# Physics 221, January 19

Key Concepts:

- Scalar Quantities and Vector Quantities
- Position, Distance, Displacement
- Average Speed, Average Velocity
- Instantaneous Speed, Instantaneous Velocity
- Average Acceleration, Instantaneous Acceleration

# Electronic Devices

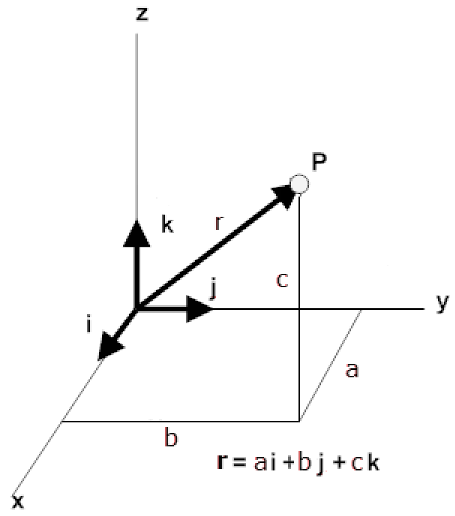
Please do not use social media during class.

# 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: $\mathbf{r} = a\mathbf{i} + b\mathbf{j} + c\mathbf{k}$
Displacement: $\mathbf{d} = (x_2 - x_1)\mathbf{i} + (y_2 - y_1)\mathbf{j} + (z_2 - z_1)\mathbf{k}$
Average velocity: $\mathbf{v} = \mathbf{d}/\Delta t$.
Instantaneous velocity: Let $\Delta t \rightarrow 0$.
Average acceleration: $\mathbf{a} = \Delta\mathbf{v}/\Delta t$.
Instantaneous acceleration: Let $\Delta t \rightarrow 0$.




Scalar quantities:
distance, average speed, instantaneous speed

Distance and displacement

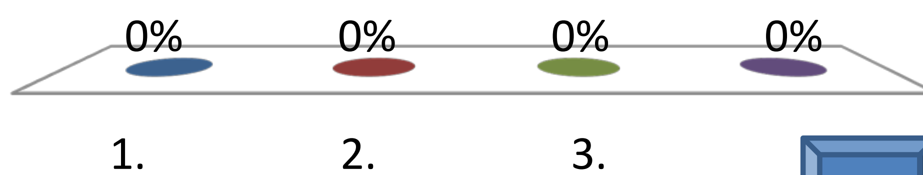
An object moves from one point in space to another. After it arrives at its destination, the magnitude of its displacement vector is

__________________________________ (insert here)

the distance it traveled.

Hint: Does the object have to move along a straight line?

1. either greater than or equal to
2. always greater than
3. either smaller than or equal to
4. always smaller than

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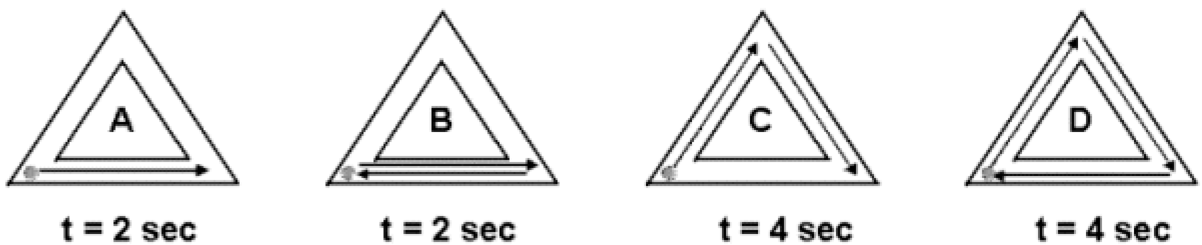
Speed and velocity

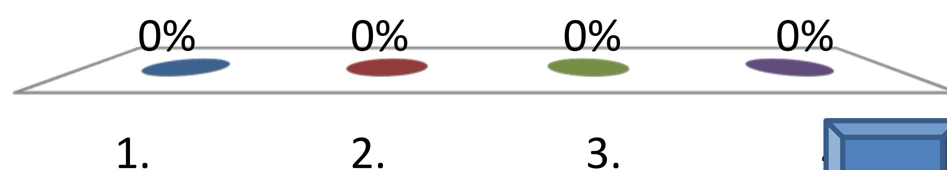
Four different mice (labeled A, B, C, and D) ran the triangular maze shown below. They started in the lower left corner and followed the paths of the arrows. The times they took are shown below each figure,

(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

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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

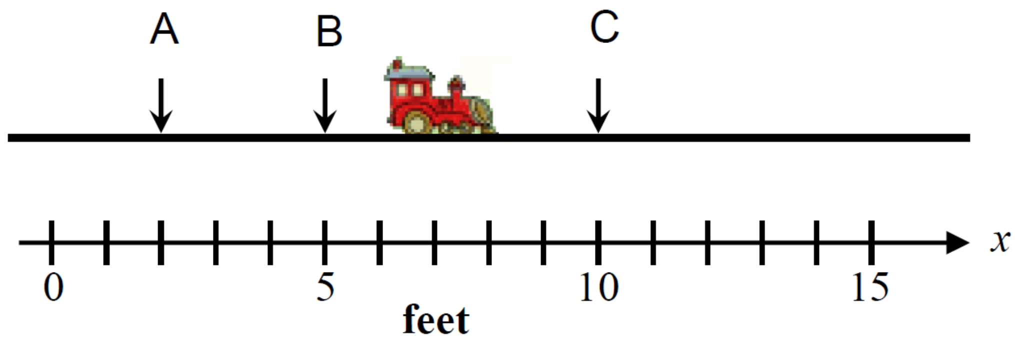
position, displacement, velocity, and acceleration

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.

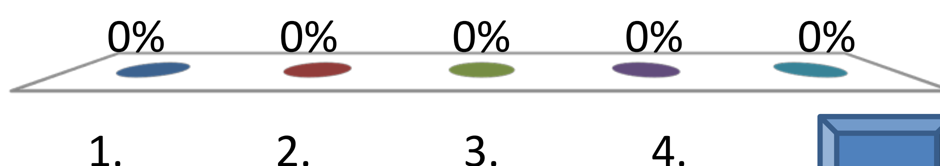
We can represent one-dimensional motion using a position versus time graph or a velocity versus time graph.

A toy train is restricted to move on a straight track. If the train moves from point B to point C and then back to point A, 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

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## Relative velocity

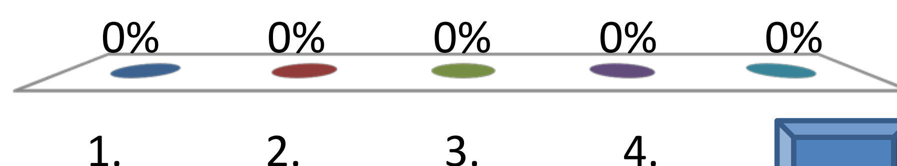
Sam and George are riding in separate cars on the freeway. The lanes they are driving in are adjacent. We choose our coordinate system so that both are traveling into the positive x-direction.

Sam travels at 65 mph and George travels at 72 mph.

(a) What is Sam's velocity relative to George?

(b) What is George's velocity relative to Sam?

1. 7 mph, -7 mph
2. -7 mph, 7 mph
3. 65 mph, 72 mph
4. 72 mph, 65 mph
5. 0 mph, 0 mph

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# Acceleration

$$\mathbf{a} = \Delta \mathbf{v} / \Delta t$$

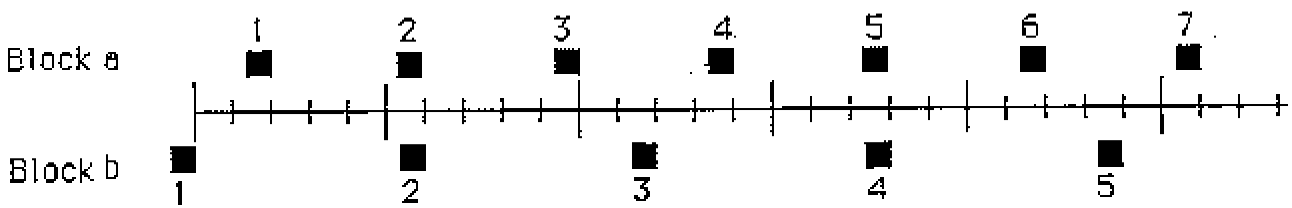
The acceleration **a** is a vector. It is the rate at which the velocity vector is changing. The velocity vector changes when its magnitude changes or its direction changes.

Whenever your velocity is CHANGING, you are accelerating.

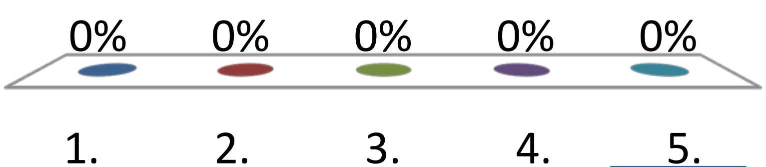
You are accelerating when you CHANGE your speed, CHANGE your direction of travel, and when you change both.

The keyword is 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.

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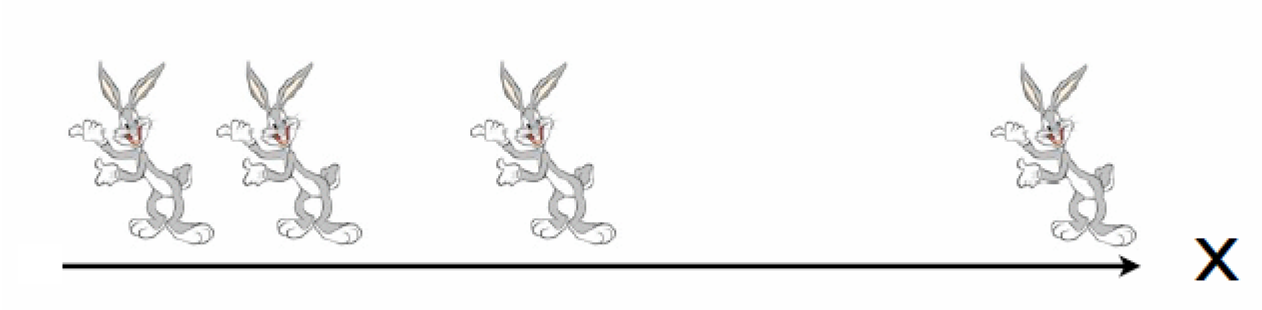
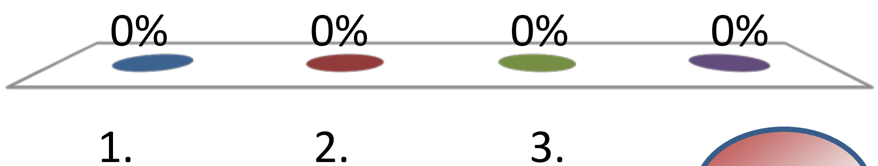
A "motion diagram" is shown. It is a series of snapshots of a bunny's position taken every 1.0 seconds. What is the direction of the acceleration vector if the bunny is moving to the left?




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.

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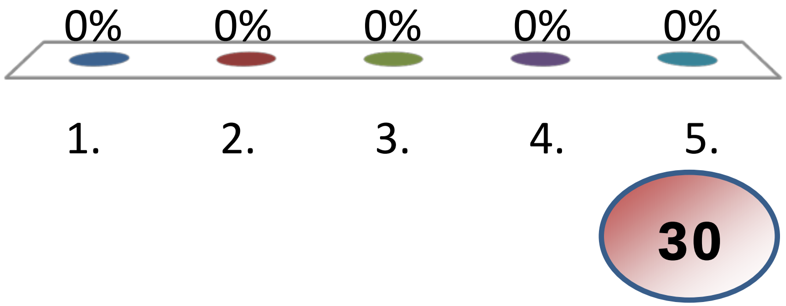
Which one of the following situations is not possible?

1. A body has zero velocity and non-zero acceleration.
2. A body travels with a northward velocity and a northward acceleration.
3. A body travels with a northward velocity and a southward acceleration.
4. A body travels with a constant velocity and a time-varying acceleration.
5. A body travels with a constant acceleration and a time-varying velocity.



# 1D Kinematic equations (constant acceleration)

Let $\Delta t = t_f - t_i$.

Then

$v_{xf} = v_{xi} + a_x \Delta t$ or $\Delta v_x = a_x \Delta t$,

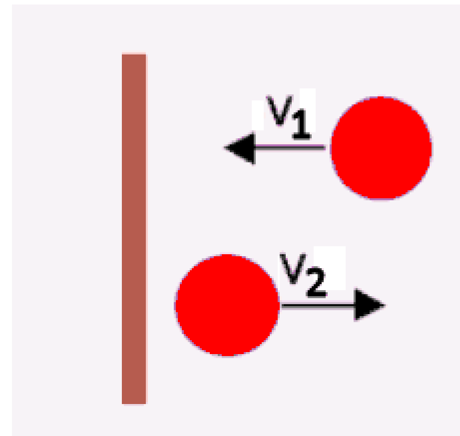
$v_{x(avg)} = (v_{xf} + v_{xi})/2$,

$x_f = x_i + v_{xi}\Delta t + ½a_x\Delta t^2$ or $\Delta x = v_{xi}\Delta t + ½a_x\Delta t^2$.

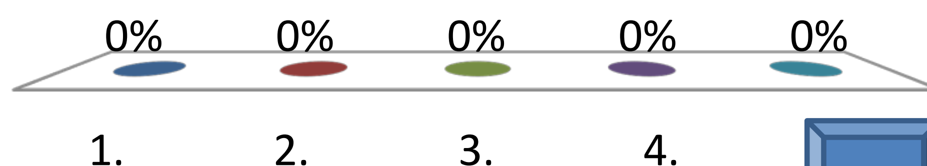
Combining these equations we get

$v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$.

A 50-g superball traveling at 25.0 m/s bounces off a brick wall and rebounds at 22.0 m/s. A high speed camera records this event. If the ball is in contact with the wall for $3.5*10^{-3}$ s, what is the magnitude of the average acceleration during this time interval?




1. 13429 $m/s^2$
2. 857 $m/s^2$
3. 47 $m/s^2$
4. 3 $m/s^2$
5. 0.01 $m/s^2$

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Hint:

$\mathbf{a} = (\mathbf{v}_f - \mathbf{v}_i)/\Delta t$

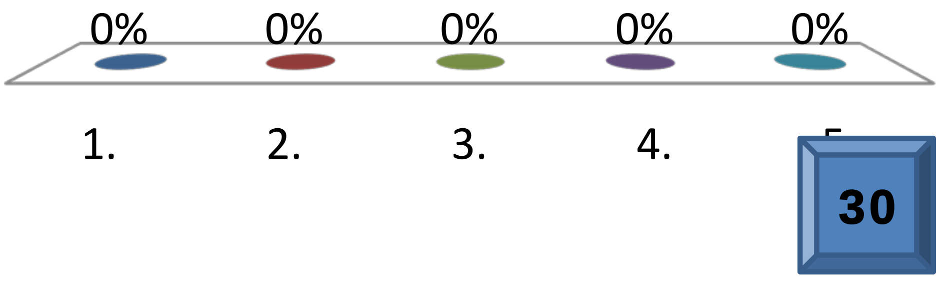
$\Delta t$ is very small (milliseconds).

$\mathbf{v}_f$ and $\mathbf{v}_i$ have opposite signs.

The magnitude of **a** is a positive number.

A particle is moving with velocity v = 60 m/s at t = 0. Between t = 0 and t = 15 s the velocity decreases uniformly to zero. What was the acceleration during this 15 s time interval?

1. 4 $m/s^2$
2. 8.6 $m/s^2$
3. 0.53 $m/s^2$
4. -0.27 $m/s^2$
5. -4 $m/s^2$



Solution:

Since the velocity decreases uniformly, the acceleration is constant. We therefore have

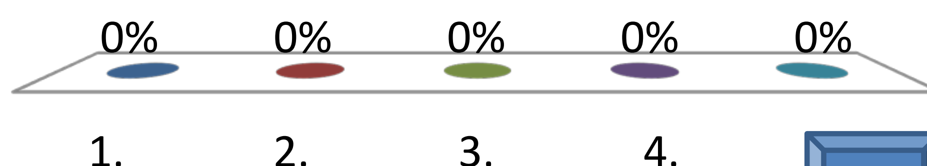
$$a = (v_f – v_i) /(t_f – t_i)$$

$$= (0 \text{ m/s} – 60 \text{ m/s})/(15 \text{ s})$$

$$= - 4 \text{m/s}^2$$

A racecar has a speed of 90 m/s when the driver releases a drag parachute. If the parachute causes a uniform deceleration of $-15 \text{ m/s}^2$, how long will it take the racecar to stop?

1. 15 s
2. 6 s
3. 4 s
4. 10 s
5. 9 s

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Solution:

Since the velocity decreases uniformly, the acceleration is constant. We therefore have

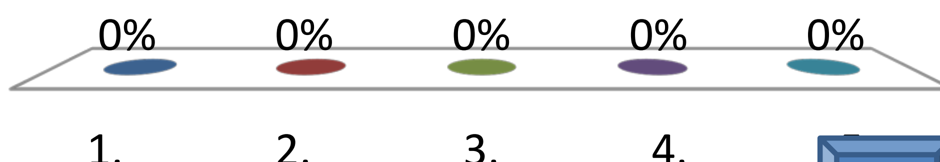
$a = -15\ m/s^2 = (v_f - v_i)/(t_f - t_i)$

$= (0\ m/s - 90\ m/s)/(\Delta t)$.

$\Delta t = (90\ m/s)/(15\ m/s^2) = 6\ s$.

A racecar has a speed of 90 m/s when the driver releases a drag parachute. If the parachute causes a uniform deceleration of –15 m/s$^2$, how far will the car travel before it stops?

1. 270 m
2. 30 m
3. 9 m
4. 600 m
5. 810 m

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Solution:

Since the velocity decreases uniformly, the acceleration is constant. We therefore have $a = -15\ m/s^2$.

$v_f^2 = v_i^2 + 2a(x_f - x_i)$.

$0 = (90\ m/s)^2 - (30\ m/s^2)\ \Delta x$.

$\Delta x = (8100/30)\ m = 270\ m$.

A friend is casually talking with you about physics concepts and brings up the following claim.

“They say that average speed for a trip is total distance divided by total time, which is true. Then they say that if the trip consists of a person traveling at two different speeds for two different times then you can get the average speed by just finding the average speeds for the two parts of the trip and then take their average.”

Is their claim true or false?

1. True
2. False


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