News: Oasis Tutorials next week

Some of you owe $0.25 for Scantrons

(and I haven't written quiz yet!)

Questions

Q: Which stays airborne longer: a bullet dropped from shoulder-height, or a bullet fired horizontally from rifle at 700 m/s ?

Q: An athlete [throws javelin / dives off cliff]. How does initial speed and direction affect (i) time of flight, (ii) distance traveled, (iii) angle of impact ?

Q: Do we need to escape Earth's gravity to be (or feel) "weightless" ?

Free-Fall in 2D : Projectile Motion

Projectile : thrown with initial velocity (not powered)

- follows a trajectory in space

"Free-fall" : accelerating downwards under gravity

- even if moving upwards!

i.e. $\vec{a} = \vec{g}$ with $|\vec{g}| = g = 9.81\,m/s^2$

(this is large! $g \rightarrow$ v changes from 0 to 60mph in ???

c.f. Sports car with $|\vec{a}| \sim 0.4g$)

$|\vec{a}| = \frac{v - 0}{t - 0}$ (v → 60mph)

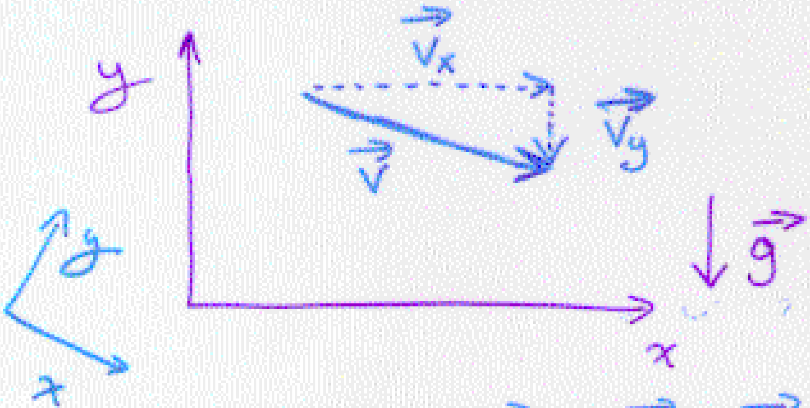
In practice, air friction provides additional accel. opposing object's velocity (and increasing with speed).

e.g. falling object reaches terminal velocity in air (skydiver : 55 m/s
feather : ~0.2 m/s)

- Neglect air friction for: dense objects (high mass, small size), and low speeds.....

Analysis of Free-fall Motion

At any point in motion, can separate object's velocity into components:



$$\vec{v} = \vec{v}_x + \vec{v}_y$$

Can write $\vec{v} = \vec{v}_x + \vec{v}_y$ with $\vec{a} = \vec{g}_y$

(or: $\vec{v} = v_x \vec{i} + v_y \vec{j}$ with $\vec{g} = -g\vec{j}$)

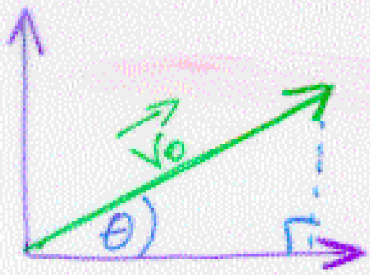
where $v_x = \frac{dx}{dt}$ $v_y = \frac{dy}{dt}$ $\frac{d^2y}{dt^2} = -g$

i.e. motion in x-direction independent of gravity

e.g. Drop cannon ball + fire another horizontally:

(Snapshots at equal time intervals) fig 3.14

Parabolic Trajectories



launch object at speed

$v_0 = |\vec{v}_0|$ at angle θ

to horizontal

Taking components:

x: $\frac{dx}{dt} = v_x = v_0 \cos\theta$ $\quad\therefore\quad$ $x(t) = (v_0 \cos\theta)t + x_0$

y: $\frac{dy}{dt} = v_y = (v_0 \sin\theta) - gt$ $\quad$ (because $\frac{d^2y}{dt^2} = -g$)

$\Rightarrow$ height $\quad y(t) = y_0 + (v_0 \sin\theta)t - \frac{1}{2}gt^2$

horiz. distance $\quad x(t) = x_0 + (v_0 \cos\theta)t$

Eliminate "t" (easiest if $x_0 = 0$, $y_0 = 0$) $\Rightarrow$ $y(x)$ is a parabola

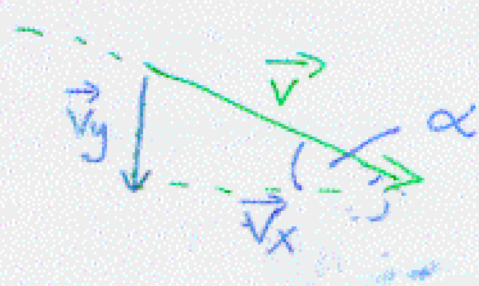
We can then find position and velocity at any instant in path

e.g. Time of flight t_f : solve $y(t_f) = 0$

Distance traveled then just $x(t_f)$

Can also find $\vec{v}(t_f)$

(size and direction)



Free-fall and "Weightlessness"

Since all freely-falling objects accelerate at g

.... in falling elevator, no net accel. of objects (keys, internal organs) relative to each other.

So a being born in a falling elevator (or space-ship) will not know that gravity exists (if no windows)

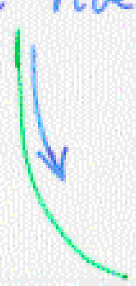
We can also launch elevator upwards and still have same result!

elevator and all objects inside follow a free-fall parabolic path

- Used by NASA for astronaut training (and "Apollo 13 movie)
  - Boeing 747 "Vomit Comet" flies in a parabolic climb/dive

  $\Rightarrow$ few minutes of "weightlessness"

"Free-fall" ride at Magic Mountain

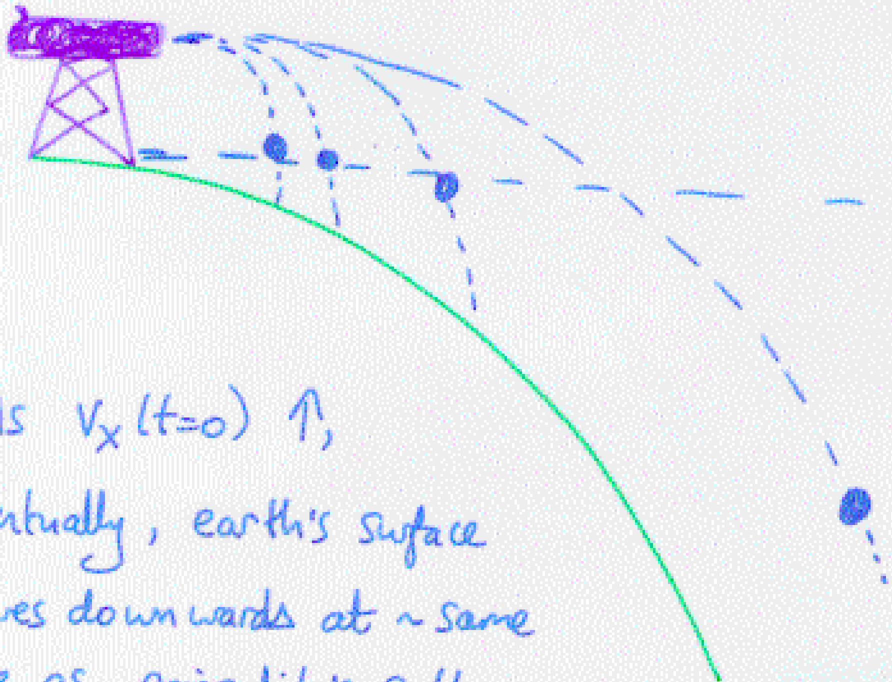


<u>But</u> height of ride $y_0 = \frac{1}{2} g t_f^2$

- expensive!

Newton's Cannon – Weightlessness in Orbit

Newton theorized: build a powerful cannon on tall mountain. Fire horizontally, increasing initial speed:



As $v_x(t=0)\uparrow$, eventually, earth's surface curves downwards at ~ same rate as projectile's path

→ projectile now in orbit!

∴ Shuttle crew in orbit are also in free-fall. Gravity is still strong close to earth but no net acceleration inside shuttle → "weightlessness".