More examples; angular momentum

Physics 211
Syracuse University, Physics 211 Spring 2022
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April 25, 2022

Announcements

- HW9 is due next Wednesday (last recitation of the semester)
- Help hours this week:
- Tuesday, 9:45-10:45ish (between classes)
- Thursday, 9:45-10:45ish (between classes) and 1:30-3:30
- Friday, 1:00-3:00

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- See the email announcement for more on makeups etc.

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- See the email announcement for more on makeups etc.
- **Also in the email: what will be on the final**

Final exam review

I will rapidly get more free time once class is over.

I am planning on holding 3-4 all-day review sessions between the last day of class and our final.

In the past, these have been smaller affairs with attendance 10-30.

The idea of having so much time available is to spread students out, so that you can get personal help with your questions.

I am working on scheduling these and will let you know when I have rooms locked in.

Last time: combining translation and rotation

How do we analyze situations where objects both rotate and translate?

- 1. Draw force diagrams for all objects
  - Objects that rotate need extended force diagrams showing *where* forces act
- 2. Write down $\tau = I\alpha$ for all objects that might rotate
- 3. Write down $\vec{F} = m\vec{a}$ for all objects that might translate
  - Sometimes the same object will do both
- 4. Apply the "no-slip" constraint if appropriate: $a = \pm\alpha r$ (think about which r)
  - Think carefully about direction: do a and α have the same sign?
- 5. Solve the system of equations
  - Often many of the r's will cancel; sometimes they won't

An example

Which way does the spool move when I pull the ribbon to the side? What about straight up?

Another example (8:00 only)

Which will make the weight fall faster?

- A: Moving the masses inward
- B: Moving the masses outward
- C: Switching to a pulley with a larger radius
- D: Switching to a pulley with a smaller radius

How fast does the weight accelerate downward?

Another example (11:00 only)

Suppose a Ping-Pong ball is resting on a picnic table; the coefficient of static friction between them is μ_s and the Ping-Pong ball has a mass m. A gust of wind blows the ball, exerting a force F_w to one side.

How large can the wind force be for the ball to still roll without slipping?

Angular momentum

Translational motion

- Moving objects have momentum
- $\vec{p} = m\vec{v}$
- Momentum conserved if there are no external forces

Rotational motion

- Spinning objects have angular momentum L
- $L = I\omega$
- Angular momentum conserved if no external torques

$\rightarrow L = I\omega =$ constant; analogue to conservation of momentum

Conservation of angular momentum

We saw that the conservation of momentum was valuable mostly in two sorts of situations:

- Collisions: two objects strike each other
- Explosions: one object separates into two

There is a third common case for conservation of angular momentum:

- Collisions: a child runs and jumps on a merry-go-round
- Explosions: throwing a ball off-center
- A spinning object changes its moment of inertia

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- Collisions: a child runs and jumps on a merry-go-round
- Explosions: throwing a ball off-center
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This last happens because moment of inertia depends on *how the mass is distributed*, not just how much there is!

Conservation of angular momentum

These problems are approached in exactly the same way as conservation of *linear* momentum problems: write down expressions for L_i and L_f and set them equal (if there are no external torques).

$$L = I\omega$$

$$\sum L_i = \sum L_f$$

What will happen when I pull the string, collapsing the ball?

- A: The ball will rotate faster
- B: The ball will rotate slower
- C: Nothing will happen

What will happen when I pull the string, collapsing the ball?

- A: The ball will rotate faster
- B: The ball will rotate slower
- C: Nothing will happen
- The bolt connecting the ball to the ceiling will fail, and the whole thing will fall on my head

Conservation of angular momentum

If I kept the mass of the Earth the same, but enlarged it so that it had twice the diameter, how long would a day be?

(Remember, the total angular momentum, $L = I\omega$, stays the same)

A: 6 hours

B: 12 hours

C: 24 hours

D: 48 hours

E: 96 hours

What will happen the person on the platform turns the wheel over?

- A: Nothing will happen
- B: They will rotate counterclockwise
- C: They will rotate clockwise
- D: They will stop rotating

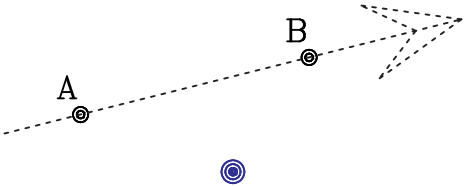
Angular momentum of a single object

A single object moving in a straight line also has angular momentum.

$$L = mv_{\perp}r = mvr_{\perp}$$

If we are to trust this relation, then the angular momentum of an object moving with constant $\vec{v}$ should be constant!

Is the angular momentum the same at points A and B?



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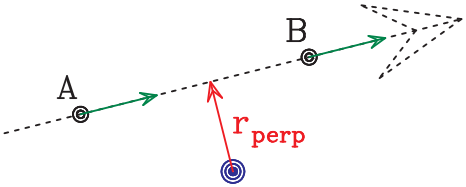
Is the angular momentum the same at points A and B?

Yes: $r_{\perp}$ (and v) are the same at both points.



Angular momentum demonstrations

What happens to the person on the platform if they catch the ball?

Angular momentum demonstrations

What happens to the person on the platform if they catch the ball?
What happens when they throw it?