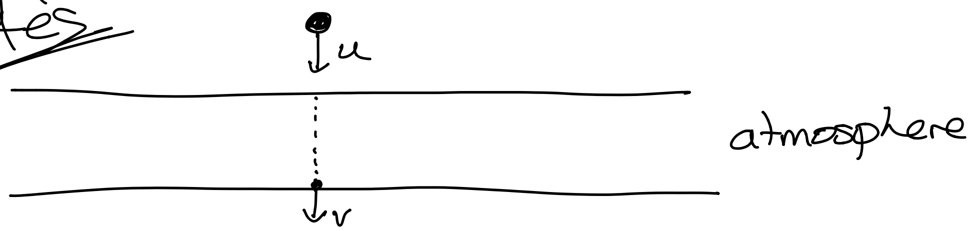
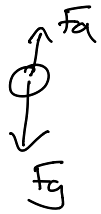
# Rough Notes




FBD




$$F_{net} = \underbrace{F_g}_{mg} - \underbrace{F_a}_{kv^2} = ma.$$

Simplist case → assume $g$ is constant
→ assume $\rho$, T etc atm. constant

Drag equation: $F_a = C_d \rho v^2 \frac{A}{2}$

$$F_a = -kv^2$$

$+\downarrow$

$$\therefore mg - kv^2 = ma \qquad a = \frac{\Delta v}{\Delta t}$$

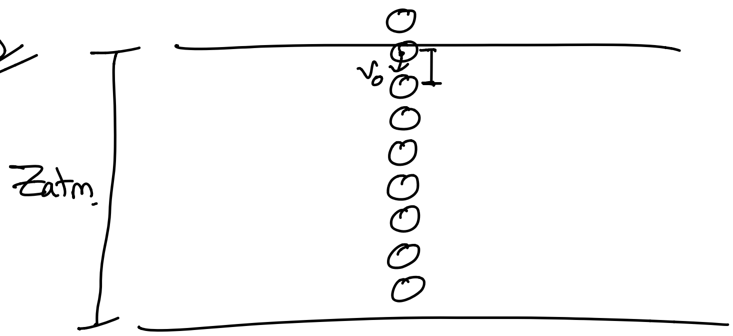
$$mg - kv^2 = m\frac{dv}{dt}$$

$$\frac{dv}{dt} = g - \frac{k}{m}v^2$$

differential equation: $\frac{dv}{dt} = g - \frac{C_d \rho A}{2m} v^2$

1. Differentiation
2. ~~Numerical integration:~~

**Rough Notes**




$$\Delta v = \left[g - \left(\frac{C_d \rho A}{2m}\right) v^2\right] \Delta t.$$

$$\Delta z = V \Delta t$$

at $t = 0$ $\quad z = 0$ $\quad u = v$

at $t_1 = \Delta t$ $\quad z_1 = z_0 + V_0 \Delta t$

$$V_1 = V_0 + \left[g - \frac{C_d \rho A}{2m} V_0^2\right] \Delta t$$

loop until $z = z_{atmosphere}$.

# Meteorite slowing through the atmosphere.

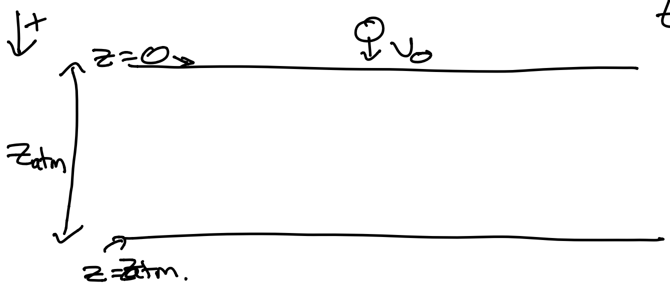
Start → asteroid velocity perpendicular to earth's surface

→ constant density atmosphere of a given thickness

→ assume acceleration due to gravity is constant

→ assume asteroid size and mass is constant

→ assume drag coefficient is constant




$t=0$

impact velocity $= V_0$

time step, $\Delta t$

calculate position and speed at each new time.

Forces: grav: $F_g = mg$ $\quad \downarrow \therefore$ +ve.

air resistance: $F_a = \frac{C_d \rho A}{2} v^2$ $\quad \uparrow \therefore$ −ve.

$$F_{net} = mg - \frac{C_d \rho A}{2} v^2$$

N's 2nd: $ma = mg - \frac{C_d \rho A}{2} v^2$

$a = \frac{\Delta v}{\Delta t}$ $\quad \cancel{m}\frac{\Delta v}{\Delta t} = \cancel{m}g - \frac{C_d \rho A}{2m} v^2$

$$\Delta v = \left(g - \frac{C_d \rho A}{2m} v^2\right)\Delta t$$

Position → assume close enough constant acceleration within $\Delta t$

const. al. eq: $s = ut + \frac{1}{2}at^2$

$$\Delta z = v\Delta t + \frac{1}{2}\left(g - \frac{C_d \rho A}{2m} v^2\right)\Delta t^2$$

## Base simulation:

Initial cond: $v = V$
$z = 0$
$t = 0$

end when $z > z_{atm}$.

$$z_1 = z_0 + \Delta z$$

$$z_i = z_0 + v_0 \Delta t + \frac{1}{2}\Big(g - \underbrace{\frac{C_d \rho A}{2m}}_{k} v_0^2\Big)\Delta t^2.$$

$$V_1 = V_0 + \Delta V$$

$$V_1 = V_0 + \Big(g - \underbrace{\frac{C_d \rho A}{2m}}_{k} v_0^2\Big)\Delta t$$

output → final v.

Possible variations:
- initial speed
- $z_{atm}$
- → $\rho$ (or $\rho(z)$)
- → $g$ (or $g(z)$)
- → $C_d$
- → $m$
- → $A$

$m$, $A$ ] → think about ablation → how asteroid "burns up" through atmosphere.

Concerns → error analysis needed *

Alec research: Find initial values to use:
asteroid: $V_0$, $m$, $A$
atmosphere: $z_{atm}$, $\rho$ ← constant density model.
$g = 9.81\ ms^{-2}$
drag coefficient ??

Things to explore:
- atmosphere models - const. den, isothermal, adiabatic, real .....
- g as a function of position ← is it worth it?
- asteroid impacts → initial vel & asteroid properties.

June 11th

→ Base simulation good

→ add radius as variable ← will be changing in loop

→ recalculate K within while loop

→ also plot $v \uparrow \underset{\rightarrow t}{}$

→ Complications:

① Add g as dependant on z.

$g = \frac{F}{m} = \frac{GM}{R^2}$ → radius of Earth = $R_{earth}$

→ $R = R_{earth} + z$

* Switch z = altitude

→ start as z == thickness

→ loop becomes z > 0

→ z —= .....

* Acceleration = $\frac{G\,M_{earth}}{R^2}$ ← in while loop

→ print acceleration → check when z = 0 acc = 9.81

z > 0 acc < 9.81

(expect acc ≈ 9.6 at top)

② Ablation of meteorites *

→ look into how people do this

e.g. model as pure iron

In while loop:

→ calculate change in GPE

→ change in KE

→ Find thermal energy, $Q = \Delta E_p - \Delta E_k$

easier way? Q → mass loss

→ use $Q = \underbrace{mc\Delta T + mL}$

the thermal energy will heat and sublimate (?)

→ find a mass loss each step

→ recalculate radius
mass
K
etc.....

∴ First simulation (w/ g & ablation)

Then the actual investigation:

Vary: • Initial radius
• Initial speed
? density
] kinetic energy at top of atmosphere.

Dependant → kinetic energy of meteorite immediately before impact.

## Analysis.

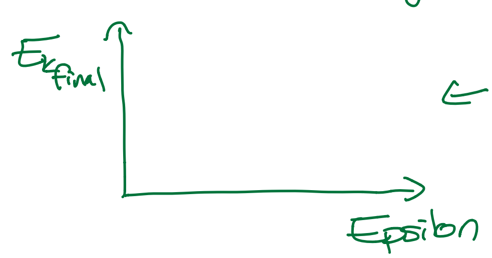
→ Check varying epsilon

↳ decide what is acceptable variation

$\frac{\%\text{ change in } E_{k_{final}}}{\%\text{ change in epsilon}}$ ?

Just once for "First simulation"

↳

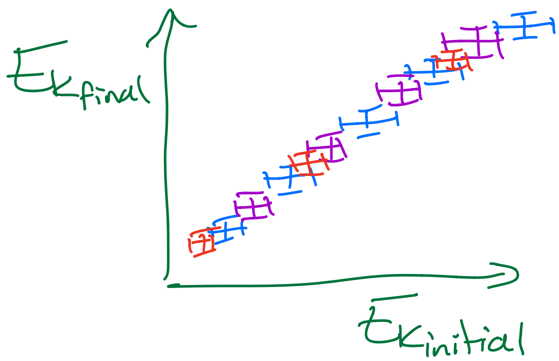



← log · log?

* Time for simulation to run?

* Trying to get to error bars?

* Alternative → When running do 3 sims for each
↳ +1% of IV
↳ −1% of IV
] → find Uncert on $E_{k_{final}}$.




← 5 values of radius (each done 3 times ↳ ±1%)

← 5 values of initial speed (each done 3 times ↳ ±1%)

← ? 5 values of density (each done 3 times ↳ ±1%)

# EE

## Background/Intro

* Sudbury context ← Why we care about $E_{K_{final}}$
* Vocab – asteroid : meteorite : meteor

## Base simulation

* Math for z & v
* Simulation (← brief) ← time step ← loop ] samples of code?

## First simulation

* Math for a ablation ] ⇒ samples of code
* Results ← compare to base.

## Investigation

→ vary r, v, ρ
→ results

→ analysis

## Conclusion & evaluation

→ what you found + why care

→ what could be better

→ further work.