Advanced Cadet Aerospace Lectures

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External Aerospace Education Officer, Colorado Wing

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As seen on www.supportstem.com

aircraft gyroscope - ... | Home

www.supportstem.com

Peter Higgins, Capt CAP, PhD

Colorado Wing, Civil Air Patrol

External Aerospace Education Officer

American Red Cross

Preparedness/Access and Functional Needs

Dr. Higgins has a PhD in Mechanical Engineering from the University of Denver, a BS in Physics, and a MS in Acoustics, both from the University of Houston. He recently taught thermodynamics, heat transfer and fluid mechanics at Metropolitan State University of Denver. Dr. Higgins was an early aerospace technologist in NASA starting Feb 1962. He initiated the first global solar patrol station network, served in the Mission Control Center as console leader for Space Environment and presented the first paper on astronaut radiation dose in space at the Gemini Summary Conference. He has many awards including the president's (Lucent Technology) Silver Medal for Innovation and NASA's Sustained Superior Performance Award. His latest paper is "Improving mini and micro channel heat transfer by acoustic fields", JEHT, and he holds an FAA glider pilots license. Phone 720-409-8393 or email peter

CAP Computer Programs Developed by Dr. Higgins

Emergency Image Analysis

CAP JAVA Sectional Grids program

CAP JAVA Sectional Grids documentation

Current Lectures

Newton's gift to Mankind - orbital mechanics

Cadet lectures - aerodynamics

How do planes fly? - aerodynamics

The most remarkable equation - mathematics

Rocket Science - rocketry

Programming robots - robotics

Who is Fourier? - physics

Image analysis - optics

The pendulum - physics

Gemini's secret - man in space history

[1]Lecture on these pages are intended as topic outlines for teachers to adapt to their class levels and class plans. On invitation, Dr. Higgins will present his interpretation of them over 1-3 class periods. The relevance of these lectures is discussed here.

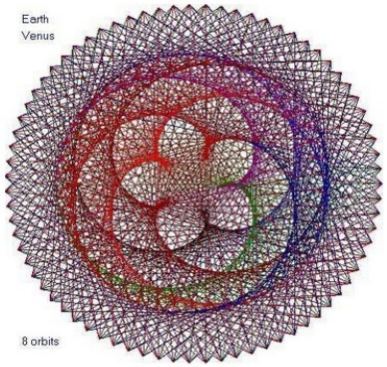
Cadet Lectures

aircraft gyroscope - ... | Higgins lectures

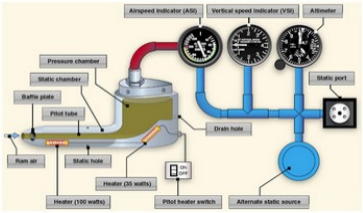
www.supportstem.com/cadet.htm

Cadet Lectures on Aerospace

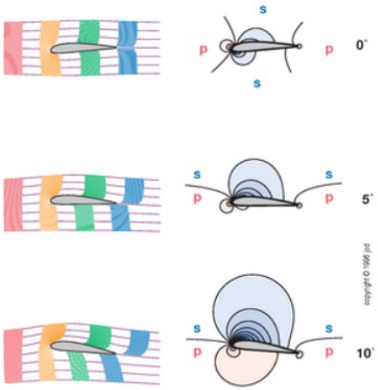
Rocketry



Orbital mechanics



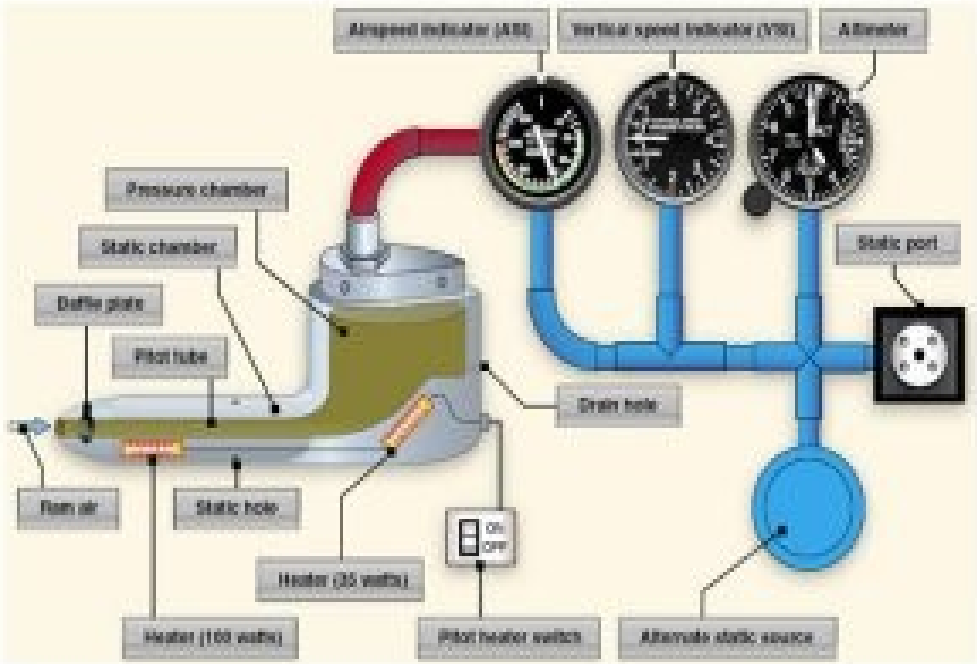
Physics of aircraft instruments



Wing design

Physics of Aircraft Instrumentation

Velocity – the Pitot Tube



Conservation of energy

Pressure/ρ + gravitational potential + kinetic energy = constant

(per unit mass)

$$\frac{\frac{F}{A}}{\frac{m}{V}} = \frac{m^2}{s^2} \qquad gz = \frac{m}{s^2} \times m = \frac{m^2}{s^2} \qquad \frac{m^2}{s^2}$$

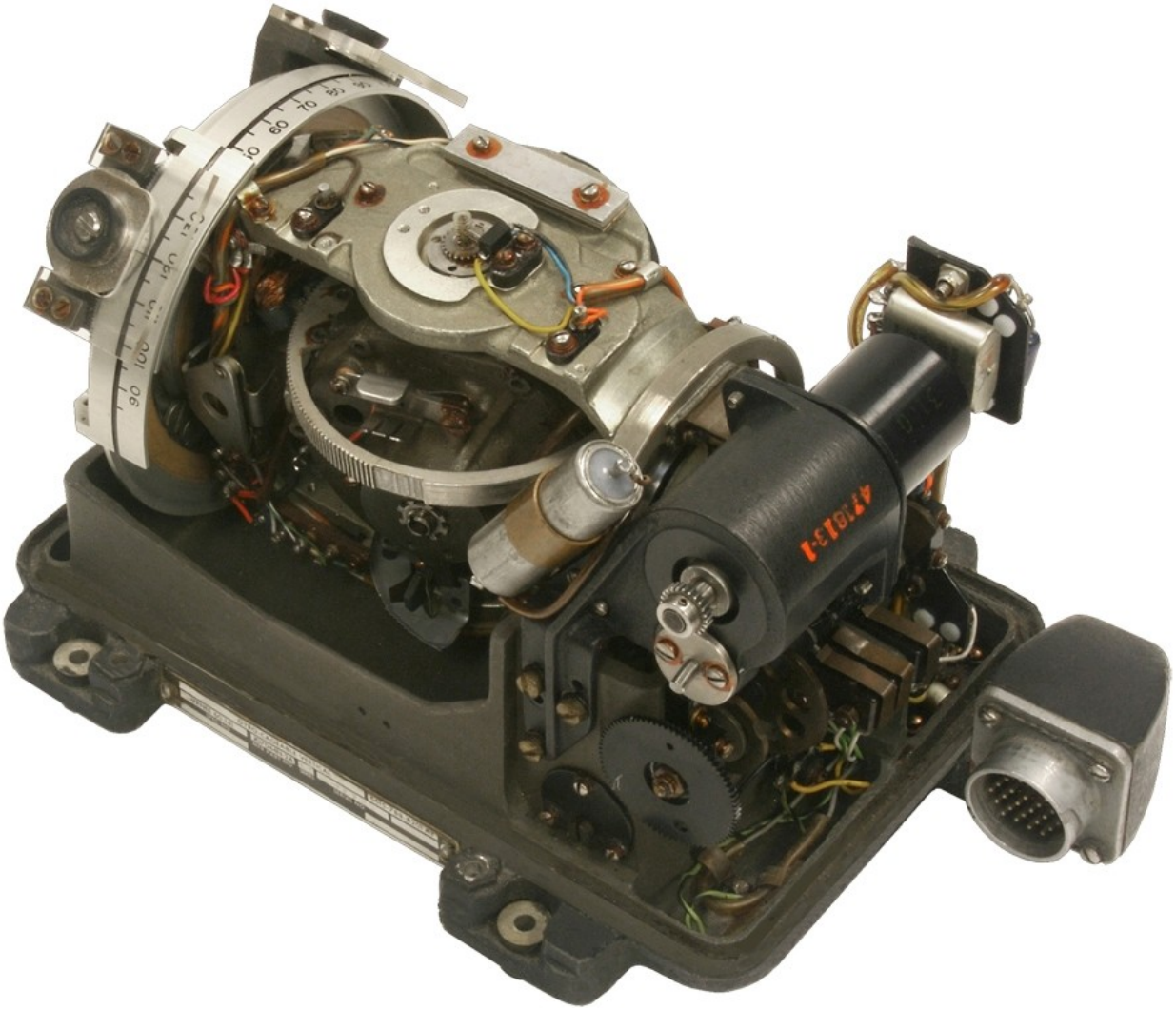
Neglecting elevation

Flowing $$\frac{p_1}{\rho}+\frac{v_1^2}{2}=\frac{p_2}{\rho}+\frac{v_2^2}{2}$$ Pressure chamber

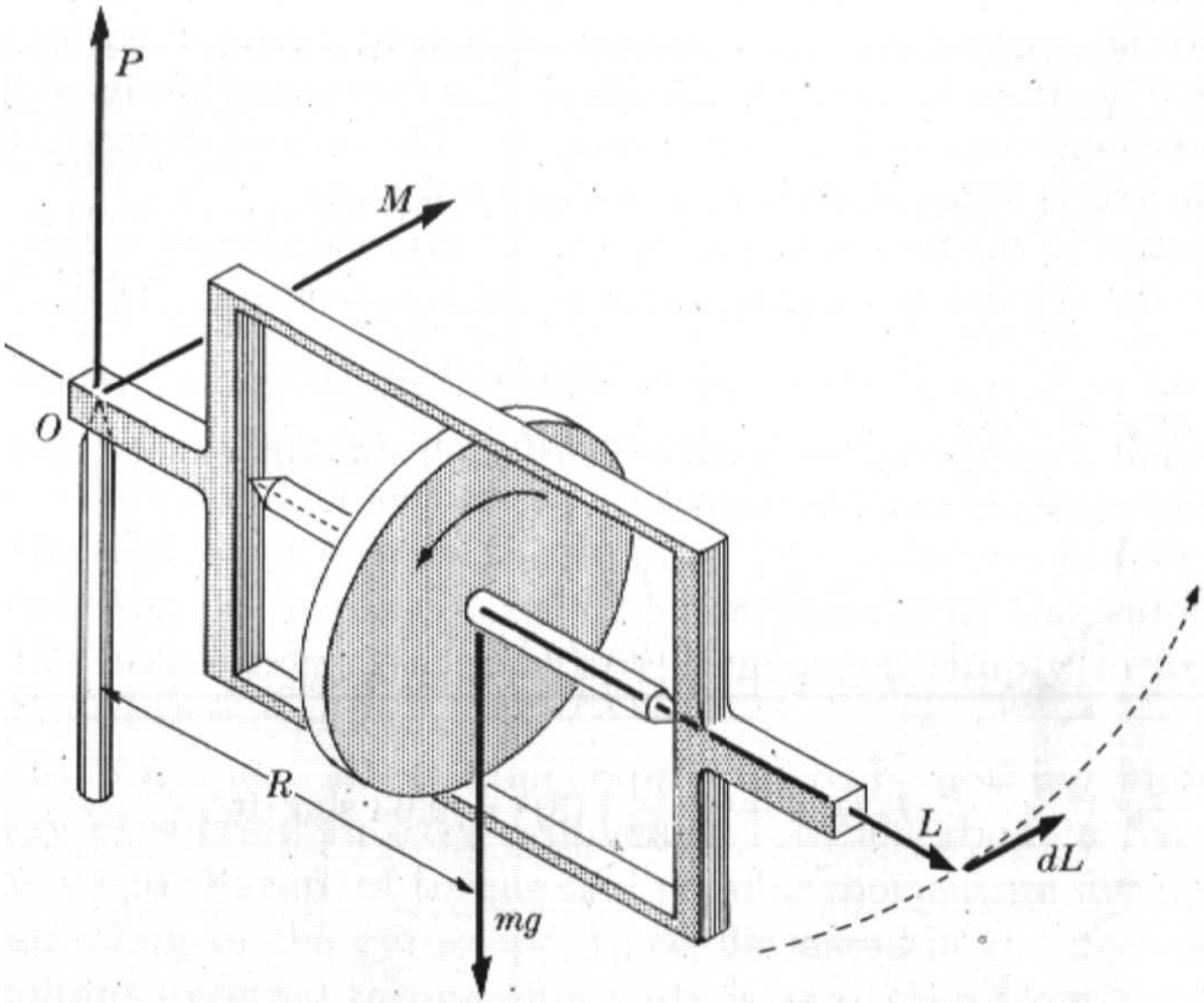
But $$v_2=0$$

so $$v_1=\sqrt{\frac{2}{\rho}\times(p_2-p_1)}$$

Heading - the Gyrocompass



The Gyroscope



Torque changes angular momentum

$$F = ma$$

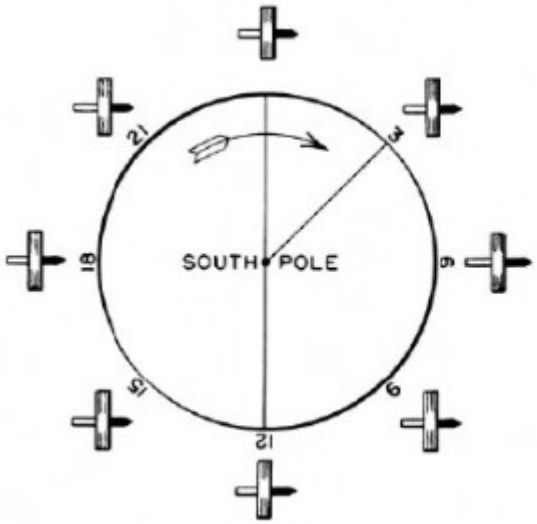
In rotation, the equivalent becomes

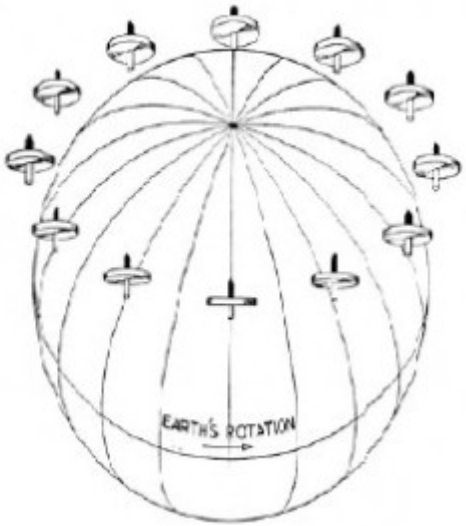
$$M = I \times \alpha = I \times \frac{d\omega}{dt} = \frac{d}{dt} I\omega$$

But $I\omega = L\left(angular\ momentum\right)$

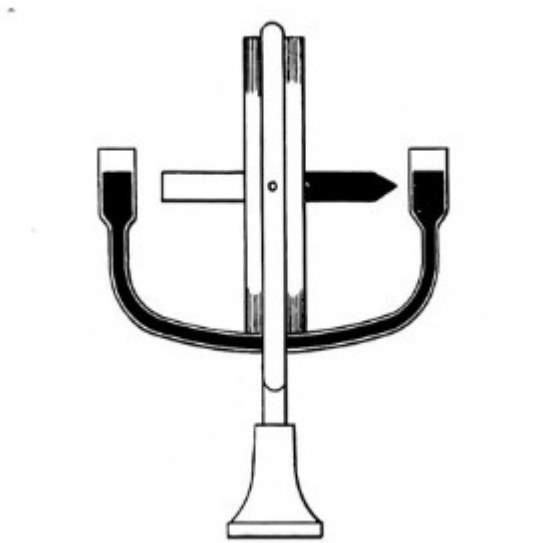
so $M = \frac{dL}{dt}$

To become a gyrocompass it must precess to follow earth's rotation



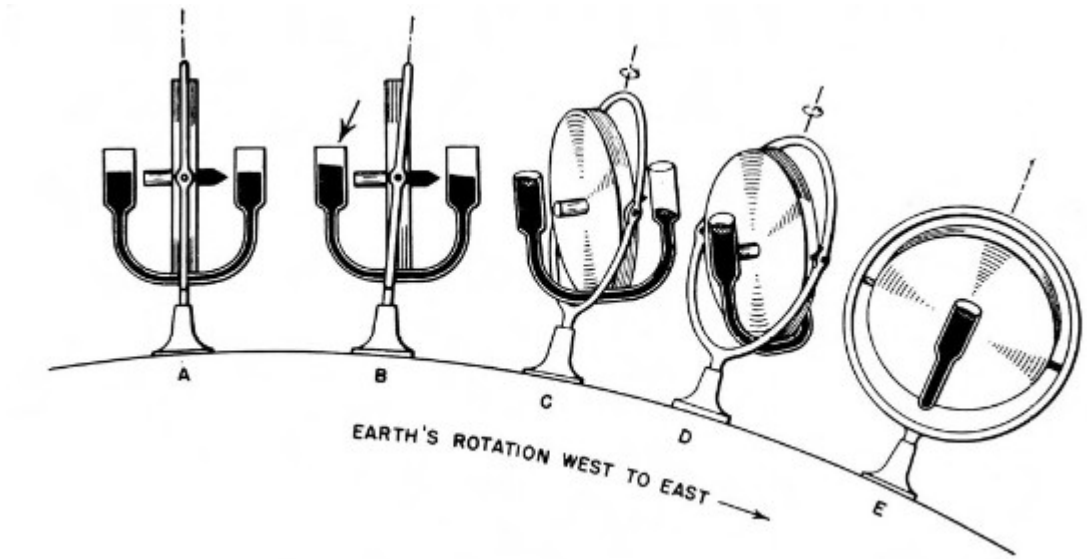


To precess we need torque applied



One method, used by Sperry, is to attach a mercury U-tube to the gimball points at right angles to the desired rotation axis providing an unbalanced force when the earth rotates.

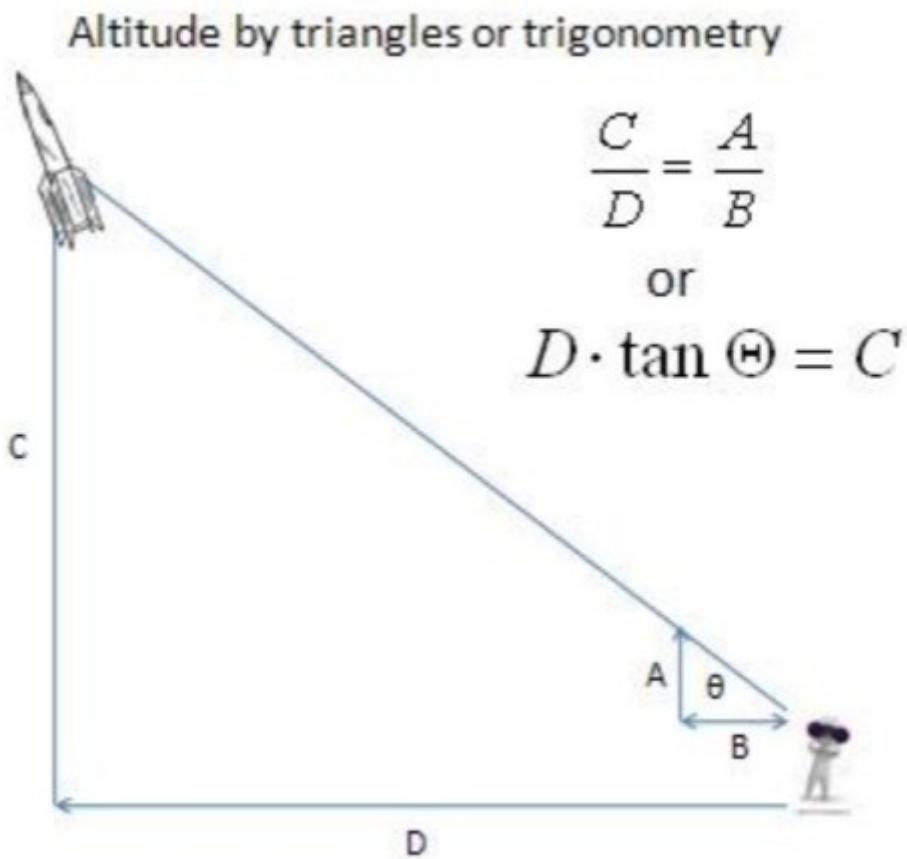
When the earth rotates



Rocketry

Model rocketry
height, velocity and drag

How high by observation

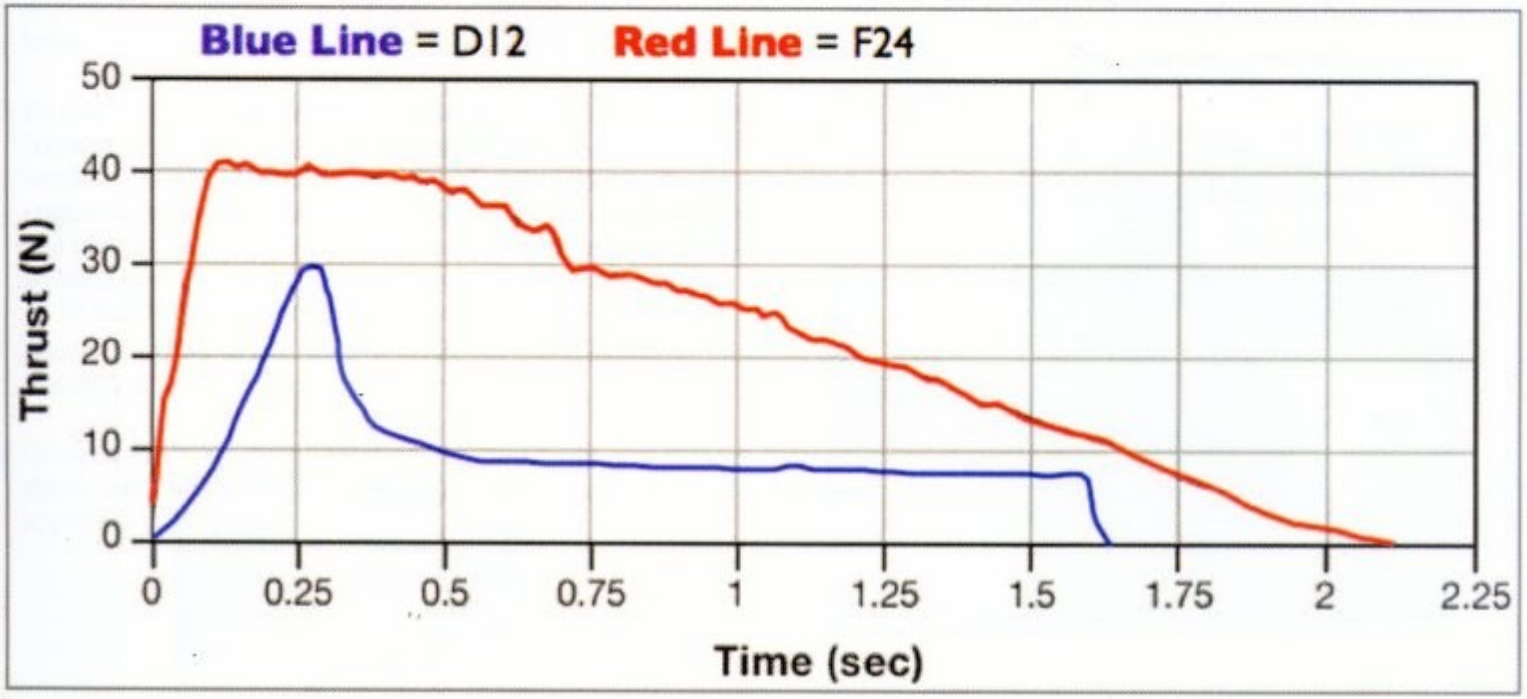


Inclinometer

Published Impulse

If you remember, the *Estes D12* has 21 grams of propellant weight, boasting 16.8 Newton-seconds of Total Impulse – the amount of power packed into it. The *Aerotech F24* on the other hand weighs a little less, 19 grams, yet has 47.3 Newton-seconds of total impulse. And where the D12 stays at its maximum thrust peak of 30 Newtons for just a moment, the F24 stays at its maximum thrust peak of 40 Newtons for much longer.

To address the significant increase in the aerodynamic stresses placed on the rocket, we need to learn how to build a stronger rocket in the next section.



What is its initial velocity?

Impulse = change in momentum

Impulse = $\int F\,dt$

Change in momentum = $m v_2 - m v_1$

But $v_1 = 0$

So $v_2 = \frac{I}{m}$

How high, ideally?

It's simple if you consider conservation of energy

Energy at lift off $\frac{1}{2} m v^2$

Energy at peak altitude $m g h$

Equating $h = \frac{v^2}{2} g$

More precisely $h = \frac{\left(m_1 \frac{v^2}{2}\right)}{\left(m_2 g\right)}$

How long to get there, ideally

The formula for velocity at any time after liftoff is

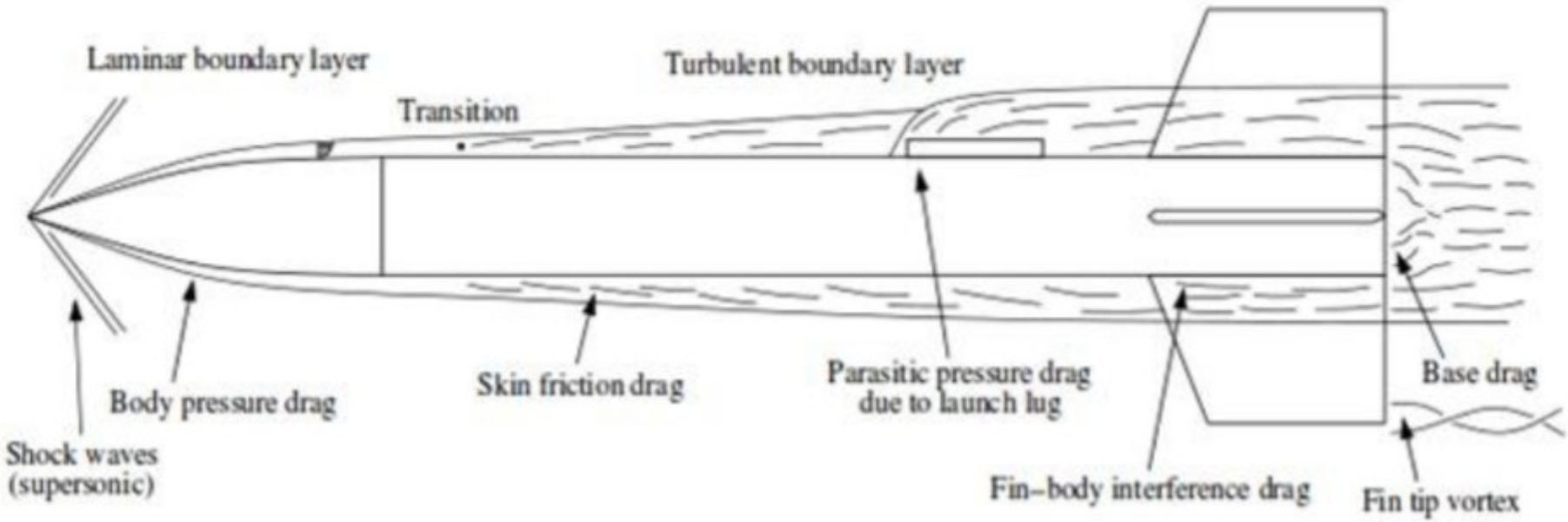
$$v(t) = v_0 + (g\,t)$$

At the top of flight, v = 0

So $$t = \frac{v_0}{g}$$

But, my rocket didn't get that high, Why?

What's drag???



In short: friction off the air stream against the parts of the rocket which slows the rocket down

Is there a formula for it?

Yes, measurement has established this relationship:

$$F_d = \left(\frac{1}{2}\right) \rho_{air} v^2 A C_d$$

Where F_d is the drag force and C_d is an experimentally determined coefficient usually measured in wind tunnels

We can use this as an extra g force, ie $g_d = \frac{F_d}{m_{rocket}}$

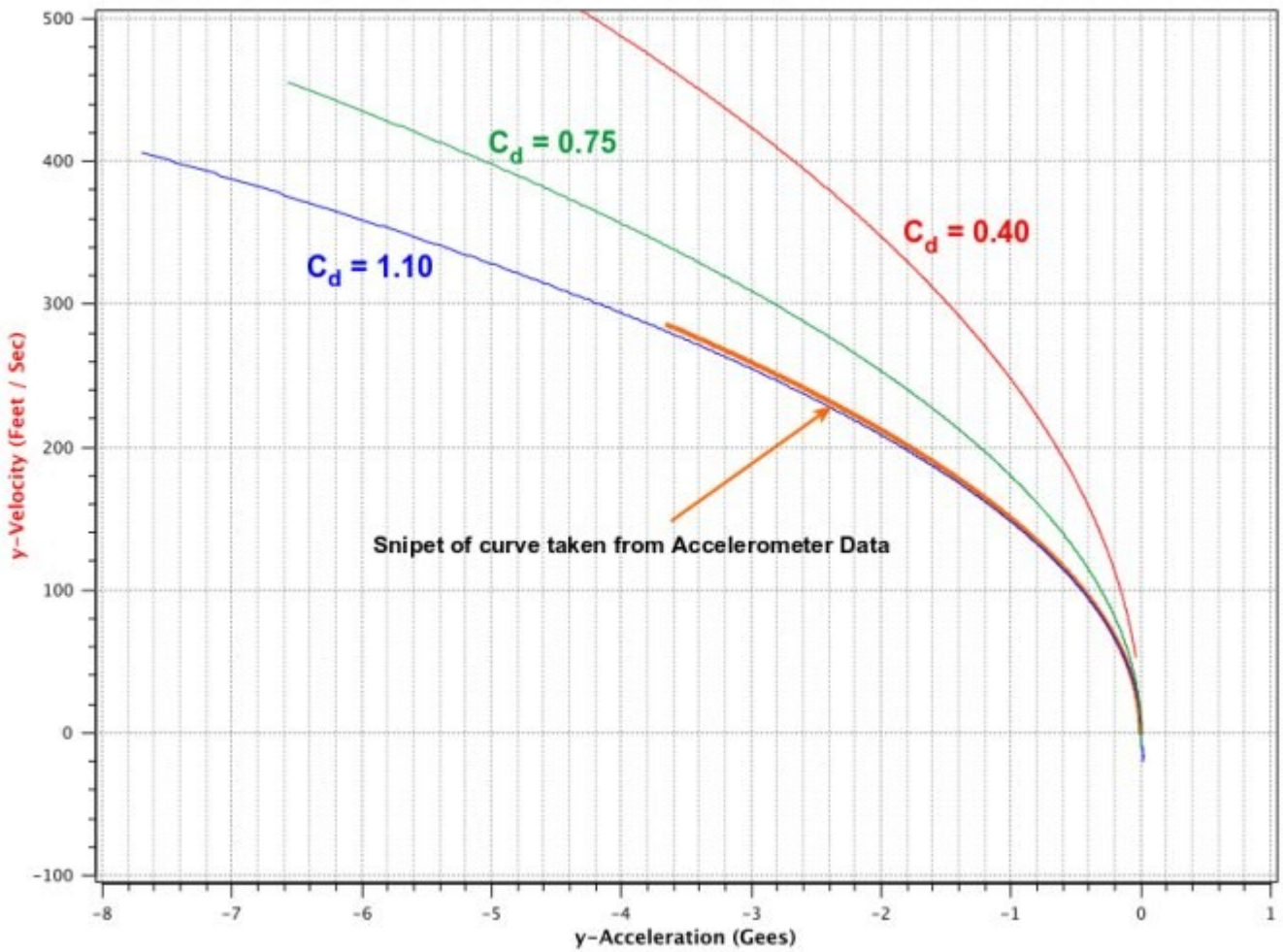
Reynolds Number and C_D

C_D, the coefficient of drag is obtained by experiment using wind tunnels. Since every possible combination of airspeed conditions cannot be tested, data is grouped by Reynolds number:

$$\Re = \frac{vD}{\upsilon}$$

Where v is aircraft velocity, D is a dimension and epsilon is kinematic viscosity.

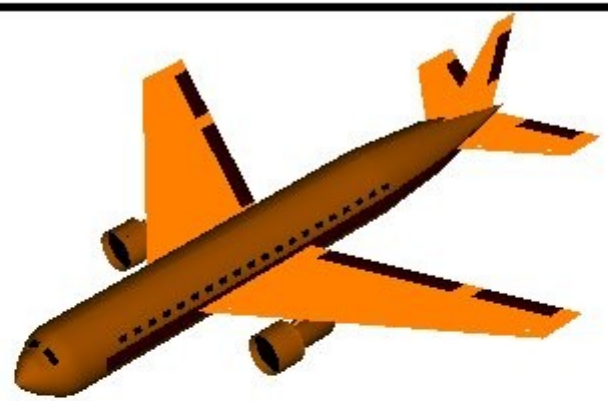
Some accelerometer data for model rockets



Determining the Drag Coefficient of A Model Rocket Using Acclerometer Based Payloads, Tim Van Milligan

The Drag Coefficient

Glenn Research Center



$$Cd = \frac{D}{\rho A V^2/2}$$

Coefficient Cd contains all the complex dependencies and is usually determined experimentally.

Choice of reference area A affects the value of Cd .

For an aircraft: $Cd = Cd_0 + \frac{Cl^2}{\pi AR e}$

(aircraft) = (skin friction + form) + (induced)

How do I use this?

Numerical analysis using $v(t) = v_0 + (g^1 t)$

Transformed to $v_{new} = v_{last} + (g_{net} \Delta t)$

Δt is called a time step

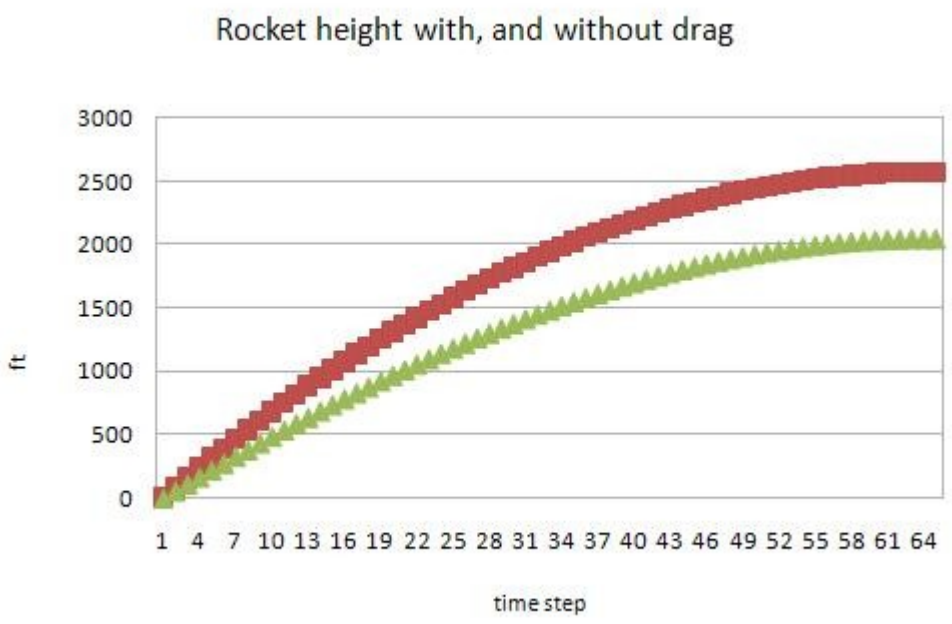
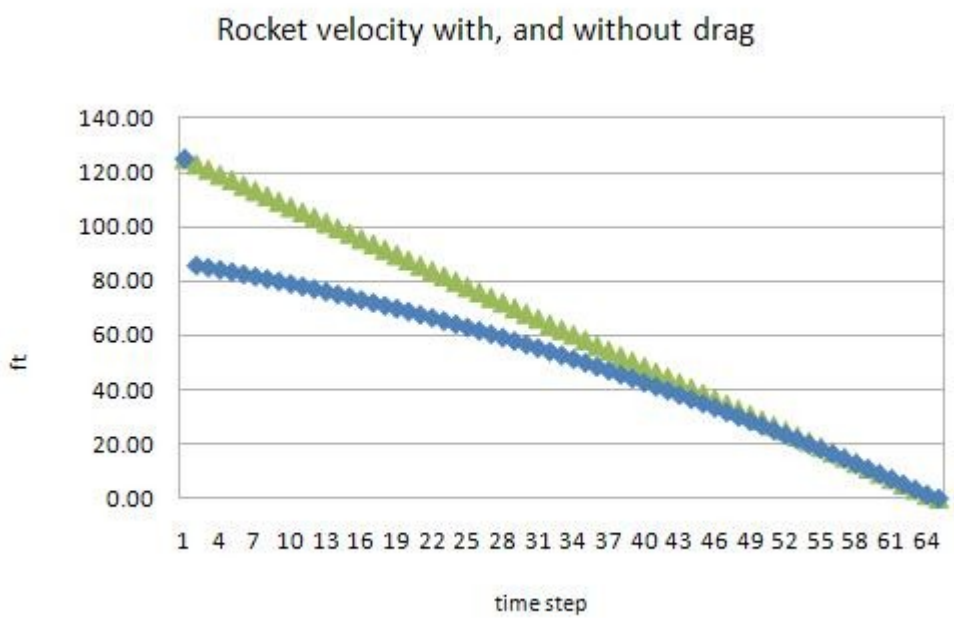
g (net), the net acceleration = g (gravity) + $\frac{F_d}{m_{rocket}}$

1. where is m? See Galileo

It's done like this

drag g		no drag	with drag	w/o drag	with drag
g'	T	v'	v	h,ft	h,ft
	0.00	125.00	125	0	0
186.44	0.20	123.04	86	81	56
180.55	0.40	121.08	85	160	112
174.74	0.60	119.11	84	238	167
169.03	0.80	117.15	83	315	222
163.42	1.00	115.19	83	391	276

Here is what we get for height



And for velocity