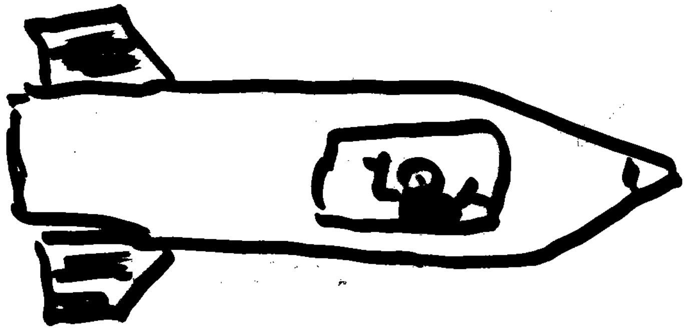


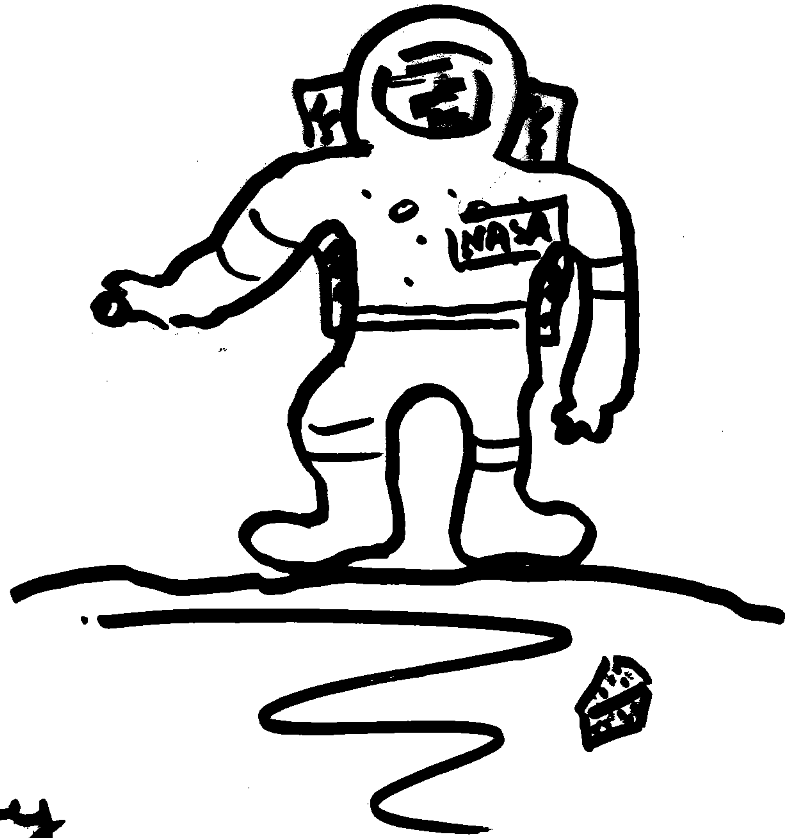
Astronauts in orbit about Earth

① Weigh exactly what they weigh on Earth

② are Weightless

③ Weigh slightly less than they ~~don~~ do on Earth

ASTRONAUT on Moon lightly places Ping pong ball in space beside him.



① Ping pong ball floats away

② Ping pong ball falls to surface of Moon

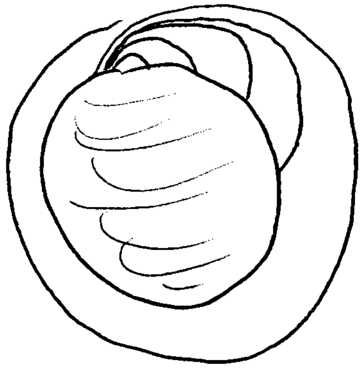
③ Ping Pong ball stays where ASTRONAUT placed it.

What is an ORBIT ?

IF in orbit ... do you have weight ?

ARE you Accelerating

Throw Ball – look at curve



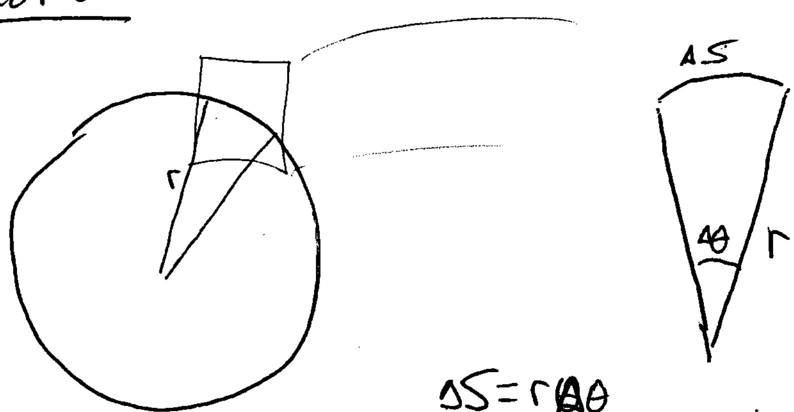
If in orbit you are constantly Accelerating

even if speed constant

$\bar{V}$ direction always changing

"Orbit" is falling in a closed circle!

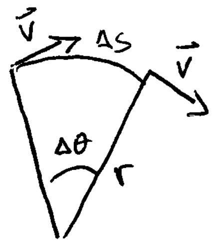
Circular Motion

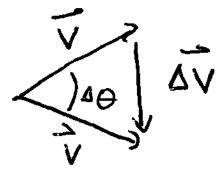


$\Delta S = r\Delta\theta$

in radians

$\Delta s = r\Delta\theta$ often see $s = r\theta$





↑ by analogy

$$\Delta v = v\,\Delta\theta$$

$$\frac{\Delta v}{\Delta t} = v\,\frac{\Delta\theta}{\Delta t} = \frac{v\,\frac{\Delta s}{r}}{\Delta t}$$

$$\frac{\Delta v}{\Delta t} = \frac{v\,\frac{\Delta s}{\Delta t}}{r}$$

in limit of $\Delta t \to$ small

$$\frac{dv}{dt} = \frac{v\,\frac{ds}{dt}}{r}$$

$$\boxed{|\vec{a}| = \frac{|\vec{v}|^2}{r}}$$

Also mention centripetal Force

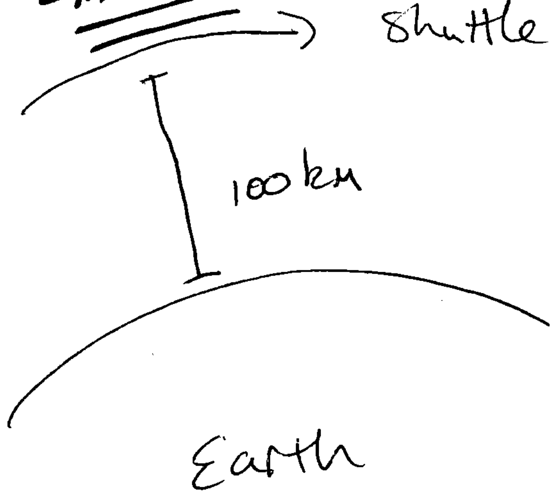
Condition for Circular Motion ⇒ radial Acceleration

acceleration is toward center of circle and has magnitude $\frac{|\vec{v}|^2}{r}$

Also called centripetal acceleration

$\vec{v}$ here often called "Tangential" velocity
→ it is just the instant. velocity which happens to be tangential because motion is circular !!

Example



assume

$g = 9.8\ m/s^2$

at shuttle height

(Not exactly true)

What is $|\vec{V}|$ of Shuttle to have closed orbit

$$a = \frac{v^2}{r} \qquad 9.8\ m/s^2 = \frac{V^2}{R_e + 100000\ m} \sim \frac{V^2\ (m/s)^2}{\cancel{6.46\times10^8}\ m\ \ \cancel{6.37\times10^6}\ \ 6.47\times10^6}$$

R_e / 6.37×10^6 ~~6.91×10^8 m~~

$$V = \cancel{82{,}588}\ 7962\ m/s$$

or

$$\cancel{82588}\ 7962\ \frac{m}{s} \cdot 100\ \frac{cm}{s} \times \frac{1\ in}{2.54\ cm} \times \frac{ft}{12\ in}\ \ \frac{mi}{5280\ ft} \times 3600\ \frac{s}{hr}$$

$$= \cancel{184{,}744}\ 17{,}812\ mi/hr$$

We will do many things/probs etc. with circular motion

Remember circular motion $\Longleftrightarrow$ $a = \frac{v^2}{r}$ radially

Newton's Laws

I: Law of inertia

A body persists in its state of motion unless acted on by an external net force.

II: Force Law

The acceleration of an object is proportional to the net force applied to it and inversely proportional to the mass of the object

$$\sum \vec{F} = m\vec{a}$$

III Law of Action and Reaction

For every action there is an equal and opposite reaction

Newton's Laws of Motion – Sir Isaac Newton (1687)

foundation of classical Mechanics

1^{ST} Law of Motion – Law of inertia

A body acted on by no force moves w/ constant velocity (possibly zero) and zero acceleration.

-or-

A body persists in its state of motion unless acted on by an external net force

-or-

others . . . All say the same thing

2^{ND} Law of Motion – Force Law

The acceleration of an object is ~~inversely~~ proportional to ~~its mass and~~ the net force applied to it and inversely proportional to the mass of the object.

2ND Law

$$\Sigma \vec{F} = m\vec{a}$$

1ST Law

$$\text{if } \Sigma \vec{F} = 0, \quad \vec{a} = 0$$

Slightly more mathematical formulations

3^{RD} Law of Motion – Law of Action + Reaction

For every action there is an equal and opposite reaction.

3RD

3RD law is hardest to see conceptually.

"Throw ball on ice" ... you apply force to ball

ball applies force to you

↳ slide back on ice

"recoil of a gun"

How to use will become clear in examples

All should become clear w/ examples

1ST

Sometimes students find the 1ST law hard to swallow

Can anyone think of an example where the 1ST law is NOT true ??

Car ... stop ~~[illegible]~~ gas to engine ... slows + stops

Cart ... stop pushing ... it stops

⇒ Think of a world w/out ~~[illegible]~~ friction or Air resistance to get a ~~concept of~~ conceptual view of the 1ST law.

↳ let objects "move on ice" + "in vacuum" in your mind.

friction + Air resistance keep the 1ST law from Seeming to be true in real life. This is incorrect

These are retarding forces ... you just aren't always aware of them

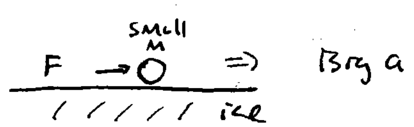
2ND

2ND law is almost intuitive

Its sort of a circular definition

↳ of Force

↳ of inertial Mass



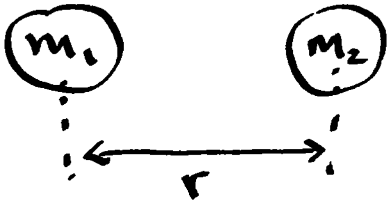
$\vec{F} = m\vec{a}$ — Force Meas. in Newtons $\equiv kg\,m/s^2$ in units

This is inertial Mass

How does this relate to weight?

Gravitational force

$$|\vec{F}| = \frac{G m_1 m_2}{r^2}$$



let $M_1 = M_{earth}$

$$|\vec{F}| = \frac{G M_e m_2}{r_e^2}$$

$r_e \equiv$ radius of earth $= 6.38 \times 10^6$ m

$G \equiv$ gravitational constant $= 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$

describes how strong gravity is as a force

$M_e \equiv 5.97 \times 10^{24}$ kg

$$\frac{G M_e}{r_e^2} \equiv g = 9.8\ m/s^2$$

Weight is the ~~for~~ magnitude of the force of gravity due to earth's grav. attraction Near earth's surface

$$\text{weight} = |\vec{F}| = mg \leftarrow 9.8\ m/s^2$$

Weight on Moon $= m\left(\frac{G M_{moon}}{r_{moon}^2}\right)$

unit of weight is Newton (NOT Kg) in MKS

↑ This is mass

System	Force	MASS	Acceleration
MKS	Newton ~~[illegible]~~	kg	m/s^2
Cgs	dyne	gm	cm/s^2
English	pound	slug	ft/s^2

in English system

$$F = ma$$

~~F~~ Weight (pounds) = Mass (slugs) $32\ ft/s^2$

$g = \frac{GM_e}{r_e^2}$ in English units

~~Enough of the preliminaries -~~

~~Newton's Laws become clear ~~thru~~ thru examples~~

~~So let's do examples!~~

Use/significance of Newton's Laws becomes clear thru examples

The Path to Enlightenment

1. understand Problem, Draw Neat diagram of overall problem
2. draw Free body diagram of ~~att~~ each relevant object - label with forces
3. Choose convenient coordinate system for each object
4. Apply Newton's Second Law $\Sigma \vec{F} = m\vec{a}$ in appropriate orthogonal coordinates (coordinates chosen for each body must be related to those chosen for other bodies)
5. Keeping Symbols in place (No #'s yet!) Solve resulting set of equations simultaneously
6. Check answer with limiting cases and dimensional Analysis!

Air-Sea Rescue

Rope Most likely to break when

1. Helicopter hovers at rest
2. Helicopter Moves upward at const speed
3. Helicopter Moves downward at const speed
4. Helicopter accelerates upward
5. Helicopter Accelerates downward