AP PHYSICS 1 BIG IDEAS – Rotational Mechanics

Torque, τ and Equilibrium - *(Twisting Force)*

Torque, τ, is defined as Force times distance perpendicular. (force times moment arm) (Units, N·m)

If force is not perpendicular to distance, multiply by the sin(θ) to find a component that is perpendicular.

Clockwise torque is negative, counterclockwise torque is positive.

When an object is in translational equilibrium, the sum of the forces equal zero.
When an object is in rotational equilibrium, the sum of the *torques* equals zero.
Equilibrium means it is not accelerating.

Rotational Inertia, I - *(Mass Concentrated Some Distance from the Pivot)*

The *further* the mass is concentrated away from the axis of rotation, the *more* rotational inertia an object has, and the *more* that object resists angular acceleration.

If mass and radius were the same, spheres have the least rotational inertia, rings have the most because their mass is concentrated for from the axis of rotation.

Just like Newton's 2nd Law, the angular acceleration, α, an object experiences is equal to the sum of the torques, $\Sigma\tau$, divided rotational inertia, I.

Angular Momentum, L - *(Rotational Inertia in Angular Motion)*

Just like momentum is mass times velocity, *angular momentum* is *rotational inertia* times *angular velocity*.

When angular momentum is conserved (no outside torque), doubling the rotational inertia would halve the angular velocity. ($I\cdot\omega = I\cdot\omega$)

Linear momentum can be transferred to angular momentum, L, if the object has some linear momentum, p, at some distance from a pivot, r. $L = p\cdot r = m\cdot v\cdot r$

Just like impulse for linear momentum, Δp, a change in angular momentum, ΔL, is equal to torque, τ, times time, Δt.

Conversions from Rotational to Translational

$s = r\cdot\theta$ $v = r\cdot\omega$ $a = r\cdot\alpha$

Rotational Kinetic Energy, K - *(Energy of Rotational Motion)*

Rotating is another form of kinetic energy. When an object rolls down a hill, its potential energy is transformed into both translational kinetic energy and rotational kinetic energy.

Simple Harmonic Motion, SHM - *(Periodic Motion, Oscillation)*

SHM is motion that follows a fixed path, returning to the same *position*, *velocity* and *acceleration* after a definite period of *time*.

Period, T, (time to make one complete cycle). $\omega = 2\pi/T$

Frequency, f, (number of complete cycles in one second, Hertz). $\omega = 2\pi f$, $\theta = 2\pi ft$.

Period is the reciprocal of frequency. $T = 1/f = 2\pi/\omega$

The position, x, velocity, v, and acceleration, a, can be can be described using the 1-dimensional components of the 2-dimensional circular motion.

Position can be found by, $x = A\cdot\cos(2\pi ft)$
Velocity can be found using Conservation of Energy, $\frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$
Acceleration can be found using Newton's 2nd Law and Hooke's Law,
$a = F/m = -kx/m$

For a mass on a spring:
maximum position, x is at the Amplitude, A, minimum position is equilibrium.
maximum velocity, v is through equilibrium, minimum velocity is at the amplitude.
maximum acceleration, a is at the amplitude, minimum acceleration is at equilibrium.

The period of a spring, T_s is only dependent on mass, m and spring constant, k.

The period of a pendulum, T_p is only dependent on length, l and gravity, g.

Period does not change with initial displacement for relatively small displacements.