Announcements – 13 Oct 2009

1. Exam problem 28—A student pointed out that you get a different answer if you use 9.8 m/s^2 for g than if you use 10 m/s^2 (what you were supposed to use). So, I decided to accept *both* answers. The Testing Center regraded all exams, and you should automatically see this problem marked right if you used 9.8 m/s^2 for g.

2. While you're waiting for class to start, see how many of the review blanks you can fill out on page 2.

Review: Three types of accelerations for rotations

Tangential Accel.: Causes speed to ______________________
Causes angular speed to _______________
Therefore, causes: ____________________

Definitions:

$\theta =$

$\omega =$

$\alpha =$

arc length $s = r\theta$
tangential $v = r\omega$
tangential $a = r\alpha$

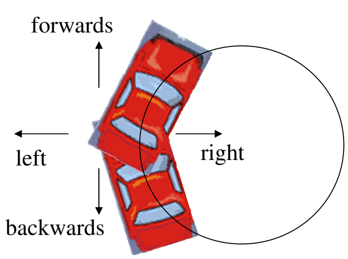
3 Angular Kinematic Equations $\begin{cases} x \rightarrow \theta \\ v \rightarrow \omega \\ a \rightarrow \alpha \end{cases}$

1. _______________
2. _______________
3. _______________

Centripetal Accel.: Causes ______________________________

Magnitude: $a_c =$ _______ Direction: __________

How to use with N2:



You are on right side of the back seat of the car. The car turns right at constant speed, moving in a circle, and you slide slowly to the left (with friction) before running up against the door.

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

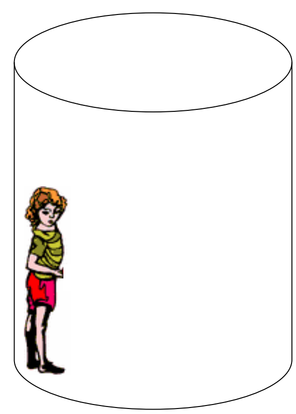
Clicker quiz: The net horizontal force on you *while you are sliding* is:

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

Question: How do answers change if no friction?
Question: What direction is the friction on the car's wheels?

Floor-dropping ride

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

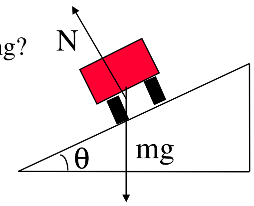


Answer: $\sqrt{\frac{rg}{\mu}}$

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, 10-5 (due tomorrow!): 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"

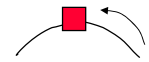
Conflict resolved:

Combined Centripetal and Tangential

Example: Going around a corner while slowing down

Clicker quiz: The centripetal acceleration at this instant is

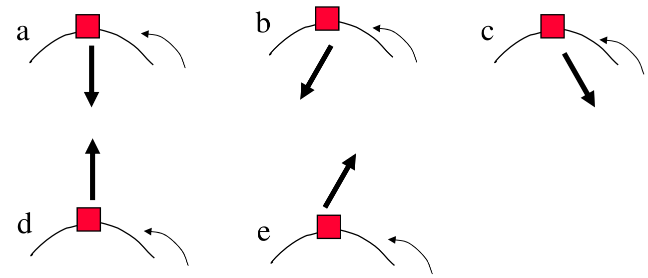
- a. up
- b. down
- c. left
- d. right
- e. zero



Clicker quiz: The tangential acceleration at that instant is

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

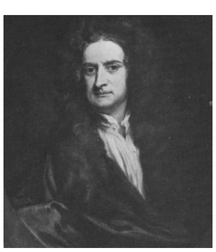
Clicker quiz: Which figure represents the total ***a*** vector?

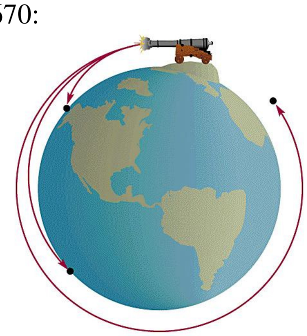


On to Gravity!!

Classical physics was invented to understand the motion of the planets

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 _______________

Newton's Law of Gravity:

All masses attract all other masses!

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

← r measured from _______________

(sometimes with negative sign)

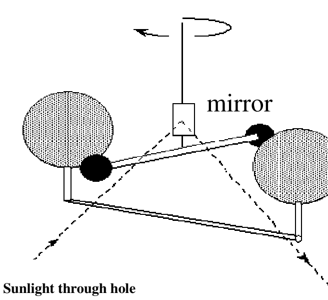
Proportionality constant: $G = 6.674 \times 10^{-11}$ N·m^2/kg^2

Near the surface of the earth:

R_{Earth} = 6371 km
$M_{Earth} = 5.974 \times 10^{24}$ kg

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

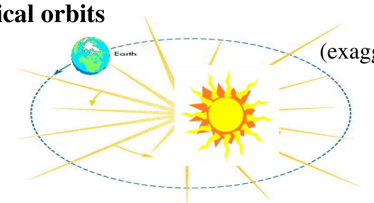
"Weighing the world"



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. **$T^2 \sim r^3$**
   (T = "orbital period" = __________)

All three can be exactly predicted using Newton's Second Law together with Newton's Law of Gravity!

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: Figure out what the proportionality constant is in Kepler's Third Law in terms of *G* and the mass of the sun. Assume a circular planetary orbit.

Problem: How long is Jupiter's year? ($r_{Jupiter} \approx 5.2\ r_{Earth}$)

Question: Does Kepler's 3rd apply to satellites orbiting the earth?

Answers: $k = 4\pi^2/GM$; 11.86 years

Orbital Velocity

On the moon (no air friction) someone *could* get into orbit by being fired horizontally off the highest mountain.

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), $2\pi r/v$

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
a. faster
b. slower
than a satellite in a lower orbit

Real satellites:

http://science.nasa.gov/RealTime/JTrack/3d/JTrack3d.html

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, average R = 381,715 km
1.022 km/s

How long does it take ISS to orbit?

Answer: 91.2 min

From warmup: The Moon does not fall to Earth because:
a. the gravitational pull of the Earth on the moon is weak
b. the moon has a sufficiently large orbital speed
c. the gravitational pull of the sun keeps the moon up
d. the moon has less mass than Earth
e. none of the above

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
a. more
b. less
initial kinetic energy than for a satellite in a low orbit

Gravitational PE

Need new $PE_{gravity}$ **PE = mgy** just won't work…
Force isn't "mg" any more!

Using calculus to calculate work done against (non-constant) gravitational force…

$$PE_G = -\frac{GMm}{r}$$

Here the negative sign is critically important!!
(not a vector direction)

Before: PE = 0 when _______________

With new equation: PE = 0 when ________________

From warmup: Ralph wonders how can PE = -GMm/r "reduce to PE = mgy close to the surface of Earth"?? It's negative!

Answer from the class:

Worked problem: How much energy would you have to provide in order to "shoot" a 100 kg satellite into a near orbit like the ISS, 6712 km from center of earth? (Assume via initial KE)

…into a much farther geostationary orbit? (42,157 km)

…to an orbit at the moon's distance (381,715 km)

Answers: 3.29E9 J, 5.79E9 J, 6.21E9 J

Escape Velocity

Same question: …into an orbit very far away from the Earth??

Hints: What is its orbital velocity?
What is its final kinetic energy?
Final potential energy?

Robert Heinlein:
"If you can get into orbit, then you're halfway to anywhere"

What is the "escape velocity" of the earth?
→ velocity needed to "escape"…end up very far away

From warmup: The "escape velocity" of a planet is the speed needed for a rocket to go from the surface of the planet into orbit.
a. true
b. false

Answers: 6.26E9 J, 11.2 km/s