Physics Unit 5: Kepler's Laws and Gravity Review

1. Know about Kepler's Laws of Planetary Motion, eccentricity, perihelion, aphelion, weight, mass, gravitational force, acceleration due to gravity, centripetal force, speed of a satellite in orbit
2. When does a satellite travel the fastest?
3. Why do astronauts seem to float?
4. A moon's average radius of orbit is 2×10^4 km and takes 20 days to orbit the earth. A communications satellite takes 3 days to orbit the earth. What is the orbital radius of the satellite?
5. The perihelion of an asteroid is 3×10^8 km, and its aphelion is 5×10^8 km. What is its orbit's eccentricity?
6. A satellite has an orbital with a perihelion of 3200 km and an aphelion of 3400 km both measured from the center of the earth. If it takes 65 minutes to orbit the earth, how much area does a line from the satellite to the earth sweep out every minute?
7. If the distance between two objects is divided by 4, what happens to the gravitation force between them?
8. Find the gravitational force of attraction between a 30-kg girl and a 40-kg boy sitting 0.5 meters apart.
9. A planet with mass 8×10^{20} kg orbits a star with mass 9×10^{30} kg. If the gravitational force between them is 6×10^{18} N, what is the planet's orbital radius?
10. What is the acceleration due to gravity at an altitude of 200 km above the earth's surface? **Note:** the radius of the earth is 6.36×10^6 m; the mass of the earth is 5.98×10^{24} kg.
11. What is the mass of a moon where the acceleration due to gravity is 7.0 m/s^2 at its surface? **Note:** the radius of the moon is 2×10^4 m.
12. Calculate the speed of a 120 kg satellite in orbit 425 m above a moon with mass 2×10^{22} kg and radius 8×10^5 m.
13. A starship is orbiting a planet at 1200 m/s. Calculate the mass of the planet if the radius of the starship's orbit is 8×10^5 m.
14. An asteroid is orbiting a star at 8×10^{10} m. If the mass of the star is approximately 2×10^{29} kg, what is the period of the asteroid's orbit?
15. A planet takes 615 days to orbit its star at a distance of 2×10^{12} m. What is the mass of the star?

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Answers

2. When it is closest to the main body such as the sun or planet
3. They are in freefall with their surroundings
4. $\frac{T_1^2}{T_2^2} = \frac{r_1^3}{r_2^3}$

   $\frac{(3\ days)^2}{(20\ days)^2} = \frac{r^3}{(2\times10^4\ km)^3}$

   $r^3(400\ days^2) = 7.2 \times 10^{13}\ days^2 km^3$

   $r^3 = 1.8 \times 10^{11}\ km^3$

   $r = \sqrt[3]{1.8 \times 10^{11}} \approx \mathbf{5650\ km}$
5. $e = \frac{c}{a}$

   $a = \frac{r_a + r_p}{2} = \frac{3\times10^8\ km + 5\times10^8\ km}{2} = 4 \times 10^8\ km$

   $c = r_a - a = 5 \times 10^8\ km - 4 \times 10^8\ km =$
   $1 \times 10^8\ km$

   $e = \frac{c}{a} = \frac{1\times10^8\ km}{4\times10^8\ km} = \mathbf{0.25}$
6. $a = \frac{r_a + r_p}{2} = \frac{3200\ km + 3400\ km}{2} = 3300\ km$

   $b = \sqrt{r_a r_b} = \sqrt{(3200\ km)(3400\ km)} = 3298\ km$

   $A = \pi ab$

   $A = \pi(3300\ km)(3298\ km) = 3.42 \times 10^7\ km^2$

   $\frac{A}{min} = \frac{3.42\times10^7\ km^2}{65\ \text{min}} = \mathbf{5.26 \times 10^5\ km^2/min}$
7. $F = \frac{GmM}{r^2}$ so $F \propto \frac{1}{r^2}$.

   $F \propto \frac{1}{\left(\frac{1}{4}\right)^2}$

   $F \propto 16$

   ***F* is multiplied by 16.**
8. $F = \frac{GMm}{r^2}$

   $F = \frac{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)(30\ kg)(40\ kg)}{(0.5\ m)^2}$

   $F = \mathbf{3.2 \times 10^{-7}\ N}$
9. $F = \frac{GMm}{r^2}$

   $6 \times 10^{18}\ N = \frac{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)(8\times10^{20}\ kg)(9\times10^{30}\ kg)}{r^2}$

   $r^2 = \frac{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)(8\times10^{20}\ kg)(9\times10^{30}\ kg)}{6\times10^{18}\ N}$

   $r = \sqrt{8.004 \times 10^{22}\ m^2} = \mathbf{2.83 \times 10^{11}\ m}$
10. $g = \frac{GM}{r^2}$

    $g = \frac{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)(5.98\times10^{24}\ kg)}{(6.36\times10^6\ m + 200\times10^3\ m)^2}$

    $g = \mathbf{9.27\ m/s^2}$
11. $g = \frac{GM}{r^2}$

    $7.0\frac{m}{s^2} = \frac{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)M}{(2\times10^4\ m)^2}$

    $2.8 \times 10^9 \frac{m^3}{s^2} = \left(6.67 \times 10^{-11}\frac{Nm^2}{kg^2}\right) M$

    $\mathbf{4.20 \times 10^{19}\ kg} = M$
12. $v = \sqrt{\frac{GM}{r}}$

    $v = \sqrt{\frac{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)(2\times10^{22}\ kg)}{425\ m + 8\times10^5\ m}} = \mathbf{1290\ m/s}$
13. $v = \sqrt{\frac{GM}{r}}$

    $1200\frac{m}{s} = \sqrt{\frac{\left(6.67\times\frac{10^{-11}Nm^2}{kg^2}\right)M}{8\times10^5\ m}}$

    $1.44 \times 10^6 \frac{m^2}{s^2} = \left(8.34 \times 10^{-17}\frac{Nm}{kg^2}\right) M$

    $\mathbf{1.73 \times 10^{22}\ kg} = M$
14. $\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$

    $\frac{T^2}{(8\times10^{10}\ m)^3} = \frac{4\pi^2}{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)(2\times10^{29}\ kg)}$

    $T^2 = \frac{4\pi^2(8\times10^{10}\ m)^3}{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)(2\times10^{29}\ kg)}$

    $T = \sqrt{1.52 \times 10^{15}\ s^2} = \mathbf{3.89 \times 10^7\ s}$
15. $\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$

    $\frac{615\ days}{1}\left(\frac{24\ hr}{1\ day}\right)\left(\frac{3600\ s}{1\ hr}\right) = 5.31 \times 10^7\ s$

    $\frac{(5.31\times10^7\ s)^2}{(2\times10^{12}\ m)^3} = \frac{4\pi^2}{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)M}$

    $\left(1.88 \times 10^5 \frac{m^3}{kg}\right) M = 3.16 \times 10^{38}\ m^3$

    $M = \mathbf{1.68 \times 10^{33}\ kg}$