Announcements

• Today: Rotation Part 1
• Next time: more rotation
• Homework #3 due on Friday
• Heads up: Exam #1 is one week from Friday, will cover Chapters 1-9, HW1-4
  – Review homework, do more problems from book for practice, look at voting questions
  – Combination of multiple choice and short problems
  – Bring Scantron 882-E and calculator

Chapter 8: Rotational Motion

Rotational Motion

In physics we distinguish two types of motion for objects:

• Translational Motion (change of location): Whole object moves through space.
• Rotational Motion - object turns around an axis (axle); axis does not move. (Wheels)

Rotational Motion

• Study rotational motion of solid object with fixed axis of rotation (axle)
• Have “angular” versions of the quantities we studied in translational motion - position, distance, velocity, acceleration
• Later look at angular versions of force, mass, momentum, and kinetic energy.
• Use Greek letters for most angular quantities

Angular Position

Definition of Angular Position, $\theta$

$\theta =$ angle measured from reference line

SI unit: radian (rad), which is dimensionless

• We will measure angular position in revolutions:
• Counterclockwise (CCW): positive rotation
• Clockwise (CW): negative rotation

Linear Distance $d$ vs. Angular distance $\Delta\theta$

For a point at radius $R$ on the wheel, $d = 2\pi R \Delta\theta$ for $\Delta\theta$ in revolutions
Ranking: Rolling Cups

- Which of the cups will roll in the straightest path?
- Which of the cups will roll in the most curved path?

Angular Velocity: $\omega$

- Avg. Angular Velocity = \# Revolutions/ (Time Taken)
  \[ \omega = \frac{\Delta\theta}{t} \]
- Unit: Revolutions/s or Revolutions/min (RPM)
- Sign convention: $\omega$ is positive for counterclockwise rotation, negative for clockwise rotation

Tangential Velocity

- Every spot on a rotating object has both angular velocity and tangential velocity.
  \[ v_t = \frac{\Delta d}{\Delta t} = 2\pi R\frac{\Delta\theta}{\Delta t} = 2\pi R\omega \]

Speed in Circular Motion

- Rotational Speed $\omega$: Rev/s per second
- Tangential speed $v_t$: distance per second
- Two objects can have the same rotational speed, but different tangential speeds!

Example: Gears

- Two wheels are connected by a chain that doesn't slip.
- Which wheel has the higher rotational speed?
- Which wheel has the higher tangential speed for a point on its rim?

Angular Acceleration

- Change in angular velocity -> angular acceleration!
- However, even if angular velocity is constant, each point also has centripetal acceleration (due to change in direction of $v_t$)
Simple vs. Complex Objects

Model motion with just Position
Model motion with position and Rotation

Rotational Inertia

- Rotational inertia depends on
  - Total mass of the object
  - Distribution of the mass relative to axis
- Farther the mass is from the axis of rotation, the larger the rotational inertia.
- Rotational inertia ~ (mass) x (axis_distance)^2

Rotational Inertia

- Depends upon the axis around which it rotates
  - Easier to rotate pencil around an axis passing through it.
  - Harder to rotate it around vertical axis passing through center.
  - Hardest to rotate it around vertical axis passing through the end.

Example: Hoop vs. Disk

- Imagine rolling a hoop and a disk of equal mass down a ramp. Which one would win?
- Which one is “easier” to rotate (i.e., has less rotational inertia)?

Torque

- Torque is the rotational analog of force.
- Depends on:
  - Magnitude of Force
  - Direction of force
  - Lever arm

- Torque = lever arm x force
- Units of N\cdot m

Examples of Lever Arm

- Lever arm is amount of perpendicular distance to where the force acts.
Example: Pedaling a Bicycle

Revisiting Newton’s Laws

1: Need a linear force to change an object’s linear motion \( \rightarrow \) Need a torque to change an object’s rotational motion
- Equilibrium:
  - Linear: \( \Sigma F = 0 \)
  - Rotational: \( \Sigma \tau = 0 \)

2: Translational acceleration \( \sim \) force, and \( \sim \) \( 1/\text{mass} \) \( \rightarrow \) Angular acceleration \( \sim \) torque, and \( \sim \) \( 1/\text{rotational inertia} \)

Example: See-Saw Balancing

Ranking

- Which meter stick requires the most torque to hold up the weight?

Main Points
- Rotational Motion
- Angular position
- Angular velocity
- Angular acceleration
- Rotational inertia
- Torque
- Balancing Torques