29. A geostationary satellite is one moving so that it stays above a fixed location on the Earth. Assuming that such a satellite has a circular orbit, find its altitude.

30. Kepler discovered three laws of planetary motion. The first is that the planets orbit the sun in ellipses, with the sun at one focus. His third law is that the square of a planet's orbital period T is proportional to the cube of the semimajor axis a of its orbit. Excepting only Mercury and Pluto, the orbits of the planets are very nearly circular. First, verify empirically that Kepler's third law holds. Use the periods and semimajor axes of the orbits of Earth, Venus, Jupiter, and Uranus. Data for the last three are given in the table. The periods are measured in tropical years, the time required for the Earth to complete one orbit about the sun. The semimajor axes are measured in astronomical units (AU), the length of the semimajor axis of Earth's orbit.

	T	a
Venus	0.61521	0.7233316
Jupiter	11.86224	5.202561
Uranus	84.01247	19.21814

Table for Exercise 30.

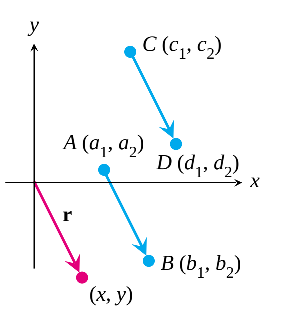
Does Kepler's third law follow from an equation similar to (26), but with M_E replaced by the mass M_S of the sun? Why or why not?

Review of Key Concepts

This chapter extends the work of Chapter 1 on rates of change into two dimensions. A major goal was to discuss the velocity and acceleration of objects in motion, two important rates of change. To describe the velocity and acceleration of an object moving in two dimensions, we defined vectors and several vector operations. The trajectories or orbits followed by objects in motion were described using parametric equations. We defined the dot product of two vectors and used it to calculate the angle between two vectors, to project a vector on a unit vector, and to calculate the work done by a force acting on an object. We introduced antidifferentiation and initial value problems in connection with Newton's three laws and his universal gravitation law.

Chapter Summary

Equivalent Vectors



Vectors $\overrightarrow{AB}$, $\overrightarrow{CD}$, and $\mathbf{r}$, where $\mathbf{r} = \langle x, y\rangle$ is a position vector with initial point at the origin, are equivalent if they have the same magnitude and direction. Specifically, vectors $\overrightarrow{AB}$, $\overrightarrow{CD}$, and $\mathbf{r}$ are equivalent if

$$b_1 - a_1 = d_1 - c_1 = x$$

and

$$b_2 - a_2 = d_2 - c_2 = y.$$

If A, B, C, and D are the points

$$(6, 1), (10, -7), (9, 12), \text{ and } (13, 4)$$

and $\mathbf{r} = \langle 4, -8\rangle$, then $\overrightarrow{AB}$, $\overrightarrow{CD}$, and $\mathbf{r}$ are equivalent because

$$10 - 6 = 13 - 9 = 4$$

and

$$-7 - 1 = 4 - 12 = -8.$$