Question 1
A bicyclist is traveling east. Can his acceleration vector ever point west?

A. No, he must first have some velocity to the west.
B. Yes, but he has to stop and turn around first.
C. Yes, if he decreases his speed.
D. Yes, if he increases his speed.
E. No, his acceleration vector can only point to the east.

The following two problems both deal with the same setup
A particle moves in one dimension with position given by $6\text{m} + 4\text{ms}^{-1} \cdot t \; - \; 2\text{ms}^{-2} \cdot t^2$.

Question 2
What is its acceleration at t = 0 s?

A. 0 m/s^2
B. 6 m/s^2
C. -6 m/s^2
D. 4 m/s^2
E. -4 m/s^2
F. 2 m/s^2
G. -2 m/s^2

$$x = 6\text{m} + 4\text{ms}^{-1} \cdot t \; - \; 2\text{ms}^{-2} \cdot t^2$$
$$v_x = \dot{x} = 4\tfrac{\text{m}}{\text{s}} - 4\tfrac{\text{m}}{\text{s}^2} t$$
$$a_x = \dot{v}_x = -4\tfrac{\text{m}}{\text{s}^2}$$

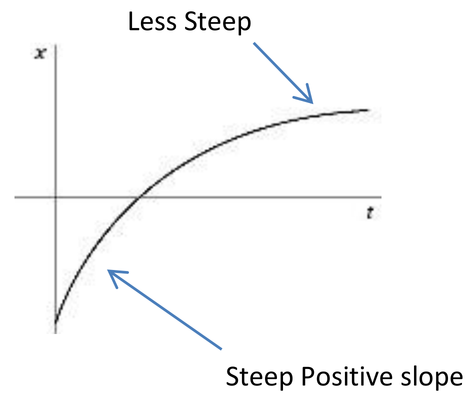
Question 3
At what time does it momentarily come to rest?

A. t = -2 s
B. t = -1 s
C. t = 0 s
D. t = 1 s
E. t = 2 s

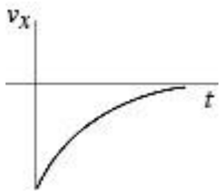
“Come to rest” means v = 0:
$$v_x = \dot{x} = 4\tfrac{\text{m}}{\text{s}} - 4\tfrac{\text{m}}{\text{s}^2} t = 0 \Rightarrow t = 1\,\text{s}$$

Question 4

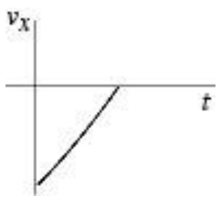
The figure at right shows the graph of position *x* as a function of time for an object moving in a straight line (along the *x*-axis). Which of the following graphs best describes the velocity along the *x*-axis as a function of time for this object?



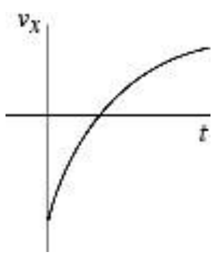
A)



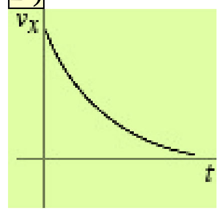
B)



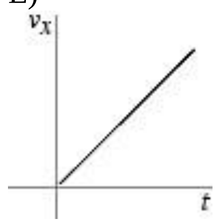
C)



D)



E)



Question 5

Two identical objects *A* and *B* fall from rest from different heights to the ground and feel no appreciable air resistance. If object *B* takes TWICE as long as object *A* to reach the ground, what is the ratio of the heights from which *A* and *B* fell?

A) $h_A/h_B = 1/\sqrt{2}$

B) $h_A/h_B = 1/2$

C) $h_A/h_B = 1/4$

D) $h_A/h_B = 1/8$

E) None of the above

For constant acceleration, starting from rest, displacements go like t^2. So if B is in the air twice as long it must fall 4 times as far.

Question 6

If $\vec{A} = 4\text{m}\hat{i} - 2\text{m}\hat{j} - 3\text{m}\hat{k}$ and $\vec{C} = -4\text{m}\hat{i} - 2\text{m}\hat{j} - 3\text{m}\hat{k}$, which of the following is closest to the magnitude of $\vec{A} - \vec{C}$?

A) 8 m
B) 7 m
C) 9 m
D) 10 m
E) 11 m

$$\vec{A} - \vec{C} = \left(4\text{m}\hat{i} - 2\text{m}\hat{j} - 3\text{m}\hat{k}\right) - \left(-4\text{m}\hat{i} - 2\text{m}\hat{j} - 3\text{m}\hat{k}\right)$$
$$= 8\text{m}\hat{i}$$

Question 7

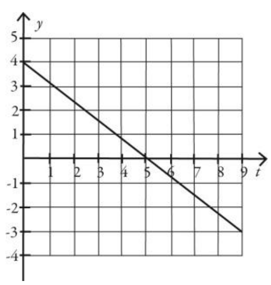
For general projectile motion, when the projectile is at the highest point of its trajectory
A) its acceleration is zero.
B) its velocity is perpendicular to the acceleration.
C) its velocity and acceleration are both zero.
D) only the horizontal component of its velocity is zero.
E) both the horizontal and vertical components of its velocity are zero.

At the highest point the vertical velocity is zero, so if it has any velocity it will be horizontal. The only acceleration is due to gravity, and hence vertical, so they are perpendicular.

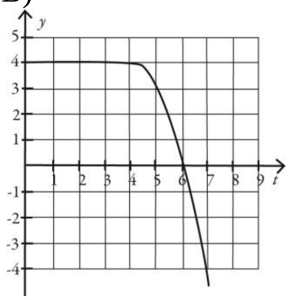
Question 8

Which one of the following graphs could possibly represent the vertical position as a function of time for an object in free fall?

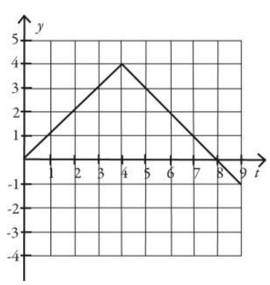
A)



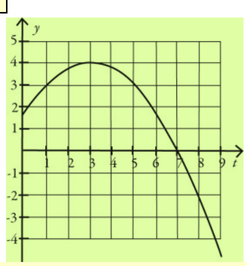
B)



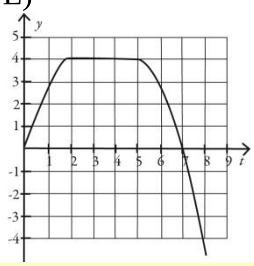
C)



D)



E)



F) More than one are OK

Free fall means constant acceleration, means linearly changing velocity (ala graph A) means parabolic position. The only plot which satisfies this is D.

Question 9

A vector $\vec{\mathbf{r}}$ has magnitude 25 m and points 30 degrees North of East. The vector $3\vec{\mathbf{r}}$

A. has magnitude 25 m and points 60 degrees South of East.

B. has magnitude 75 m and points 30 degrees North of East.

C. has magnitude 75 m and points 30 degrees North of West.

D. has magnitude 75 m and points 30 degrees South of West.

E. has magnitude 75 m and points 60 degrees South of West.

Changing the magnitude doesn't change the angle.

Question 10

You are flying from State College to Chicago via Detroit, going approximately due west the whole time. From State College to Detroit, your aircraft flies the 400 km distance at 300 km/h. You have a one hour layover in Detroit, then fly the remaining 350 km to Chicago at 350 km/h. If there is no wind, what is your average speed for the entire trip?

A. 225 km/h

B. 250 km/h

C. 323 km/h

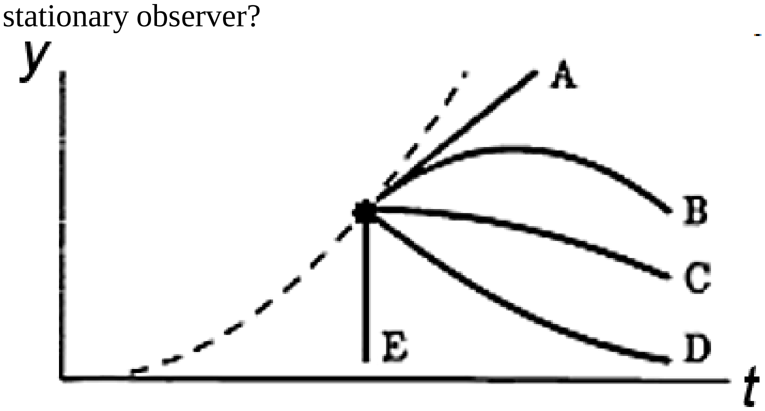
D. 325 km/h

E. None of the above

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{400\text{km}+350\text{km}}{400\text{km}/300\,\frac{\text{km}}{\text{hr}} + 1\text{hr} + 350\text{km}/350\,\frac{\text{km}}{\text{hr}}} = \frac{750\text{km}}{3\frac{1}{3}\,\text{hr}} = \frac{750\text{km}}{\frac{10}{3}\,\text{hr}} = 225\,\frac{\text{km}}{\text{hr}}$$

Question 11

A glass elevator is moving upwards with a constant acceleration. The dashed curve in the figure shows the position *y* of the ceiling of the elevator as a function of time *t*. At the instant indicated by the dot, a bolt breaks loose inside the elevator and drops from the ceiling. Which curve best represents the position of the bolt as a function of time as viewed by an external, stationary observer?

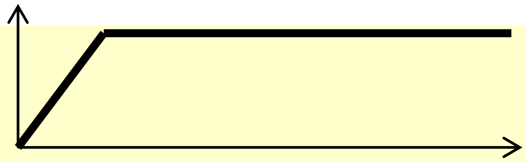


The bolt, when it breaks, starts with an initial velocity equal to the elevator's velocity. It enters free fall, meaning that it undergoes constant acceleration downward. This is figure **B**.

Question 12

A sprinter runs the 100 m dash. Assuming he accelerates from rest at 10 m/s^2 during the first second and runs at constant speed afterwards, how long does it take him to reach the finish line?

A. 9.0 s
B. 9.5 s
C. 10.0 s
D. 10.5 s
E. None of the above



Accelerate at 10 m/s^2 for 1 second

v_{max} = (10 m/s^2)(1 s) = 10 m/s in 5 m

Constant speed until d = 100 m

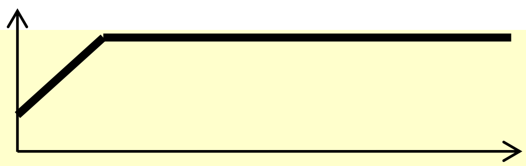
Δt = 95 m/10 m/s = 9.5 s

Total time = 9.5 s + 1 s = 10.5 s

Question 13

A shark swims in a straight line at 3.0 m/s. At t = 0 s, it accelerates at 4.0 m/s^2 until t = 2.0 s and then continues to swim at constant speed. At what time does it reach 47 m away from its position at t = 0 s?

A. 3.0 s
B. 4.3 s
C. 5.0 s
D. 5.7 s
E. 16 s



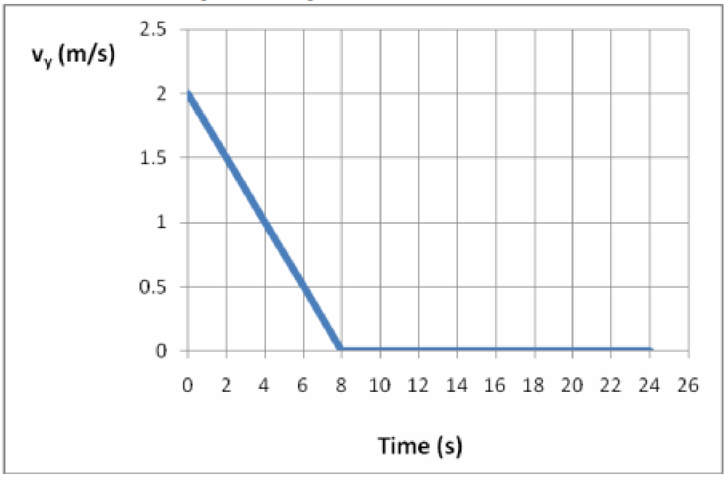
Constant acceleration section:

$$\Delta x = v_0 \Delta t + \tfrac{1}{2} a \Delta t^2 = \left(3\tfrac{\text{m}}{\text{s}}\right)(2\text{s}) + \tfrac{1}{2}\left(4\tfrac{\text{m}}{\text{s}^2}\right)(2\text{s})^2 = 14\text{m}$$

To go the next 33 m at 11 m/s takes 3 s

Total time = 2 s + 3 s = 5 s

Question 14
The plot below shows the vertical component of velocity versus time for an object, with the usual convention that the positive direction is upward and that g = 9.8 m/s^2. Which physical situation could correspond to this plot?



A. A lump of putty falls to the floor and sticks to it.
B. A ball, thrown vertically upward, is caught and held by your friend at a 3rd floor window
C. A ball rolls down a sloped street and reaches a level part of the road.
D. An object is sent sliding up a ramp, and it comes to rest (and is caught) at the top
E. An elevator traveling downward comes to a halt

Note that the magnitude of acceleration (2 m/s)/(8 s) = ¼ m/s^2, is much lower than gravity, so this can't be a free fall situation (like B). But the object has upward yet slowing velocity, so it can't be A, C, E.

Question 15
A car travels North on an interstate highway at 15 m/s. It enters an interchange to a different highway, emerging in an Easterly direction at 20 m/s. If the time spent in the interchange is 5 s, what is the magnitude of the average acceleration that the car underwent?
A. 1.0 m/s^2
B. 4.0 m/s^2
C. 5.0 m/s^2
D. 25 m/s^2
E. Impossible to calculate since we don't know the shape of the interchange

$$\vec{\mathbf{a}}_{avg} = \frac{20\,\frac{m}{s}\,\hat{\mathbf{i}} - 15\,\frac{m}{s}\,\hat{\mathbf{j}}}{5\text{ s}} = (4,-3)\,\frac{m}{s}$$

$$\left|\vec{\mathbf{a}}_{avg}\right| = 5\,\frac{m}{s}$$