# Bumper Cars

Turn off all electronic devices



## Observations about Bumper Cars

Moving cars tend to stay moving
Changing a car's motion takes time
Impacts alter velocities and angular velocities
Cars often appear to exchange their motions
The fullest cars are the hardest to redirect
The least-full cars get slammed during collisions



## 5 Questions about Bumper Cars

1. Does a moving bumper car carry a force?
2. How is momentum transferred from one bumper car to another?
3. Does a spinning bumper car carry a torque?
4. How is angular momentum transferred from one bumper car to another?
5. How does a bumper car move on an uneven floor?



## Question 1

Q: Does a moving bumper car carry a force?
A: No, the bumper car carries momentum.

Momentum is a conserved vector quantity
- cannot be created or destroyed, but it can be transferred
- has an amount <u>and a direction</u> (unlike energy)
- has no potential form and cannot be hidden (unlike energy)
- combines bumper car's inertia and velocity

momentum = mass · velocity



## Question 2

Q: How is momentum transferred from one bumper car to another?
A: The bumper cars push on one another for a period of time.

Bumper cars exchange momentum via impulses

impulse = force · time

When $car_1$ gives an impulse to $car_2$, $car_2$ gives an equal but oppositely directed impulse to $car_1$.
- Individual momenta change as the result of an impulse
- The total momentum doesn't change
- Car with least mass changes velocity most, so the littlest riders get pounded



## Question 3

Q: Does a spinning bumper car carry a torque?
A: No, the bumper car carries angular momentum

Angular momentum is a conserved vector quantity
- cannot be created or destroyed, but it can be transferred
- has an amount <u>and a direction</u> (unlike energy)
- has no potential form and cannot be hidden (unlike energy)
- combines bumper car's rotational inertia and velocity

angular momentum = rotational mass · angular velocity

## Question 4

Q: How is angular momentum transferred from one bumper car to another?

A: The bumper cars twist one another for a period of time.

Bumper cars exchange angular momentum via angular impulses

angular impulse = torque · time

When $car_1$ gives an angular impulse to $car_2$, $car_2$ gives an equal but oppositely directed angular impulse to $car_1$.

- Individual angular momenta change due to an angular impulse
- The total angular momentum doesn't change
- Car with least rotational mass changes angular velocity most.



## Rotational Mass can Change

Object's mass cannot change

- Its velocity can change only if its momentum changes
- This observation underlies Newton's first law of translational motion

Object's rotational mass cannot change <u>if it is rigid</u>

- Its angular velocity can change only if its angular momentum changes
- This observation underlies Newton's first law of rotational motion

If an object's shape can change, so can its rotational mass!

- Its angular velocity can change without its angular momentum changing
- Newton's first law of rotational motion does not apply



## Question 5

Q: How does a bumper car move on an uneven floor?

A: It accelerates in the direction that reduces its potential energy as quickly as possible

Forces and potential energies are related!

- A bumper car accelerates in the direction that reduces its total potential energy as quickly as possible
- The bumper car accelerates opposite to the <u>potential energy gradient</u>
- On an uneven floor, that is down the steepest slope



## Summary about Bumper Cars

During collisions, bumper cars exchange

- momentum via impulses
- angular momentum via angular impulses

Collisions have less effect on

- cars with large masses
- cars with large rotational masses