Aviation for Science Teachers (UW-Parkside class at EAA-838)

(1) Objective: *Do you want to inform, persuade, inspire, or entertain? Draft succinct Objective*

Expose teachers to applications of science in aviation and get them to use EAA 838 as a resource in their own classes.

(2) Audience Assessment: *Who are they? Cultural differences? What is at stake for them? Attitudes? Fear?*

Grade School & High School science teachers doing post-graduate work. Liability for flights would probably concern them.

(3) What is to be presented?: *Capture elements that may be used. Develop word pictures, sound bites, visuals.*

Welcome & Linkage: First of all, I want to correct a misconception. EAA is not just a bunch of old boys with expensive toys. Our chapter includes 3 teachers who own their own planes. 2 of them built and flew in their own aircraft. Aviation is not as expensive as people think. In 1986 I bought a used car for $13,500 and a used Piper Cherokee for $11,500. 20 years later, the car is long gone, but would be worth at most $100 today. The plane is worth $27,000 and going strong. Not a bad investment.

Introduction: As a scientist I believe the best way to understand any complex subject is to study the relationship between CAUSE & EFFECT. Aviation offers obvious opportunities to demonstrate Cause & Effect in Physics and Math, but we often build in Chemistry, Geography and more. I'll provide examples. Your students are like what many EAA members were as kids. We all flew vicariously long before we became pilots. I remember reading that the airfoil shape explains how airplanes fly, but it didn't explain how airplanes could fly upside down. Cause & Effect were not in balance. I still remember the rush I got when I put Cause & Effect together for the full story. Are you teaching kids to think or pass tests? As a manager of scientists, I know which one I want.

Point #1: Our Young Eagles program provides kids with a free flight and a groundschool that includes history & science.

* On the 2nd Saturday of every month we start a 45-60 minute ground school class at 9:00 AM. Attendance is manditory.
* A walk-around preflight inspection of the plane follows, and then a 30 minute flight. Signed parental permission is a must.
* Our goal of 1 million kids by the 100th anniversary of the Wright Brothers 1st flight was met, but the program continues.
* The Wright Brothers, the epitome of Yankee ingenuity, were screwed by intellectual snobbery in the US science establishment.
* We also do a 6-week course for the San Juan Diego Charter School and include paradigms, history, logic, and even some French.
* "Mayday" is a French word, *m'aidez* (help me), as is fuselage (spindle shape), empennage (arrow's feathers), aileron (little wing).

Point #2: Simple demonstrations are used to demonstrate aviation's principles and 4 Forces (Lift, Drag, Gravity, &Thrust)

* Upside-down glass of H_2O with loose lid demonstrates 14 psi of air. A square inch column of air above a point weighs 14 lbs.
* **THRUST** is demonstrated with a balloon, as is Newton's 3rd Law (Every action has an equal and opposite reaction).
* **DRAG** is demonstrated by throwing a flat sheet of paper at the ceiling, crumpling it, and then throwing again (Weight change?).
* Demonstrate **GRAVITY**. Follow with discussion of Newton's 1st & 2nd Laws and the difference between WEIGHT & MASS.
* Show the airfoil shape and blow a similarly curved sheet of paper to demonstrate lift via the Bernouilli Principle.
* The 'airfoil only' paradigm is an incomplete explanation, as it says an upside-down airplane would be sucked down.
* Link **Newton's 3rd Law** to the snowplow effect and demonstrate why aircraft can fly upside-down.
* Candle & Coke can demonstrate how air follows a curved surface, and why frost has to be removed from the top of a wing.

Point #3: 'Paradigm Paralysis' results when a rule controls thinking without one knowing it, e.g. the Wright Flyer

* e.g. Because bicycles replaced horses, the seat is called a 'saddle' and its shape challenges the male anatomy. There is no horse!
* Why was the Wright Flyer a "pusher"? (They never saw a propeller at the front of a boat, the same was true for rudders).
* Why was their elevator in front and most aircraft since had it in the back? (a) Balance Vs. the rudder, (b) you can't push a rope.
* Explaining LIFT via Newton rather than Bernouilli or the airfoil is something of a "Paradigm Shift" for many people.
* Use **LEVER PRINCIPLE** to explain **WEIGHT** & **BALANCE, CENTER OF GRAVITY**, & **LONGITUDINAL STABILITY**.
* Define & demonstrate how **WING DIHEDRAL** contributes to **LATERAL STABILITY**.
* Use **GAS LAWS** (Boyle's, Charles', and Ideal) to show why planes need longer runways on hot days & high elevation airports.

Transition: The hand-outs are an invitation to you as teachers to use us as a resource, either here or in your own classroom. If you bring your class on a regular Young Eagle day, we will have aircraft and pilots available. Some teachers and scout troops use us as a reward for achieving some goal. We also have had teachers coordinate what they were teaching with what we present. The permission slips have to be signed by parents. If you want separation between you and the flights for liability reasons, you could do what the Girl Scouts do. They attend the class as a troop and then kids come with their families on a separate day to fly.

Close: Our goal is to get new generation interested in aviation and the mission of EAA Chapter 838 is eduction. We also want to get American kids more interested in STEM (Science, Technology, Engineering, and Math). I have tried to give you a flavor of what we cover and my objective is to see if we can link your class to ours for our mutual benefit. If one of my teachers had told me that I would get to fly a in a plane if I did such-and-such, then such-and-such would get done!

(Option: Do the canary quiz? The Cherokee on the Moon question?)

Aviation Class for Science Teachers

by Seán G. Dwyer

Good morning!

My <u>role</u> is to tell you about our Young Eagles program here in EAA Chapter 838.
My <u>goal</u> is to get some of you to use our program as an adjunct to your class, . . .
either as a reward . . . or as an exciting, real world application of what you teach.

The best way to really learn is to understand the relationship between CAUSE and EFFECT. The more exciting the cause or the effect, then the more interesting is the subject to the student. Aviation offers obvious opportunities to demonstrate Cause & Effect in Physics, and Math, but depending on the ages of the kids or available time, we build in Geography, Chemistry & more.

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But first of all, I want to correct a misconception. EAA – the Experimental Aircraft Association – is not just a bunch of **old boys with expensive toys.**

Racine's aviation community includes at least three teachers: Bob Hyatt is a music teacher and built his own plane. Gerry Bovitz was a shop teacher and built his own autogyro, but now flies a C-172. Fred Fleischmann recently retired as an art teacher and owns three airplanes, some of which he rents out. The diversity of their fields is typical of the small airplane community.

Aviation is not as expensive as you might think. In 1986 I bought a plane and a car, both previously owned. The plane cost less than the car, $11,500 to be precise. The car cost c. $13,500. What do you think that car that I bought in 1986 is worth today? $100? Probably less.

Today, the plane is worth more than twice what I paid for it, $27k. A good investment, yes?

Flying is cheaper than country club golf. It is also more exciting, . . . think about it . . . the thrill of *" I shot two under par"* pales in comparison with *"I'm alive, I'm still alive"*.

<u>Introduction</u>

Let's get to our topic, the **Young Eagles** program, and **how we can help you**, & **you help us**.

Many of your students are like what our EAA members were as kids. Every one of us flew vicariously long before we became pilots. Some of us were turned on by anything mechanical or technical, and planes are very mechanical and technical. Others got turned on by the rush that accompanied *"I get it!"* when they finally understood something complex or made a connection, i.e. the Cause & Effect relationship mentioned earlier.

I remember, as a child, reading that the airfoil shape explains how airplanes fly. It was easy to demonstrate how the airfoil contributed to lift, but it was incomplete. It didn't explain how aircraft could fly upside down. Cause & Effect were not in balance. I'll show you what we teach. Question for you: Do you want to teach kids to think? . . . Or to pass tests? Both are important, but as a person who used to manage R&D scientists, I know which one I want.

YOUNG EAGLES: What? When? Why? And How Much does it Cost?

On the **2nd Saturday** of each month at **9:00 AM** we start a 45-60 minute **ground school**.

This is followed by a **walk-around** inspection of the plane, a requirement for scout merit badges.

The **flight** is 25-30 minutes. Ground school continues until we have flown all the kids.

There is **no charge** for the flight; the pilots donate time & $'s; some even rent planes for the YE flights. Their payment is excitement of the kids + the opportunity to **share the thrill** of flight.

Children **age 8-17** are eligible. Signed **parental permission** is an absolute requirement. Teachers are not responsible. Put that worry out of your head, but **challenge me if you don't agree**!

Our goal was **1,000,000 YEs by the 100th anniversary** of the Wright Brothers' 1st flight in December 2003. The objective was met in November of 2003. This EAA chapter flew 2,782 kids. The EAA goal from now forward is 100,000 per year.

Why do we do this? We want to get kids interested in aviation; we remember how it turned us on as kids – and still does. Also, some of us see aviation as a way to get kids interested in STEM (Science Technology Engineering Math), something America needs desperately in the Information Age. We graduate <80,000 engineers each year. China graduates 800,000!

Walk-ins are OK. Many groups are **scout troops**, & we administer the Aviation Merit Badge test. Teachers have brought **science classes** and linked what we do to what they do in their own classes. One year **Park High School had an Aviation Career Day** here in Chapter 838, and one of the Lower School science teachers in Prairie School brings her class here every year.

We also had an annual 6-week course in which a class from the **San Juan Diego** school came here for a class every week. Mike Frontier, a former Principal in one of the Unified schools, was involved and described their objective to me. They wanted to expose at-risk kids to **ideas and experiences** that would trigger their interest in going further in the learning spectrum. I taught one of the classes, and found the kids very well behaved & responsive, much more so than some scout troops.

Physics, math, geography, meteorology, and mechanics all have obvious connections. But chemistry, logic, paradigms, history, and languages all play roles that we can and do include.

"Mayday" is what pilots say it when in trouble. Where did it come from? A Communist holiday? You may guess it if I spell it **"m'aidez".** That is French for "Help me".

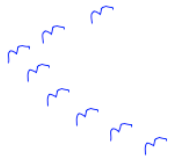
How about ***fuselage*****?** (French for "spindle-shaped"); ***empennage*** (French for "put the feathers on the arrow"); ***aileron*** ("little wing"). Who invented the airplane? How did the French get to name so many parts of it? There is a story in there which is very relevant to anybody who

challenges a scientific paradigm. The Wright brothers, the **epitome of Yankee ingenuity**, were screwed by the intellectual snobbery of the US scientific establishment. Two bicycle mechanics did what Prof. Langley, Director of the Smithsonian Institute could not do. I could go on. Intellectual snobbery is a real problem for innovators, because they usually come from outside the field of the innovation.

FOUR FORCES OF FLIGHT:

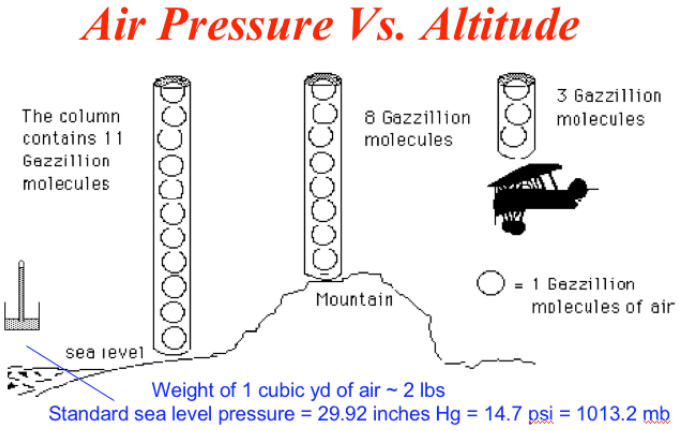
Gravity, Drag, Thrust, and Lift are the four forces of flight, and that is pretty much the order in which they were discovered. But we are going to cut to the chase and start with Lift. After all, if you don't have Lift, you don't have flight!

TRICK QUESTION: (Drawing of a flock of geese in flight) What does this picture represent? Why is one arm of the V always longer than the other? I posed that question to a bunch of pilots in this classroom and they got all tangled up in an explanation that involved the upwind side Vs. the downwind side. A complicated explanation was expected, but the answer is really simple. There are more birds on one side than on the other. KISS Principle – don't make it complicated. Understanding flight is similar if you match Cause with Effect.



Cause & Effect demonstrations for kids

Does a gold fish know he is in water? Not only is he surrounded by it, but water inside his mouth exerts the same pressure as the H_2O outside. The only way he feels the presence of water is if you take him out of it. That gets his attention. The same is true for us with air.



Show upside-down glass of H_2O w. loose lid. Why does the lid stay on and water not spill? **14 psi** of air pressure presses on the lid and exerts more pressure than the weight of the water in the glass. 14 lbs is also the **weight of a 1 square inch column of air** above this spot.

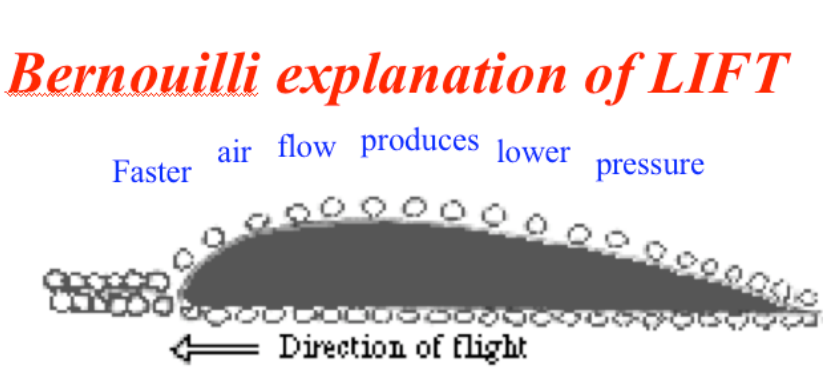
Could one do the same demo in Denver? Possibly not, as the column of air over Denver is almost a mile shorter and it therefore weighs less than a column of air that starts at sea level.

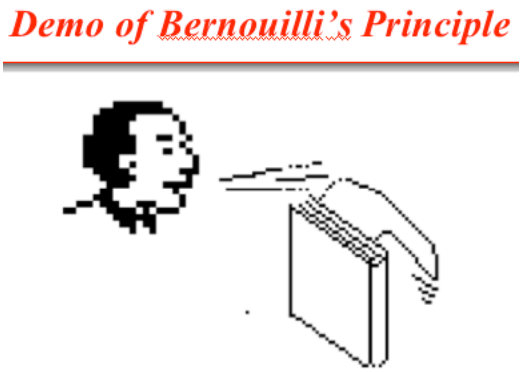
Less weight = less air pressure = higher altitude

This phenomenon, pressure measurement, provides the means to determine how high aircraft are. Students can demonstrate it with a simple barometer in an elevator. (Cause & Effect)

Importantly, existence of this all encompassing and low density fluid (air) allows aircraft to fly by "high speed surfing" on air in the same way that a surfboard does on higher density water.

DEMO: Show an airfoil. Most explanations of Lift focus on the airfoil shape of wings.



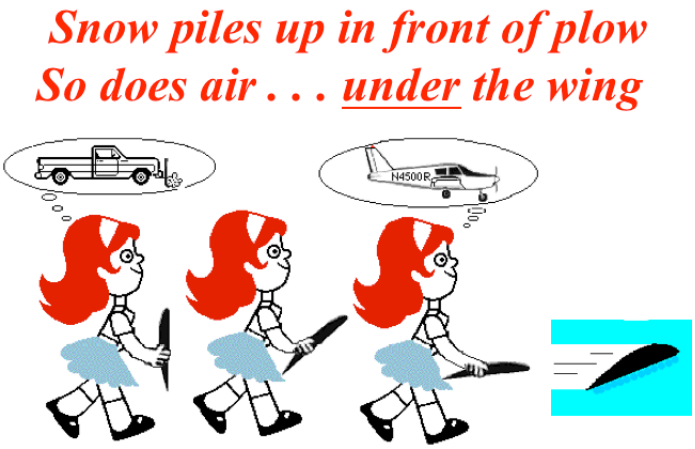


DEMO: Bernouilli Principle (Blow on a sheet of paper extending out from top of a book) Aeronautical engineers use the Bernouilli Principle to explain why air traveling faster over a curve exerts less pressure on the top of a wing. Specifically, ***The total energy in a steadily flowing fluid is a constant along the flow path, so an increase in the fluid's speed must be matched by a decrease in its pressure.***

Believe them if you want, the demo certainly shows that it is true (Cause & Effect), but this explanation also came from the same people who conclusively proved that Bumble Bees can't fly. Anyway, Bernouilli's Principle made your eyes glaze over, mine too! Definitely not KISS!

PARADIGM CHALLENGE: Airfoil-only paradigm is an incomplete explanation
If Lift is dependent only on the curve at the top of an airfoil, then airplanes should not be able to fly upside-down. The curve would suck the plane down. Therefore, some other effect must (a) exist and (b) be dominant. i.e. It must be more powerful than the airfoil! (Cause & Effect?)

NEWTON's 3rd Law – *Every action has an equal and opposite reaction*



Air is pushed down by the bottom of the wing and pulled down into the empty space left above the wing as it moves forward. How much air? At least as much as the weight of the airplane

DEMO: Use wing in Snowplow position. Where does snow pile up? In front or in back?

Lower the blade's **angle-of-attack** to that of a wing and go 100 miles per hour.
Where does the air pile up? The bottom is still the front and is pressurizing the air ahead of it.
Action-Reaction (Cause & Effect) If you push enough air down, an airplane will go up.
This also explains how airplanes can fly upside-down, but it is not the whole story.

If air was a solid, a moving wing would cut a hole and leave empty space behind it. But air is a fluid, and air filling the void can come from above faster than from below.

While the **bottom** of the wing **pushes** air down, the **top** of the wing **pulls** air down. Acton/Reaction, if enough air goes down, the airplane will fly. (Cause & Effect)

DEMO: Candle shielded by either a flat ruler or a fatter Coke can

Show how airflow will follow the curved surface of the can. This replicates the top of an airfoil. The trick is to keep the air flowing smoothly over the surface. If it burbles, then airflow separates from the wing and the wing "stalls". That is what happens when the angle of attack is too high. (Cause & Effect)

Why do you see bombs and fuel tanks under a wing and never on top? A snowplow that runs into a garbage pail will still plow the same amount of snow. On the other hand, just a little frost on top of a wing will disrupt airflow over the wing to the point where the aircraft cannot take-off. The top must be smooth so that air can follow the contour. (Cause & Effect)

Airfoils are important for lift, but they are NOT the only factor, or even the key factor.

PARADIGM SHIFTS: Explaining Lift using Newtonian theory as opposed to Bernouilli theory or airfoil theory is a paradigm shift. As a person who used to manage R&D divisions for Johnson Wax, I always encouraged scientists and engineers to understand what paradigms were controlling their thinking. "Paradigm" means "Rule" in Greek. If you follow a rule without knowing that you are doing so, then you suffer from **"Paradigm Paralysis"**.

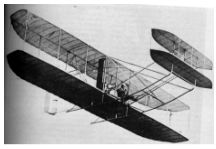
The design of the bicycle saddle is a good example of paradigm paralysis. Bicycles replaced horses, so the paradigm was a horse saddle, which had to sit on top of a horse. When you take the male anatomy into account, can you think of a worse design than the current narrow saddle? The paradigm was so powerful, it even controlled the name. In Europe, we refer to a bicycle "saddle", not a bicycle "seat". What do you call it? **There's no horse!** A seat like that on a tractor makes more sense.

Do you know why our railroad tracks are 4'8.5" apart? Early US railways were designed by English engineers, and English rails are 4'8.5" apart. Why? Horse drawn trams in London that preceded railways rode on rails 4' 8.5" apart. Why? The trams were built by the same people who built horse carts, and English horse carts had a wheel span equal to 4'8.5". Why?

Well, back in the 1800s, the only paved road in England was the old Roman Road and that had grooves that were 4'8.5" apart. If you didn't design your cart wheels to fit in these grooves, then the wheels would be constantly slipping in and out, and would break. Finally, some Cause & Effect. But why were the grooves 4'8.5" apart? It turns out that Imperial Rome had a specification for the design of war chariots. That is where the distance came from, and it was based on the width of a horse's behind.

Here is where it gets interesting and relates to aviation. Do you know that the rocket boosters used with the space shuttle are built by Morton Thiokol in their plant in Utah? NASA wanted to make them bigger, but had to take into account the fact that they would be transported by rail to Cape Kennedy. That railroad ran through several tunnels, and – predictably – the width of tunnels was based on the width of the tracks. So – arguably – the development of the most complicated aircraft of the last century was **design limited by a 2,000 year old specification from Imperial Rome that was based on the width of a horse's ass**. That takes Cause & Effect to an extreme.

Let's look at the role of paradigms in the design of the Wright Flyer. Most propeller driven aircraft have the prop at the front and the aircraft is pulled through the air. This allows the propeller to meet uniform air that is undisturbed by the rest of the aircraft. Conversely, the Wright Flyer was a **"pusher"**, and it is easy to understand why.



The only propellers they had ever seen were on boats, and they are always at the back. The same is true for the rudder. They are always at the back. However, the rudder on a boat is pushing against water, a much more dense fluid than air. So the Wright brothers put their rudder out on the end of a boom in order to benefit from the Lever Principle. That is another good Cause & Effect example that you can use.

Why did the Wrights put their elevator in front? Balance is probably the main reason, what with the rudder way out at the back. In fact, the Wright brothers called the elevator "the horizontal rudder". However, almost all aircraft for the next 70 years had the elevator at the back. It is intriguing to think that they might have been influenced by the only powered vehicle that could travel under control in three dimensions prior to the Wrights. It was about 40 years earlier. Can anybody guess what it was?

The Confederate submarine Hunley had dive planes, which are what elevators are, at the front.

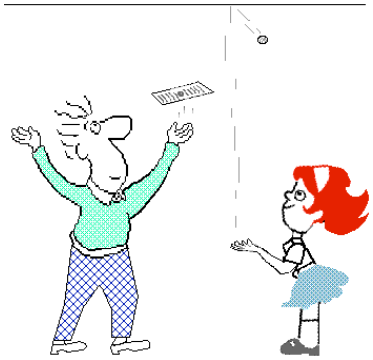
Anyway, whatever their reason for putting the elevator at the front, the Wrights could get away with it because their **Flyer was so slow**. Once aircraft started flying faster, an elevator at the front would have had to be made much stronger, and that would add weight. The design history is a good example of Cause & Effect. If you **pull a rope** it will be straight, regardless of whether it is as thin as a thread or thick as a chain. On the other hand, if you **push a rope**, its shape will change unpredictably. You can't afford to have a plane change shape unpredictably. So designers combined the elevator and rudder at the back and moved the engine forward to achieve balance. This continued until materials that were both light and strong became available, as in Burt Routan's Varieze, with its canard elevator at the front and the propeller at the back.

Routan Varieze

<u>Some more Demos that work with kids</u>

Thrust is easy to demonstrate with balloons. It also works well with as an example of Newton's 3rd Law, *Every action has an equal and opposite reaction*. However, I would suggest that you don't simply blow up a balloon and let it go. Its trajectory will be erratic. You can control it in an impactful way if you tape the balloon to a straw that rides along a taut thread. I am sure that you could develop an experiment whereby the kids measure how high they can go, do statistics, etc.

Drag is demonstrated by asking the biggest boy in the front row to try hit the ceiling with a flat sheet of paper. Then I crumple up the sheet of paper and ask a small girl to hit the ceiling. That lends itself to a discussion of what was different. Some kids will insist that the weight changed, which of course is not true.



The crumpled paper experienced less drag than the flat sheet.

Gravity is easy to demonstrate and it is also a guarantee that we never leave any kids up there.

Weight & Balance are critical to a safe flight, and they involve plenty of **math** and **physics**.

Balance calculations use the **Principle of the Lever**. Basically, an aircraft is a see-saw without a fulcrum. The pilots needs to ensure that that the aircraft is not loaded so as to be either nose heavy, tail heavy, or too heavy.

Lateral & Longitudinal stability

If you are teaching the use of vectors, then wing dihedral is a good real life application. Lateral stability delivered by wing dihedral lends itself to a demonstration. I ask a child to extend arms (i.e. wings) while holding two rulers that show the direction of lift perpendicular to the top surface of the wing. Weights dangling from the rulers show the direction of gravity, which is always straight down. When the volunteer raises his arms to simulate dihedral, lift no longer directly opposes gravity. Some lift is lost, but the difference between lift and gravity is the same for both sides. Have the volunteer bend to one side to simulate a dipped wing and it

Fig. 1 No wing dihedral

Volunteer shows directly opposing lift and gravity

Fig. 2 Positive dihedral

Wing dihedral costs some lift relative to gravity

Fig. 3 Dihedral in a bank

Low wing has more lift in opposition to gravity

becomes obvious that more of the low wing's lift is available to oppose gravity, while the high wing's lift vector relative to gravity is further reduced. The net result is a force to raise the low wing and drop the high wing, i.e. lateral stability. I always ask kids to observe which has more dihedral, low wing Pipers or high wing Cessnas. The reasons for the difference can be a good discussion for a physics class.

Chemistry teachers know Boyle's Law, Charles' Law and the Theory of Avogadro.
But I wonder if they know that the Montgolfier hot air balloon, the first aircraft to successfully carry people aloft in 1783 got its lift from Charles' Law, or that two weeks later the team that came 2nd with a hydrogen filled balloon got their lift via Avogadro's Law, which is captured by PV=nRT. Interestingly, the team that came 2nd included Jacques Charles, who promulgated the law used by the winners.

Boyle's Law: At constant T, the volume & pressure of a gas are inversely related ($P_1V_1 = P_2V_2$)
Charles' Law: At constant P, V is directly proportional to T ($V_1/T_1 = V_2/T_2$)
Ideal Gas Law: PV = nRT

These laws also explain why an airplane needs a longer runway to **take off on a hot day** or from a **high elevation airport**. When you heat a gas, it expands. So unless you increase the pressure to constrain the volume increase, there would be fewer molecules of air in a given volume. Fewer molecules means lower mass per unit volume, so an airplane will need to go faster to push the required mass of air down.

PV = nRT explains why **humid air is less dense** than dry air, which is counter intuitive. Basically, if you replace any of the major air molecules with water vapor, you are replacing a heavier molecule with a lighter one, i.e. lower mass. The molecular weights of Nitrogen, Oxygen, and Carbon Dioxide are 28, 32, and 44 respectively. Water has a molecular weight of 18. Thus an aircraft needs a longer take-off roll on a humid day than on a dry day.

Finally, we have **map reading** and **geography**. We use them on days when we have a lot of kids to fly or we have to wait for weather to clear up. We split up the kids into small groups and different pilots show them how to use aviation maps. One question that often comes up is why do we use "Zulu time" or GMT. Another one that gets attention is the fact that the **magnetic North Pole is not at the North Pole**. That does not affect us much in eastern Wisconsin, but it can be a navigation problem in Ireland where I grew up.

<u>Transition</u>
I had better bring this to a conclusion. We have Young Eagles scheduled for this coming Saturday morning. If you would like to bring your kids , or would simply like to see what we do with kids, you would be very welcome.

Are there any questions that anybody would like to ask? *(Option: Do the canary quiz?)*

<u>Summary</u>
I have tried to give you a flavor of what we cover, and my objective is to see if we can **link your class to ours** for our mutual benefit.

If one of my teachers had told me that I would get to fly in a plane if I did such-and-such, then – believe me – such-and-such would get done.

Quick poll: Is anybody interested in scheduling their class? _____
Let us know and we will work something out.

If not, then what is the barrier? _____ *(probe)*

In conclusion, **we are here** . . . . **and we invite you to work with us**;

When learning is fun, learning gets done. . . . and flying <u>is</u> fun.