Chapter 11

Terms

Be able to define or discuss the following terms and ideas, with their SI units if appropriate.

1. translational angular momentum
2. rotational angular momentum
3. right-hand rule
4. cross product
5. moment of inertia
6. angular velocity
7. angular speed
8. torque
9. line of action
10. moment arm
11. angular momentum principle
12. conservation of angular momentum
13. equilibrium (i.e. static equilibrium)
14. quantized angular momentum in the Bohr Model
15. quantum mechanical model of hydrogen and the four quantum numbers
16. s,p,d orbitals and their corresponding angular momentum
17. orbital diagram

Equations

Understand the meaning and know the SI units of all symbols in these equations; know how to perform each mathematical operation, such as trig functions; know how to solve for any unknown quantity; understand how changing one quantity affects another quantity (if all other quantities remain constant); be able to apply one or more equations to solve a problem.

- Translational angular momentum

$$\begin{aligned} \vec{L}_{trans,A} &= \vec{r}_A \times \vec{p} \\ |\vec{L}_{trans,A}| &= |\vec{r}_A||\vec{p}| \sin\theta \\ |\vec{L}_{trans,A}| &= r_\perp |\vec{p}| \end{aligned}$$

- Rotational angular momentum (about the center of mass, CM)

$$\vec{L}_{rot,CM} = I\vec{\omega}$$

- Total angular momentum of a system of bodies:

$$\vec{L}_{tot,A} = \vec{L}_{trans,A} + \vec{L}_{rot,CM} = \vec{L}_{A,1} + \vec{L}_{A,2} + \cdots$$

- Torque:

$$\begin{aligned} \vec{\tau}_A &= \vec{r}_A \times \vec{F} \\ |\vec{\tau}_A| &= |\vec{r}_A||\vec{F}| \sin\theta \\ |\vec{\tau}_A| &= r_\perp |\vec{F}| \end{aligned}$$

- Angular Momentum Principle:

$$\vec{\tau}_{net,A} = \frac{d\vec{L}}{dt}$$

- Total kinetic energy of a system of particles (non-relativistic):

$$K_{tot} = K_{trans} + K_{rot}$$

- Translational kinetic energy:

$$K_{trans} = \frac{1}{2} M v_{cm}^2$$

- Rotational kinetic energy:

$$K_{rot} = \frac{1}{2} I \omega^2$$

- Conservation of Energy for the point-particle system:

$$\Delta K_{trans} = \vec{F}_{net} \cdot \Delta \vec{r}_{cm} \quad \text{for a constant net force}$$

- Conservation of Energy for the real system:

$$\begin{aligned} \Delta E_{sys} &= W + Q \\ \Delta E_{sys} &= \vec{F}_1 \cdot \Delta \vec{r}_1 + \vec{F}_2 \cdot \Delta \vec{r}_2 + \cdots + Q \end{aligned}$$

- Moment of inertia:

$$\begin{aligned} \text{point particle:} \quad & I = mr^2 \\ \text{solid disk rotating about its center:} \quad & I = 1/2MR^2 \\ \text{hollow ring rotating about its center:} \quad & I = MR^2 \\ \text{sphere rotating about its center:} \quad & I = \frac{2}{5}MR^2 \\ \text{thin rod rotating about an axis through its center perpendicular to the rod:} \quad & I = \frac{1}{12}ML^2 \end{aligned}$$

- Bohr Model

$$L = N\hbar$$

- Quantum Mechanical Model

$$\begin{aligned} L &= \sqrt{l(l+1)}\hbar \qquad l = 0, 1, 2, \ldots (n-1) \\ L_z &= m_l\hbar \qquad m_l = -l, \ldots, l \\ S &= \sqrt{s(s+1)}\hbar \qquad s = \frac{1}{2} \text{ for an electron} \\ S_z &= m_s\hbar \qquad m_s = \pm\frac{1}{2} \text{ for an electron} \end{aligned}$$

Skills

1. Calculate the angular momentum of a particle.
2. Calculate the angular momentum of a system of particles.
3. Calculate the angular momentum of a rigid body (like a wheel or rotor).
4. Apply conservation of angular momentum to a system.
5. Calculate torque due to a force.
6. Calculate the torque on a system and apply the angular momentum principle.
7. Apply the angular momentum principle to a system in equilibrium and solve for an unknown torque and/or force.
8. Apply the energy principle to a system with translational and rotational motion.
9. Apply the right-hand rule to determine the direction of a cross product of two vectors.
10. Calculate the cross product of two vectors.
11. Determine the possible quantum numbers for an electron in a hydrogen atom if given its principal quantum number n
12. sketch the possible orbital angular momentum vectors and spin angular momentum vectors for each possible value of m_l and m_s.
13. Sketch an orbital diagram for an atom.

Lab Skills

1. Predict what force should be applied to a beam at a given location in order for the beam to be in equilibrium.