Supplemental Instruction Schedule

Tuesdays 8:30 - 9:20 am..............JWB 308
Wednesdays 3:00 - 3:50 pm.........JFB B-1
Thursdays 11:30am - 12:20 pm......LCB 121

Reminder of Important Dates

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<th>Events</th>
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<td>Labor Day holiday</td>
<td>Monday, September 7</td>
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<td>Tuition payment due</td>
<td>Friday, September 4</td>
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<td>Classes begin</td>
<td>Monday, August 24</td>
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<td>Last day to add without a permission code</td>
<td>Sunday, August 30</td>
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<td>Last day to add, drop (delete), elect CR/NC, or audit classes</td>
<td>Friday, September 4</td>
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<td>Last day to withdraw from classes</td>
<td>Friday, October 23</td>
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Relative velocities are especially important in navigation. In strong “cross-winds”: airplanes have to point in a different direction than runway in order to land.

We had $\vec{v}_B = \vec{v}_{BA} + \vec{v}_A$

Here: $\vec{v}_r = \vec{v}_p + \vec{v}_w$

**B: plane**

$\vec{v}_r$: ground velocity

$\vec{v}_p$: air velocity (relative to air)

**A: wind**

$\vec{v}_w$: wind velocity (relative to ground)

B52 bombers have (for a long time classified) feature of articulated landing gears that allow the wheels to point forward while the plane is rotated to offset the wind velocity.

http://www.youtube.com/watch?v=TCUHQL6Qg
Example 3.2 (1/2)

You are traveling on an airplane. The velocity of the plane with respect to the air is 130 m/s due east. The velocity of the air with respect to the ground is 47 m/s at an angle of 30° west of due north.

(a) What is the speed of the plane with respect to the ground?

```
(%i1) /* let east be +x and north be +y  plane's velocity components relative to air are */
v_pa_x: +130; v_pa_y: 0;
(%o1) 130
(%o2) 0
(%i3) /* 30 deg west of north is 30+90 deg = 120 deg CCW from +x */
phi: 120*%pi/180, numer;
(%o3) 2.094395102393195
(%i4) /* speed of air is 47 m/s ... calculate components */
v_ag: 47;
(%o4) 47
(%i5) v_ag_x: v_ag*cos(phi);
(%o5) - 23.49999999999999
(%i6) v_ag_y: v_ag*sin(phi);
(%o6) 40.70319397786862
(%i7) /* now calculate components of velocity of plane  relatve to ground */
v_pg_x: v_pa_x + v_ag_x;
(%o7) 106.5
(%i9) v_pg_y: v_pa_y + v_ag_y;
(%o9) 40.70319397786862
(%i10) /* speed relatve to ground */
v_pg: sqrt(v_pg_x^2+v_pg_y^2);
(%o10) 114.0131571354815
```

Answer: (a) 114 m/s
You are traveling on an airplane. The velocity of the plane with respect to the air is 130 m/s due east. The velocity of the air with respect to the ground is 47 m/s at an angle of 30° west of due north.

(b) What is the heading of the plane with respect to the ground? (Let 0° represent due north, 90° represents due east)

(c) How far east will the plane travel in 1 hour?

Answer (b) 69 deg east of north

Answer (c) 383.4 km
A girl twirls a rock on the end of a string in a horizontal circle above her head.

The diagram illustrates how this looks from above.

If the string breaks at the instant shown, which arrow best represents the path the rock will follow?
Uniform Circular Motion: The speed is constant
\[
\frac{dv}{dt} \equiv \frac{d|\vec{v}|}{dt} = 0
\]
But the direction of the velocity changes continuously:
\[
\vec{a} \equiv \frac{d\vec{v}}{dt} = -\left(\frac{v^2}{r}\right)\hat{r}
\]

Centripetal Acceleration
\[
a_c \equiv |\vec{a}_c| = \frac{v^2}{r}
\]

Very good supplemental material
Kinematics of Uniform Circular Motion

A similar video was shown in the prelecture

http://www.youtube.com/watch?v=h-85rpR-mRM
Uniform Circular Motion

\[ v = \frac{s}{t}, \quad s = r\phi \]
(\(\phi\) expressed in radians)
\[ \vec{v} = \frac{r\phi}{t} \quad \Rightarrow \quad \phi = \frac{vt}{r} \]

**Position vector:**
\[ \vec{r} = x\hat{i} + y\hat{j} = r\cos\phi\hat{i} + r\sin\phi\hat{j} \]
\[ = r\left[ \cos\left(\frac{v}{r}t\right)\hat{i} + \sin\left(\frac{v}{r}t\right)\hat{j} \right] \]

**Velocity vector:**
\[ \vec{v} \equiv \frac{d\vec{r}}{dt} = \frac{d}{dt}\left[ r\cos\left(\frac{v}{r}t\right)\hat{i} + r\sin\left(\frac{v}{r}t\right)\hat{j} \right] \]
\[ = v\left[ -\sin\left(\frac{v}{r}t\right)\hat{i} + \cos\left(\frac{v}{r}t\right)\hat{j} \right] \]
\[ = \frac{v}{r} \left[ -y\hat{i} + x\hat{j} \right] \]

**Acceleration vector:**
\[ \vec{a} \equiv \frac{d\vec{v}}{dt} = v \frac{d}{dt}\left[ -\sin\left(\frac{v}{r}t\right)\hat{i} + \cos\left(\frac{v}{r}t\right)\hat{j} \right] = \frac{v^2}{r} \left[ -\cos\left(\frac{v}{r}t\right)\hat{i} - \sin\left(\frac{v}{r}t\right)\hat{j} \right] \]
\[ = -\left(\frac{v^2}{r}\right)\hat{r} \]
\[ = -\left(\frac{v^2}{r}\right)\hat{r} \]

**Centripetal Acceleration**
\[ a_c \equiv |\vec{a}_c| = \frac{v^2}{r} \]
If the speed $v$ is allowed to vary, then the total acceleration also has a tangential component:

$$\mathbf{a} = \frac{d\mathbf{v}}{dt} = \mathbf{a}_r + \mathbf{a}_t$$

Components are NOT magnitudes.... They carry a sign to indicate left/right, CCW/CW, east/west, forward/backward.
At the Utah State Fair you are strapped to the outer wall of a centrifuge of radius 1.5m that spins at 60 rpm.

(a) What is the velocity at which you are traveling?

(b) What is the direction and magnitude of the acceleration?

Answer: (a) v=9.42 m/s Directed tangential to the circumference
Example 3.3 (2/2)

(%i5) /* the centripetal (center-seeking) acceleration is given by */
ac: v^2/r;

2                          2
4 %pi  r rpm
------------
 2
Dt

(%o5)

(%i6) ac, r=1.5, rpm=60, Dt=60, numer;
(%o6) 59.21762640653615

(%i8) %/9.81;
(%o8) 6.036455291186152

Answer: ac=59.2 m/s^2, or about 6g directed toward the center
Inertial Reference Frames and Newton’s First Law

Newton’s first law: An object subject to no external forces is at rest or moves with constant velocity if viewed from an inertial reference frame. This law serves to define “inertial reference frames.”

Force, Mass and Newton’s Second Law

Mass is the property of an object that determines how hard it is to change its velocity.

Force is the thing that is responsible for an object’s change in velocity.

Newton’s second law: A force that acts on an object causes that object to accelerate in the same direction that the force acts, and the magnitude of this acceleration is proportional to the magnitude of the force

\[
\vec{a} = \frac{\vec{F}_{\text{Net}}}{m}
\]

This law provides the link between mass and force.
Newton’s Third Law

Newton’s third law: For every action there is an equal and opposite reaction.

All forces come in pairs but act on different objects.

\[ \vec{F}_{AB} = -\vec{F}_{BA} \]

Instructor’s Note:
smartPhysics uses the rather unusual convention of using \( \vec{F}_{AB} \) to denote the force exerted by A on B. Even then it does not do so consistently.

Most other textbooks uses the reverse convention
Scientific Laws:

Generalizations of observed phenomena

Newton’s 1st Law (N1L):

In the absence of (non-zero) net external force (acting on it), an object travels at constant velocity

– Net: “vector sum of all... “

– Absence of net external force DOES NOT MEAN there are no forces acting on the object: **just that they add VECTORIALLY (component-by-component) to ZERO**

– Constant velocity means constant magnitude (speed) AND direction (Cartesian components, \(v_x\), \(v_y\), and \(v_z\) are constant)

– **Internal Forces do NOT count**: They cancel (Newton’s 3rd Law)
Conceptual Example 4.1

The Space Shuttle used to glide on final approach to landing at a constant ~500 mi/hr, and at an angle of 20 degrees below the horizontal.

What forces act ON it?

(1) Force of gravity of magnitude $M \times g$ downward
(2) Lift on the wings (up)
(3) Drag force of air (backwards)

But if the shuttle is traveling at constant speed and direction then all these forces (These are external) add (component by component) to ZERO
Newton’s 2\textsuperscript{nd} Law (N2L)

An \textbf{(ONE!!)} object \textbf{undergoes} acceleration $\ddot{a}$ when acted upon by a \textbf{net} external force given by

$$\ddot{a} \equiv \frac{d\dot{v}}{dt} \equiv \frac{d^2\vec{r}}{dt^2} = \frac{\vec{F}}{m}$$

Where $m$ is the mass of the object; $\ddot{a}$ and $\vec{F}$ are both vectors: $a_x = \frac{F_x}{m}$, $a_y = \frac{F_y}{m}$ (and $a_z = \frac{F_z}{m}$ for 3d cases)

The \textbf{net external force} $\vec{F}$ is the vector sum of all the external forces acting on the \textbf{(ONE)} object

$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots$$

$$F_x = F_{1x} + F_{2x} + F_{3x} + \cdots \quad F_y = F_{1y} + F_{2y} + F_{3y} + \cdots$$

Units: $[F] = [m][a] = \text{kg}\cdot\text{m}/\text{s}^2 = \text{N}$ (newton)

\textbf{Note:} N1L is a special case of N2L
The net force on a box is in the positive x direction.

Which of the following statements best describes the motion of the box? (limited by the information given)

A. Its velocity is parallel to the x axis.
B. Its acceleration is parallel to the x axis.
C. Both its velocity and its acceleration are parallel to the x axis.
D. Neither its velocity nor its acceleration need to be parallel to the x axis.

Net Force:
\[ \vec{F} = \vec{F}_1 + \vec{F}_2 \]
The speed of the head of a redheaded woodpecker reaches 4 m/s before impact with the tree. The mass of the head is 0.060 kg and the magnitude of the force (treated as constant) on the head during impact is 5.5 N.

(a) Find the acceleration of the head (assuming constant acceleration) in km/s\(^2\).

(%i1) /* assuming the forward motion of the head is in the +x direction, we actually then have a=-5.5N and vi=4/ms, vf=0 */
   a: F/m, F=-5.5, m=0.060;
   (%o1) - 91.66666666666667
(%i3) /* change of units: multiply by l=1.0km/1000m */
   a/1000;
   (%o3) - 0.09166666666666667
   Answer (a) -0.0917 km/s\(^2\)

(b) Find the depth of penetration into the tree in cm

(%i4) /* depth of penetration into the tree: we use */
   eqn1: 2*a*Dx = vf^2 - vi^2;
   (%o4) - 183.3333333333333 Dx = vf^2 - vi^2
(%i5) soln1: solve(eqn1, Dx);
   (%o5) [Dx = ------------------]
           550
Example 4.2 (2/2)

... 4 m/s before impact ... mass is 0.060 kg ... magnitude of the force is 5.5 N.

(b) Find the depth of penetration into the tree in cm (continued)

\[
\begin{align*}
\text{Dx: } & \text{ rhs(soln1[1]), vi=4.0, vf=0, numer;} \\
& 0.08727272727272728 \\
\text{/* this is in meters, multiply by } 1=100\text{cm}/1\text{m */} \\
& \text{Dx*100;} \\
& 8.727272727272728 \\
\text{Answer (b) 8.73 cm}
\end{align*}
\]

(c) Find the time it takes for the head to come to a stop in milliseconds.

\[
\begin{align*}
\text{Dt: } & \text{ (vf - vi)/a;} \\
& -0.010909090909090909 (vf - vi) \\
\text{Dt, vf=0, vi=4;} \\
& 0.04363636363636363636 \\
\text{/* convert from s to ms, multiply by } 1=1000\text{ms}/1\text{s */} \\
& \text{Dt*1000, vf=0, vi=4;} \\
& 43.63636363636363636 \\
\text{Answer: 43.6 ms}
\end{align*}
\]