A Spacecraft Voyage, Part 3

Kinetic and Potential Energy

**OBJECTIVES**

In this activity you will analyze the flow of energy between kinetic energy and potential energy in a multiparticle system. You will

• calculate and graph the kinetic energy, potential energy, and the sum of  as a function of time for the system of a spacecraft and the Earth (at first, without the influence of the Moon)

• calculate and graph , , and  vs. time for the system of the spacecraft, Earth, and Moon

• graph , , and  as a function of separation of the spacecraft from the Earth

• study the effect of your choice of  (deltat) on the accuracy of your predictions

**Resources you will find useful:**

Start from a copy of your program to predict the motion of a spacecraft interacting with the Earth and Moon

**TIME**

You should finish this activity in 40 minutes or less.

On Your Whiteboard

**1** **Predictions: Spacecraft and Earth only (no Moon)**

Draw graphs of kinetic energy  (in green), potential energy  (in red), and  (in blue) vs. time (not separation!) for the system of spacecraft + Earth, for the following situations (not including the Moon):

• Spacecraft orbits the Earth in an elliptical orbit

• Spacecraft orbits the Earth in a circular orbit

• Spacecraft heads straight away from the Earth and does not return

**Compare your predictions to those of a nearby group, then ask a INSTRUCTOR to check your predictions.**

**2** **Adding graphs to your program: Energy vs. time**

• Immediately after the **from visual import\***, add the following two lines:

**from visual.graph import\*** **## invoke graphing routines**

**scene.y = 400** **## place graph 400 pixels below top of screen**

• Just before the while loop, add the following three lines:

**Kgraph = gcurve(color=color.yellow)**  **## create a gcurve for kinetic energy**

**Ugraph = gcurve(color=color.red)**  **## create a gcurve for potential energy**

**KplusUgraph = gcurve(color=color.cyan)**  **## create a gcurve for sum of K+U**

• Inside the while loop, at the end, calculate and plot kinetic energy, potential energy, and the sum of kinetic and potential energy as a function of time. Omit the Earth-Moon potential energy term, which does not change, but include all others:

**K = ## you must complete this line**

**U = ## you must complete this; omit the constant term for the Earth-Moon interaction**

**Kgraph.plot(pos=(t,K))**  **## add a point to the kinetic energy graph**

**Ugraph.plot(pos=(t,U))**  **## add a point to the potential energy graph**

**KplusUgraph.plot(pos=(t,K+U))**  **## add a point to the K+U graph**

**3** **Testing your program: A zero mass Moon**

* In order to compare your predictions to your results, set the mass of the Moon to zero. This will have the same effect as temporarily removing the Moon from your program, without having to change any code.
* Set the initial velocity of the spacecraft to a velocity that produces an elliptical orbit.
* Run your program.
* Compare your graphs to your predictions. Are your graphs correct? How can you tell?

**4** **Additional questions to answer**

* Experiment with the size of the time step deltat. How large can you make deltat before the calculated values become inconsistent with the Energy Principle? What do you observe in your graphs that indicates that deltat is too large?
* Plot energy vs. separation instead of time. Are your graphs correct? It is useful in your gcurve specification to say ``dot=True'' in which case a moving dot is plotted on the graph, so that you can see where the plotting is taking place on a repetitive graph (VPython 5.3 or later; you can determine the version with ``print(version)'').
* Revert to plotting energy vs. time, and set the mass of the Moon back to the correct mass. Set the initial velocity of the spacecraft to a velocity that produces a figure-eight type path. Make sure you calculate all energy terms, except that you may omit the potential energy due to the Earth-Moon interaction, which is large and constant, and makes it difficult to see other effects. You can drag the mouse over the graph to see crosshairs that let you read values accurately off the graph (VPython 5.61 or later).
* Explain the resulting graphs.

**Compare your results and explanations to those of a nearby group, then ask a Instructor to check your predictions.**

**Post your program to your blog. The program you submit should produce energy vs. time graphs for the spacecraft-Earth-Moon system, for a figure-8 type path. Your blog entry should include answers to the questions and images of both the figure-8 path and the graphs you generated.**