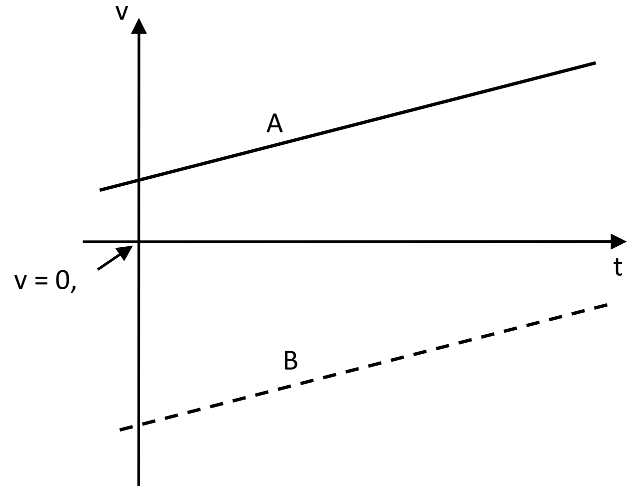
Question 1

Two cars, labeled A and B, are traveling along a long straight road. The road runs east and west. East is chosen as the positive direction; West is the negative direction. The graphs of velocity vs. time for the two cars are shown in the graph. Consider the following statements: During the time period shown in the graph…



I. one car is always moving East and the other car is always moving West.
II. the distance between the cars changes as they move.
III. one car is slowing down and the other car is speeding up.

How many of the above statements **must** be true, given the information in the graph?

A) exactly one statement is true B) exactly 2 statements are true

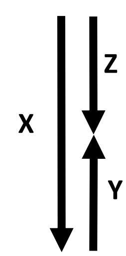
C) all 3 statements are true D) None are true

A is moving forward (East) and speeding up. B is moving west and slowing down. The distance between them is increasing, as the change is the area between the two plots.

Question 2

Three vectors, $\vec{X}$, $\vec{Y}$, and $\vec{Z}$ are shown.

Which one of the following vector equations correctly describes this diagram?



A) $\vec{\mathbf{X}}+\vec{\mathbf{Y}}+\vec{\mathbf{Z}}=\mathbf{0}$

B) $\vec{\mathbf{X}}=\vec{\mathbf{Y}}+\vec{\mathbf{Z}}$

C) $\vec{\mathbf{X}}+\vec{\mathbf{Y}}=\vec{\mathbf{Z}}$

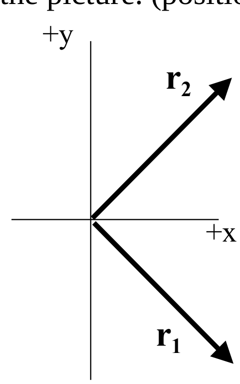
D) $\vec{\mathbf{X}}+\vec{\mathbf{Z}}=\vec{\mathbf{Y}}$

E) None of the above equations are correct.

Think of giving directions (first walk X then Y, you will end up with displacement Z)

Question 3

A particle moves with constant velocity. Its position vectors at two different times are shown in the picture. (position r_1 occurs earlier than r_2) What is the direction of the velocity of the particle?

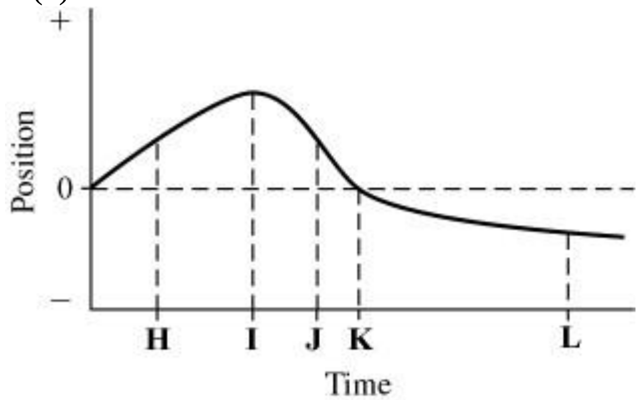


A. To the right (+x direction)
B. To the left (-x direction)
C. Straight up (+y direction)
D. Straight down (-y direction)
E. None of the above

The velocity goes like the displacement, which is final – initial position ($r_2 - r_1$).

Question 4

The graph in the figure shows the position of an object as a function of time. The letters H-L represent particular moments of time. At which moments shown (H, I, etc.) is the speed of the object (a) the greatest and (b) the smallest?



A. (a) I and (b) L
B. (a) I and (b) K
C. (a) H and (b) I
D. (a) H and (b) L
E. None of the above

The speed is the magnitude of the derivative (slope) of the position plot. This plot is steepest at J and shallowest at I.

Question 5

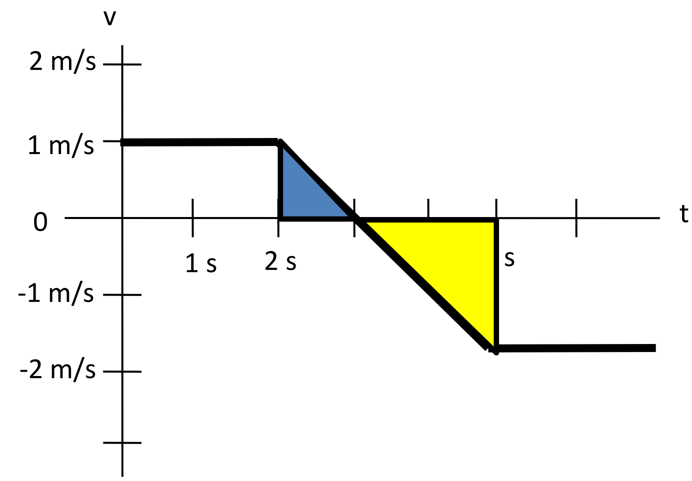
A newspaper deliverer throws rolled-up papers out of his car window just as he drives by his customers' driveways. To save time, he throws newspapers out of the driver's side window as he drives forward, then he drives in reverse and throws newspapers out of the passenger's side window. To have the newspapers land on customers' driveways just as he drives by, he must

A. throw the newspapers perpendicular to the car's motion
B. throw the newspapers partly perpendicular and partly parallel to the car's motion
C. throw the newspapers partly perpendicular and partly anti-parallel to the car's motion
D. throw the newspapers parallel to the car's motion
E. throw the newspapers anti-parallel to the car's motion
F. a combination of B and C (one for driving forward, the other for driving in reverse)
G. a combination of D and E (one for driving forward, the other for driving in reverse)

Perpendicular to get them out of the car and over to the driveway. Anti-parallel to cancel out the velocity of the car moving (whether going forward or backward)

Question 6

An object moves along the x-axis with the velocity shown in the graph. What is the **magnitude** of the displacement of the object $|x - x_0|$ between t = 2 s (when its velocity is v = 1 m/s) and t = 5 s (when it's velocity is v = –2 m/s)?



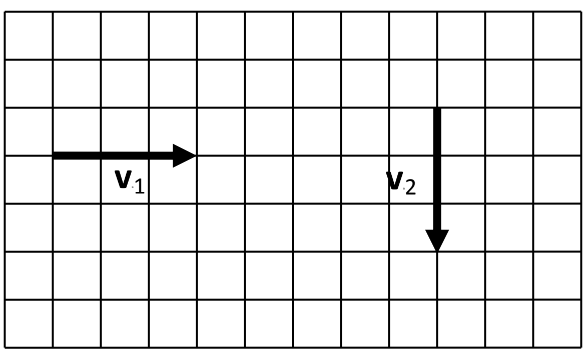
A) 1.0 m   B) 1.5 m   C) 3.0 m

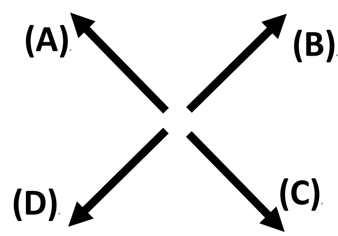
D) 3.5 m   E) None of these

We calculate the area under the plot between those times (the triangles). The colors are different because we subtract the "negative (yellow) area."
$\Delta x = \frac{1}{2}\left(1\frac{m}{s}\right)(1s) - \frac{1}{2}\left(2\frac{m}{s}\right)(2s) = -1.5\text{ m}$. But we want the magnitude of this displacement

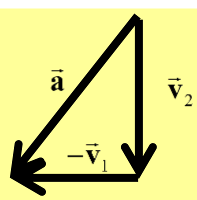
Question 7

The velocity of an object undergoing a constant acceleration is shown at two different times. The velocity at the early time is $\mathbf{v}_1$, the velocity at the later time is $\mathbf{v}_2$. What is the direction of the acceleration?





(E) None of these. Acceleration points some other direction or is zero.

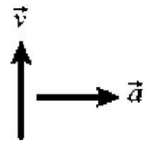


The (constant) acceleration points in the direction of the difference of the velocities (final minus initial). It points down and to the left, so **(D)**

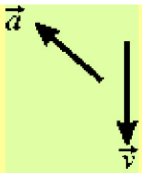
Question 8

Shown below are the velocity and acceleration vectors for a person in several different types of motion. In which case is the person slowing down and turning to his right?

A)



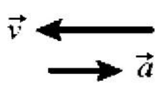
B)

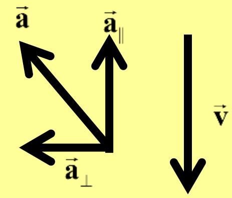


C)

D)

E)





The (anti-)parallel component of the acceleration slows it.
The perpendicular component makes it turn (in this case to the right of how it was going)

Question 9

The Mars rover races across a flat plain, with a position vector given by

$\vec{\mathbf{r}} = (-1\tfrac{\text{m}}{\text{s}^2}t^2 + 3\tfrac{\text{m}}{\text{s}}t + 1\text{m})\hat{\mathbf{i}} + 4\text{m}\hat{\mathbf{j}}$

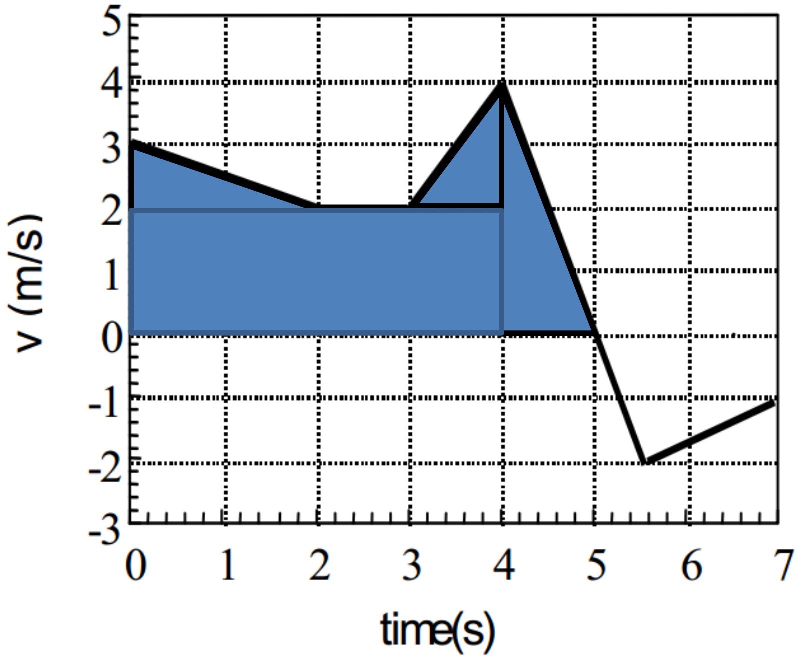
What is the *velocity* of the rover at t = 2 seconds?

A. (-1 $\hat{\mathbf{i}}$ + 0 $\hat{\mathbf{j}}$) m/s
B. (-2 $\hat{\mathbf{i}}$ + 0 $\hat{\mathbf{j}}$) m/s
C. (-2 $\hat{\mathbf{i}}$ + 4 $\hat{\mathbf{j}}$) m/s
D. (3 $\hat{\mathbf{i}}$ + 4 $\hat{\mathbf{j}}$) m/s
E. None of these is correct

$$\vec{\mathbf{r}} = (-1\tfrac{\text{m}}{\text{s}^2}t^2 + 3\tfrac{\text{m}}{\text{s}}t + 1\,\text{m})\hat{\mathbf{i}} + 4\,\text{m}\hat{\mathbf{j}}$$
$$\vec{\mathbf{v}} = \dot{\vec{\mathbf{r}}} = (-2\tfrac{\text{m}}{\text{s}^2}t + 3\tfrac{\text{m}}{\text{s}})\hat{\mathbf{i}}$$
$$\vec{\mathbf{v}}(t) = -1\tfrac{\text{m}}{\text{s}}\hat{\mathbf{i}}$$

Question 10

The figure shows the velocity as a function of time for a particle. What is the particle's position at time t = 5s if it starts at x = 5 m at t = 0s?



A. 7.5 m
B. 8.75 m
C. 9.25 m
D. 12 m
E. 14.25 m
F. 17 m
G. None of the above

Kinematics: Displacement is the area under the velocity graph which is the area of a rectangle and three triangles shaded above which is:

$$\Delta x = \left(2\tfrac{\text{m}}{\text{s}}\right)(4\text{s}) + \tfrac{1}{2}\left(1\tfrac{\text{m}}{\text{s}}\right)(2\text{s}) + \tfrac{1}{2}\left(2\tfrac{\text{m}}{\text{s}}\right)(1\text{s}) + \tfrac{1}{2}\left(4\tfrac{\text{m}}{\text{s}}\right)(1\text{s}) = 12 \text{ m}$$

Since we started at x = 5 m at t = 0 this displacement brings us to x = 17 m

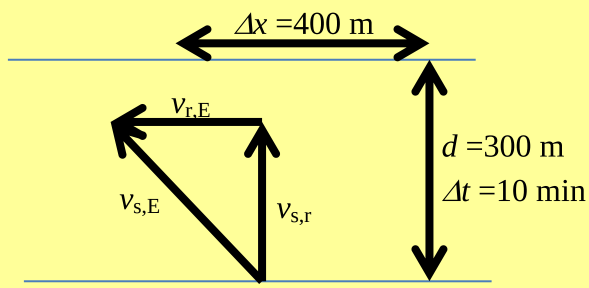
The following two problems both deal with the same setup
A swimmer swims as fast as she can, heading directly across a river 300 m wide. She reaches the opposite bank in 10 min, during which time she is swept downstream 400 m.

Question 11
How fast can she swim in still water?

A. (1/2) m/s
B. (2/3) m/s
C. (5/6) m/s
D. 5 m/s
E. 30 m/s
F. None of the above

Question 12
What is the speed of the current?

A. (2/3) m/s
B. (4/9) m/s
C. (5/6) m/s
D. (8/9) m/s
E. (20/3) m/s
F. 40 m/s
G. None of the above



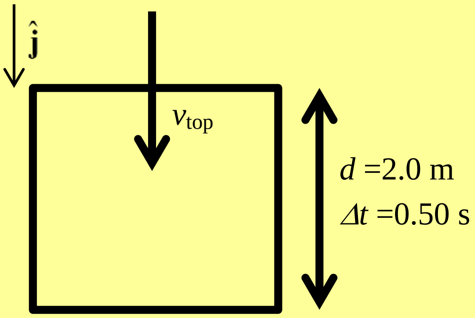
$$d = v_{s,r}\Delta t$$
$$\Rightarrow v_{s,r} = d/\Delta t = 300\,\text{m}/10\text{ min}$$
$$= 30\tfrac{\text{m}}{\text{min}}\cdot\tfrac{1\text{min}}{60\text{ s}} = \tfrac{1}{2}\tfrac{\text{m}}{\text{s}}$$

$$\Delta x = v_{r,E}\Delta t$$
$$\Rightarrow v_{r,E} = \Delta x/\Delta t = 400\,\text{m}/600\text{ s} = \tfrac{2}{3}\tfrac{\text{m}}{\text{s}}$$

Question 13

A procrastinating student staring out her window observes a falling nut passing from its top to bottom. The window is 2.0 m tall and it takes 0.50 s for the walnut to pass the window. What is the approximate ***speed*** of the walnut when it is first seen passing the top of the window?

A. 1.0 m/s
B. 1.5 m/s
C. 2.0 m/s
D. 4.0 m/s
E. 6.5 m/s
F. 9.0 m/s
G. None of the above



Constant Acceleration

$$d = v_{top}\Delta t + \tfrac{1}{2}a\Delta t^2$$

$$\Rightarrow v_{top} = \frac{1}{\Delta t}\left(d - \tfrac{1}{2}a\Delta t^2\right)$$

$$= \frac{1}{\tfrac{1}{2}\,\mathrm{s}}\left(2\ \mathrm{m} - \tfrac{1}{2}\left(10\tfrac{\mathrm{m}}{\mathrm{s}^2}\right)\left(\tfrac{1}{2}\,\mathrm{s}\right)^2\right)$$

$$= 2\tfrac{\mathrm{m}}{\mathrm{s}}\left(2 - \tfrac{5}{4}\right) = \boxed{\tfrac{3}{2}\tfrac{\mathrm{m}}{\mathrm{s}} = v_{top}}$$

The following two problems both deal with the same setup

A tennis ball is travelling to the right (parallel to the ground) with velocity $\vec{\mathbf{v}} = 6\tfrac{\mathrm{m}}{\mathrm{s}}\hat{\mathbf{i}}$ at the instant it crashes into brick wall.

Question 14

What is the direction of acceleration of the ball as it runs into the wall then bounces back?

A. Always to the right
B. Always to the left
C. To the right, zero, then to the left
D. To the left, zero, then to the right
E. None of the above

The acceleration is always to the left (the wall is always pushing it back to the left while they are in contact)

Question 15

Just before hitting the wall, Sam gets her racket on the ball, giving it an acceleration of $\vec{\mathbf{a}} = \left(3\tfrac{\mathrm{m}}{\mathrm{s}^4}t^2 - 10\tfrac{\mathrm{m}}{\mathrm{s}^3}t\right)\hat{\mathbf{i}} + 4\tfrac{\mathrm{m}}{\mathrm{s}^2}\hat{\mathbf{j}}$ for the two seconds (from t = 0 s to 2 s) the racket and ball are in contact. Roughly how fast is the ball travelling when it leaves the racket?

A. 2 m/s
B. 5 m/s
C. 8 m/s
D. 10 m/s
E. 14 m/s
F. 20 m/s

$$\Delta\vec{\mathbf{v}} = \int_0^{2\mathrm{s}} \vec{\mathbf{a}}\cdot dt = \left(1\tfrac{\mathrm{m}}{\mathrm{s}^4}t^3 - 5\tfrac{\mathrm{m}}{\mathrm{s}^3}t^2\right)\hat{\mathbf{i}} + 4\tfrac{\mathrm{m}}{\mathrm{s}^2}t\hat{\mathbf{j}}\Big|_0^{2\mathrm{s}} = -12\tfrac{\mathrm{m}}{\mathrm{s}}\hat{\mathbf{i}} + 8\tfrac{\mathrm{m}}{\mathrm{s}}\hat{\mathbf{j}} \Rightarrow \vec{\mathbf{v}}_f = \vec{\mathbf{v}} + \Delta\vec{\mathbf{v}} = -6\tfrac{\mathrm{m}}{\mathrm{s}}\hat{\mathbf{i}} + 8\tfrac{\mathrm{m}}{\mathrm{s}}\hat{\mathbf{j}}$$

Our speed is just the magnitude of this $v = \sqrt{\left(-6\tfrac{\mathrm{m}}{\mathrm{s}}\right)^2 + \left(8\tfrac{\mathrm{m}}{\mathrm{s}}\right)^2} = 10\tfrac{\mathrm{m}}{\mathrm{s}}$ (345 triangle*2)