The Physics Behind SpaceBaby

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Using Kepler’s First Law in a polar coordinate system,

where *r* is the distance from the focus at which the object is located, *a* is the semi-major axis of the ellipse, *e* is the eccentricity, and *θ* is the angle formed by the semi-major axis and *r*. All angles are to be expressed in radians.

As the orbital eccentricities of the planets around the sun are much less than one, we assume constant angular velocity and that the sun is approximately at the center of the ellipse.

To model the orbits, we find *θ* as a function of time *t* using Kepler’s method of finding an “auxiliary” quantity to express *θ.* By drawing a circle around the ellipse and projecting the position of the planet on its elliptical orbit onto the circle, one can find the angle E, measured from the major axis on the the perihelion side (point closest to the sun) to the projected position of the planet.

Using the average angular speed of an orbiting planet, given by Kepler’s Second Law,

where *T* is the period, we can use Kepler’s equation:

where *t*0 is the planet at perihelion passage. In this case, we take this initial time to be zero. We have also taken *e* to be very small, so we can neglect the sine term. Plugging in the expression for time period *T,* which takes into account Mplanet << Msun and uses *G* and *a* in terms of astronomical units (AU),the equation reduces to:

where *t* is in years. With values for the angle *θ* as a function of time *t*, we can now use the original equation for *r* as a variable “radius” and use parametric equations to represent the location of the planet in rotation around the sun.