Momentum

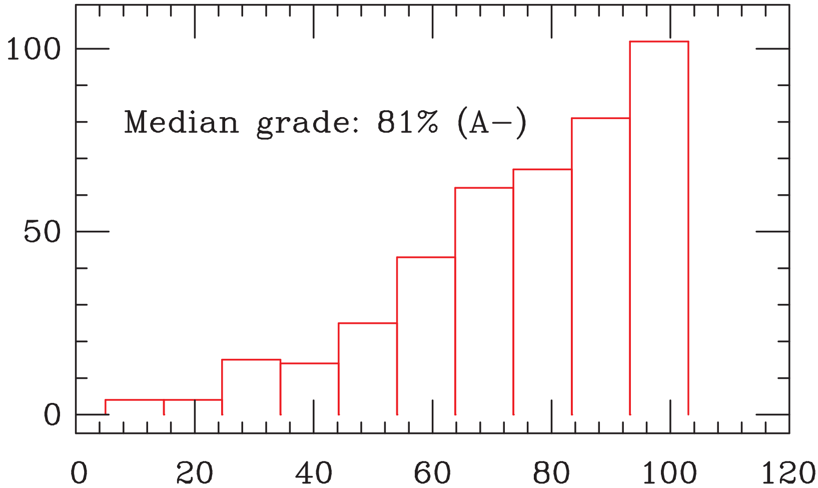
Physics 211
Syracuse University, Physics 211 Spring 2020
Walter Freeman

March 10, 2020

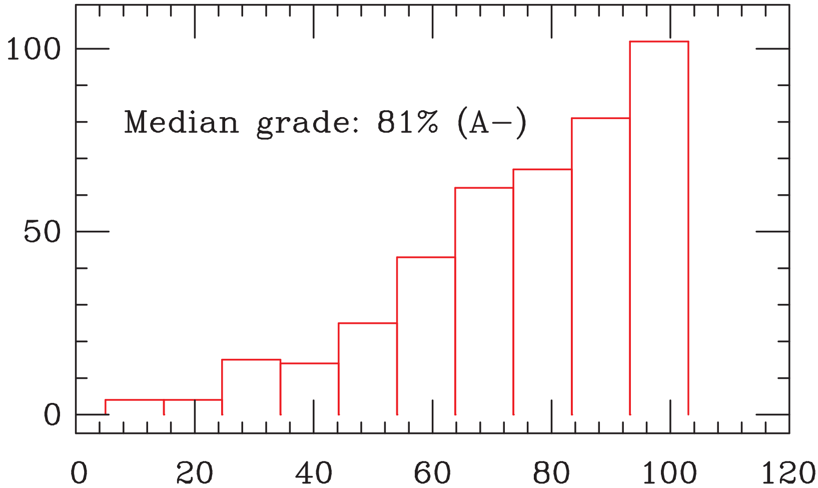
Announcements

- Homework help hours today a bit abbreviated: 1:30-3:00
- HW8 posted tomorrow, due on the Wednesday after Spring Break
- I'll also be providing homework help tomorrow: 3-5 pm
- **Anyone attending this help session with their homework partially done, but with good questions to ask, may turn their homework in on Friday with no penalty. (I'll sign your paper.)**

Exam 2 recap



Exam 2 recap



You all have done **extraordinarily** well on this exam.

This means that there were more A's and A-'s than *all other grades put together*. Congratulations!

The novel coronavirus and our class

Homework questions?

Momentum: overview

We call $m\vec{v}$ the *momentum*, just so we have a name for it, and use the letter $\vec{p}$ for it. Thus we can write, instead:

$$\sum \vec{p}_i = \sum \vec{p}_f$$

- Momentum is the time integral of force: $\vec{p} = \int \vec{F}\,dt$
- Momentum is a **vector**, transferred from one object to another when they exchange forces
- Another way to look at it: **force is the rate of change of momentum**
- Newton's 3rd law says that total momentum is constant
- Mathematically: $\vec{p} = m\vec{v}$
- Helps us understand **collisions** and **explosions**, among others

Conservation of momentum

- Newton's third law means that forces only *transfer* momentum from one object to another
- The force between A and B leaves the total momentum constant; it just gets transferred from one to the other
- The total change in momentum is zero!
- **Remember momentum is a vector!**
- Solving problems: create "before" and "after" snapshots
- Just add up the momentum before and after and set it equal!

When we need this idea: collisions and explosions

Often things collide or explode; we need to be able to understand this.

- Very complicated forces between pieces often involved: can't track them all
- These forces are huge but short-lived, delivering their impulse very quickly
- Other forces usually small enough to not matter during the collision/explosion
- Use conservation of momentum to understand the collision

The procedure is always the same:

$$\sum \vec{p}_i = \sum \vec{p}_f \text{ “Momentum before equals momentum after”}$$

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$$\sum \vec{p}_i = \sum \vec{p}_f \quad \text{“Momentum before equals momentum after”}$$

Make very sure your “before” and “after” variables mean what you think they mean!

It is always a good idea to draw clear pictures of different moments in the motion, and identify which are your “before” and “after” snapshots for using conservation of momentum.

Applying conservation of momentum to problems

- 1. Identify what process you will apply conservation of momentum to
  - Collisions
  - Explosions
  - Times when no external force intervenes
- 2. Draw clear pictures of the "before" and "after" situations
- 3. Write expressions for the total momentum before and after, in both x and y
- 4. Set them equal: Write $\sum p_i = \sum p_f$ (in both x and y if needed), and solve

A child on skis has a mass of 40 kg and is skiing North at 3 m/s. He throws a giant snowball of mass 1 kg at his friend; after he throws it, the snowball has a velocity of 10 m/s directed 45 degrees south of west.

What is the child's velocity after he throws the snowball?

Two people, Alice and Bob, are sledding on frozen Lake Onondaga, with essentially no friction. They are both moving straight east at a speed $v_{x,0}$. Alice is north of Bob, and a little ahead of him.

Each person and their sled has a mass M. Alice also carries a bowling ball of mass m.

She rolls it straight south at a speed v_b to Bob; he catches up to it and picks it up.

Sample problems: sledders with a bowling ball

Before Alice rolls the bowling ball, her velocity is $\vec{v} = (v_{x,0}, 0)$. What will happen to her velocity once she releases the ball, if it rolls directly south in the $-y$ direction?

A: Her x-velocity will increase; her y-velocity will become positive.

B: Her x-velocity will stay the same; her y-velocity will become positive.

C: Her x-velocity will decrease; her y-velocity will become positive.

D: Her x-velocity will stay the same; her y-velocity will become negative.

E: None of the above.

Sample problems: sledders with a bowling ball

Four students are arguing about what will happen when Alice rolls the ball. Who is right?

Ashley: Alice wants the ball to travel straight south, moving only in the y-direction. Pushing it directly south (in the y-direction) doesn't affect Alice's motion in the x-direction, and so her v_x doesn't change. Since she pushes it south (negative y-direction), it exerts an equal and opposite force on her in the positive $y-$direction, and so her v_y will become positive.

Bryn: But the ball is moving while Alice is holding it. Before Alice rolls it, it has a positive v_x – it's moving east with her sled. If she exerted a force on it straight south, then it would keep the same v_x as before. But she wants to roll it straight south. So she has to push *backwards* on it a little bit, in order to stop it from continuing to move forwards, in addition to pushing it south.

Charlie: Alice is rolling the ball directly south, in the negative y-direction. It doesn't carry any x-momentum with it. So this won't affect Alice's v_x; she will recoil north (giving her a positive v_y), but her v_x will stay the same, since the ball is moving straight south.

Daniel: You're forgetting that the ball has momentum in the positive x-direction before Alice rolls it. If it's going to move directly south, she has to take away its $x-$momentum. Since momentum is conserved as she rolls it, if she's taking away its $x-$momentum, the only place for that momentum to be transferred is to *her*, and so her v_x will increase.

Sample problems: sledders with a bowling ball

Before Bob catches the bowling ball, his velocity is also $\vec{v} = (v_{x,0}, 0)$. What will happen to his velocity once he picks up the ball, if it rolls directly south in the $-y$ direction?

A: His x-velocity will increase; his y-velocity will become negative.

B: His x-velocity will stay the same; his y-velocity will become negative.

C: His x-velocity will decrease; his y-velocity will become negative.

D: His x-velocity will stay the same; his y-velocity will become positive.

E: None of the above.

Sample problems: a mad scientist with a problem

A mad scientist wants to remove a boulder from a frozen lake. Because she's a mad scientist, she gets the bright idea of drilling a hole into it, sticking a piece of dynamite in there, and blowing it up.

The boulder splits into two pieces; one is three times as massive as the other. (Both have the same coefficient of kinetic friction against the ice.)

If the large one slides 10 meters before coming to a stop, how far does the small one slide?

Sample problems: a mad scientist with a problem

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Approach:

- Identify different stages in the motion:
  - The explosion itself
  - The pieces sliding on the ice

- Determine which techniques we will use to understand each:
  - The explosion $\rightarrow$ conservation of momentum (it's an explosion)
  - The sliding $\rightarrow$ $\vec{F} = m\vec{a}$ and kinematics (we want to relate the force of friction to the acceleration it causes, and acceleration to distance traveled using kinematics)
- It may seem like you don't have enough information, but you actually do!