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?

1. It will spin faster.
2. It will spin slower.
3. It will spin at the same rate.

Observations About Bumper Cars

- Moving or spinning cars tend to keep doing so
- It takes time to change a car’s motion
- Impacts change velocities & ang. velocities
- Cars often seem to exchange their motions
- Heavily loaded cars are hardest to redirect
- Heavily loaded cars pack the most wallop

Momentum

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

Momentum = Mass \cdot Velocity

Exchanging Momentum

- Impulse
  - The only way to transfer momentum
  - Impulse = Force \cdot Time
  - Impulse is a directed (vector) quantity
- Because of Newton’s third law:
  An impulse of one object on a second is accompanied by an equal but oppositely directed impulse of the second on the first.

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

\[ \text{Angular momentum} = \text{Moment of inertia} \times \text{Angular velocity} \]

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.

Exchanging Angular Momentum

• Angular Impulse
  – The only way to transfer angular momentum
  – Angular impulse = Torque \times Time
  – Angular impulse is a directed (vector) quantity
• Because of Newton’s third law of rotation:
  An angular impulse of one object on a second is accompanied by an equal but oppositely directed angular impulse of the second on the first.

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:
  \[ \text{Kinetic energy} = \frac{1}{2} \cdot \text{Mass} \cdot \text{Speed}^2 \]
• A spinning bumper car has kinetic energy:
  \[ \text{Kinetic energy} = \frac{1}{2} \cdot \text{Moment of inertia} \cdot \text{Angular speed}^2 \]
• Overall, a bumper can can have both
• Colliding at high speeds releases lots of energy!

Physics Concept

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