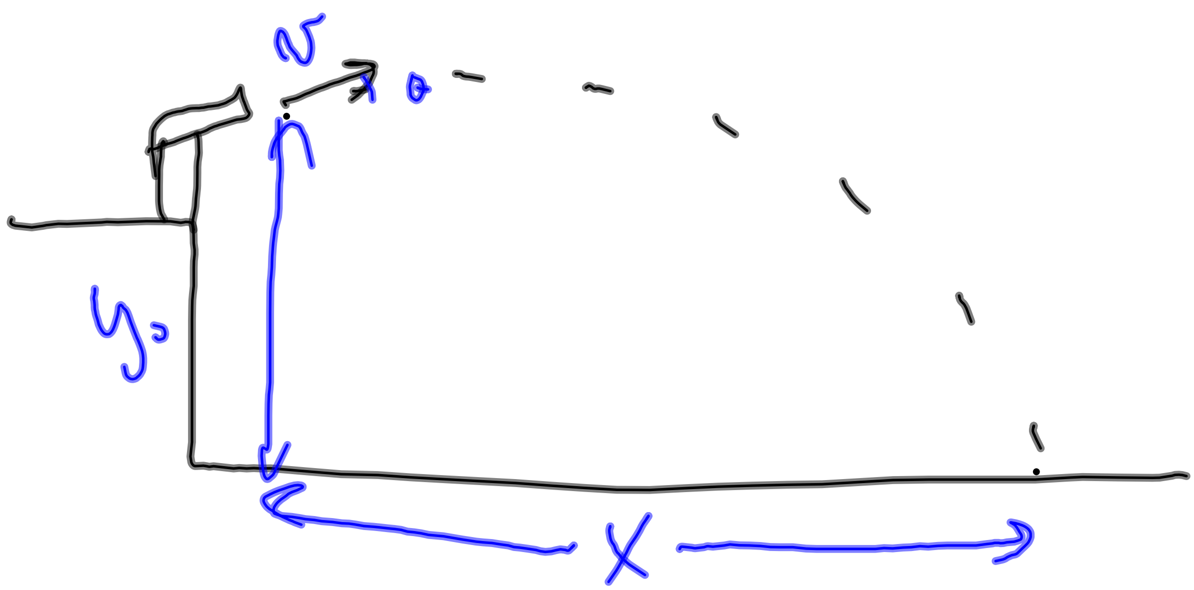
DRAG FORCES

1. PASCO Launcher Prediction
2. Free Fall and Drag
3. Coffee Filters - Lab
4. Coffee Filters - Prediction
5. From Forces to Motion: $F = kv^2$
6. From Forces to Motion: $F = kv$

1. PASCO Launcher Prediction



1. PASCO Launcher Prediction

v	theta	notes
4.215	0	two trials; .02 m distance difference
4.56	0	
4.295	0	
4.2133	0	
4.46	0	
3.16	45	
4.16	0	
4.46	45	two trials; insignificant distance difference
3.63	45	
4.12814444	Full average	
3.75	45 degree average	
4.31721667	0 degree average	
Q1 = 4.16		
Q3 = 4.46		
IQR = 0.3		
Q3 + (1.5)(IQR) = 4.91		
Q1 - (1.5)(IQR) = 3.71		
Average without outliers = 4.337588889		

2. Free Fall and Drag

Drag depends on...

density / viscosity

relative v

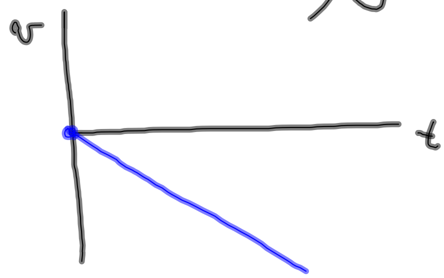
shape

texture

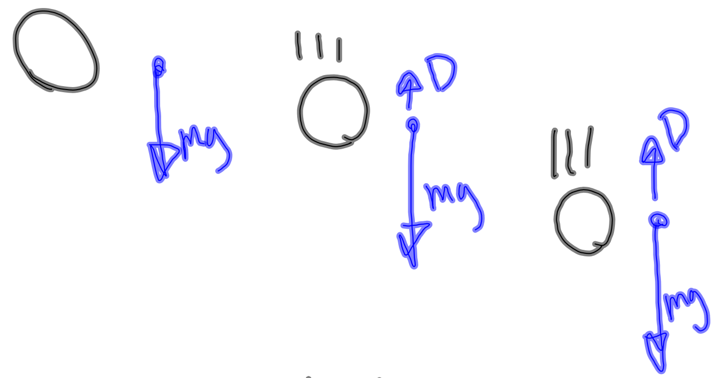
cross-sectional area

Free fall

$$a = (-9.8\,\mathrm{m/s^2})\,\hat{j}$$

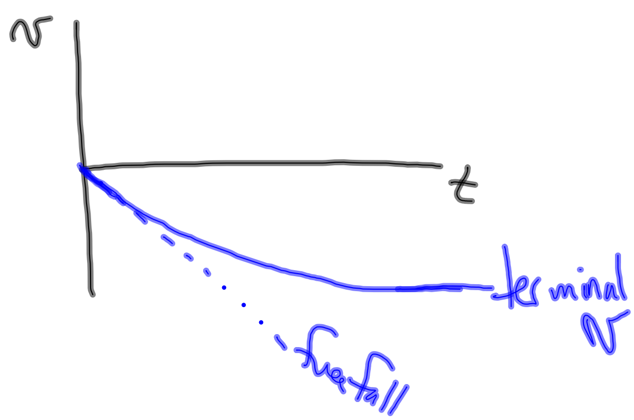


not free fall



eventually...

$$\sum F = 0$$
$$D - mg = 0$$



We want to isolate the dependence of drag forces on velocity

Drag depends on...

density / viscosity

shape

texture

cross-sectional area

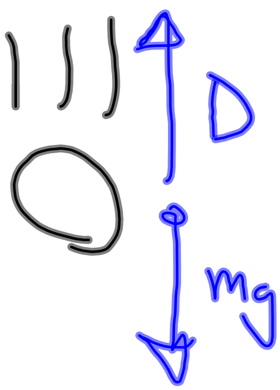
hold constant

THOUGHT #1

relative v

We want to isolate the dependence of drag forces on velocity

eventually . . .



$$\sum F = 0$$

$$D - mg = 0$$

THOUGHT #2

at $v_{Terminal}$

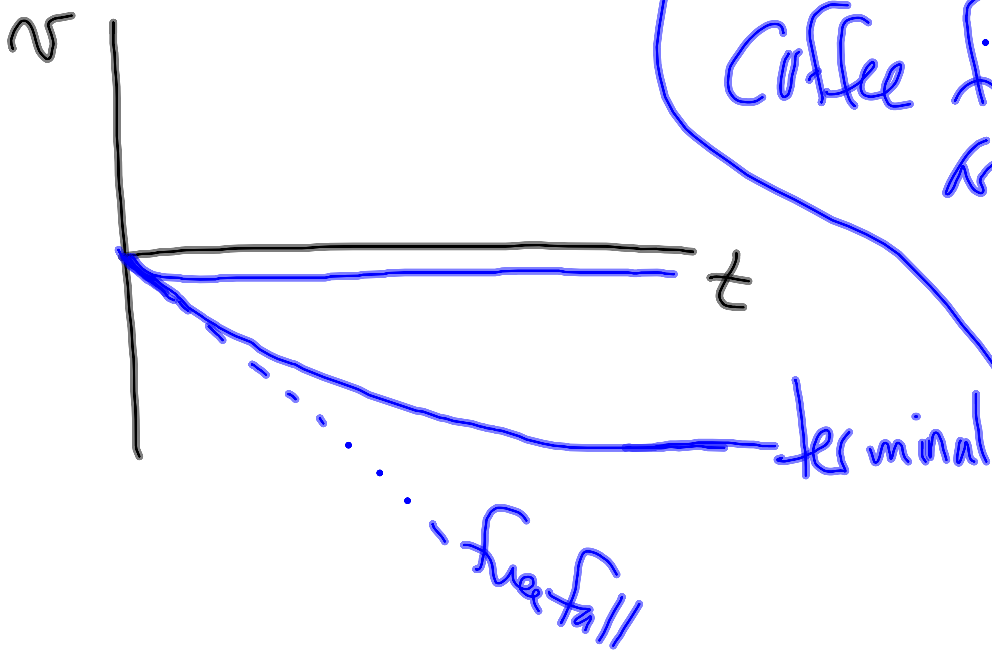
$$D = mg$$

mass of one coffee filter: 0.94 grams

We want to isolate the dependence of drag forces on velocity

THOUGHT #3

Coffee filters are almost const. v

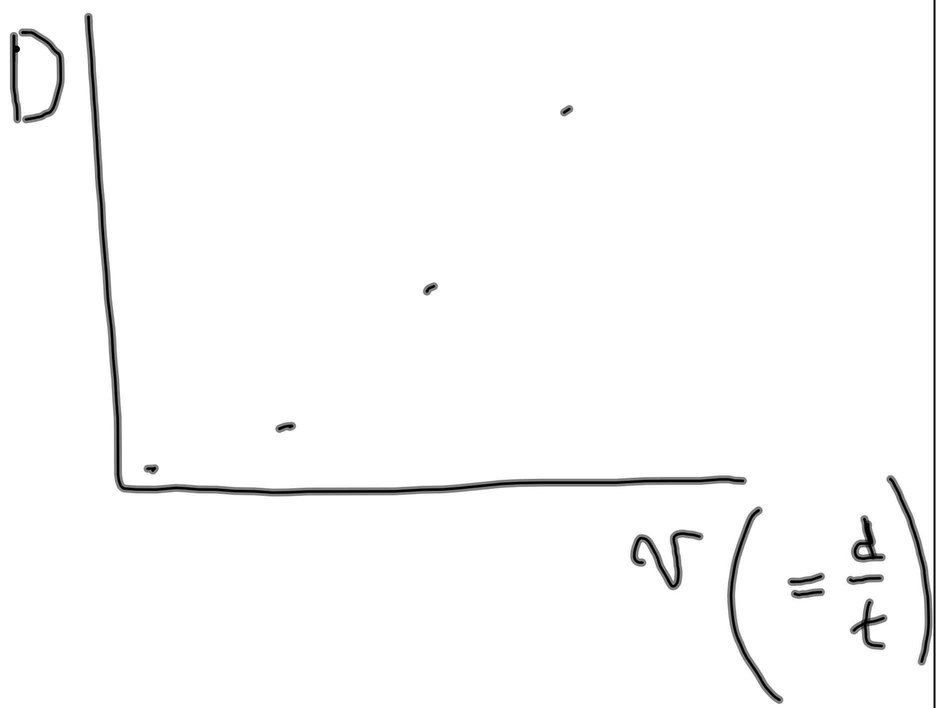


3. Coffee Filters - Experiment

What is the relationship between drag force and velocity?

$D = kv^n$

(=mg)



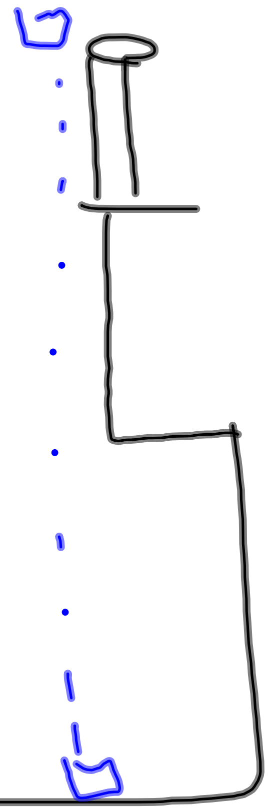
v	F

4. Coffee Filters - Prediction

yo = 4.55 m

$t = 2\ s$

coffee filters



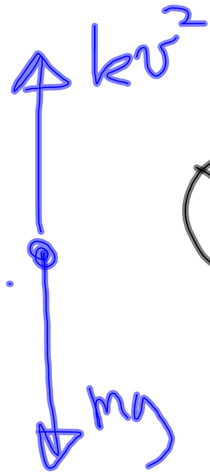
$D = kv^n$

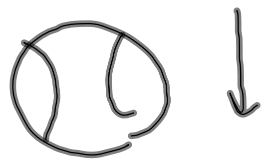
5. From Forces to Motion: $F = kv^2$

$$D = kv^2$$

a lot packed in

at terminal v ...



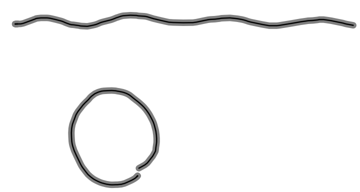


$$kv^2 - mg = 0$$

$$kv^2 = mg$$

$$v = \sqrt{\frac{mg}{k}}$$

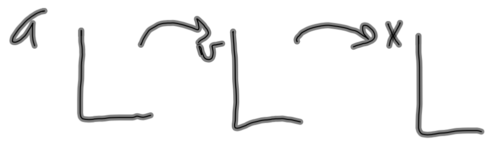
$$D = kv$$



$$ma = kv$$

$$m\frac{dv}{dt} = kv$$

Antiderivative = Integration example



$$a = 3t - 2$$

$$v = \frac{3t^2}{2} - 2t + v_0$$

$$a = 3t - 2$$

$$\frac{dv}{dt} = 3t - 2$$

$$dv = 3t\,dt - 2dt$$

$$\int_{v_0}^{v} dv = \int_0^t 3t\,dt - \int_0^t 2dt$$

$$\left[v\right]_{v_0}^{v} = \left[\frac{3t^2}{2}\right]_0^t - \left[2t\right]_0^t$$

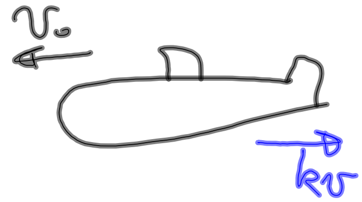
$$\left(v - v_0\right) = \left[\frac{3t^2}{2} - \frac{3(0)^2}{2}\right] - \left[2t - 2(0)\right]$$

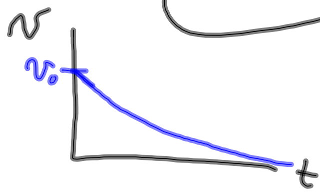
$$v - v_0 = \frac{3t^2}{2} - 2t$$

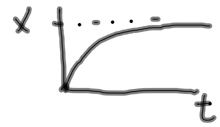
$$v = \frac{3t^2}{2} - 2t + v_0$$

6. From Forces to Motion: D = kv

$$D = kv \quad (\text{water})$$







$$\sum F = ma \qquad x = \frac{m v_0}{k}\left(1 - e^{-\frac{kt}{m}}\right)$$

$$-kv = ma$$

$$-kv = m\frac{dv}{dt}$$

constants

$$-kv\,dt = m\,dv$$

$$-\frac{k}{m}dt = \frac{dv}{v} \qquad \frac{v^0}{0}$$

$$\int_0^t -\frac{k}{m}dt = \int_{v_0}^{v}\frac{dv}{v}$$

$$-\frac{k}{m}\left[t\right]_0^t = \int_{v_0}^{v} v^{-1}dv$$

$$-\frac{k}{m}\left(t\right)_0^t = \left[\ln(v)\right]_{v_0}^{v}$$

$$-\frac{k}{m}\left[t - 0\right] = \left[\ln(v) - \ln(v_0)\right]$$

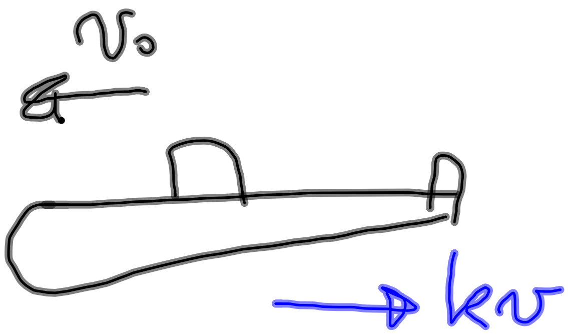
$$-\frac{k}{m}t = \ln(v) - \ln(v_0)$$

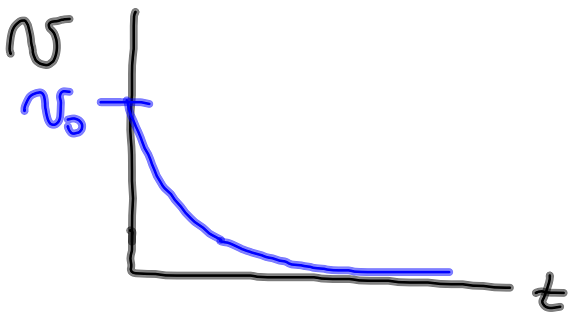
$$-\frac{k}{m}t = \ln\left(\frac{v}{v_0}\right)$$

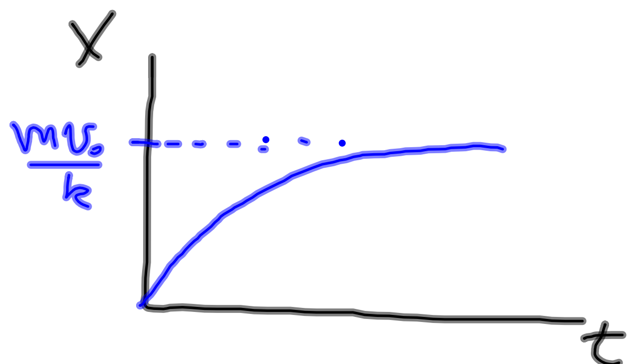
$$e^{-\frac{k}{m}t} = \frac{v}{v_0} \qquad v = v_0 e^{-\frac{kt}{m}}$$

$$\frac{dx}{dt} = v_0 e^{-\frac{kt}{m}}$$

SUMMARY 1





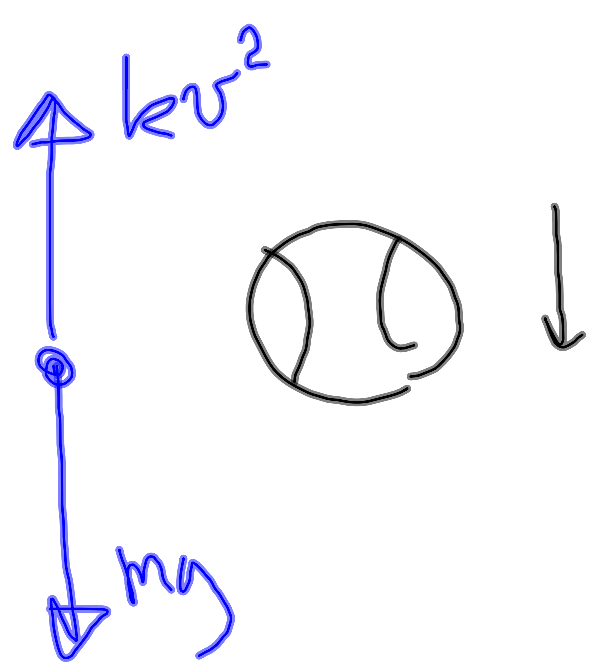


$$v = v_0 e^{-\frac{k}{m}t}$$

$$x = \frac{mv_0}{k}\left(1 - e^{-\frac{kt}{m}}\right)$$

SUMMARY 2

at terminal v ...

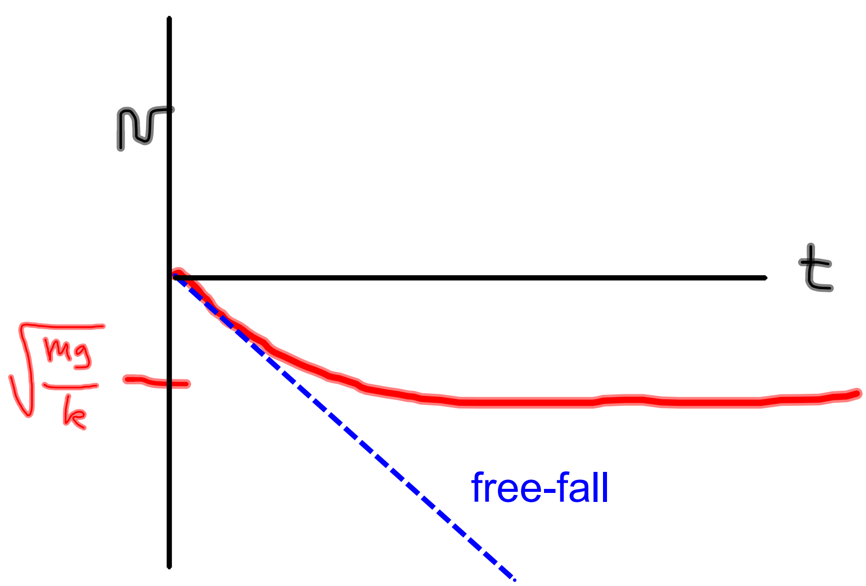


$$kv^2 - mg = 0$$

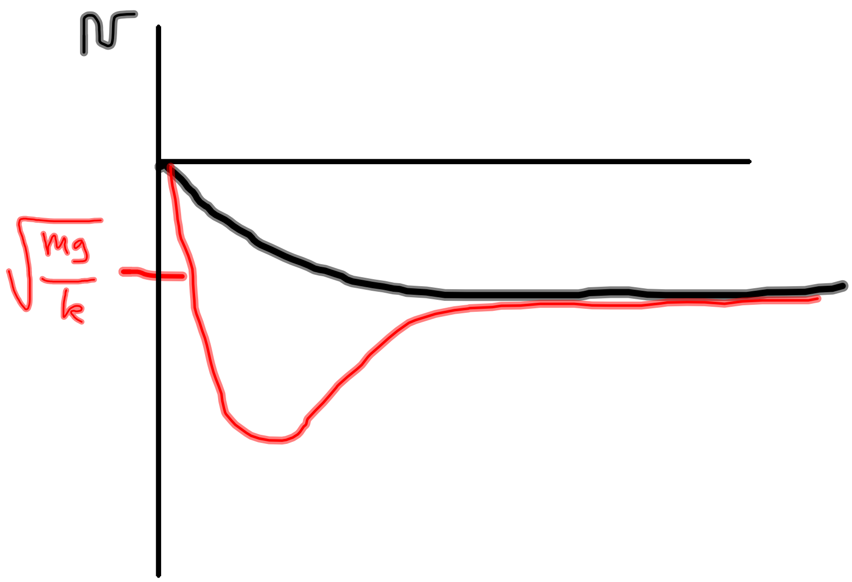
$$kv^2 = mg$$

$$v = \sqrt{\frac{mg}{k}}$$

terminal velocity for kv^2



What if something is propelled faster than its terminal velocity?



free-fall