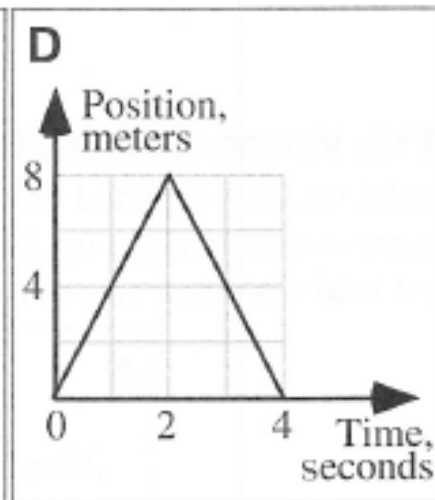
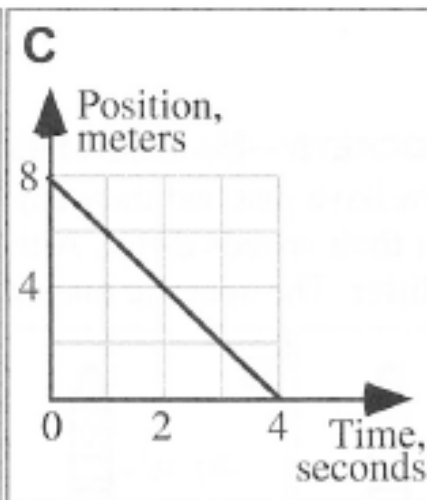
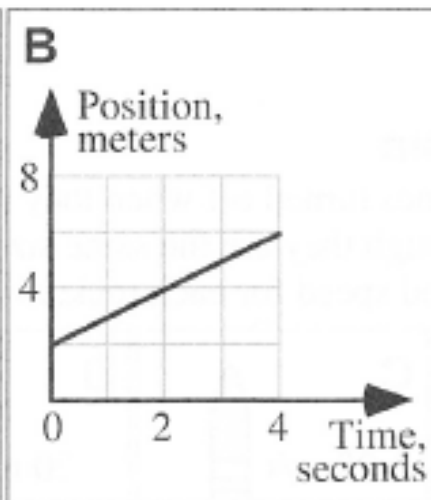
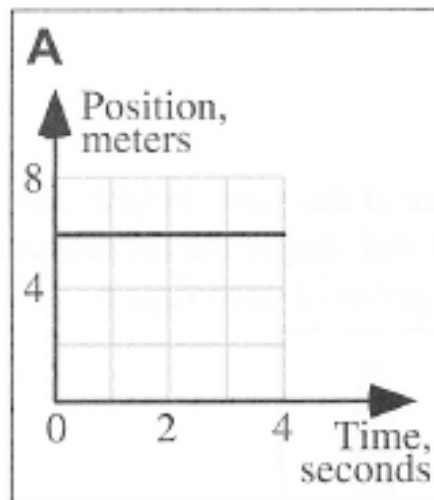


**B1-RT13: POSITION-TIME GRAPHS—DISPLACEMENT**

Each graph below shows the position of an object as a function of time.



Rank the magnitude of the displacement during the time interval from 0 to 4 seconds.

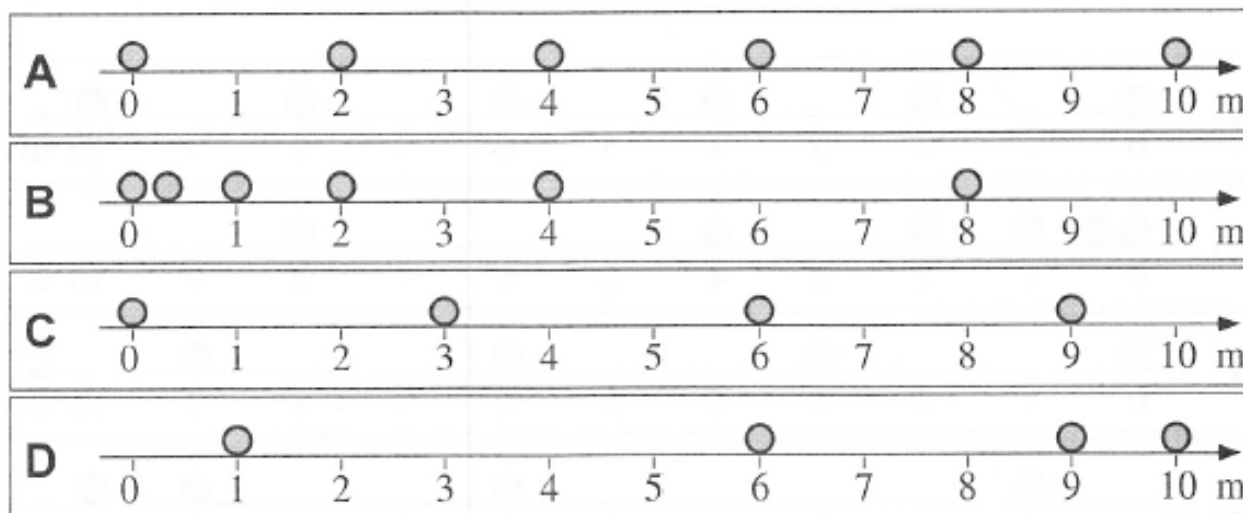
|                      |                      |                      |                      |    |                      |                      |                      |
|----------------------|----------------------|----------------------|----------------------|----|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | OR | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| 1                    | 2                    | 3                    | 4                    |    | All                  | All                  | Cannot               |
| Greatest             |                      |                      | Least                |    | the same             | zero                 | determine            |

Explain your reasoning.

*Answer:  $C > B > A = D$ .*

*The displacement is given by the change in position over the time interval. Object C has a displacement with a magnitude of 8 m; B's displacement has a magnitude of 4 m and A and D both have zero displacements since they are at the same point at the start and end of the time interval.*

In each case, a sphere is moving from left to right next to a tape marked in meters. A strobe (flash) photograph is taken every second, and the location of the sphere is recorded. The total time intervals shown are not the same for all spheres.



Rank the magnitude of the average velocity over the first 3 seconds.

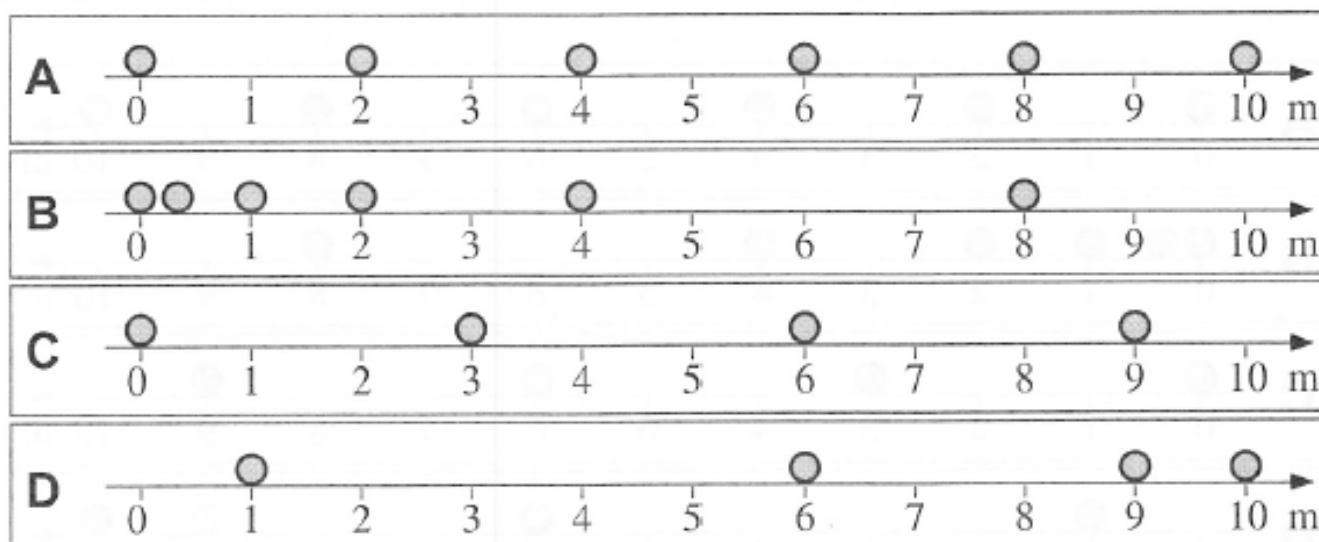
|                      |                      |                      |                      |    |                      |                      |                      |
|----------------------|----------------------|----------------------|----------------------|----|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | OR | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| 1                    | 2                    | 3                    | 4                    |    | All                  | All                  | Cannot               |
| Greatest             |                      |                      | Least                |    | the same             | zero                 | determine            |

Explain your reasoning.

*Answer:  $C = D > A > B$ .*

*Average velocity is defined as the displacement during a time interval divided by the time interval. The time interval is the same for all four cases, so the average velocities are determined by the displacements, which are proportional to the distances traveled in the first three seconds.*

In each case, a sphere is moving from left to right next to a tape marked in meters. A strobe (flash) photograph is taken every second, and the location of the sphere is recorded. The total time intervals shown are not the same for all spheres.



Rank the magnitude of the average velocity over the first 2 seconds.

|                      |                      |                      |                      |    |                      |                      |                      |
|----------------------|----------------------|----------------------|----------------------|----|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | OR | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| 1                    | 2                    | 3                    | 4                    |    | All                  | All                  | Cannot               |
| Greatest             |                      |                      | Least                |    | the same             | zero                 | determine            |

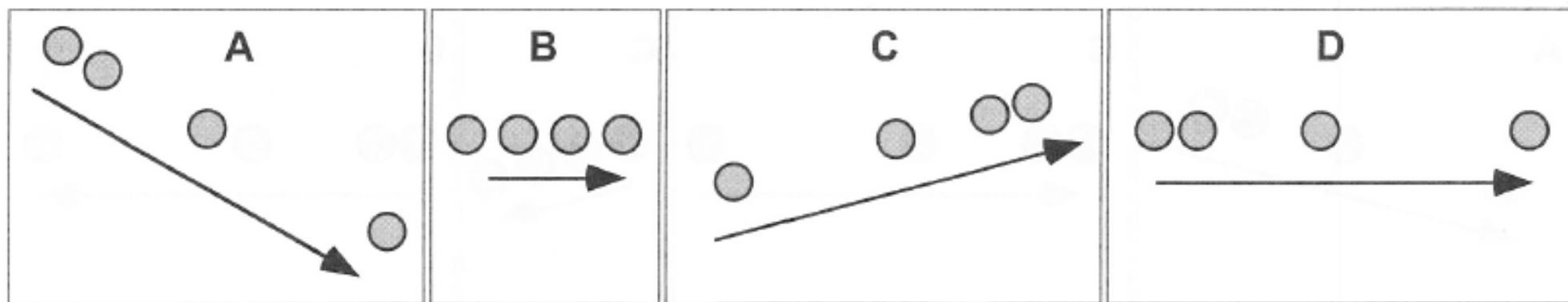
Explain your reasoning.

*Answer:  $D > C > A > B$ .*

*Average velocity is defined as the displacement during a time interval divided by the time interval. The time interval is the same for all four cases, so the average velocities are determined by the displacements, which are proportional to the distances traveled in the first two seconds. The displacements for C during the first two seconds was 6 m reading directly from the drawing, for D it was 8 m being the difference between 9 m and 1m, the location at zero, A is 4 m and smallest is B at 1m.*

### B1-RT05: BALL STROBE DIAGRAMS—AVERAGE VELOCITY

The following drawings represent strobe (flash) photographs of a ball moving in the direction of the arrow. The circles represent the positions of the ball at succeeding instants of time. The time interval between successive positions is the same in all cases.



Rank the magnitude of the ball's average velocity in the last time interval.

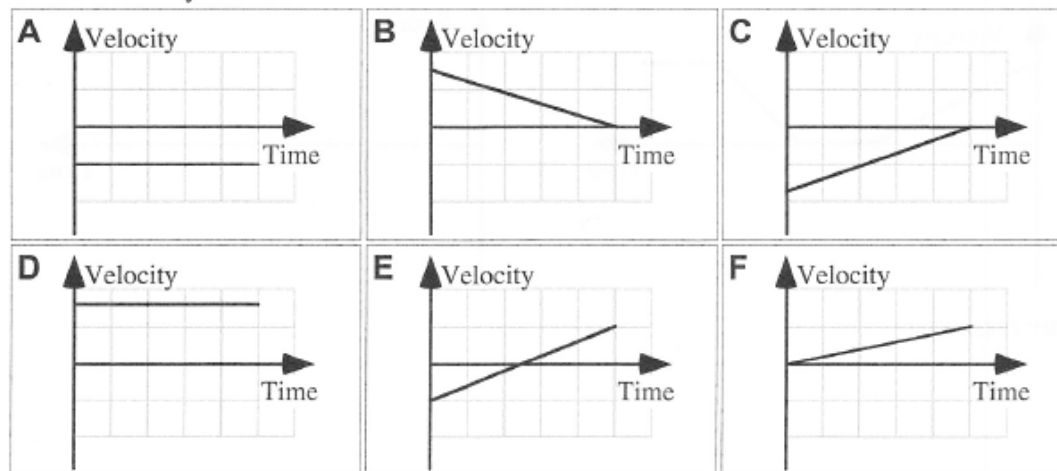
|                      |                      |                      |                      |    |                      |                      |                      |
|----------------------|----------------------|----------------------|----------------------|----|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | OR | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| 1                    | 2                    | 3                    | 4                    |    | All                  | All                  | Cannot               |
| Greatest             |                      |                      | Least                |    | the same             | zero                 | determine            |

Explain your reasoning.

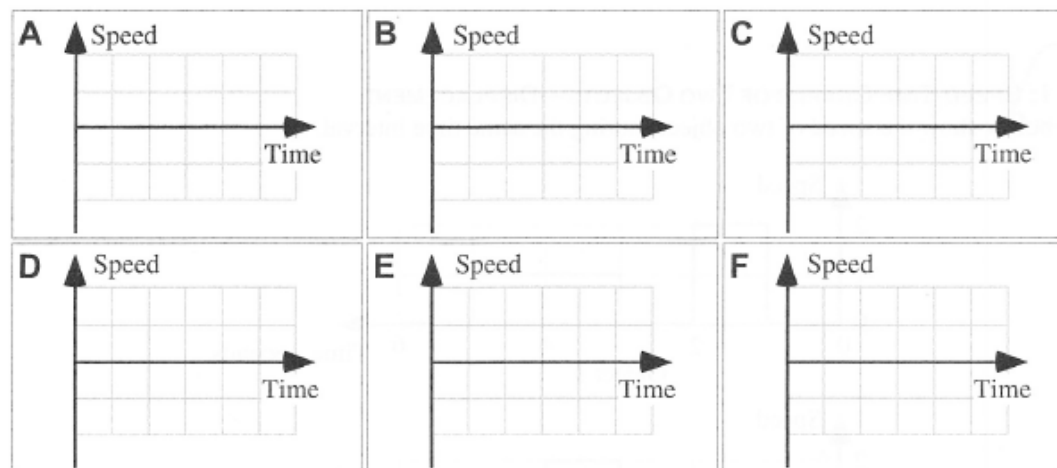
*Answer:  $A = D > B > C$ .*

*Since the time intervals are the same in all cases, the distance between any two adjacent positions of the ball will be proportional to the magnitude of the average velocity of the ball in the time interval between when those photographs were taken. By comparing the spacing between the last two positions for each case we can determine the magnitude of the average velocity in the last time interval.*

Velocity versus time graphs for six toy cars that are traveling straight along a hallway are shown. All graphs have the same time and velocity scales.

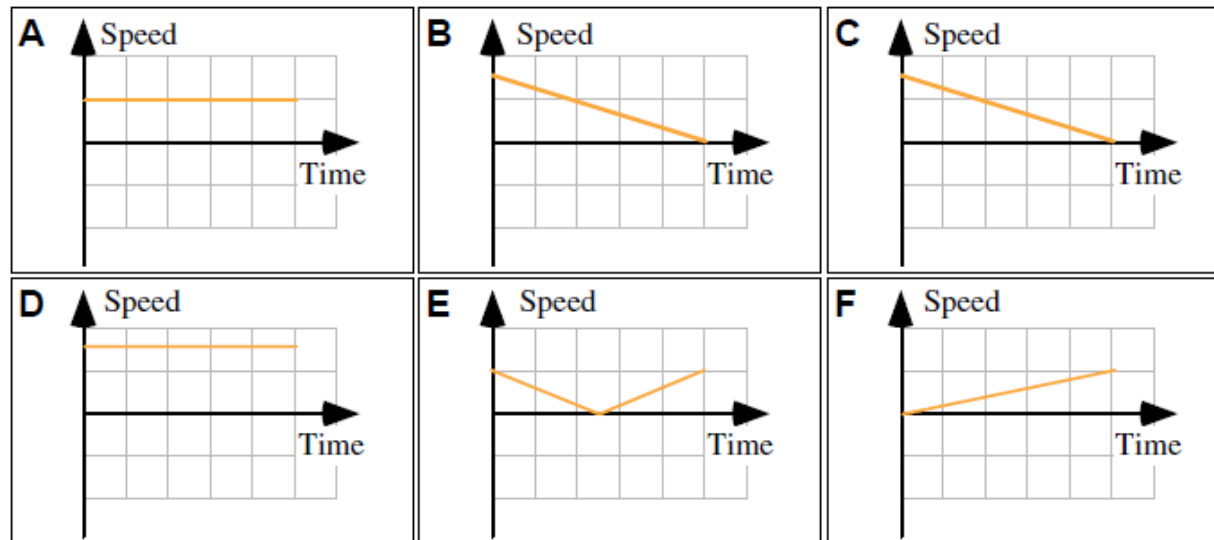


Draw below the speed versus time graphs for these graphs.



Explain your reasoning.

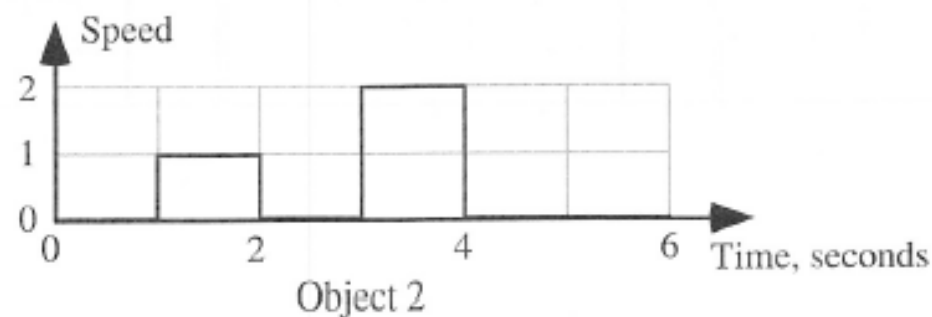
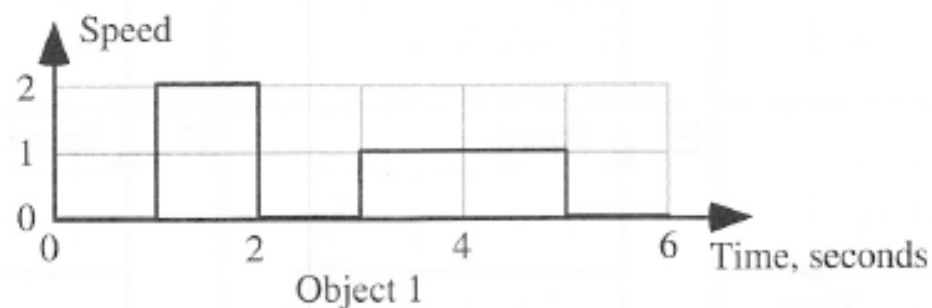
Draw below the speed versus time graphs for these graphs.



Explain your reasoning.

*Answer: Graph A shows a constant velocity motion which means the speed is also constant and positive since speed is a scalar. Graph B shows a decreasing positive velocity which means the speed is decreasing. Graph C is also a decreasing velocity, but a decreasing negative velocity, which means the speed, again positive because it is a scalar, is decreasing. Graph D is another constant velocity, so we again have a constant speed. Graph E shows a situation where the velocity is initially negative, but there is a constant positive acceleration so the negative velocity decreases constantly to zero and then the velocity increases, but in the positive direction. That means the speed decreases to zero, and then increases constantly. Graph F is an increasing positive velocity, which means the speed is increasing constantly.*

The graphs below show the speed of two objects during the same time interval.



A student considering these two graphs states:

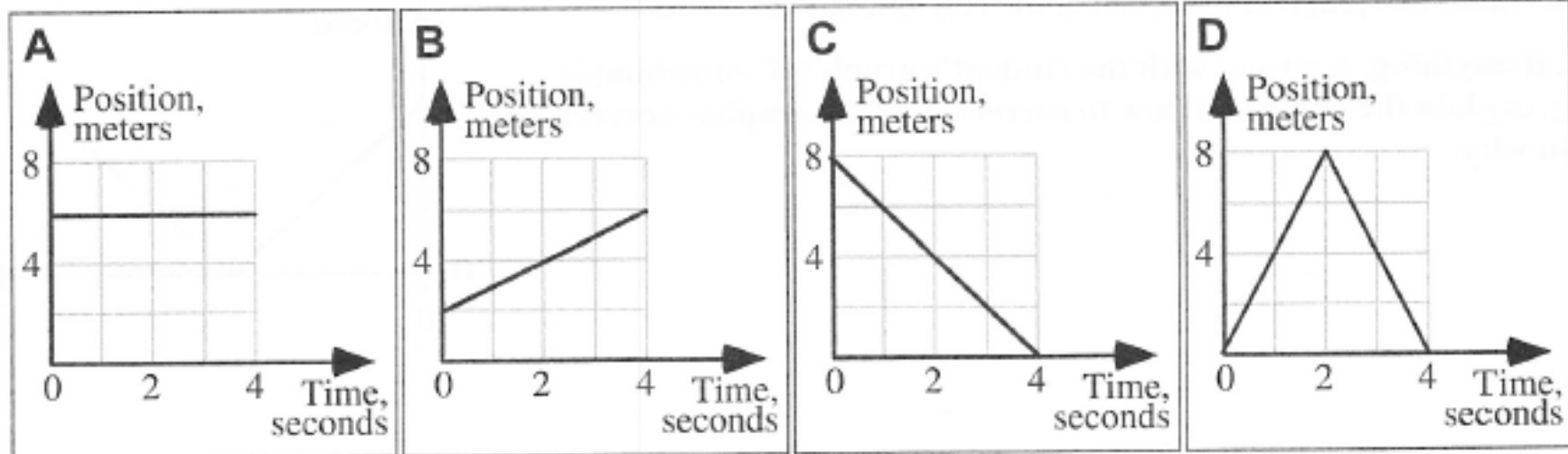
*"Object 1 will be farther from its starting point after this 6-second interval than Object 2 because Object 1 had a larger displacement than Object 2."*

**What, if anything, is wrong with the student's statement? If something is wrong, explain the error and how to correct it. If the graph is correct, explain why.**

*Answer: The student's statement is problematic since we cannot determine the displacements from these graphs. The area under the line or curve in a speed versus time graph tells us the distance traveled, but we have no idea whether the objects were traveling in one direction or if they reversed direction. Consequently, we cannot say anything about displacements.*

**B1-RT14: POSITION-TIME GRAPHS—AVERAGE SPEED**

Each graph below shows the position of an object as a function of time.



Rank the average speed of the object during the time interval from 0 to 4 seconds.

|                      |                      |                      |                      |    |                      |                      |                      |
|----------------------|----------------------|----------------------|----------------------|----|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | OR | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| 1                    | 2                    | 3                    | 4                    |    | All                  | All                  | Cannot               |
| Greatest             |                      |                      | Least                |    | the same             | zero                 | determine            |

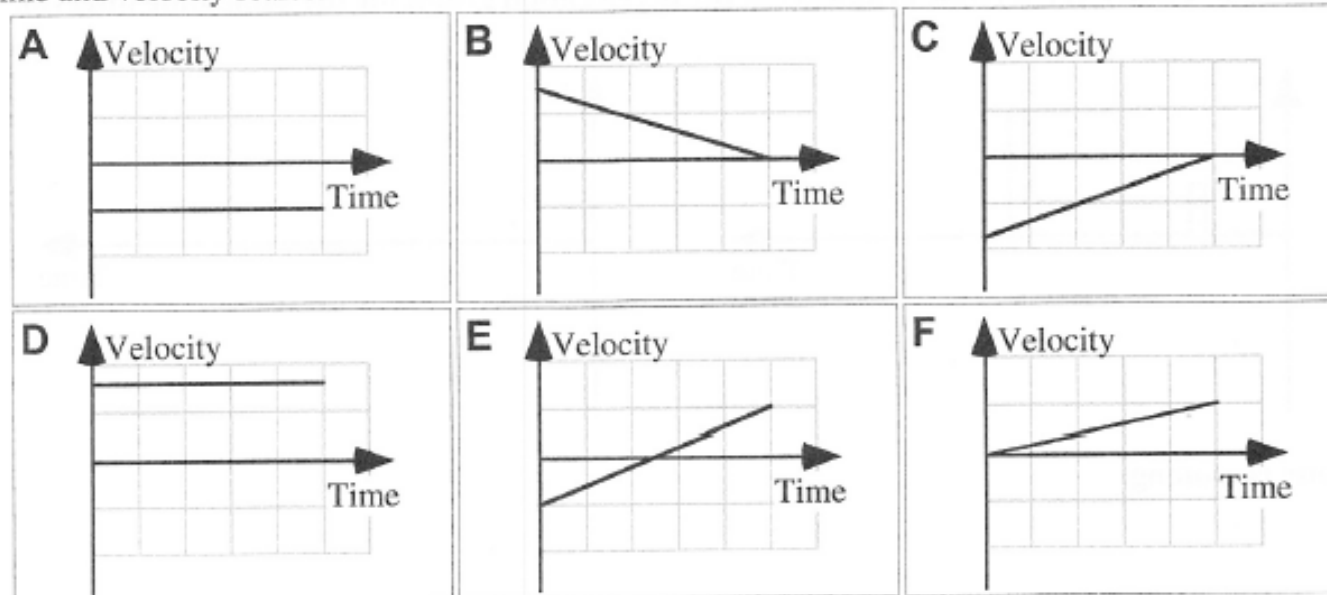
Explain your reasoning.

*Answer:  $D > C > B > A$ .*

*The average speed is the distance traveled divided by the time interval. For D, the average speed is 4 m/s (the object traveled 8 meters in one direction and then 8 meters back for a total of 16 meters in 4 seconds); for C it is 2 m/s; for B it is 1 m/s; and for A it is zero.*

**B1-RT23: VELOCITY-TIME GRAPHS—DISPLACEMENT**

Shown below are six velocity-time graphs for toy robots that are traveling along a straight hallway. All graphs have the same time and velocity scales.



Rank the magnitudes of the displacements during these intervals.

|                      |                      |                      |                      |                      |                      |    |                      |                      |                      |
|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | OR | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| 1                    | 2                    | 3                    | 4                    | 5                    | 6                    |    | All                  | All                  | Cannot               |
| Greatest             |                      |                      |                      |                      | Least                |    | the same             | zero                 | determine            |

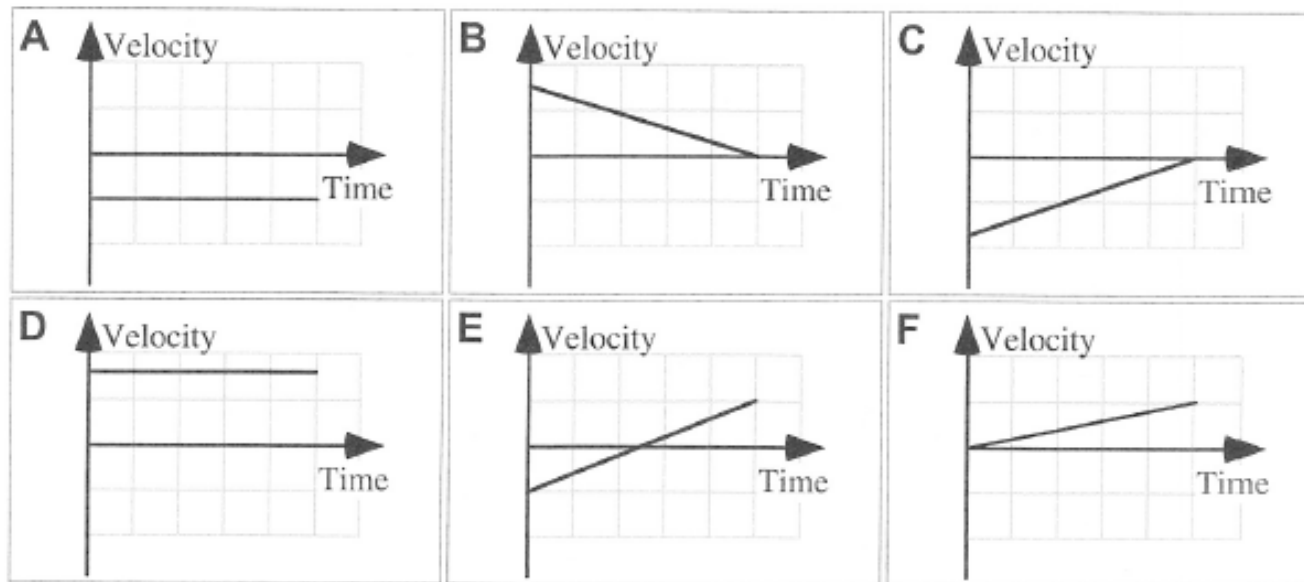
Explain your reasoning.

*Answer:  $D > A > B = C > F > E$*

*Since these are velocity versus time graphs the displacements are given by the areas “under” (between the lines and the time axis) the lines in the graphs.*

**B1-RT29: VELOCITY-TIME GRAPHS—DISTANCE TRAVELED**

Velocity-time graphs for six toy robots that are traveling along a straight hallway are shown. All graphs have the same time and velocity scales.



Rank the distance traveled during these intervals.

|          |   |   |   |   |       |    |          |      |           |
|----------|---|---|---|---|-------|----|----------|------|-----------|
|          |   |   |   |   |       | OR |          |      |           |
| 1        | 2 | 3 | 4 | 5 | 6     |    | All      | All  | Cannot    |
| Greatest |   |   |   |   | Least |    | the same | zero | determine |

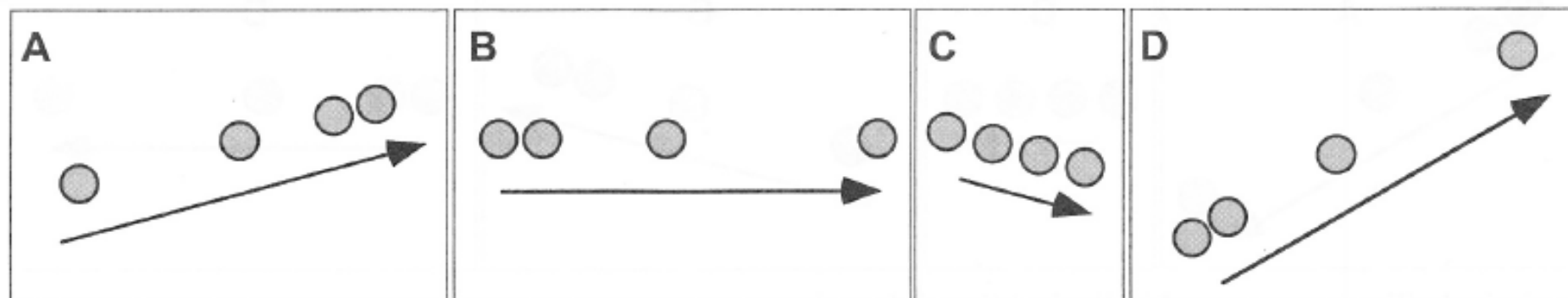
Explain your reasoning.

*Answer:  $D > A > B = C > E = F$ .*

*The distance traveled is the sum of the absolute values of the areas between the horizontal axis and the line on each graph. For graphs of motion that don't change direction (all cases except E), the magnitude of the displacement is the same as the distance traveled. For case, E, the distance traveled is the sum of the distance traveled backward and the distance traveled forward. The absolute value of the two areas in case E is the same as the area in case F.*

**B1-RT06: BALL STROBE DIAGRAMS—ACCELERATION**

The following drawings represent strobe (flash) photographs of a ball moving in the direction of the arrow. The circles represent the positions of the ball at succeeding instants of time. The time interval between successive positions is the same in all cases. Assume all accelerations are constant.



Rank the magnitude of the acceleration based on the drawings.

|                      |                      |                      |                      |    |                      |                      |                      |
|----------------------|----------------------|----------------------|----------------------|----|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | OR | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| 1                    | 2                    | 3                    | 4                    |    | All                  | All                  | Cannot               |
| Greatest             |                      |                      | Least                |    | the same             | zero                 | determine            |

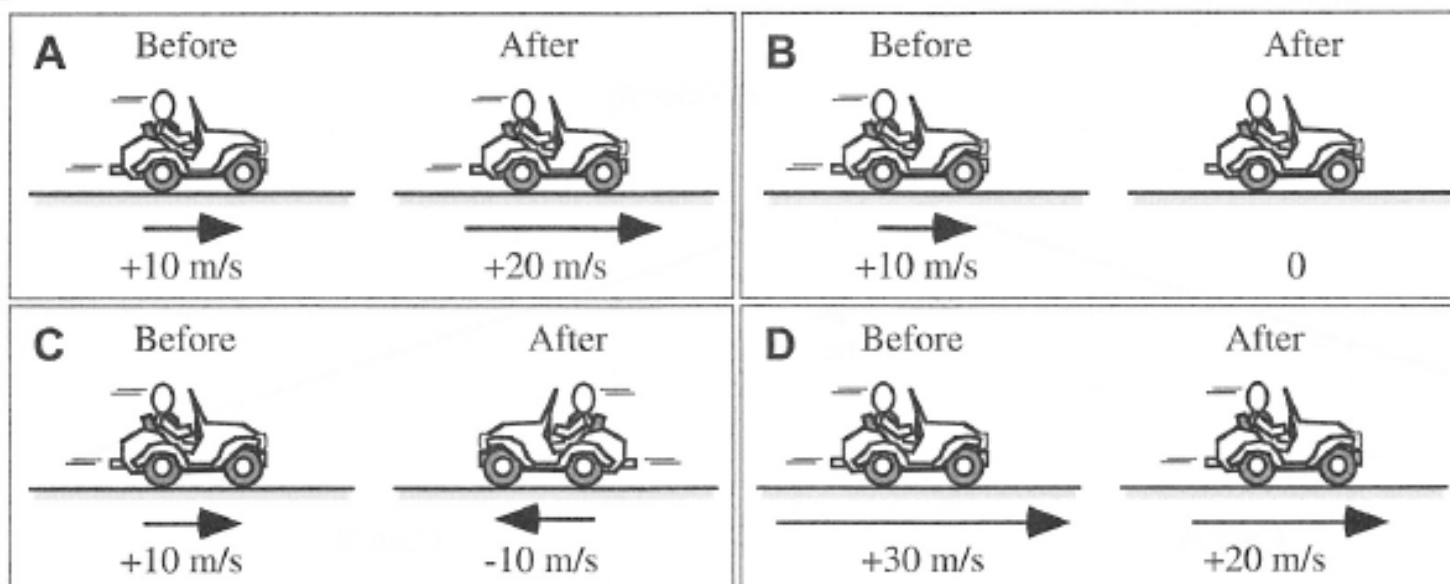
Explain your reasoning.

*Answer:  $B = D > A > C$ .*

*The spacing of the successive position changes given determine the direction of the acceleration and give an indication of the relative magnitude of the acceleration. In cases B and D, the acceleration is the same, in the direction of the arrow, and fairly large, because the speed of the ball is increasing quite a bit in each time interval.*

*In case A the acceleration points opposite to the direction of the arrow and has a slightly smaller magnitude than B and D. In case C, the acceleration is zero since the ball has a constant direction and rate of motion.*

In each figure below, a car's velocity is shown before and after a short time interval.



Rank the magnitude of the change in velocity during the time interval.

|                      |                      |                      |                      |    |                      |                      |                      |
|----------------------|----------------------|----------------------|----------------------|----|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | OR | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| 1                    | 2                    | 3                    | 4                    |    | All                  | All                  | Cannot               |
| Greatest             |                      |                      | Least                |    | the same             | zero                 | determine            |

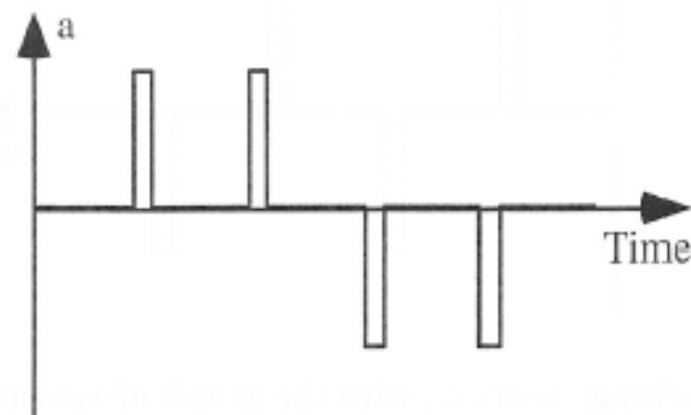
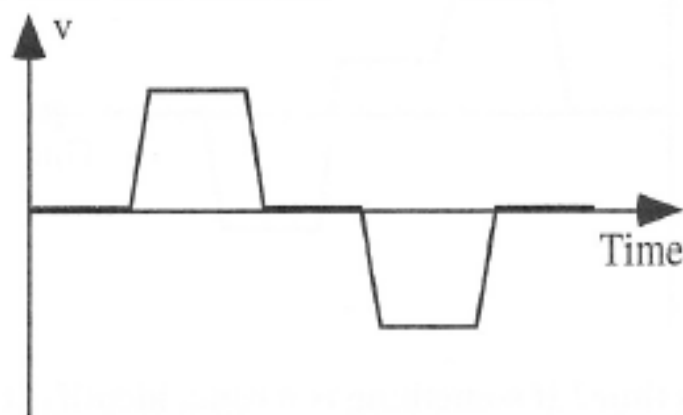
Explain your reasoning.

*Answer:  $C > A = B = D$ .*

*The magnitude of the change in velocity for C is 20 m/s while the other three all experience a change of 10 m/s in the magnitude of their velocity.*

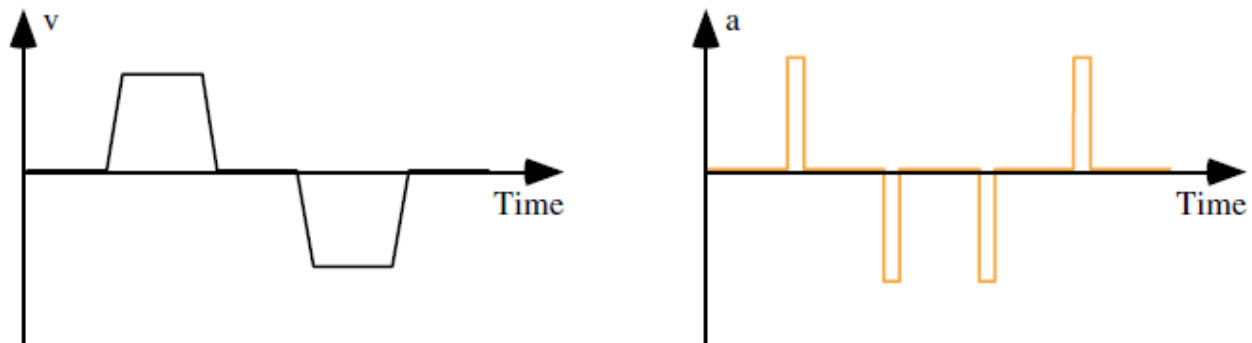
**B1-WWT17: VELOCITY-TIME GRAPH—ACCELERATION-TIME GRAPH**

A student obtains a graph of an object's velocity versus time and then draws the graph of the acceleration versus time for the same time interval.



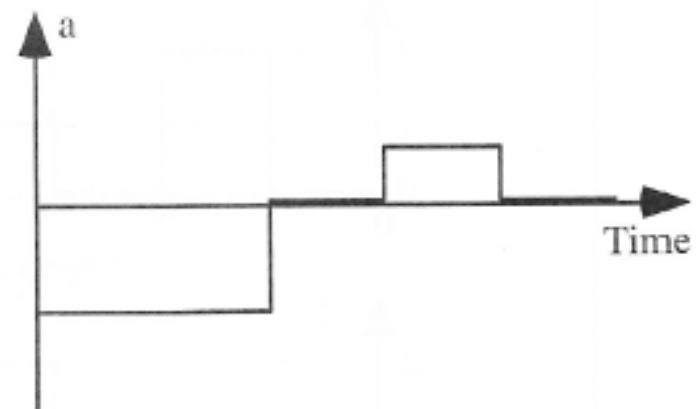
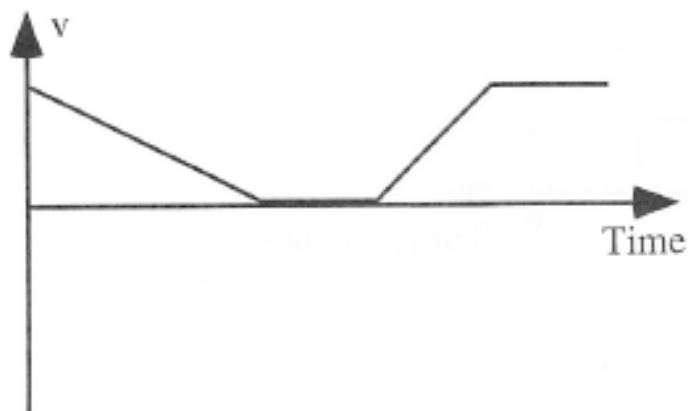
What, if anything, is wrong with the graph of the acceleration versus time? If something is wrong, identify it and explain how to correct it. If the graph is correct, explain why.

*Answer: The acceleration is the slope of the velocity graph. Thus, the second and fourth peaks should be reversed as shown below because the sign of the acceleration is the same as the sign of the slope of the velocity-time graph.*



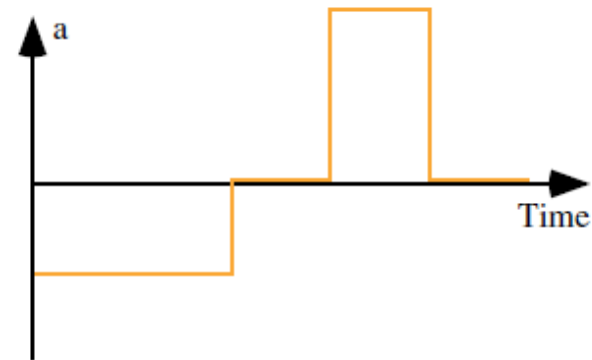
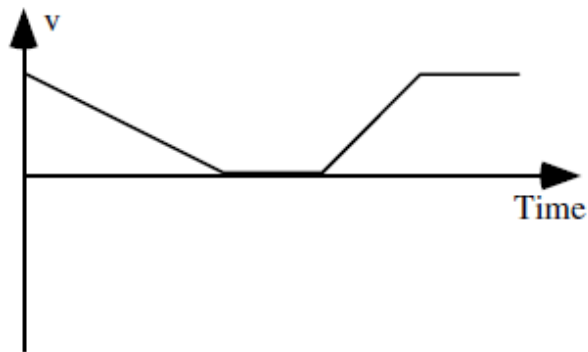
### B1-WWT20: VELOCITY-TIME GRAPH—ACCELERATION-TIME GRAPH

A student obtains a graph of an object's velocity versus time and then draws the graph of the acceleration versus time for the same time interval.



What, if anything, is wrong with the graph of the acceleration versus time? If something is wrong, identify it and explain how to correct it. If the graph is correct, explain why.

*Answer: Since the acceleration-time graph is related to the slope of the velocity-time graph, the magnitude of the acceleration should be proportional to the slope of the velocity-time graph at each point. For the third segment of the velocity-time graph, the (positive) slope has a greater magnitude than the (negative) slope of the first segment, and so the acceleration should have a greater positive value for this segment than the negative value of the first segment. (The change in velocity for the object over the entire time interval is zero, so the area under the curve of the acceleration time graph should be zero. We need to adjust the acceleration graph to bring the velocity back to the original value, and the rectangles above and below the zero axis should have the same area.)*



**B1-QRT33: POSITION-TIME GRAPH—DIRECTION**

A bicyclist is moving along a straight street oriented east—west. In drawing the graph, positions to the east of the origin were marked as positive and positions to the west were marked as negative.

(a) At 1 second, is the cyclist moving?

If so, in what direction?

Explain your reasoning.

(b) At 1 second, is the cyclist accelerating?

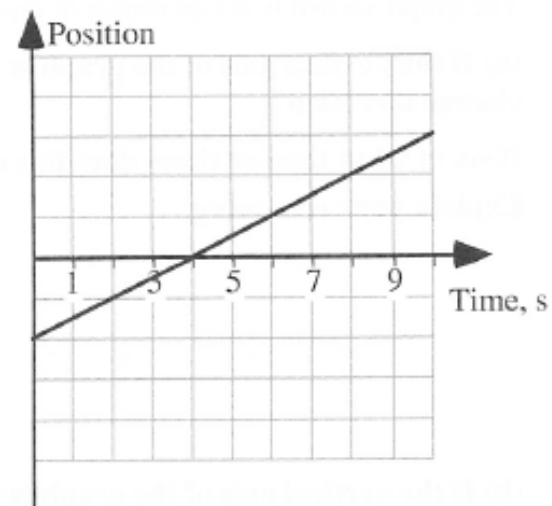
If so, in what direction?

Explain your reasoning.

(c) At 9 seconds, is the cyclist moving?

If so, in what direction?

Explain your reasoning.

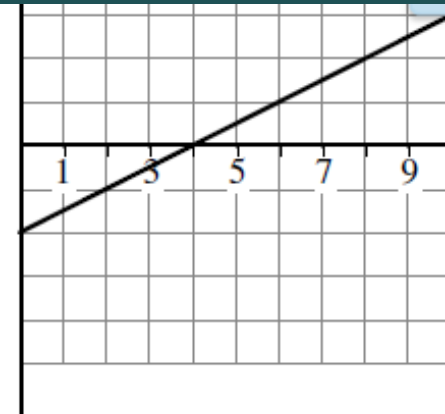


(a) At 1 second, is the cyclist moving?

If so, in what direction?

Explain your reasoning.

*Answer: At one second the cyclist is moving East since the slope of the graph is positive at that instant.*



(b) At 1 second, is the cyclist accelerating?

If so, in what direction?

Explain your reasoning.

*Answer: The line has a constant slope throughout, so the acceleration is zero throughout.*

(c) At 9 seconds, is the cyclist moving?

If so, in what direction?

Explain your reasoning.

*Answer: At nine seconds the cyclist is still moving East since the slope of the line is still positive.*

(d) At 9 seconds, is the cyclist accelerating?

If so, in what direction?

Explain your reasoning.

(e) At 4 seconds, is the cyclist moving?

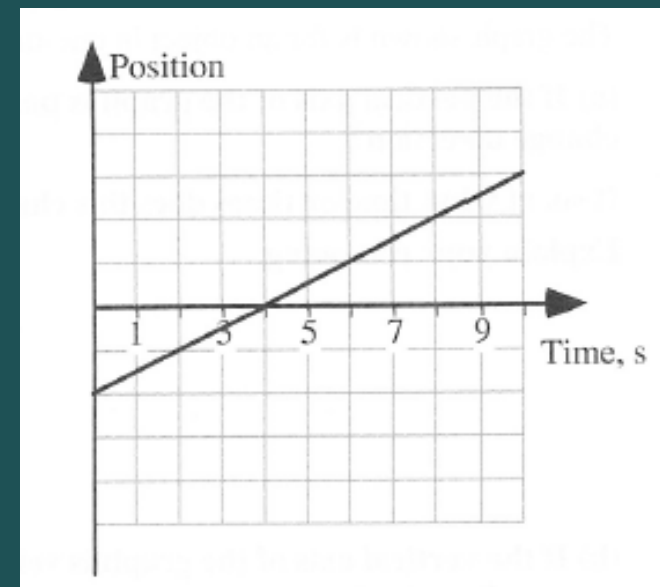
If so, in what direction?

Explain your reasoning.

(f) At 4 seconds, is the cyclist accelerating?

If so, in what direction?

Explain your reasoning.



(d) At 9 seconds, is the cyclist accelerating?

If so, in what direction?

Explain your reasoning.

*Answer: No, the cyclist moves with a constant velocity throughout.*

(e) At 4 seconds, is the cyclist moving?

If so, in what direction?

Explain your reasoning.

*Answer: At four seconds the cyclist is moving East since the slope is positive.*

(f) At 4 seconds, is the cyclist accelerating?

If so, in what direction?

Explain your reasoning.

*Answer: No, the cyclist moves with a constant velocity throughout.*

**B1-QRT34: VELOCITY-TIME GRAPH—DIRECTION**

A unicyclist, someone riding a single-wheel cycle, is moving along a straight street oriented east—west. In drawing the graph, east was taken as the positive direction and west the negative direction.

(a) At 1 second, is the cyclist moving?

If so, in what direction?

Explain your reasoning.

(b) At 1 second, is the cyclist accelerating?

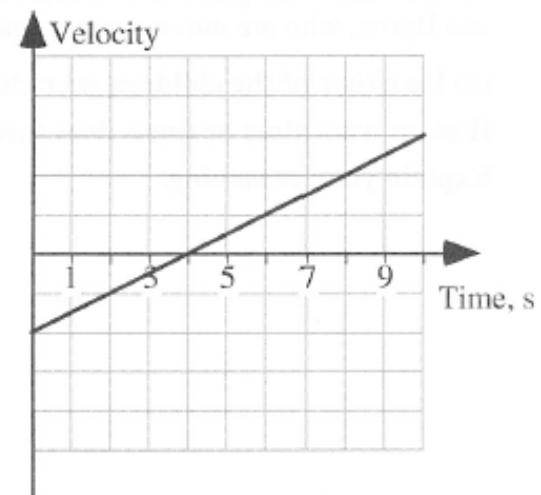
If so, in what direction?

Explain your reasoning.

(c) At 9 seconds, is the cyclist moving?

If so, in what direction?

Explain your reasoning.

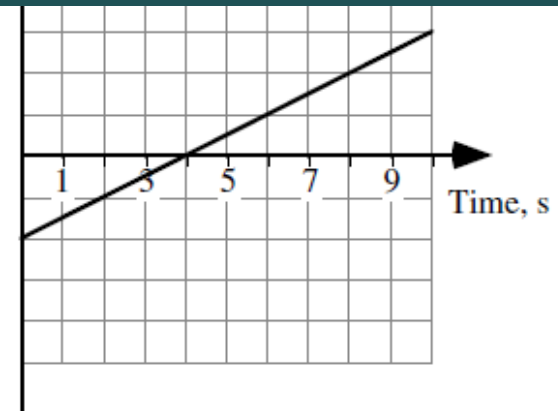


(a) At 1 second, is the cyclist moving?

If so, in what direction?

Explain your reasoning.

*Answer: The cyclist is moving West at one second since the velocity is negative at that time.*



(b) At 1 second, is the cyclist accelerating?

If so, in what direction?

Explain your reasoning.

*Answer: The cyclist is accelerating to the East since the slope of the line, which tells us the acceleration, is positive. The acceleration is constant throughout the interval graphed.*

(c) At 9 seconds, is the cyclist moving?

If so, in what direction?

Explain your reasoning.

*Answer: At nine seconds the cyclist is moving East since the velocity is positive at that time.*

**d) At 9 seconds, is the cyclist accelerating?**

**If so, in what direction?**

**Explain your reasoning.**

**(e) At 4 seconds, is the cyclist moving?**

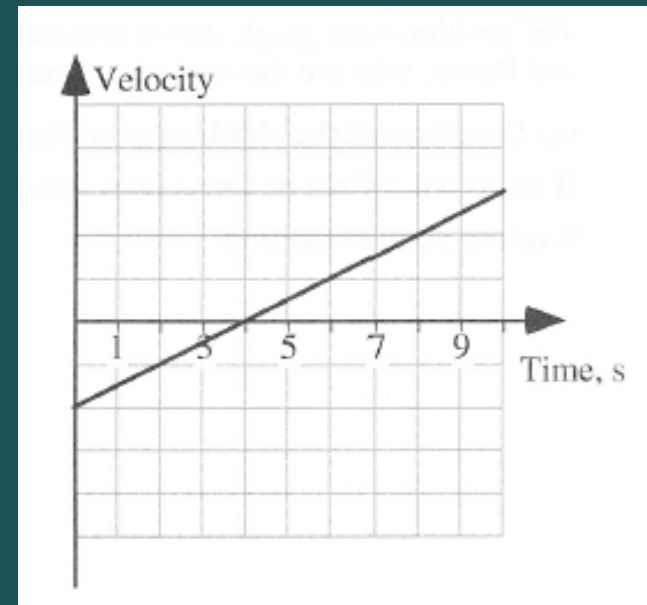
**If so, in what direction?**

**Explain your reasoning.**

**(f) At 4 seconds, is the cyclist accelerating?**

**If so, in what direction?**

**Explain your reasoning.**



d) At 9 seconds, is the cyclist accelerating?

If so, in what direction?

Explain your reasoning.

*Answer: The cyclist is accelerating to the East throughout.*

(e) At 4 seconds, is the cyclist moving?

If so, in what direction?

Explain your reasoning.

*Answer: At four seconds the cyclist is stopped instantaneously while changing direction.*

(f) At 4 seconds, is the cyclist accelerating?

If so, in what direction?

Explain your reasoning.

*Answer: As stated above the cyclist is accelerating to the East throughout.*

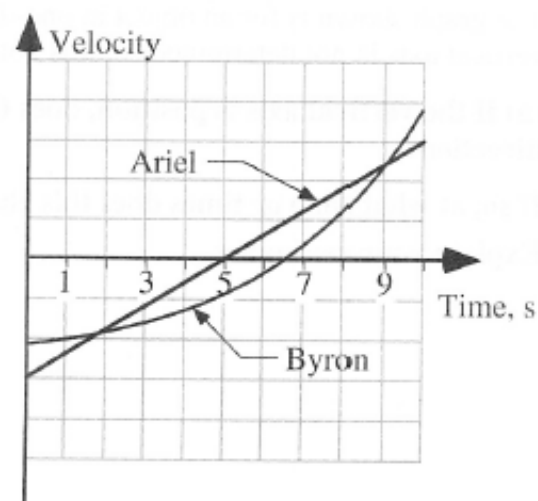
**B1-QRT36: VELOCITY-TIME GRAPHS OF CHILDREN—KINEMATIC QUANTITIES**

The velocity-time graph shown represents the motion of two children, Ariel and Byron, who are moving along a narrow, straight hallway.

(a) Do either of the children ever change direction?

If so, at what time or times does this change in direction occur?

Explain your reasoning.



(b) Do the two children ever have the same velocity?

If so, at what time or times does this occur?

Explain your reasoning.

(c) Do the two children ever have the same acceleration?

If so, at what time or times does happen?

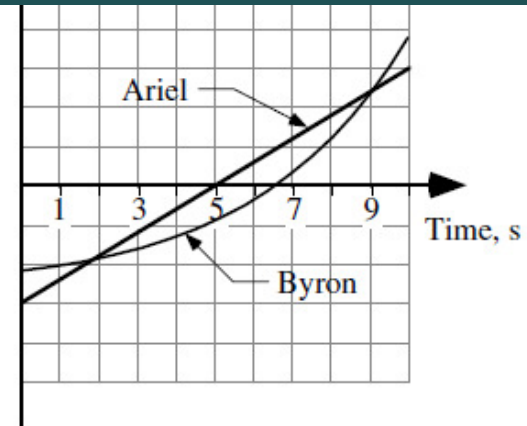
Explain your reasoning.

(a) Do either of the children ever change direction?

If so, at what time or times does this change in direction occur?

Explain your reasoning.

*Answer: The velocity of each child is given by the value on the vertical axis of the graph, so Ariel's velocity changes from negative to positive at time 5 seconds, and Byron's velocity changes from negative to positive approximately at time 6.5 seconds. So Ariel changes direction at 5 seconds and Byron changes direction at 6.5 seconds. Between 5 and 6.5 seconds, the children are moving in opposite directions along the hallway.*



(b) Do the two children ever have the same velocity?

If so, at what time or times does this occur?

Explain your reasoning.

*Answer: The velocity of each child is given by the value of the y-axis of the graph, so Ariel's velocity is the same as Byron's velocity at times 2 seconds and 9 seconds.*

(c) Do the two children ever have the same acceleration?

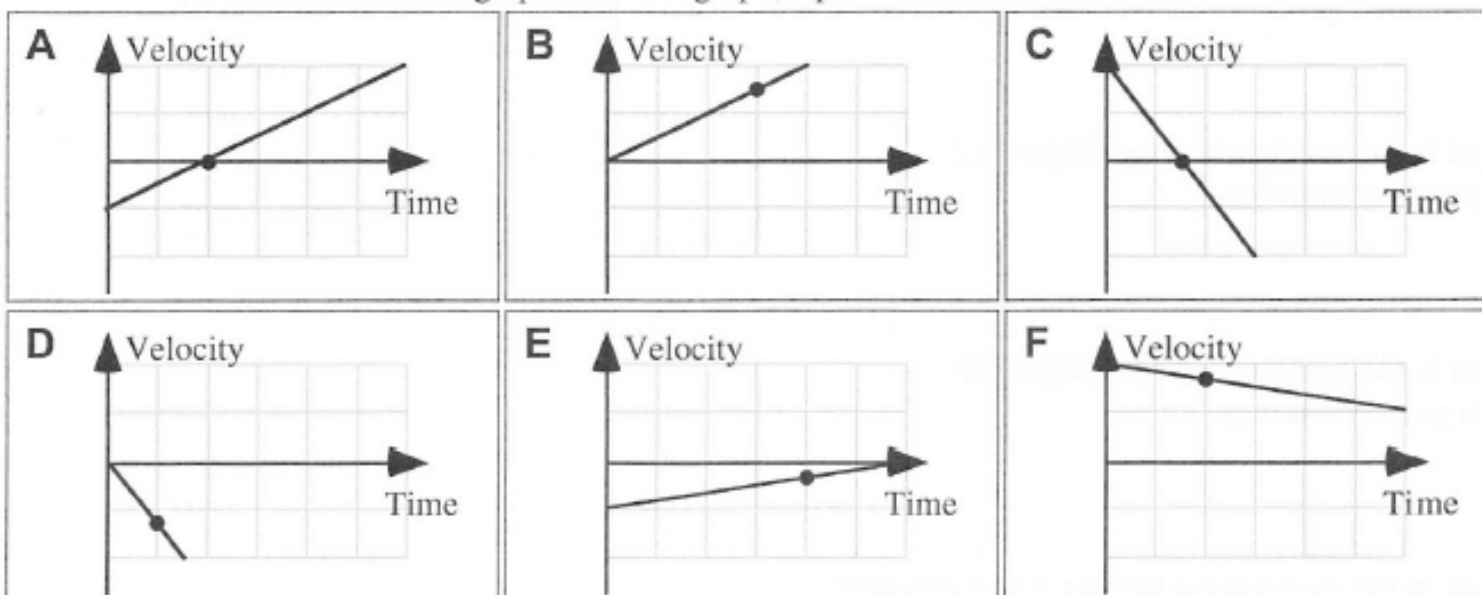
If so, at what time or times does happen?

Explain your reasoning.

*Answer: The acceleration of each child is given by the slope of the graph, so Ariel's acceleration is the same as Byron's acceleration when the graphs have the same slope, at around time 6 seconds.*

**B1-RT42: VELOCITY-TIME GRAPHS—INSTANTANEOUS VELOCITY**

The graphs below show the velocity versus time for boats traveling along a straight, narrow channel. The scales on both axes are the same for all of these graphs. In each graph, a point is marked with a dot.



Rank the magnitude of the velocity of the boat at the point indicated.

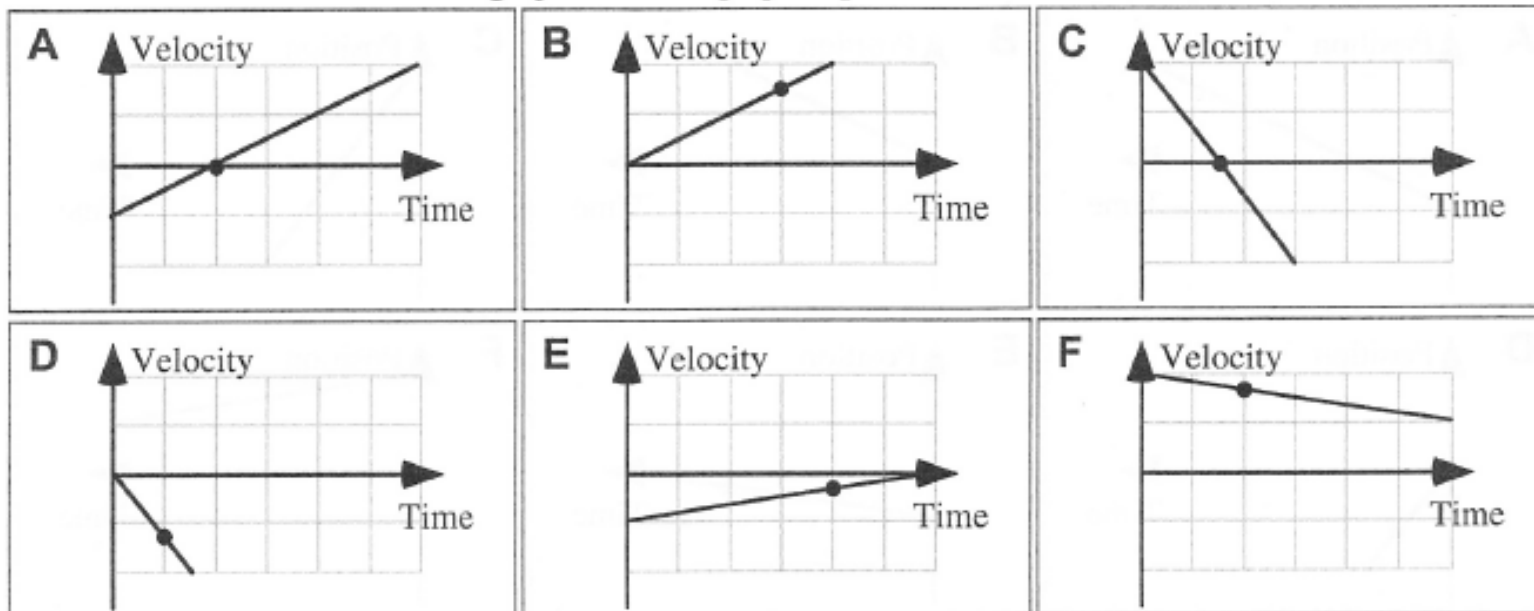
|          |   |   |   |   |       |    |          |      |           |
|----------|---|---|---|---|-------|----|----------|------|-----------|
|          |   |   |   |   |       | OR |          |      |           |
| 1        | 2 | 3 | 4 | 5 | 6     |    | All      | All  | Cannot    |
| Greatest |   |   |   |   | Least |    | the same | zero | determine |

Explain your reasoning.

*Answer:  $F > B > D > E > C = A$ . These values can be read directly off the vertical axes.*

**B1-RT43: VELOCITY-TIME GRAPHS—ACCELERATION**

The graphs below show the velocity versus time for boats traveling along a straight, narrow channel. The scales on both axes are the same for all of these graphs. In each graph, a point is marked with a dot.



Rank the magnitude of the acceleration of the boat at the point indicated.

|          |   |   |   |   |       |    |          |      |           |
|----------|---|---|---|---|-------|----|----------|------|-----------|
|          |   |   |   |   |       | OR |          |      |           |
| 1        | 2 | 3 | 4 | 5 | 6     |    | All      | All  | Cannot    |
| Greatest |   |   |   |   | Least |    | the same | zero | determine |

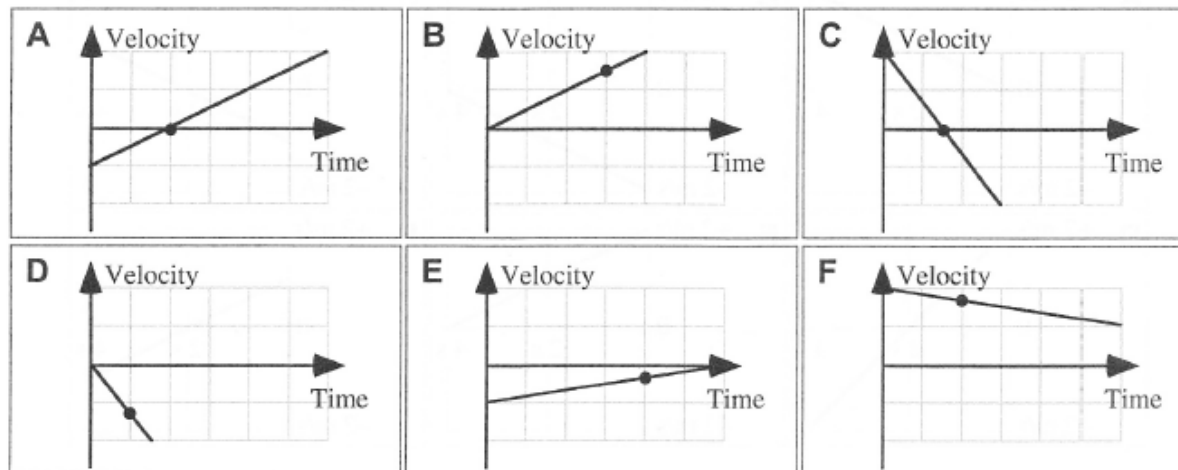
Explain your reasoning.

*Answer:  $C = D > A = B > E = F$ .*

*The instantaneous accelerations are determined by the slopes of the velocity-time graphs at the given points on the graphs. Since these graphs are straight lines, the slopes (and the accelerations) do not change as a function of time.*

**B1-QRT51: VELOCITY-TIME GRAPHS—DIRECTION**

The graphs below show the velocity versus time for boats traveling along a straight, narrow channel. The scales on both axes are the same for all of these graphs, and the boats all start at the same origin. In each graph, a point is marked with a dot.



Indicate in the chart below if the position, velocity, and acceleration directions of the boat at the points indicated are in the positive (+), negative (–), or no direction (0)

|   | Position | Velocity | Acceleration |
|---|----------|----------|--------------|
| A |          |          |              |
| B |          |          |              |
| C |          |          |              |
| D |          |          |              |
| E |          |          |              |
| F |          |          |              |

Explain your reasoning.

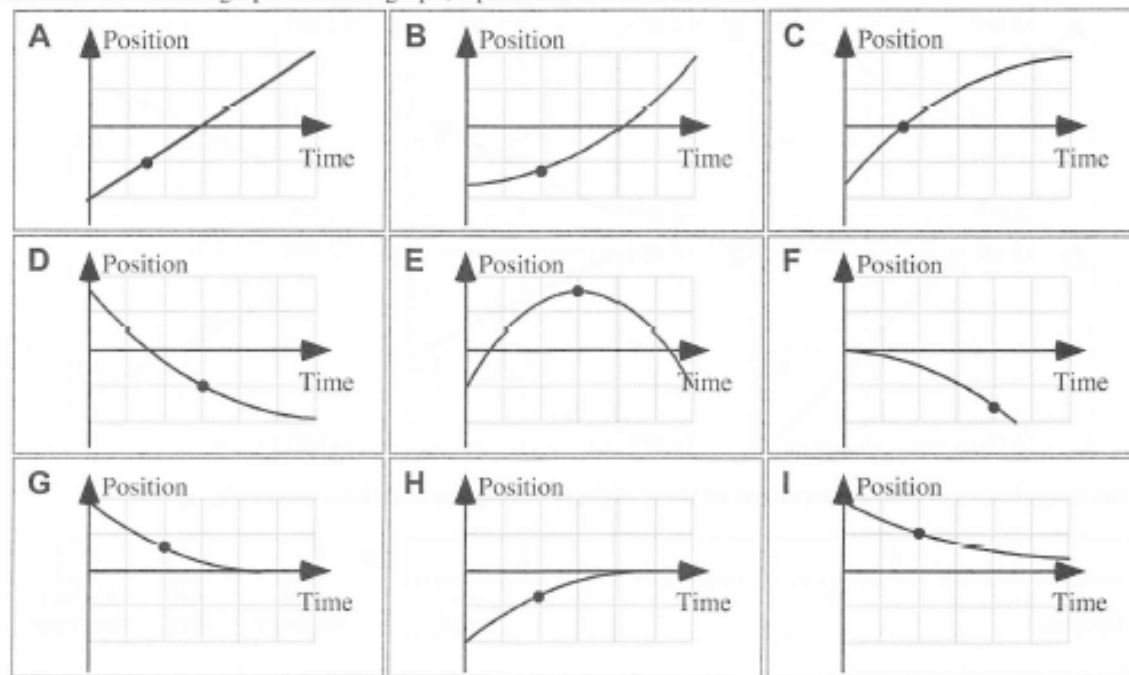
**Acceleration:** The accelerations are determined by the slopes of the velocity-time graphs at the points on the graphs. Since these graphs are straight lines, the slopes (accelerations) do not change as a function of time.

**Velocity:** These values can be read directly off the vertical axes.

**Position:** The position is the area under the graph up to the point since the boats all start from the same origin. For A, D, and E it is negative. For A it is about -1 square while for D it is about -0.5 and for E about -2.5 squares. For B the area is about +2.25squares, for C about +1.5 squares, and for F (the largest) it is about +3.5 squares.

|   | Position | Velocity | Acceleration |
|---|----------|----------|--------------|
| A | —        | 0        | +            |
| B | +        | +        | +            |
| C | +        | 0        | —            |
| D | —        | —        | —            |
| E | —        | —        | +            |
| F | +        | +        | —            |

Position versus time graphs for boats traveling along a narrow channel are shown below. The scales on both axes are the same for all of these graphs. In each graph, a point is marked with a dot.



(a) For which of these cases, if any, is the position zero at the indicated point?  
Explain your reasoning.

(b) For which of these cases, if any, is the position negative at the indicated point?  
Explain your reasoning.

(c) For which of these cases, if any, is the velocity zero at the indicated point?  
Explain your reasoning.

(d) For which of these cases, if any, is the velocity negative at the indicated point?  
Explain your reasoning.

(e) For which of these cases, if any, is the acceleration zero at the indicated point?  
Explain your reasoning.

(f) For which of these cases, if any, is the acceleration negative at the indicated point?  
Explain your reasoning.

(a) For which of these cases, if any, is the position zero at the indicated point?

Explain your reasoning.

*Answer: The position is zero for the indicated point in graph C, which can be read directly off of the graph.*

(b) For which of these cases, if any, is the position negative at the indicated point?

Explain your reasoning.

*Answer: The position is negative for A, B, D, F, H.*

(c) For which of these cases, if any, is the velocity zero at the indicated point?

Explain your reasoning.

*Answer: The velocity is zero if the slope of the graph is zero at the indicated point, which is the case only for graph E.*

(d) For which of these cases, if any, is the velocity negative at the indicated point?

Explain your reasoning.

*Answer: The velocity is given by the slope of the position-time graph, and a negative velocity corresponds to a downward-sloping graph at the indicated point. Graphs D, F, G, and I have negative slopes at the indicated point.*

(e) For which of these cases, if any, is the acceleration zero at the indicated point?

Explain your reasoning.

*Answer: A zero acceleration corresponds to a constant velocity, which in turn corresponds to a linear position-time graph. The acceleration is zero for graph A.*

(f) For which of these cases, if any, is the acceleration negative at the indicated point?

Explain your reasoning.

*A negative acceleration corresponds to a velocity graph whose slope is negative, which in turn corresponds to a position-time graph that curves downward (i.e., the slope becomes less positive or more negative with time. The accelerations are negative for graphs C, E, F, and H.*