


The Physics of Paper Airplanes

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PHYS 420C



Goals for today!

- Get to know the behind-the-scenes physics action on why our paper airplanes behave the way they do
 - Forces, free-body diagrams, and torque!
- Fly some paper airplanes through a launcher
- Get candy while learning physics
 - Starbursts/skittles regardless of answer correctness!
 - Pretty sweet deal

A Brief History of Airplanes

- First heavier-than-air flight accomplished in 1903 by the Wright Brothers
- The principle behind heavier-than-air flight involves passing air quickly enough over wings to generate **lift** and overcome **gravity**.

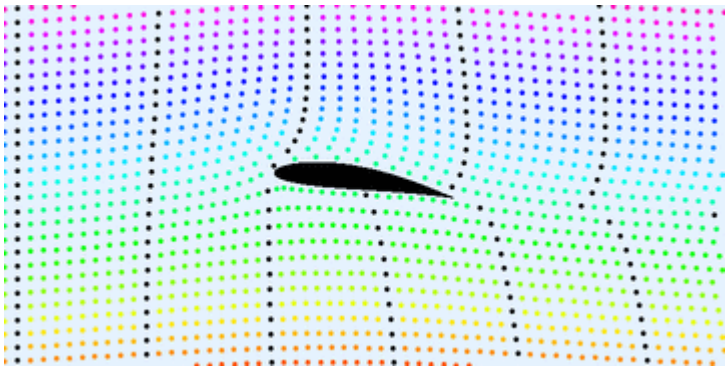


Image Credit:
[https://en.wikipedia.org/wiki/Lift_\(force\)#/media/File:Karman_trefftz.gif](https://en.wikipedia.org/wiki/Lift_(force)#/media/File:Karman_trefftz.gif)



Image credit: <https://airandspace.si.edu/stories/editorial/first-flight>

Airplane history cont'd

- Airplane designs really improved over the years, but the main theme behind these improvements are usually better engines for **thrust** and reduced **drag** for less energy waste / better performance.

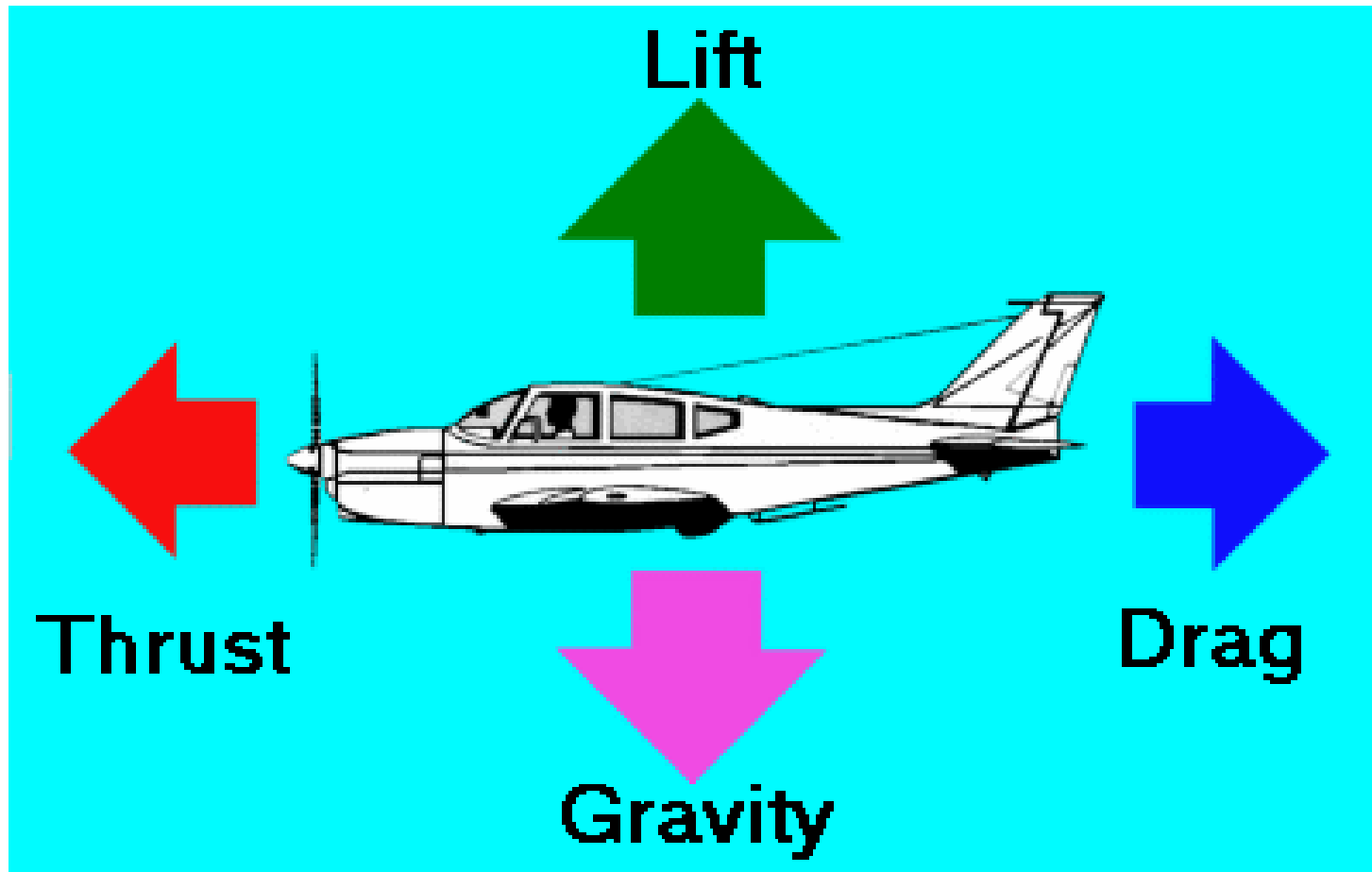


Image Credit: <http://www.aviation-history.com/theory/force.htm>

Motivation

- Know a bit more on the theory behind paper airplanes!
- Find the intuition behind some Free Body Diagrams (FBDs)
- Apply intuitions from Free Body Diagrams and torque to the performance of airplanes

**What are some
examples of a force?**

Try to name two or three forces on your worksheet

Some examples of forces

- Gravitational force
- Electromagnetic force
- Frictional force
- Buoyant force

Newton's Third Law

- Cornerstone of our lesson!
- Newton's Third Law says, all actions have an equal and opposite reaction to it
- More physicsy term: every force has an equal and opposite reaction force
- Example: we don't fall towards the center of the earth!
 - Why is that? (Hint: the theory is in this slide)

Normal force!

- A force that supports us directly
- We give the ground a downwards force, and Newton's Third Law gives us an equal and opposite force (upwards)

What are some examples we can find for Newton's Third Law?

Feel free to write an example along with your own definition of Newton's Third Law

Newton's Third Law cont'd

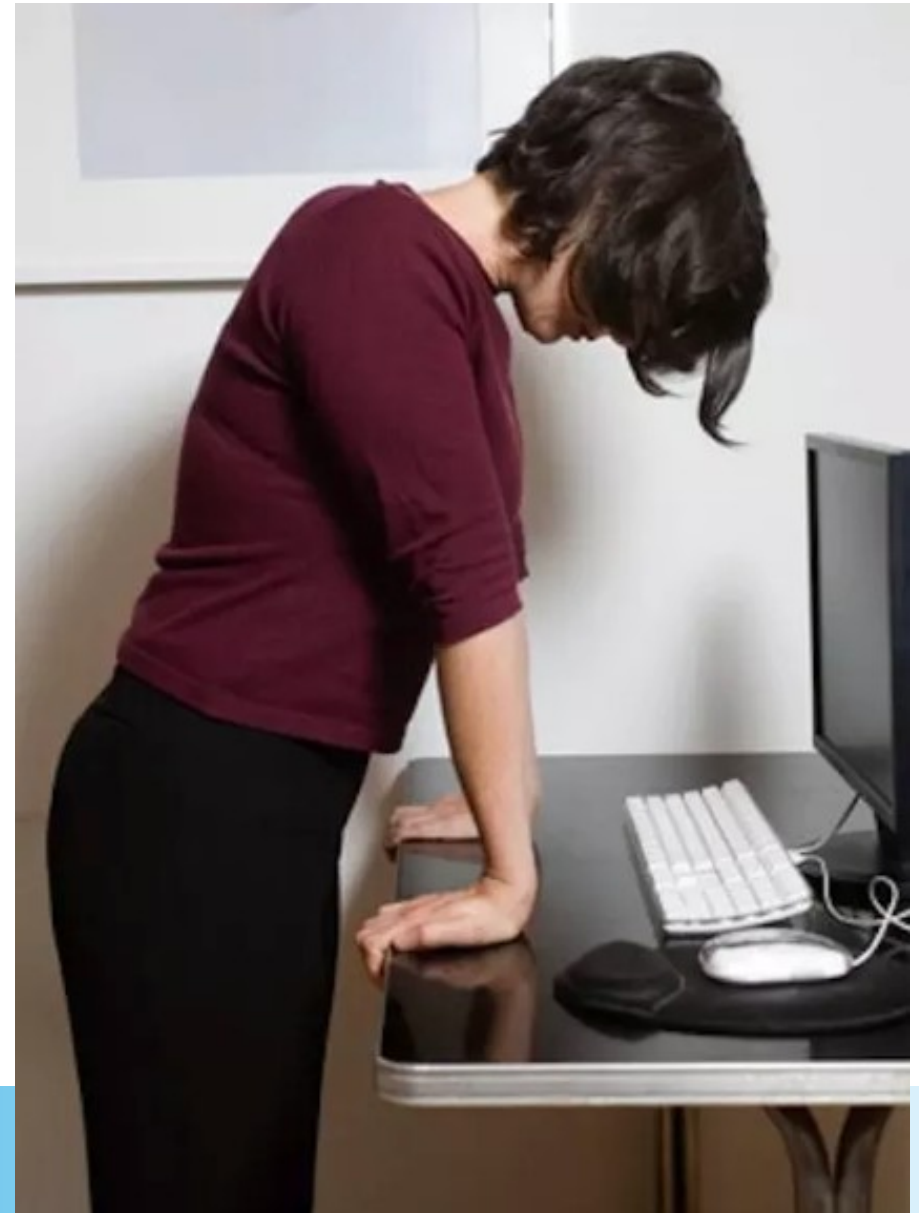
- For example, when you push a door, a door pushes back on you.
- Hitting a stationary puck: the puck moves forward due to acceleration, and the stick receives a “push” in the opposite direction of the puck's movement.

Questions so far?



Feel the Force!

- Put your hands the other
- way, and try pushing
- downwards
- Should feel the table...
- the table can only be felt
- if it's pushing back at
- you!



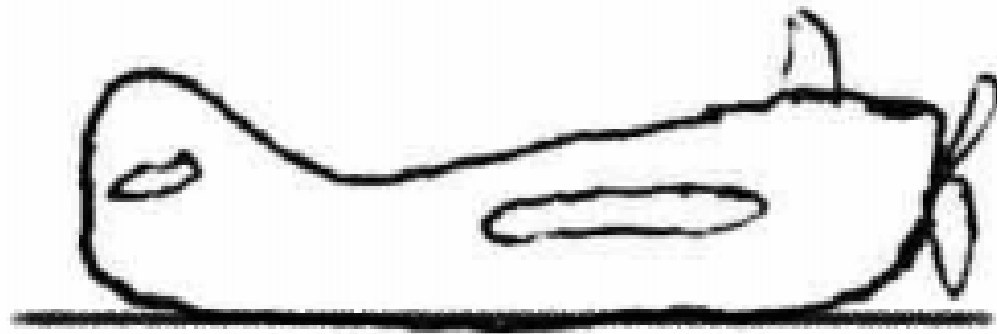
**How can we represent this in
Physics?**

Free Body Diagrams!

- A useful way for us to abstract our information down to just what we need
 - Approximate an object with point mass
 - No need for shape, color or size of object!

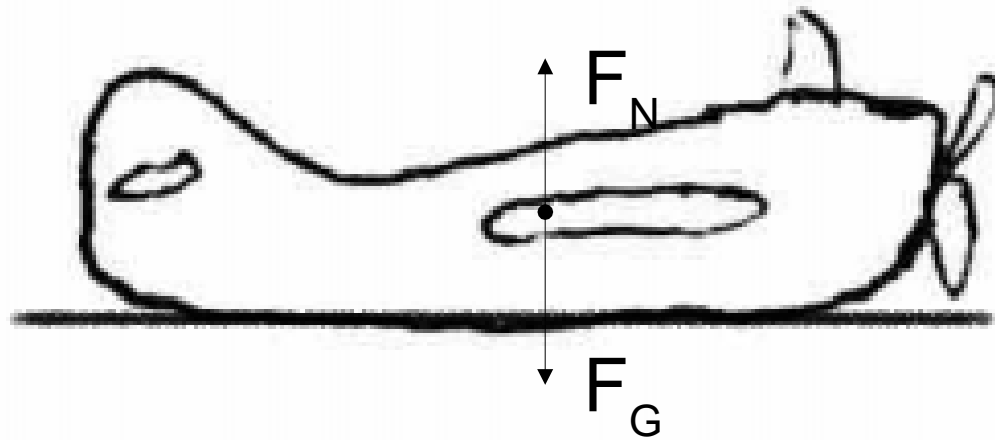
Okay, what does all of this have to do with paper airplanes?

A plane on the ground

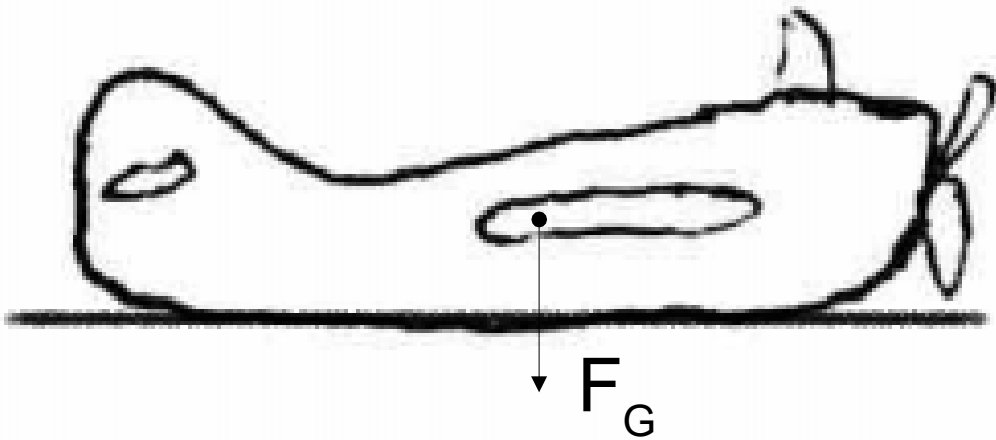


A plane on the ground FBD

- Note that the two lines are roughly the same in length; this expresses that the magnitudes on the two forces are similar

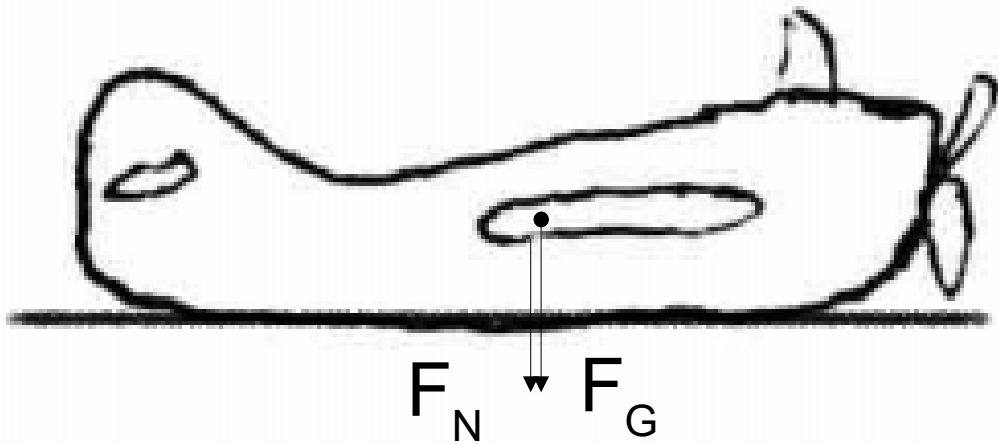


What's inconsistent with this diagram?



- There is no normal force! The object in the FBD would keep on accelerating towards the earth

And this one?

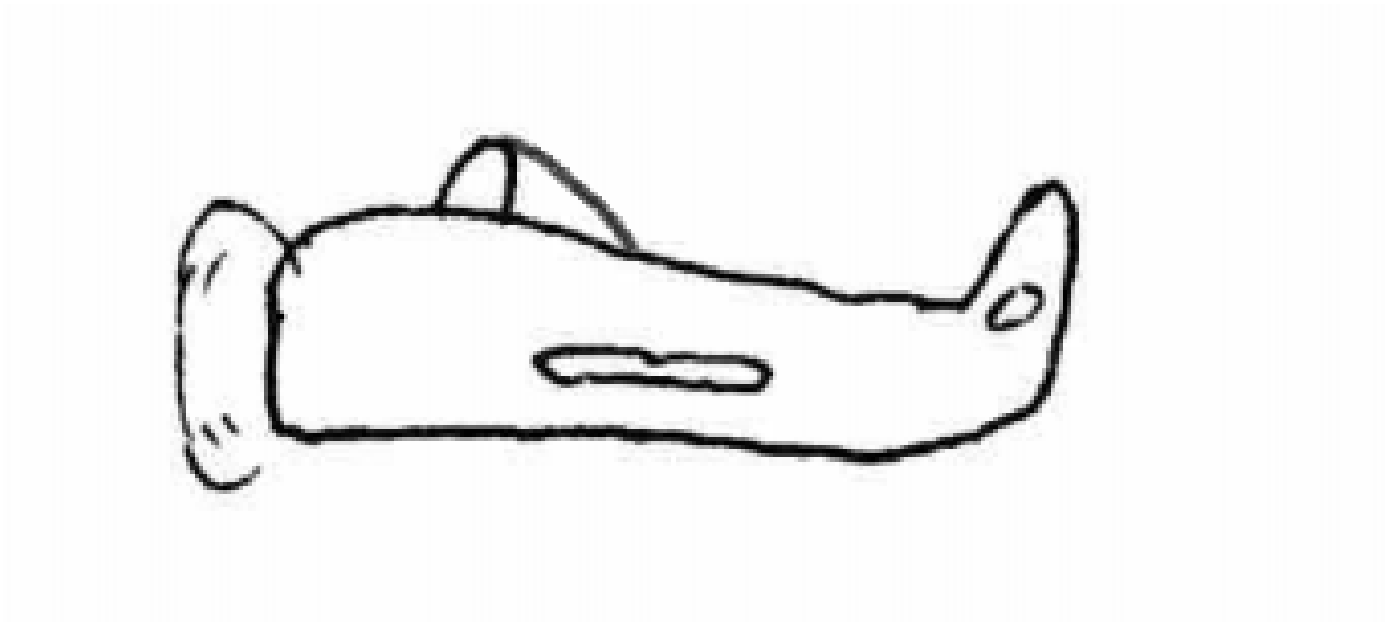


- Normal force is here now, but in the wrong direction! Newton's Third Law tells us that the two forces have to be equal in magnitude, and opposite in direction.

Questions so far?

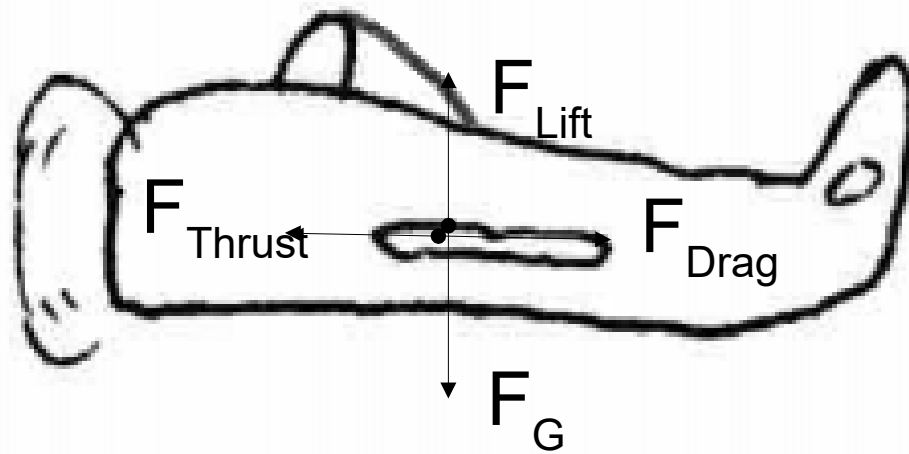


A plane flying midair, with NO acceleration in any direction!



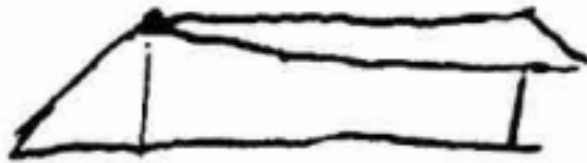
In-class activity

Plane FBD



Paper airplane travelling in air

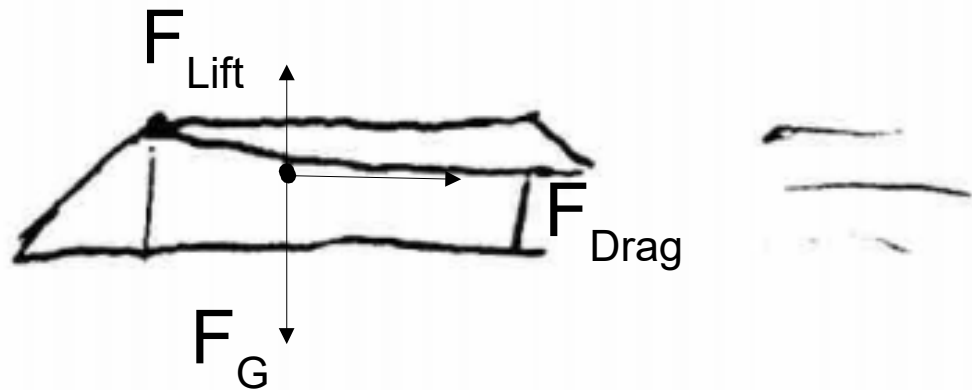
(Addendum: the paper airplane isn't travelling fast enough, so it is falling downwards)



In-class activity

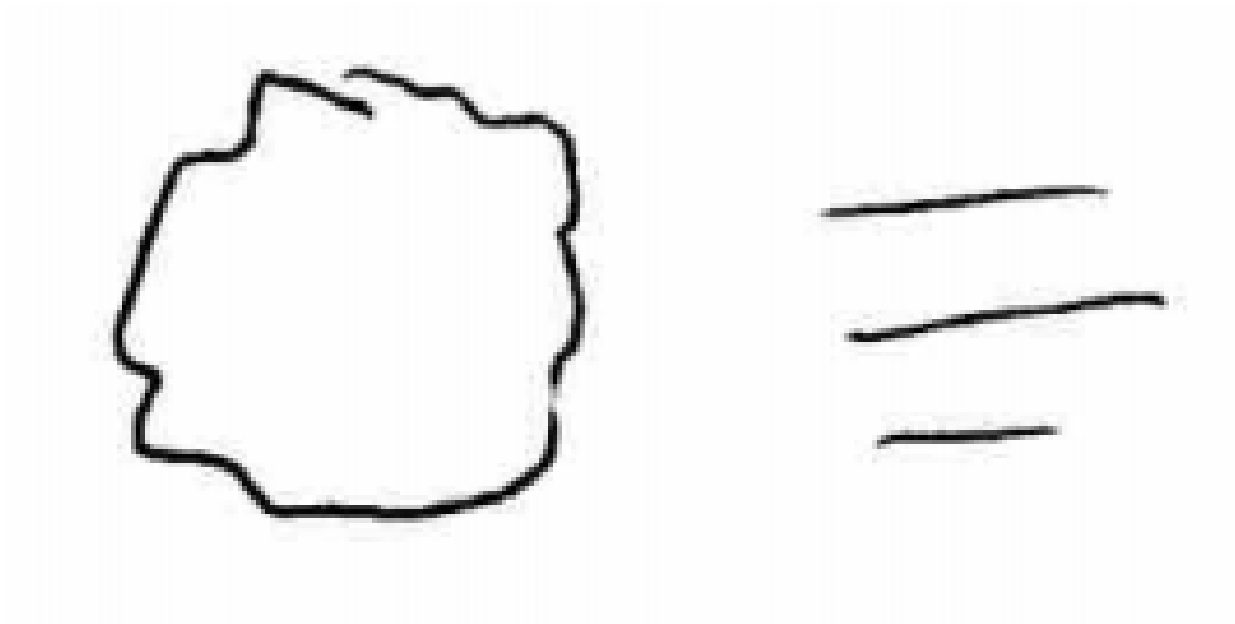
Paper airplane travelling in air

- Note the absence of force from thrust
- In here, the plane is falling because it doesn't have enough speed to generate lift.



- What happens if we throw this plane again, but faster?

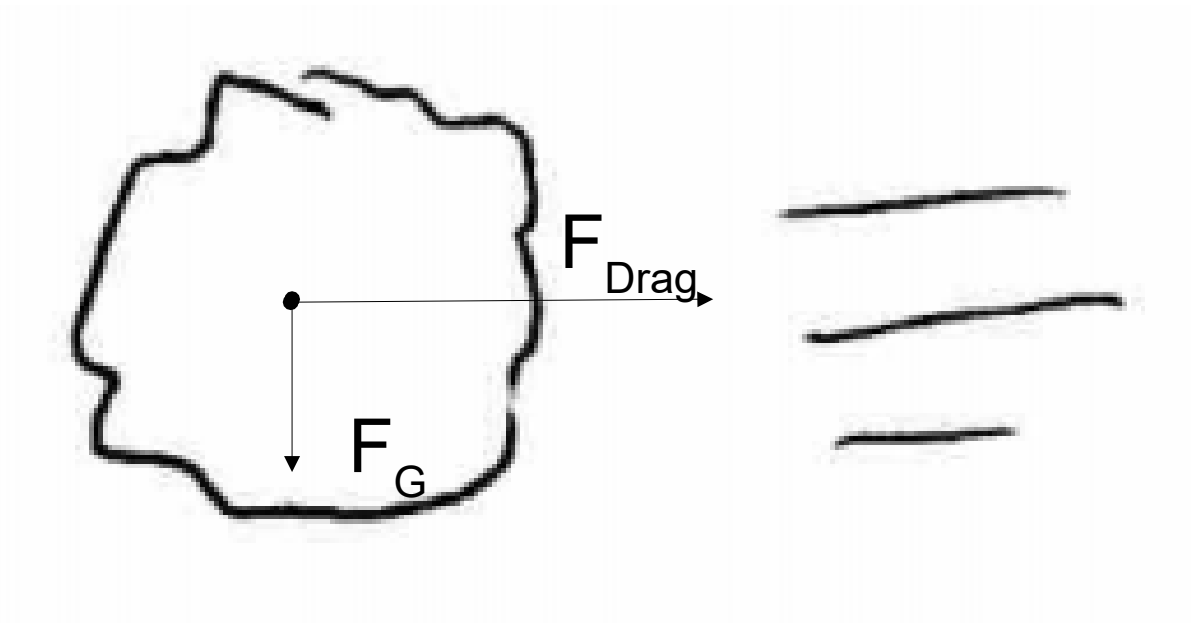
Crumpled paper ball?



In-class activity

Crumpled paper ball?

- Paper ball has little to no lift, so there is no F_{Lift} for the ball; lots of drag however

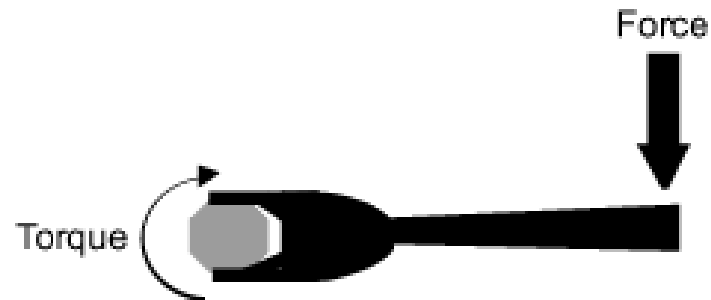


What is FBD's useful for?

- Free Body Diagrams are good for intuition, but they also have their limitations
 - Mostly useful on showing net forces, and representing objects that don't rotate too much
- Torque can fill in more details on a plane's trajectory

What is torque?

- A force that is not applied directly on the center of mass, will result in torque
 - Torque makes an object turn faster in one direction (clockwise/counterclockwise)!

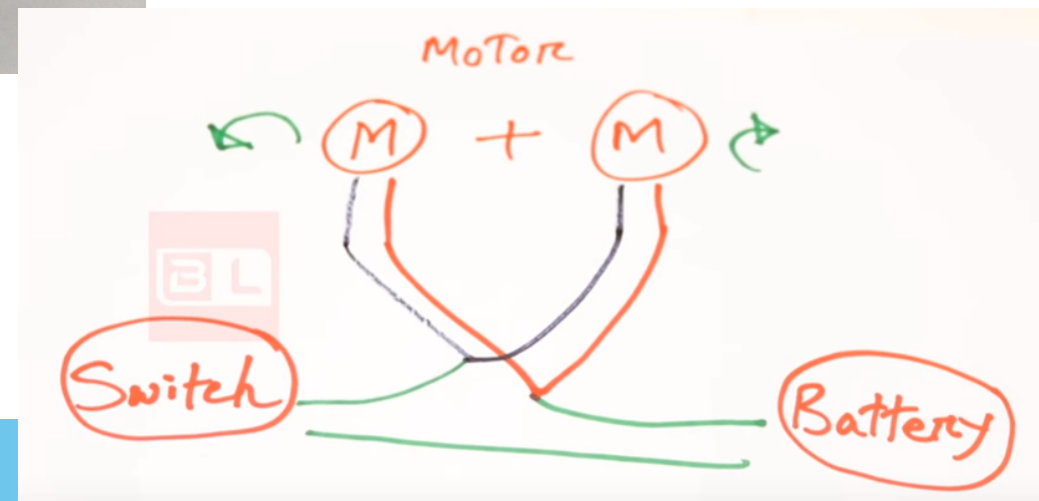
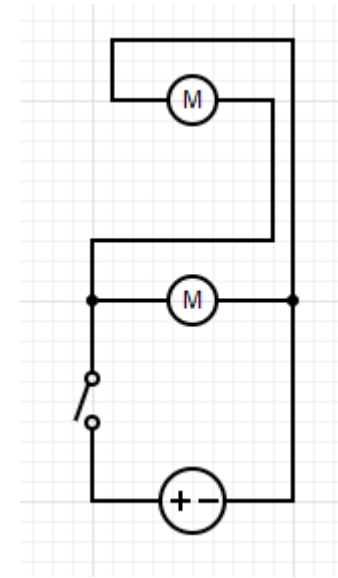
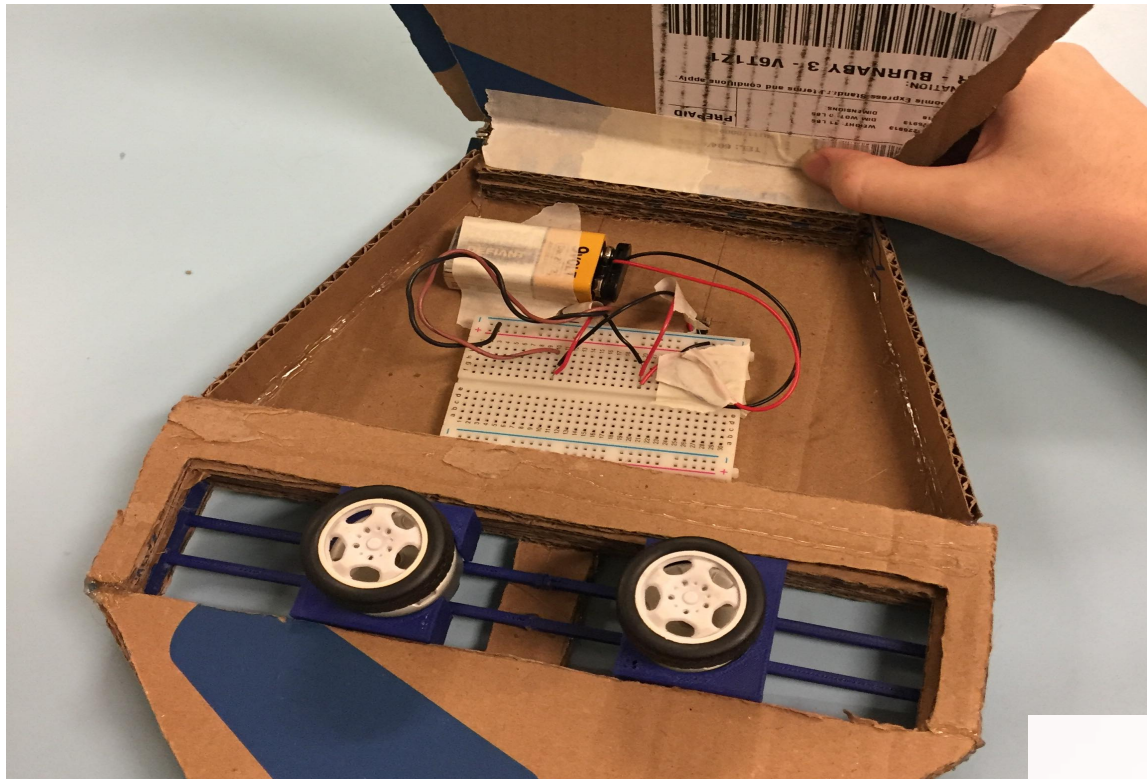


Questions so far?



Video and analysis

Apparatus!

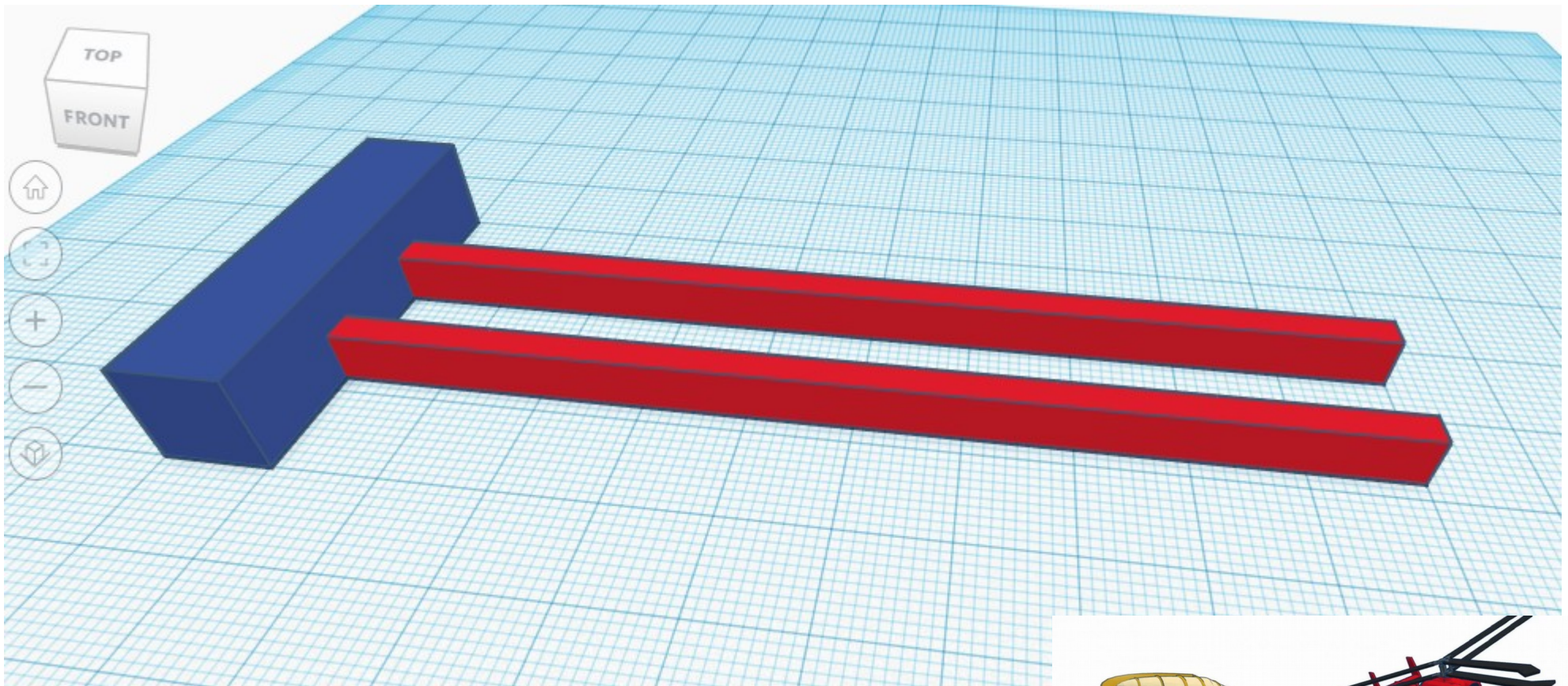


Inspiration

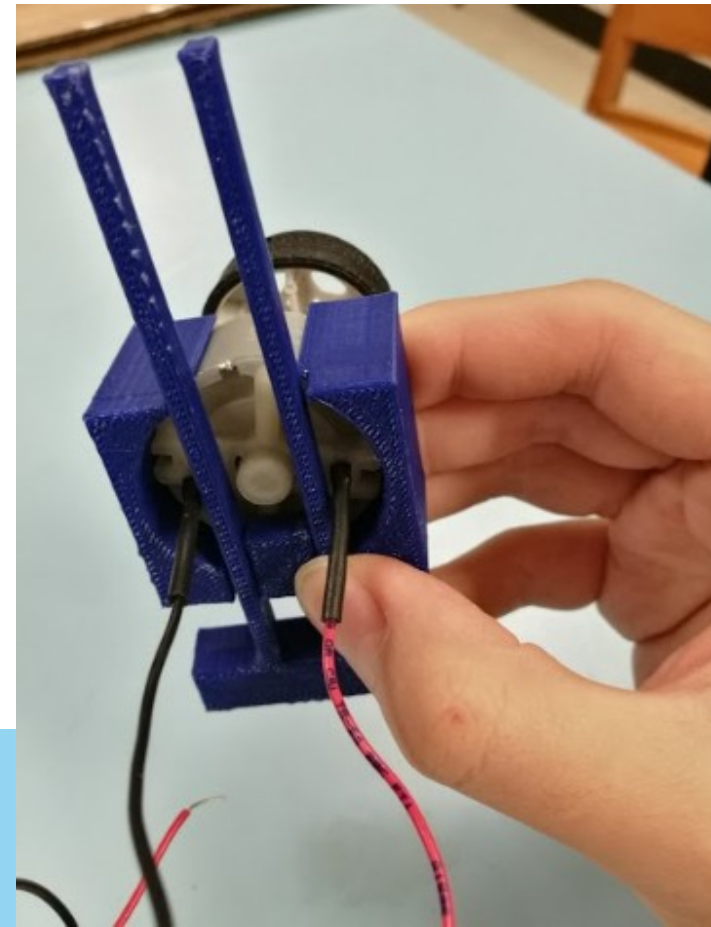
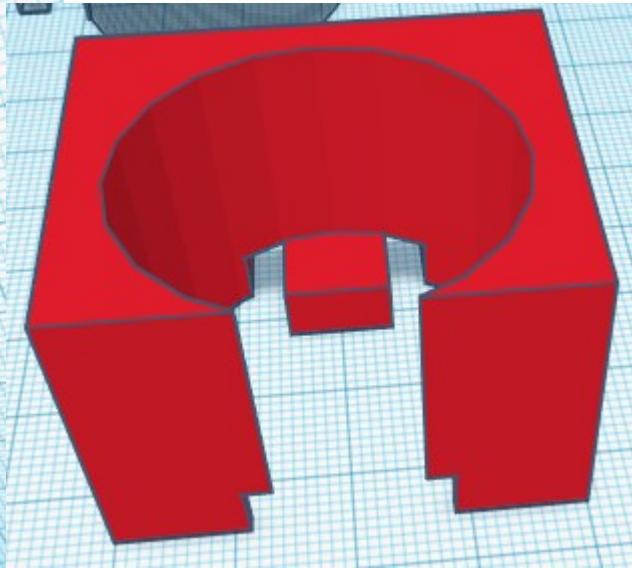
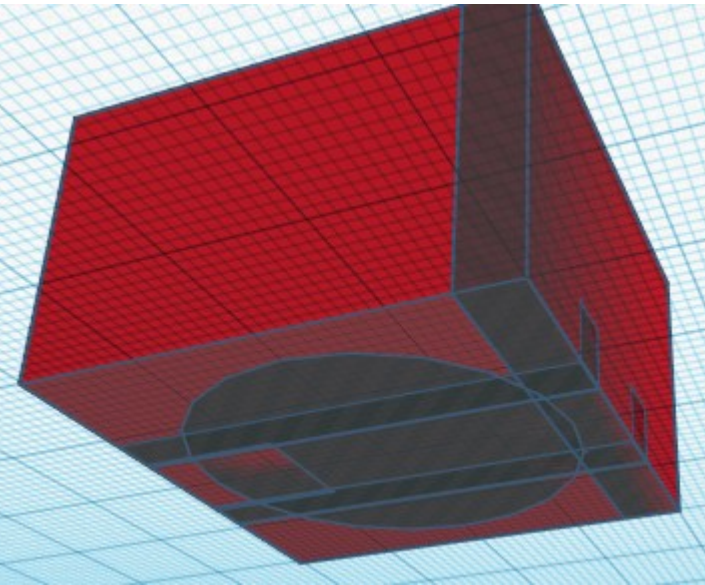
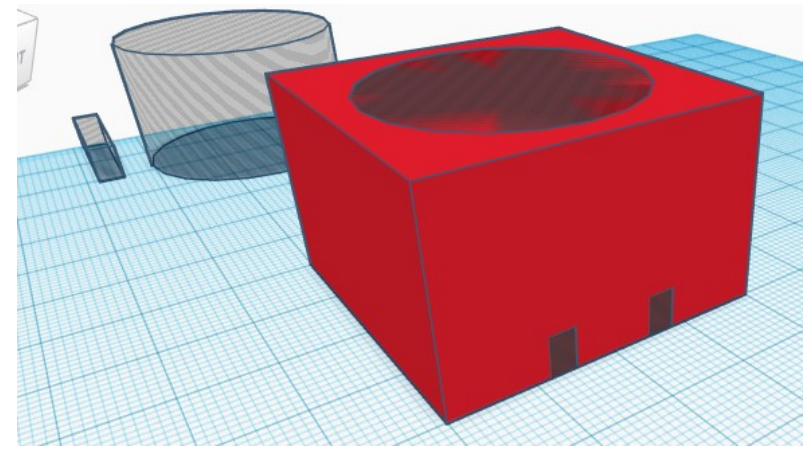
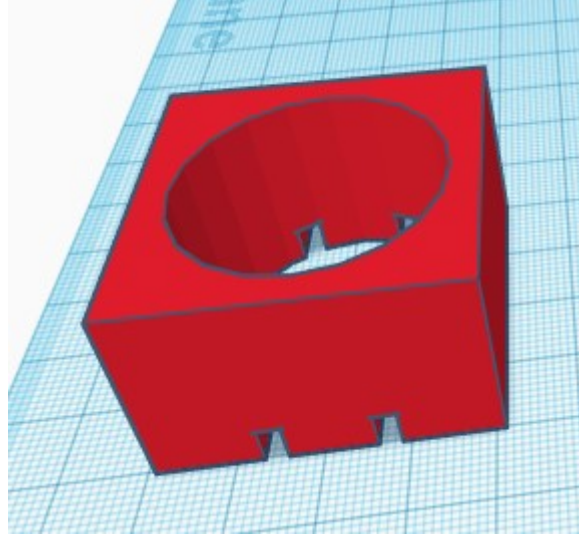
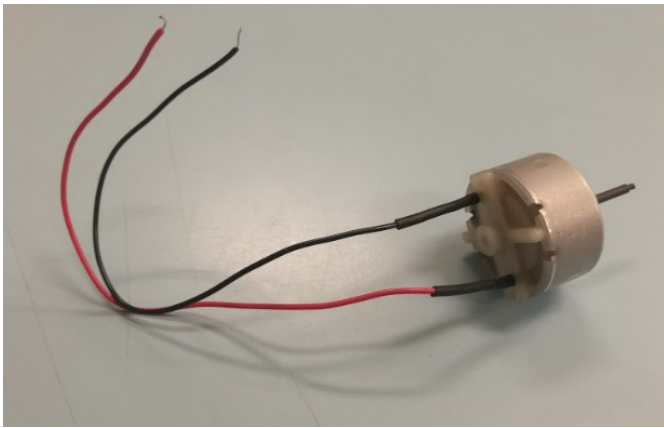


FYI: <https://www.youtube.com/watch?v=kYITs3JG1eE>

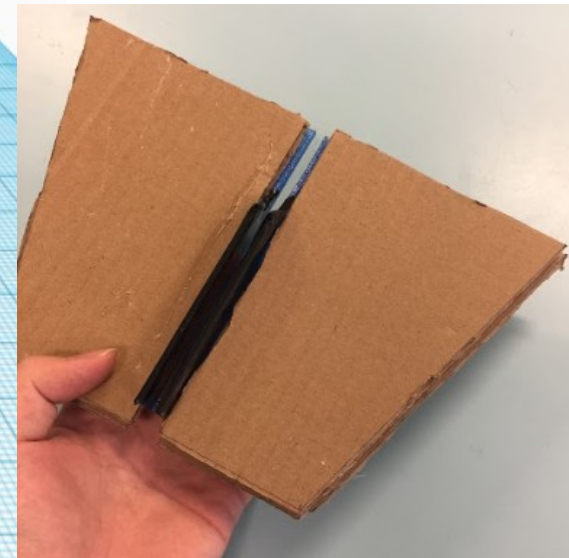
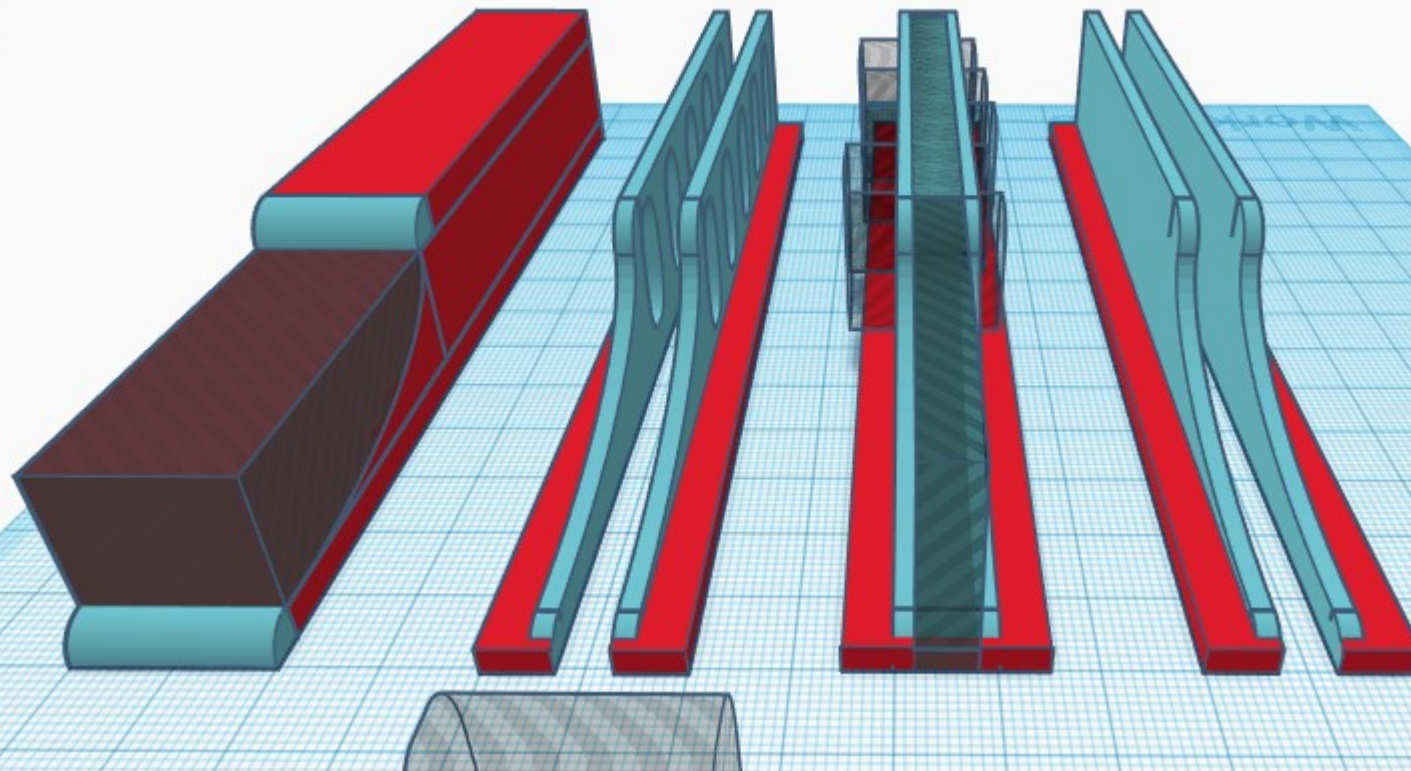
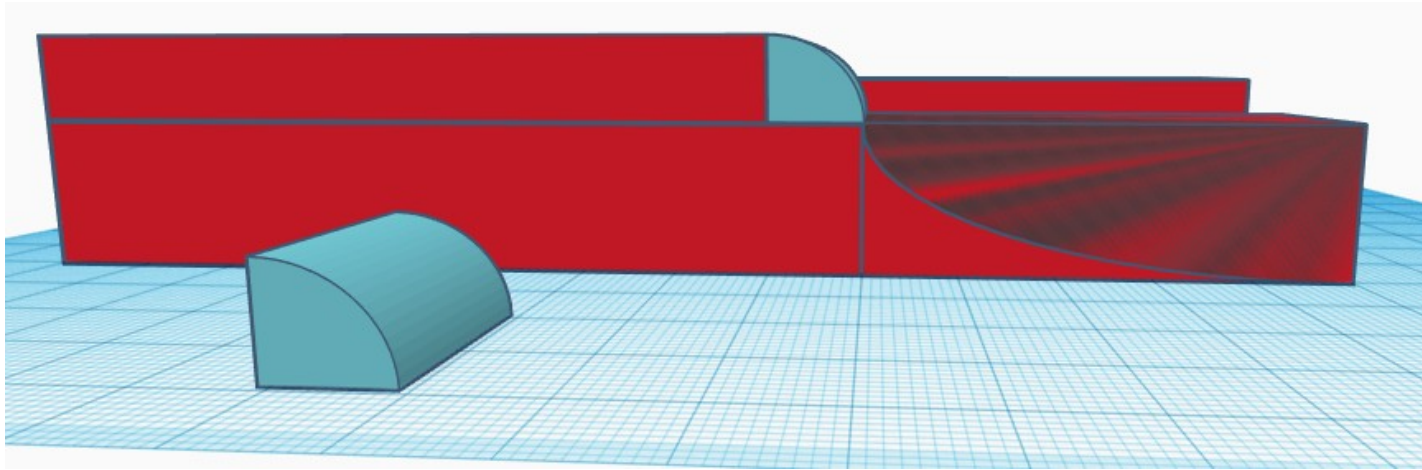
Design of motor rails



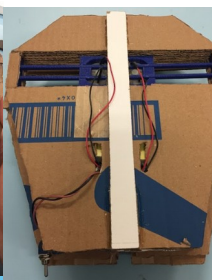
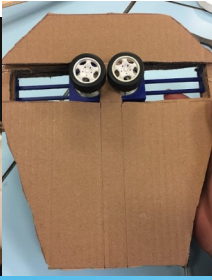
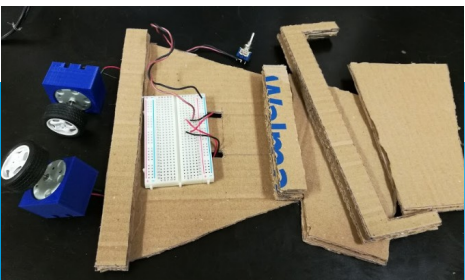
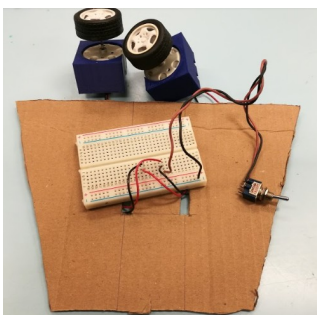
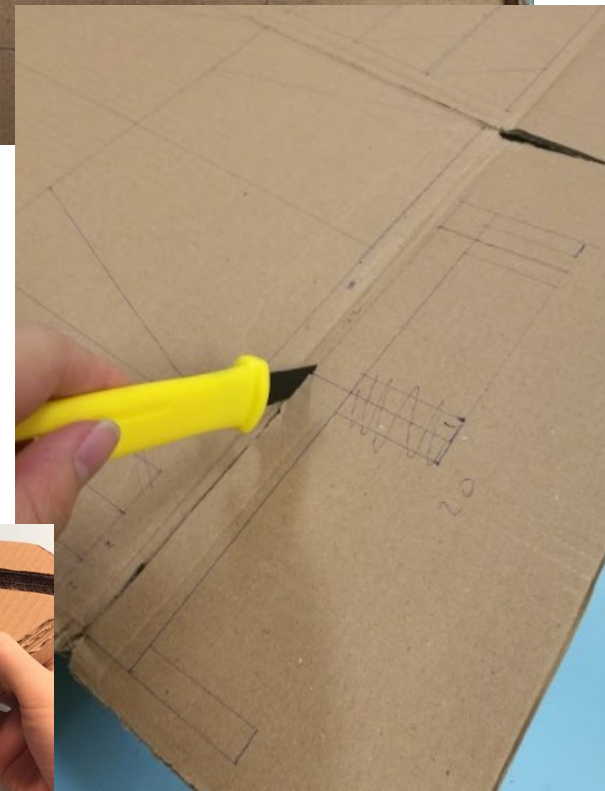
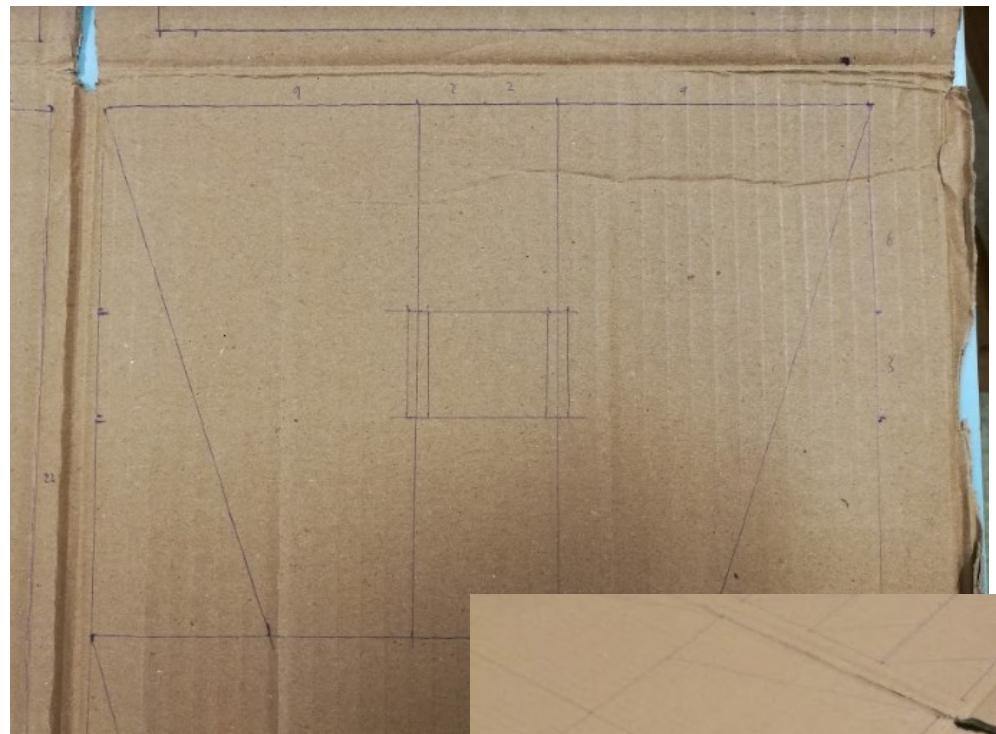
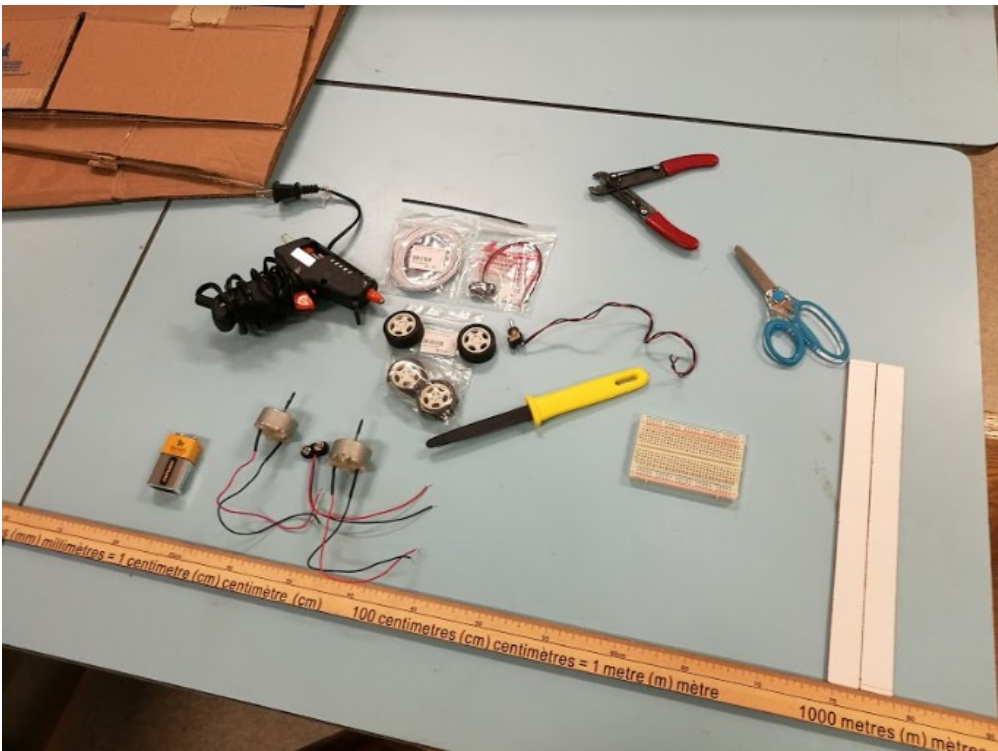
Figuring out the motor's housing



Creating the airplane guiding rails



Creating the rest of the project



Let's make some planes!

References

- <https://www.khanacademy.org/science/ap-physics-1/ap-forces-newtons-laws/introduction-to-forces-and-free-body-diagrams-ap/v/types-of-forces-and-free-body-diagrams>
- <https://www.physicsclassroom.com/class/newtlaws/Lesson-2/The-Meaning-of-Force>
- <http://www.aviation-history.com/theory/force.htm>
- https://wiki.mattrude.com/images/4/44/Bernoulli_Newton_Lift.pdf
- <https://www.youtube.com/watch?v=kYITs3JG1eE>
- https://www.teachengineering.org/lessons/view/cub_airplanes_lesson06

Further Reading

- Below are some links that might interest those who enjoy flying paper airplanes:
- Walkalong gliders! Quite fascinating to see
 - <https://sites.google.com/site/controllableslopesoaring/>
 - https://www.instructables.com/id/Paper_Airplane_Walkalong_Glider/
 - <https://sciencetoymaker.org/airsurf/make-your-own-gliders/>
- More airplane designs: <https://www.foldnfly.com/index.html#/1-1-1-1-1-1-1-1-2>
- And some more: <http://web.mit.edu/swe/www/PaperAirplanes.pdf>
- Learn from NASA: <https://www.grc.nasa.gov/www/k-12/airplane/guided.htm>
- Veritaseum talks about lift (Bernouilli vs Newton):
<https://www.youtube.com/watch?v=aFO4PBolwFg>

Bonus Slide

Isaac Newton: *slaps roof of car*

Car: *slaps Isaac Newton*

