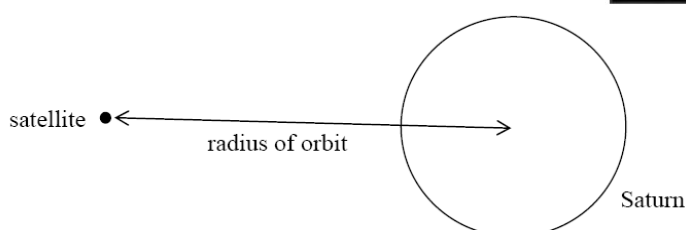


State Examination Commission – Physics Higher Level, 2005

Question 6

Define (i) angular velocity, (ii) centripetal force.
State Newton's Universal Law of Gravitation (18)

A satellite is in a circular orbit around the planet Saturn. Derive the relationship between the period of the satellite, the mass of Saturn and the radius of the orbit. (15)



The period of the satellite is 380 hours. Calculate the radius of the satellite's orbit around Saturn. (9)

The satellite transmits radio signals to earth. At a particular time the satellite is 1.2×10^{12} m from earth. How long does it take the signal to travel to earth? (9)

It is noticed that the frequency of the received radio signal changes as the satellite orbits Saturn.

Explain why. (5)

(Universal gravitational constant = 6.7×10^{-11} N m² kg⁻² ; mass of Saturn = 5.7×10^{26} kg; speed of light = 3.0×10^8 m s⁻¹)

Define (i) angular velocity, (ii) centripetal force. State Newton's Universal Law of Gravitation. (18)

Definitions – Must know

A satellite is in a circular orbit around the planet Saturn. Derive the relationship between the period of the satellite, the mass of Saturn and the radius of the orbit. (15)

$$\begin{aligned}
 \text{Centripetal force} &= \text{Gravitational force} \\
 mv^2/r &= GMm/r^2 \\
 \text{So, } v^2 &= GM/r \\
 \text{Now the period, } T &= 2\pi r/v \quad (\text{distance travelled in one orbit/speed}) \\
 T^2 &= 4\pi^2 r^2/v^2 \\
 T^2 &= 4\pi^2 r^3/GM
 \end{aligned}$$

The period of the satellite is 380 hours. Calculate the radius of the satellite's orbit around Saturn. (9)

$$\begin{aligned}
 T &= 380 \times 60 \times 60 = 1.37 \times 10^6 \text{ s} \\
 T^2 &= (1.37 \times 10^6)^2 = 4\pi^2 r^3 / (6.7 \times 10^{-11})(5.7 \times 10^{26}) \\
 \text{Solving for } r &\text{ gives } r = 1.2 \times 10^9 \text{ m}
 \end{aligned}$$

The satellite transmits radio signals to earth. At a particular time the satellite is 1.2×10^{12} m from earth. How long does it take the signal to travel to earth? (9)

$$\begin{aligned}
 v &= s/t \\
 3.0 \times 10^8 &= 1.2 \times 10^{12}/t \\
 t &= 4000 \text{ s}
 \end{aligned}$$

It is noticed that the frequency of the received radio signal changes as the satellite orbits Saturn. Explain why. (5)

Because of the relative motion between the satellite and the detector of the signal on Earth – i.e. The Doppler effect.