Part I

1. The reason the Moon does not fall down and collide with the Earth is because

   (a) It is being pulled by the Sun and planets as well as by Earth.

   (b) The net force on it is zero.

   (c) It is beyond the main pull of Earth's gravity.

   (d) None of the above.

   Answer (d): With no net force the earth would move away from the earth because it is moving relative to the Earth. The Earth in fact pulls on the moon with just the right force to keep the moon from escaping but not so much that it crashes into the Earth.

2. Two identical satellites orbit the earth in circular orbits. If the radius of satellite A is less than the radius of satellite B then

   (a) the kinetic energy of A is less than that of B;

   (b) the potential energy of A is less than that of B;

   (c) the acceleration of A is less than that of B;

   (d) all of the above.

   Answer (b). Acceleration and kinetic energy are greater for lower orbits

3. The path of comets around the sun is elliptical and so the distance from the comet to the sun varies. The point of closest approach is called the perigee and the point of furthest reach is called the apogee. Suppose that for a particular comet the apogee is twice as far from the sun as the perigee. Comparing the strength of the force between the sun and the comet at the apogee and the perigee the force is

   (a) four times as strong at the perigee.

   (b) twice as strong at the perigee.

   (c) the same at the apogee and the perigee since acceleration constant along a closed orbit.

   (d) half as strong at the perigee.

   Answer (a): Because of the inverse square law of Gravitation when an object moves to twice the original distance from the sun it feels 1/4 the force.

4. The escape velocity of a spaceship from a planet depends on

   (a) The mass of the planet and the mass of the spaceship.

   (b) The mass and the diameter of the planet.

   (c) The mass of the planet only.

   (d) The diameter of the planet only.

Answer (b)

5. Which of the following statements is true of a satellite orbiting the earth on a circular path?
    (a) It moves with constant speed and acceleration of zero magnitude.
    (b) It moves with constant velocity and acceleration of constant magnitude.
    (c) It moves with variable velocity and acceleration of zero magnitude.
    (d) It moves with constant speed and acceleration of constant magnitude.

    Answer (d).

Part II

1. Suppose a satellite with mass m orbits the Earth with period T and radius R.
    (a) If another satellite with a larger mass orbits the Earth with the same period, would the radius of the orbit be larger, smaller or the same? Explain your answer.
    The radius would be the same since gravitational acceleration is independent of the mass.
    (b) If another satellite with the same mass orbits the earth with a longer period would the radius of the orbit be larger, smaller or the same? Explain your answer.
    The radius would increase. A longer period means a smaller velocity and hence less centripetal force is needed. The orbit would need to be further from earth.
    (c) If a small amount of air resistance were to act on the satellite describe what would happen to the period and the radius of the orbit over time. Explain your answer.
    The system loses energy and hence drops to a lower orbit. In a lower gravitational orbit the speed is faster and hence the period will be shorter.

2. A 6.8×10^4 kg spaceship orbits a distant planet circling with a period of 26 hours and an orbital radius of $16{\times}10^6$ m.

(a) Find

(i) the velocity of the spaceship.

$$v = \frac{2\pi r}{T} = \frac{2\pi \times 16 \times 10^{16}}{26 \times 60 \times 60} = 1070 \text{ m/s}$$

(ii) the centripetal acceleration of the spaceship.

For centripetal acceleration $a = \frac{v^2}{r} = \frac{1070^2}{16 \times 10^6} = 0.072 \text{ m/s}^2$

(iii) the mass of the planet.

The acceleration can be related to the mass of the planet through Newton's 2nd Law. $F_{\text{net}} = ma \Rightarrow \frac{GmM}{r^2} = ma \Rightarrow M = \frac{ar^2}{G} = 2.76 \times 10^{23}$ kg

(iv) the total energy of the spaceship.

For an object in orbit $E_{\text{orbit}} = -\frac{1}{2}\frac{GMm}{r} = -\frac{1}{2}\frac{(6.67 \times 10^{-11})(2.76 \times 10^{23})(6.8 \times 10^4)}{16 \times 10^6} =$ 3.9×10^{10} J

(b) (i) What forces if any act on the astronauts inside the spaceship?

The only force acting on the astronauts is the their weight – ie the force of gravity acting on them.

(ii) Explain why the astronauts feel weightless.

The astronauts feel weightless because they are in 'freefall'. That is, they are accelerating toward the planet at a rate equal to the acceleration of gravity at that point. (Note: The sensation of weight is actually the normal force of a surface acting on your body in order to limit your acceleration. When acceleration is zero the normal force must equal your actual weight. When your acceleration is equal to the acceleration of gravity the normal force is zero and you feel weightless.)

(c) The spaceship decreases its orbital radius to get a closer view of the planet.

(i) In this lower orbit will its speed be greater or smaller? Explain.

The speed will be greater since the centripetal force provided by gravity is greater and $F_c \propto v^2$.

(ii) Will its total energy be decreased or increased? Explain.

Total energy is decreased. Although kinetic energy is increased potential energy is decreased by more.

(iii) In order for it to drop into a lower orbit will the captain need to apply forward or reverse thrusters? Explain.

Reverse thrusters should be applied as this causes a loss of mechanical energy and hence a drop in orbit.