Building Things in Physics Classes

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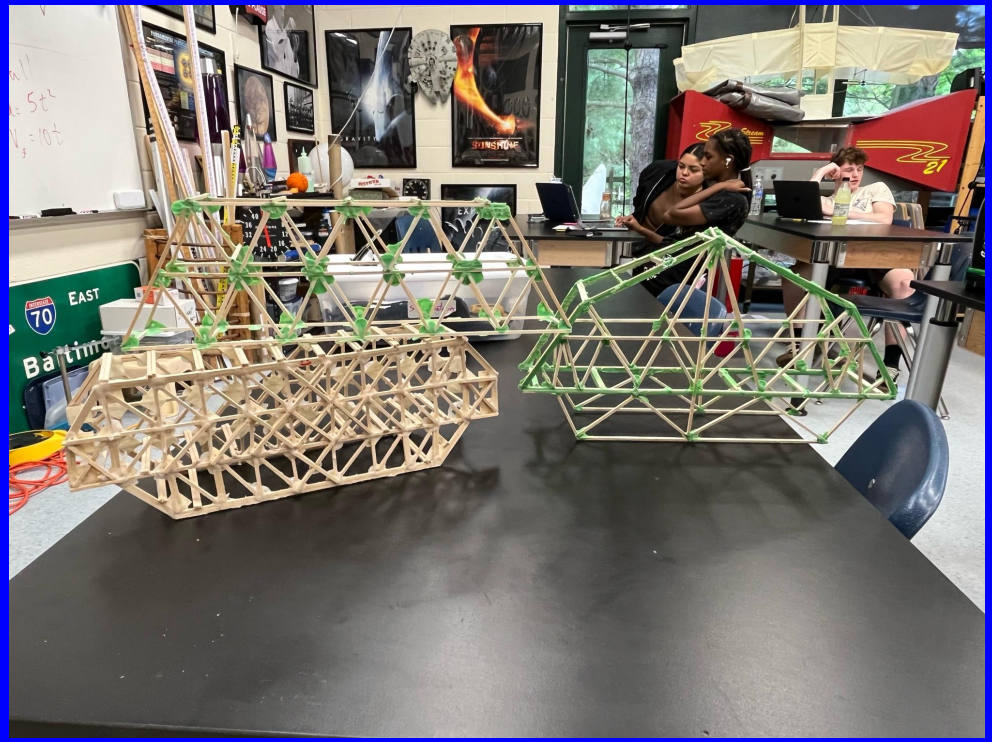
Building?

You might be surprised (and perhaps a little dismayed) to learn how few of your students have actually built things with their own hands. Physics teachers have a unique opportunity to allow students to build their own lab devices.

I will also discuss some things that you can build with your students.



Why?

When students build things, I have found that students usually take ownership of their learning and better understand how things work.

In this talk (a brief version of a workshop I offer), I will describe several of the things I build or have students build (toy cars, mobiles, motors, microphones, speakers, musical instruments, etc.)

Ideally, I will give you some ideas for play!

Some general philosophy

I teach very differently from the way I taught for years. Upon starting my teaching career, I only had university professors as models - and as it happens, they weren't very good models. I hope I have figured out better strategies by now.

I have taught in public and private schools, public and private universities and colleges. I have taught gifted and talented kids, and kids with severe learning differences. I have had many rich students, and many more of very humble backgrounds. All of them want and need good teaching.

Most recently, I have been teaching students with dyslexia and related learning issues (most of whom are considered to "twice or thrice exceptional").

Some general philosophy

II always try to remember: I am teaching students, first and foremost, not physics. Of course, you want them to understand physics - but you must remember what it is like to be a (confused, at times) kid.

This may be the first and last time your students ever take a physics class. I think it is critical to capture their attention and imagination.

Recommended tools and material to have on hand

- Small drill
- Hand saws
- Table vice (that clamps onto a lab desk)
- Dremel
- Sandpaper
- Wire strippers / cutters
- Needle nose pliers
- Screwdrivers (including a jeweler’s set)
- Hex wrench, SAE and metric
- Hammer
- Staple gun

Recommended tools and material to have on hand

- Meter tapes
- Level
- Ramp protractors
- String
- Hobby knives
- Scissors
- Adjustable wrench

The ever-popular tackle box

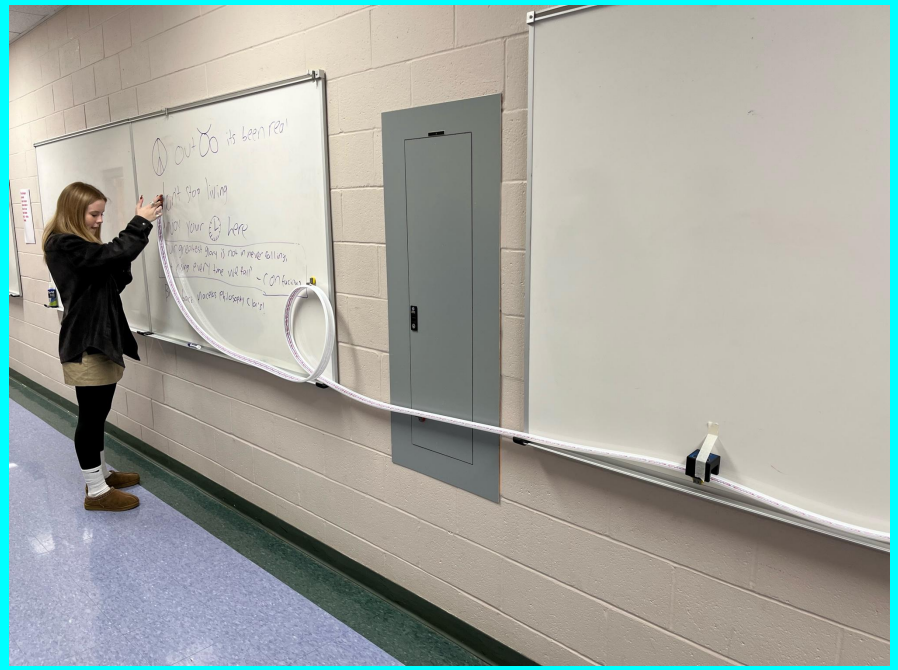
The ever-popular tackle box

- A variety of wire spools: enameled, vinyl coated
- Wire stripper/cutter
- Soldering iron, solder
- Jewelers screwdrivers
- Electrical tape
- Grounded electrical plug adapter
- Universal adapter
- USB cables with different ends
- Measuring tapes

Take-home Physics Kits

- String
- Weights (fishing weights, washers)
- Ruler
- Measuring tape (with inches side X’d)
- Protractor
- Binder clip
- Pencil
- Bulbs, wire, sockets, multimeter, batteries, enameled wire, magnet
- Marbles, Hot Wheels cars, balls?

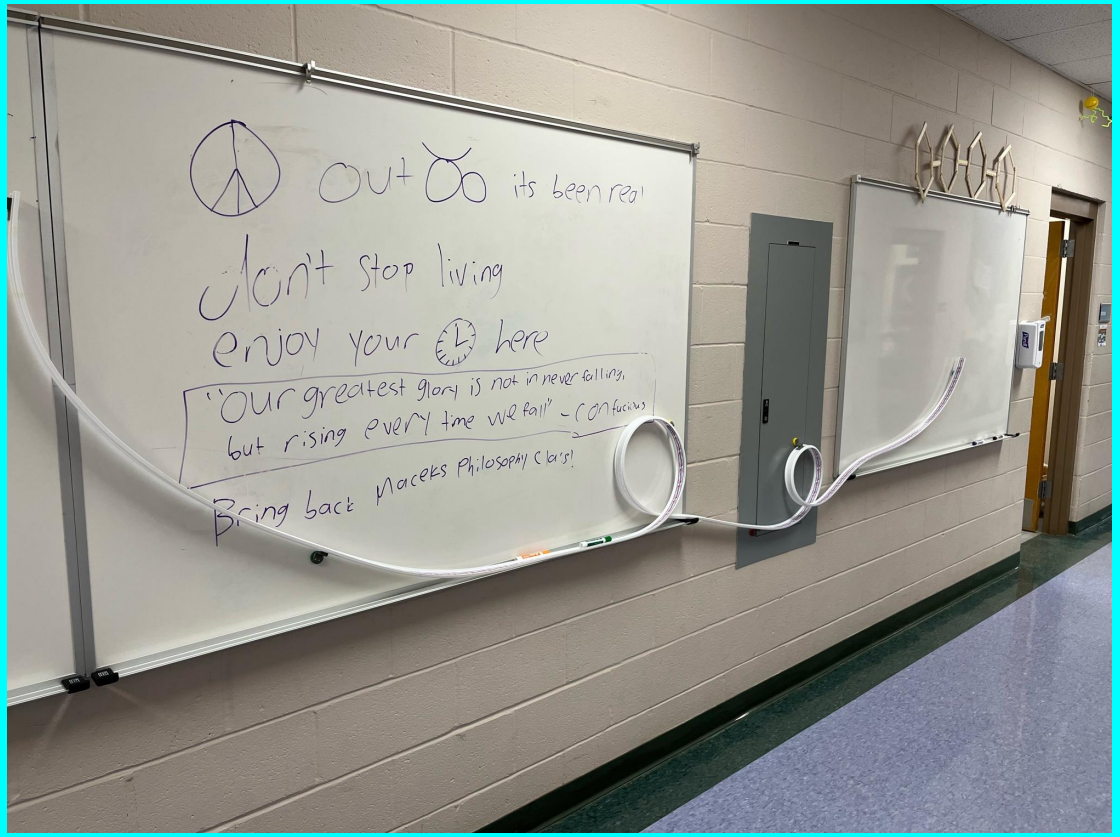
Hot Wheels



https://www.thingiverse.com/thing:3029194

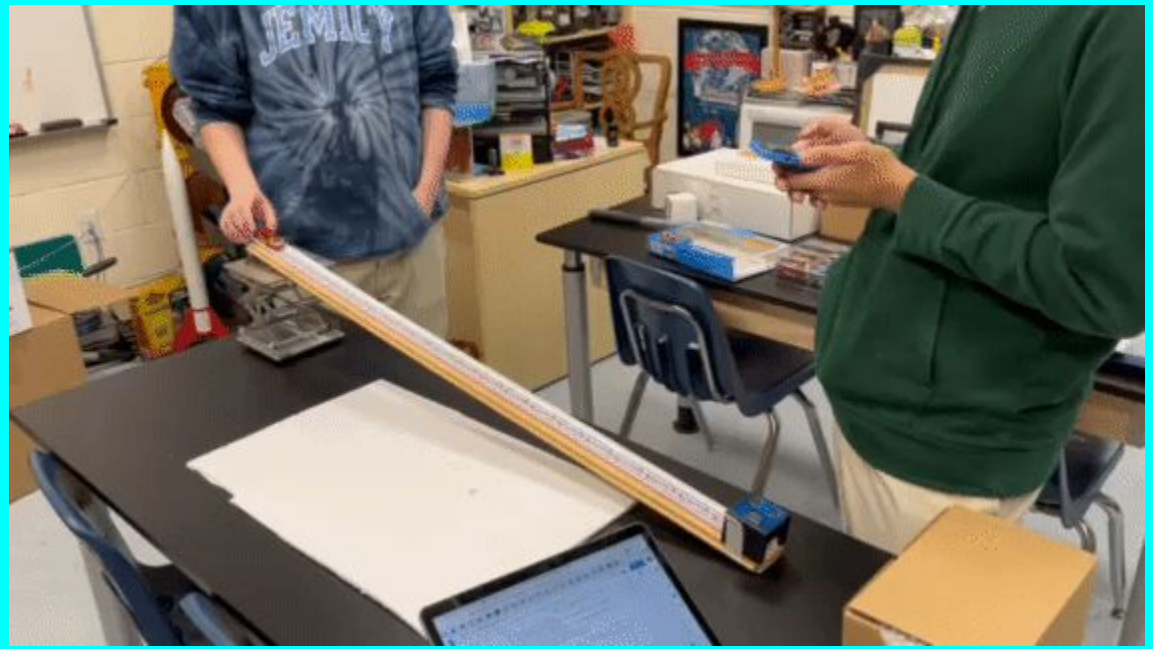
3D printed track clips superglued to Home Depot rubberized magnets (white board safe).

Hot Wheels



Rolls of HW track (50-100 feet) can usually be found online. Individual 2 ft tracks can be found at dollar stores.

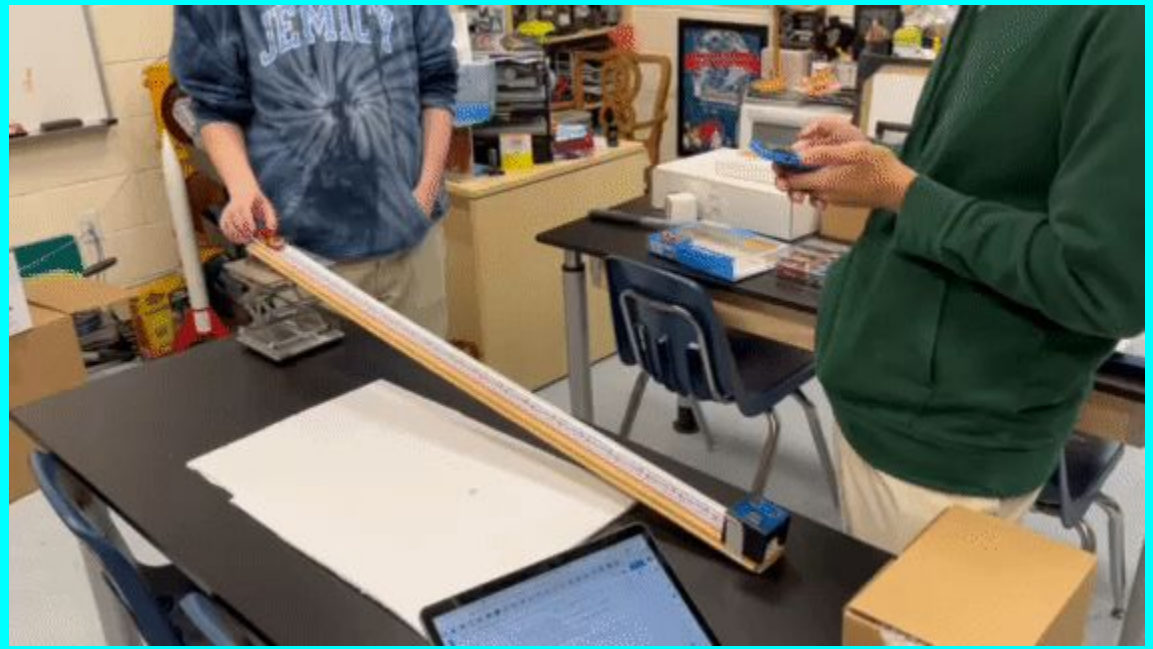
Hot Wheels



Old HW track stapled to 1x2 boards.

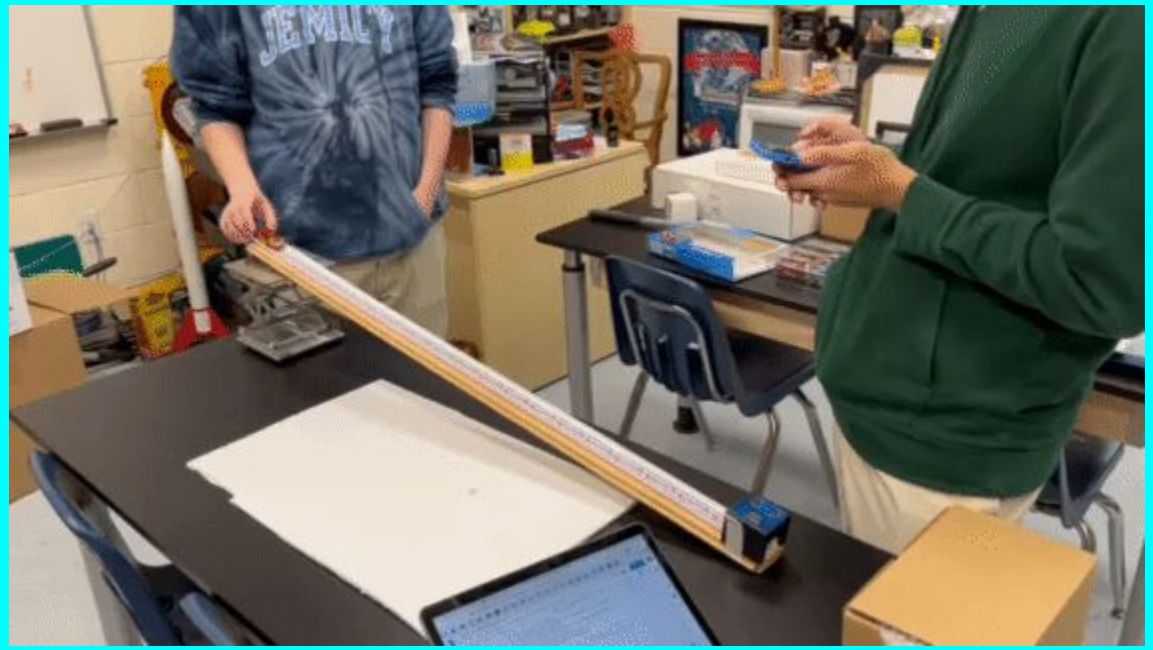
Photogates are HW size (Arbor Scientific, etc)

Hot Wheels



Cheap lab jacks are available on Ebay or Amazon (2x4 chunks also work.)

Hot Wheels



It is also worthwhile to take phone videos and use video analysis software.

Center of Mass

Coat hanger wire and tennis balls

Balls of clay also work well.

Basswood bridges

Design online first, then build. Materials from Pittco.

https://ei.jhu.edu/truss-simulator/

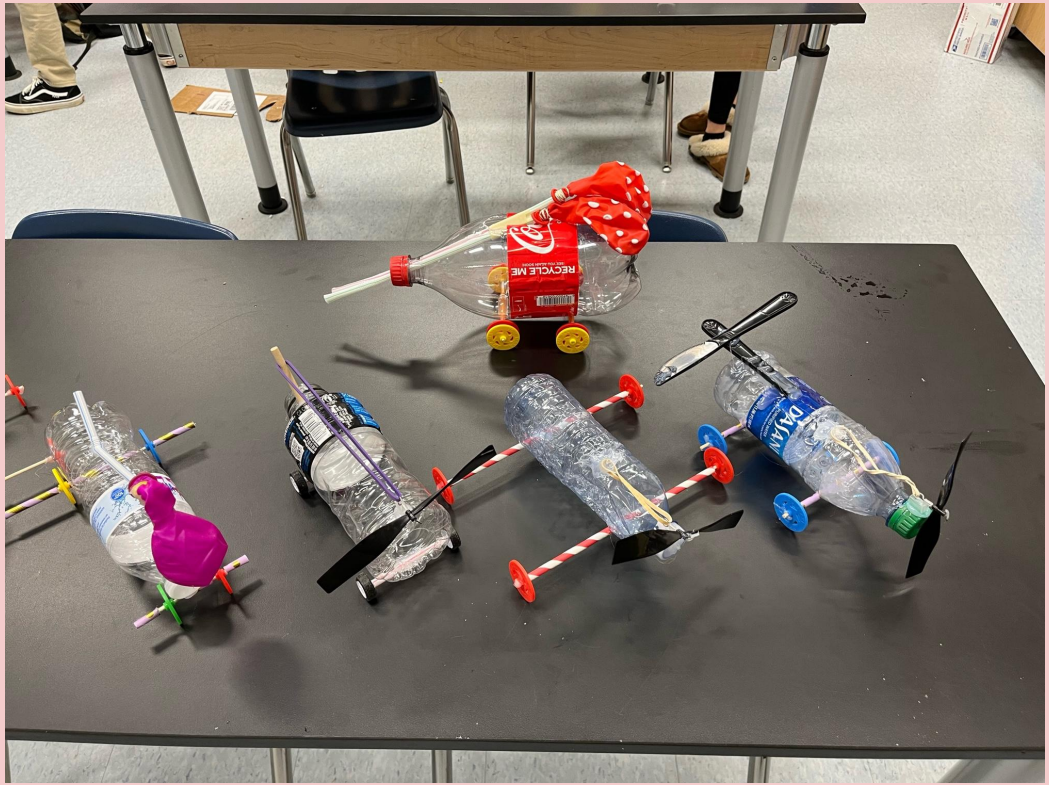
- 30 cm separation
- Max weight requirement
- Gusset plates (cardstock)?
- White glue, build on wax paper
- Small block of wood
- Screw eye
- Chain and weight holder
- 1kg masses

Mobiles

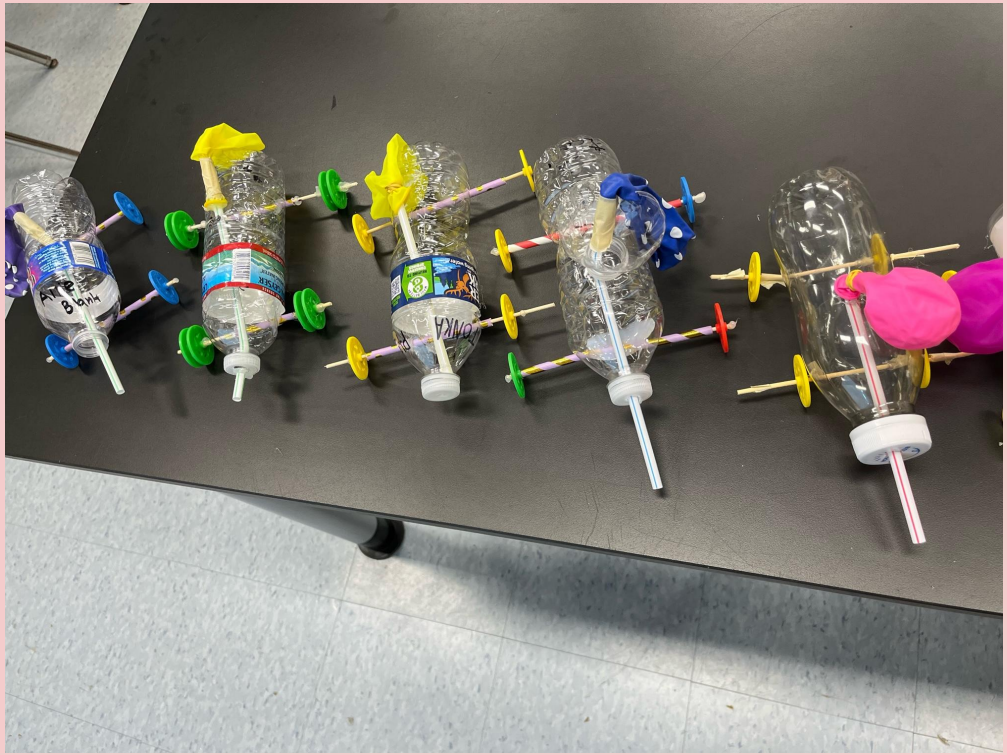
Project must:

- Be balanced
- Have torque/moment calcs
- Say something about you
- Dowel rods are provided

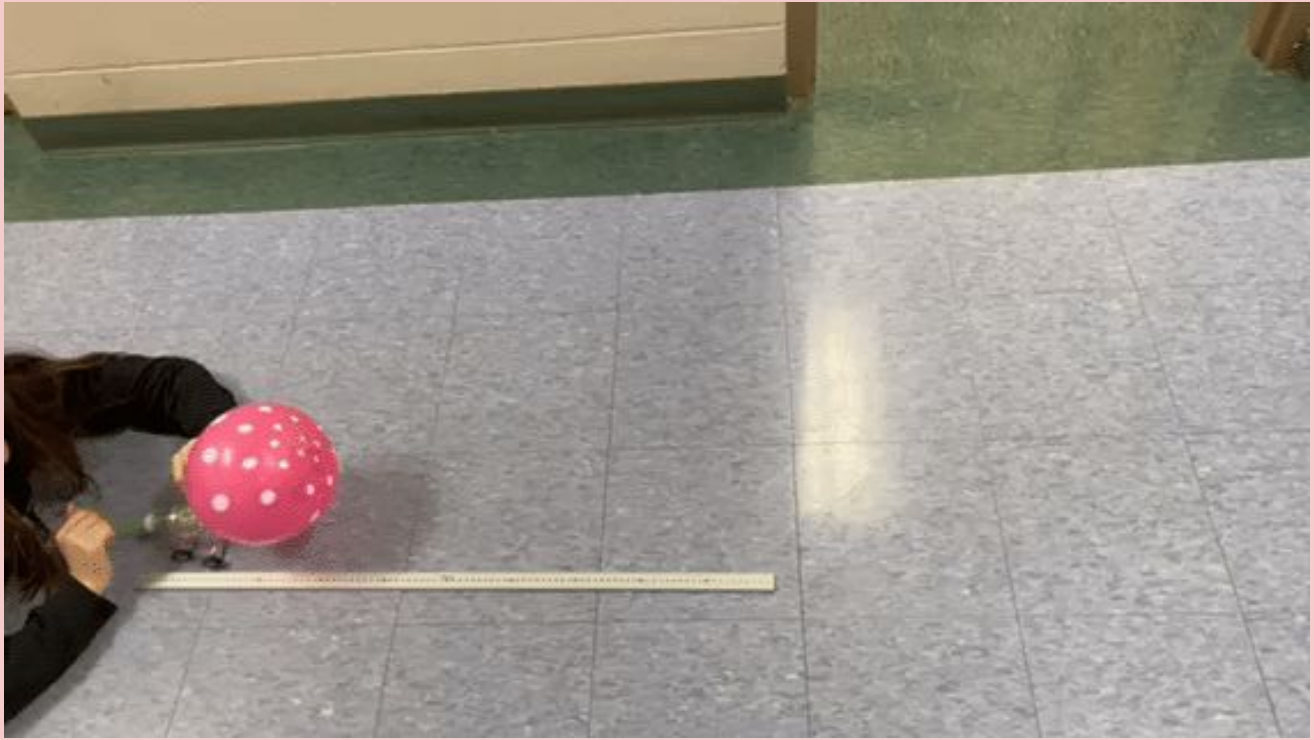
Car project



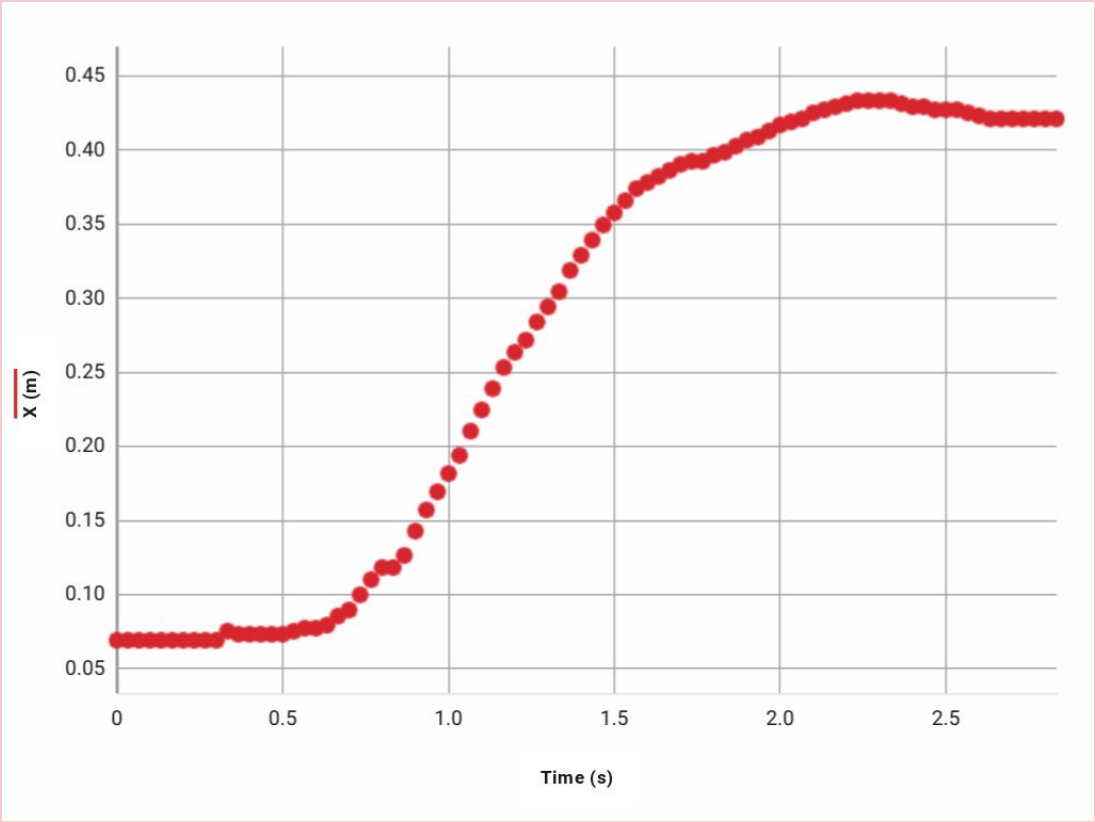
Car project



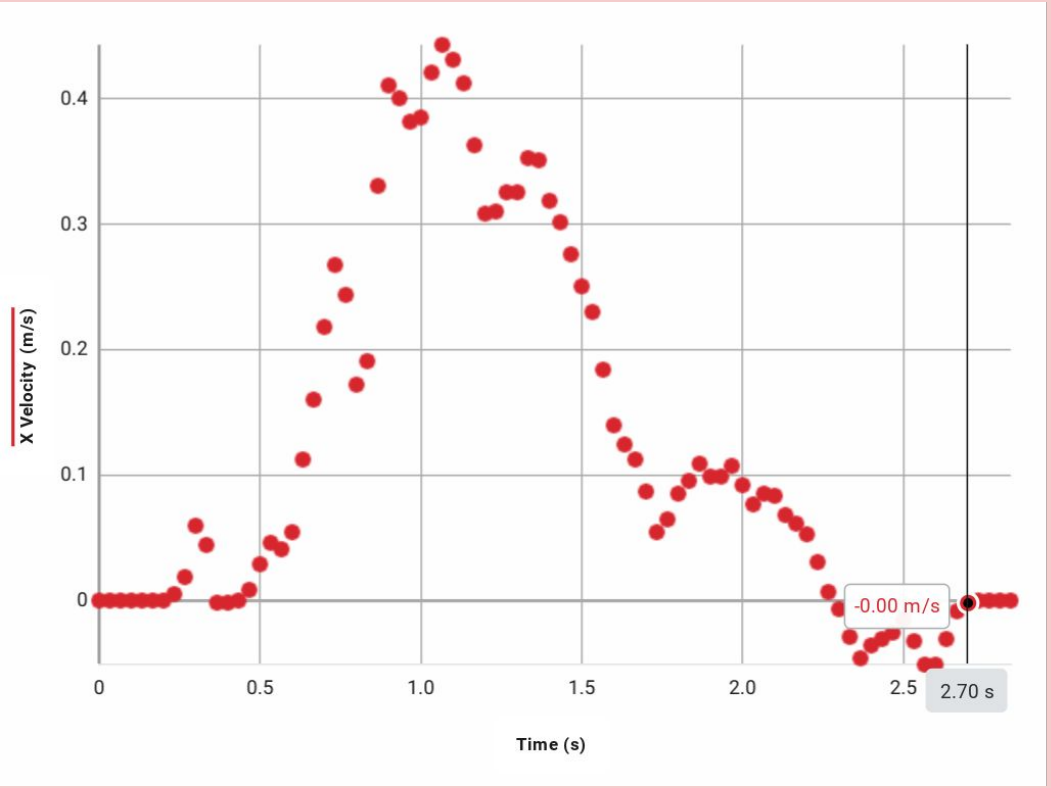
Car project

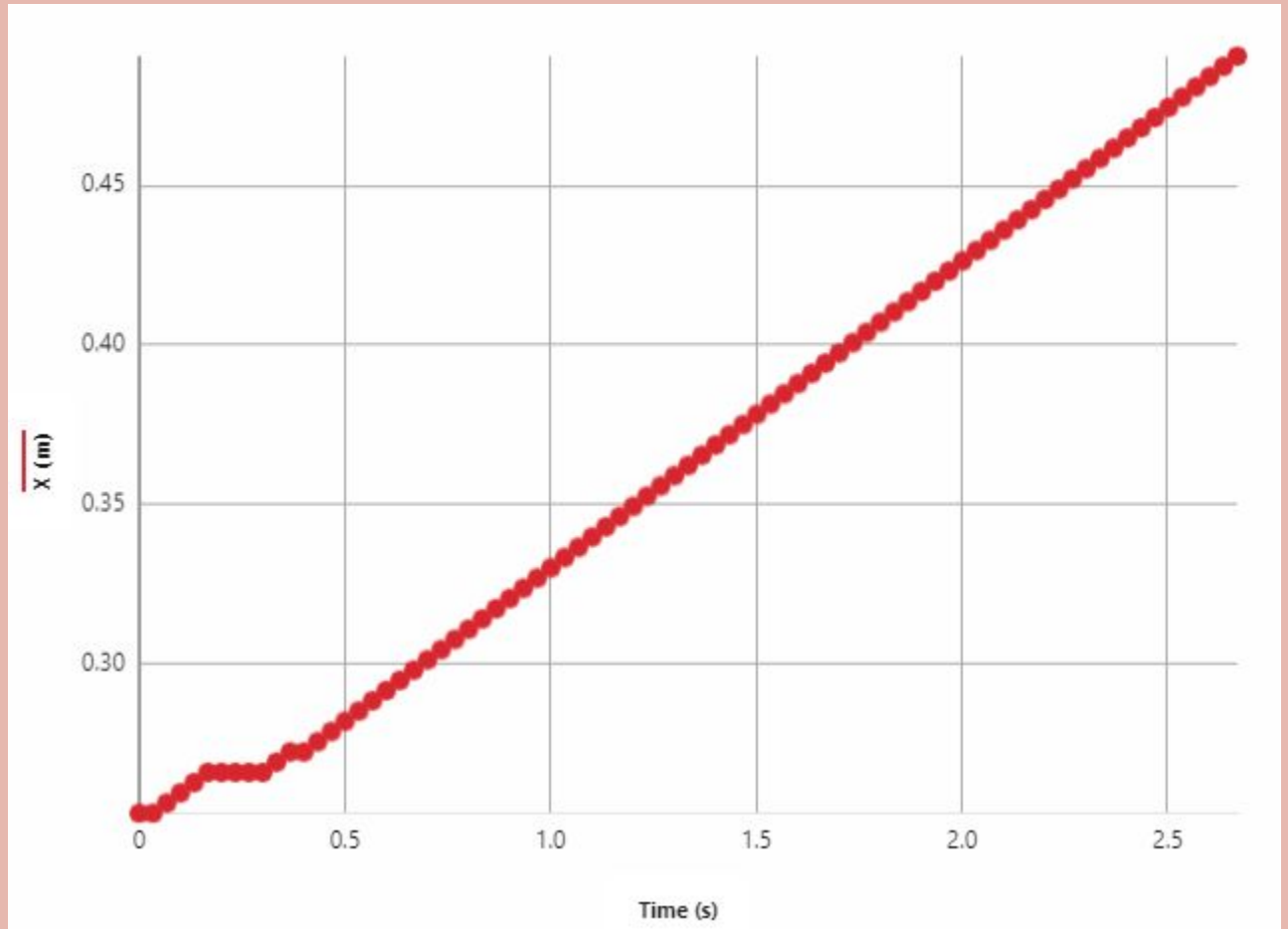


Car project



Car project




0.45
0.40
0.35
0.30
X (m)
0
0.5
1.0
1.5
2.0
2.5
Time (s)

3D printed rocket parts

For less than purchase price, students can design and print their own model rocket parts. Purchase body tubes and engine mounts in bulk, and build flying model rockets on the cheap.

Don’t have a 3d printer? Make friends with your tech department and/or parents in the community.

Rocket project

Determine (predicted) initial velocity, altitude, drag coefficient (with wind tunnel)

Use onboard electronics (Altimeter 2 from Jolly Logic) to get actual data:

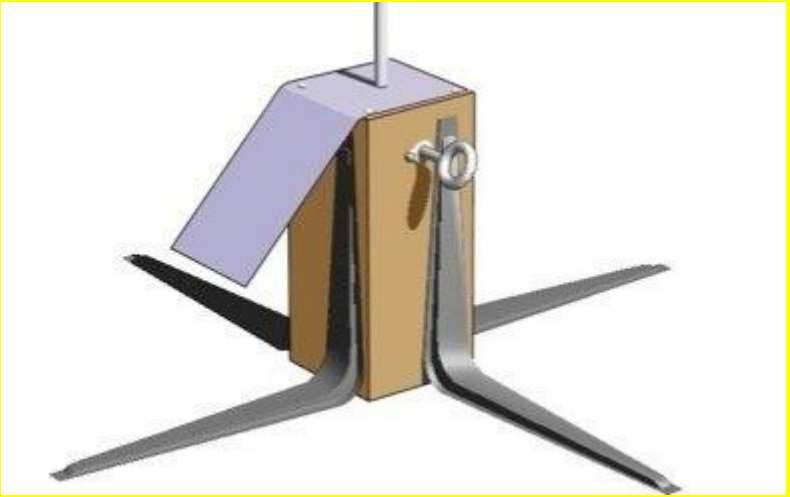
https://jollylogic.com/products/altimetertwo/

Rocket launch pad with 4x4 post piece

Shelf brackets (x 4)

Galvanized steel for blast deflection

Post hole drilled for launch rod



Credit:

http://www.raydunakin.com/Site/Launch_Pad.html

Rocket launch pad with 4x4 post piece

Or something more ambitious, like this launch pad from Rocketry Words. It is a relatively simple thing to construct from PVC.

https://www.rocketryworks.com/cape-canaveral-6-pad-launch-pad/

Projectile launcher project

- Must provide repeatable results
- Determine the initial velocity
- Catapult, trebuchet, ballista, etc.

Kites

A lift expression exists for kites:

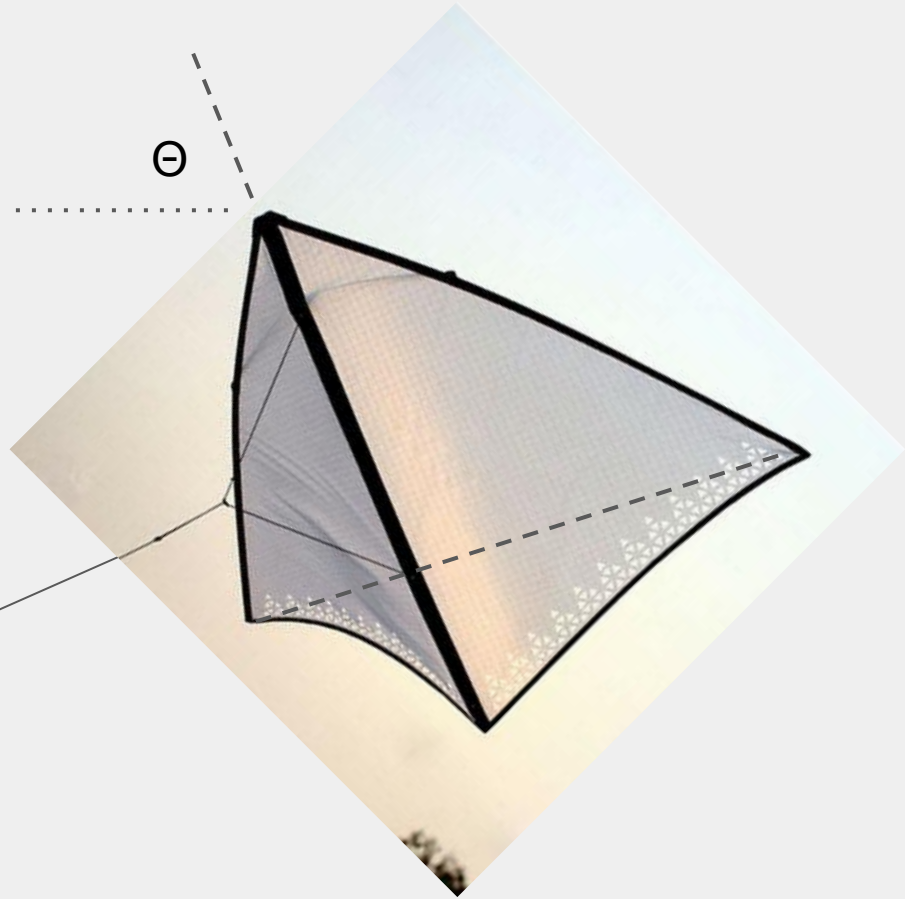
(Delta kite is shown)

$$L = \tfrac{1}{2} C_l A \rho v^2$$

Θ is angle of attack (in radians)

Span = length across (dotted line)

Aspect Ratio (AR) = $span^2$ / Area



Kites

To compute lift coefficient, we use 2 factors:

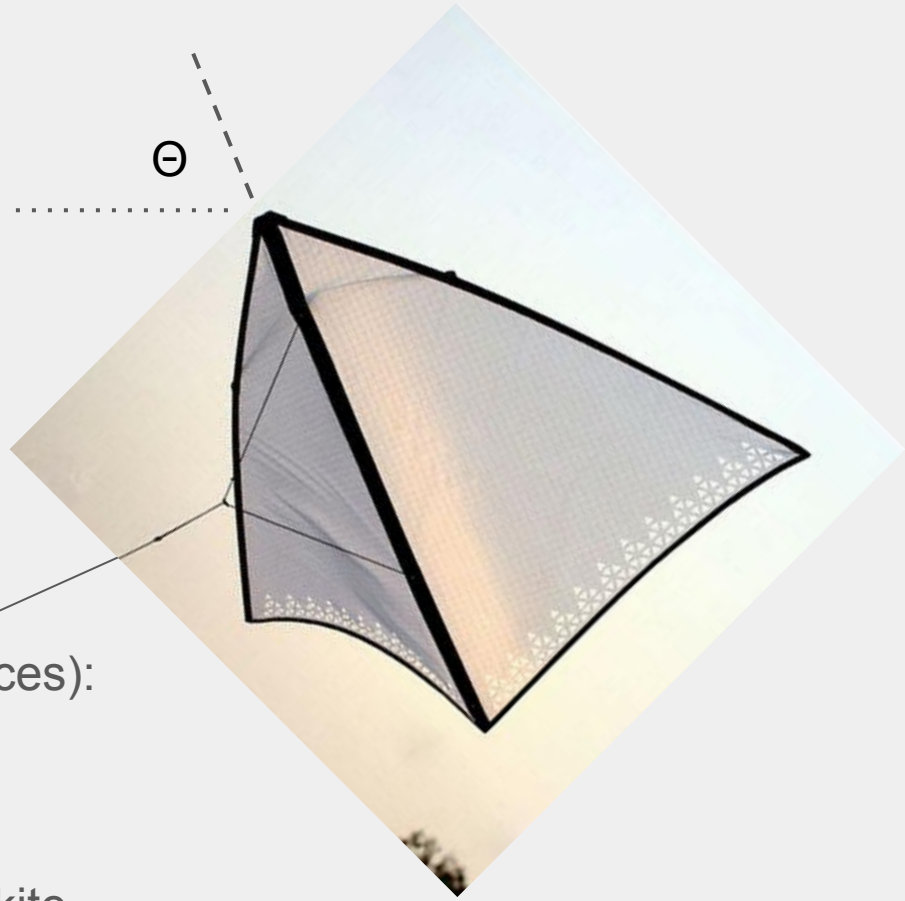
Shape / inclination effect:

$C_{lo} = 2 \pi \Theta$

Downwash effects (due to pressure differences):

$C_l = C_{lo} / [1 + C_{lo} / (\pi AR)]$

This yields a “corrected” lift coefficient for a kite.



Kites

A small assortment of kite design help here:

https://www.kiteplans.org/

https://www.my-best-kite.com/how-to-make-a-kite.html

http://www.kitebuilder.com/plans.html

https://www.sciencefriday.com/wp-content/uploads/2017/02/Susans-Delta-Kite-Building-Instructions.pdf

I recommend Delta kites for your first build and/or flight. Also, don't fly during a thunderstorm…..

Kites

Materials

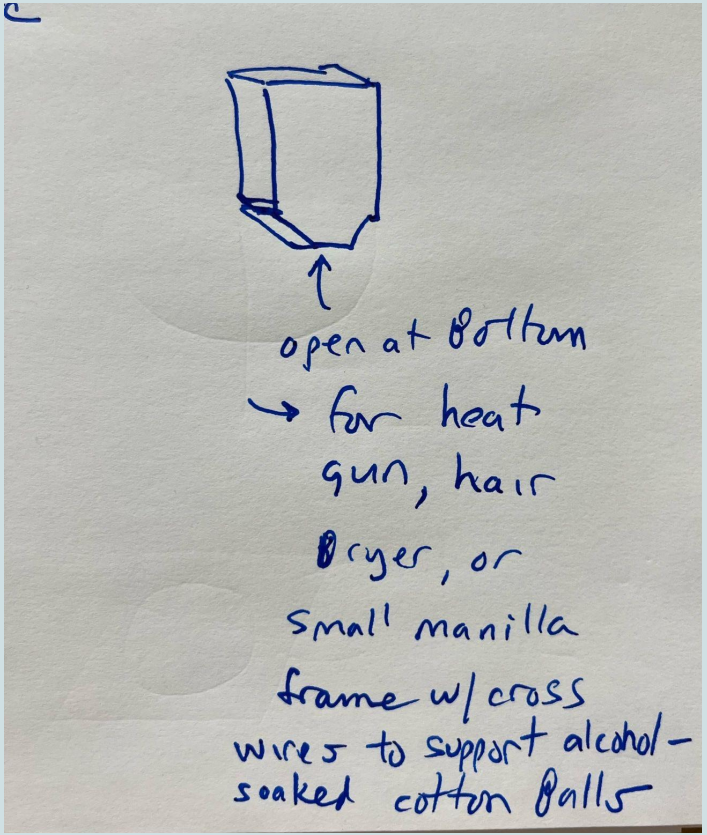
Dowels work well for support spars: ⅛” or so.
Straws and skewers can also work.

For fabric, rip-stop nylon works best, as it is internally ribbed. However, you can have success with garbage bag plastic, plastic sheeting, cut up Ikea bags, newspaper, etc.

You should build your kite and video or photograph a successful flight for analysis later.

Happy flying!

Hot air balloons (tissue)



Hot air balloons (tissue)

Search for many different gore templates

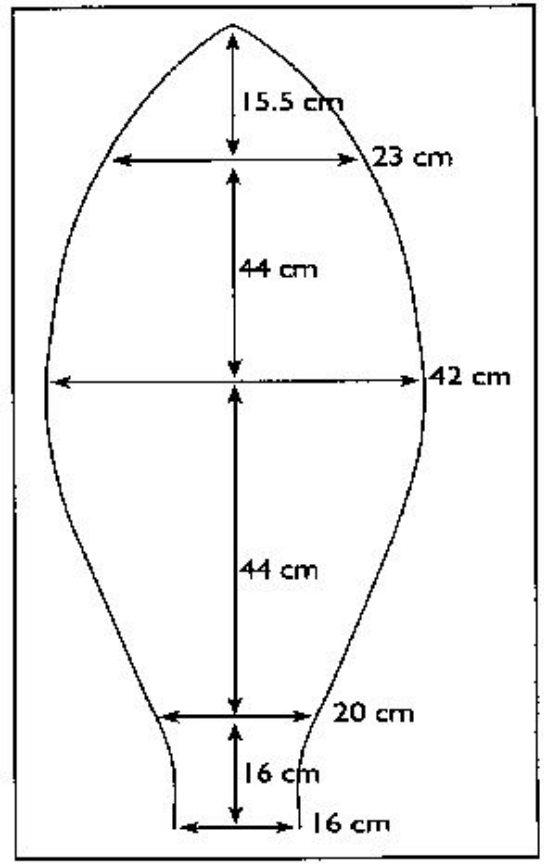


Figure 1

Kite calculations

Determine the following for your kite:

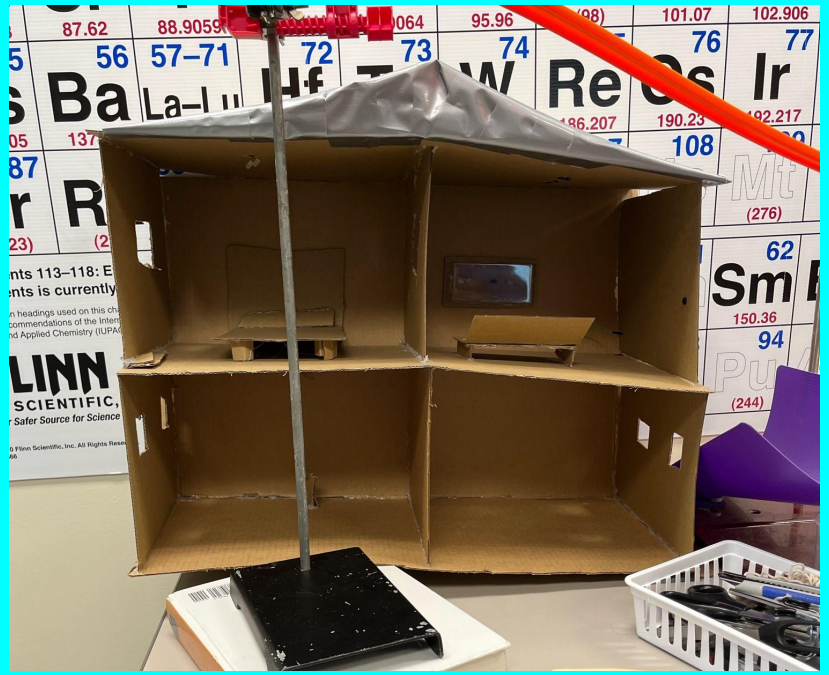
1. Area (in m^2)
2. Span (in m)
3. Aspect Ratio, AR
4. Approximate angle of flight (convert to rads)
5. Shape / inclination effect
6. Downwash effects
7. Weight (which equals lift, L)
8. Approximate angle of flight (in rads)
9. Minimum speed to fly (in m/s)

Wired house project

The cheapest option is to butcher holiday lights (which are typically around 3 to 6-V each).

Provide each student with a battery holder, lights, and wire. They can create their own simple switches for each room. You can also require at least one series and one parallel circuit.

Students must also provide schematic.



Cheapo series and parallel boards

Butcher some cheap holiday lights - typically around 6-V or so.

Add alligator clips as desired.

Other ideas….

Electrostatics: electroscope, electrophorus, capacitor

Circuits: simple circuit boards, blinking circuits (555), wired house project

Magnetism: world's simplest motor, speaker, microphone, guitar pickup, telegraph

Waves/Sound: wind chimes, pipes of Pan, wave machine, musical instruments

Misc: Arduino, CPX, observatory, Dobsonian telescope

Optics: pinhole camera, sound triggered photo

Ambitious: Kinetic Sculpture Race (Baltimore), go-cart (with donated engine)

Some more ideas…

- Holograms (Litiholo)
- Acoustic levitation
- 3D photos
- Radio telescope
- Manilla structure (one manila folder and white glue)
- Spaghetti bridge
- Rube Goldberg Device
- Crystal radio
- Kaleidoscope
- DIY laser
- Stirling engine - see the Amateur Scientist coffee can version

Physics “Olympics” events

- Paper tower
- Spaghetti tower
- Index card tower
- Slowest parachute
- Longest lever with craft sticks
- Egg drop
- Fermi questions
- Strongest Al foil boat
- Hit the target

Observatory

Design for a rotating portable observatory from “Cover your Astro.” Book is no longer available, but you can see the gist of the PVC and Tyvek construction here.

Cost is around $300 or so.

Kinetic Sculpture (Race)

Each year, our school competes in the Baltimore “Kinetic Sculpture Race.” We repurpose donated bikes to build vehicles that can travel on land, sand, and water (with styrofoam pieces to aid in floating). It’s a lot of work, but it is riotous fun and incredibly rewarding.

Kinetic Sculpture (Race)

After the race, our students build motorized bikes or go-carts.

You can often find cheap or free engines with side shafts - from these, you can attach a centrifugal clutch. With a cable from the throttle to the front accelerator pedal, and some repurposed brakes, it is relatively easy to build a go-cart. If welding is not in your wheelhouse, try makerpipe (or reusing old go-cart frames).

Kinetic Sculpture (Race)

Other ideas

- KSR: https://kineticbaltimore.com/
- Go-carts, mopeds, Gopeds, scooters from Craigslist
- Maker pipe (https://makerpipe.com/)
- https://makezine.com/

Thank you very much.

Very special thanks Tatsu and CSAAPT.

Also, a big thank you to my Jemicy, HCC, JHU, and Towson students.

All images and video are by Sean Lally, unless noted otherwise.

Contact: seanplally@gmail.com

(The P is for Physics.)