Kepler's Laws and Univeral Gravitation Problem Set

1. Between March 21 and September 21, there are three days more than between September 21 and March 21. These two dates are the spring and fall equinoxes when the days and nights are of equal length. Between the equinoxes, Earth moves 180° around its orbit with respect to the sun. Using Kepler's laws, explain how you can determine the part of the year during which the Earth is closest to the Sun.
2. The international space station (ISS) has an altitude of about 400 km above the surface of the Earth. What is it's period of orbit? What is its speed?
3. There is speculation that a ninth planet may exist (its existence would explain some anomalies in the orbits of some distant trans-Neptunian objects - TNOs). It is estimated that it would have a period of approximately 15 000 Earth years. What would its average radius or orbit be?
4. Why do we ignore the gravitational force of attractions between two ordinary sized objects (for example two cars)? Justify your answer mathematically using reasonable estimates.
5. A satellite of mass 800 kg is desired to be placed in a circular orbit around Mars at an altitude of 500 km above the surface of the planet.
   (a) What would the period of this orbit be?
   (b) What would the speed of the satellite be?
   (c) What gravitational field does the satellite experience at this radius?
   (d) What does the satellite weigh in this orbit?
   (e) Using your answers to the previous questions, calculate the mass of Mars. Compare this to the value on your data sheet.
6. As the altitude of an Earth satellite in circular orbit increases, does the speed of the satellite increase, decrease or remain the same?
7. How hard does the Earth pull on the Moon? How hard does the Moon pull on the Earth? What does this, and knowing the masses of the objects tell you about whether the Earth orbits the Moon or the Moon orbits the Earth? Explain.
8. The original orbit of the ISS was about 350 km above the Earth's surface. To conserve fuel, it was boosted to its current altitude of 400 km. The mass of the space station is about 420 000 kg.
   (a) What change in gravitational potential energy was required?
   (b) What was the speed of the space station in its original orbit? It's new orbit? (You may use information from question 2 for this.)
   (c) What was the change in the kinetic energy of the space station?
   (d) If a litre of hydrogen liquid produces about 5.4 MJ of energy, how many litres of hydrogen would be required to do this?
9. What is the escape velocity from the surface of Mars?