LAST TIME: to describe motion of objects

Introduce coordinates: choose origin, +ve directions

describe motion by $(x(t), y(t), z(t))$

Useful concepts:

similar for v_y, v_z

Velocity: $V_x = \frac{\Delta x}{\Delta t}$ in limit where $\Delta t \to 0$

- (defines derivative $\frac{dx}{dt} = \lim_{\delta t \to 0} \frac{x(t+\delta t) - x(t)}{\delta t}$)

$v(t)$: slope of $x(t)$ graph at time t

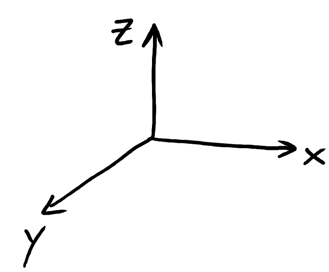
acceleration: $a_x = \frac{\Delta v_x}{\Delta t}$ in limit where $\Delta t \to 0$ $\equiv \frac{dv}{dt}$

$a(t)$: slope of $v(t)$ graph at time t

PHYSICS:

1st observation: Need 3 space coordinates to describe locations of objects (plus 3 more to describe their orientation in space - see clicker Q. answer)

We live in 3 dimensions



Extra coordinate: time

locations can change w. time:

$(x(t), y(t), z(t))$ ← 3 functions = 3x infinity numbers

PHYSICS allows us to predict these from

$(x(0), y(0), z(0))$ and $(V_x(0), V_y(0), V_z(0))$ + knowledge of object's environment.

Simplest environment: outer space
(far from planets, etc...)

empty space: lots of SYMMETRY

move in any direction by any amount:
looks the same TRANSLATIONAL SYMMETRY

turn in any direction by any angle:
looks the same ROTATIONAL SYMMETRY

wait some amount of time:
looks the same TIME TRANSLATION SYMMETRY

(also: "boost" symmetry - no perceptible difference if we are moving at constant velocity)

EMMY NOETHER 1882-1935
proved that SYMMETRIES imply CONSERVATION LAWS

translation symmetry $\Rightarrow$ conservation of momentum

time translation sym $\Rightarrow$ conservation of energy

rotation sym $\Rightarrow$ cons. of angular momentum e.g.

$\boxed{\text{CONSERVATION OF MOMENTUM}}$

same story for y, z

for an object in an environment with translational symmetry in the x direction, there is a quantity p_x associated ith the object that is constant (unchanging) in time

small velocities
$|v| \ll 3 \times 10^8 \, m/s$

approximately equal to

$$p_x \approx m v_x$$

generally

$$p_x = \frac{m v_x}{\sqrt{1 - \frac{v_x^2 + v_y^2 + v_z^2}{c^2}}}$$

Constant $\vec{p} = (p_x, p_y, p_z)$ implies constant $\vec{v}$

Conclusion: for an isolated object (i.e. no interactions w. other things) $\vec{v}$ is constant in time

$\boxed{\text{NEWTON'S 1ST LAW}}$