Announcements – 25 Sep 2014

1. Prayer

2. Exam 1!!
    a. Thursday Oct 2 – Tuesday Oct 7 (2 pm) in the Testing Center, late fee after Oct 6, 2 pm
    b. Covers through today's lecture (unless we don't quite finish, in which case it covers through start of Tuesday's lecture)
    c. Covers through HW 9 (due Wed, Oct 1)
    d. Exam review sessions by Jerika, both in room C295 ESC:
        1. Wed Oct 1, 7 - 8:30 pm
        2. Thurs Oct 2, 6 - 7:30 pm
    e. I will give you conversion factors (but not basic metric system)
    f. Bring a note card! (I won't give you any equations)
    g. 28-30 problems
    h. Probably will take ~2 hours average. Some students <1 hour, other students >3 hours

"Which of the problems from last night's HW assignment would you most like me to discuss in class today?"

Accelerating Reference Frames

Demo: Rotating chair, Ball on string

To be able to ascribe accelerations to *real* forces, you must be observing the motion from a **non-accelerating (constant velocity) point of view**

Physics lingo: “point of view” = “reference frame”

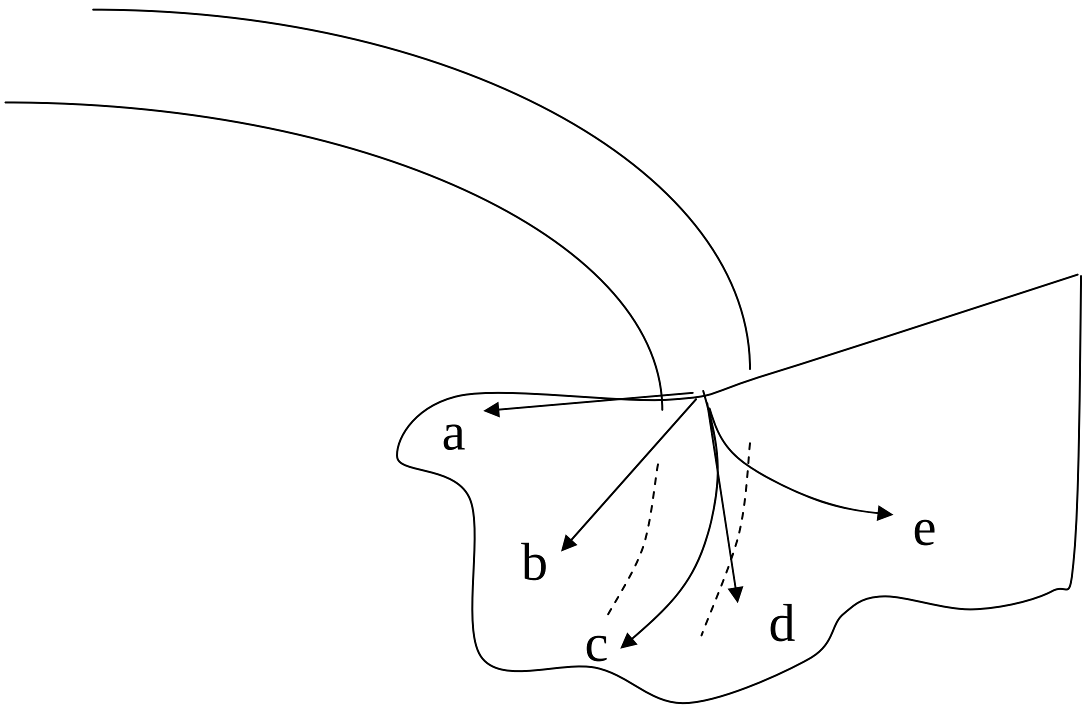
Fictitious Forces

In **accelerating** reference frames, we tend to invent fictitious forces.

Other examples: Coriolis force, car hits brakes

Clicker quiz

A car hits a large icy spot on the road at point P. What is the path of the car if there is no friction on the ice?



Demo

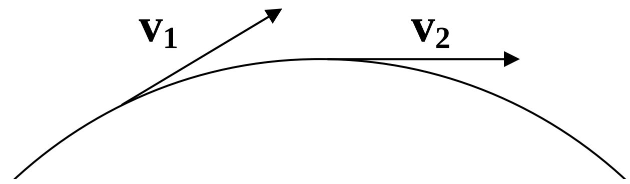
Ball on string

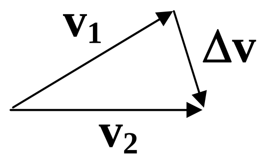
Constant speed: is the ball accelerating?

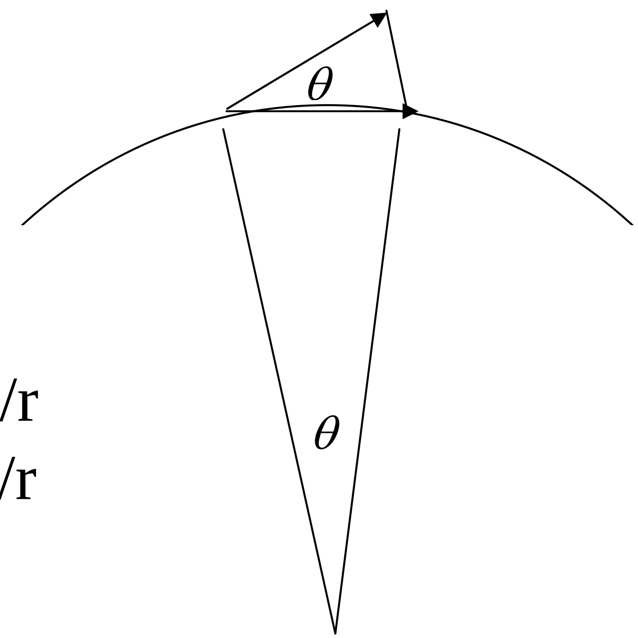
Centripetal Acceleration

$$a_c = \frac{v^2}{r}$$

Derivation:







$$\vec{\mathbf{a}} = \frac{\Delta\vec{\mathbf{v}}}{\Delta t}$$

Similar triangles: $\Delta v/v = \Delta x/r$

$\Delta v = v\,\Delta x/r$

Piece together: $$\frac{\Delta v}{\Delta t} = \frac{\left(v\Delta x/r\right)}{\Delta t}$$

$$= \left(\frac{v}{r}\right)\frac{\Delta x}{\Delta t}$$

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

Direction of centripetal acceleration?

_______________ → always call that positive!

Bottom line:

If the object is in circular motion, then there is an acceleration.

This acceleration (v^2/r) goes on the **right hand side** of N2

From warmup

A ladybug sits on the outer edge of a merry-go-round that is turning around counter-clockwise without speeding up or slowing down. In what direction is the friction force that sticks the ladybug to the merry-go-round?

a. clockwise
b. counter-clockwise
c. inward
d. outward

From warmup

Ralph is confused about centripetal and centrifugal forces. When he is in a car which is turning to the left, he feels a force pushing him to the right. But the textbook says that the actual force is pushing him to the left. Can you explain this to him? What is he feeling during the turn?

“Think-pair-share”

- Think about it for a bit
- Talk to your neighbor, find out if he/she thinks the same as you
- Be prepared to share your answer with the class if called on

Clicker: I am now ready to share my answer if randomly selected.

a. Yes

Note: you are allowed to "pass" if you would really not answer.

Worked Problem

You swing a ball (mass *m*) in a vertical circle with a string; its speed is constant (*v*) through the whole circle. (a) What is the tension at the lowest point? (b) At the highest point?

(a) Picture:

Equation:

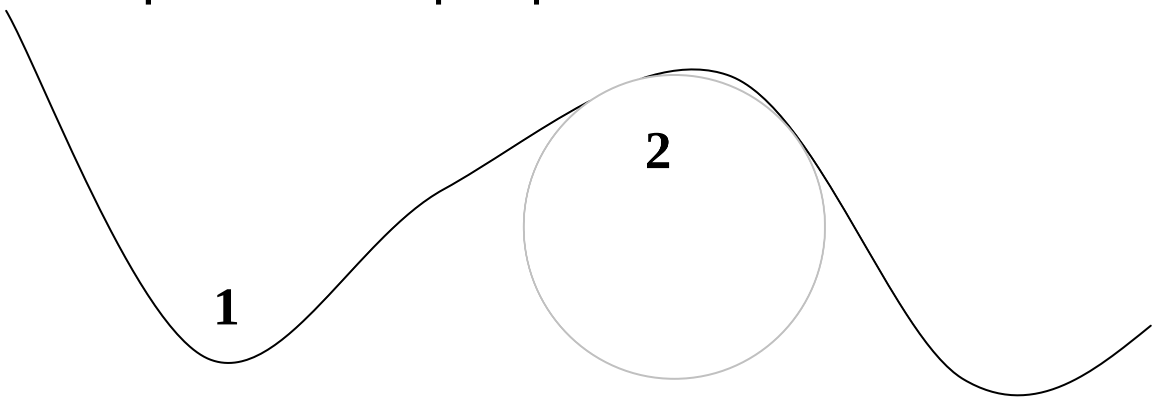
(b) Picture:

Equation:

Answers: $mg + mv^2/r$, $mg - mv^2/r$

Unsafe roller coasters (no seatbelts)

For the top of an *outside* curve (pt 2), radius of curvature = 8 m, what is the maximum speed if the people are **not to fall out**?



What's the difference between pt 1 and pt 2?

Free-body diagrams:

What happens to Normal force at pt 2 as speed increases?

→ Just as people fall out, the normal force is _______________.

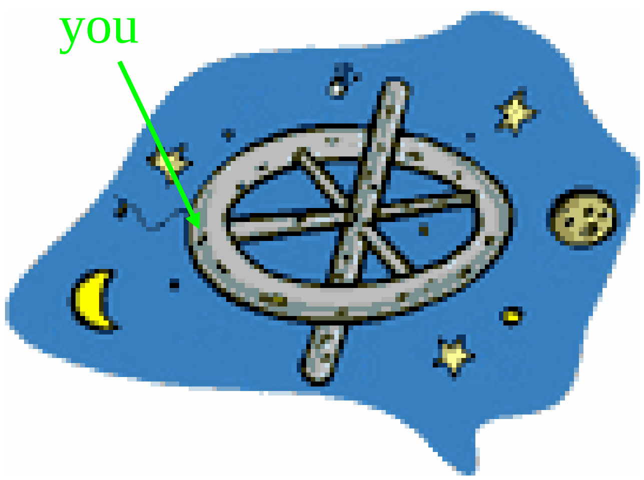
Solution to the problem (with 8 m radius of curvature):

Answer: 8.85 m/s

Question

Rotation of **earth** (1 rev/24 hours) gives speed at Provo = 792 mph! Why don't we fly off?

Space stations and "artificial gravity"



You are standing on a 50 m radius space station that rotates at just the right speed so that the **normal force** is

$N = m \times 9.8\ \text{m/s}^2$.

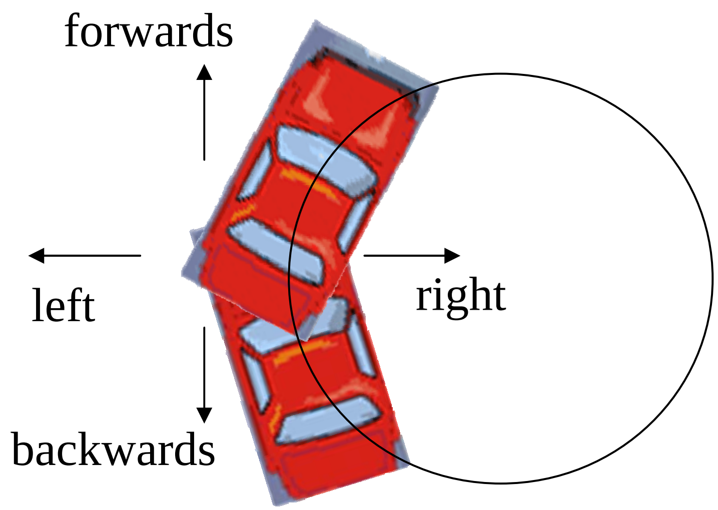
Your usual normal force on Earth = mg, so this normal force feels "normal" to you! ☺

What direction do your feet face?

How fast must the space station rotate (rpm) in order to cause this?

Answer: 4.23 rpm

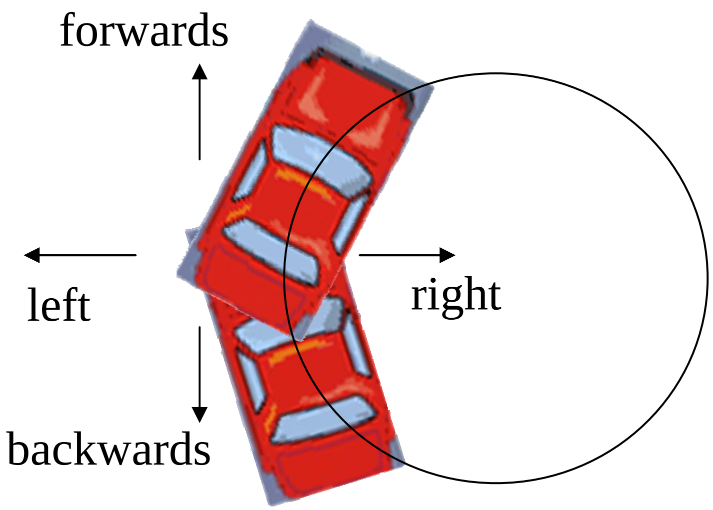
Scenario: Back Seat of Car



You are in the middle of the back seat of a car. The car turns right at constant speed, moving in a circle.

Question: What happens to you if no friction from seat?

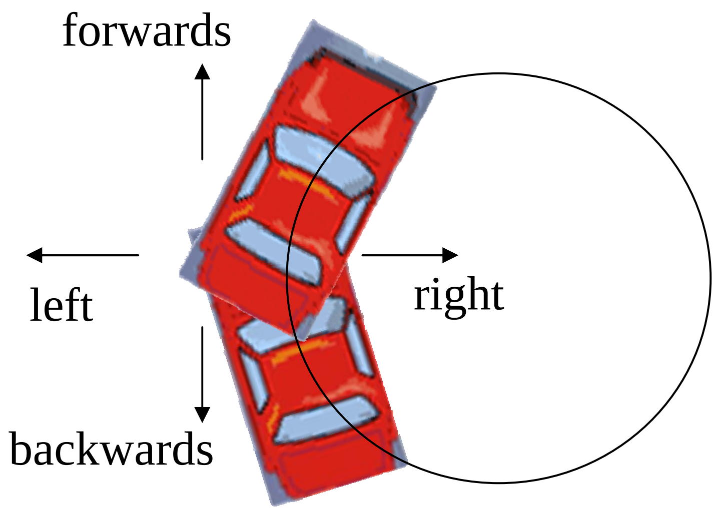
Clicker Quiz



The net horizontal force on you *after you are pressed up against the door* is:

a. Towards the left
b. Towards the right
c. Forwards
d. Backwards

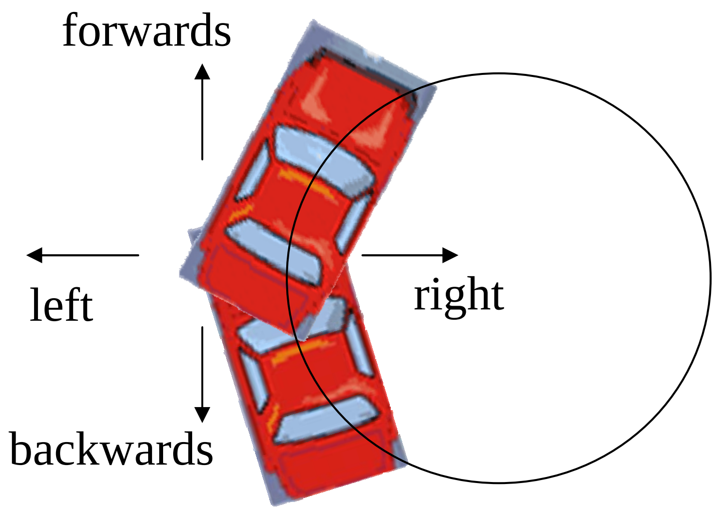
Clicker Quiz



What if there's enough static friction so that you do not slide? In what direction is the static friction?

a. Towards the left
b. Towards the right
c. Forwards
d. Backwards

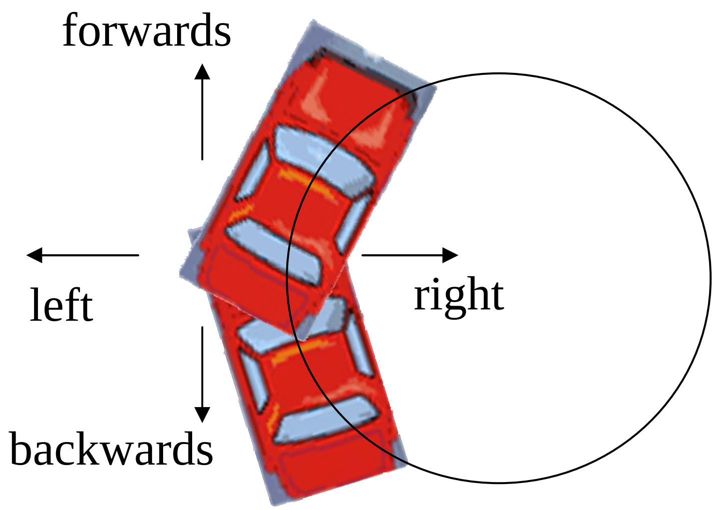
Clicker Quiz



What if there's only a little bit of friction, so that you are sliding, but not as much as if no friction. In what direction is this kinetic friction?

a. Towards the left
b. Towards the right
c. Forwards
d. Backwards

Clicker Quiz

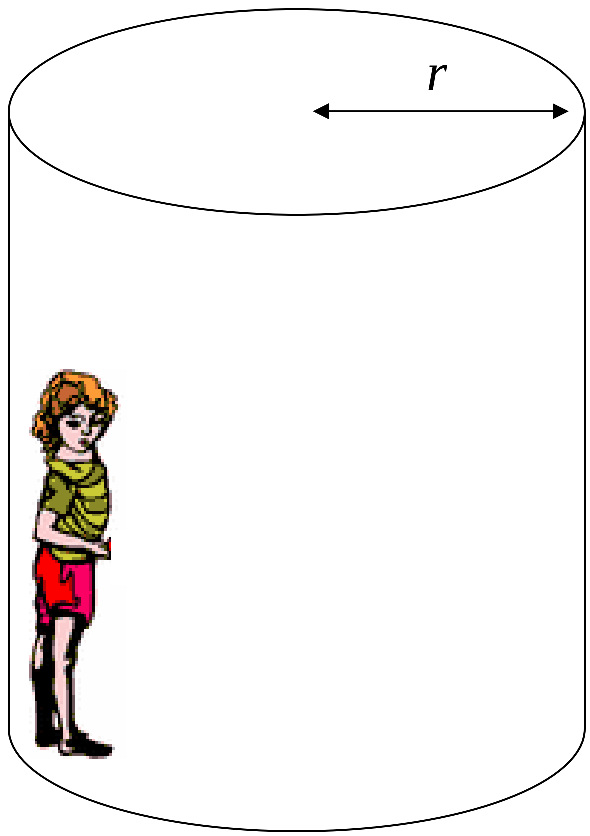


In what direction is the friction force from the road acting on the car's tires?

a. Towards the left
b. Towards the right
c. Forwards
d. Backwards

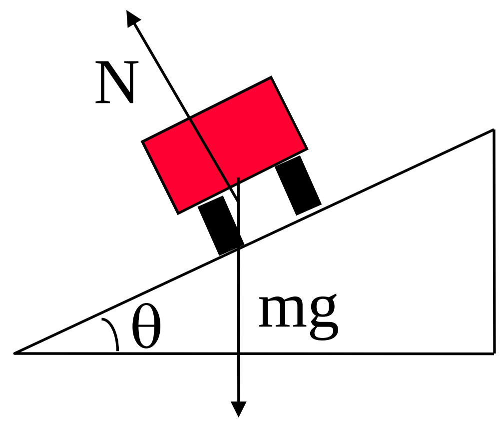
Worked Problem: Floor-dropping ride

If the coefficient of friction is μ, what minimum speed *v* must you be going before the floor is removed?



Answer: $\sqrt{\frac{rg}{\mu}}$

Banked roadways



Consider turn with no friction…
What direction will car go if slight banking?
What direction if steep banking?

In between?

So, why do they bank turns?

HW Problem, 9-2: what should the banking angle be so that there is no sideways friction force needed? (given overall turn radius and speed)

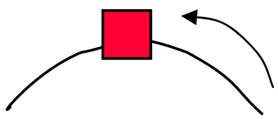
Hardest part: which way to draw the axes?? Conflicting advice:

- Colton: "Make the positive x-axis be along the inclined plane"
- Colton: "Make the positive x-axis be towards the center of the circle"

Conflict resolved:

Combined Centripetal and Tangential

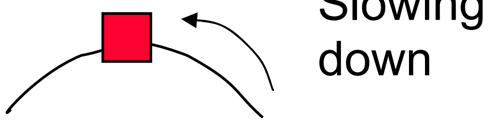
Example: Going around a corner while slowing down



Clicker quiz: The centripetal acceleration at this instant is

a. up
b. down
c. left
d. right
e. zero

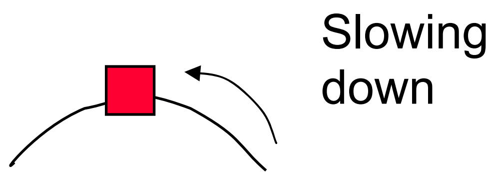
Clicker quiz



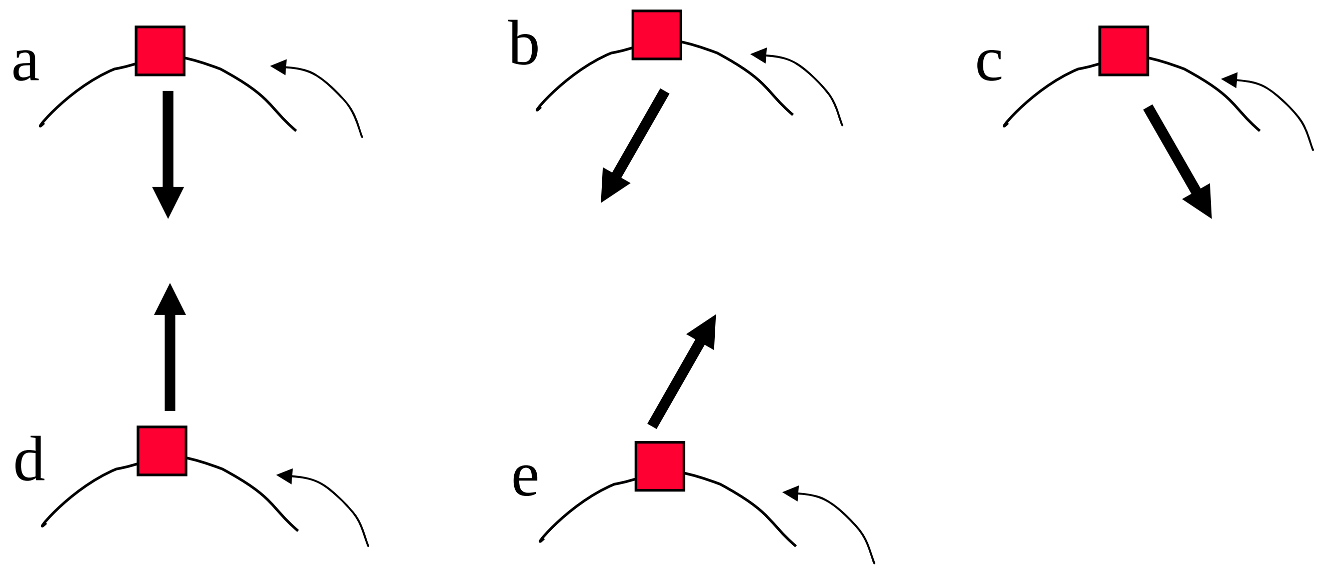
The <u>tangential</u> acceleration at that instant is

a. up
b. down
c. left
d. right
e. zero

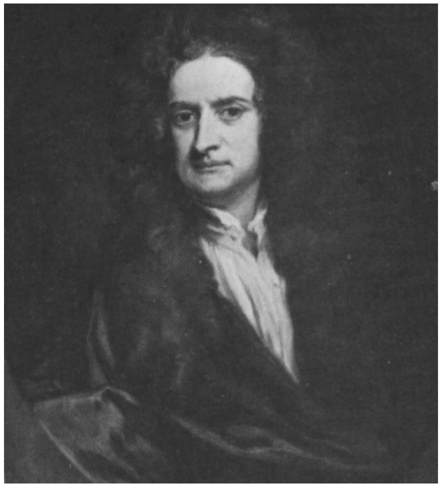
Clicker quiz



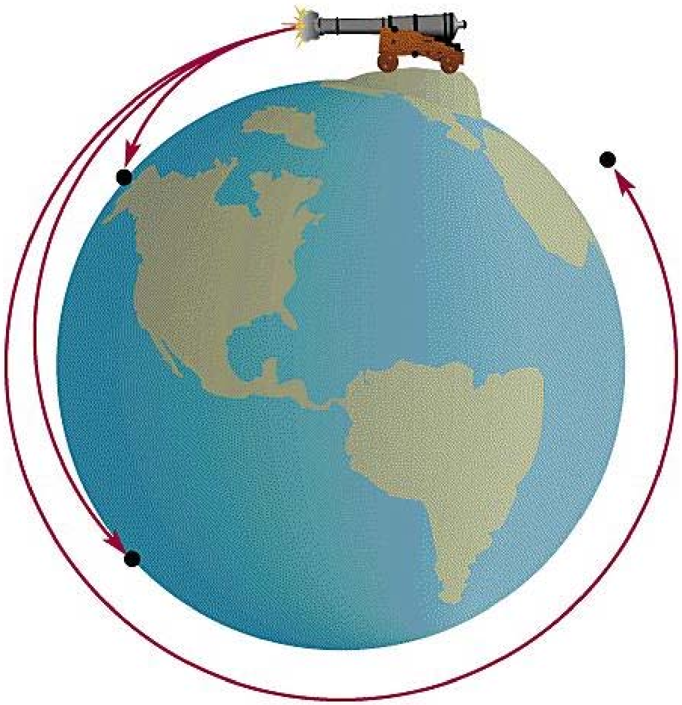
Which figure represents the <u>total</u> ***a*** vector?



On to Gravity!!



Newton's thoughts about the moon's orbit and projectile motion, c. 1670:



Parabola of projectile turns into a circle.
The apple, the cannonball, and the Moon

→ all are in ________________

From warmup

If the Earth attracts the moon with gravitational force, why doesn't the moon fall into the Earth? Give an explanation that a friend in junior high school could follow.

(We won't do this as a think-pair-share)

Newton's Law of Gravity

All masses attract all other masses!

$$F_G = G\frac{mM}{r^2}$$

r measured from ______________________

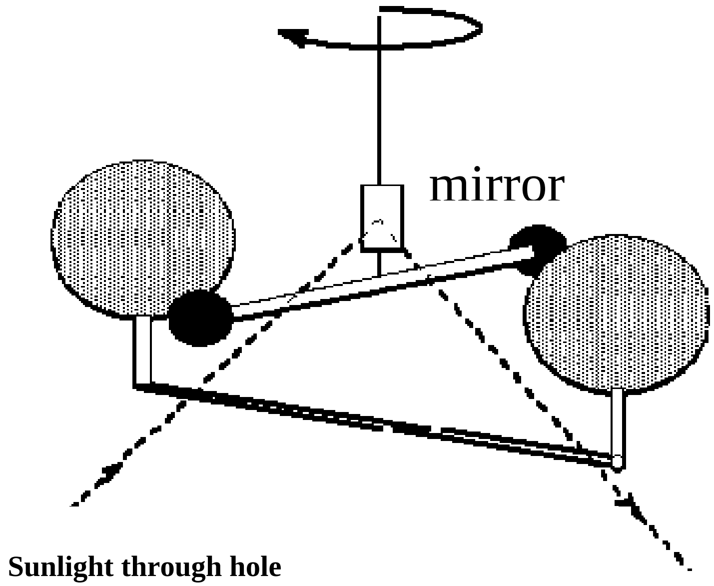
(sometimes written with negative sign)

Proportionality constant: $G = 6.674 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$

Near the surface of the earth:

$R_{Earth} = 6.371 \times 10^6$ m
$M_{Earth} = 5.974 \times 10^{24}$ kg

Cavendish Experiment



1783: first measurement of forces between “regular” masses, by Cavendish.

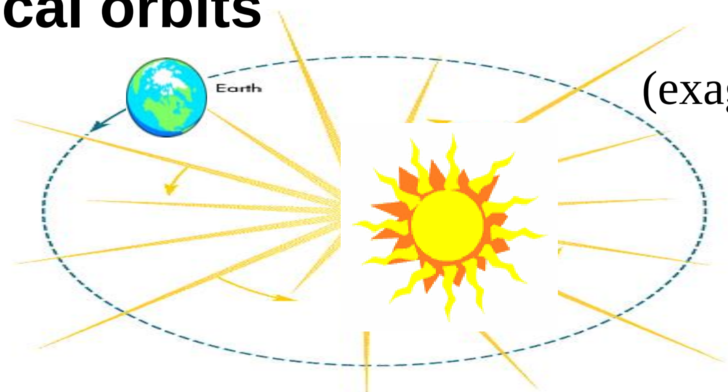
“Weighing the world” vs. determining *G*

→ Most accurate such measurement for 102 years!
(only 1% off of today’s value)

How did Newton know it was **inverse square**?

Kepler's laws (about 1600) came from observations of the planets in our solar system:

1. Elliptical orbits



(exaggerated ellipse)

2. Equal areas in equal times: fastest close to Sun

3. $\mathbf{T^2 \sim r^3}$

(T = "orbital period" = __________)

All three can be exactly predicted using Newton's Second Law together with Newton's Law of Gravity! (Done in Phys 321)

From warmup

Which is not one of Kepler's laws?

a. Planets all move in the same plane
b. Planets move in elliptical orbits
c. Equal areas swept out in equal time: faster closer to sun
d. The period of orbit increases as r increases

Worked Problem

How long is Jupiter's year? ($r_{Jupiter} \approx 5.2\ r_{Earth}$)
(hint: $T^2 \sim r^3$)

Answer: 11.86 years

Worked Problem

Figure out what the proportionality constant is in Kepler's Third Law, $T^2 \sim r^3$, in terms of *G* and the mass of the sun. Assume a circular planetary orbit.

Answer: $4\pi^2/(GM)$

Satellites

Question: What’s the difference between the earth revolving around the sun, and a satellite revolving around the earth?

Orbital Velocity

On the moon (no air friction, mass M) someone really *could* get into orbit by being fired horizontally off the highest mountain (radius r).

How fast would you have to shoot that person?

How long would it take him to go around once?

"orbital period"

Answers: v=sqrt(GM/r), 2πr/v

Circular orbits

For each *v*, only one *r* will work

For each *r*, only one *v* will work!

Clicker quiz: A satellite in a higher orbit will be going ________ than a satellite in a lower orbit.

a. faster

b. slower

Real satellites:

http://science.nasa.gov/realtime/jtrack/3d/JTrack3D.html/

(may need to change security settings in Java control panel)

International space station, 340.5 km above surface of Earth (R_e = 6,371 km)	7.707 km/s
Geostationary orbit, 35,786 km above surface	3.075 km/s
Moon, r = 381,715 km	1.022 km/s

Worked Problem: How long does it take ISS to orbit?

Answer: 91.2 min

Clicker quiz

You are on planet Xarthon, which has a mass of 2× that of the earth and a radius 2× as big. If you throw a ball at the surface, and you will find that $g_{Xarthon}$ is ____ g_{earth}

a. larger than
b. smaller than
c. the same as

Clicker quiz

Satellites in higher orbits are travelling slower, so to “shoot” a satellite from the surface of the earth into a high orbit (i.e. with a cannon), you would provide it with ________ initial kinetic energy than for a satellite in a low orbit

a. more
b. less
c. same

Review

Centripetal Acceleration:

Causes ___________________________ but not ___________________________

Direction: ___________

Magnitude: a_c = ________

How to use with N2: Always include on the r______ h_____ s______

How to use with Newton's Law of Gravity: Always include GmM/r^2 on the l______ h_____ s______