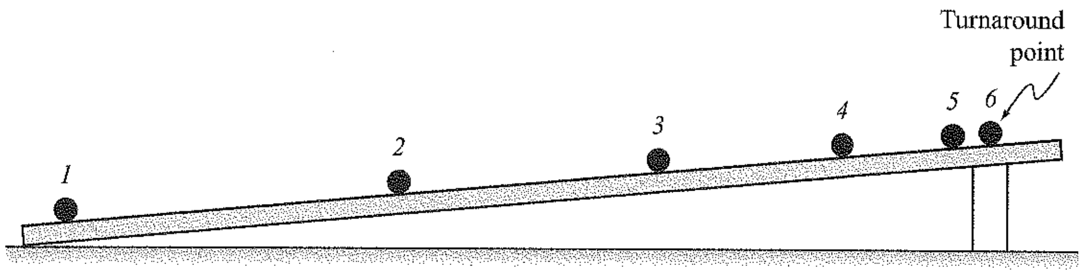
I. Motion with decreasing speed

The diagram below represents a strobe photograph of a ball as it rolls *up* a track. (In a strobe photograph, the position of an object is shown at instants separated by *equal time intervals.*) The ball is already in motion at instant 1.



A. Draw vectors on your diagram that represent the instantaneous velocity of the ball at each of the instants shown. If the magnitude of the velocity is zero at any instant, indicate that explicitly. Explain why you drew the vectors as you did.

We will call diagrams like the one you drew above *velocity diagrams.* Unless otherwise specified, a velocity diagram shows both the location and the velocity of an object at instants in time that are separated by equal time intervals.

B. In the space at right, compare the velocities at instants *1* and *2* by sketching the vectors that represent those velocities. Draw the vectors side-by-side and label them $\vec{v}_1$ and $\vec{v}_2$, respectively.

$\vec{v}_1$, $\vec{v}_2$, and $\Delta\vec{v}$

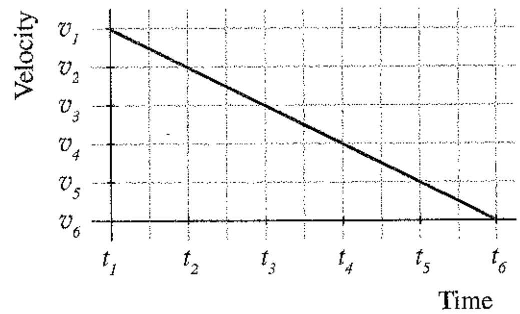
Draw the vector that must be *added* to the velocity at the earlier time to equal the velocity at the later time. Label this vector $\Delta\vec{v}$.

Why is the name *change in velocity* appropriate for this vector?

How does the direction of the change-in-velocity vector compare to the direction of the velocity vectors?

Would your answer differ if you were to select two *different* consecutive instants (*e.g.*, instants *3* and *4)* while the ball was slowing down? Explain.

How would the magnitude of the change-in-velocity vector between instants *1* and *2* compare to the magnitude of the change-in-velocity vector between two *different* consecutive instants (*e.g.,* instants *3* and *4*)? Explain. (You may find it useful to refer to the graph of *velocity* versus *time* for the motion.)



Note: The positive direction has been chosen to be *up* the track.

C. Consider the change-in-velocity vector between two instants on the velocity diagram that are not consecutive, *e.g.,* instants *1* and *4*.

Is the direction of the change-in-velocity vector different than it was for consecutive instants? Explain.

Is the length of the change-in-velocity vector different than it was for consecutive instants? If so, how many times larger or smaller is it than the corresponding vector for consecutive instants? Explain.

D. Use the definition of acceleration to draw a vector in the space at right that represents the acceleration of the ball between instants *1* and *2*.

Acceleration vector

How is the direction of the acceleration vector related to the direction of the change-in-velocity vector? Explain.

E. Does the acceleration change as the ball rolls up the track? Would the acceleration vector you obtain differ if you were to choose (1) two different consecutive instants on your diagram or (2) two instants that are not consecutive? Explain.

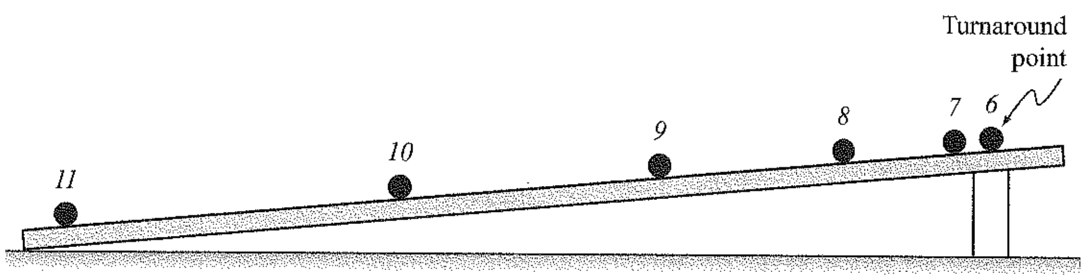
F. Generalize your results thus far to answer the following question:

What is the relationship between the direction of the acceleration and the direction of the velocity for an object that is moving in a straight line and slowing down? Explain.

Describe the direction of the acceleration of a ball that is rolling up a straight inclined track.

II. Motion with increasing speed

The diagram below represents a strobe photograph of a ball as it rolls *down* the track.



A. Choose two consecutive instants. In the space at right, sketch the velocity vectors corresponding to those instants. Draw the vectors side-by-side and label them $\vec{v}_i$ and $\vec{v}_f$, respectively.

Determine the vector that must be added to the velocity at the earlier time to equal the velocity at the later time. Is the name *change in velocity* appropriate for this vector?

$\vec{v}_i$, $\vec{v}_f$, and $\Delta\vec{v}$

How does the direction of the change-in-velocity vector compare to the direction of the velocity vectors in this case?

Would your answer differ if you were to select two *different* instants during the time that the ball was speeding up? Explain.

B. In the space at right, draw a vector to represent the acceleration of the ball between the instants chosen above.

How is the direction of the change-in-velocity vector related to the direction of the acceleration vector? Explain.

Acceleration vector

Generalize your results thus far to answer the following question:

What is the relationship between the direction of the acceleration and the direction of the velocity for an object that is moving in a straight line and speeding up? Explain.

Describe the direction of the acceleration of a ball that is rolling down a straight incline.

III. Motion that includes a change in direction

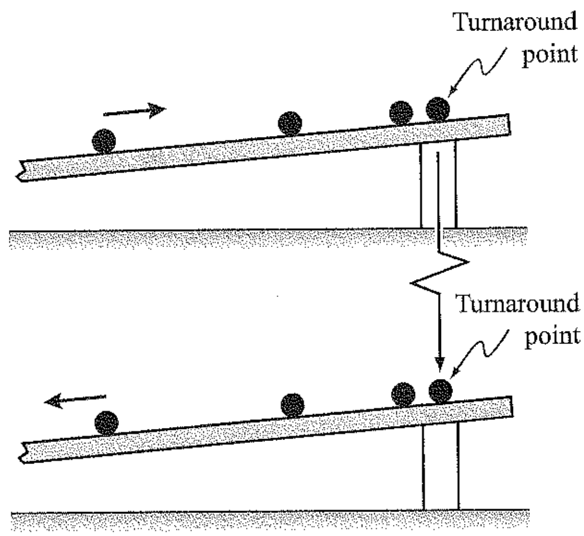
A. Complete the velocity diagram below for the portion of the motion that includes the turnaround.

B. Choose an instant *before* the turnaround and another *after*.

In the space below, draw the velocity vectors and label them $\vec{v}_i$ and $\vec{v}_f$.

Draw the vector that must be added to the velocity at the earlier time to obtain the velocity at the later time.

Is the name *change in velocity* that you used in sections I and II also appropriate for this vector?



C. Suppose that you had chosen the turnaround as one of your instants.

What is the velocity at the turnaround point?

Would this choice affect the direction of the change-in-velocity vector? Explain why or why not.

$\vec{v}_i$, $\vec{v}_f$, and $\Delta\vec{v}$

D. In the space at right, draw a vector that represents the acceleration of the ball between the instants you chose in part C above.

Compare the direction of the acceleration of the ball at the turnaround point to that of the ball as it rolls: (1) up the track and (2) down the track.

Acceleration vector