Did you know?

We generally speak of the moon orbiting Earth, but they are actually both in orbit around the center of mass of the Earth-moon system. Because Earth is so much more massive than the moon, their common center of mass lies inside Earth. Thus, the moon appears to orbit Earth. The center of mass does not always lie inside one of the bodies. For example, Pluto and its moon, Charon, orbit a center of mass that lies between them. Also, many binary star systems have two stars that orbit a common center of mass between the stars.

Kepler's third law describes orbital period

According to Kepler's third law, $T^2 \propto r^3$. The constant of proportionality between these two variables turns out to be $4\pi^2/Gm$, where m is the mass of the object being orbited. (To learn why this is the case, try the Quick Lab on the previous page.) Thus, Kepler's third law can also be stated as follows:

$$T^2 = \left(\frac{4\pi^2}{Gm}\right)r^3$$

The square root of the above equation, which is shown below on the left, describes the period of any object that is in a circular orbit. The speed of an object that is in a circular orbit depends on the same factors that the period does, as shown in the equation on the right. The assumption of a circular orbit provides a close approximation for real orbits in our solar system because all planets except Mercury have orbits that are nearly circular.

PERIOD AND SPEED OF AN OBJECT IN CIRCULAR ORBIT

$$T = 2\pi\sqrt{\frac{r^3}{Gm}} \qquad v_t = \sqrt{G\frac{m}{r}}$$

$$\textbf{orbital period} = 2\pi\sqrt{\frac{(\textbf{mean radius})^3}{(\textbf{constant})(\textbf{mass of central object})}}$$

$$\textbf{orbital speed} = \sqrt{(\textbf{constant})\left(\frac{\textbf{mass of central object}}{\textbf{mean radius}}\right)}$$

Note that m in both equations is the mass of the central object that is being orbited. The mass of the planet or satellite that is in orbit does not affect its speed or period. The mean radius (r) is the distance between the centers of the two bodies. For an artificial satellite orbiting Earth, r is equal to Earth's mean radius plus the satellite's distance from Earth's surface (its "altitude"). **Table 1** gives planetary data that can be used to calculate orbital speeds and periods.

Table 1 Planetary Data

Planet	Mass (kg)	Mean radius (m)	Mean distance from sun (m)
Earth	5.97×10^{24}	6.38×10^6	1.50×10^{11}
Earth's moon	7.35×10^{22}	1.74×10^6	——
Jupiter	1.90×10^{27}	7.15×10^7	7.79×10^{11}
Mars	6.42×10^{23}	3.40×10^6	2.28×10^{11}
Mercury	3.30×10^{23}	2.44×10^6	5.79×10^{10}
Neptune	1.02×10^{26}	2.48×10^7	4.50×10^{12}
Saturn	5.68×10^{26}	6.03×10^7	1.43×10^{12}
Sun	1.99×10^{30}	6.96×10^8	——
Uranus	8.68×10^{25}	2.56×10^7	2.87×10^{12}
Venus	4.87×10^{24}	6.05×10^6	1.08×10^{11}