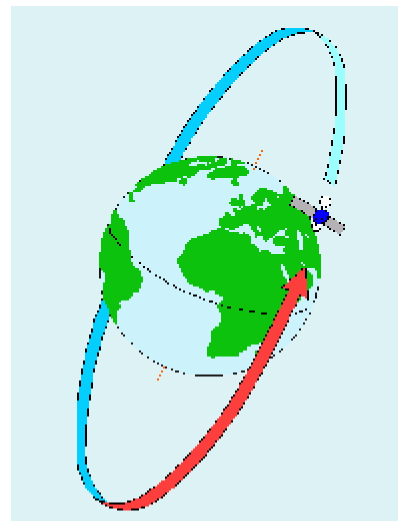
9-12 Activity

Keeping Track Of All The Pieces

Student Sheet(s)

Background Information



Johannes Kepler was a German astronomer who lived from 1571-1630. He introduced three important laws of planetary motion and helped the Copernican model of the solar system gain general acceptance. An original problem with Copernicus' heliocentric theory was its inability to explain the periodic retrograde (apparent backward motion) of planet Mars. Kepler inherited Tycho Brahe's observational data on Mars following Brahe's death and showed that Mars's orbit was really elliptical, and thus may occasionally appear to retrograde. In fact, all planetary orbits are elliptical. This new revelation contradicted the age old belief that heavenly bodies traced out perfect circles.

Today's activity will have you using Kepler's Third Law (with an added Newton's Law of Gravitation) along with a circular equation of motion. Kepler's Third Law with Newton's Law of Gravitation looks like this:

$$\mathbf{T^2 = (4\ p^2 / G\ M)\ r^3},$$

where T is the period of the orbiting object in seconds (sec), G is the Universal Gravitational Constant (6.67×10^{-11} N m^2/kg^2), M is the mass of the orbited object (like the Earth in this activity) in kilograms (kg), and r is the orbital radius, which includes the radius of the planet in meters (m) and the altitude of the orbiting object. The radius of the Earth is 6.37×10^6 m, and the mass of the Earth is 5.98×10^{24} kg. You will couple the above equation with a circular equation of motion: **v = 2 pr / T**, where v is the orbital speed in meters per second (m/s) or kilometers per second (km/s).

- Your answers found through each can be compared to the existing data from the chart below. If the orbital period is too long (large) compared to the stable value, then the object will decay. The decay time will depend on the relative difference between the answers. If the orbital period is too short (small) compared to the stable value, then the object will move to a higher orbit (and most likely fall back to Earth much later). If the velocity is above 11.2 km/s, then the object will leave Earth orbit. If the orbital period is within about 1 percent of the stable value, then the object should maintain that orbit unless acted upon by another force. Of course, without boosting, drag will eventually cause it to fall back to Earth.

Materials

- Scientific Calculators

1. Here is a list of the individual pieces (other than the pay load) that will make it into orbit.

Piece	Speed (km/s)	Altitude (km)
upper stage booster	6.48	320
Bolts	7.61	500
panel door	7.05	370
expended tank	5.1	340
Wiring	8.42	475
payload shield	7.68	410

2. Write down the pieces that you think will be necessary to track.

Piece	**Period**	**Stable period**	**Result**

3. Using the altitude given, determine the stable orbital period for each piece.

4. Using the speed given, determine the actual orbital period for each piece.

5. What will happen to each of these pieces? Explain your reasoning.

Keeping Track Of All The Pieces

Teacher Sheet(s)

Objective:	To use Kepler's and Newton's Laws to determine the trajectory of pieces that have fallen off a launched vehicle.
Level:	9-12
Subjects(s):	Algebra, Physics
Prep Time:	Less than 10 minutes
Duration:	35 minutes
Materials Category:	General Classroom

National Education Standards

Science:	3d, 7e
Math:	1a, 2a, 3b, 12a
Technology (ISTE):	
Technology (ITEA):	
NGS Geography Standards:	

Materials:

- Student Sheets
- Scientific calculators

Related Links:

NASA's Goddard Space Flight Center—From Stargazers To Starships: Kepler And His Laws

Windows To The Universe

Supporting NASAexplores Article(s):

What Goes Up Doesn't Always Come Down

Pre-Lesson Instructions:

- Duplicate the Student Sheets (one per student). This activity can be done in groups of two or three if desired.
- Have each student bring a calculator to class. A scientific calculator would be best, since students will need to use the exponent button.
- Review Kepler's Laws (orbital mechanics) and Newton's Law of Gravitation. If you have not covered these topics yet, you may want to wait before doing this activity. The information provided here is a great review or supplemental information to your existing curriculum.

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Student answers found through each can be compared to the existing data from the chart in the Student Sheets. If the orbital period is too long (large) compared to the stable value, then the object will decay. The decay time will depend on the relative difference between the answers. If the orbital period is too short (small) compared to the stable value, then the object will move to a higher orbit (and most likely fall back to Earth much later). If the velocity is above 11.2 km/s, then the object will leave Earth orbit. If the orbital period is within about 1 percent of the stable value, then the object should maintain that orbit unless acted upon by another force. Of course, without boosting, drag will eventually cause it to fall back to Earth.

Guidelines:

1. Read orally the 9-12 NASAexplores article, "What Goes Up Doesn't Always Come Down."
2. Distribute the Student Sheets.
3. Have students identify the pieces that they will be following.
4. Instruct students to find the speed or orbital period for each piece.
5. With the calculated data, have students determine what happens to each piece.

Discussion/Wrap-up:

- Ask students, "Do you know that there is a junkyard orbiting the Earth?" NASA does the best it can to keep the junk to a minimum. However, there are some things that cannot be avoided, or provide a very small risk.
- If time allows, give students an opportunity to reflect on the objects that are orbiting over them. Have a class discussion of the problems and possible solutions to the ever-increasing junkyard in orbit.
- Answers to the problems (students may choose to ignore the bolts and wires):

Piece	Actual speed (km/s)	Stable speed (km/s)	Period (sec)	Stable period (sec)	Result

booster	6.48	***7.72***	***6486.8***	***5443.7***	***orbit decays quickly***
bolts	7.61	***7.62***	***5672.2***	***5664.9***	***nearly stable orbit***
panel door	7.05	***7.69***	***6006.9***	***5504.1***	***orbit decays slowly***
expended tank	5.1	***7.71***	***8266.7***	***5468.3***	***orbit decays quickly***
wiring	8.42	***7.63***	***5107.9***	***5634.1***	***goes to higher orbit***
payload shield	7.68	***7.67***	***5546.9***	***5554.3***	***stable orbit***