Splat?

An example of computational Physics in action!

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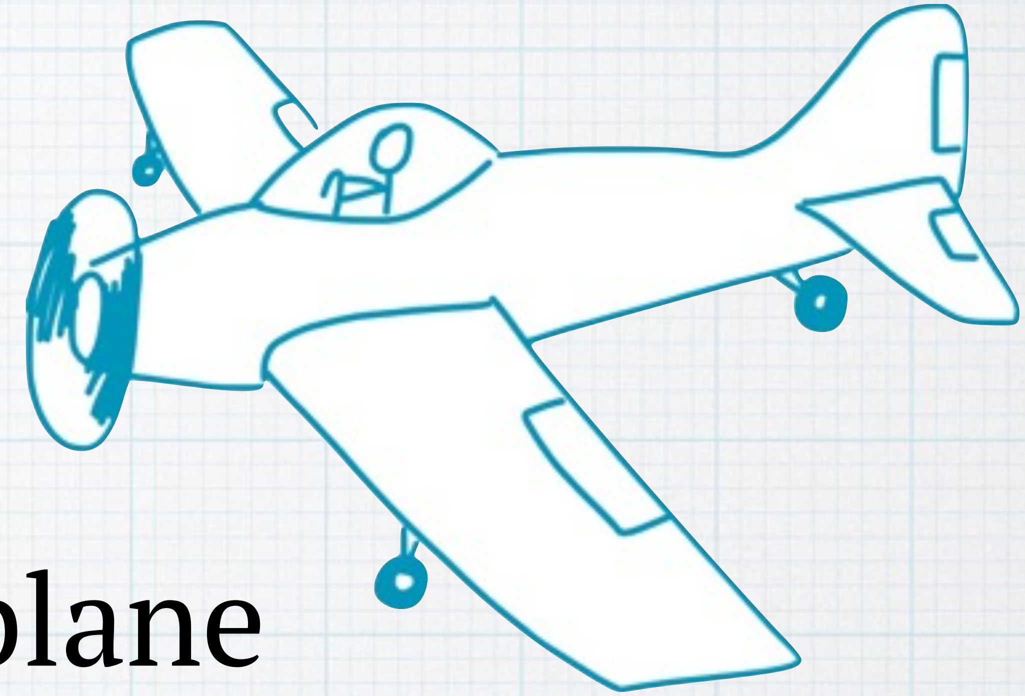
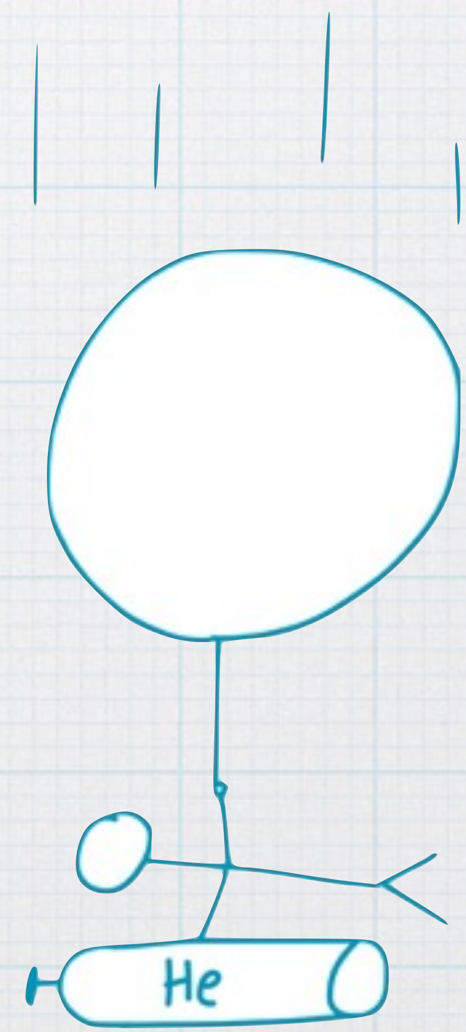
Why not just use pen and paper?

- A lot of the equations aren’t "solvable" (no analytic solutions)
- There are too many variables in play
- Saves time
- Neat graphs

The question:



A human leaps out of a plane holding a pressurised tank of helium and a weather balloon.



What happens next?

The details:

- Air resistance and buoyancy
- Pressure, temperature and density vary with altitude
- Radius of the balloon depends on the pressure inside the balloon and atmosphere
- Speed of inflation of the balloon depends on pressure in the tank and in the balloon

The Physics:

Gravity:

$$F_G = mg$$

Drag Force:

$$F_D = \frac{1}{2} C_D A \rho v^2$$

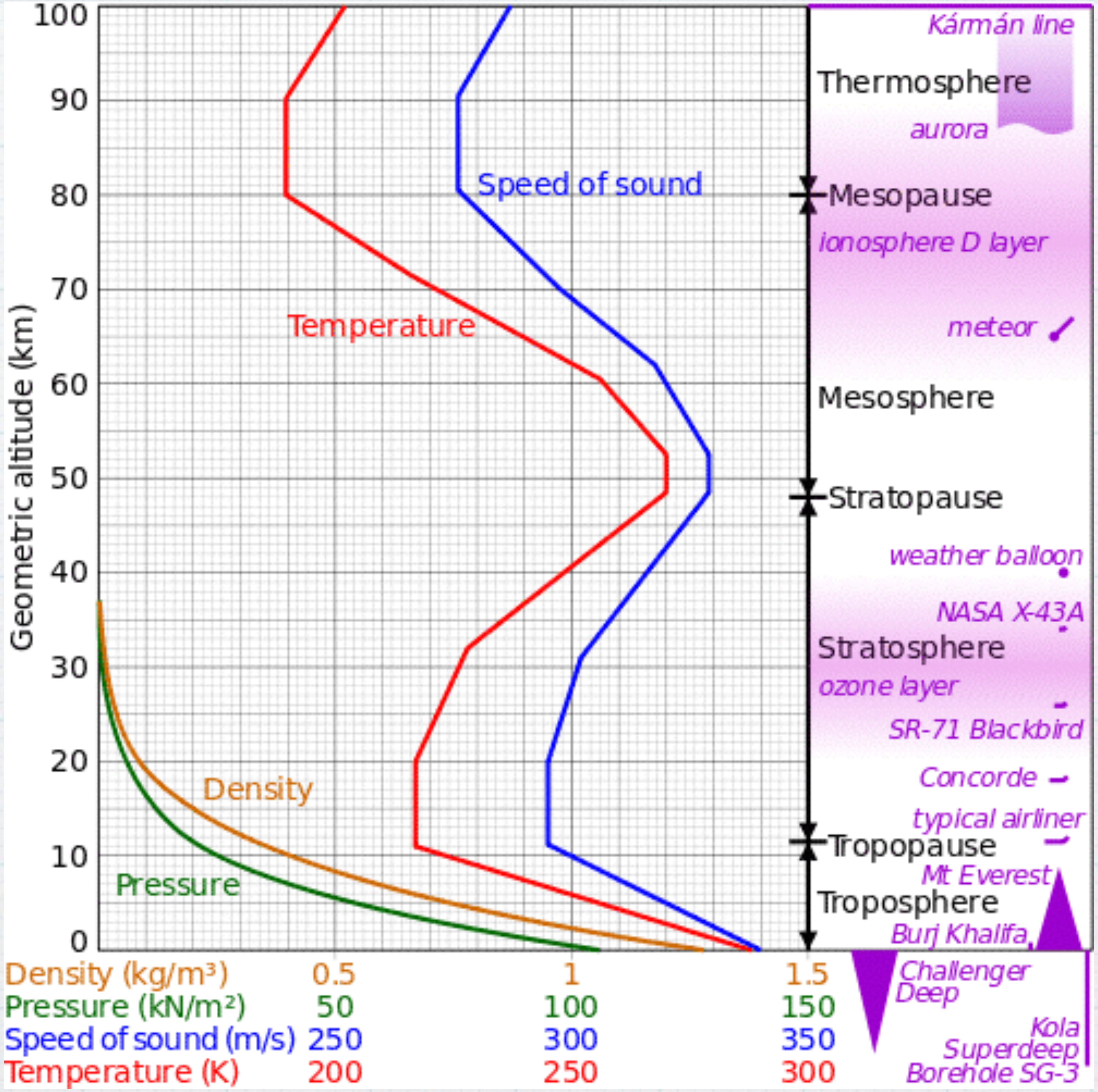
Buoyancy:

$$F_B = \rho g V$$

Reynolds Number:

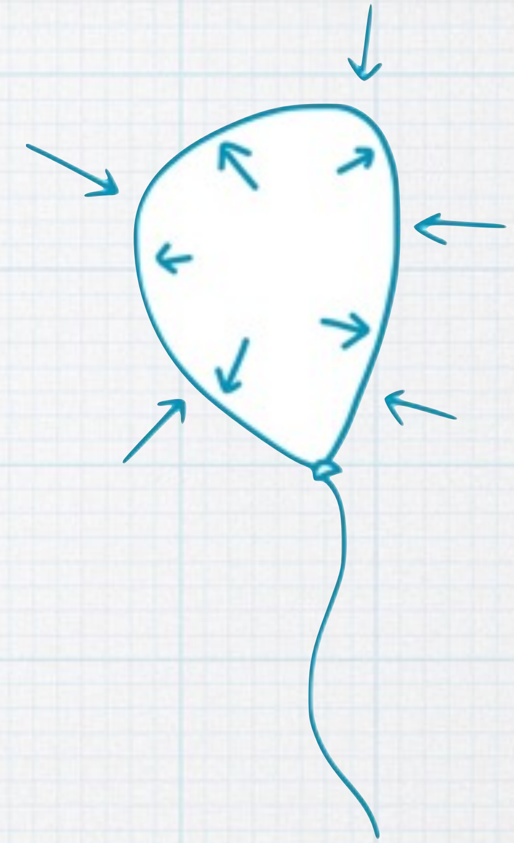
$$R_e = \frac{vD}{\nu}$$

The Physics



Geometric altitude (km)
100
90
80
70
60
50
40
30
20
10
0
Temperature
Speed of sound
Density
Pressure
Density (kg/m³) 0.5 1 1.5
Pressure (kN/m²) 50 100 150
Speed of sound (m/s) 250 300 350
Temperature (K) 200 250 300
Kármán line
Thermosphere
aurora
Mesopause
ionosphere D layer
meteor
Mesosphere
Stratopause
weather balloon
NASA X-43A
Stratosphere
ozone layer
SR-71 Blackbird
Concorde
typical airliner
Tropopause
Mt Everest
Troposphere
Burj Khalifa
Challenger Deep
Kola Superdeep Borehole SG-3

The Physics

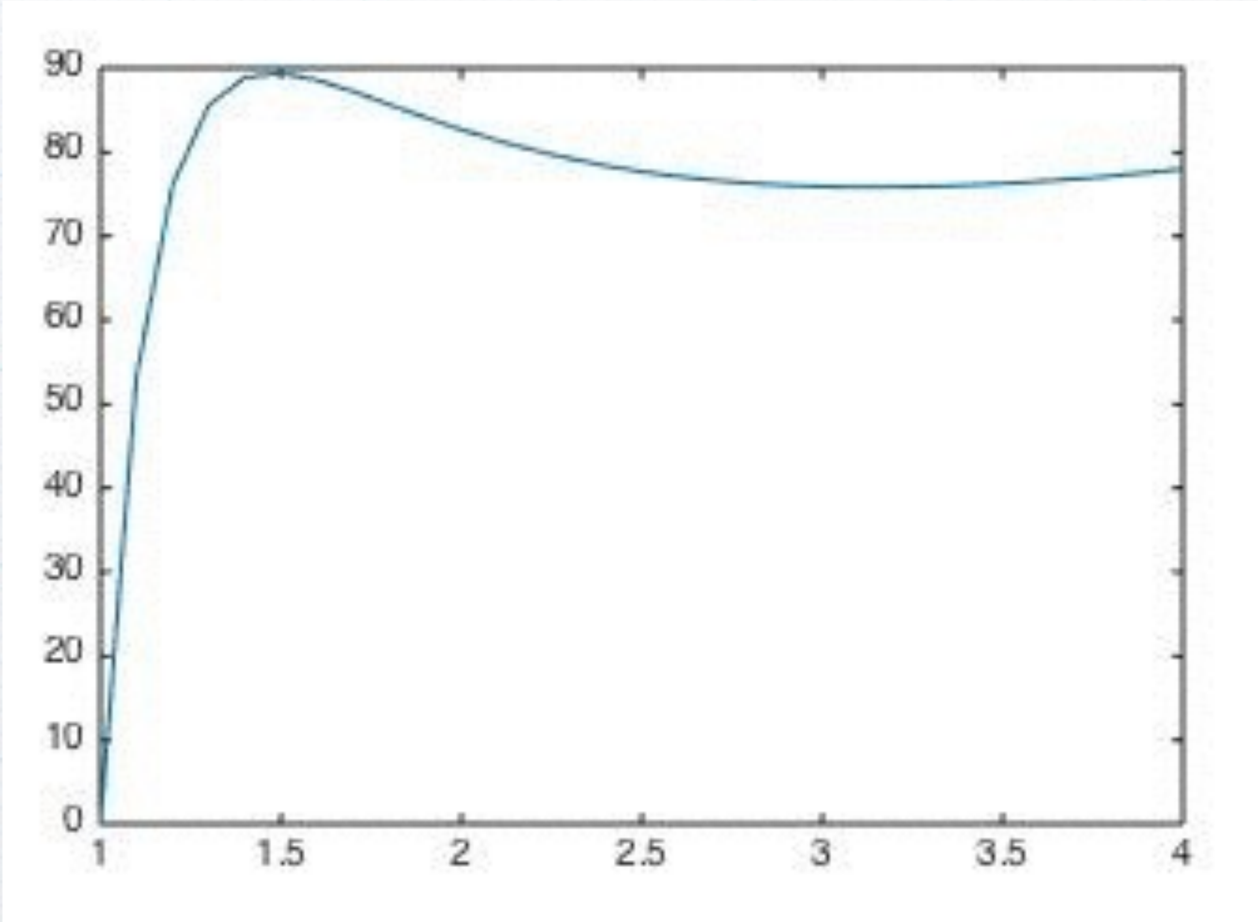


The Mooney-Rivlin model:

$$\Delta P = 2\mu \frac{t_0}{r_0}\left(\left(\frac{r_0}{r}\right) - \left(\frac{r_0}{r}\right)^7\right)\left(1 + \frac{1-\alpha}{\alpha}\left(\frac{r}{r_0}\right)^2\right)$$

$$P_{atmospheric} = P_{balloon} - \Delta P$$

$$P_{balloon} = \frac{nRT}{\frac{4}{3}\pi r^3}$$



MATLAB's built-in functions
make life so much easier!

The Balloon

SN: 400-8242

μ = 300,000 Pa α = 10/11

r_0 initial non-inflated balloon radius = 0.54m

m balloon mass = 0.8kg

r_{max} maximum radius = 3.4m

t_0 initial balloon thickness = 0.2mm

The Tank:

SN: HP Steel 50

$P_{tank}(t = 0)$ = 2900psi = 20,000,000Pa

V_{tank} = 50L = 0.05m^3

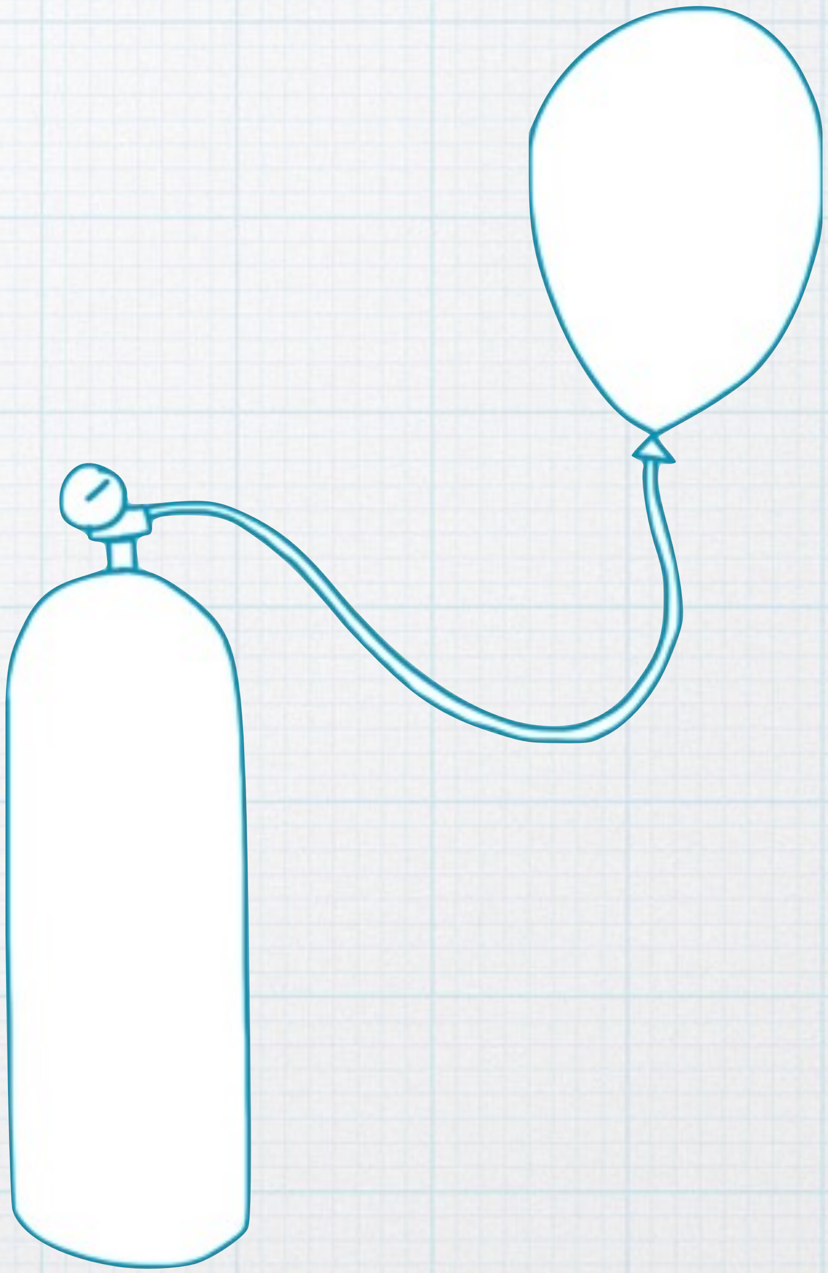
m_{tank} = 60kg

The Physics

Use Bernoulli's equation:

$$\frac{1}{2}\rho v^2 + \rho g z + P = constant$$

$$\frac{dn}{dt} \propto v \propto \sqrt{P_{tank} - P_{ballon}}$$



The MATLAB

Set initial values

Find $\sum F(t)$

update $a(t) \rightarrow a(t + dt)$

update $v(t)$ and $h(t)$

yes $t = t_{max}$ no

Plot graph

Falling with MATLAB

The MATLAB

Set initial values

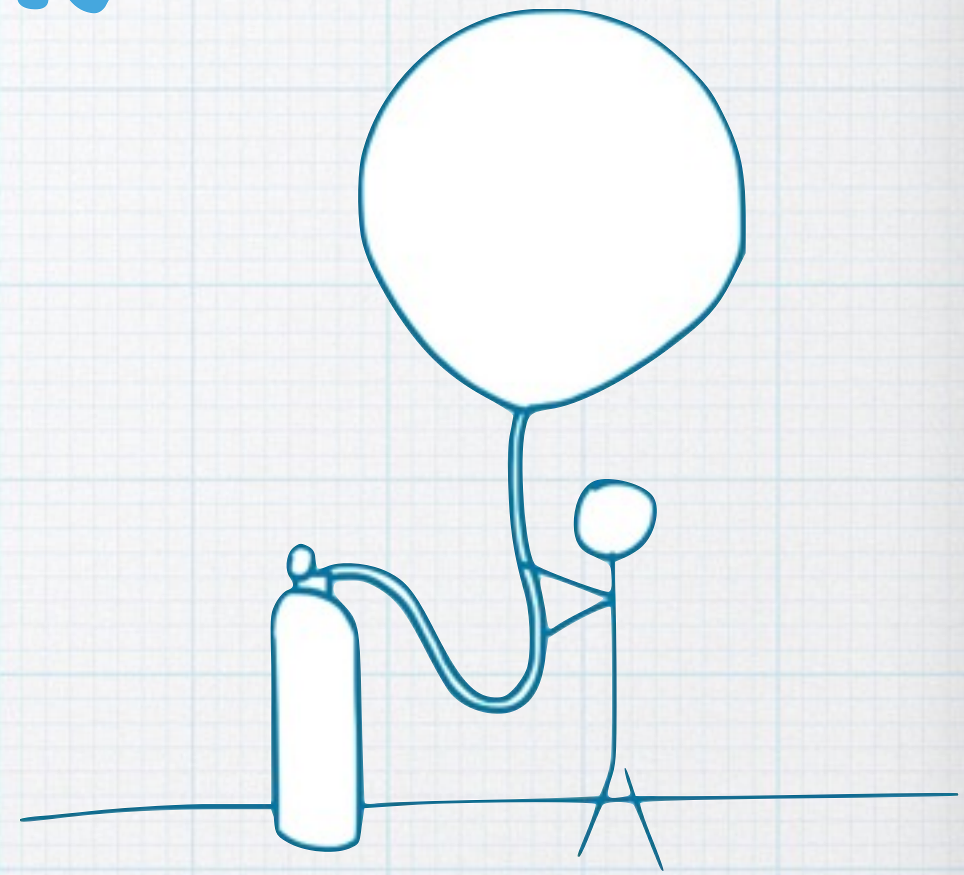
$$\frac{dn}{dt} = C\sqrt{P_{tank} - P_{balloon}}$$

Find $n_{balloon}$; $n_{tank} \rightarrow P_{tank}$

$r_{balloon} \rightarrow V_{balloon}$ & $P_{balloon}$

yes $t = t_{max}$ no

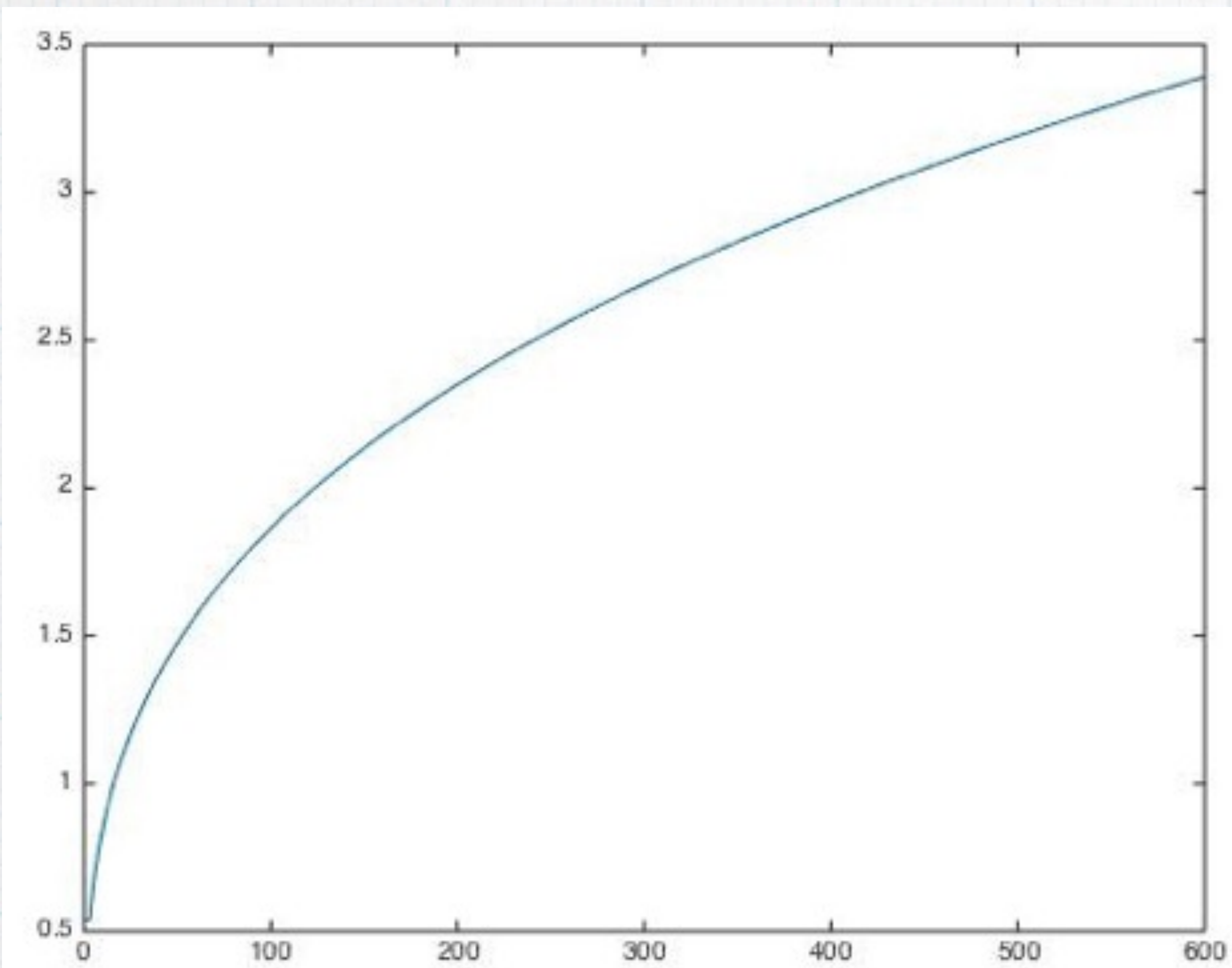
Plot graph



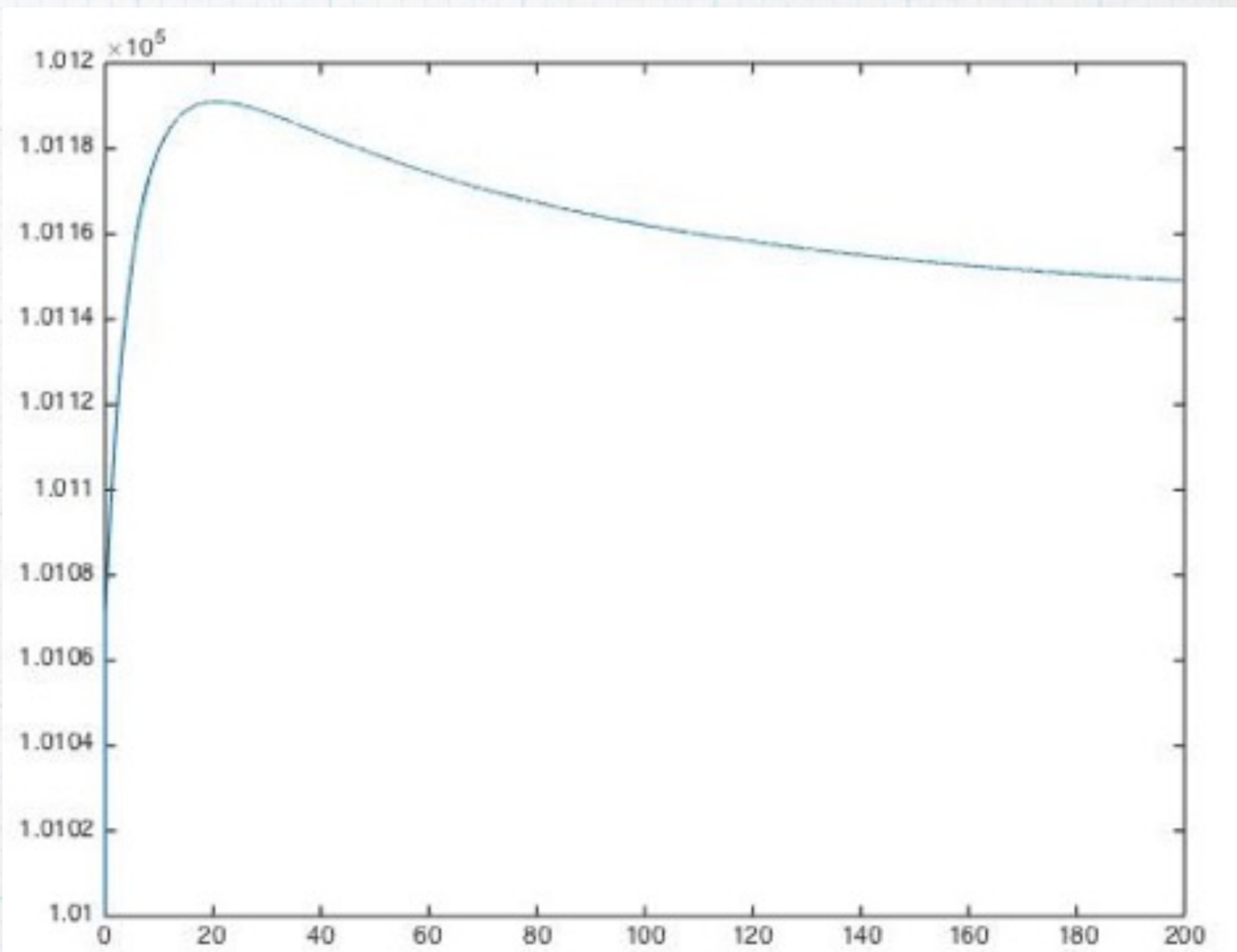
Test: Inflating a balloon at ground level

The Results

Test: Inflating a balloon at ground level

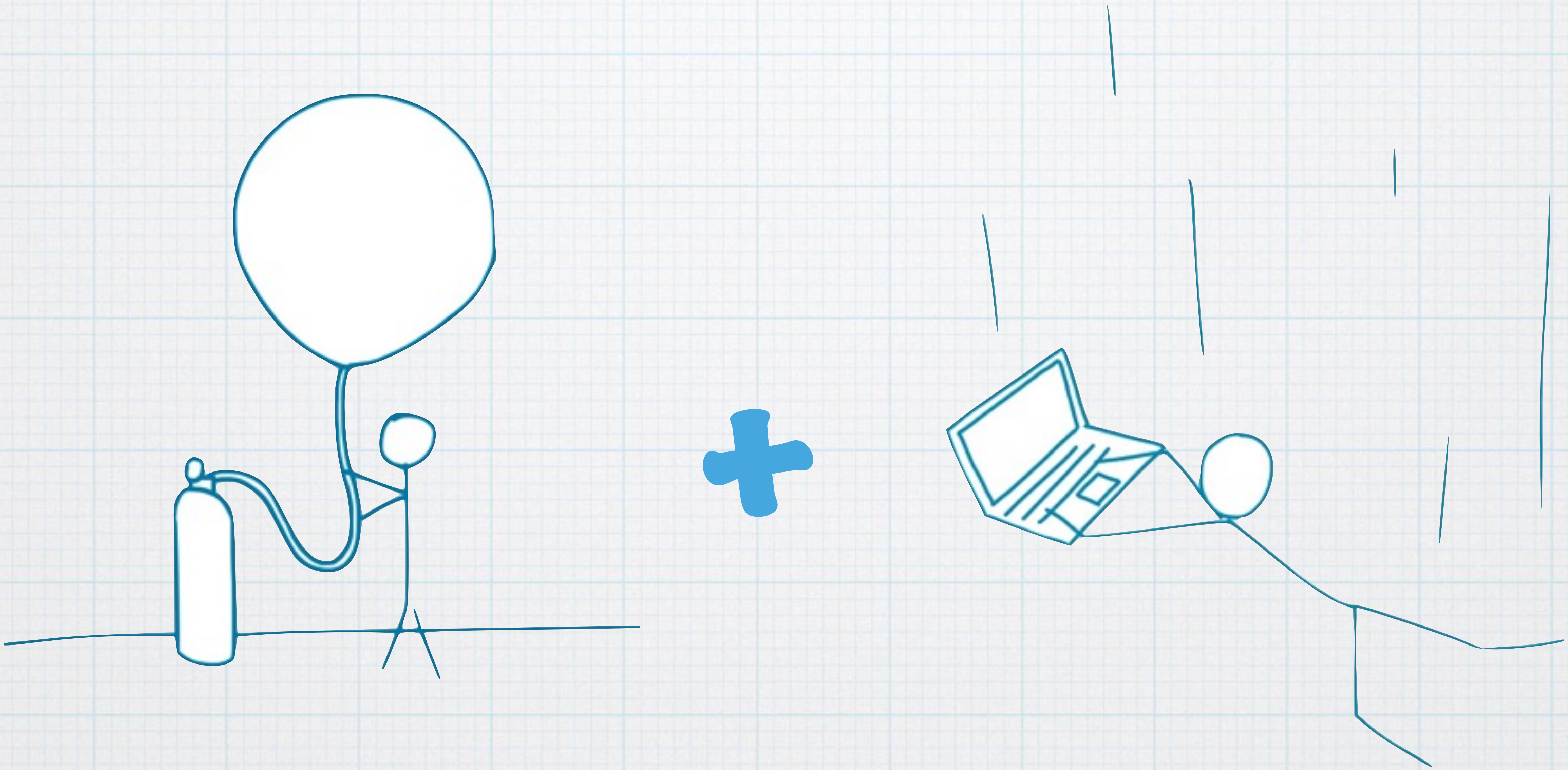


$R_{balloon}\ vs\ t$



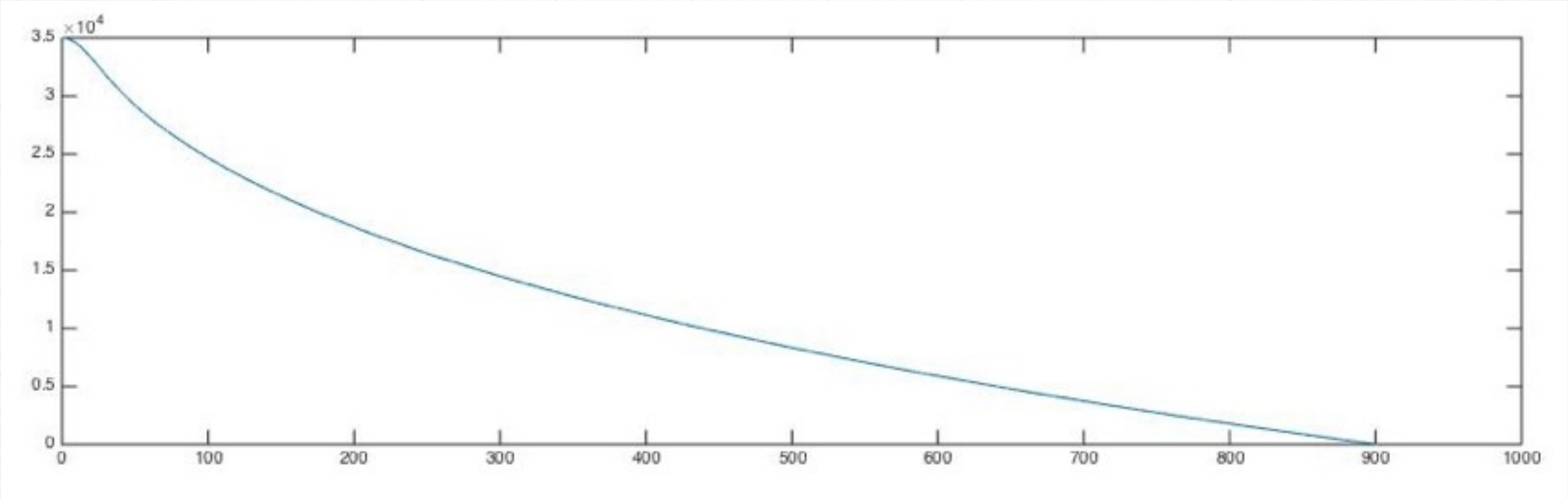
$P_{balloon}\ vs\ t$

The Main Code

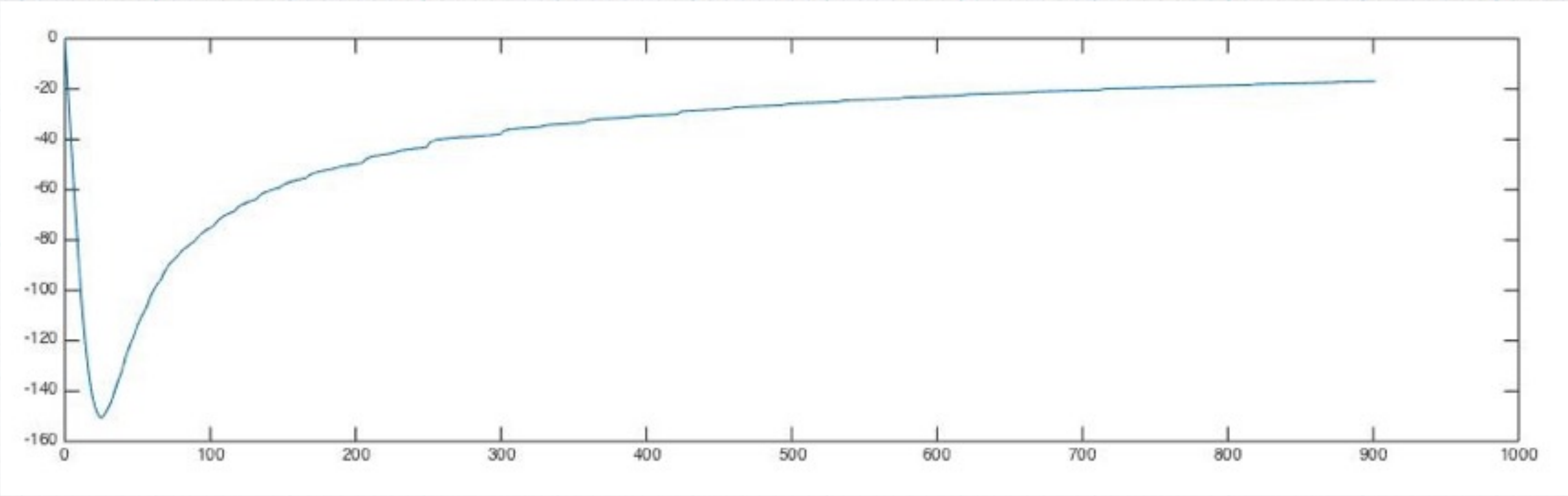


Some neat graphs!

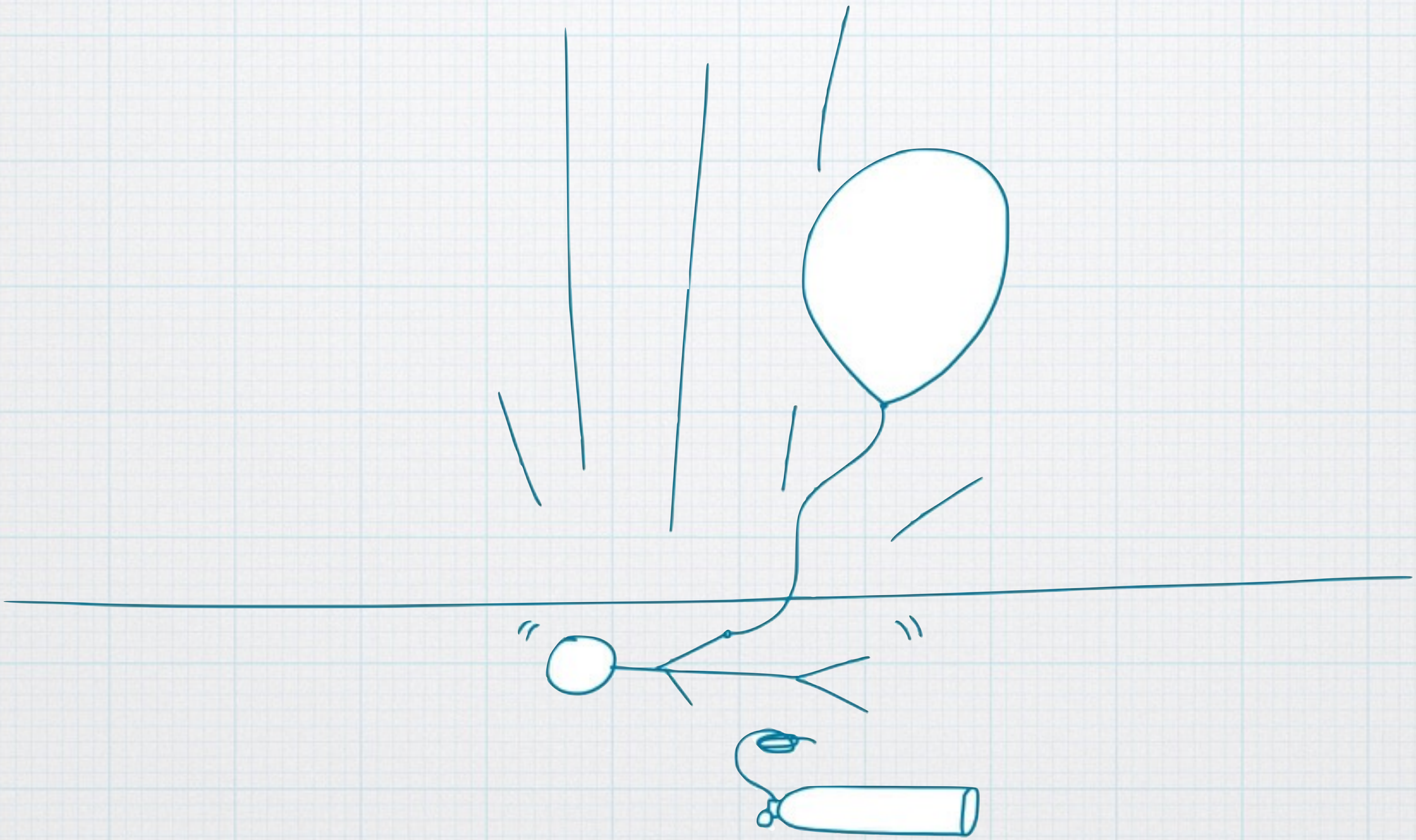
$y(t)$



$\dot{y}(t)$

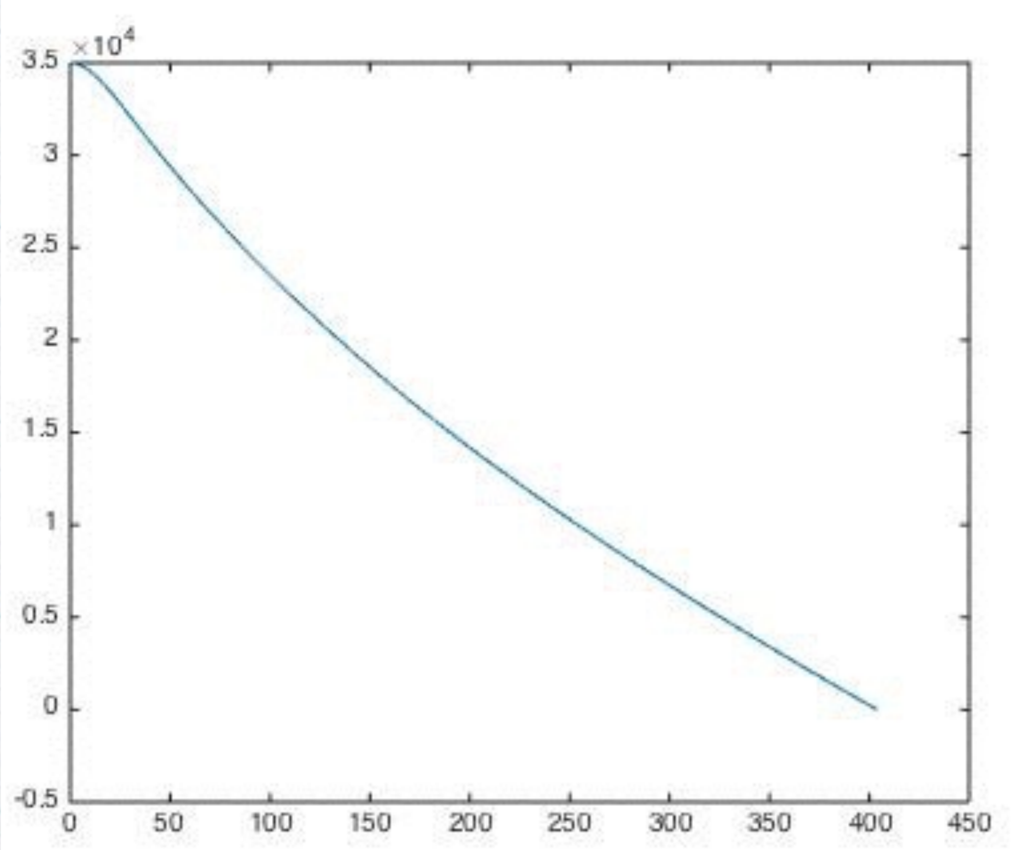


So what happens?

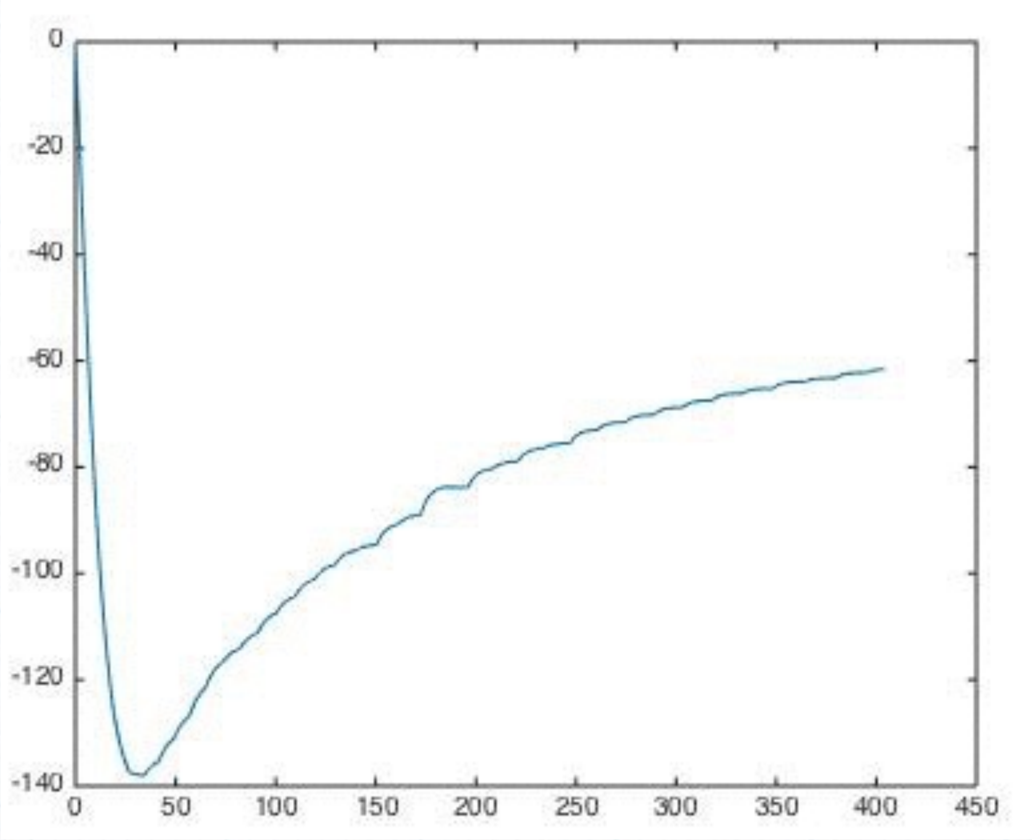


What if the balloon was already inflated?

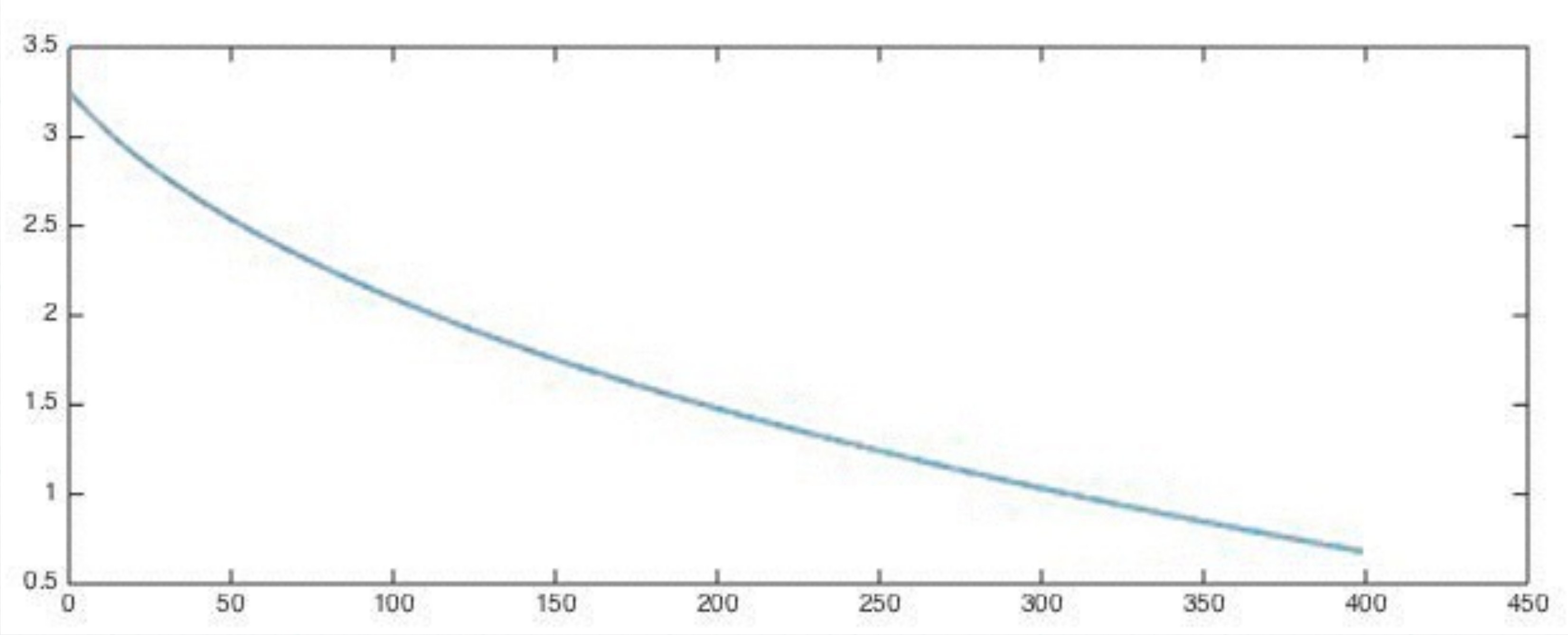
$y(t)$



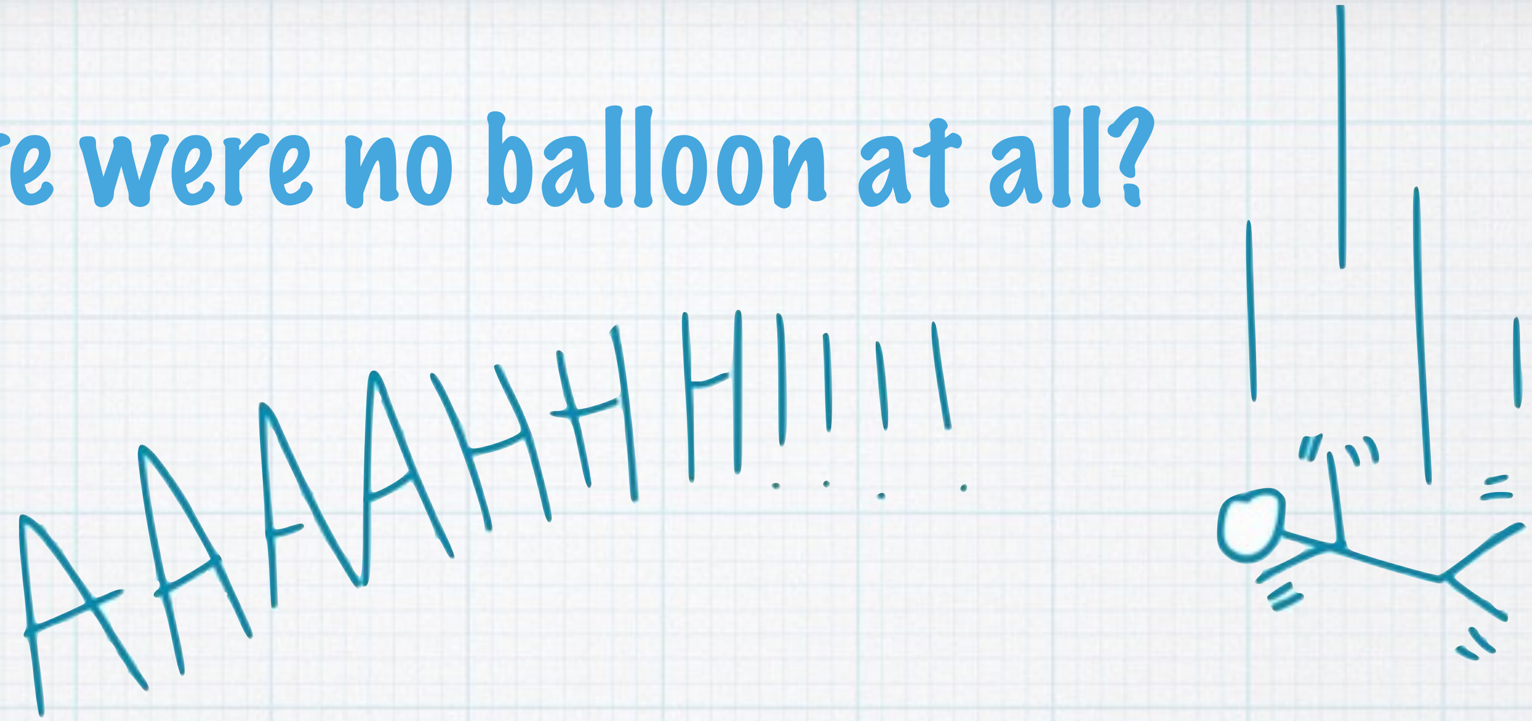
$\dot{y}(t)$

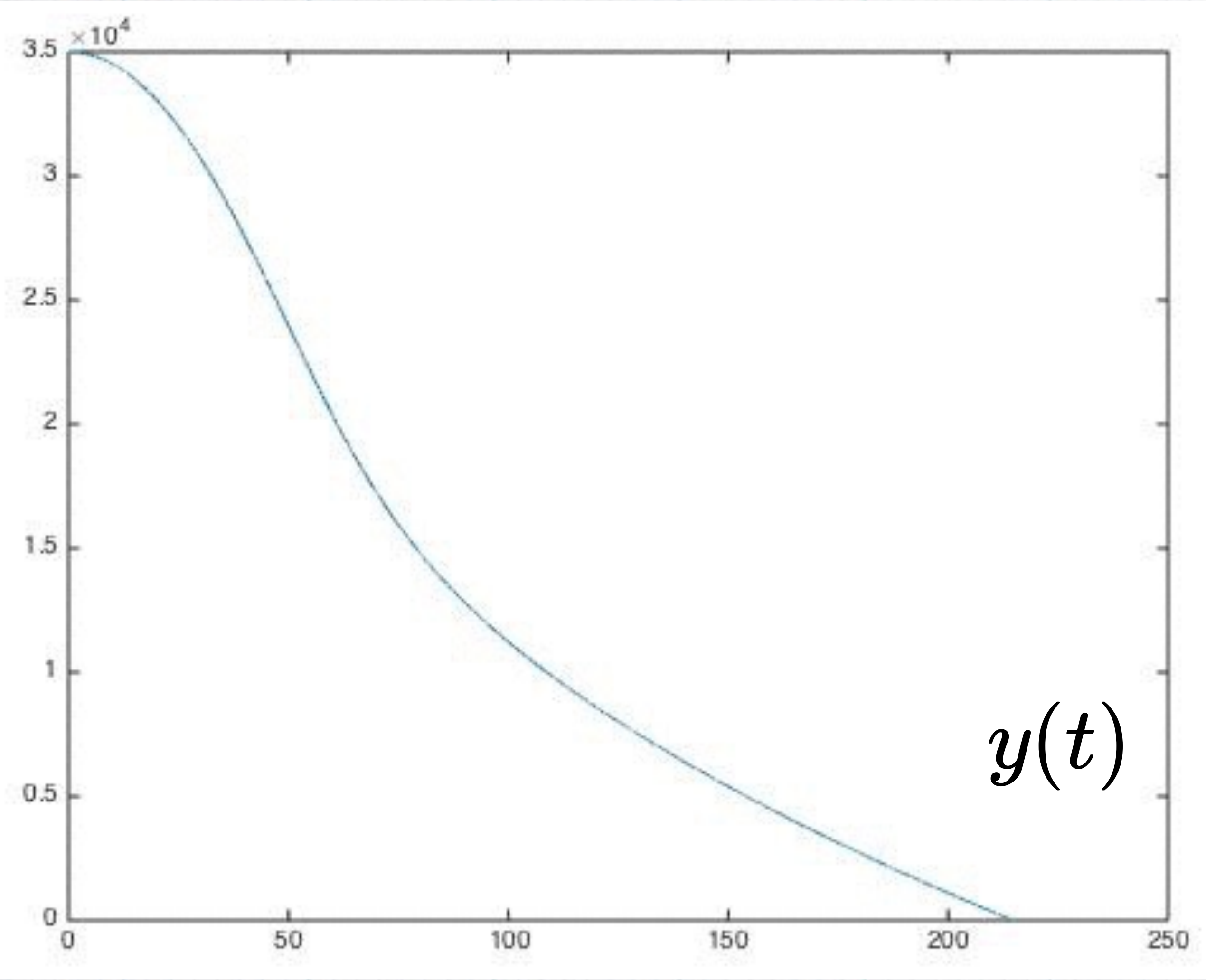


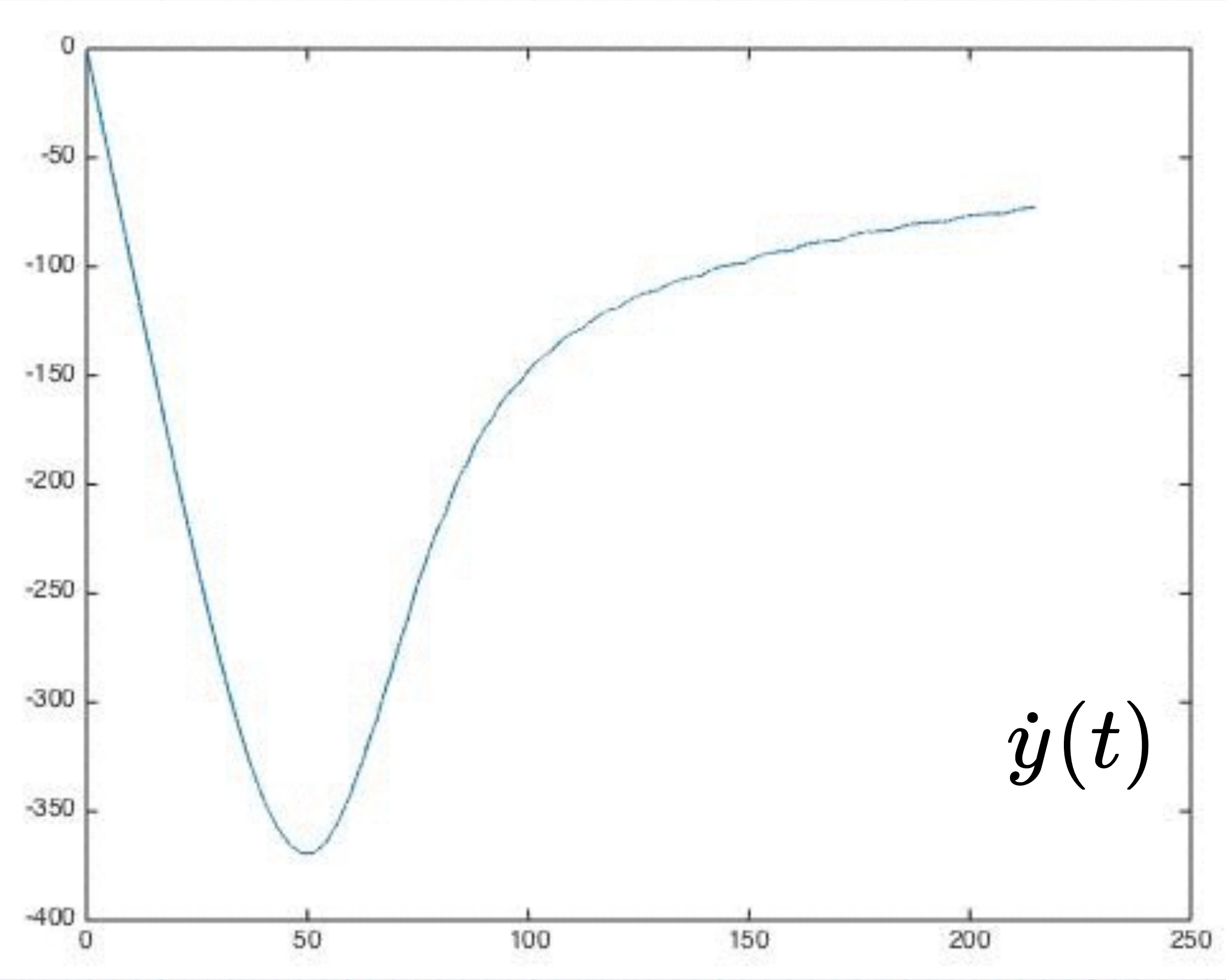
$r_{balloon}(t)$



What if there were no balloon at all?







Thank You!