Important Information

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New Course Webpage *(To be setup by this weekend)*

http://people.physics.tamu.edu/tyana/PHYS218/

All grade distributions, homework, and Smart Physics assignments will remain the same. All deadlines, test days etc. will be unchanged.
Motion in 2 and 3 Dimensions

• Relative Motion

• Uniform Circular Motion

✧ Chapter 3 examples
Reminder from last time: 2D projectile motion

A ball is fired up in the air with velocity $V_0$ and angle $\theta_0$. (Ignore air resistance.)

What is the final velocity?

Right here

**Hint:** it is **NOT** zero!
Example: Football Punt

A football is kicked at an angle $\theta_0$ with a velocity $v_0$. The ball leaves his foot at a height $h$ above the ground. Find:

a) The velocity at the maximum height.
b) How far it travels, in the $x$-direction, before it hits the ground.

\[
v = \frac{d}{t}
\]
\[
 a_y = -g
\]

\[
 v_y \text{ top} = 0
\]
\[
 v_x \text{ top} = v_{x0} = \text{const} \quad a_x = 0
\]

\[
 v_{0x} = v_0 \cos \theta
\]

\[
 y = y_0 + v_{y0}t + \frac{1}{2}a_y t^2
\]
\[
 0 = h + v_0 \sin \theta t - \frac{1}{2}gt^2
\]
\[
 t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}
\]
\[
 = \frac{2a}{2(-g)}
\]
\[
 = \frac{v_0 \sin \theta}{g} \pm \frac{1}{g} \sqrt{(v_0 \sin \theta)^2 - 4 \left(\frac{1}{2}g\right)h}
\]

\[
 t = \frac{v_0 \sin \theta}{g} \pm \frac{1}{g} \sqrt{(v_0 \sin \theta)^2 - 2gh}
\]

\[
 d = v_x t
\]
Clicker Question

In the previous problem, what angle minimizes the horizontal distance traveled?

A) $\theta = 0$ degrees

B) $\theta = 30$ degrees

C) $\theta = 45$ degrees

D) $\theta = 90$ degrees
High School Survey Question

• How familiar are you with the concepts of relative motion and centripetal acceleration from your high school course.

A) I already know this stuff
B) It seems familiar, but I need a review
C) We didn't learn this in high school

About 4/5 of you don’t feel very comfortable with this material.
**Pre-lecture and Checkpoint Questions**

**Relative Motion**

- A = Mike
- B = Train
- C = Ground

\[\vec{V}_{ac} = \vec{V}_{ab} + \vec{V}_{bc}\]

\[v_{Mike, Ground} = \frac{1\text{ m}}{s}\]

\[v_{Train, Ground} = \frac{30\text{ m}}{s}\]

What you just did:

\[\vec{V}_{ac} = \vec{V}_{ab} + \vec{V}_{bc}\]
The diagram shows a snapshot at time $t = 0$ of two balls on a collision course. At $t = 0$, the balls are separated by a distance $D = 12$ m. The blue ball moves with constant velocity $v_B = 6$ m/s due East, while the red ball moves with constant velocity $v_R = 2$ m/s due West.

Which of the following graphs correctly describes the motion of the blue ball in the reference frame of the red ball? Take the origin to be the position of the red ball and the positive direction to be East.
Prelecture: Question 1 Answer

(a)  
(b)  
(c)  
(d)  

First Answer Choice Distribution (N = 109)

<table>
<thead>
<tr>
<th>Option</th>
<th>% of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7.3</td>
</tr>
<tr>
<td>B</td>
<td>36.7</td>
</tr>
<tr>
<td>C</td>
<td>22</td>
</tr>
<tr>
<td>D</td>
<td>33.9</td>
</tr>
</tbody>
</table>
A swimmer wishes to swim across the stream as shown. She knows she can maintain a constant speed $v_s = 0.4 \text{ m/s}$ with respect to the water. The water in the stream moves with speed $v_w = 0.5 \text{ m/s}$ as shown.

Which of the following statements is true?

a) She will not be able to cross the stream since $v_s < v_w$.

b) She will be able to cross the stream but since $v_s < v_w$, she will never be able to reach any point upstream of $X$, but will be able to reach point $X$ by choosing an appropriate heading.

c) She will be able to cross the stream but since $v_s < v_w$, she will never be able to reach point $X$, no matter what heading she chooses.
Prelecture: Question 2 Answer

a) She will not be able to cross the stream since $v_s < v_w$.
b) She will be able to cross the stream but since $v_s < v_w$, she will never be able to reach any point upstream of X, but will be able to reach point X by choosing an appropriate heading.
c) She will be able to cross the stream but since $v_s < v_w$, she will never be able to reach point X, no matter what heading she chooses.

First Answer Choice Distribution (N = 108)

![Histogram showing the distribution of first answer choices with 50.9% for option B and 44.4% for option C. The options are labeled A, B, and C, with A having 4.6% of the students.]
A girl stands on a moving sidewalk (conveyor belt) that is moving to the right at a speed of 2 m/s relative to the ground.
A dog runs on the belt toward the girl at a speed of 8 m/s relative to the belt.

1) What is the speed of the dog relative to the ground?

\[ v_{\text{dog,ground}} = v_{\text{dog, belt}} + v_{\text{belt, ground}} \]

a) 6 m/s  
b) 8 m/s  
c) 10 m/s

\[ v_{\text{dog,ground}} = (-8 \, \text{m/s}) + (2 \, \text{m/s}) = -6 \, \text{m/s} \]
1) What is the speed of the dog relative to the girl?
   a) 6 m/s
   b) 8 m/s
   c) 10 m/s
What is the speed of the dog relative to the girl?

A) Because the girl is actually moving and the two vectors are opposite, so together they make 6 m/s

B) Because the girl is not moving relative to the belt, and the dog is going 8 m/s relative to the belt, the dog is also moving 8 m/s relative to the girl..

C) The dog and girl are running towards each other so when you add the two velocities together it would be 8+2.

A) 6 m/s  B) 8 m/s  C) 10 m/s
What is the speed of the dog relative to the girl?

B) Because the girl is not moving relative to the belt, and the dog is going 8 m/s relative to the belt, the dog is also moving 8 m/s relative to the girl.

Using the velocity formula:

\[ v_{\text{dog, girl}} = v_{\text{dog, belt}} + v_{\text{belt, girl}} \]

\[ = -8 \text{ m/s} + 0 \text{ m/s} \]

\[ = -8 \text{ m/s} \]
A man starts to walk along the dotted line painted on a moving sidewalk toward a fire hydrant that is directly across from him. The width of the walkway is 4 m, and it is moving at 2 m/s relative to the fire-hydrant. If his walking speed is 1 m/s, how far away will he be from the hydrant when he reaches the other side?

A) 2 m  
B) 4 m  
C) 6 m  
D) 8 m
A man starts to walk along the dotted line painted on a moving sidewalk toward a fire hydrant that is directly across from him. The width of the walkway is 4 m, and it is moving at 2 m/s relative to the fire-hydrant. If his walking speed is 1 m/s, how far away will he be from the hydrant when he reaches the other side?

A) 2 m
B) 4 m
C) 6 m
D) 8 m
So how did we find that again???

If the sidewalk wasn’t moving:

Time to get across:

$$\Delta t = \frac{\text{distance}}{\text{speed}}$$

$$= \frac{4 \text{m}}{1 \text{m/s}}$$

$$= 4 \text{ s}$$
Just the sidewalk

\[ \vec{V}_{\text{sidewalk, hydrant}} \]

2 m/s

4 m
Combination of motions

\[ \vec{v}_{\text{man, hydrant}} = \vec{v}_{\text{man, sidewalk}} + \vec{v}_{\text{sidewalk, hydrant}} \]
Finding the distance the sidewalk travels relative to the hydrant

\[ D = (\text{speed of sidewalk}) \cdot (\text{time to get across}) \]

\[ = (2 \text{ m/s}) \cdot (4 \text{ s}) = 8 \text{ m} \]
Clicker Question

- Three swimmers can swim equally fast relative to the water. They have a race to see who can swim across a river in the least time. Relative to the water, Beth swims perpendicular to the flow, Ann swims upstream at 30 degrees, and Carly swims downstream at 30 degrees.

\[ |v| = \text{const.} \]

- Who gets across the river first?

- A) Ann   B) Beth   C) Carly
Look at just water & swimmers

Time to get across $= \frac{D}{V_y}$

$V_{y,Beth} = V_o$

$V_{y,Ann} = V_o \cos(30^\circ)$

$V_{y,Carly} = V_o \cos(30^\circ)$
Three swimmers can swim equally fast relative to the water. They have a race to see who can swim across a river in the least time. Relative to the water, Beth swims perpendicular to the flow, Ann swims upstream at 30 degrees, and Carly swims downstream at 30 degrees. Beth makes it across first.

Who gets across the river second?

A) Ann    B) Carly    C) Both same
You want to cross the river so that the boat gets exactly from A to B. The river has a current $v_c = 4 \text{ km/h}$. Your boat’s speed in still water is $v_B = 20 \text{ km/h}$?

What is the angle $\theta$ you should aim at to do that?

$V_{\text{boat, river}} = -20 \text{ km/h} \sin \theta$

$V_{\text{river, ground}} = 4 \text{ km/h}$

$0 = -20 \text{ km/h} \sin \theta + 4 \text{ km/h}$

$\sin \theta = \frac{1}{5}$

$\theta = 11.5^\circ$
In previous problem, is it possible to get from A to B for any values for \( v_B \) and \( v_C \)?

A. Yes, always possible

B. Only possible if \( v_B > v_C \)

C. Only possible if \( v_B > 2v_C \)

D. Only possible if \( v_B \gg v_C \) (much larger)
Check Point Circular Motion

A girl twirls a rock on the end of a string around in a horizontal circle above her head as shown from above in the diagram.

If the string breaks at the instant shown, which of the arrows best represents the resulting path of the rock?

After the string breaks, the rock will have no force acting on it, so it cannot accelerate. Therefore, it will maintain its velocity at the time of the break in the string, which is directed tangent to the circle.
Uniform Circular Motion

- Fancy words for moving in a circle with constant *speed*
- We see this around us all the time
  - Moon around the earth
  - Earth around the sun
  - Merry-go-rounds
• Velocity vector = $|V|$ tangent to the circle

• Is this ball accelerating?
  ➢ Why?
Centripetal Acceleration

\[ \vec{a} = \frac{d\vec{v}}{dt} \approx \frac{(\vec{v}_2 - \vec{v}_1)}{dt} \]

- Vector difference \( \vec{V2} - \vec{V1} \) gives the direction of acceleration \( \vec{a} \)

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09/17/2014
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Centripetal Acceleration
Centripetal Acceleration

Angular Velocity

\[ \omega = \frac{v}{R} = \frac{d\theta}{dt} \]

Centripetal Acceleration

\[ a_c = \frac{v^2}{R} = \omega^2 R \]
Angular Velocity

\[ v = \omega R \]

\( \omega \) is the rate at which the angle \( \theta \) changes:

\[ \omega = \frac{d\theta}{dt} \]

Once around:

\[ v = \frac{\Delta x}{\Delta t} = \frac{2\pi R}{T} \quad [\text{m/s}] \]

\[ \omega = \frac{\Delta \theta}{\Delta t} = \frac{2\pi}{T} \quad [\text{rad/s}] \]
Speed = distance/time

- Distance in 1 revolution divided by the time it takes to go around once

\[ \text{Speed} = \frac{2\pi r}{T} \]

Note: The time to go around once is known as the Period, or \( T \)
A model of a helicopter rotor has 4 blades, each 3.40 m long from the center. It is rotated at 550 rpm.

a) What is the linear speed of the tip, in m/s?
b) What is the radial acceleration of the tip, in g's?

\[
v = \frac{\text{dist}}{\text{time}} = \frac{550 \times (2\pi R)}{60 \text{ sec}} = 196 \text{ m/s}
\]

\[
a_c = \frac{v^2}{R} = \frac{(196 \text{ m/s})^2}{3.40 \text{ m}} = 11298 \text{ m/s}^2 \times \frac{1 \text{ g}}{9.8 \text{ m/s}^2} = 1153 \text{ g}
\]
A pendulum swings back and forth, reaching a maximum angle of 45° from the vertical. Which arrow shows the direction of the pendulum bob’s acceleration at $P$ (the far left point of the motion)?

a) #1 (up and to the left)
b) #2 (up and to the right)
c) #3 (down and to the right)
d) #4 (straight down)
e) #5 (down and to the left)