Worksheet – Kepler's 3rd Law

You can complete this worksheet in groups of up to three people

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Planets in our Solar System

1. Neptune is 30.6 AU from the Sun. How long is the year for Neptune?

   a) $P^2 = a^3 = 30.6^3 = 28650$
   b) $P = \sqrt{28650} = 169$ years

2. Mars orbits the Sun in 1.87 Earth years. How far is Mars from the Sun?

   a) $a^3 = P^2 = 1.87^2 = 3.4969$
   b) $a = \sqrt[3]{3.4969} = 1.52$ AU

3. Venus orbits the Sun in about 223 (Earth) days. How far is Venus from the Sun?

   a) 2 = 223 days * 1 year / 365 days = 0.611
   b) $a^3 = P^2 = 0.611^2 = 0.3733$
   c) $a = \sqrt[3]{0.3733} = 0.72$ AU

4. There is a region beyond Neptune known as the Kuyper Belt, which includes a lot of small objects, including Pluto. Pluto is itself 39.8 AU from the Sun. How long does it take to orbit once? (Note Pluto was only discovered in 1930 by Clyde Tombaugh. It has not had time to complete more than a fraction of its orbit since its discovery.)

   a) $P^2 = a^3 = 39.8^3 = 63045$
   b) $P = \sqrt{63045} = 251$ years

Exoplanets

5. The star HD 4203 has a planet orbiting at a distance of 2.07 AU. The planet takes 432 days to orbit once. What is the mass of HD 4203? (You can leave your answer in Solar Masses).

   a) P = 432 days * 1 year/365 days = 1.184 years
   b) $M = a^3/P^2 = 2.07^3/ 1.184^2 = 6.33$ Solar masses

6. Suppose a planet takes 4.9 Earth years to orbit around a star of mass 2.5 solar masses. How far is the planet from its "Sun"?

   a) $a^3 = M P^2 = 2.5 * 4.9^2 = 60.025$
   b) $a = \sqrt[3]{60.025} = 3.92$ AU

7. Suppose a planet orbits a star of mass 0.8 Solar masses. If the orbit is cicular with a radius of 0.8 AU, how long does it take the planet to to make one complete orbit?

   a) $P^2 = a^3/M = 0.8^3 / 0.8 = 0.8^2$
   b) P = 0.8 years

Planets and Moons

8. The moon Io orbits Jupiter in 1.77 days, and is 4.2×10^8 m from the planet. The Moon Europa also orbits Jupiter, and is 6.7×10^8 m from the planet. How many days does it take Europa tp orbit once?

$$\frac{(4.2 \times 10^8)^3}{1.77^2} = \frac{(6.7 \times 10^8)^3}{P^2_{Europa}}$$

$$P^2_{Europa} = \frac{1.77^2 * (6.7 \times 10^8)^3}{(4.2 \times 10^8)^3} = 12.72$$

$P_{Europa} = 3.57$ days

9. The Moon is 3.84×10^8 m from the Earth, and takes 27.3 days to orbit once
   a) What is the distance in AU? 3.84×10^8 m * 1 AU/1.5×10^{11} m = 0.00256 AU
   b) What is the orbital period in years? 27.3 / 365 = 0.0748 years
   c) What is the mass of the Earth in solar masses? $M = a^3/P^2 = 0.00256^{\,3}/\ 0.0748^2 = 2.999 \times 10^{-6}$ Solar masses
   d) What is the mass of the Earth in kg? (1 solar mass = 2×10^{30} kg) $(2.999 \times 10^{-6}) * 2 \times 10^{30} = 6 \times 10^{24}$ kg

10. Use the data in question 8 to find the mass of Jupiter in kg.
    a) What is the distance in AU? 4.2×10^8 m * 1 AU/1.5×10^{11} m = 0.0028 AU
    b) What is the orbital period in years? 1.77 / 365 = 0.00485 years
    c) What is the mass of the Earth in solar masses? $M = a^3/P^2 = 0.0028^{\,3}/\ 0.00485^2 = 0.000933$ Solar masses
    d) What is the mass of the Earth in kg? (1 solar mass = 2×10^{30} kg) $0.000933 * 2 \times 10^{30} = 1.87 \times 10^{27}$ kg