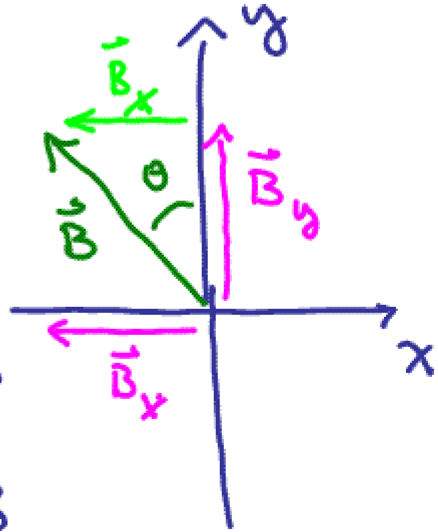
Physics 113 – September 21, 2006
Circular Motion, Newton's Laws

Last Time

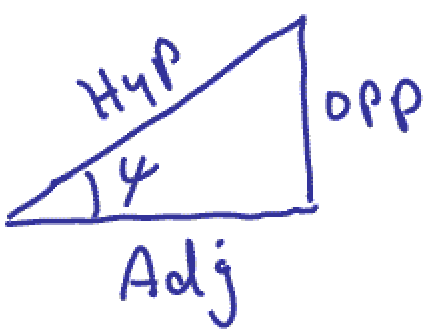
Breaking vector $\vec{B}$ into components

"Resolving" vector B



$B_y = B\cos\theta$

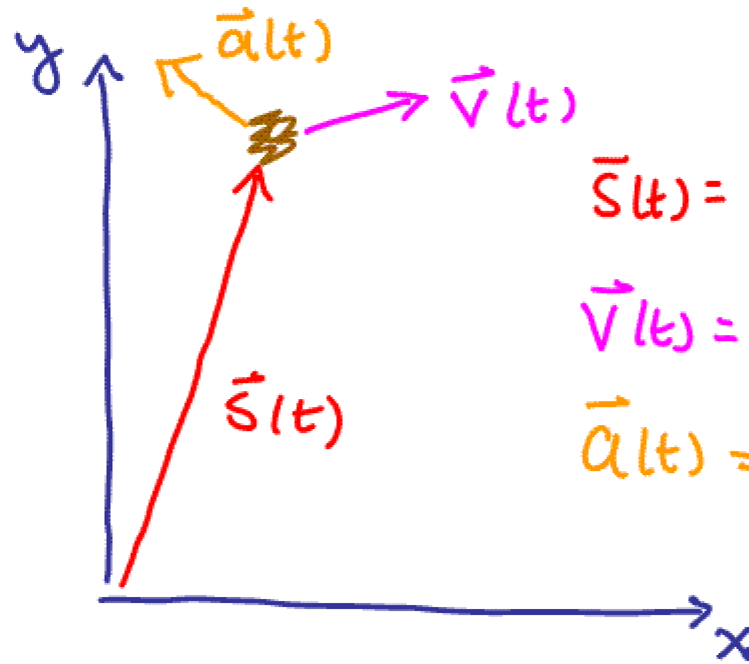
$B_x = B\sin\theta$



$\sin\psi = \frac{opp}{hyp}$

$\cos\psi = \frac{Adj}{hyp}$

$\tan\psi = \frac{opp}{Adj}$



$\vec{s}(t) = s_x \hat{i} + s_y \hat{j} + s_z \hat{k}$

$\vec{v}(t) = v_x \hat{i} + v_y \hat{j} + v_z \hat{k}$

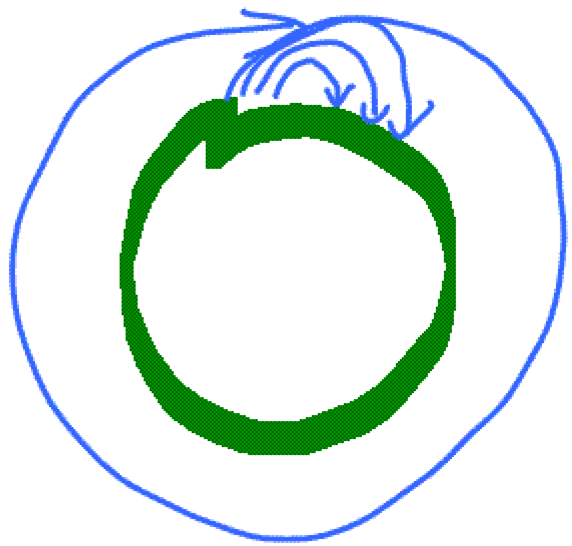
$\vec{a}(t) = a_x \hat{i} + a_y \hat{j} + a_z \hat{k}$

General 3-d motion:

$\vec{s}(t), \vec{v}(t), \vec{a}(t)$ not independent

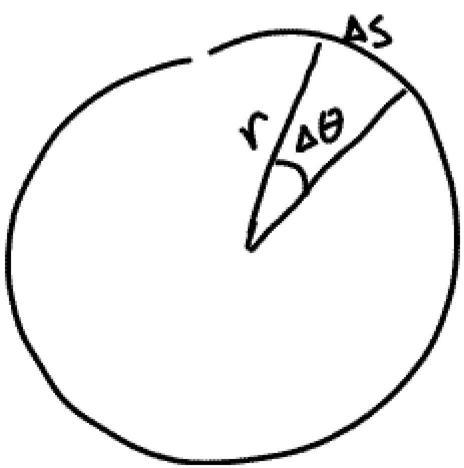
Resove components of vectors along chosen axes

Solve 3 1-d problems simultaneously



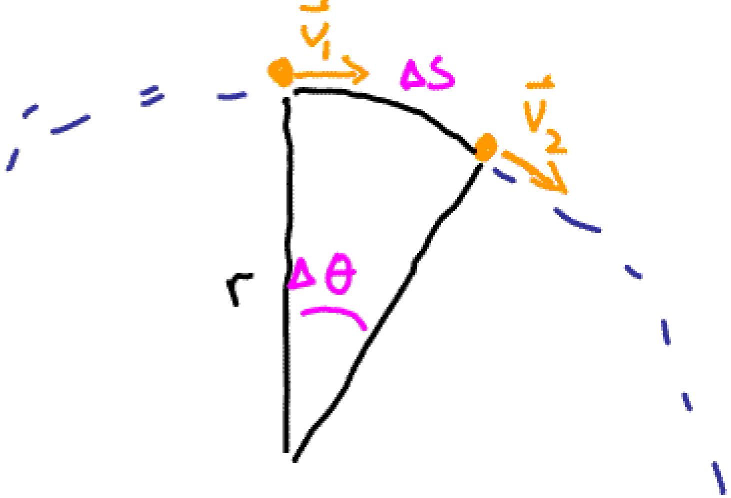
Orbit

Circular motion

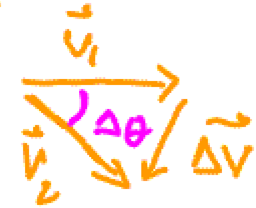


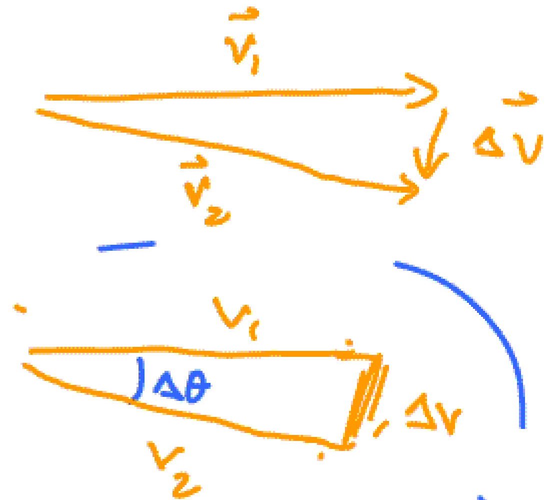
radians

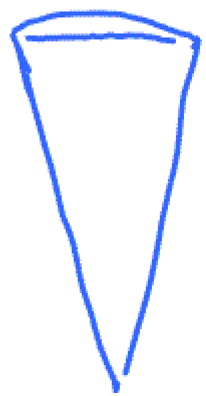
$$\Delta s = r\,\Delta\theta$$



$|\vec{v}_1| = |\vec{v}_2| = V$







$S = r\,\Delta\theta$

object moving on
circle
radius r

$\Delta V = V\,\Delta\theta$

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

$\Delta s = r\,\Delta\theta \rightsquigarrow \Delta\theta = \frac{\Delta s}{r}$

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

limit of small Δt

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

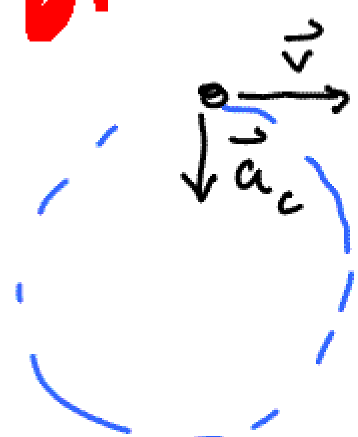
$\frac{ds}{dt}$ — also just v

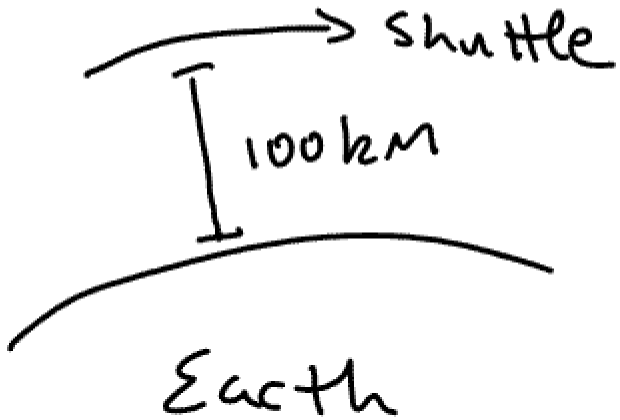
acceleration

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

for motion on circle

Centripetal Acceleration $\vec{a}_c$





assume

$g = 9.8\ m/s^2$

at shuttle ht.

What is $|\vec{v}|$ of shuttle

circular orbit

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

$$9.8\ m/s^2 = \frac{v^2}{R_e + 100{,}000\,m}$$

R_e = $6.37 \times 10^6\ m$

$v = 7962\ m/s$

$= 17{,}812\ mi/hr$

Sir Issac Newton

The younger years

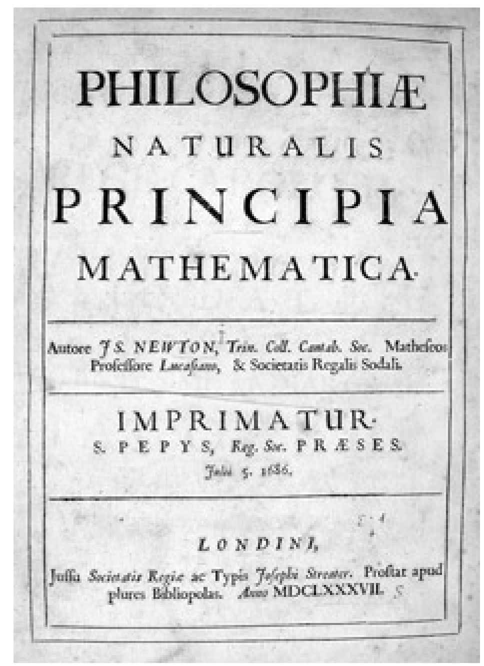
Sir Issac Newton

1643-1727

Born in Lincolnshire, England

Cambridge University

Philosophie Naturalis Principia Mathematica



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore J S. NEWTON, Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

LONDINI,
Jussu Societatis Regiæ ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.

Optics, mechanics, gravitation, calculus

Sir Issac Newton

1643-1727

Newtonian physics

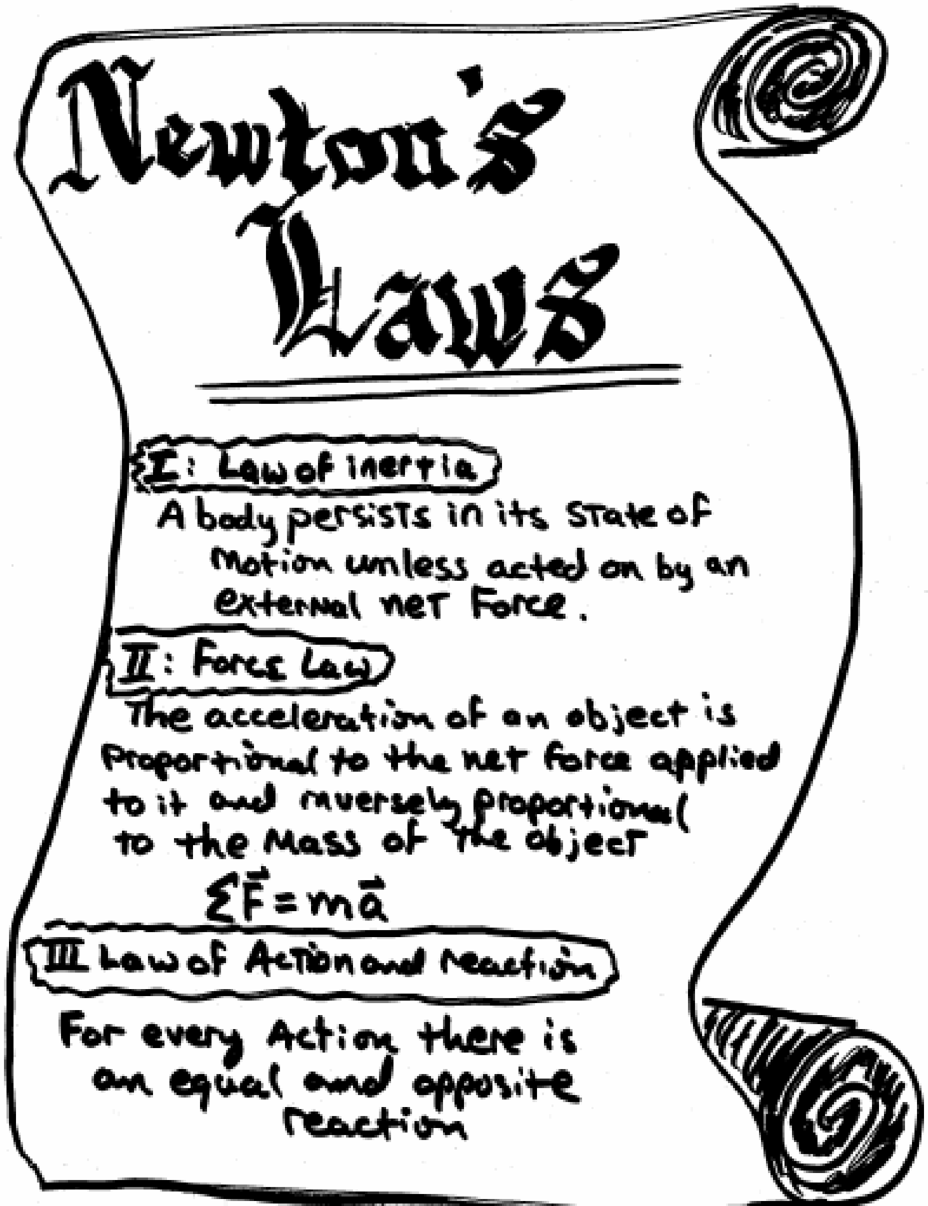
Newtonian universe

Includes everything but …

Electromagnetism

Quantum mechanics

Mechanics of extreme velocities or extreme density


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
ΣF⃗ = ma⃗
III Law of Action and reaction
For every action there is an equal and opposite reaction

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

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

III Law of Action and reaction

For every action there is an equal and opposite reaction

$\vec{F} = m\vec{a}$ ← inertial mass

$\vec{F}$ in MKS: Newtons (unit of force)

Force of gravitation

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

in special case $m_1 = M_{earth}$, $r = r_{Earth}$

$$|\vec{F}| = \frac{G M_{earth}}{r_{Earth}^2} m_2$$

$r_{earth} \doteq 6.38 \times 10^6 M$

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

$M_{earth} = 5.97 \times 10^{24}\ kg$

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

Weight $\equiv$ magnitude of Force of grav. due to Earth's grav. attraction near Earth's surface.

$$\text{weight} = |\vec{F}| = m g$$

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

g_{moon}

$$F = \frac{G M_1 M_2}{r^2} \qquad F = ma$$

M_1, M_2: gravitational mass

m: inertial mass

gravitational mass $\equiv$ inertial mass

NOT a priori obvious it has to be this way but it is ... at least as far as we can tell from experimentation

Systems	Force	Mass	Accel
MKS	Newton	kg	m/s^2
cgs	dynes	gram	cm/s^2
English	pound	slug	ft/s^2