Physics 221, January 21

Key Concepts:

• Scalar Quantities and Vector Quantities
• Position, Distance, Displacement
• Average Speed, Average Velocity
• Instantaneous Speed, Instantaneous Velocity
• Average Acceleration, Instantaneous Acceleration
Electronic Devices

Please do not use social media during class.
Vector addition

Add two vectors, \( \mathbf{A} \) and \( \mathbf{B} \).

\[ \mathbf{R} = \mathbf{A} + \mathbf{B} \]

Find the x- and y-components of each vector.

Find the components of \( \mathbf{R} \).

\[
\begin{align*}
A_x &= 12 \cos 20^\circ = 11.3 \\
A_y &= 12 \sin 20^\circ = 4.1 \\
B_x &= 25 \cos 60^\circ = 12.5 \\
B_y &= 25 \sin 60^\circ = 21.7
\end{align*}
\]

\[
\begin{align*}
R_x &= A_x + B_x = 11.3 + 12.5 = 23.8 \\
R_y &= A_y + B_y = 4.1 + 21.7 = 25.8
\end{align*}
\]

Find the magnitude and direction of \( \mathbf{R} \).

\[
\begin{align*}
R &= \sqrt{R_x^2 + R_y^2} \\
R &= \sqrt{23.8^2 + 25.8^2} = 35.05 \\
\theta &= \tan^{-1} \frac{R_y}{R_x} = \tan^{-1} 1.084 \\
\theta &= 47.3^\circ
\end{align*}
\]
What is the magnitude and direction of the vector \( \mathbf{C} = \mathbf{A} + \mathbf{B} \)?

1. 13, \( \theta = 238 \text{ deg} \)
2. 5, \( \theta = 58 \text{ deg} \)
3. 2.23, \( \theta = 297 \text{ deg} \)
4. 3.61, \( \theta = 326 \text{ deg} \)
5. 2.83, \( \theta = 34 \text{ deg} \)
Hint:

\[ A_x = 0, \quad A_y = -2 \]
\[ B_x = 3, \quad B_y = 0 \]
\[ C_x = A_x + B_x, \quad C_y = A_y + B_y \]
\[ |C| = (C_x^2 + C_y^2)^{1/2} \]
\[ \tan \theta = \frac{C_y}{C_x} \]

Solve for \( \theta \! \)

There are more than one solutions. Which one do you choose?
Vector $A$ has magnitude 30 and vector $B$ has magnitude 20. What is NOT a possible magnitude of vector $C = A + B$?

Hint:
When adding two vectors, their directions matter. Which relative orientation produces the biggest sum vector? Which produces the smallest sum vector?

1. 5
2. 10
3. 40
4. 30
5. 20
Physics: the key word is **change**!

**Matter** interacts and the **interactions** change the physical state of matter. 
The laws of physics predict when and how the physical state of matter changes.

The laws of mechanics predict **when and how things move**. 
We have to agree on a way to describe motion. 
We use **vector quantities** with magnitude and direction and **scalar quantities** with only magnitude to describe motion.

**Vector quantities:**
- **Position:** \( \mathbf{r} = ai + bj + ck \)
- **Displacement:** \( \mathbf{d} = (x_2 - x_1)i + (y_2 - y_1)j + (z_2 - z_1)k \)
- **Average velocity:** \( \mathbf{v} = \mathbf{d}/\Delta t \).
- **Instantaneous velocity:** Let \( \Delta t \to 0 \).
- **Average acceleration:** \( \mathbf{a} = \Delta \mathbf{v}/\Delta t \).
- **Instantaneous acceleration:** Let \( \Delta t \to 0 \).

**Scalar quantities:**
- distance, average speed, instantaneous speed
Distance and displacement
A person walks from A to B along a circular path of radius 10.00 m around 1/2 of the circle. What is the magnitude (in m) of the displacement vector?

- A. 0 m
- B. 62.8 m
- C. 10 m
- D. 5 m
- E. 31.4 m
- F. 20 m
Speed and velocity

Four different mice (labeled A, B, C, and D) ran the triangular maze shown below. They started in the lower left corner and followed the paths of the arrows. The times they took are shown below each figure,

(i) Which mouse had the greatest average speed?
(ii) Which mouse had the greatest average velocity?

1. (i) D, (ii) C
2. (i) B, (ii) A
3. (i) A, (ii) D
4. (i) B, (ii) C
Hint:
speed = total distance traveled/time

|velocity| = |displacement|/time

Example: Mouse C

speed = 2L/(4 s)

|velocity| = L/(4 s)

L = length of one side of the triangle
Motion in 1 dimension

If an object is restricted to move in one dimension, for example along the x-axis, we can specify the vector quantities

position, displacement, velocity, and acceleration

by a signed number with units. The sign of the number than specifies the direction.

In one dimension, if the x-component of a vector is positive, the vector is pointing in the positive x-direction, and if the x-component of a vector is negative, the vector is pointing in the negative x-direction.

We can represent one-dimensional motion using a position versus time graph or a velocity versus time graph.
Below is shown a straight track along which a toy train can move. If the train moves from point B back to point A and then to point C, what is its resulting displacement?

Hint: When finding the displacement vector, we only care about the initial and the final position. In one dimension, the sign is the direction indicator.

1. -3 ft
2. +5 ft
3. +9 ft
4. +11 ft
5. +3 ft
A man walks his dog on a very straight path in a park. He can walk back and forth as slow or fast as he wants to, but he has to stay on the path. Which of the following statements is correct for an arbitrary time interval?

1. His average speed can be greater than the magnitude of his average velocity.
2. His average speed must be equal to the magnitude of his average velocity.
3. His average speed can be less than the magnitude of his average velocity.
4. Since he is walking along a straight path, his average acceleration must be zero.
5. His average velocity must be zero.

Hint:
Is the man required to always travel in the same direction on the straight line path?
Relative velocity

The water of a river flows with a velocity of +2 m/s in the positive x-direction with respect to the shore. A boat has a velocity of +7 m/s in the positive x-direction with respect to the shore. What is the velocity of the boat with respect to the water?

1. +9 m/s
2. +7 m/s
3. +5 m/s
4. -2 m/s
5. -5 m/s

1. 0%
2. 0%
3. 0%
4. 0%
5. 0%

30
Acceleration

\[ \mathbf{a} = \frac{\Delta \mathbf{v}}{\Delta t} \]

The acceleration \( \mathbf{a} \) is a vector. It is the rate at which the velocity vector is changing. The velocity vector changes when its magnitude changes or its direction changes.

Whenever your velocity is \text{CHANGING}, you are accelerating.

You are accelerating when you \text{CHANGE} your speed, \text{CHANGE} your direction of travel, and when you change both.

The keyword is \text{CHANGE}. 
The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving towards the right. The accelerations of the blocks are related as follows:

1. The acceleration of a is greater than the acceleration of b.
2. The acceleration of a equals the acceleration of b. Both accelerations are greater than zero.
3. The acceleration of b is greater than the acceleration of a.
4. The acceleration of a equals the acceleration of b. Both accelerations are zero.
5. Not enough information is given to answer the question.
Consider motion in one dimension along the x-axis. Which statement is TRUE?

1. An object that is slowing down always has a positive acceleration, regardless of the direction it travels.
2. An object that is slowing down always has a negative acceleration, regardless of the direction it travels.
3. An object that is slowing down while traveling in the negative x-direction always has a positive acceleration.
4. An object that is speeding up while traveling in the negative x-direction always has a positive acceleration.
5. An object that is speeding up always has a positive acceleration, regardless of the direction it travels.
A “motion diagram” is shown. It is a series of snapshots of a bunny’s position taken every 1.0 seconds. What is the direction of the acceleration vector if the bunny is moving to the left?

1. In the positive x-direction
2. In the negative x-direction
3. The acceleration is zero.
4. The acceleration does not have a direction.

1. 2. 3. 4. 0% 0% 0% 0% 30
Motion Graphs for 1D motion

**Position versus time graph:**
The slope gives the instantaneous velocity.
Positive slope → positive velocity
Negative slope → negative velocity
Constant slope → constant velocity
Changing slope → acceleration
(The position versus time graph of motion with constant acceleration is a section of a parabola.)

**Velocity versus time graph:**
The slope gives the instantaneous acceleration
Positive slope → positive acceleration
Negative slope → negative acceleration
Constant slope → constant acceleration
Velocity versus time graphs are shown for 4 objects, A, B, C, and D. Which statement is true?

1. Sometime between t = 16 and 17 s the objects have the same acceleration.
2. Object A is at rest.
3. All objects are moving with constant velocity.
4. None of the above.
Which of the position versus time graphs represents motion with constant acceleration?

1. a only
2. b only
3. c only
4. All of them
5. None of them