CHAPTER 2

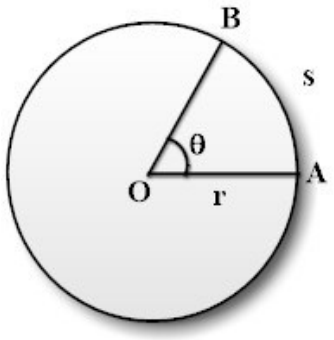
ROTATIONAL MOTION

1. Derive the relation between linear velocity and angular velocity of a body moving along a circular path.

Consider a particle moving along the circumference of a circle of radius *r* with a linear velocity *v*. When the body moves from A to B in time t seconds and covers a distance s, the angular displacement, θ is given by

$$\theta = \frac{s}{r}$$

$$s = r\theta$$



Linear velocity of the particle is given by

$$v = \frac{s}{t} = \frac{r\theta}{t}$$

Since angular velocity, $\omega = \frac{\theta}{t}$,

$$v = r\omega$$

2. Explain the terms angular velocity and angular acceleration.

The angular displacement per unit time is called angular velocity.

$$\text{Angular velocity} = \frac{\text{angular displacemet}}{\text{time}}$$

$$\omega = \frac{\theta}{t}$$

Angular acceleration is the rate of change of angular velocity. If the angular velocity of a body changes from ω_1 to ω_2 in t seconds, the angular acceleration α is given by

$$\alpha = \frac{\omega_2 - \omega_1}{t}$$

3. What is centripetal force? Give two examples of centripetal force.

The force which, acting along the radius towards the centre of the circular path, causes the body to move in a circle with constant speed is called centripetal force. If m is the mass of the body moving along a circle of radius r, centripetal force

$$F_c = \frac{mv^2}{r}$$

1. In the case of planets revolving around the sun, the necessary centripetal force is provided by the gravitational attraction between them.
2. When an electron moves around the nucleus of an atom, the centripetal force is provided by the electrostatic force of attraction between electron and proton.

4. Explain the term banking of roads. Derive an expression for the angle of banking.

When a vehicle goes around a curve, it travels along a nearly circular path. Centripetal force is required to keep an object in a circular path. In a horizontal unbanked curve, the weight of the vehicle is balanced by the normal reaction whereas the necessary centripetal force is provided by the friction between the wheels (tyres) and the surface of the road. If the friction is inadequate, the vehicle skid off the road. To avoid skidding, the outer edge of the road is raised above the level of the inner edge at the curves. This is known as the banking of roads.

Angle of banking is the angle made by the elevated path with the horizontal. Let AB and AC represent the horizontal and banked paths respectively. Let θ be the angle of banking. Consider a vehicle of mass m takes a curved path of radius r with a speed v. The weight of the vehicle mg acts vertically downwards. The normal reaction N of the road on the vehicle will be perpendicular to the AC. The normal reaction can be resolved into vertical and horizontal components.

The vertical component is equal to the weight of the body.

$$N\cos\theta = mg$$

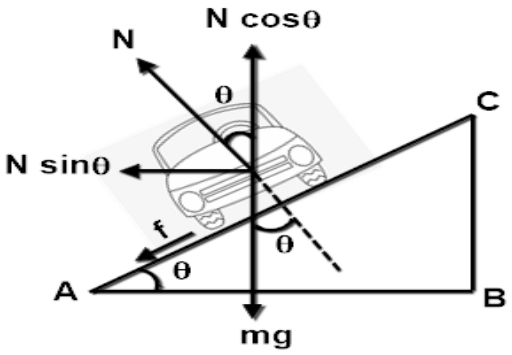
The horizontal component provides the centripetal force

$$N\sin\theta = \frac{mv^2}{r}$$

Dividing second equation by the first gives

$$\tan\theta = \frac{v^2}{rg}$$

$$\theta = \tan^{-1}\left\{\frac{v^2}{rg}\right\}$$



Banked road

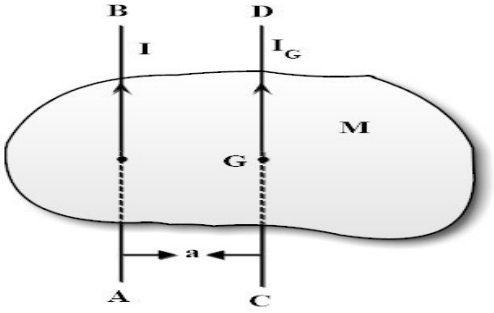
5. Define moment of inertia of a body.

The moment of inertia of a particle about a given axis is defined as the product of the mass of the particle and the square of the distance of the body from the axis.

6. State and explain parallel axes theorem.

Parallel axes theorem states that the moment of inertia of any rigid body about a given axis is equal to the sum of its moment of inertia about a parallel axis passing through the centre of gravity and the product of the mass of the body and the square of the distance between the axes.

Let I be the moment of inertia of a body about an axis AB. Let I_G be the moment of inertia about another axis CD which is parallel to AB and passing through the centre of gravity G of the body. Let M be the mass and *a* be the distance between the two axes. Then according to the parallel axes theorem,



7. **Define the term torque.**

Torque is defined as the product of the force and the perpendicular distance between the line of action of the force and the axis of rotation. $\tau = Fr$

8. **State the law of conservation of angular momentum**.

The law of conservation of angular momentum states that, if no external torque acts on a system, the total angular momentum of the system remains constant. If I be the moment of inertia of a body about a given axis of rotation and ω be its angular velocity, then L = I ω = constant.

9. **Door handles are usually fitted at the edge of the plank of the door. Why?**

Torque is the product of force applied and the distance between where you apply the force and the axis of rotation. If you apply a force near the axis of rotation, the torque would be small because the distance is small. If you apply the same force farther away from the axis, the torque is larger. Hence, the door opens easily with less effort.