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Assignment 16: Kepler's Laws

1. The Earth has a minimum distance from the Sun of 1.471 x 10^{11}m. Its maximum distance from the Sun is 1.521 x 10^{11} m. What is the eccentricity of the Earth?

$$\varepsilon = \frac{r_{max} - r_{min}}{r_{max} + r_{min}} = \frac{1.521\times10^{11}\,m - 1.471\times10^{11}\,m}{1.521\times10^{11}\,m + 1.471\times10^{11}\,m} = \boxed{0.0167}$$

2. Pluto has a maximum distance from the sun of 7.311 x 10^{12} m. Its eccentricity is 0.2488. What is the minimum distance that Pluto is from the Sun?

$$\varepsilon = \frac{r_{max} - r_{min}}{r_{max} + r_{min}}$$

$$\varepsilon(r_{max} + r_{min}) = r_{max} - r_{min}$$

$$\varepsilon r_{max} + \varepsilon r_{min} = r_{max} - r_{min}$$

$$\varepsilon r_{min} + r_{min} = r_{max} - \varepsilon r_{max}$$

$$r_{min}(\varepsilon + 1) = r_{max}(1 - \varepsilon)$$

$$r_{min} = \frac{r_{max}(1-\varepsilon)}{(\varepsilon+1)} = \frac{7.311\cdot10^{12}\,m\,(1-0.2488)}{(0.2488+1)} = \boxed{4.398\times10^{12}\,m}$$

3. The Earth has an average distance from the Sun of 1.496 x 10^{11}m. It takes the earth 365.24 days to orbit the sun. Pluto has an average orbital radius is 5.874 x 10^{12} m. What is the time it takes pluto to orbit the sun?

$$\frac{T_p^2}{R_p^3} = \frac{T_e^2}{r_e^3} \qquad T_p = \sqrt{\frac{T_e^2 R_p^3}{r_e^3}} = \sqrt{\frac{(365.24\,days)^2\cdot(5.874\times10^{12}\,m)^3}{(1.496\times10^{11}\,m)^3}} = \boxed{89,863.195\,days = 246.039\,years}$$

4. Ceres is a dwarf planet in the asteroid belt. Its average distance from the sun is 4.138 x 10^{11} m. What is the orbital period of Ceres?

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5. Io is 4.217 x 10^8 m from Jupiter. It orbits Jupiter in 42.459 hours.
   a) If Callisto is also a moon of Jupiter, with a period of 16.689 days, what is its distance from Jupiter?

   b) As Io orbits Jupiter, the gravity of the giant planet causes Io to warp and deform, heating the mantle of Io and producing extreme volcanic activity. Why does this not happen to Callisto?

6. The moon has a minimum distance from the earth of 3.625 x 10^8 m. Its average distance is 3.844 x 10^8 m from the Earth. It orbits the earth in 27.322 days, and has an eccentricity of 0.0549.
   a) What is the maximum distance of the moon from the earth?

   b) In 1 billion years, the moon will be 4.844 x 10^8 m from the earth. What will the orbital period of the moon be?

7. It takes the sun approximately 250,000,000 years to orbit the center of the Milky Way Galaxy. Its distance from the galactic center is 2.5×10^{20} meters. What is the time it would take a star with an orbital radius of 3.5×10^{12} m to orbit the center of the galaxy?