LAB 12

Exoplanets

For this lab, we will explore the nearby exoplanet system Trappist-1, which hosts a red dwarf star surrounded by seven Earth-sized planets. Some of the planets' parameters are:

Planet	***Orbital Period* [days]**	***Planet Radius* [R⊕]**	***Planet Mass* [M⊕]**
b	1.5109	1.086	0.79
c	2.4218	1.056	1.63
d	4.0498	0.772	0.33
e	6.0996	0.918	0.24
f	9.2065	1.045	0.36
g	12.3528	1.127	0.566
h	18.7663	0.715	0.086

Note: R⊕ = Earth radius = 6371 km, M⊕ = Earth mass = 5.972×10^{24} kg

a) Use Kepler's third law, $P^2 = a^3$, where P is the orbital period *in years*, to calculate the semi-major axis length a of each planet's orbit in AU, where an AU is an Astronomical Unit, equal to the average distance between the Sun and the Earth.

b) Print the a values for each planet using a loop and the formatting:

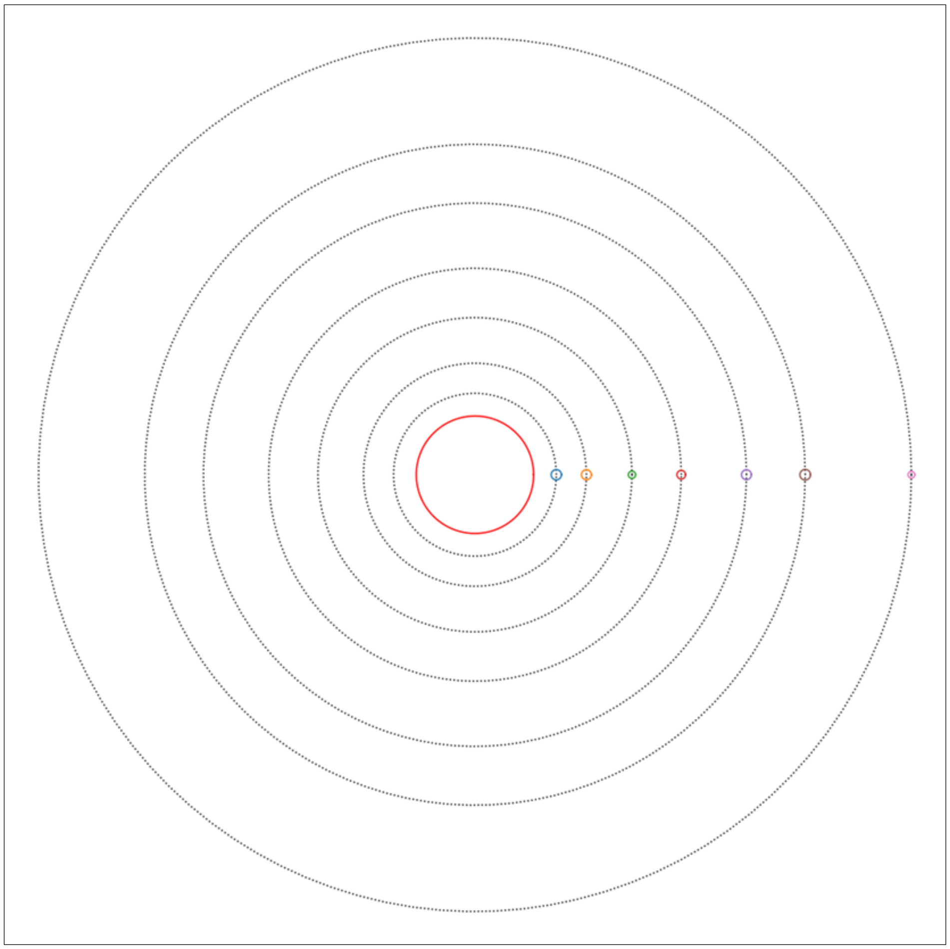
```
Planet X: semi-major axis = XXX AU = XXX km
```

(Note that 1 AU = 1.5×10^8 km)

c) Create a function to draw a circle. The inputs should be: the x_0 and y_0 coordinates of the circle's center, the circle's radius R, and the number of points around the circle. The outputs are the x and y coordinates around the circle: $x = R \cos \theta + x_0$, $y = R \sin \theta + y_0$. You will need to set up an array of angles θ around the circle and compute x and y inside your function, then return x and y.

d) Once you set up your function to make a circle, plot each planet's orbit as a circle using a dotted black line. All of the orbits should be plotted together on the same plot. Be sure to include appropriate plot annotations, i.e. a title, axes labels, units, etc.

e) Now, draw a red circle at the center of the orbits to represent the star. The star's radius is 12.45 $R_\oplus$ (Earth radii), but you will not show it exactly to scale. Instead, scale the circle by a factor of 35, which is enough to make it visible and fit inside the smallest orbit. Finally, add each planet as a small circle drawn on its orbit at location $y = 0$, with the circle size scaled relative to the central star (see planet radii in the table above). If you have done everything correctly, your plot of the planets, star, and the orbits should look something like the following, but with the proper axes, labels, title, etc.



f) Next, create a version of the table of planet data above that uses nice HTML-like formatting. To do this, download the file `Lecture_Advanced_Plots_Widgets_And_Tables.ipynb` under 'Files,' 'Lectures' on Canvas, which provides the necessary "class" as well as an example of how to use it.

g) Now, add as columns to your table in part f) the following quantities (which you will need to compute): semi-major axis length a and total orbital energy $E = -GMm/(2a)$, where G is the gravitational constant, M is the mass of the star, and m is the mass of the planet. Express E in Earth units (i.e. compute E for the Earth-Sun system and express E for each planet in Trappist-1 in units of this Earth-Sun E). The star in Trappist-1 has a mass of 0.08 solar masses, and you will need to look up the values for other physical constants. You will also need to round your calculations when adding them to your table. *Be VERY careful with units and make sure that your units are consistent in your calculations!*

h) Finally, plot each planet's total energy vs distance, i.e., plot E vs a (plot all planets together on the same figure).

Submit your final Jupyter Notebook to Canvas.