UBC
a place of mind
FACULTY OF EDUCATION
Department of
Curriculum and Pedagogy

Physics
Uniform Circular Motion

Science and Mathematics
Education Research Group

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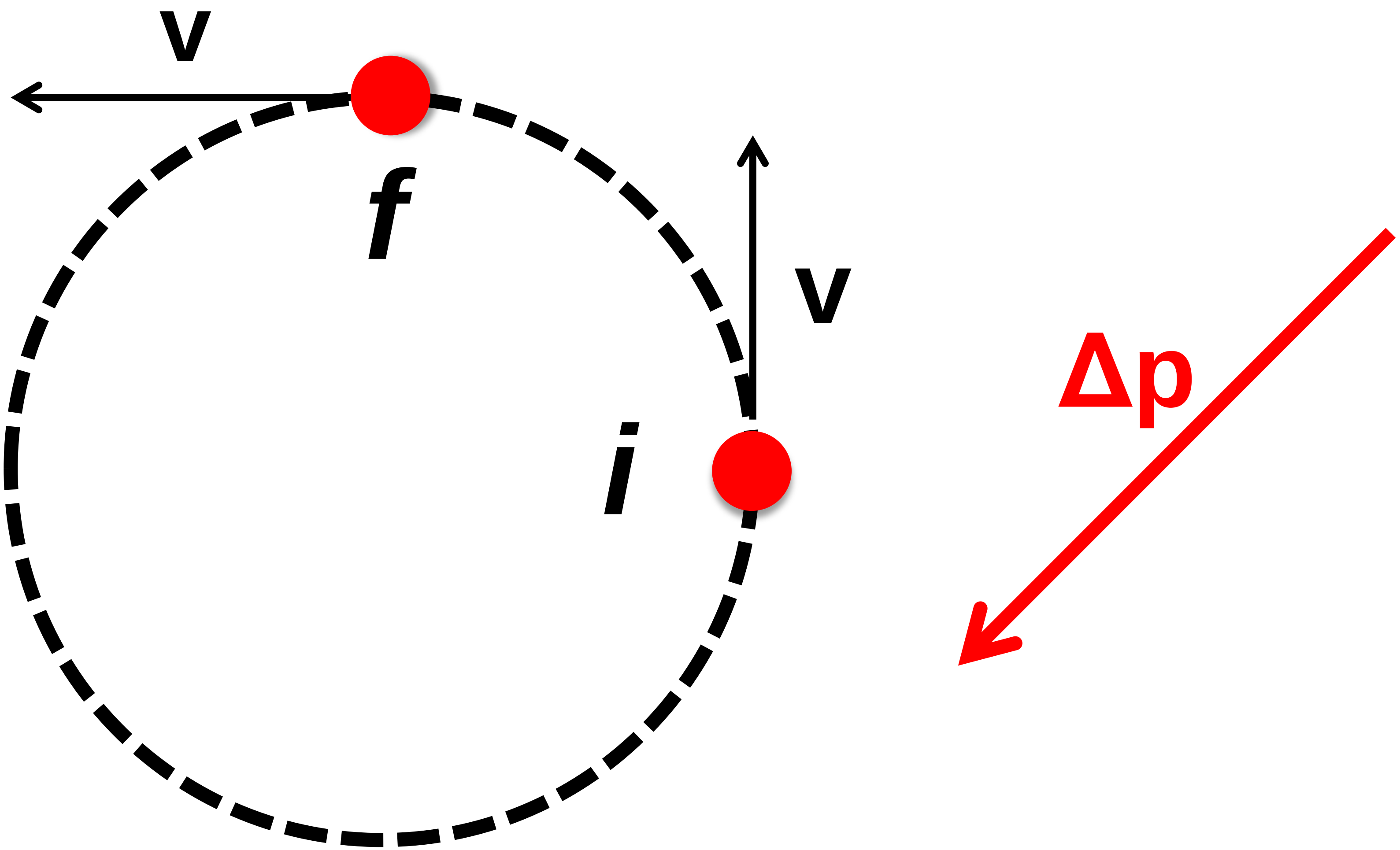
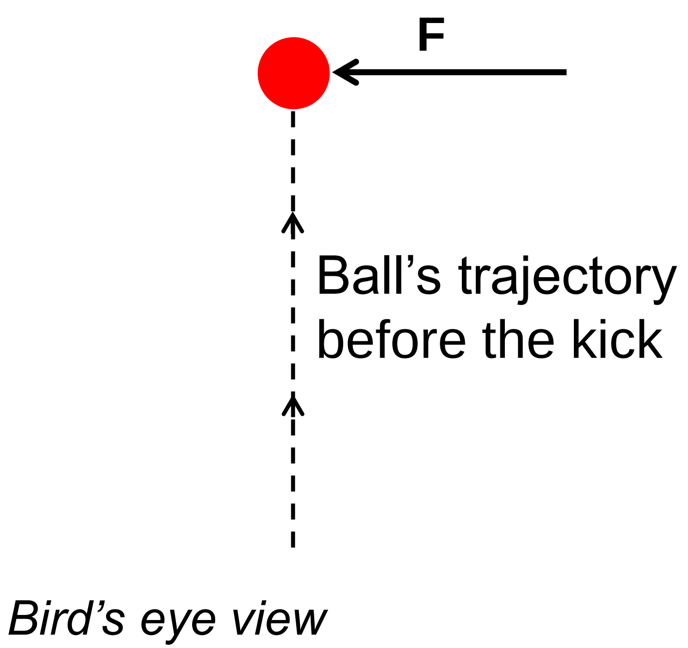
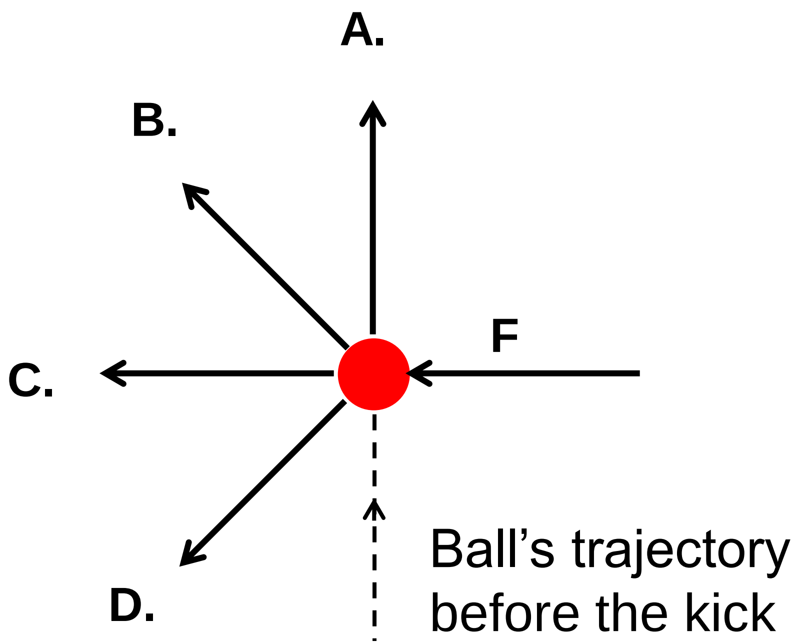
Forces in Circular Motion



Change in Momentum I

A ball is rolling in a straight line on a horizontal surface. You decide to kick the ball from the right, applying a strong force over a short period of time as shown. Along which path will the ball move?





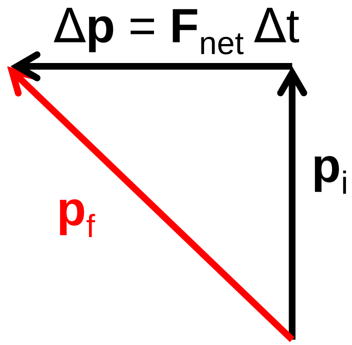
Solution

Answer: B

Justification: The force from the kick will change the momentum of the ball.

The final momentum of the ball is found by adding the change in momentum created by the force to the initial momentum.

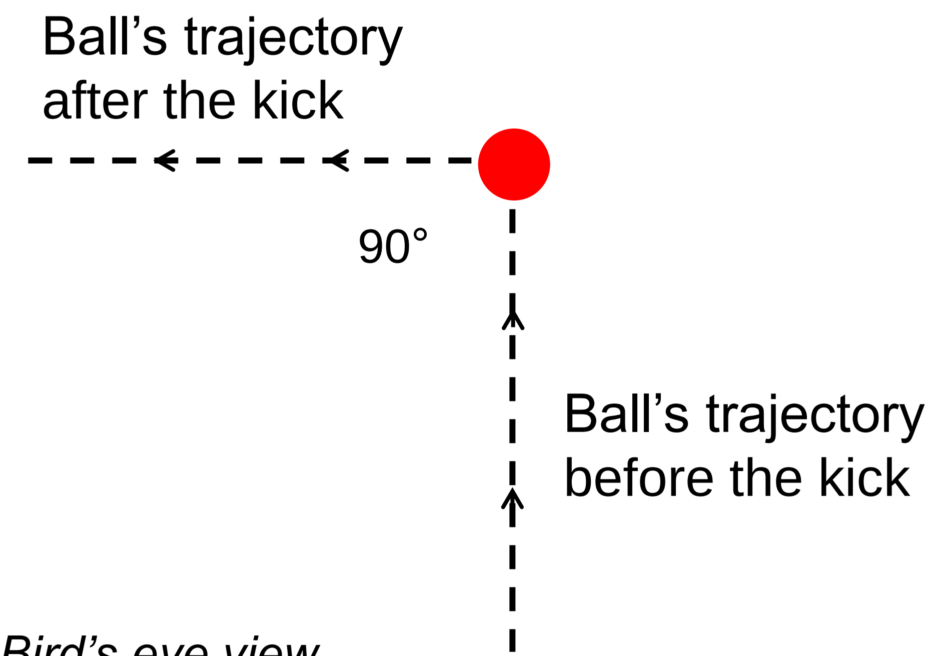
$$\mathbf{p}_f = \mathbf{p}_i + \mathbf{F}_{net}\Delta t$$



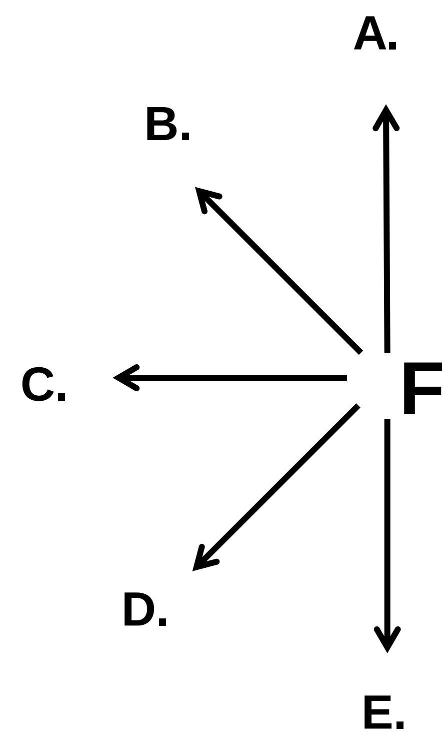
Adding the two vectors $\mathbf{p}_i$ and $\Delta\mathbf{p}$ gives the vector $\mathbf{p}_f$:

Change in Momentum II

A ball is rolling in a straight line on a horizontal surface. You want the ball to make a 90° turn after you kick the ball. In which direction should you apply the force on the ball?



Bird's eye view



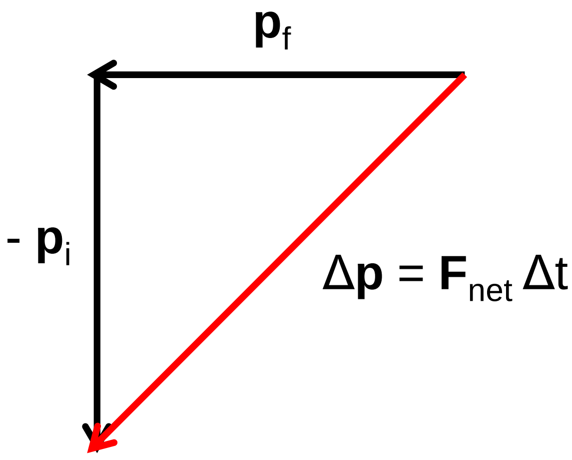
Solution

Answer: D

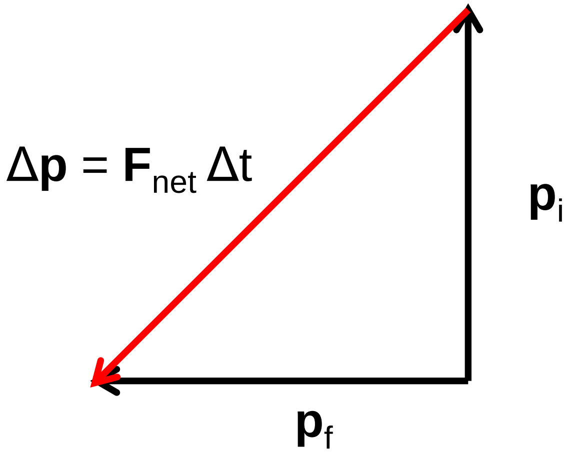
Justification: The force from the kick should be in the direction of the change in momentum.

$$\mathbf{F}_{net} = \frac{\Delta \mathbf{p}}{\Delta t}$$

Subtracting the initial momentum from the final momentum gives the direction of the change in momentum:

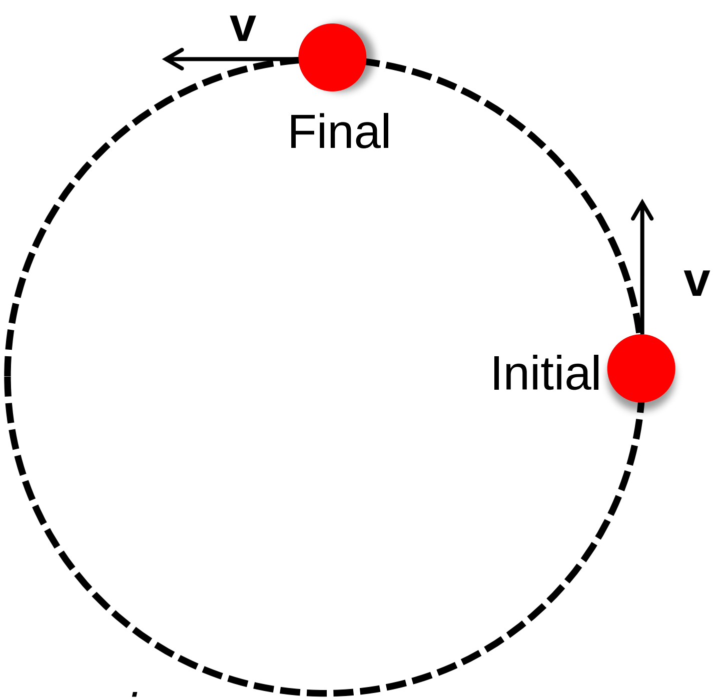


OR



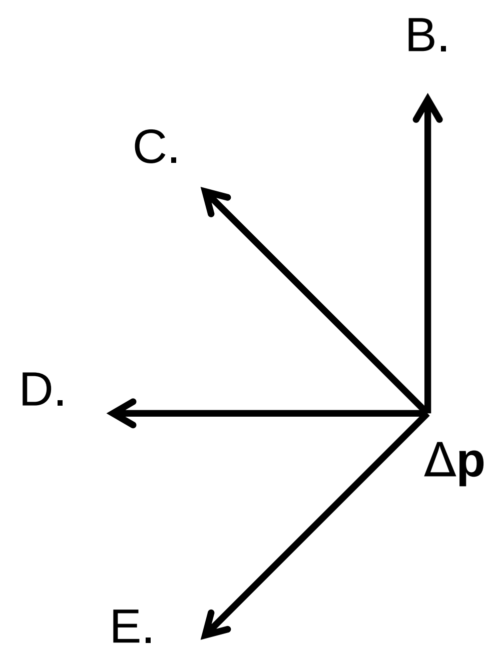
Change in Momentum III

A ball is rolling in a counter-clockwise circle on a horizontal surface at *constant speed*. Consider the initial and final points along the circle as shown. Has the momentum of the ball changed? If so, what is the direction of the change in momentum?



Bird's eye view

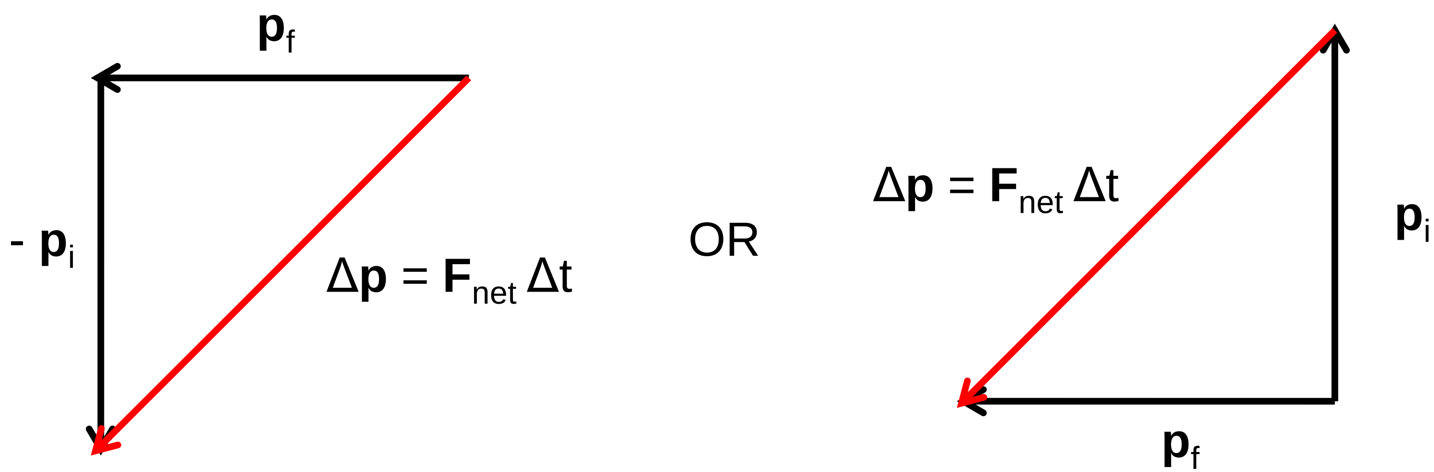
A. No change in momentum



Solution

Answer: E

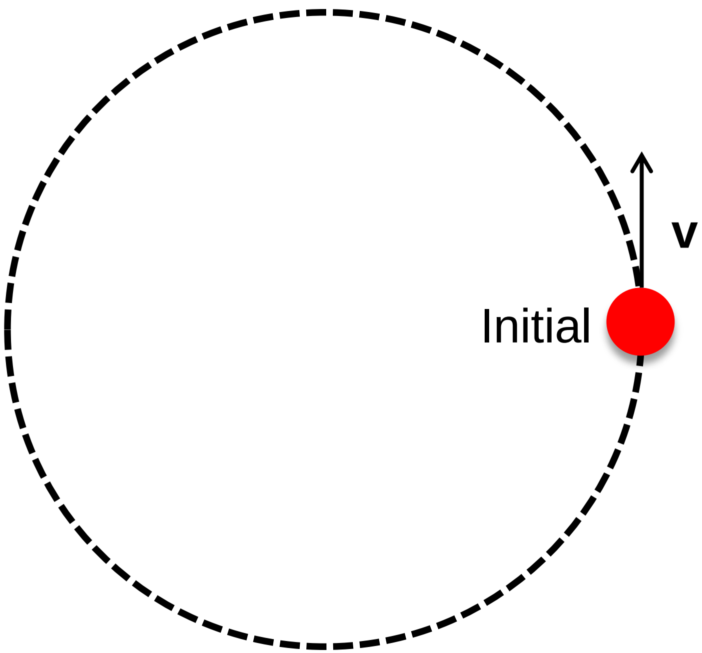
Justification: Subtracting the initial momentum from the final momentum gives:



Even though the ball is moving with constant speed, the direction of velocity has changed. A force must be applied to the ball in order for it to change direction.

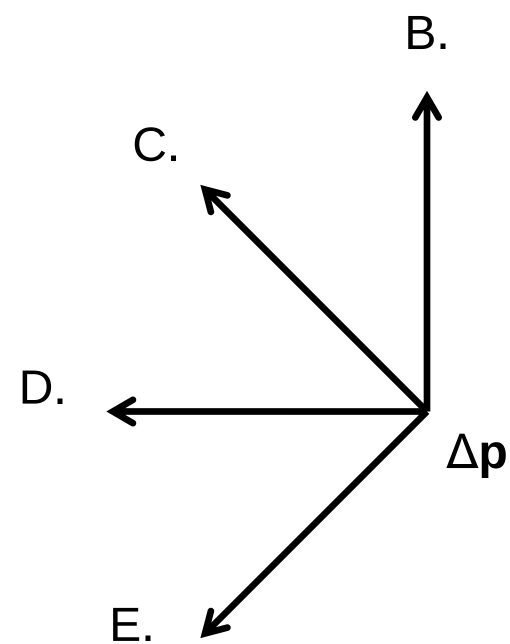
Change in Momentum IV

A ball is rolling in a counter-clockwise circle on a horizontal surface at <u>*constant speed*</u>. Consider the ball at the initial position shown. A fraction of a second later, the ball has moved a small distance along the circle. What is the direction of the change in momentum, if any?



Bird's eye view

A. No change in momentum

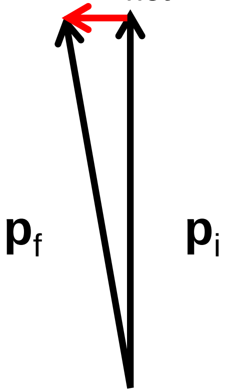


Solution

Answer: D

Justification: A fraction of a second later, the final momentum will be in the direction shown:

$\Delta\mathbf{p} = \mathbf{F}_{net}\,\Delta t$

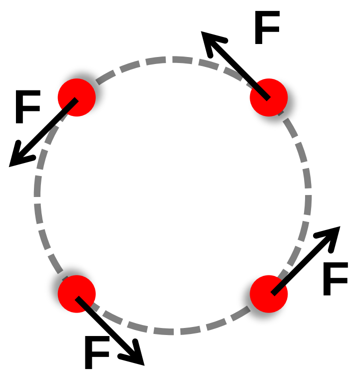


Even though the ball is moving at constant speed, there is still a force required to change the direction of the ball.

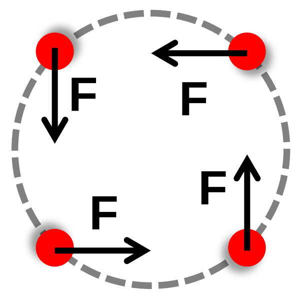
Forces in a Circle I

A red ball is moving counter-clockwise at constant speed. Which of the following correctly shows the direction of the *force* acting on the ball at the given positions?

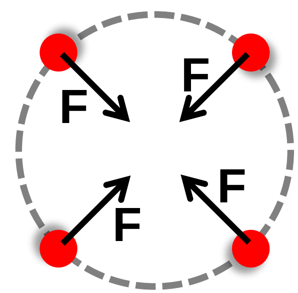
A.



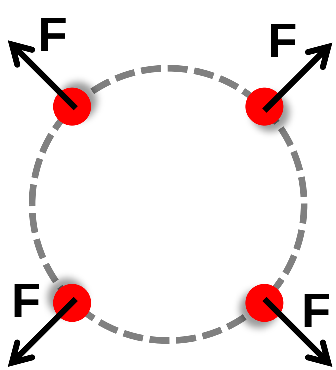
B.



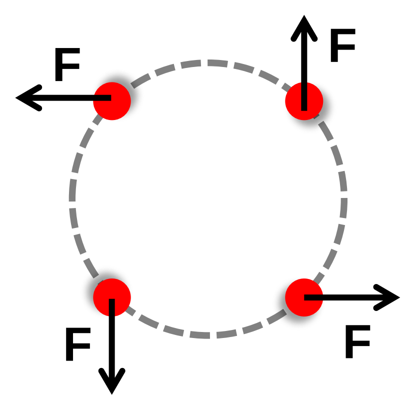
C.



D.



E.



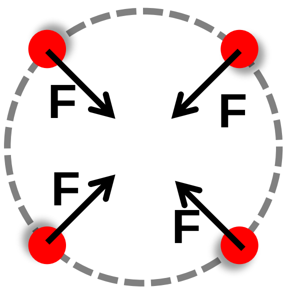
Bird's eye view

Solution

Answer: C

Justification: From the previous question, we saw the force changing the direction of the ball acts perpendicular to the velocity of the ball, pointing towards the center.

C.



The force that causes the ball to move in its circular path is called the centripetal force. The centripetal force points towards the center of the curve.

Important: *The "centripetal force" has a misleading name since it is not a new kind of force. It simply describes another force, such as tension or friction.*

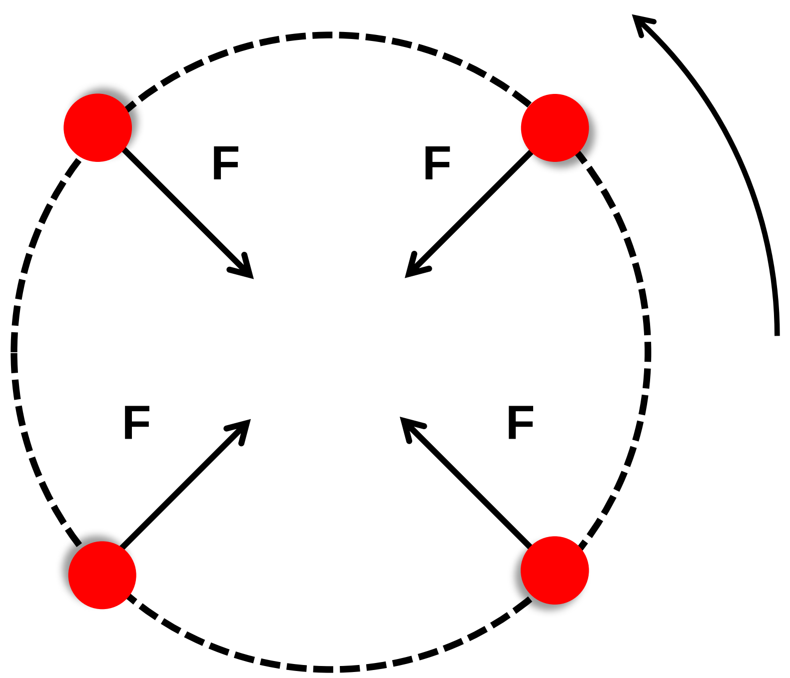
Solution continued

Looking at all the options:

A. This is the tangential force which would cause a change in the magnitude of the velocity
B. This is a partly tangential and partly radial (or centripetal) force it is a resultant vector of options A & C when combined. The tangential component of this vector would cause a change in the magnitude of velocity
C. This is a radial (or centripetal) force whose only affect is to change the direction of motion. In this case, it is keeping the ball moving in a circular motion. This is the correct option for this scenario.
D. This is a force along the radius of the circle but since it is pointing outwards it would pull the ball away from its current path.
D. This is a resultant vector of options A & D when combined. The tangential and radial components of this vector would cause a change in the magnitude of velocity.

Forces in a Circle II

The diagram below shows the forces on a ball at various points along a circle when moving counter-clockwise. How do the forces look when moving clockwise?



Bird's eye view

A. All forces point in the opposite direction

→ ←

B. All forces are rotated 90° in the clockwise direction

→ ↓

C. All forces are rotated 90° in the counter-clockwise direction

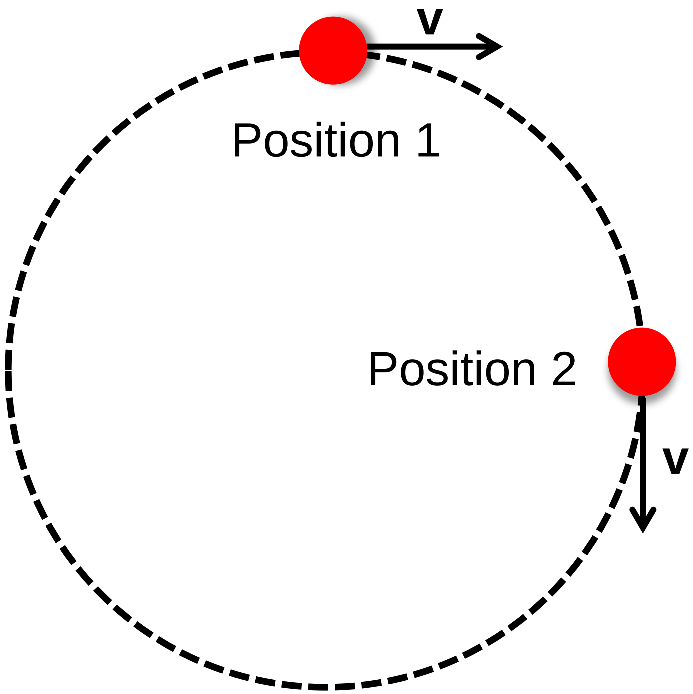
→ ↑

D. No change in direction

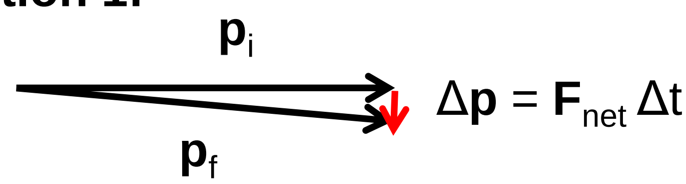
Solution

Answer: D

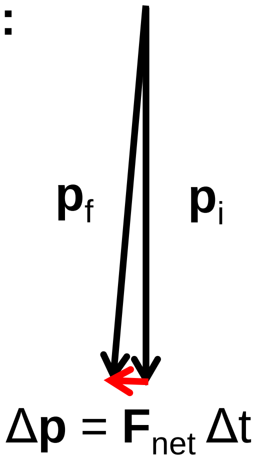
Justification: The force acting on the ball will still point towards the center of the circle, whether the ball is moving clockwise or counter-clockwise. The diagrams show the direction of the force when the ball is at two different positions:



Position 1:

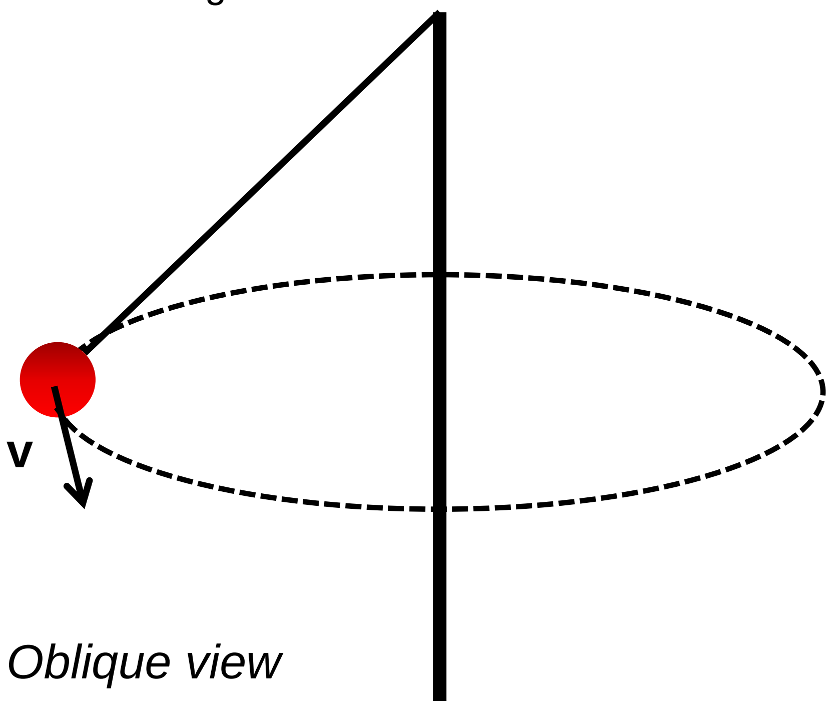


Position 2:

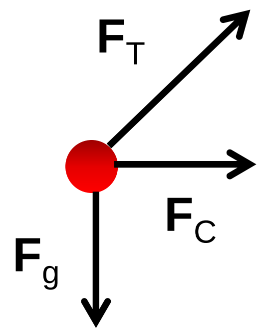


Forces in a Circle III

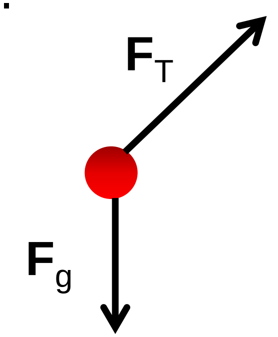
A ball attached to a vertical pole swings around in a counter-clockwise circle at a constant speed. Which of the following free-body diagrams correctly shows the forces acting on the ball? The ball in the free-body diagrams are moving out of the page. (Ignore air resistance, $\mathbf{F}_T$ = tension, $\mathbf{F}_g$ = gravitational, $\mathbf{F}_C$ = centripetal)



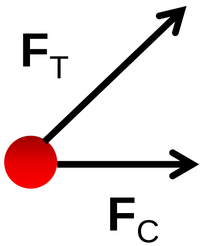
A.



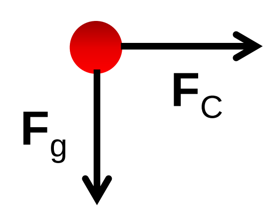
B.



C.



D.



Solution

Answer: B.

Justification: There is only the force of gravity and tension from the string acting on the ball. Notice that the vertical component of the tension force is balanced by the gravitational force. The remaining horizontal component of the tension force pulls the ball in the circle.

Important: *The "centripetal force" has a misleading name since it is not a new kind of force. It simply describes another force directed towards a centre of a circle, such as the tension force in this case.*