law, the Law of Harmony, the period of revolution of Planet “**” and its orbit radius to determine the constant in Kepler's Third Law.

6) Use Kepler’s Third Law, the constant you just found and the radius of the Hohmann transfer orbit to evaluate the period of the Hohmann transfer orbit.

7) Remember, to escape your current planet and reach your destination, you need to travel half a period of the Hohmann transfer orbit. How long will your journey be? Give your answer in **days**.

8) Use Kepler’s Third Law, the constant you just found and the orbit radius of planet “%%” to evaluate its period of revolution. Give your answer in **days**.

9) If you know the period of revolution of planet “%%” , you know how long it will take to travel 360 degrees. How many degree will planet “%%” travel in the time it takes you to travel half of the Hohmann transfer orbit?

10) Where should planet “%%” be if you decide to launch when your current planet is situated at its right x-intercept? Plot your position on your graph.

Congratulations you and your colony will be safe!