11 Physics Worksheet ***SOLUTIONS***

Gravitation and Satellites

1. The force vector on each mass is equal in magnitude and opposite in direction, which fits with Newton's third law $\vec{F}_1 = -\vec{F}_2$.

2. (a) $F = G\frac{m_1 m_2}{r^2} = 6.67\times10^{-11}\times\frac{4.5\times10^9\times2.2\times10^8}{\left(6.8\times10^7\right)^2} = 1.4\times10^{-8}$ N

   The gravitational force is on the moon is 1.4×10^{-8} N (2 s.f.) towards the centre of the planet.

   (b) 1.4×10^{-8} N towards the centre of the moon.

   (c) $a = \frac{F}{m} = \frac{1.4\times10^{-8}}{4.5\times10^9} = 3.17\times10^{-18}$ ms^{-2}

   The acceleration of the planet is 3.2×10^{-18} ms^{-2} (2 s.f.) towards the centre of the moon.

   (d) $a = \frac{F}{m} = \frac{1.4\times10^{-8}}{2.2\times10^8} = 6.49\times10^{-17}$ ms^{-2}

   The acceleration of the moon is 6.5×10^{-17} ms^{-2} (2 s.f.) towards the centre of the planet.

3. The moon has a much smaller mass, and acceleration is inversely proportional to mass, as shown by $a = \frac{F}{m}$

4. $a = \frac{GM}{r^2} = \frac{6.67\times10^{-11}\times4.5\times10^9}{(9.0\times10^4)^2} = 3.71\times10^{-11}$ ms^{-2}

   The acceleration at the surface of the planet is 3.7×10^{-11} ms^{-2} (2 s.f.) towards the planet's centre.

5. The force is greater by the same ratio that the mass is greater. Since $a = \frac{F}{m}$, increasing the force *and* the mass leads to the same acceleration.

6. (a) $v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67\times10^{-11}\times4.5\times10^9}{6.8\times10^7}} = 6.644\times10^{-5}$ ms^{-1}

   The speed of the moon is 6.64×10^{-5} ms^{-1} (2 s.f.)

   (b) $T = \frac{2\pi r}{v} = \frac{2\pi\times6.8\times10^7}{6.64\times10^{-5}} = 6.43\times10^{12}$

   The period of the moon's motion is 6.4×10^{12} s (2 s.f.)

   (c) $6.4\times10^{12}\times5 = 3.2\times10^{13}$ s (2 s.f.)

7. The centripetal acceleration for the satellite's circular motion must be provided by the force of gravity. This force is always towards the centre of the circle of motion and towards the centre of the planet. Since for these orbits the centre of the circle of motion and the centre of the planet do not match, the orbits are impossible.

8. (a) A geostationary satellite moves around Earth in the direction of rotation and is over the same point on the Earth all the time. A polar satellite orbits to some degree north and south, and can be over many points on the Earth at various times.
   (b) Polar satellites are close to the Earth and hence give better images. They also can be above any point, whereas geostationary satellites can only ever be above the equator.