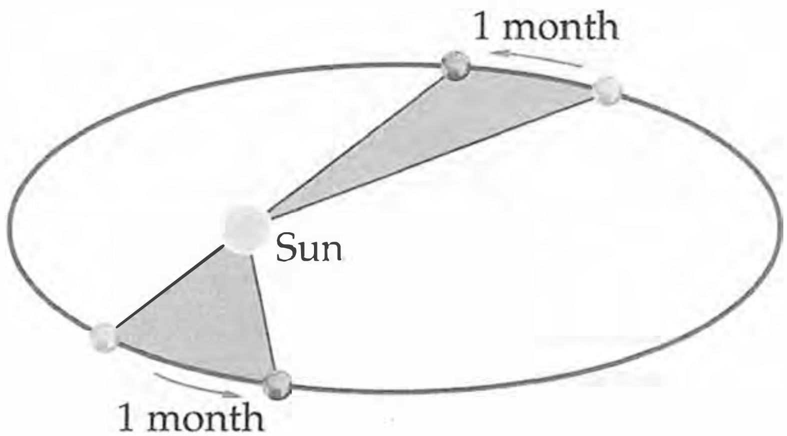
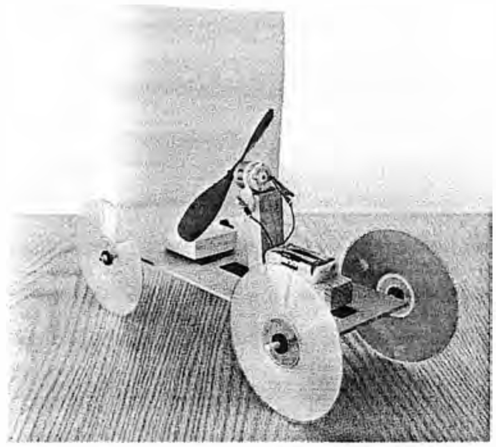
Planetary Motion in the Solar System



[M1U5]

Module 1 Unit 5: Planetary Motion
Lesson 1: Will it move?



HS-PS2-3: Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

Goals: Students will be able to explain and describe the interaction of the forces in a system as well as the period of the planets using their designed and built fancart.

Introduction:

You and a few friends are on a sailboat on a warm summer day. The sails are up and the warm summer breeze pushes the sailboat to the middle of the lake. As the sun goes down, you want to get back to shore, but there is no wind, and you have no gas in your boat motor. One of your friends has a brilliant idea: if you hook up all the electric fans on the boat to the powerful batteries on board, and direct the wind generated from the fan to the sail, you could get to shore.

Part 1:

1. Students get in group of 4: Lead scientist, recorder, reporter, and quartermaster.
2. Lead scientist facilitate the discussion: will the sailboat move? Record your claim and supporting evidence (recorder). (5 minutes: each member of the group have 1 minute to contribute to the discussion)
3. Reporter: report out (1 minute or less)

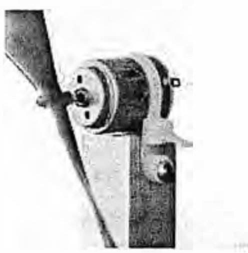
Part 2: build your sailboat and put it to the test.

1) **Materials:**

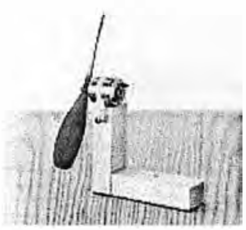
- plastic drinking straws
- Scissors
- Hot glue gun and glue sticks
- Masonite platform (10 x 30 cm) - [Alternatively, buy molding of the proper width and cut to needed length.]
- 4 beveled faucet washers, 1/4L (19/32" O.D) or Single Hole Rubber stoppers
- 4 CDs for the wheels
- 2 wooden dowels, 3/16 x 6 inches (0.5 x 15 cm), for the axles
- 3 wooden dowels, 3/16 x 7 inches (0.5 x 18 cm), for the mast and spars
- Manila file folder for the sail
- Wood block, 2 x 2 x ¾ inches (5 x 5 x 2 cm)
- Electric drill and bits: 3/16 inch (0.5 cm), ⅛ inch (0.3 cm), and 5/64 inch (0.2 cm)
- Cable tie with mounting head for screw, 7-½ or 8 inches (19 or 20 cm)
- DC hobby motor, 1.5 volt
- 2 wood blocks, 1 x 3 x ¾ inches (2.5 x 7.5 x 2 cm)
- Two-blade 6-inch (15 cm) propeller
- Phillips pan-head sheet-metal screw, 8 x ¾ inches (20 x 2 cm)
- Phillips screwdriver
- Wire strippers
- Battery holder for two AA batteries

- 2 mini alligator clips2
- Needle-nose pliers
- Two AA batteries
- Sticky-back velcro, about 9 inches (23 cm)
- Ruler
- Stopwatch (can use the built in stopwatch in your smartphone)

2) **Assembly:**
    a) Cut the straws to size, and attach them (via hot glue) to the Masonite platform.
    b) Insert the 15-cm wooden-dowel axles into the straws, then assemble the washers and CD wheels.
    c) Design and build the mast and sail using wooden dowels, manila file folder, and hot glue.
    d) Drill a 3/16 inch (0.5 cm) hole in the center of the large, 2-inch-square (2-cm square) wood block and insert the sai assembly.
    e) Motor assembly: use the cable tie, sheet-metal screw to attach the motor onto the small wood block, then attach the propeller onto the motor as shown in the pic below. (use ⅛ drill bit to drill a pilot hole for the sheet-metal screw)

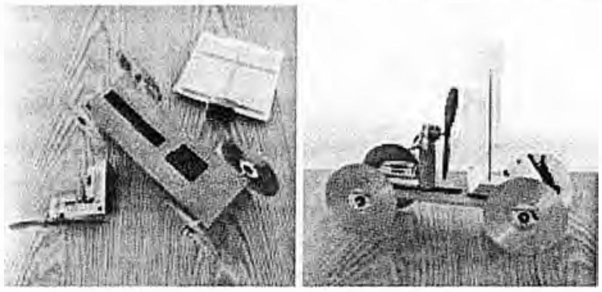


    f) Hot glue the remaining small wood block to the motor assembly as shown in the pic below.



    g) Battery assembly: use the wire-strippers and needle-nose pliers to attach the alligator clips onto the battery holder wires. Then hot glue the battery holder to the horizontal wood block as shown in pic below.

h) Cut the velcro into 2 pieces and attach them to the bottom of the sail and motor assembly as shown in the pic below.



3) Investigation 1:

a) Attach just the motor assembly on the cart.
b) Put the cart on a course of 6.28 m long.
c) Find the speed of the car (speed = distance/time)
d) Put 100 g mass on the cart, then find the speed.
e) Put 300 g mass on the cart, then find the speed.
f) Data table:

	Distance	Time	Speed
Cart			
Cart + 100 g			
Cart + 300 g			

g) Discussion:
   i) What make the cart move?
   ii) What are the factors that affect the speed of the cart?
   iii) How much time did it take the cart to complete the course?
   iv) If you double the distance (12.56 m) would the time double? Verify and discuss.

4) **Investigation 2:**
    a) Attach the sail to the cart
    b) Put the cart on the course, and turn the fan on.
    c) Record your observation. Did the cart behave as you predicted?
    d) Discussion:
        i) What cause the cart to move or not move?
5) **Investigation 3:**
    a) Remove the sail from the cart.
    b) Attach a string from the center of the cart to a dowel so that the distance between the cart and the dowel is exactly 1 m long.
    c) Turn-on the fan, and record your observation.
    d) Record the time it took for the cart to complete 1 cycle around the wooden dowel.
    e) Discussion:
        i) What is the circumference of the circle that the cart just completed?
        ii) Compare the circumference with the distance traveled in investigation 1.
        iii) Compare the time in investigation 1 with the time in investigation 3.
    f) Double the length of the string that attach the cart to the dowel.
    g) Discussion:
        i) The time to complete one cycle is also known as the period. What do you expect the period now? Would it be double the period when the string is 1 meter.
    h) Test your theory

<u>Part 3:</u> Application to our solar system

1) The ratio of the distances in investigation 3 was 2/1. What was the ratio for the period?
2) The distance from the sun to the Earth is also call 1 astronomical unit (1 AU). Look up the NASA website to find the distance for other planets in our solar system. What do you expect the periods for those planets would be comparing to Earth? Would they have the same period? How much more? How much less?

Kepler's 1st Laws and Planetary Motion

Purpose: The purpose of this activity is to become more familiar with Kepler's Laws of Planetary Motion

Materials:
Cardboard, pencil, 2 push pins, cotton twine, calculator, paper and ruler.

Procedure:

1. Obtain a piece of cardboard, two push pins, and a piece of string about 25 centimeters long.
2. Tie your piece of string in a loop.
3. Place your paper on the cardboard and put your push pins in the middle of the page length wise. The push pins should be about 10 centimeters apart. Changing this distance will change the shape of your ellipse.
4. Put your loop of string over the ends of the push pins. Draw the loop tight with the tip of your pencil and form a triangle with your string. Keep the loop tight and draw an ellipse.
5. Remove the string and push pins from your paper.
6. Label each hole made by the push pins focus 1 and focus 2.
7. Choose one of these foci and label it Sun.
8. Choose a place on the outline of your ellipse and place a dot there. Label the dot with a planet name of your choosing. Ex.) Planet Traegon.
9. Find the point on the outline of the ellipse that is closest to the dot that you made the Sun. Label this point Perihelion.
10. Find the point on the outline of the ellipse that is farthest from the dot that you made the Sun. Label this point Aphelion.
11. Put an X directly in the center of your ellipse exactly halfway between the two foci.
12. Draw a line from the X to the dot that you denoted as the Sun. Label this line as c.
13. Draw another line from the X through the focus that does not denote the Sun and all the way to the point that you denoted Aphelion. Label this line as a. In math, we call this line the semi-major axis. It is similar to the radius of a circle.
14. Eccentricity is the measurement of how stretched out an ellipse is. It ranges from zero to one. Zero is the eccentricity of a circle and one is the eccentricity of a straight line. Calculate the value of the eccentricity for the ellipse you drew by measuring the length of line c and measuring the length of line a. Calculate the eccentricity of the ellipse by taking c and dividing it by a. Put your data below.

Length of line "c" in cm	Length of line "a" in cm	Eccentricity of the ellipse you drew (c/a)

15. After doing this activity, what does Kepler's First Law of Planetary Motion say?

Explore further - Change aspects of the setup and respond to the following questions.

16. Fill out the table below changing several variables of the lab setup and describing the results. (examples i.e. speed, distance, string length...)

Variable changed	How variable was changed	Resulting effect on ellipses

Questions:

1. How can this help scientists find planets around other stars?
2. Please construct a short paragraph that explains the effect that several of the variables you tested have on the orbit of planets around the sun.

Kepler's 2nd Law and Planetary Motion

Calculating the Eccentricity of Planet Orbits

1. Calculate the eccentricity of each planet by using the formula e = c/a. Fill in your data in the chart below. State your answer in the proper number of significant figures.

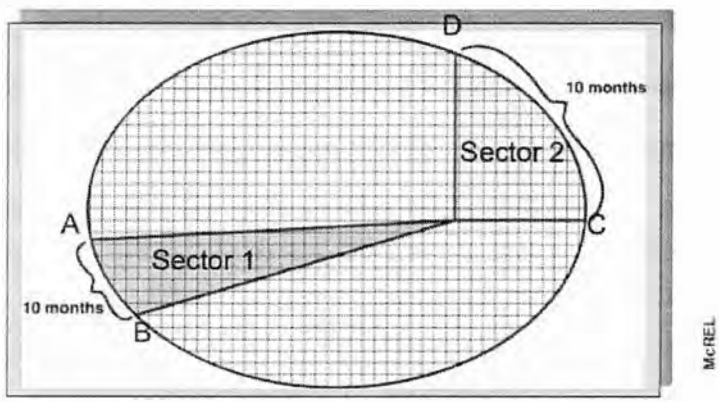
Planet	Distance from center of ellipse to focus in Astronomical Units (c)	Semi-Major Axis in Astronomical Units (a)	Eccentricity (e)
Mercury	0.080	0.387	
Venus	0.005	0.723	
Earth	0.017	1.000	
Mars	0.142	1.524	
Jupiter	0.250	5.203	
Saturn	0.534	9.540	
Uranus	0.901	19.180	
Neptune	0.271	30.060	
Pluto (Dwarf Planet)	9.821	39.440	

2. Which of the planets orbits is the most eccentric? Assume that Pluto is still a planet for this question.
3. Which of the planets orbits is the least eccentric (closest to a circle s eccentricity of zero)? Assume that Pluto is still a planet for this question.
4. Which two planets have the most similar eccentricity?
5. Which planet has an eccentricity most similar to Earth's eccentricity?
6. The average eccentricity of the Moon's orbit around the Earth is 0.054900489. Would you say the eccentricity of the Moon's orbit is low, medium, or high with respect to most of the planets orbits around the Sun?
7. How could the eccentricity of a planet's orbit affect the amount of solar radiation it receives from the Sun?

Kepler's Laws and Planetary Motion - 3

Kepler's Second Law of Planetary Motion

1. Go to the Phet Simulation. Set up an orbit of a moon around the Earth that is fairly elliptical by adjusting the planets mass. Run the animation. Let the animation play, so long as you have created a stable elliptical orbit. (insert a screenshot below)
2. How does the speed of a planet's orbit at perihelion compare to the speed of a planet's orbit at aphelion? Why is there a difference in speed?
3. Look at the diagram below. Count the number of squares in sector 1 and in sector 2.
    a. Squares in sector 1
    b. Squares in sector 2



4. What can you say about the number of squares in Sector 1 compared to the number of squares in Sector 2? What does the number of squares imply about each sector s area?
5. If it takes the same amount of time for a planet to move from point A to point B as it does for a planet to move from point C to point D, then what must a planet do in terms of its speed in each sector? Speed equals distance over time. Note that the distance between A and B is shorter than the distance between C and D.

Speed from A to B (Faster or Slower?)	Speed from C to D (Faster or Slower?)

6. Based on what you have seen here, Kepler's Second Law says that planets sweep out equal ________________ in equal ____________________. To do this, planets ______________________ when closer to the Sun and they ____________________ ________ when farther from the Sun.
7. Earth's perihelion is in January and its aphelion is in July, so, why is this not the reason for the seasons on Earth?
    a. If it was, would the Northern Hemisphere on Earth would be hotter in January and colder in July? why?

Kepler's Laws and Planetary Motion - 4

Use the following chart to answer the questions that follow.

Planet	Mean Orbital Velocity and Mean Distance to the Sun								
	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Mean Orbit Velocity in km/s	47.87	53.02	29.79	24.13	13.07	9.67	6.84	5.48	4.75
Mean Distance to the Sun (a) in Astronomical Units (AU)	0.39	0.72	1.00	1.52	5.20	9.54	19.19	30.07	39.48

1. How does the distance from the Sun of a planet affect the planet's orbital velocity? In other words, do planets that are farther from the Sun travel faster or do they travel slower?
2. Based on your response to number 1, what does Kepler's Third Law of Planetary Motion say?

Conclusion:
All of this work means nothing if you don't use it. How might Kepler's Laws be used by JPL to plan missions to other planets in terms of timing the mission launches? If you have time, go back to the simulator and play with it to see how crazy planetary orbits can get! Share some of your results here.

Motion in the Solar System and Formation of the Earth Assessment

Multiple Choice

1. Which of the following is one of Kepler's Laws of Planetary Motion
   a. planets move on elliptical orbits with the Sun at one focus
   b. gravitational force between two objects decreases as the distance squared
   c. an object in motion remains in motion
   d. inner planets orbit in a different direction than outer ones

2. Suppose a planet has an elliptical orbit. The speed of the planet is 20 km/s when it is at its average distance from the sun. Which of the following is most likely to be the planet's speed when it is nearest the sun?
   a. 10 km/s
   b. 15 km/s
   c. 20 km/s
   d. 25 km/s

3. A hypothetical planet orbits the sun a distance of 3 AU. What is its orbital period?
   a. 2.8 years
   b. 3.0 years
   c. 5.2 years
   d. 9.0 years

It takes the same amount of time for a planet to move from P1 to P2 as it does to move from P3 to P4.

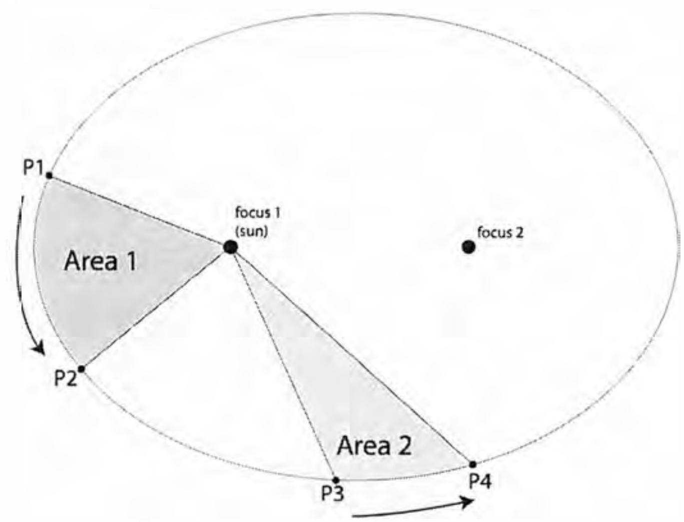


Image 1

4. In image 1, what is true about Area 1 and Area 2
    a. Area 1 = Area 2
    b. Area 1 > Area 2
    c. Area 1 < Area 2
    d. Area 1 does not relate to Area 2

5. Which of the following would be attracted toward a negatively charged sheet of metal?
    a. alpha particle
    b. beta particle
    c. gamma ray
    d. none of the above

6. Isotope A has a half-life measured in minutes, whereas isotope B has a half-life of millions of years. Which is more radioactive?
    a. isotope A
    b. isotope B
    c. Both are equally dangerous.
    d. It depends on the sample size.

7. Radiation can be a hazard to living organisms because it
    a. produces ionization along its path of travel.
    b. disrupts chemical bonds.
    c. generates free polyatomic ions.
    d. all of the above

8. The age of the Earth is currently thought to be
    a. about 6,000 years old
    b. about 6 billion years old
    c. about 4,500,000 years old
    d. about 4,500,000,000 years old
    e. none of the above

9. Living organisms have been on Earth for ______ of Earth's history?
    a. less than 1%
    b. about 20%
    c. about 50%
    d. about 80%

10. What caused dust and condensing material to accrete into planetesimals?
    a. heating of gases
    b. gravitational attraction and collisions
    c. nuclear fusion
    d. rotation of the proto-sun

Free Response

1. The average orbital distance of Mars is 1.52 times the average orbital distance of the Earth. Knowing that the Earth orbits the sun in approximately 365 days, use Kepler's law of harmonies to predict the time for Mars to orbit the sun.

Given: $R_{mars} = 1.52 \cdot R_{earth}$ and $T_{earth} = 365$ days

Use Kepler's third law to relate the ratio of the period squared to the ratio of radius cubed

$(T_{mars})^2 / (T_{earth})^2 \cdot (R_{mars})^3 / (R_{earth})^3$

$(T_{mars})^2 = (T_{earth})^2 \cdot (R_{mars})^3 / (R_{earth})^3$

Jupiter's Moon	Period (s)	Radius (m)	T2/R3
Io	1.53 x 105	4.2 x 108	A.
Europa	3.07 x 105	6.7 x 108	B
Ganymede	6.18 x 105	1.1 x 109	C
Callisto	1.44 x 106	1.9 x 109	D.

2. Determine the T2/R3 ratio (last column) for Jupiter's moons.
   A.

   B.

   C.

   D.

3. What pattern do you observe in the last column of data? Which law of Kepler's does this seem to support?

4. The earth is a unique planet in our solar system. Give at least 3 PHYSICAL ways the earth is different from the other planets. Explain how each of these characteristics relates to the formation of life on our planet.