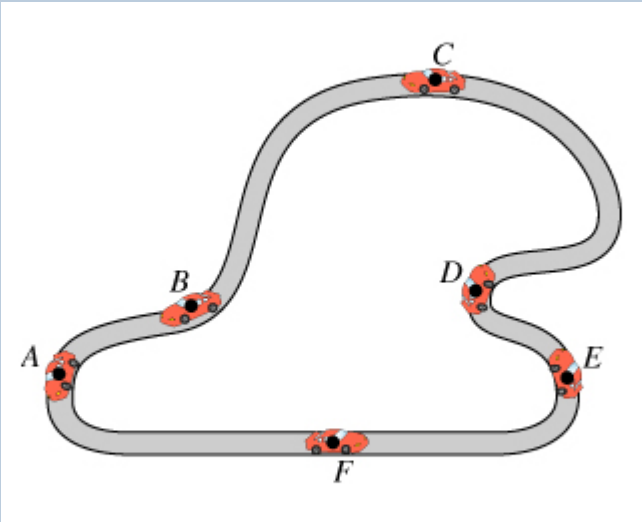
#6 2D Motion & Relative Motion Pre-class

Due: 11:00am on Wednesday, September 5, 2012

Note: You will receive no credit for late submissions. To learn more, read your instructor's Grading Policy

Accelerating along a Racetrack

A road race is taking place along the track shown in the figure . All of the cars are moving at constant speeds. The car at point F is traveling along a straight section of the track, whereas all the other cars are moving along curved segments of the track.



Part A

Let $\vec{v}_A$ be the velocity of the car at point A. What can you say about the acceleration of the car at that point?

Hint 1. Acceleration along a curved path

Since acceleration is a vector quantity, an object moving at constant speed along a curved path has nonzero acceleration because the direction of its velocity $\vec{v}$ is changing, even though the magnitude of its velocity (the speed) is constant. Moreover, if the speed is constant, the object's acceleration is always perpendicular to the velocity vector $\vec{v}$ at each point along the curved path and is directed toward the center of curvature of the path.

ANSWER:

- The acceleration is parallel to $\vec{v}_A$.
- The acceleration is perpendicular to $\vec{v}_A$ and directed toward the inside of the track.
- The acceleration is perpendicular to $\vec{v}_A$ and directed toward the outside of the track.
- The acceleration is neither parallel nor perpendicular to $\vec{v}_A$.
- The acceleration is zero.

Correct

Part B

Let $\vec{v}_C$ be the velocity of the car at point C. What can you say about the acceleration of the car at that point?

Hint 1. Acceleration along a curved path

Since acceleration is a vector quantity, an object moving at constant speed along a curved path has nonzero acceleration because the direction of its velocity $\vec{v}$ is changing, even though the magnitude of its velocity (the speed) is constant. Moreover, if the speed is constant, the object's acceleration is always perpendicular to the velocity vector $\vec{v}$ at each point along the curved path and is directed toward the center of curvature of the path.

ANSWER:

- The acceleration is parallel to $\vec{v}_C$.
- The acceleration is perpendicular to $\vec{v}_C$ and pointed toward the inside of the track.
- The acceleration is perpendicular to $\vec{v}_C$ and pointed toward the outside of the track.
- The acceleration is neither parallel nor perpendicular to $\vec{v}_C$.
- The acceleration is zero.

Correct

Part C

Let $\vec{v}_D$ be the velocity of the car at point D. What can you say about the acceleration of the car at that point?

Hint 1. Acceleration along a curved path

Since acceleration is a vector quantity, an object moving at constant speed along a curved path has nonzero acceleration because the direction of its velocity $\vec{v}$ is changing, even though the magnitude of its velocity (the speed) is constant. Moreover, if the speed is constant, the object's acceleration is always perpendicular to the velocity vector $\vec{v}$ at each point along the curved path and is directed toward the center of curvature of the path.

ANSWER:

- The acceleration is parallel to $\vec{v}_{\rm D}$.
- The acceleration is perpendicular to $\vec{v}_{\rm D}$ and pointed toward the inside of the track.
- The acceleration is perpendicular to $\vec{v}_{\rm D}$ and pointed toward the outside of the track.
- The acceleration is neither parallel nor perpendicular to $\vec{v}_{\rm D}$.
- The acceleration is zero.

Correct

Part D

Let $\vec{v}_{\rm F}$ be the velocity of the car at point F. What can you say about the acceleration of the car at that point?

Hint 1. Acceleration along a straight path

The velocity of an object that moves along a straight path is always parallel to the direction of the path, and the object has a nonzero acceleration only if the magnitude of its velocity changes in time.

ANSWER:

- The acceleration is parallel to $\vec{v}_F$.
- The acceleration is perpendicular to $\vec{v}_F$ and pointed toward the inside of the track.
- The acceleration is perpendicular to $\vec{v}_F$ and pointed toward the outside of the track.
- The acceleration is neither parallel nor perpendicular to $\vec{v}_F$.
- The acceleration is zero.

Correct

Part E

Assuming that all cars have equal speeds, which car has the acceleration of the greatest magnitude, and which one has the acceleration of the least magnitude?

Use A for the car at point A, B for the car at point B, and so on. Express your answer as the name the car that has the greatest magnitude of acceleration followed by the car with the least magnitude of accelation, and separate your answers with a comma.

Hint 1. How to approach the problem

Recall that the magnitude of the acceleration of an object that moves at constant speed along a curved path is inversely proportional to the radius of curvature of the path.

ANSWER:

D,F

Correct

Part F

Assume that the car at point A and the one at point E are traveling along circular paths that have the same radius. If the car at point A now moves twice as fast as the car at point E, how is the magnitude of its acceleration related to that of car E.

Hint 1. Find the acceleration of the car at point E

Let r be the radius of the two curves along which the cars at points A and E are traveling. What is the magnitude $a_{\rm E}$ of the acceleration of the car at point E?

Express your answer in terms of the radius of curvature r and the speed $v_{\rm E}$ of car E.

Hint 1. Uniform circular motion

The magnitude a of the acceleration of an object that moves with constant speed v along a circular path of radius r is given by

$$a = \frac{v^2}{r}.$$

ANSWER:

$a_{\rm E}$ = $\frac{{v_E}^2}{r}$

Hint 2. Find the acceleration of the car at point A

If $v_A = 2v_E$, what is the acceleration $a_{\rm A}$ of the car at point A? Let r be the radius of the two curves along which the cars at points A and E are traveling.

Express your answer in terms of the speed $v_{\rm E}$ of the car at E and the radius r.

Hint 1. Uniform circular motion

The magnitude of the acceleration of an object that moves with constant speed v along a circular path of radius r is given by

$$a = \frac{v^2}{r}.$$

ANSWER:

$a_{\rm A}$ = $\frac{4{v_E}^2}{r}$

ANSWER:

- The magnitude of the acceleration of the car at point A is twice that of the car at point E.
- The magnitude of the acceleration of the car at point A is the same as that of the car at point E.
- The magnitude of the acceleration of the car at point A is half that of the car at point E.
- The magnitude of the acceleration of the car at point A is four times that of the car at point E.

Correct

An Object Accelerating on a Ramp

Learning Goal:

Understand that the acceleration vector is in the direction of the change of the velocity vector.

In one dimensional (straight line) motion, acceleration is accompanied by a change in speed, and the acceleration is always parallel (or antiparallel) to the velocity.
When motion can occur in two dimensions (e.g. is confined to a tabletop but can lie anywhere in the x-y plane), the definition of acceleration is

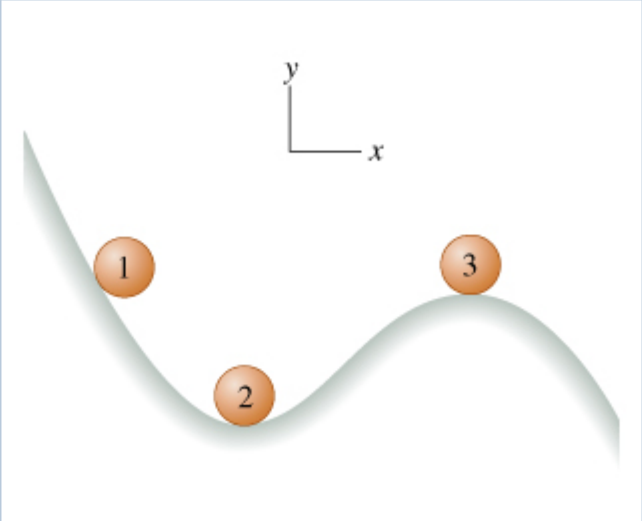
$$\vec{a}(t) = \frac{\vec{v}(t+\Delta t) - \vec{v}(t)}{\Delta t} \text{ in the limit } \Delta t \to 0.$$

In picturing this vector derivative you can think of the derivative of a vector as an instantaneous quantity by thinking of the velocity of the tip of the arrow as the vector changes in time. Alternatively, you can (for small Δt) approximate the acceleration as

$$\vec{a}(t) \approx \frac{\vec{v}(t+\Delta t) - \vec{v}(t)}{\Delta t}.$$

Obviously the difference between $\vec{v}(t+\Delta t)$ and \vec{v}(t) is another vector that can lie in any direction. If it is longer but in the same direction, \vec{a}(t) will be parallel to \vec{v}(t). On the other hand, if $\vec{v}(t+\Delta t)$ has the same magnitude as \vec{v}(t) but is in a slightly different direction, then \vec{a}(t) will be perpendicular to $\vec{v}$. In general, $\vec{v}(t+\Delta t)$ can differ from \vec{v}(t) in both magnitude *and* direction, hence \vec{a}(t) can have any direction relative to \vec{v}(t).

This problem contains several examples of this.Consider an object sliding on a frictionless ramp as depicted here. The object is already moving along the ramp toward position 2 when it is at position 1. The following questions concern the direction of the object's acceleration vector, a_vec. In this problem, you should find the direction of the acceleration vector by drawing the velocity vector at two points near to the position you are asked about. Note that since the object moves along the track, its velocity vector at a point will be tangent to the track at that point. The acceleration vector will point in the same direction as the vector difference of the two velocities. (This is a result of the equation \vec{a}(t) \approx (\vec{v}(t+\Delta t) - \vec{v}(t))/\Delta t given above.)



Part A

Which direction best approximates the direction of a_vec when the object is at position 1?

Hint 1. Consider the change in velocity

At this point, the object's velocity vector is not changing direction; rather, it is increasing in magnitude. Therefore, the object's acceleration is nearly parallel to its velocity.

ANSWER:

- straight up
- downward to the left
- downward to the right
- straight down

Correct

Part B

Which direction best approximates the direction of a_vec when the object is at position 2?

Hint 1. Consider the change in velocity

At this point, the speed has a local maximum; thus the magnitude of $\vec{v}$ is not changing. Therefore, no component of the acceleration vector is parallel to the velocity vector. However, since the direction of $\vec{v}$ is changing there is an acceleration.

ANSWER:

- straight up
- upward to the right
- straight down
- downward to the left

Correct

Even though the acceleration is directed straight up, this does not mean that the object is moving straight up.

Part C

Which direction best approximates the direction of a_vec when the object is at position 3?

Hint 1. Consider the change in velocity

At this point, the speed has a local minimum; thus the magnitude of $\vec{v}$ is not changing. Therefore, no component of the acceleration vector is parallel to the velocity vector. However, since the direction of $\vec{v}$ is changing there is an acceleration.

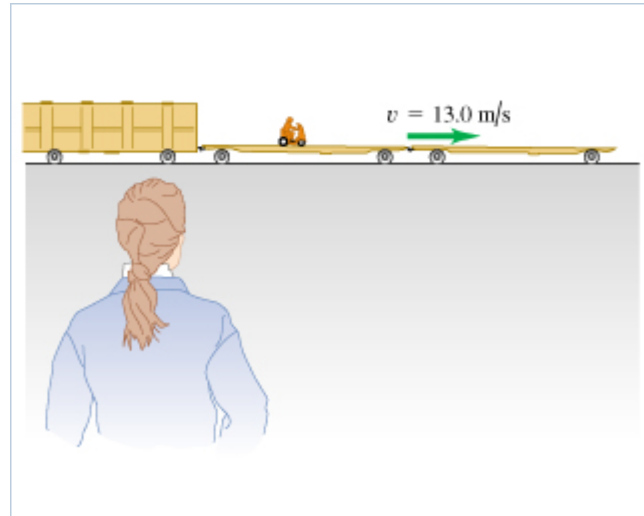
ANSWER:

- upward to the right
- to the right
- straight down
- downward to the right

Correct

Exercise 3.36

A railroad flatcar is traveling to the right at a speed of 13.0 $\mathrm{m/s}$ relative to an observer standing on the ground. Someone is riding a motor scooter on the flatcar .



Part A

What is the magnitude of the velocity of the motor scooter relative to the flatcar if its velocity relative to the observer on the ground is 18.0 $\mathrm{m/s}$ to the right?

Express your answer using two significant figures.

ANSWER:

v = 5.0 $\mathrm{m/s}$

Correct

Part B

What is the direction of the velocity of the motor scooter relative to the flatcar in this case?

ANSWER:

- (selected) To the right
- To the left

Correct

Part C

What is the magnitude of the velocity of the motor scooter relative to the flatcar if its velocity relative to the observer on the ground is 3.0 m/s to the left?

ANSWER:

v = 16.0 $\mathrm{m/s}$

Correct

Part D

What is the direction of the velocity of the motor scooter relative to the flatcar in this case?

ANSWER:

- To the right
- To the left

Correct

Part E

What is the magnitude of the velocity of the motor scooter relative to the flatcar if its velocity relative to the observer on the ground is zero?

ANSWER:

v = 13.0 $\mathrm{m/s}$

Correct

Part F

What is the direction of the velocity of the motor scooter relative to the flatcar in this case?

ANSWER:

- To the right
- To the left

Correct

Exercise 3.41: Crossing the River I

A river flows due south with a speed of 2.2$\mathrm{m/s}$. A man steers a motorboat across the river; his velocity relative to the water is 3.2$\mathrm{m/s}$ due east. The river is 650m wide.

Part A

What is the magnitude of his velocity relative to the earth?

Express your answer using two significant figures.

ANSWER:

v = 3.9 $\mathrm{m/s}$

Correct

Part B

What is the direction of his velocity relative to the earth?

Express your answer using two significant figures.

ANSWER:

\phi = 35 ° between his velocity and the direction to the east

Correct

Part C

How much time is required to cross the river?

Express your answer using two significant figures.

ANSWER:

t = 200 {\rm s}

Correct

Part D

How far south of his starting point will he reach the opposite bank?

Express your answer using two significant figures.

ANSWER:

L = 450 m

Correct

Score Summary:

Your score on this assignment is 70.1%.
You received 14.01 out of a possible total of 20 points.