The Physics of Air

\[ L = C_L \times \rho \times \frac{V^2}{2} \times A \]

\[ \frac{L}{D} = \frac{\Delta S}{\Delta H} = \frac{v_{\text{forward}}}{v_{\text{down}}} \]

Weniger 151, January 11th 2015
Why do some bubble float, some bubbles sink?

Demo #1: Kids blow bubbles, someone makes bubbles from a He tank and a propane tank
Air is made of tiny tiny tiny particles...

Demo #2: Open the scales of the universe website and zoom from human scale to atomic scale
Demo #3: Colorful juggling balls (balloons stuffed with dry rice) are used to represent gas molecules of different mass, do some juggling!
When you blow on your hand, you are feeling millions and millions of these tiny atoms colliding with your hand.
The starting point for explaining...

Things that float
Things that fly

Wind energy
crazy adventure sports
The Physics of Air

Physics: Explaining "what sets objects into motion?" "where will objects end up?"

The Physics of Air

What makes things move? How do I predict where things will move?

Physics: Trying to answer questions like:

- What makes things move?
- What variables control the system?
- What makes patterns and shapes emerge in natural systems?

Working definition for today:
Carefully observing things move (like atoms and planets...) Asking how and why.

**physics** noun plural but singular or plural in construction

/ˈfi-ziks/

: a science that deals with matter and energy and the way they act on each other
When I blow leaves, why do they move?

Demo #4: The “land yacht”. Use a cart that has minimal rolling friction. Give it a “sail”. Blow the cart across the room with a leaf blower. Now do the same thing by throwing the colorful juggling balls into the sail. Discuss the equivalence. In both cases we transfer momentum from high velocity particles (air molecules or juggling balls).
Demo #5: Make a beach ball float in the airstream of the leaf blower
How hard can I push something using air?

Time for a physics equation!

(experiment to validate the physics equation)

Demo #6: Measure the velocity of air coming out of the leaf blower. Do a back of the envelop calculation to estimate the force exerted by the air onto a sail. Discuss the units that I use to measure things like velocity and air density. Verify the calculation by attaching a sail to a Newton meter. The force will be a couple Newtons. Discuss the role of math. Discuss how physics predicts relationships between quantities that have different unit (e.g. relationship between air velocity and force).
Demo #7: Use a Newton meter to see how much force it would take to lift a 5-year-old kid (the kid can hang on the Newton meter). The leaf blow gives 2 N... is it enough?
Demo #8: The toy helicopter is much lighter than a kid. In this case, blowing air downward gives enough force. Pilot a toy helicopter around the room. Let people feel the down draft.

Air goes down, helicopter is pushed up
Flying into the air from the recoil of air molecules
Floating on a bed of invisible air molecules

Demo #9: If we can’t fly like a helicopter… what’s the next best thing I can do with a leaf blower? Give a kid a ride on a homemade hoverboard. Everyone else gets a turn at the end of the event.
Demo #10: Explain how the hover board worked using this PHET simulation. A small excess of air molecules in the chamber increases the pressure.
What about hot air balloons?

The best way to understand something is to build it...

Activity #1: Teams of two kids with one parent overseeing. Build hot air balloon.
Try 5 short candles

Trim the 4 ends of the cross. It should fit snugly in the opening of the bag.

Make the struts into a cross. Wrap center with tape.

With the cross in the bag, tape the candle platform to the cross.

Cut in half

Expose the wicks

Melt the bottom

“Glue” to foil
Demo #10: Explain how the hot air balloon worked using the same PHET simulation. A small input of heat makes the air molecules move faster, fewer air molecules in the chamber needed to maintain atmospheric pressure.
Every good theory makes a prediction...

If hot gas molecules fill more space...

cold gas molecules fill less space

Demo #11: Kids inflate balloons (balloons must be filled with humid air), then balloons are put into a cooler that has liquid nitrogen. Remember, safety first! Kids need clear instructions about keeping themselves safe from LN2. (typical freezer -18°C)
Beyond the physics of air

Physics (working definition for today):
Carefully observing how things move (things like atoms and planets...)
Asking how and why.

(Short lecture about how Physics informs philosophy)
Example 1: Earth-at-the-center-of-everything theory

(by carefully observing the trajectories of the planets, seeing that Venus and Mars travelled in “loop-the-loop” paths relative to earth, physicists understood that a more elegant explanation was that the earth was also making circular orbits)
Far out in the uncharted backwaters of the unfashionable end of the western spiral arm of the Galaxy lies a small unregarded yellow sun. Orbiting this at a distance of roughly ninety-two million miles is an utterly insignificant little blue green planet..."
Example 2:
The microscopic world (quantum mechanics)

Observation of atoms

Quantum mechanics is probabilistic

Everything is a game of chance
Careful observation

Change the way people think about things
Final Exam

Consider gas molecules that are 2x heavier than surrounding air and 3x hotter than surrounding air...

Demo #12: The spectacular explosion at the end of the show. Involves 6” diameter soap bubbles filled with propane. Remember safety first! Kids need clear instructions where to stand.
Thanks for coming!

Line up in foyer for 1\textsuperscript{st}-round of hover board rides

Come sit in the front rows if you’d like to ask questions (and get 2\textsuperscript{nd}-round hover board rides)