Announcements

HOMEWORK	LABS	TEST
Unit 8 Practice Problems (1-15)	• Gravitation Interactive (RSVCP) • Orbital Motion Interactive (RSVCP)	Unit 8 Test Thursday Dec.20

10. Find the orbital speed of a satellite in a geosynchronous circular orbit 3.58×10^7 m above the surface of the Earth.

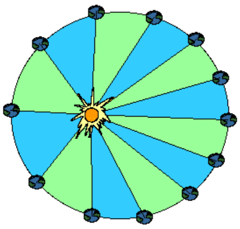
11. Phobos, one of the moons of Mars, orbits at a distance of 9378 km from the center of the red planet. What is the orbital period of Phobos?

12. GPS (Global Positioning System) satellites orbit at an altitude of 2.0×10^7 m. Find **(a)** the orbital period, and **(b)** the orbital speed of such a satellite.

8.3	Kepler's Laws and Planetary Motion

LEARNING TARGETS

8.3	I can define, explain, and apply Kepler's laws to solve problems involving satellite motion.



Planetary Motion and Gravitation

Key Concepts

- Newton's law of universal gravitation

$$F = G\frac{m_1 m_2}{r^2}$$

- All objects have gravitational fields surrounding them.

$$g = \frac{Gm}{r^2}$$

- The speed of an object in circular orbit is given by the following expression.

$$v = \sqrt{\frac{Gm_E}{r}}$$

- The period of a satellite in a circular orbit is given by the following expression.

$$T = 2\pi\sqrt{\frac{r^3}{Gm_E}}$$

WARM UP

The Sun's Mass

7. Determine the mass of the Sun given the Earth's distance from the Sun as $R_{ES} = 1.5 \times 10^{11}$ m.

$$T = 2\pi\sqrt{\frac{r_{ES}^3}{G M_s}}$$

$$T = 365 \times 24 \times 3600$$

$$T^2 = \frac{4\pi^2 r_{ES}^3}{G M_s}$$

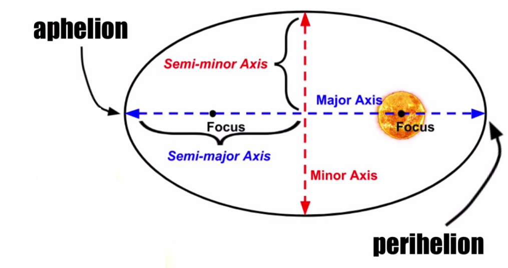
$$T = 31{,}536{,}000 \text{ s}$$

$$M_s = \frac{4\pi^2 r_{ES}^3}{G \cdot T^2} = \frac{4\pi^2 (1.5\times10^{11})^3}{(6.67\times10^{-11})(31536000)^2}$$

$$M_s = 2.0 \times 10^{30} \text{ kg}$$

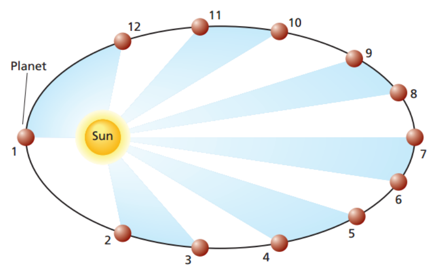
The Law of Ellipses

Kepler's first law - sometimes referred to as the **law of ellipses** - states that planets move in elliptical orbits, with the Sun at one focus.



The Law of Equal Areas

Kepler's second law - sometimes referred to as the **law of equal areas** - states that an imaginary line from the Sun to a planet sweeps out equal areas in equal times.



The Law of Harmonies

Kepler's third law - sometimes referred to as the **law of harmonies** - states that the square of the ratio of the periods of any two planets is equal to the cube of the ratio of their distances from the Sun.

$$\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_A}{r_B}\right)^3$$

The Law of Harmonies

Planetary data for the nine planets are shown below. Radius and period data are expressed relative to the Earth's radius and period. Taking two planets at a time, compare the ratio of the square of the period to the ratio of the cube of their radius.

Planet	Period (Earth years)	Ave. Radius (astron. units)
Mercury	0.241	0.39
Venus	0.615	0.72
Earth	1.00	1.00 AU
Mars	1.88	1.52
Jupiter	11.8	5.20
Saturn	29.5	9.54
Uranus	84.0	19.18
Neptune	165	30.06
Pluto	248	39.44

$(T_{Neptune} / T_{Mars})^2 = \left(\frac{165}{1.88}\right)^2$ $(R_{Neptune} / R_{Mars})^3 = \left(\frac{30.06}{1.52}\right)^3$

$7700 = 7730$

Where is Mars?

Mars' period was noted by Kepler to be about 687 days, which is = 1.88 Earth years. Determine the mean distance of Mars from the Sun using the Earth as a reference.

$\left(\frac{T_E}{T_m}\right)^2 = \left(\frac{r_E}{r_m}\right)^3$ 1.5×10^{11} m

$\left(\frac{1 yr}{1.88 yr}\right)^2 = \left(\frac{1 AU}{r_m}\right)^3$

$\sqrt[3]{0.28} = \left(\frac{1 AU}{r_m}\right)^3$

$0.28 \wedge (1/3)$

$0.65 = \frac{1 AU}{r_m}$

$r_m = 1.5 AU (1.5 \times 10^{11} m)$

PRACTICE

UNIT 8 PROBLEMS (9-15)