

' $I$ ', and his angular speed  $\omega_i$ . The product " $I\omega_i$ " is the angular momentum which remains constant. When he pulls the dumbbells towards his chest, his moment of inertia ' $I_2$ ' decreases. Now he spins faster as ' $\omega_f$ ' increases to keep ' $I_2\omega_f = \text{const.}$ '

**Q. 5.13 :-** A geo-stationary satellite covers  $120^\circ$  of longitude, so the whole of the Earth's surface for global transmission can be covered by three correctly positioned geo-stationary satellites.

## NUMERICAL PROBLEMS

Note :- The solutions to the numerical problems are given below. For Problems see last page.

**P. 5.1 :-** As given :- Diameter of beam = arc length =  $s = 2.5 \text{ m}$   
Distance of moon = radius of circle =  $r = 3.8 \times 10^8 \text{ m}$

$$\theta = ? \quad \text{Using: } s = r\theta, \quad \theta = \frac{s}{r} = \frac{2.5}{3.8 \times 10^8}$$

$$\therefore \theta = 6.6 \times 10^{-9} \text{ rad.} \quad = 6.6 \times 10^{-9} \text{ rad}$$

**P. 5.2 :-** As given :- Initial angular velocity =  $\omega_i = 0$

Final angular velocity =  $\omega_f = 45 \text{ rev/min}$

$$\text{or } \omega_f = \frac{45 \times 2\pi}{60} = \frac{45 \times 2 \times 3.14}{60}$$

$$\therefore \omega_f = 4.71 \text{ rad s}^{-1}$$

$$t = 1.6 \text{ s}, \quad \alpha = \text{ang. acc.} = ?$$

using the eq.  $\omega_f = \omega_i + \alpha t$

Putting values:  $4.71 = 0 + \alpha(1.6) \Rightarrow \alpha = \frac{4.71}{1.6}$

$$\therefore \alpha = 2.94 \text{ rad s}^{-2}$$

P. 5.3 :- As given: Moment of Inertia =  $I = 0.8 \text{ kg m}^2$

Constant Angular velocity =  $\omega = 100 \text{ rad s}^{-1}$

(i) Angular momentum =  $L = ?$

(ii) Torque = ?

→ (i) Using the eq.  $L = I\omega = 0.8 \times 100 \text{ kg m}^2 \text{ s}^{-1}$

$$\text{or } L = 80 \text{ kg } \frac{\text{m}^2}{\text{s}} \times \frac{\text{s}}{\text{s}} = 80 \text{ kg } \frac{\text{m}^2}{\text{s}^2} \times \text{m} \times \text{s}$$

$$\therefore L = 80 \text{ Nm s} = 80 \text{ Js}$$

→ (ii)  $\therefore \tau = I\alpha$ , but as  $\omega$  is constant,

$$\text{so } \alpha = 0, \therefore \tau = 0$$

P. 5.4 :- As given :-  $m = 5 \text{ kg}$ ,  $F = 0.6 \text{ N}$ ,

$r = 0.2 \text{ m}$ ,  $\alpha = 90^\circ$  ( $\therefore \vec{r} \perp \vec{F}$ ).

(i)  $\tau = ?$ , (ii)  $\alpha = ?$

→ (i) using relation:  $\tau = rF \sin \alpha$

$$\text{Putting values: } \tau = 0.2 \times 0.6 \times \sin 90 = 0.12 \text{ Nm}$$

$$\therefore \tau = 0.12 \text{ Nm}$$

→ (ii) using the relation:  $\tau = I\alpha$

$$\text{but: } I = \frac{1}{2} m r^2, \therefore \tau = \frac{1}{2} m r^2 \alpha$$

$$\text{Putting values: } 0.12 = \frac{1}{2} \times 5 \times (0.2)^2 (\alpha)$$

$$0.12 = 0.1 (\alpha) \Rightarrow \alpha = \frac{0.12}{0.1} = 1.2 \text{ rad/s}^2$$

$$\therefore \alpha = 1.2 \text{ rad s}^{-2}$$

P. 5.5 :- As given :-  $M = 2 \times 10^{30} \text{ kg}$ ,  $R = 7 \times 10^5 \text{ km} = 7 \times 10^8 \text{ m}$ ,

$$T = 20 \text{ days} = 20 \times 86400 = 1.728 \times 10^6 \text{ s}$$

(i)  $L = ?$  (ii)  $K.E._r = ?$

→ (i) using eq.  $L = I\omega$ , where  $I = \frac{2}{5} MR^2$  for

a sphere, because heavenly bodies are considered as

spheres. Therefore:  $L = \frac{2}{5} MR^2 \times \frac{2\pi}{T}$  ( $\because \omega = \frac{2\pi}{T}$ )

Putting values:  $L = \frac{2}{5} \times 2 \times 10^{30} \times (7 \times 10^8)^2 \times \frac{2 \times 3.14}{1.728 \times 10^6}$

$$\therefore L = 1.42 \times 10^{42} \text{ Kg m}^2 \text{ s}^{-1}$$

(ii)  $\rightarrow \therefore K.E. = \frac{1}{2} I \omega^2 = \frac{1}{2} \times \frac{2}{5} MR^2 \times \left(\frac{2\pi}{T}\right)^2$

Putting values:  $K.E. = \frac{1}{2} \times (2 \times 10^{30}) \times (7 \times 10^8)^2 \times \left(\frac{2 \times 3.14}{1.728 \times 10^6}\right)^2$

$$\therefore K.E. = 2.59 \times 10^{36} \text{ J}$$

P.5.6 :- As given:  $m = 1000 \text{ kg}$ ,  $v = 144 \text{ km/hr}$

or  $v = \frac{144 \times 1000}{3600} = 40 \text{ m/s}$ ,  $r = 100 \text{ m}$ ,

$$F_c = ?$$

using the relation:  $F_c = \frac{mv^2}{r} = \frac{1000 \times (40)^2}{100} = 16000 \text{ N}$

$$\therefore F_c = 16000 \text{ N} = 1.6 \times 10^4 \text{ N}$$

P.5.7 :- As given:  $r = 1000 \text{ m}$ ,  $v = ?$ ,  $g = 9.8 \text{ m/s}^2$

using the relation:  $T + W = \frac{mv^2}{r}$  (at highest pt.)

$\therefore$  for a plane  $T = 0$  (no string, no tension).

$$\therefore 0 + mg = \frac{mv^2}{r} \Rightarrow r/g = \frac{r \cdot v^2}{r}$$

or  $v = \sqrt{gr} = \sqrt{9.8 \times 1000} = 98.99 = 99 \text{ m/s}$

$$\therefore v = 99 \text{ m/s}$$

P.5.8 :- As given: Radius of moon =  $r_m = 1.74 \times 10^6 \text{ m}$ ,

Distance between Earth and Moon =  $r = 3.85 \times 10^8 \text{ m}$ ,

$L_s$  = spin angular momentum,

$L_o$  = orbital " " ,  $\frac{L_s}{L_o} = ?$

$$\therefore L_s = I\omega = \frac{2}{5} m r_m^2 \omega, \quad L_o = m r^2 \omega$$

$$\Rightarrow \frac{L_s}{L_o} = \frac{\frac{2}{5} m r_m^2 \omega}{m r^2 \omega} = \frac{2}{5} \left(\frac{r_m^2}{r^2}\right) = \frac{2}{5} \times \frac{(1.74 \times 10^6)^2}{(3.85 \times 10^8)^2}$$

$$\therefore \frac{L_s}{L_o} = 8.17 \times 10^{-6}$$