7. Gravitation

Definitions

Gravitational field strength: Defined as the force per unit mass acting at that point
Gravitational potential energy: GPE of a mass in a gravitational field is defined as the work done
by an external force in bringing the mass from infinity to that point.

Geostationary satellite: A geostationary satellite is a satellite that remains at a fixed position relative to any point on the Earth's surface. (benefit: signal from the satellite can be tracked continuously)

- Gravitational field strength (g) is inversely proportional to square of r (for outside a uniform sphere or due to a point mass)
- **HOWEVER when inside the uniform sphere, g is proportional to r**.
- The formula g = -d(potential)/dr indicates that the gravitational field points in the direction of decreasing potential.
- **Kepler's 3rd law** shows that T^2 is proportional to r^3 (for satellite motion)
- To derive the above equate the centripetal force and the gravitational force.
- **Newtons's law of gravitation** states that the gravitational force between 2 masses is directly proportional to the product of their masses and inversely proportional to the square of their separation.

Questions

1. Why is gravitational potential energy always negative?
Ans: Gravitational potential energy is taken to be zero at infinity. Gravitational force is attractive in nature and thus the external force must be acting away from the Earth. The direction of the force is thus opposite to the displacement of the mass and as a result, work done by the external force is negative.

2. Explaining the potential graph between two different masses.
Ans:

- Establish that the potential at any point between the two masses is given by potential (due to A) plus potential (due to B) (scalar addition)
- Use the potential formula to explain why the potential is greater (in magnitude) nearer to either of the masses, and reaches a peak point (lowest magnitude) but eventually decreases again
- Asymmetrical due to the different mass of the 2 masses

3. Explain why satellites used in communication are placed in an orbit with a period of one day.
Ans: Satellites remain at a fixed point on the equator and hence receiving satellites do not have to track the satellite OR signal from geostationary satellite can be accessed continually.

4. What happens to the orbit when total energy is reduced?
Ans: The total energy becomes more negative, radius decreases, orbit becomes smaller but velocity increases as radius decreases.

5. Explain why the acceleration of free fall is different at the equator and at the poles.

Ans: The equator undergoes circular motion about the Earth’s axis whereas the poles do not. At the equator, part of the gravitational acceleration has to provide for the centripetal acceleration and hence the acceleration of free fall is lower. However there is little difference as the angular velocity of earth is small and hence the centripetal acceleration of an object will be small.