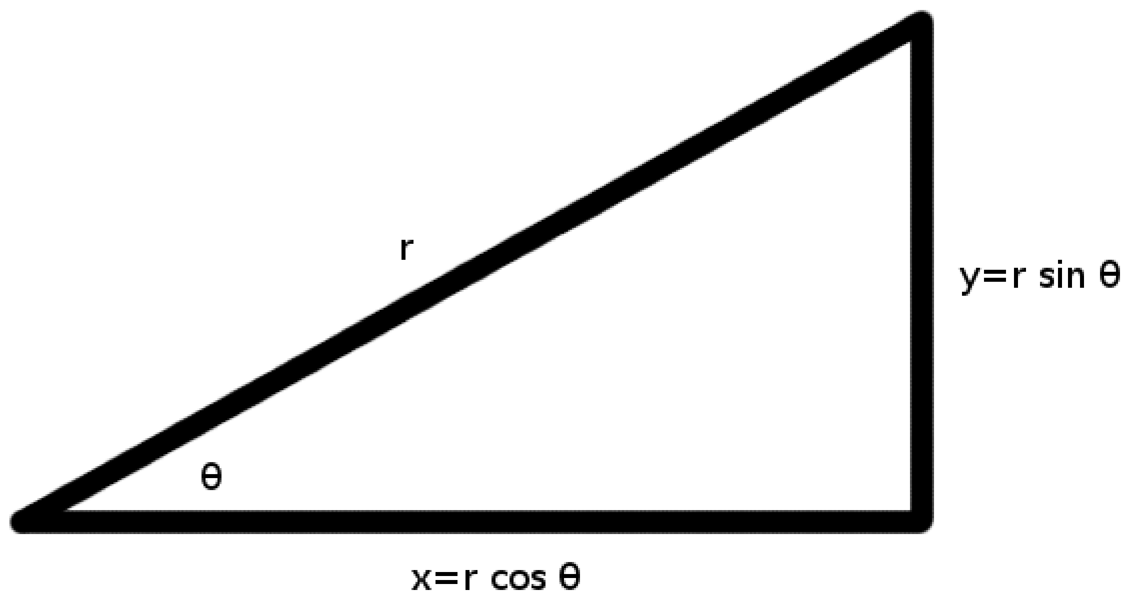
Air Resistance

September 2011

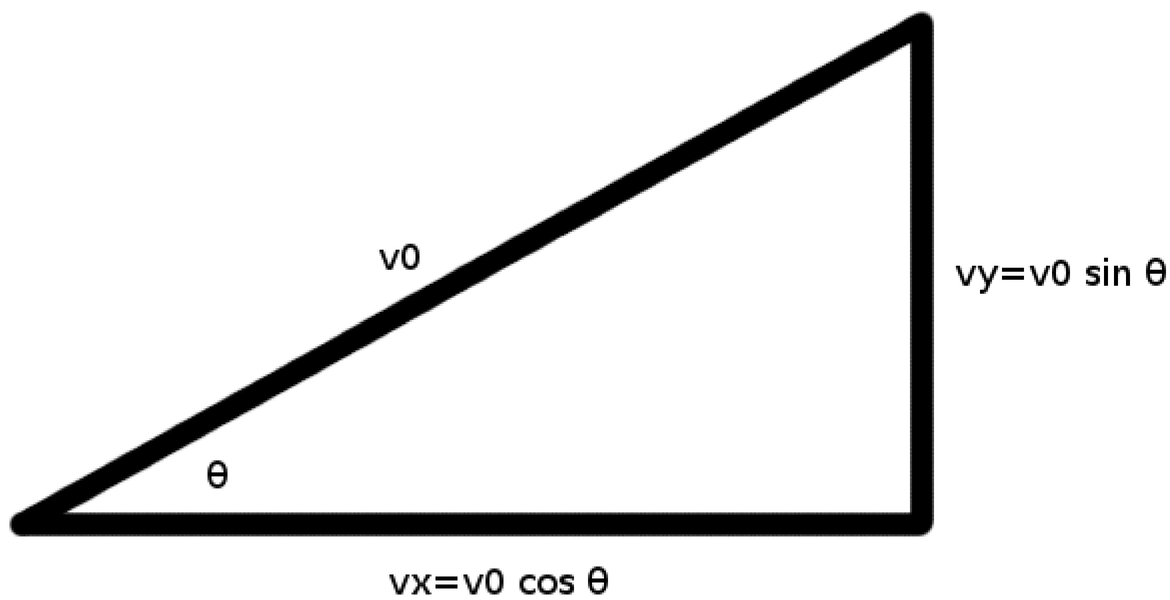
Background, in a right triangle the following relations hold...



Initial Conditions

```
#
t     = 0.0              # seconds
#
x     = 0.0              # meters
y     = 0.0
#
v0    = 26.82            # meters per second
theta = 30.0*(pi/180.0)
#
```

Translate into horizontal and vertical velocities...



Timestep Loop

```
dt=0.001
while y>=0.0:
   #
   y+=(vy*dt) # distance = rate × time
   x+=(vx*dt)
   vy+=(g*dt)
   #
   t+=dt
   print t,x,y
```

Output and Gravity

```
0.000 0.000 0.000
0.001 0.023 0.013
0.002 0.046 0.027
0.003 0.070 0.040
0.004 0.093 0.054
...
```

```
...
2.731 63.432 0.053
2.732 63.456 0.039
2.733 63.479 0.026
2.734 63.502 0.013
2.735 63.525 -0.001
```

- Near the surface of the Earth $g = -9.81$ m/s^2.
- Near the surface of the Moon $g = -1.62$ m/s^2.

Write the Results to a File

```
python parabola.py > parabola.txt
```

. . . *or* . . .

IDLE

- Highlight All and Copy
- Spreadsheet then Paste
- Text $\longrightarrow$ Table

Gnuplot Script

```
set terminal png
set output "parabola.png"
set title "Deconstructed Parabola"
set xlabel "Distance, meters"
set ylabel "Height, meters"
set xtics nomirror
set ytics nomirror
set xrange[:70]
plot "parabola.txt" using 2:3 w l notitle, 0 w l
```

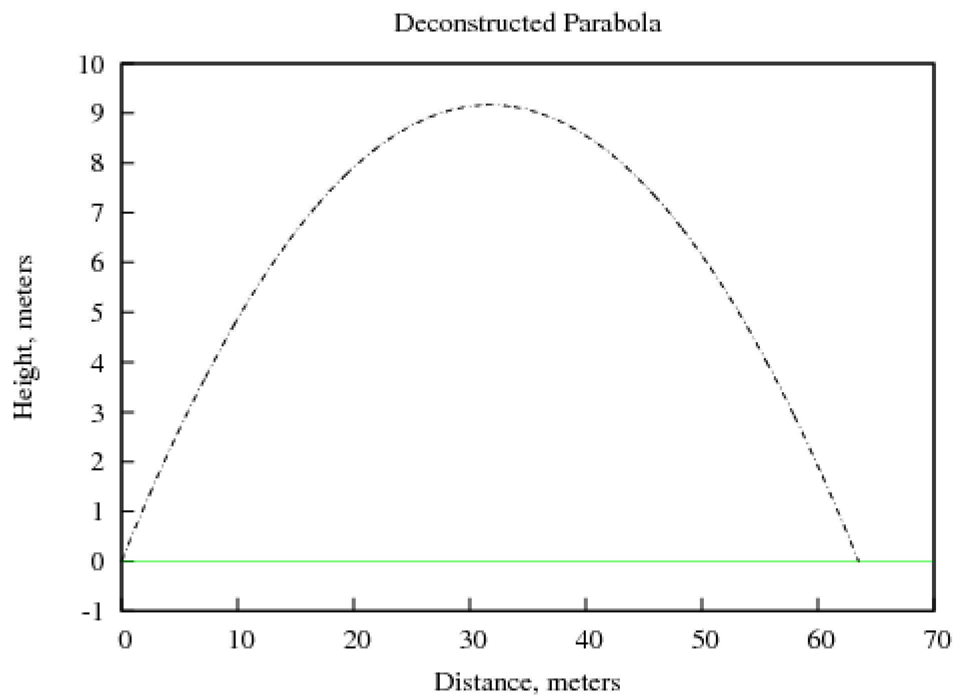
Compare to Parabola

```
while y>=0.0:
   ...
   t+=dt
   print t,x,y,(0.5*g*t*t+v0*sin(theta)*t)
```

Gnuplot Script

```
...
plot "parabola.txt" using 2:3 w l notitle,0 w l, \
     "parabola.txt" using 2:4 w l notitle
```

Plot of Results



- Two dash patterns: simulation and formula

Air Resistance Terms

```
while y>=0.0:
   #
   x  += (vx*dt)
   y  += (vy*dt)
   vx += (ax*dt)
   vy += (ay*dt)
   #               # TWO BIG IDEAS
   ax  = ( -c1*vx) # 1 oppose direction of motion
   ay  = (g-c1*vy) # 2 scale with increased speed
```

Lab Assignment: Air Resistance

- Set $c_1 = 0.50$ and compare to the no air resistance parabola.
- Try $c_1 = 0.01$, $c_1 = 0.05$, $c_1 = 0.10$, $c_1 = 0.25$ and $c_1 = 1.00$.
- (A better model for high speeds is $a = -c_1 v - c_2 v^2$ but we are assuming $c_2 = 0.00$ only because this makes the coding easier.)
- Compare:
  - The effect on peak height.
  - The effect on overall range.
- How do the different c_1 values compare?

Next Topic → Wind