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?

A. It will spin faster.
B. It will spin slower.
C. It will spin at the same rate.
D. It will stop spinning.
When bumper cars collide

Their velocities change
Their angular velocities change

Equally loaded cars often exchange their motions

A heavily loaded car experiences less change
An empty car experiences more change
The cars exchange energy and momentum

Momentum

Newton called momentum the “quantity of motion”

\[
\text{Momentum} = \text{mass} \times \text{velocity}
\]

A translating bumper car carries momentum.
Momentum is a conserved quantity.
Momentum is a directed (vector) quantity.

Newton’s second law: The rate of change of momentum of an object is equal to the net force acting on it.

\[
\text{Force} = \text{mass} \times \text{acceleration}
\]
\[
\text{Force} = \text{mass} \times \text{rate of velocity change}
\]
\[
\text{Force} = \text{rate of momentum change}
\]
Exchanging Momentum

When bumper cars collide they push on each other. These pushes cause the momentum of each car to change.

Bumper cars exchange momentum via impulses (a directed vector quantity)

\[ \text{Impulse} = \text{force} \times \text{time} \]

The impulse is the momentum change of one of the cars.

When car 1 gives an impulse to car 2, car 2 gives an equal, but oppositely directed impulse to car 1

Head-On Collisions

Cars exchange momentum via impulses
The total momentum never changes
The car with the least mass changes velocity most
Question

An empty sled is sliding on ice when Susan drops vertically from a tree above onto the sled. When she lands, the sled

A. speeds up
B. slows up
C. continues at the same speed

Question

A compact car and a large truck collide head on and stick together. Which undergoes the larger momentum change?

1. car
2. truck
3. The momentum change is the same for both vehicles.
4. Can’t tell without knowing the final velocity of combined mass.
**Question**

A person attempts to knock down a large wooden bowling pin by throwing a ball at it. The person has two balls of equal size and mass, one made of rubber and the other of putty. The rubber ball bounces back, while the ball of putty sticks to the pin. Which ball is most likely to topple the bowling pin?

1. the rubber ball  
2. the ball of putty  
3. makes no difference  
4. need more information

**Question**

You are given two carts, $A$ and $B$. They look identical, and you are told that they are made of the same material. You place $A$ at rest on an air track and give $B$ a constant velocity directed to the right so that it collides elastically with $A$. After the collision, both carts move to the right, the velocity of $B$ being smaller than what it was before the collision. What do you conclude?

1. Cart $A$ is hollow.  
2. The two carts are identical.  
3. Cart $B$ is hollow.  
4. need more information
Question

Two carts are fitted with magnets so that they push apart when placed close together. The red cart is more massive than the blue cart. The carts are tied near each other with a string and placed on a seesaw so that the seesaw balances. When the string is burned and the carts move apart,

1. the seesaw remains balanced.
2. the red end goes down.
3. the blue end goes down.

Angular Momentum

A spinning bumper car carries angular momentum

\[
\text{Angular momentum} = (\text{rotational mass}) \times (\text{angular velocity})
\]

Angular momentum is a conserved quantity
Angular momentum is a directed (vector) quantity

**Newton’s second law for rotational motion:** The net external torque acting on a system is equal to the rate of change of the angular momentum of the system.

\[
\text{Torque} = (\text{rotational mass}) \times (\text{angular acceleration})
\]
\[
\text{Torque} = (\text{rotational mass}) \times (\text{rate of angular velocity change})
\]
\[
\text{Torque} = \text{rate of angular momentum change}
\]
Exchanging Angular Momentum

Bumper cars exchange angular momentum via angular impulse

\[ \text{Angular impulse} = \text{torque} \times \text{time} \]

The angular impulse is the angular momentum change of one of the cars.

When car 1 gives an angular impulse to car 2, car 2 gives an equal but oppositely directed angular impulse to car 1.

Newton’s third law for 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.

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