


Circular Motion

Unit 3: Circular Motion, Work and Energy



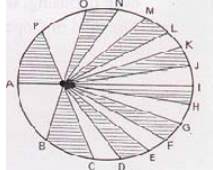
WELCOME TO HIGH SCHOOL PHYSICS.
WHERE EVERYTHING'S IN A VACUUM, AND AIR RESISTANCE DOESN'T MATTER

3.4 Kepler's Laws of Planetary Motion

An astronomical observer named Tycho Brahe (1546-1601) spent more than 20 years making careful measurements and observations of the heavens. His measurements were accurate to 1/1000th of a degree. Johannes Kepler, an assistant to Brahe, wanted to use Brahe's data to plot the orbit of Mars. For years Brahe kept promising the data to Kepler. Finally, Kepler stole Brahe's data after Brahe died in 1601. Kepler spent 16 years working on and plotting the orbit of Mars, producing 900 pages of calculations. Fortunately for Kepler, Mars' orbit is just enough of an ellipse that Brahe's data could not be forced to conform to a circular orbit. Kepler discovered three laws of planetary motion:

1. Planets orbit the sun in *elliptical* orbits with the sun at one focus of the ellipse.
2. A straight line joining the sun to a planet sweeps out equal areas in equal times.
3. The cube of a planet's mean distance (r) from the sun is proportional to the square of the period of revolution (T) of a planet.


$$\frac{r^3}{T^2} = k$$



Kepler's Law of Areas: A planet moves along its orbit at a rate such that the line from the sun to the planet sweeps over areas which are proportional to the time-intervals. The time taken to cover AB is the same as that for BC, CD, and so on.

Random Scientist Facts

- Kepler's mother was accused of witchcraft.
- Kepler devised the eyeglass for nearsightedness and farsightedness
- Tycho Brahe liked to drink and get in fights...his nose was cut off so he had a bronze nose made and obsessively rubbed it with oil. He had a gold nose for special occasions.



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Kepler gave no explanation of why planets go around the sun. His laws are only descriptive. However, Sir Isaac Newton provided the explanation for why the moon, Earth, Sun, planets and stars moved and behaved as they did. Newton was able to explain Kepler's three laws of planetary motion. He reasoned that if we make the approximation that a planet's orbit is circular, then the gravitational attraction between the planet and the Sun provides the centripetal force to maintain the planet's orbit around the Sun.

$$F_c = F_g$$


$$\frac{4\pi^2 mr}{T^2} = G \frac{Mm}{r^2}$$


$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

or

$$\frac{r^3}{T^2} = k \quad \text{where } k = \frac{GM}{4\pi^2} = 3.35 \times 10^{16} \text{ m}^3/\text{s}^2 \text{ for the Sun}$$

This is Kepler's third law.



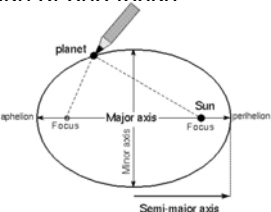


Kepler's First Law: planets move in ellipses, with the Sun at one focus

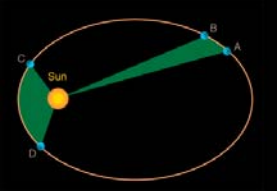
Kepler's Second Law: planets sweep out equal areas in equal times (ie. their orbital speed is not fixed)

Kepler's Third Law: the square of the period of a plane orbit divided by the cube of its orbital radius is a constant

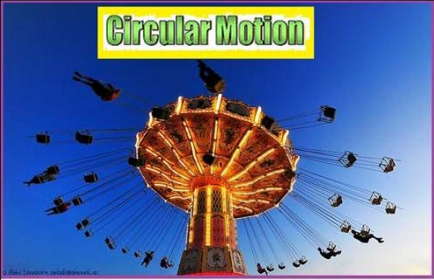
$$\frac{r^3}{T^2} = k$$




Drawing an ellipse: Loop string around thumb tacks at each focus and stretch string tight with a pencil while moving the pencil around the tacks. The Sun is at one focus.



A diagram showing a planet on its elliptical orbit around the Sun. The shaded areas are of equal size, and were swept out in equal time, i.e., it took the same amount of time for the planet to move from A to B and from C to D.





Kepler's Third Law was "proven" with data that Tycho Brahe had collected. Years later, Newton determined that gravity keeps planets in their orbits and that centripetal force is supplied by gravity proving Kepler's Third Law.

Homework: Unit Assignment