PHY 211 Lecture 18

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Reminders

- Best bet for recorded lectures is the Youtube channel, working on uploading elsewhere for those in China
- Remember to submit recitation journal for participation credit: check the Blackboard recitation tab
- Homework 9 extended until end of day today
- More info on changes to the class available on the website

Momentum and energy

- Goal for today is to explore how we can use momentum and energy conservation to understand many different types of “before and after processes” like:
  - Motion with conservative forces
  - Collisions
- When we can do this, it is much simpler than trying to use forces to solve directly
- This can be very difficult at first! We will see many different things happening!

When is momentum conserved?

Pre-lecture question 1

- A ball bounces off the wall of a room. If the system we care about is the ball, is momentum conserved?

  (a) Yes (50%)

  (b) No ✓ (49%)

Bouncing ball

Question

- If the ball has a mass of 0.1 kg and both the initial and final speeds are 2 m/s, what are the initial and final momenta?

A. $p_i = 0.2\,\mathrm{kg\,m/s}$, $p_f = 0.2\,\mathrm{kg\,m/s}$
B. $p_i = -0.2\,\mathrm{kg\,m/s}$, $p_f = 0.2\,\mathrm{kg\,m/s}$
C. $p_i = 0.2\,\mathrm{kg\,m/s}$, $p_f = -0.2\,\mathrm{kg\,m/s}$
D. $p_i = -0.2\,\mathrm{kg\,m/s}$, $p_f = -0.2\,\mathrm{kg\,m/s}$

Answer

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C. $p_i = 0.2\,\mathrm{kg\,m/s}$, $p_f = -0.2\,\mathrm{kg\,m/s}$ ✓
D. $p_i = -0.2\,\mathrm{kg\,m/s}$, $p_f = -0.2\,\mathrm{kg\,m/s}$

- We say momentum is not conserved when a net external force acts on the system of interest
- Even if this force leaves the object with the same speed, if it changes direction then momentum is not conserved

Question

- In the previous setup, is the kinetic energy of the ball the same after the collision?

(a) Yes

(b) No

Answer

- In the previous setup, is the kinetic energy of the ball the same after the collision?

(a) Yes ✓ (b) No

- Kinetic energy doesn't care about direction!

Is energy conserved?

How do we know?

- Are the only forces acting conservative? Yes, energy is conserved because we account for potential energy

Throwing a rock

Say you want to throw a rock off a bridge into the water. No matter which direction you throw, it always leaves your hand with the same speed. Air resistance is negligible. Which way should you throw to make the rock have the highest speed when it hits the water?

(a) Angled up (b) Straight ahead (c) Angled down (d) It doesn't matter

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- Think about the problem using energy instead of projectile motion

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- Is there any other external force acting on the combined system?
  - If there is a net force it can add energy to or subtract it from the system if it does work: No, energy is not conserved
  - But if they do no work, *e.g.* normal force when sliding on a track: Yes, energy is conserved

Example with momentum and energy

Joe and Ed are wearing harnesses and are hanging from the ceiling by means of ropes attached to them. They are face-to-face and push off against one another. Joe has a mass of 110 kg, and Ed has a mass of 73 kg. Following the push, Joe swings upward to a height of 0.30 m above his starting point. To what height above his starting point does Ed rise?

Collision problems

Strategy

1. Identify before/after the collision
   - There may be more than one pair!

Collision problems

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   - There may be more than one pair!
2. For each pair, answer: are energy and momentum conserved?
   - FYI: you will need to answer this and give a reason on the exam

What was conserved?

While they push off

(a) Energy and momentum

(b) Momentum, but not energy

(c) Energy, but not momentum

(d) Neither energy nor momentum

What was conserved?

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What was conserved?

While they swing up

(a) Energy and momentum

(b) Momentum, but not energy

(c) Energy, but not momentum

(d) Neither energy nor momentum

What was conserved?

While they swing up

(a) Energy and momentum

(b) Momentum, but not energy

(c) Energy, but not momentum ✓

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Collision problems

Strategy

1. Identify before/after the collision
   - There may be more than one pair!
2. For each pair, answer: are energy and momentum conserved?
   - FYI: you will need to answer this and give a reason on the exam
3. Use equations to relate before and after:
   - $p_{i,x} = p_{f,x}$ and $p_{i,y} = p_{f,y}$ if momentum is conserved
   - $K_i + U_i = K_f + U_f$ if energy is conserved

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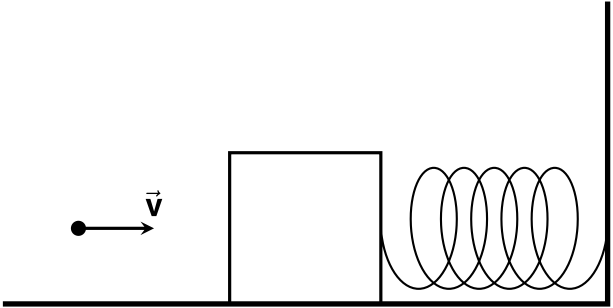
4. Sometimes you need a little bit of extra input to solve
   - This might be simply “a solution where the objects pass through each other is not physical”
   - Or maybe you need to determine the angle something bounces at which depends on the angle of the force between two objects

Example

A 2 kg wooden block is connected to a spring with spring constant 4×10^4 N/m, which is in turn connected to a rigid wall as shown. Treat the floor as frictionless. A bullet with a mass of 10 g is fired at the block, and gets buried in it. After the collision, the spring is found to get compressed by 5 cm. Determine the initial speed of the bullet.



What was conserved?

While the bullet goes into the block

(a) Energy and momentum

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(d) Neither energy nor momentum

What was conserved?

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What was conserved?

While the spring compresses

(a) Energy and momentum

(b) Momentum, but not energy

(c) Energy, but not momentum

(d) Neither energy nor momentum

What was conserved?

While the spring compresses

(a) Energy and momentum

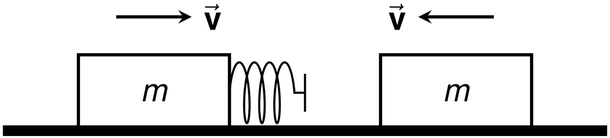
(b) Momentum, but not energy

(c) Energy, but not momentum ✓

(d) Neither energy nor momentum

Another example

Two blocks of the same mass are sliding towards each other on a frictionless surface with the same speed. One of the blocks has a spring attached that will provide all the force when the two collide. After the collision, what are the velocities of blocks 1 and 2?



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What will happen to the cars?

(a) Stick together and stop

(b) Bounce off with the same speed they started with

(c) Bounce off with a different speed than they started with

(d) One will stop and the other bounce off

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How do we know?

- Are the only forces acting conservative? Yes, energy is conserved because we account for potential energy
- Is there any other external force acting on the combined system?
  - If there is a net force it can add energy to or subtract it from the system if it does work: No, energy is not conserved
  - But if they do no work, *e.g.* normal force when sliding on a track: Yes, energy is conserved
- Are there dissipative forces like friction acting, even between objects inside the combined system? No, not conserved
  - Main things to look for are friction, objects becoming deformed, or objects sticking together

Pre-lecture question 3

- Two objects of equal mass are moving with equal and opposite velocities when they collide. Can all the kinetic energy be lost in the collision?

  (a) Yes ✓(76%) (b) No (22%)

- Think about what will happen if they stick together

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  - Main things to look for are friction, objects becoming deformed, or objects sticking together
- Words that indicate energy conservation — *elastic collisions*

Pre-lecture question 2

- If a moving object collides with a stationary object with the same mass, and the moving object comes to a stop (while the stationary object starts moving), what kind of collision is this?

(a) Totally inelastic collision (14%)

(b) Inelastic collision (16%)

(c) Elastic colision ✓(70%)

Question

- In this collision, what will happen to the initially stationary object?

  (a) Move with speed of moving object

  (b) Remain stationary

  (c) Move with some other speed

Answer

- In this collision, what will happen to the initially stationary object?

  (a) Move with speed of moving object ✓

  (b) Remain stationary

  (c) Move with some other speed
- Can't forget about momentum conservation!
- All the kinetic energy gets transferred to the stationary object
- The definition of elastic collision doesn't care which has the kinetic energy, just that the total is the same