Bumper Cars

Question:

- You are riding on the edge of a spinning playground merry-go-round. If you pull yourself to the center of the merry-go-round, what will happen to its rotation?
- It will spin faster.
- It will spin slower.
- It will spin at the same rate.

Observations About Bumper Cars

- Moving cars tend to stay moving
- It takes time to change a car's motion
- Impacts alter velocities & ang. velocities
- Cars seem to exchange their motions
- Heavily loaded cars are hardest to redirect
- Heavily loaded cars pack the most wallop

Momentum

- Translating bumper car carries momentum
- Momentum
  - A conserved quantity (can't create or destroy)
  - A directed (vector) quantity
  - Measures difficulty reaching velocity

$$\text{Momentum} = \text{Mass} \cdot \text{Velocity}$$

Exchanging Momentum

- Impulse
  - The only way to transfer momentum
  - Impulse is a directed (vector) quantity

$$\text{Impulse} = \text{Force} \cdot \text{Time}$$

- Because of Newton's third law, if object 1 gives an impulse to object 2, then object 2 gives an equal but oppositely directed impulse to object 1.

Head-On Collisions

- Cars exchange momentum via impulse
- Total momentum remains unchanged
- The least-massive car experiences largest change in velocity

Angular Momentum

- A spinning car carries angular momentum
- Angular momentum
  - A conserved quantity (can't create or destroy)
  - A directed (vector) quantity
  - Measures difficulty reaching angular velocity

Angular momentum =
Moment of inertia · Angular velocity

Newton's Third Law of Rotational Motion

- For every torque that one object exerts on a second object, there is an equal but oppositely directed torque that the second object exerts on the first object.

Exchanging Angular Momentum

- Angular Impulse
  - The only way to transfer angular momentum
  - Angular impulse is a directed (vector) quantity

Angular impulse = Torque · Time

- Because of Newton's third law, if object 1 gives an angular impulse to object 2, then object 2 gives an equal but oppositely directed angular impulse to object 1.

Glancing Collisions

- Cars exchange angular momentum via angular impulse
- Total angular momentum about a chosen point in space remains unchanged
- The car with smallest moment of inertia about that chosen point experiences largest change in angular velocity

Changing Moment of Inertia

- Mass can't change, so the only way an object's velocity can change is if its momentum changes
- Moment of inertia can change, so an object that changes shape can change its angular velocity without changing its angular momentum

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Kinetic Energy

- A moving bumper car has kinetic energy:
  $$\text{Kinetic energy} = \tfrac{1}{2} \cdot \text{Mass} \cdot \text{Speed}^2$$
- A spinning bumper car has kinetic energy:
  $$\text{Kinetic energy} = \tfrac{1}{2} \cdot \text{Moment of inertia} \cdot \text{Angular speed}^2$$
- A typical bumper car has both
- High impact collisions release lots of energy!

Physics Concept

- Acceleration always occurs toward the direction that reduces an object's potential energy as rapidly as possible.

Summary about Bumper Cars

- During collisions, they exchange
  - momentum via impulses
  - angular momentum via angular impulses
- Collisions have less effect on
  - cars with large masses
  - cars with large moments of inertia