Pneumatic Rocket Launcher

The paper rocket launcher uses compressed air from a bicycle pump to launch paper rockets built by students. The launcher electronics are powered by a battery for portability, and it can also be powered by AC power.

SAFETY FIRST!!!

The rocket launcher is designed to be safe, but we need to be proactive by anticipating what could go wrong and taking steps to minimize the impact if those things should happen. The rockets are light weight, but fly very fast, so one obvious danger is getting hit by a flying rocket. Make sure the launch tube is always pointed in a safe direction, and keep everyone out of the flight path while operating the launcher. In the past we set up a 15’ wide corridor in the gym using cones and insisted everyone stay out of that zone at all times.

Just as in real life, these rockets can explode when launched, so everyone should be at least 10 feet behind the launcher when launching rockets. The launch control key and launch button are on long cords, and the launch supervisor should not enable the launcher until everyone is out of the way.

There are several safety interlocks built into the launcher to help ensure student safety. They include the following:

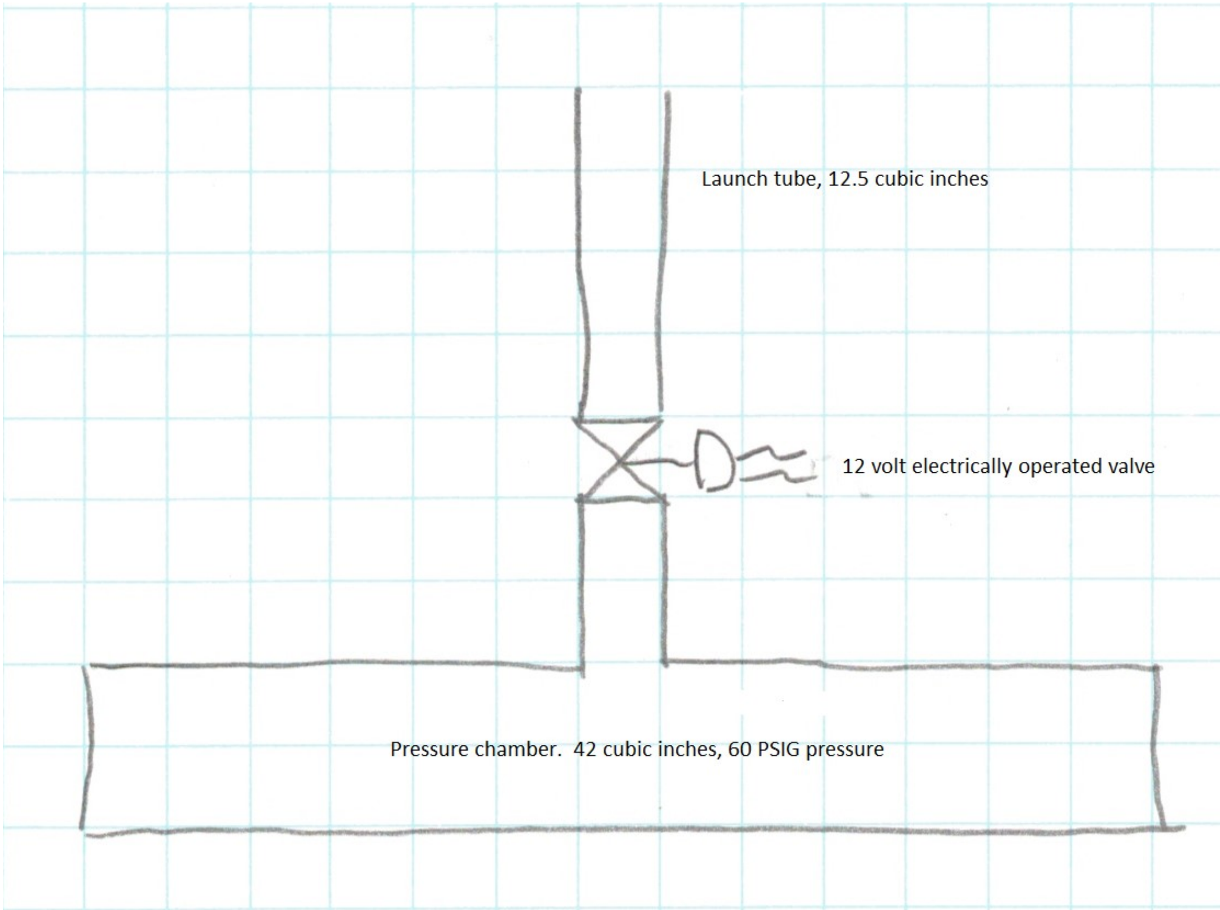
- Red mushroom shutdown switch on top that shuts off all power to the launcher and prevents launching. This is also the on/off switch, and **pressing it shuts off all power** preventing any launching. Turning the red button clockwise turns on the power and you should see a flashing red LED light on the back of the electronics box on the top of the launcher indicating power is on.
- A key switch that a launch supervisor (teacher) runs that enables and disables launching. This switch must be **turned off after each launch**, and then back on to enable launching. When on, the orange light on the launcher flashes to indicate a launch is about to happen.
- A launch button operated by the students. Pressing this button for a second will start the launch sequence with a 5 second period of beeping followed by the launch.
- A pressure relief valve set at about 80 psi. This valve releases air if you go above the 80 psi setting dropping the pressure back to about 50 psi. Too much pressure will make the paper rockets blow apart, so a pressure of 60 psi seems to be optimal for good flight and long life.

The attached video shows the launcher in operation:

Building the Rockets

Rockets are built by rolling a sheet of card stock around a form to create a cylinder, attaching a nose cone, adding tail fins, and inserting a foam plug to reinforce the nose cone. You will need both single sided and double sided cellophane tape, card stock, and pieces for the nosecone and tail fins. You also need a form to build the rocket on, a marker, scissors, and a jig to show you where the tail fins attach.

The attached video shows how I build the rockets.



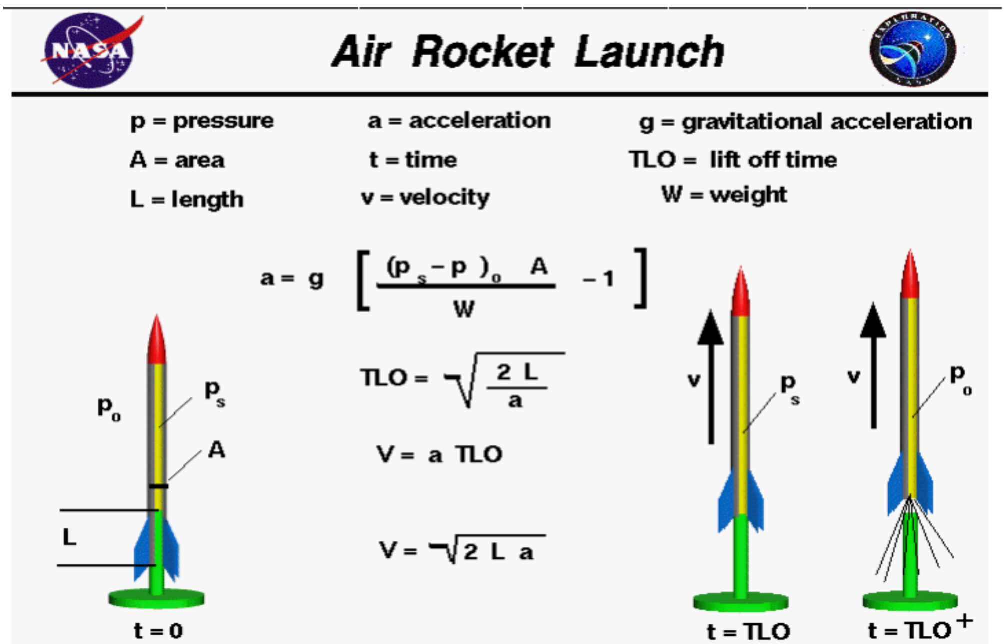
How the Launcher Works

The launcher has a small pressure chamber that gets pressurized to about 60 psi by a bicycle pump, and an electrically operated valve between the launch tube and air chamber. Once the valve is activated, it quickly opens and pressurizes the launch tube. Pressure in the launch tube presses in all directions on the rocket body, but the rocket tube cannot expand so the only way the rocket can move is to slide on the launch tube. The initial pressure in the pressure chamber drops from 60 psig to 55psig due to air flowing into the launch tube. The cross sectional area of the rocket is 1.36 square inches, so about 75 pounds of force is applied to the rocket which weighs less than half an ounce. The rocket accelerates rapidly due to the internal pressure, and the fins help stabilize it and keep it flying straight.

Real Rocket Science

If you want to learn more about the science behind paper rocket launchers, this NASA site:

https://spaceflightsystems.grc.nasa.gov/education/rocket/rktslaunch.html shows the calculations needed to calculate the initial velocity of the rocket. This is an example of using Newton's second law to determine how rockets respond to the forces exerted on them.



I did the calculations for our launcher and rockets, and the results are shown in the table below:

Paper Rocket Calcs:	Name	British Engineering Units (feet/lbf/seconds)		MKS Units (Meters, Kilograms, Seconds)		Comments
W	Weight of rocket	0.42	oz	0.11676	Newton	Assume 1.33 sheets card stock, including tape
ps-p0	pressure	55	psig	379208.5	Pascals or N/m^2	Pressure in pipe after valve opens
A	Area	1.36	sq in	0.000877419	sq m	Area of launch tube
g	gravitational acceleration	32.2	ft/sec^2	9.8	m/sec^2	depends on location on earth's surface
a	acceleration	91722.4667	ft/sec^2	27916.74846	m/sec^2	a=g*((ps-p0)*A/W-1)
L	Length Launch Tube	10	in	0.254000508	m	subtract 1" foam in nose from 11" paper
TLO	time lift off	0.00426272	sec	0.004265794	sec	TLO=sqrt(2*L/a)
v	velocity	390.986928	ft/sec	119.0870966	m/sec	v=a*TLO
		266.581996	mph			

These calculations indicate the initial velocity could be as high as 390 feet per second which is 266 miles per hour! Keep in mind that as soon as the rocket leaves the launch tube it starts to slow down due to drag forces, so 266 mph is just the initial velocity.

Also, keep in mind that the NASA calculations make a lot of assumptions such as the air valve opening instantly, which are probably not realistic, but are necessary to keep the calculations manageable. It might be interesting to try to use slow motion photography to film a launch to see if we can determine the actual initial velocity.