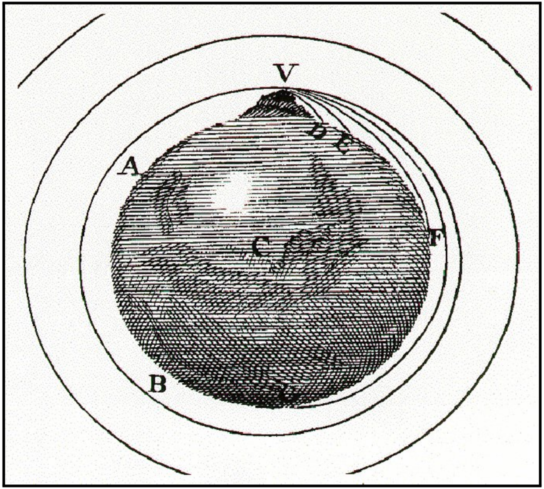
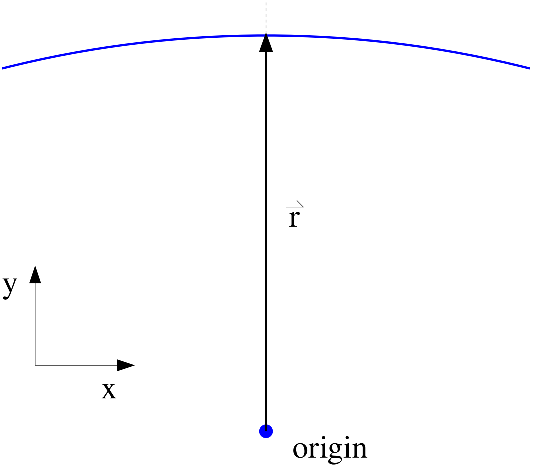
Is the Galaxy Blowing Up? 1

The stars on the rim of our Milky Way Galaxy take about 800 million years to orbit in a circle about the galactic core which is a distance $r_G = 9 \times 10^{20}\ m$ away. At this distance from the Galactic center the acceleration due to the gravity created by the other stars in the Galaxy is $g_G = 5.3 \times 10^{-34}\ m/s^2$. Should these stars on the Galactic rim stay in orbit or fly off?

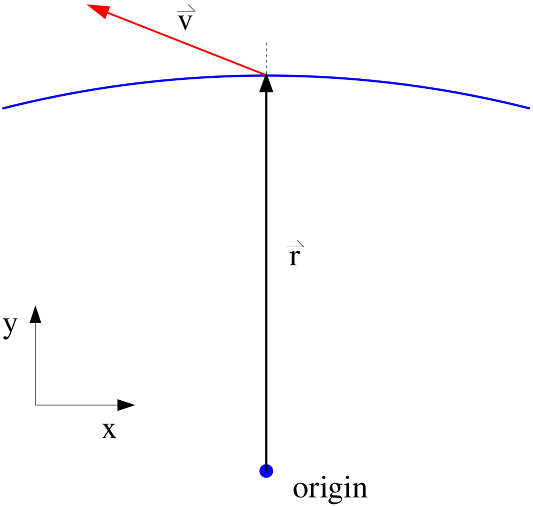
In the 17th century Isaac Newton envisioned the possibility of space flight with the picture shown below that is taken from *Principia*. He just needed to find a high enough mountain and a big enough cannon.



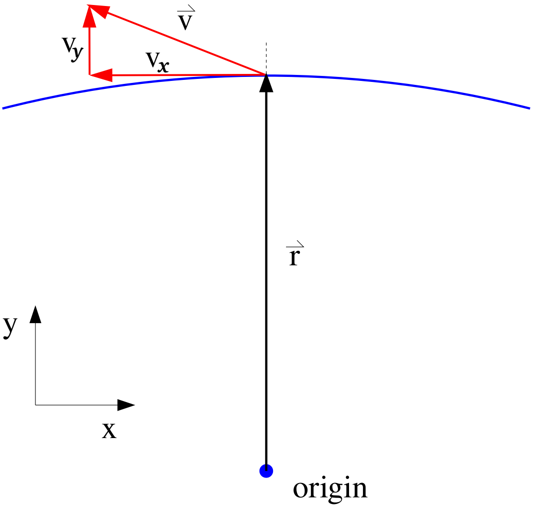
Circular Motion - 2 3



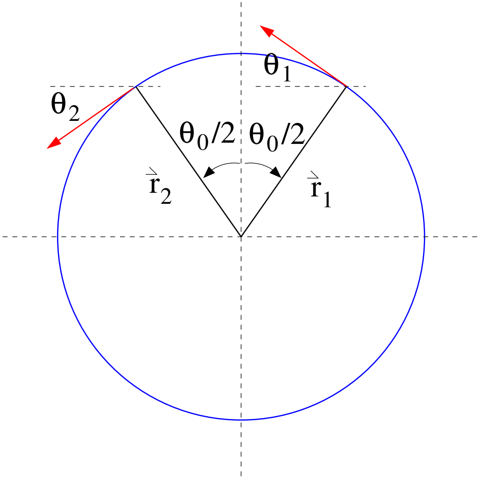
Circular Motion - 2 4

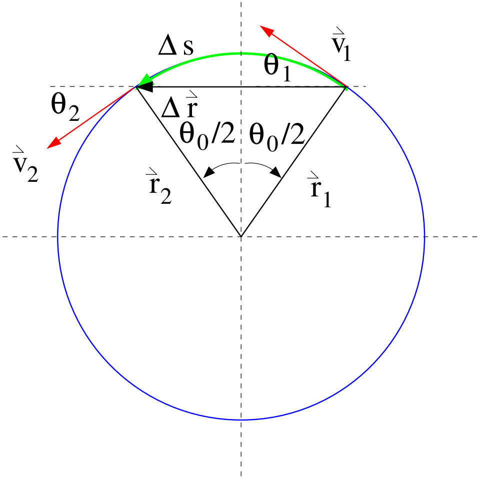


Circular Motion - 2 5



Circular Motion - 3 6





Δ s
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θ_2
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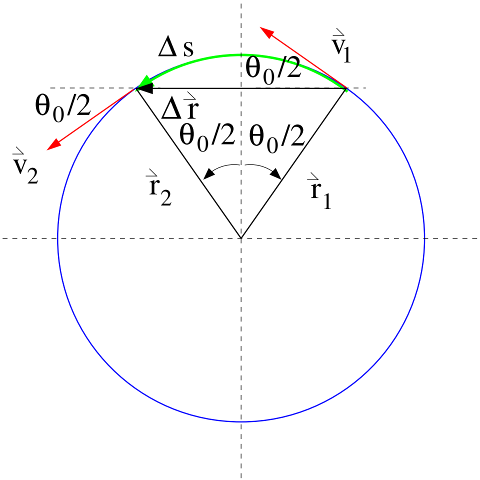
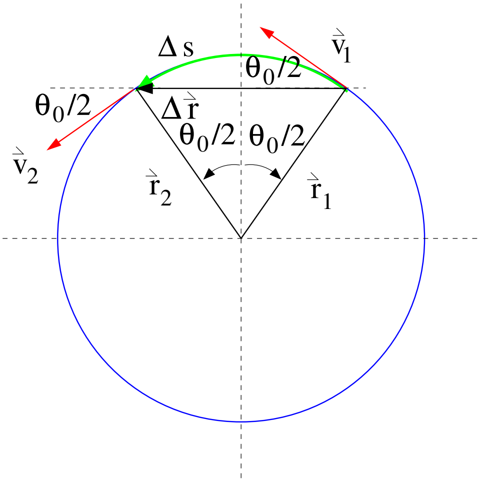
Circular Motion - 3 8

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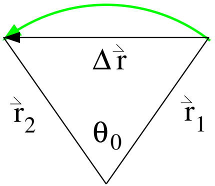
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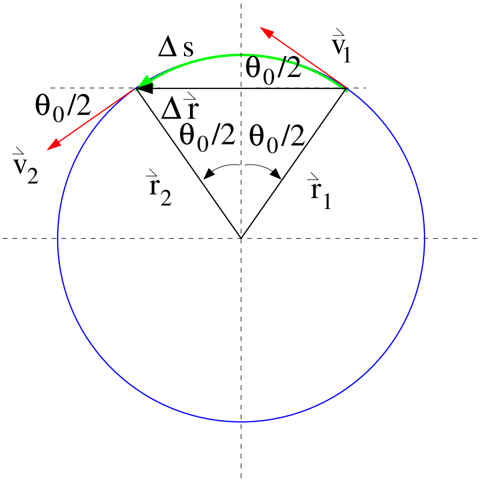
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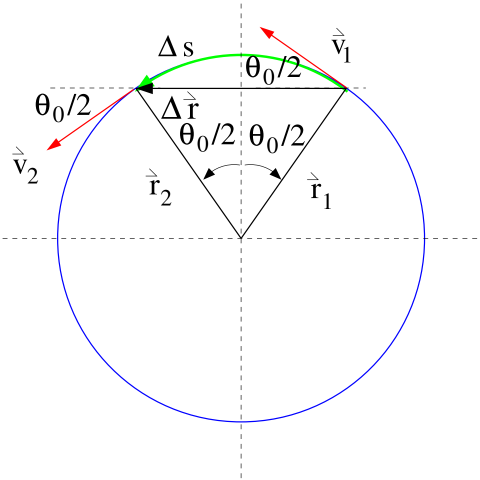
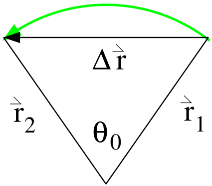
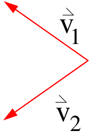
$\vec{v}_1$

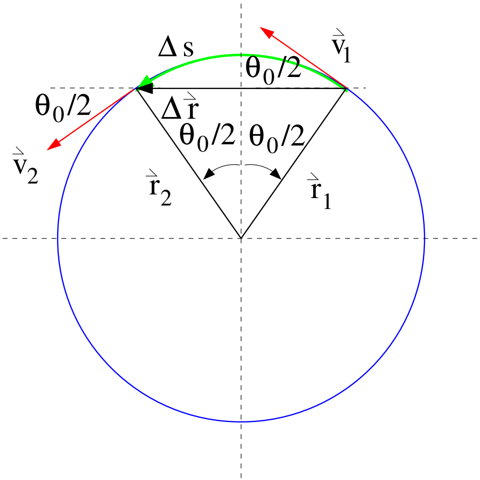
Circular Motion - 3

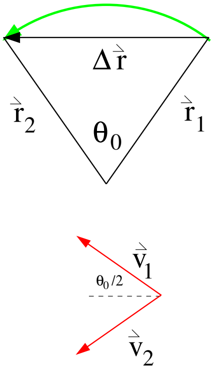






Circular Motion - 3 12





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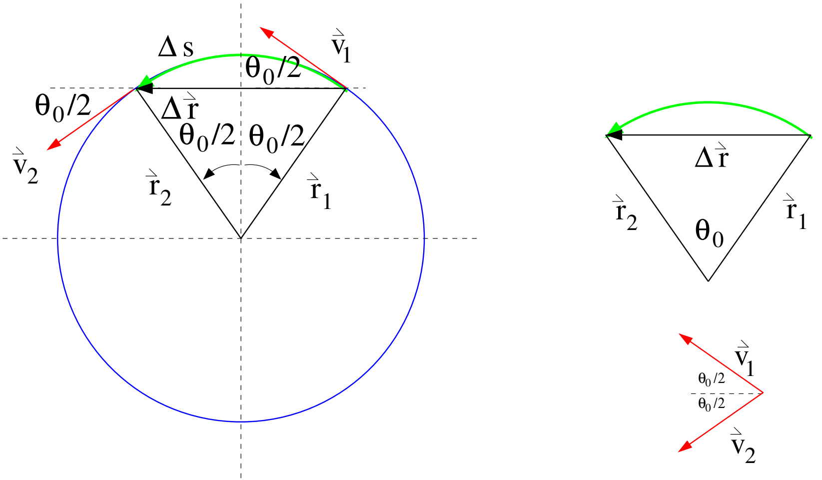

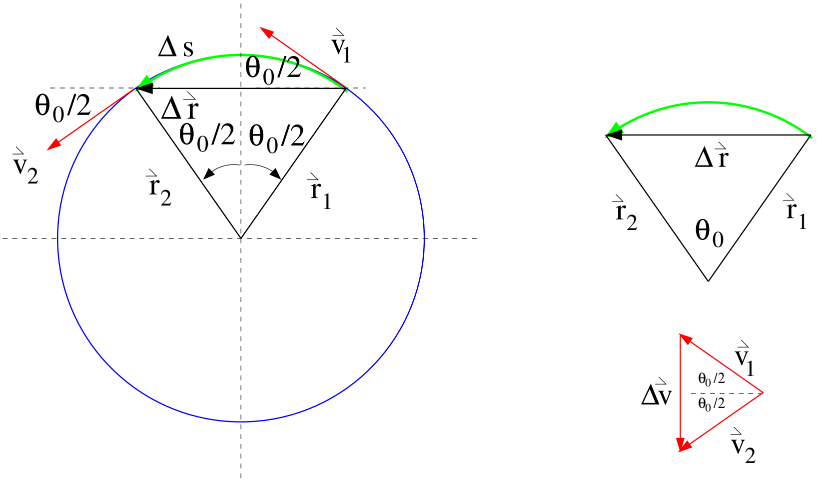
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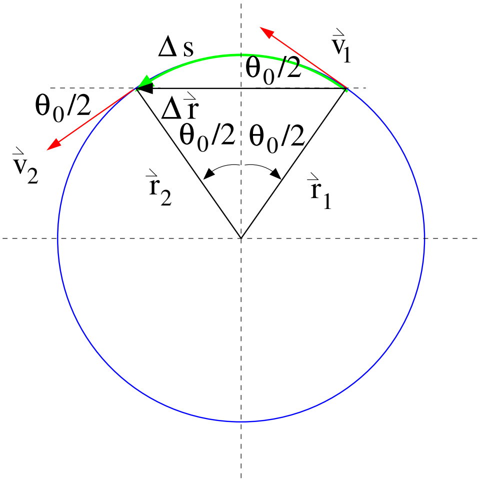
Δ s
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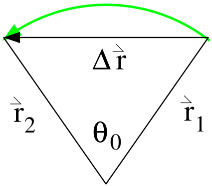
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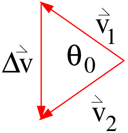
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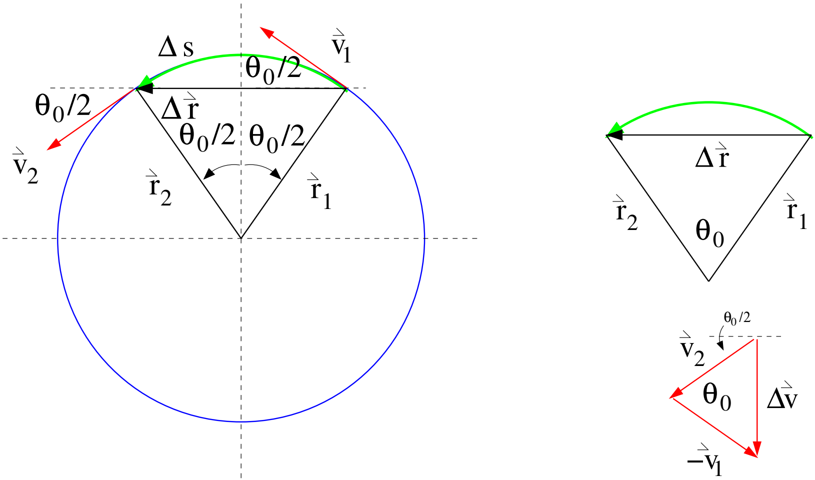
Δ s
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$\Delta\vec{r}$
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θ_0
$\vec{r}_1$
$\theta_0/2$
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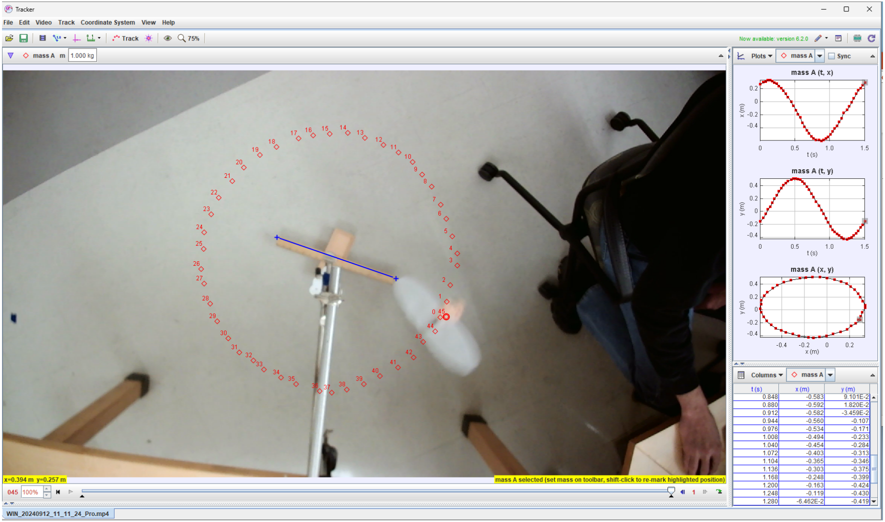
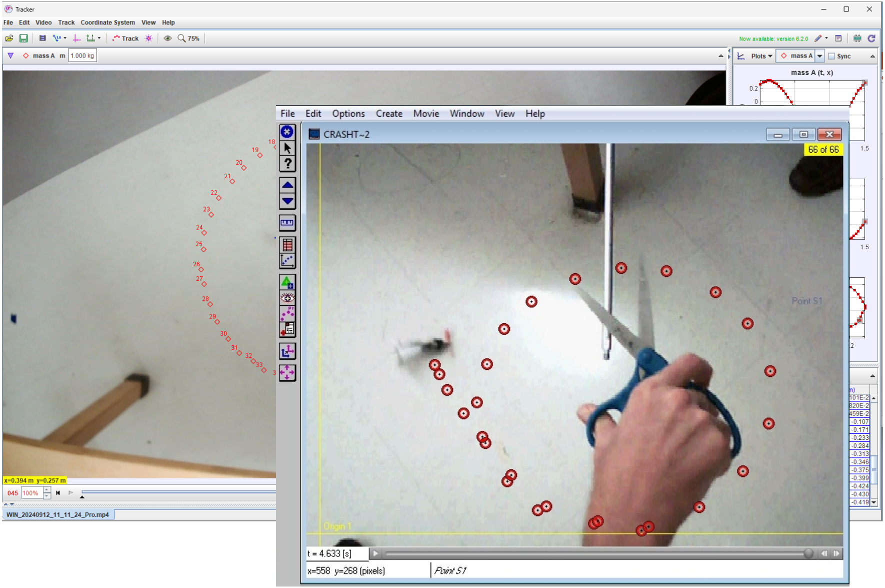
θ_0
$\Delta\vec{v}$
$-\vec{v}_1$

Circular Motion - 4 17



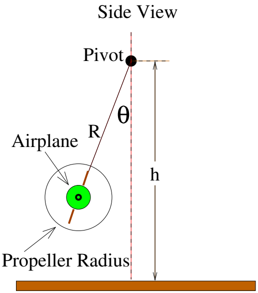

Tracker
File Edit Video Track Coordinate System View Help
mass A m 1.000 kg
mass A (t, x)
File Edit Options Create Movie Window View Help
CRASHT~2
66 of 66
Point S1
Origin 1
t = 4.633 [s]
x=558 y=268 (pixels)
Point S1
x=0.394 m y=0.257 m
WIN_20240912_11_11_24_Pro.mp4

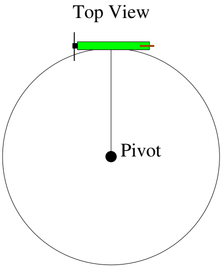
Are We Going To Crash? 19

Consider the model airplane hanging from a string and flying in a circle as shown in the figure. The centripetal acceleration is $1.5\ \mathrm{m/s^2}$. What is the speed of the model airplane? If the string suddenly breaks, then how long does it take for the airplane to hit the floor? How far does it travel in the horizontal direction before it hits the floor?

Some useful information

Pivot height(h)	1.3 m
Vertical Angle(θ)	25°
String length(R)	0.7 m





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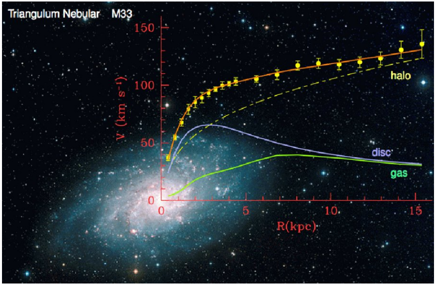
Maybe we can see stuff we can't see!!

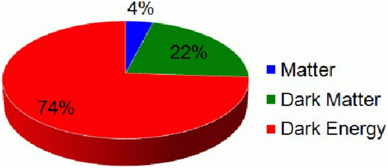


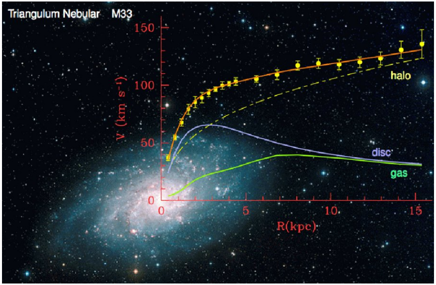
Some of the matter in the Universe is invisible or 'dark'.

Maybe we can see stuff we can't see!!

Some of the matter in the Universe is invisible or 'dark'.

Actually most of it dark!





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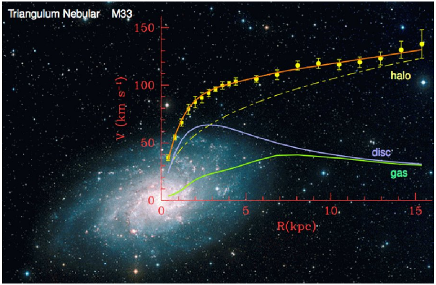

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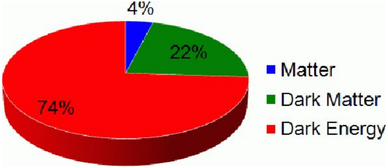
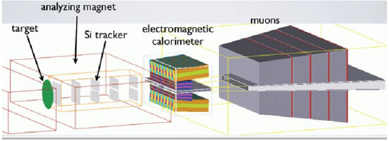


We're going hunting!

Heavy Photon Search at JLab



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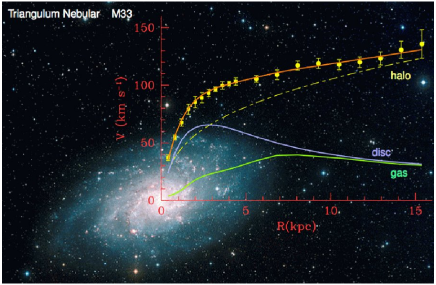

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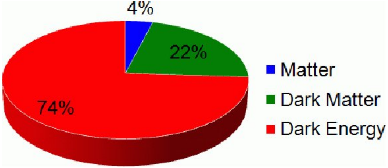

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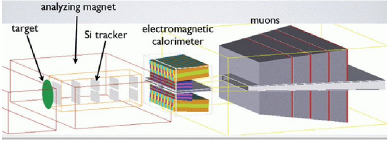
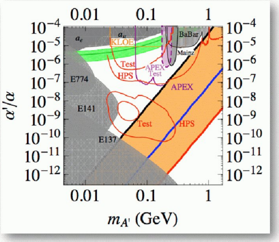




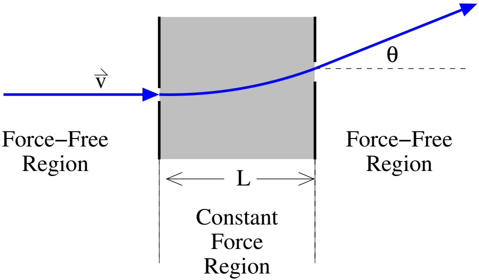
Are We Going To Fall Off? 25

As we stand on the Earth's surface we orbit the center of our planet. A centripetal acceleration a_c is required to maintain our circular orbit otherwise we might go flying off into outer space. How does this acceleration a_c compare with the known acceleration of gravity g at the Earth's surface? Do you expect this acceleration a_c to be bigger, smaller, or the same as g, the acceleration of gravity at the Earth's surface? At what speed will things start to 'fly off' the Earth's surface? At this speed what is the length of one 'day'? Some useful parameters are listed below.

Earth's radius: $6.37 \times 10^6\ m$ Earth's mass: $5.98 \times 10^{2}4\ kg$ g: $9.8\ m/s^2$

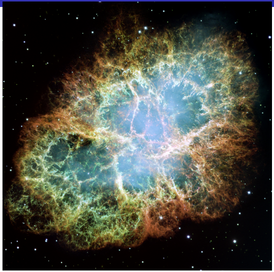
Weighing The Invisible 26

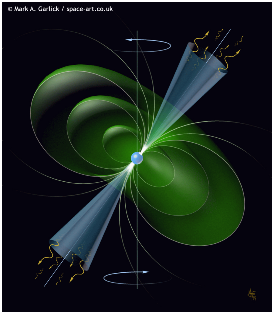
A spectrometer is a device for determining the mass of atomic and subatomic particles like protons, mesons, *etc*. Consider the spectrometer below. Two different particles enter the device with the same speed $v = 3.0 \times 10^7\ m/s$. They pass through and 'feel' the same centripetal force of $F = 1.3 \times 10^{-12}\ N$. The constant-force region has a width $L = 0.5\ m$. They are deflected by different amounts so one particle is bent through an angle $\theta_1 = 21^\circ$ while the other one is bent by $\theta_2 = 19^\circ$. What are the masses of the two particles? Identify them from the list of particles below.



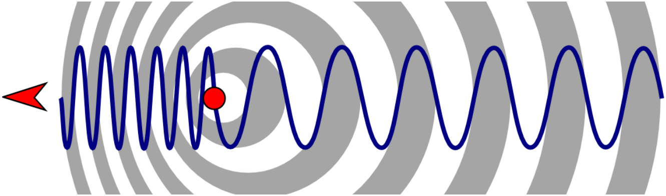
Particle	Mass (kg)
Proton	1.67×10^{-27}
Deuteron	3.34×10^{-27}
π meson	2.49×10^{-28}
η meson	9.74×10^{-28}
Λ baryon	1.98×10^{-27}
Δ baryon	2.19×10^{-27}

The neutron star in the Crab Nebula has a mass $m_{CN} \approx 3.4 \times 10^{30}\ kg$, a radius $R_{CN} = 12\ km$, and a rotational frequency $f_{CN} = 30\ rev/s$. The acceleration of gravity at its surface is $a_{CN} = 1.9 \times 10^{16}\ m/s^2$. Would you be able to stand there and not fly off?





- A special feature of any wave (sound, water, light) is that the motion of the source can change the frequency of wave as measured by a stationary observer.
- In the case of sound, the moving source 'catches up ' to each sound wave emitted when the source is moving toward the stationary observer.



- The effect for sound is demonstrated here.
- The effect for light is demonstrated here (stellar red shift).

Orbiting Airplanes 29