Lesson Study Final Report (Short Form)

Title: Rocketry: Design and Build a Rocket Body, Fabricate a Chemical Motor and Determine the Total Altitude Achieved

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Discipline or Field: Physics and Chemistry

Date: August 17, 2007

Course Name: General Physics l / General Physics ll (calculus based course)
General Chemistry l / General Chemistry ll

Course Description: General Physics l & ll is the calculus based Physics course taught at UW-Baraboo/Sauk County. This course presents the basic concepts of physics as they apply to mechanics, heat, wave motion, sound, thermodynamics, electricity, magnetism, light and nuclear physics. It consists of lectures, discussion, and labs. The lectures and discussions emphasize conceptual understanding as well as problem solving. The labs use a hands-on, activity-based approach to learning physics concepts. This course is designed for students whose program requires 1 year of physics or those who plan to take further courses in physics. This project would allow the students to utilize their knowledge of mechanics and motion to design an aerodynamic rocket body to house a chemical motor and to calculate its max. altitude theoretically and compare the value to an experimental one.

General Chemistry l & 2 is a one-year course in college chemistry. It consists of lectures, discussion, and labs. This course is designed for students whose program requires 1 year of chemistry or those who plan to take further courses in chemistry. This project would allow the students to utilize their knowledge of chemistry to fabricate a safe chemical motor.

Summary: The Physics students never did get to work with the Chemistry students as a team; however, they each individually designed a model rocket body to house a chemical motor propellant. We also had (3) lectures/discussions pertaining to rockets. The 1st one was discussing the physics behind rockets- more in depth than the textbook material. The 2nd one was an open discussion on how to calculate the max. altitude of a rocket theoretically and group work solving a sample problem similar to how we would do it during the lesson study. The 3rd meeting was a hands-on experiment launching a toy model rocket (no motor included) and then we used geometrical methods to determine the actual altitude of the rocket.

I spent several hours obtaining useful information pertaining to this lesson study. Compiled a handout titled- Design a Model Rocket, another one titled- Procedure to Determine Rocket Motor Thrust and was working on a 3rd handout- Rockets (rough 1st draft).

The chemistry students did fabricate some rocket motors and launched them on the last few days of class; unfortunately we were not informed of the completed motors in time to participate.

Attachments: Please see attachments: Handout- Design a Model Rocket, (5) completed student assignments, Handout- Procedure to Determine Rocket Motor Thrust, Handout-Rockets

Rockets

Theory-

Rockets are like other forms of propulsion in that they expend energy to produce a thrust force via an exchange of momentum with some reaction mass in accordance with Newton's Third Law of Motion. But rockets differ from all other forms of propulsion since they carry the reaction mass with them (self contained) and are, therefore, independent of their surrounding environment. Other forms of propulsion depend on their environment to provide the reaction mass. Cars use the ground, airplanes use the air, boats use the water and sailboats use the wind. The rockets we are most familiar with are chemical rockets in which the propellants (reaction mass) are the fuel and oxidizer. With chemical rockets, the propellants are also the energy source.

According to Newton's Second Law, the thrust force is equal to the rate of change of momentum of the ejected matter, which depends on both how much and how fast propellants are used (mass flow rate) and the propellant's speed when it leaves the rocket (effective exhaust velocity).

Sir Isaac Newton set forth the basic laws of motion- the means by which we analyze the rocket principle. Newton's three laws of motion apply to all rocket-propelled vehicles.

Newton's laws of motion are stated briefly as follows:

Newton's 1st Law (Inertia)

Every body continues in a state of uniform motion in a straight line, unless it is compelled to change that state by a force imposed upon it.

Newton's 2nd Law (Momentum)

When a force is applied to a body, the time rate of change of momentum is proportional to, and in the direction of, the applied force.

Newton's 3rd Law (Action-Reaction)

For every action there is a reaction that is equal in magnitude but opposite in direction to the action.

The first law says, in effect, that the engines must develop enough thrust force to overcome the force of gravitational attraction between the Earth and the launch vehicle. The engines must be able to start the vehicle moving and accelerate it to the desired velocity. Another way of expressing this for a vertical launch is to say that the engines must develop more pounds of thrust than the vehicle weighs.

When applying the second law, we must consider the summation of all the forces acting on the body; the accelerating force is the net force acting on the vehicle. This means if we launch a 200,000lbf vehicle vertically from the Earth with a 250,000lbf thrust engine, there is a net force at launch of 50,000lbf–the difference between engine thrust and vehicle weight. Here the force of gravity is acting opposite to the direction of the thrust of the engine. As the rocket operates, the forces acting on it change. The force of gravity decreases as the vehicle's mass decreases, and it also decreases with altitude. As the rocket passes through the atmosphere, drag increases with increasing velocity and decreases with altitude (lower atmospheric density). As long as the thrust remains constant, the acceleration profile changes with the changing forces on the vehicle. The predominate effect is that the acceleration increases at an increasing rate as the vehicle's mass decreases.

To relate Newton's third law, or "action-reaction law" to rocket theory and propulsion, consider what happens in the rocket motor. All rockets develop thrust by expelling particles (mass) at high velocity from their nozzles. The effect of the ejected exhaust appears as a reaction force, called thrust, acting in a direction opposite to the direction of the exhaust. The rocket is exchanging momentum with the exhaust.

It is his Third Law of Motion that explains the working principle of all propulsion systems. A rocket engine is basically a device for expelling small particles of matter at high speeds producing thrust through the exchange of momentum.

Rockets are systems where we can not assume that the total mass of the system remains constant. Most of the mass of a rocket on its launching pad is fuel, all of which will eventually be burned and ejected from the nozzle of the rocket engine.

We can handle the variation of the mass of the rocket as the rocket accelerates by applying Newton's second law, not to the rocket alone but to the rocket and its ejected combustion products taken together. The mass of this system does not change as the rocket accelerates.

Rocket Equation-

The *linear momentum* (p), or simply *momentum*, of a particle is the product of its mass and its velocity. That is,

(1.1) $$p = mv$$

Newton expressed his second law of motion in terms of momentum, which can be stated as "the resultant of the forces acting on a particle is equal to the rate of change of the linear momentum of the particle". In symbolic form this becomes

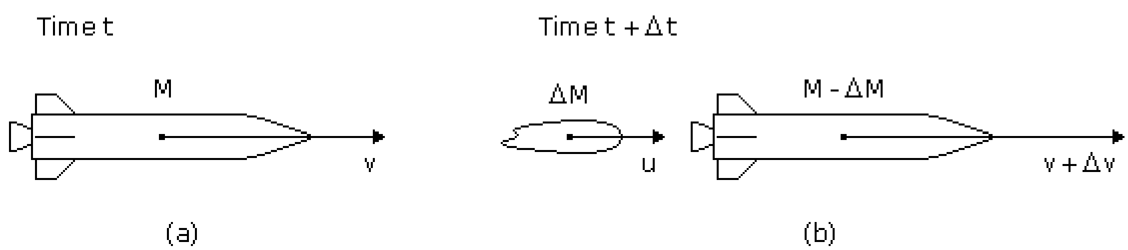
(1.2) $$F = \frac{dp}{dt}$$

which is equivalent to the expression $F=ma$.

If we have a system of particles, the total momentum P of the system is the sum of the momenta of the individual particles. When the resultant external force acting on a system is zero, the total linear momentum of the system remains constant. This is called the principle of *conservation of linear momentum*. Let's now see how this principle is applied to rocket mechanics.

Consider a rocket drifting in gravity free space. The rocket's engine is fired for time Δt and, during this period, ejects gases at a constant rate and at a constant speed relative to the rocket (exhaust velocity). Assume there are no external forces, such as gravity or air resistance.

Figure (a) shows the situation at time *t*. The rocket and fuel have a total mass *M* and the combination is moving with velocity *v* as seen from a particular frame of reference. At a time Δt later the configuration has changed to that shown in figure (b). A mass ΔM has been ejected from the rocket and is moving with velocity *u* as seen by the observer. The rocket is reduced to mass M-ΔM and the velocity *v* of the rocket is changed to $v+\Delta v$.



Because there are no external forces, *dP/dt=0*. We can write, for the time interval Δt

(1.3)
$$0 = \frac{\Delta P}{\Delta t} = \frac{(P_2 - P_1)}{\Delta t}$$

where P_2 is the final system momentum, figure (b), and P_1 is the initial system momentum, figure (a). We write

(1.4)
$$0 = \frac{[(M - \Delta M)(v + \Delta v) + \Delta M u] - Mv}{\Delta t}$$

If we let Δt approach zero, $\Delta v/\Delta t$ approaches *dv/dt*, the acceleration of the body. The quantity ΔM is the mass ejected in Δt; this leads to a decrease in the mass *M* of the original body. Since *dM/dt*, the change in mass of the body with time, is negative in this case, in the limit the quantity $\Delta M/\Delta t$ is replaced by *-dM/dt*. The quantity $u-(v+\Delta v)$ is V_{rel}, the relative velocity of the ejected mass with respect to the rocket. With these changes, equation (1.4) can be written as

(1.5)

$$M\left(\frac{dv}{dt}\right)=(u-(v+\Delta v))\left(\frac{dM}{dt}\right), \text{ or}$$

$$M\left(\frac{dv}{dt}\right)=v_{rel}\left(\frac{dM}{dt}\right)$$

The right-hand term depends on the characteristics of the rocket and, like the left-hand term, has the dimensions of a force. This force is called the *thrust*, and is the reaction force exerted on the rocket by the mass that leaves it. The rocket designer can make the thrust as large as possible by designing the rocket to eject mass as rapidly as possible (dM/dt large) and with the highest possible relative speed (V_{rel} large).

In rocketry, the basic thrust equation is written as

(1.6) $$T = qV_e+(P_e-P_a)A_e$$

where q is the rate of the ejected mass flow, V_e is the exhaust gas ejection speed, P_e is the pressure of the exhaust gases at the nozzle exit, P_a is the pressure of the ambient atmosphere, and A_e is the area of the nozzle exit. The product qV_e, which we derived above (V_{rel} x dM/dt), is called the momentum, or velocity, thrust. The product $(P_e-P_a)A_e$, called the pressure thrust, is the result of unbalanced pressure forces at the nozzle exit. Note: The maximum thrust occurs when $P_e=P_a$.

If we include external forces acting on the rocket, they would include gravity (F_g);

(1.7) $F_g = mg$, where g = 9.8m/s^2

an aerodynamic drag force (F_D);

(1.8) $F_D = \frac{1}{2}\rho v^2 C_D A$, where ρ = density of air = 1.2kg/m^3, C_D = the drag coefficient, A = the cross-sectional area of the rocket (area of body tube and the leading edge area of the fins)

[Note: The drag coefficients from each part of the rocket can be determined by adding up the effects of drag from each part:

(1.8a) $C_D = C_D(\text{nose cone \& body}) + C_D(\text{base}) + C_D(\text{fins}) + C_D(\text{interference}) + C_D(\text{launch lug})$

Typical values are:

Typical values are:	C_D (nose cone and body)	0.205 ± .050
	C_D (fins)	0.205 ± .050
	C_D (interference)	0.154 ± .020
	C_D (base)	0.064 ± .015
	C_D(launch lug)	0.103 ± .015
	C_D(total)	0.912 ± .125

Note the large % uncertainty. Uncertainties always add. They never subtract or get smaller. One has to guesstimate a true drag value, depending on whether the individual rocket is very smooth or not, etc. For example, a smoother than normal rocket will have a drag coefficient less that the .912 while a rougher than normal rocket will have a substantially higher value of drag coefficient. This matters in how high the rocket will actually go.]

a constraint force during takeoff (F_C);

(1.9) $$F_C = T - mg$$

and the pressure thrust (F_P) due to the unbalance in the pressure of the exhaust and the ambient pressure of the atmosphere,

(1.10) $$F_P = (P_e - P_a)A_e$$

Assuming that the values of C_D, ρ and P_a are constant, Equation *(1.2)* can be rewritten (now including the external forces) as follows:

(1.11) $$M(dv/dt) = V_{rel}(dM/dt) - F_g - F_D + F_C + F_P$$

Calculating the Altitude-

Using known data and some simple equations, a rocket's altitude can be theoretically calculated.

The **mass, m**** (in kg) and the **area, A** (in m^2)of the rocket needs to be determined. (Note: $A = \pi r^2$).

Since the **velocity, *v*** is unknown, the **drag force, F_D** is not calculated; however, the wind resistance factors can be lumped into one **coefficient, k**

(1.12) $k = \frac{1}{2}\rho C_D A$, where ρ = density of air = 1.2kg/m^3, C_D = the drag coefficient, A = the cross-sectional area of the rocket (area of body tube and the leading edge area of the fins)

The values of the **burnout time, t** (in sec), **thrust, T** (in N), and **impulse, I** (in NS) are obtained from the Xplorer GLX. There is a direct relationship between these three variables:

(1.13) $$t = \frac{I}{T}$$

Compute some useful terms:

(1.14) $$q = \sqrt{\frac{T - mg}{k}}$$

(1.15) $$x = \frac{2kq}{m} = 2\frac{\sqrt{(T - mg)k}}{m}$$

where **q** and **x** are simply coefficients.

Now the **burnout velocity, v** (in m/s) can be calculated:

(1.16) $$v = q\frac{1 - e^{-xt}}{1 + e^{-xt}}$$

Finally, the **altitude at burnout, y_b** and the **coasting distance, y_c** can be calculated:

(1.17) $$y_b = \frac{-m}{2k}\ln\left(\frac{T - mg - kv^2}{T - mg}\right)$$

(1.18) $$y_c = \frac{m}{2k}\ln\left(\frac{mg + kv^2}{mg}\right)$$

The **peak attitude, y** is simply the sum of the altitude at burnout and the coasting distance,

(1.19) $$y = y_b + y_c$$

Note: **Mass, m: As previously mentioned, rockets are systems where we can't assume that the total mass of the system remains constant. Most of the mass of a rocket on its launching pad is fuel, all of which will eventually be burned and ejected from the nozzle of the rocket engine. Therefore, (3) values of mass need to obtained: the **empty (no motor) mass of the rocket, m_r**; the **loaded mass of the motor, m_e**; and the **mass of the propellant, m_p**.

The average mass during boost is: $m_r + m_e – m_p/2$. This is the mass valued used in Equation (1.17) to calculate the altitude at burnout, y_b.

The mass during the coast is: $m_r + m_e – m_p$. This is the mass valued used in Equation (1.18) to calculate the coasting distance, y_c.

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Physics 202- Rocket Project
Design a Model Rocket Body
Due date: May 9th, 2007

Objective: Design on paper a rocket body, including recovery system and safety concerns. Your design must include any and all components of the rocket body (ie. body, fins, nose, recovery system, motor mounts, launch mounts, etc). A detailed sketch must be included. These designs will be used next semester in the actual construction of rocket bodies.

The following parameters will be used:

Total Max Lift off weight (mass): 85g

Rocket Body Specifications:

Length: 11 -15 inches
Outside Diameter: approx 1 inch
Max weight (mass) including recovery system: 60g

You will not be designing the rocket motor; however, you must take into consideration that the motor parameters for this body design will be:

Rocket Motor Specifications:

Length: 2.75 inches (70mm)
Outside Diameter: 0.70 inches (18mm)
Max weight (mass): 25g
Total Impulse: 10N-sec

Note: The rocket motor will be a KN-Sucrose motor that the chemistry students will be producing (as previously discussed).

Procedure: Must be typed.

- You must include a detailed materials list for the entire design. You may either include the entire list all together or it may be listed in individual sections for each part of construction.
- You must include a detailed explanation of the design of each component of the rocket body, including dimensions and assembly, as well as a detailed explanation of the assembly of each part to one another.
- You must include a step discussing aesthetics (paint, decals, etc.)
- You must include a discussion of safety precautions that should be followed when launching a rocket.

- You must include a detailed sketch of the total rocket body. Any other sketches that would be useful in the construction are optional.

Procedure to Determine Rocket Motor Thrust

Introduction-

In order to calculate the altitude or how high a rocket will go one needs to have some basic knowledge of the rocket's engine. We will be calculating the total impulse of the engines provided by the chemists.

Let's start by looking at some basic definitions-

Total impulse is the total thrust produced by the motor and is measured in Newton-seconds (Ns). This measures the total amount of energy the motor produces for propelling a rocket upward. The total impulse tells you how high the motor can push your rocket.

Average thrust is the average instantaneous force the motor produces during its burn and is measured in Newtons (N). Note that because most thrust curves are not flat, most of the time the motor is not producing the average thrust. The average thrust tells you how heavy a rocket the motor can lift, although since different motors produce different shaped thrust curves, it can be misleading. (Average thrust is determined by dividing the total thrust over the official burn time-within the 5% threshold.)

Maximum thrust is the maximum amount of force produced by the motor during its burn. Like average thrust, this is measured in Newtons (N). Generally, there is a small spike near the beginning; which has the highest thrust, although the shape of the curve varies with the motor design and propellant mixture.

Burn time is the number of seconds for which the motor produces thrust. This tells you how long the motor will keep pushing your rocket. (Burn time is determined by chopping off the ends of the curve when the thrust is below 5% of the maximum.)

We will use the Xplorer GLX Datalogger to obtain the thrust (force) vs. burn time of rocket engines fabricated by the chemistry students. This data can then be integrated to obtain the impulse of those rocket engines.

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Equipment needed-

Rocket Engine Test Bracket (ME-6617)
Force Sensor (PS-2104)
Xplorer GLX (PS-2002)
Support Rod
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Setup-

Set up the Equipment:

1. Use a screwdriver to connect the Rocket Engine Test Bracket to the Force Sensor.
2. Mount the Force Sensor on the support rod. Either horizontally or vertically will work.
3. Insert the rocket engine into the test stand with the engine's exhaust port pointing away from the Force Sensor.

Set up Xplorer GLX Datalogger:

1. Attach the Force Sensor to the Xplorer GLX to obtain the necessary data.
2. Open a graph display. A graph will be generated from two data sources: one on the vertical axis (the sensor measurement, Force) and one on the horizontal axis (time). Note: When the Force Sensor is connected to the GLX, the graph will automatically set the sensor measurements as the vertical data source, with time as the horizontal data source.

Prepare for Ignition:

1. Move the equipment to the launch site.
2. Press the **Zero** button on the Force Sensor to tare it.
3. Check the exhaust area to ensure it is clear of any combustible material, people, or animals.

Data Collection: (Note: See Important Safety Notes **)

1. Press the (>) button on the GLX to begin recording data and move at least 15 feet away from the Rocket Engine Test Bracket.
2. Ignite the rocket engine.
3. After the burn has completed, stop recording data again by pressing the (>) button on the GLX.
4. Save data obtained.

Data Analysis:

1. The Xplorer GLX can be used to determine the impulse of a rocket engine. Select the *Integration* option and click the Autoscale button to resize the graph previously obtained.
2. Select the area under the curve and record the integrated value. This is the impulse of the rocket engine tested.

*** Important Safety Notes ***

Even when just testing the rocket motor, safety *must* be enforced.

** Wear safety glasses at all times.

** Choose a launch area free of any combustible material, animals, or people. Ignite the rocket motor outdoors, in a large open area and in safe weather conditions with wind speeds no greater than 20mph. Ensure that there is no dry grass close to the launch pad, and that the launch site does not present risk of grass fires.

** Use a countdown before ignition and make sure that everyone is paying attention and is a safe distance of at least 15 feet away from the exhaust of the rocket engine.

** Wait 10 minutes after ignition of the rocket engine before touching the Rocket Engine Test Bracket- **it will be *hot.***

** Upon ignition, if the motor misfires or does not launch, wait at least 60 seconds after the last launch attempt before allowing anyone to approach the rocket motor.

** If you are uncertain about safety or stability of an untested rocket engine, do not ignite it.

How To Make A Rocket

Ethan Bosgraaf
Rocket design
Physics-202
5/2/2007

Rocket Design

Materials:

- Fishing line
- Poster board
- Balsa wood
- Glue (super or regular your choice)
- Industrial strength garbage can liner
- Protractor
- Tape (masking)
- Drinking straw

Procedure:

First off, based on the rocket propellant that is made determine what inner diameter is needed for a rocket body (approximately one inch). Take a piece of poster board (11"x 6") and roll the paper the long way so that the propellant fits snugly in the end of the body. Pull up the exposed flap of paper and run a bead of glue down the body and seal shut. Apply tape to flap to hold down paper while drying. Make sure that propellant can still fit snugly in both ends of the rocket before glue is dry.

Next make fins for the rocket. Take a piece of poster board and cut out three right angle triangles with one leg measuring 3.5" and the other measuring 5". One the five inch side make 9 perpendicular cuts in the paper .5" apart and .5" deep, alternate folding the paper bending one piece to the left then to the right so on up the paper. Do this to all three fins. Next draw a circle on a piece of paper the same size as the outer diameter of the rocket body. Take a protractor and cut the circle in three equal pieces (120°) with a pencil. Then put the rocket body on the center of the circle and mark each 120° mark on the rocket body. Extend the mark five inches up the body making sure it is straight.

Take the three fins and apply glue to each tab and put them on the rocket so they are in line with the marks made on the body and so the bottom of the fins are flush with the bottom of the body. Tape as needed to hold fins in place while drying.

Next a nose cone will be made by drawing a 9" diameter circle on a piece of poster board. Find the center of the circle and mark it clearly. Then make a straight cut from the outside to the center mark. Then roll the circle into a cone shape evenly so that the bottom of the cone will fit over the rocket body by about .5" with a ¼" gap around the out side of the cone to the rocket body. This will provide a pocket for air to get under to lift off the nose cone and deploy the recovery system. Pull up the exposed flap of paper and run a bead of glue down the nose cone and seal shut. Apply tape to flap to hold down paper while drying.

To hold the rocket in place cut out a 1" long piece of balsa wood with an outer diameter that will slide snugly in the rocket body. Next measure the length of the rocket propellant (approximately 2.75"). Apply glue to the outside of the balsa wood (roughen up the surface with sand paper) then from the top of the rocket push the balsa wood down to the point where the propellant will fit flush with the bottom of the rocket. Don't push the balsa wood up from the bottom because the glue my affect the propellant from fitting.

Next create a recovery system. This will be done by cutting out a 15" x 15" square piece out of an industrial strength garbage liner. Then cut out 4 pieces of fishing line 1' long. Tie one end if the fishing line to a corner of the garbage can liner. Reinforce corners with tape to avoid tearing. Repeat with remaining corners. Then put four pin sized holes 90° apart ¼" down from the top of the rocket. Then take the remaining end of the fishing line and tie through the holes in the rocket. Reinforce holes with tape. Make sure to not cross lines and keep the line the same size. Make sure the "parachute" can fit and will be able to deploy from under nose cone. Play with the folding styles to get it right before launch.

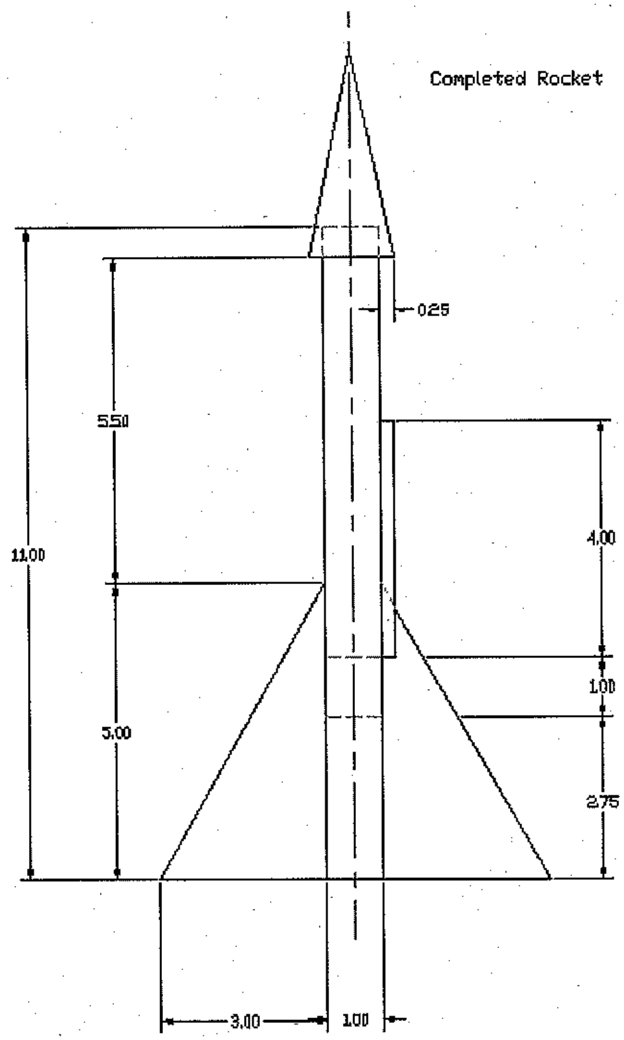
Finally a guide will have to be placed on the rocket to make sure it flies off straight and not a people unless that is the desired effect? To do so, cut a piece of a drinking straw 4" long and glue to the side of the rocket body directly in the middle (measure for alignment because if it is not straight the rocket will start off at an angle). Reinforce the straw with masking tape to hold firmly in place. Also, glue in an area that is between two of the fins to avoid the fins from hitting the launching rod.

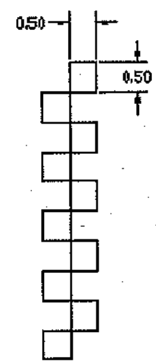
This concludes the rocket assembly. Now paint and decal your rocket as desired.

Safety When Launching:

- Wear safety goggles when launching due to possible shrapnel.
- Stand at a safe distance or behind a protective shield.
- Have a automated switch to ignite the propellant so it can be ignited from a safe distance
- Have a fire extinguisher to put out any rockets that may start on fire.
- Launce in an open field away from trees and buildings

Completed Rocket





Wing configuration

Rocket Project

Nick Kovalaske

Materials Needed:

(Body)

- 11"x14" Poster board
- Glue (Spray glue works best)
- Double-Stick Tape
- ¾" Appropriately-sized dowel
- Ruler
- Knife

(Nose Cone)

- 3"x5" Note Card
- Screw-Eye

(Fins)

- 12"x1 ½"x 3/32" modeling hardwood (maple, basswood, poplar, or balsa)
- Xacto-Knife
- Sandpaper

(Launch Holder)

- Straw

(Recovery System)

- Surveyor's Tape

Procedure

(Body):

You can buy the poster board at Wal-Mart or at any office supply store. Each sheet is 22 inches wide by 28 inches long, and it is 0.012 inch in thickness. One sheet will make four body tubes. You can use 3M Super 77 Adhesive which works very well with paper and light wood adhesion and is available at most hardware stores. Use the double-stick tape for the first winding of the paper around the dowel. The spray adheres immediately and you don't want the dowel to become attached to the tube.

A sheet of poster board is cut into four equal rectangles, each 11 inches wide by 14 inches long. Each rectangle, rolled the long way, will make one body tube 11 inches long. Attach double-stick tape on one of the edge. The double-stick tape secures the first turn of the tube, making the spray-glue operation much simpler. Remove the dowel from the tube to keep it from getting glued. The first turn is now secured with double-stick tape. Take the paper outside and spray it with glue. It doesn't take much, but try to get an even coating. Take it back to the flat rolling-board, re-insert the dowel, and roll it up. Be especially careful to get the finishing edge of the poster board stuck down evenly and firmly. Otherwise, it will peel away and be non-aerodynamic.

(Fins):

Mark the strip at the halfway point of the strip of wood. Mark a point one inch from each end, and one inch from the centerline on the opposite side. Connect the one-inch points with diagonal lines. These are the cut lines. They are also the edge which will be glued to the rocket body tube. The root edge needs to be sanded. That must be fixed, as the edge must mate well with the body tube to glue well, and it must be squared with the flat so the fin will stand up straight. First, align the top edges. This will minimize the amount of sanding you have to do. If you have some small clamps you can try using them to hold the fins. Lay a piece of fine sandpaper on a flat surface, and rub the root edge of the fin group on it until they are all flat and even. Do the same to the other edges to make them all uniform. To align the fins on the body you can trace the body tube on a piece of paper and draw perpendicular lines thru the center of the circle to use for guidelines. You can use Elmer's Glue to attach the fins also glue the launch holder to the side of the body.

(Nose Cone):

Start by making a mark in the middle of one long edge of a 3x5 index card. This is where the apex of the cone will be. To get the angle right, make a mark on the other edge 1 inch from the side, and draw a line between the two. Top-left side is bent down to make a partial fold you can then roll the cone. Glue the cone to the body and trim off the excess. After it has dried cut off about a ½" below the cone, this will be where the recovery system is located. Glue a wooded dowel, about 1 ¼" long, into the cone and attach a screw-eye into the bottom of it.

(Aesthetics):

Now that you rocket is done you may want to decorate it. Use paint or decals, whatever you want, give it a personal touch.

(Finalizing):

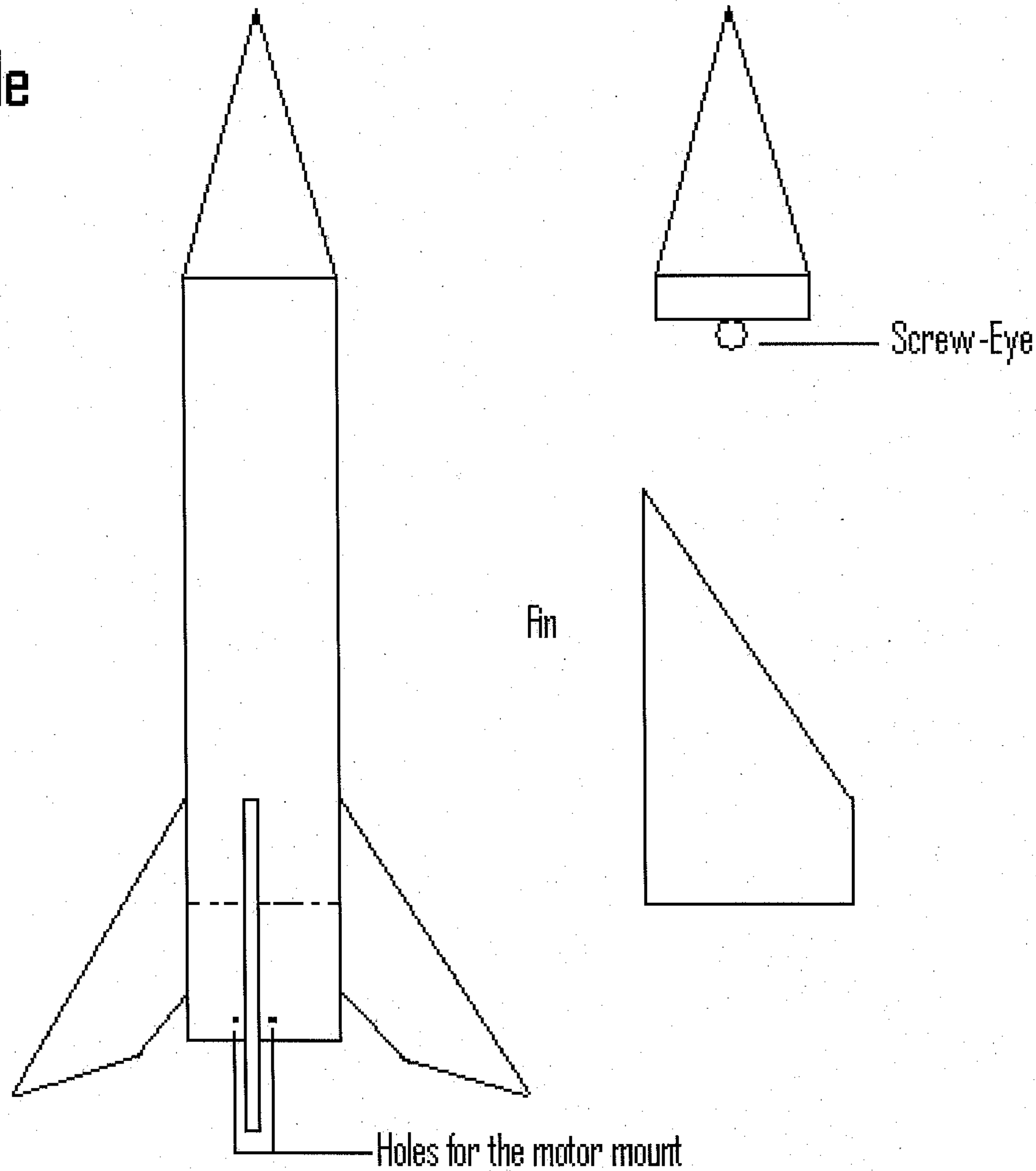
You'll need to make a thrust ring and a shock cord for the recover system to work. A length of elastic tied to a ½" tube made of another note card will work. It shouldn't need to be very long. The elastic will be fed thru the body and attached to the screw-eye in the cone. Glue the thrust ring in place, should be fine in the middle of the rocket. Tie a strip of surveyors tape to the elastic band and place all in tube. The surveyors tape will create drag when the rocket comes down causing it to slow down. Put the cone back in place. Measure ¼" from the bottom of the cone. This will be where the motor is mounted and where the motor mounts will be attached, in this case a paper clip.

Put a hole through both sides of the rocket body closer together so that the paper clip will not be in direct path of the propellant.

(Safety):

Have a fire extinguish on hand. Wear eye protection. Keep a good distance. Now go set it off.

Not to Scale



Rocket Design

Physics 202
5/9/07

Julia Malmborg

Materials:

- 15" length spiral wound paper tube with 1" diameter
- 4 sheets about 5" X 5" of 1/8" thick balsa wood
- Super glue
- Scissors
- Masking or duct tape
- 30 toothpicks
- Exacto knife
- Pencil, black marker
- Ruler
- Aluminum foil (approx 1.5' X 10")
- A small strip of cloth or plastic for recovery system
- Half of a plastic Easter egg
- Spray paint (any color)
- Markers (optional)
- Stickers (optional)
- Cinder block for launch pad

Procedure/ Construction:

Using the piece of spiral wound paper tube, cut length to approximately 12 inches. Insulate inside of tube with aluminum foil making several layers. Tape the ends of the tube so the aluminum foil stays in place. Stick about 7 or 8 toothpicks perpendicular directly through the rocket tube 3 inches from one end until they poke out the other side. Criss-cross them so it will create a support for the motor. Place the motor inside the tube, centered, and poke another hole on the rocket body to allow the wick to be exposed for ignition. Line the hole for the wick with aluminum foil so it doesn't catch on fire when lit. Place 7-8 more toothpicks 5.75 inches from the bottom above the motor so the motor is in place. Place super glue on the toothpicks and the rocket body so they stay in place. Once the glue is dry, double check to make sure all are secure then clip the ends of the toothpicks as close to the body as possible with scissors. There will be four fins that will be attached to the rocket body. The sides will be 3in X 3in X 1in X 3.75 in. On a piece of balsa wood draw these dimensions with a pencil so it is in the shape of the drawing provided. Carefully cut out the fin using an exacto knife. Trace the shape of the already cut out fin onto the other three sheets of balsa wood so they are the exact same size. Cut out fins with the exacto knife. Once fins are cut out they can be attached to the rocket body. Attach fins quarterly so they are equal distance from each other. If you are having trouble, try placing the rocket vertically on a piece of paper and tracing the circumference of the tube. Then draw two lines through the center perpendicular to each other. Where the lines intersect the outside of the circle is where the fins should go. On the rocket body mark with a black marker where the fins should go based on the lines on the piece of paper. Glue the fins on the rocket body where the marks are. Make sure the fins are perpendicular to the ground so the rocket stands on it's own. Use the drawing provided to ensure the fins are put on the correct way.

Next is the recovery system and nose cone. Since the rocket itself is relatively light we will be using just a small piece of cloth to slow down the speed as it comes back down to the ground. Cut the piece of cloth about 1" X 9" or best fit for it to fit into the nose cone and rocket body. Tape one end of the piece of cloth into the tip of the rocket body. Make sure it is secure. Don't fold up until it's ready to launch otherwise it'll get stuck in the rocket and won't open up properly. The half Easter egg should fit on the top of the rocket body when ready to launch and will be used as a nose cone covering the strip of cloth. Secure it with a small piece of tape to the side of the rocket body so it can easily come off. After the rocket is assembled make sure everything is secured. Glue or tape anything that seems to be loose. Put a few strips of tape around the rocket body for support.

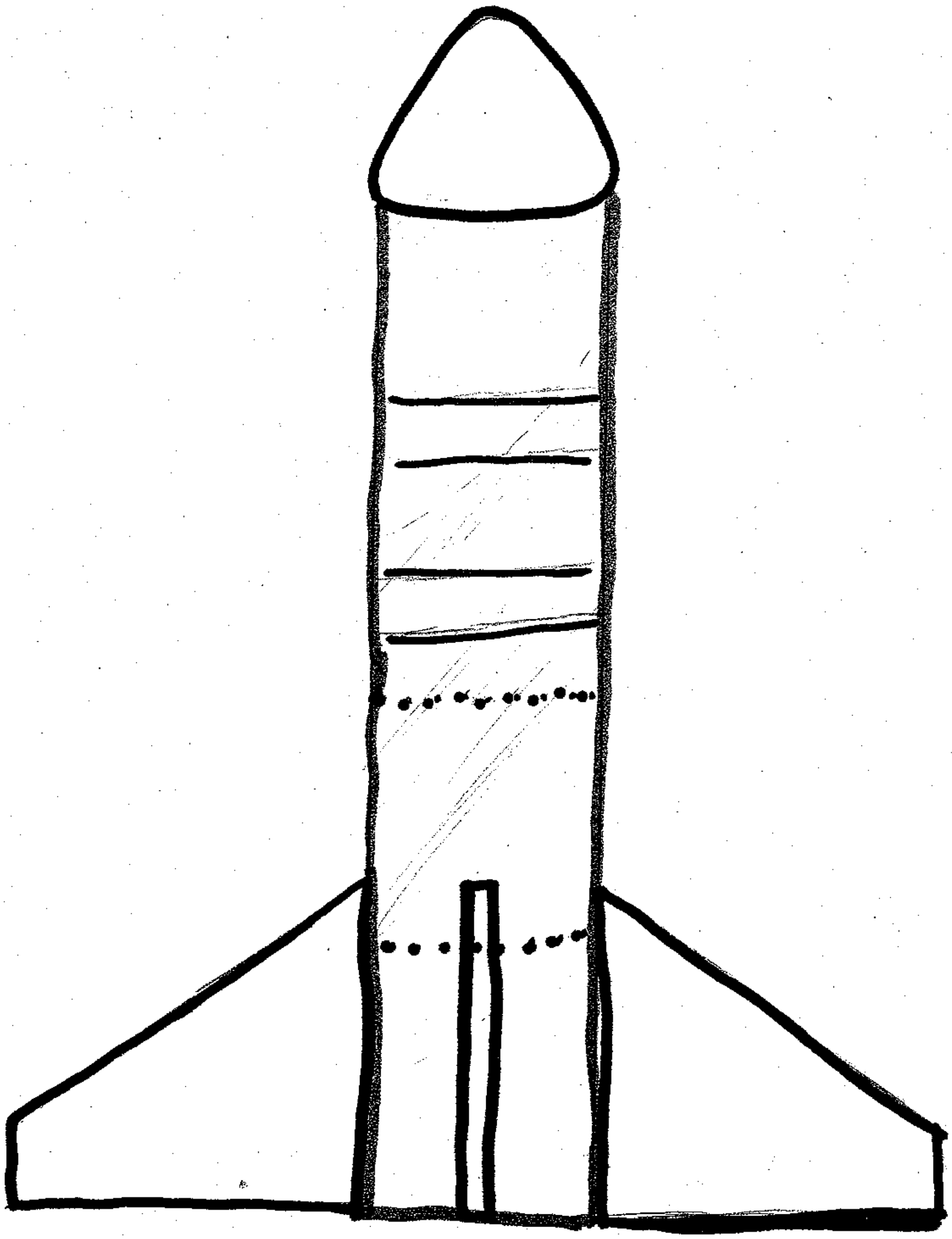
When the construction is done spray paint the entire rocket and wait until it's dry. Decorate as you wish using stickers or markers or anything of that kind but don't add too much. Keep weight into consideration. After the assembly and decoration is done the rocket will be ready to launch. As a launch pad use a cinder block on a fairly level surface so rocket will go straight up.

Safety Precautions:

Since this is a chemically propelled rocket there are some chances of it combusting. Make sure to have a fire extinguisher at launch site and also everyone is to wear safety goggles. Whoever lights the rocket should be able to run fast so they can get away immediately after ignition. Stand at least 50 feet back from the rocket when observing. Everyone should pay close attention to what's going on and when it's being lit. Enjoy!

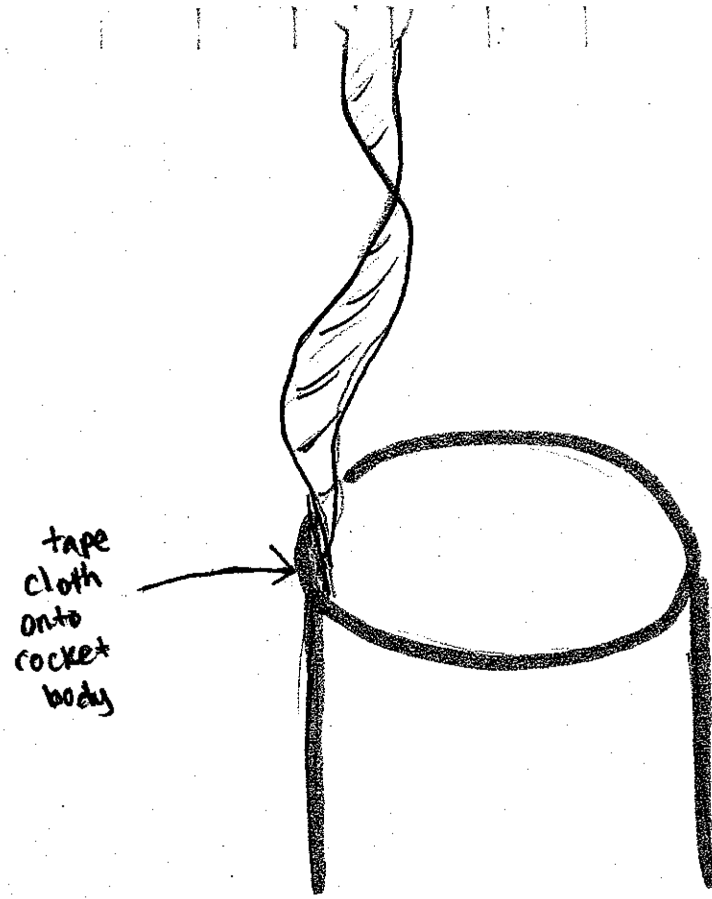
Julia Malmborg

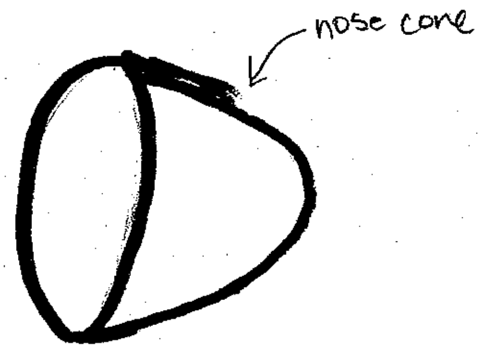
Rocket Design

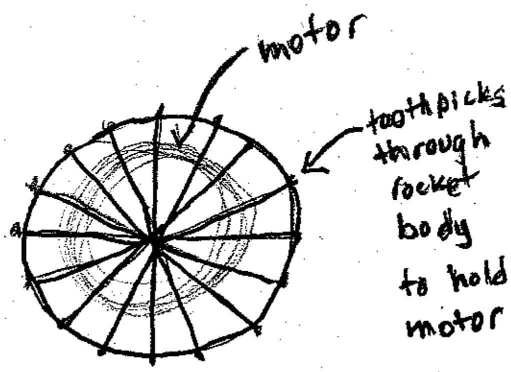


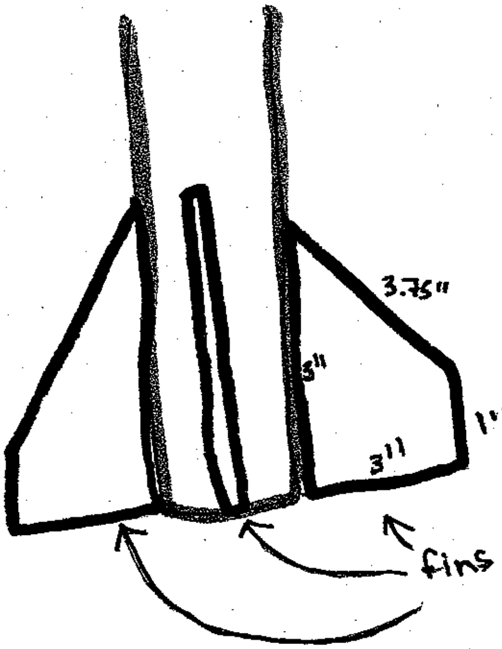
NOT ACTUAL SIZE

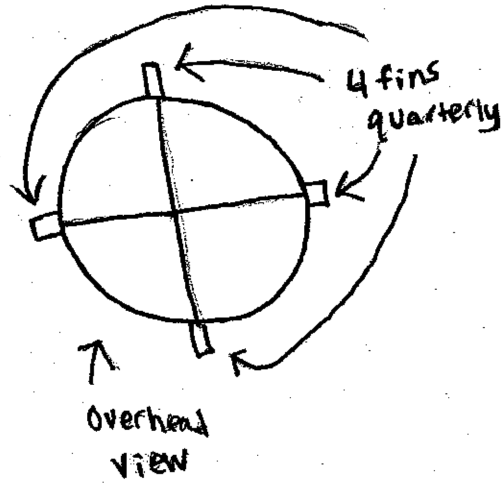
Julia Malmborg











Model Rocket Design

Shawn O'Donnell

-- Materials --

1. Rocket Engine

2. T-20 Body Tube

-- Specifications

- Inner Diameter .71"
– Outer Diameter .739"
– Length 12"
– Weight 6g
-- Product Number T-20/12

3. T-20 Wood Nose Cone "B"

-- Specifications

- Length 1.7"
- Diameter .739"

-- Product Number BNC20B

4. Balsa Bulkhead

-- Specifications

- Size 20
- Diameter .71"
- Length 1.5"

-- Product Number BH20

5. Basswood Sheet (for fins)

-- Specifications

- 3" x 24" x 1/32"

-- Product Number BAS-1323

6. Fine Sand Paper

7. Paint

8. Strong glue and/or small screws/nails

9. Kite String

-- Specifications

- Length 30"

Note: include some extra length for knot tying etc.

10. Sport 'Chute

-- Specifications

- Diameter 9"

-- Product Number SC-9

11. (2) small eye screws

The body tube, nose cone, bulkhead, parachute and basswood sheet can all be ordered from: www.asp-rocketry.com

-- Construction --

1. Cut the kite string into a 25" (main line) piece and a 5" (cone line) piece, don't forget to leave extra on each line for knots.

2. Screw an eye screw into the center of the bulkhead, then tie the main line to the screw. The bulkhead should be inserted into the body so that the side closest to the bottom of the rocket is 2.75" away from the bottom, and that the eye screw is pointing towards the top of the body. Securely attach the bulkhead with strong glue or small screws/nails (minimum of 8).

3. Cut out the fins from the sheet of basswood. For fin design see diagram 2.

4. Sand the nose cone, body, and fins with a fine grained sand paper until smooth then paint. After the paint has dried sand them again until there is only a thin smooth layer of paint.

5. Attach the fins to the end of the rocket body using strong glue. See diagram 3.

6. Assemble the parachute then attach the free end of the 25" main line to the parachute's shroud lines. About 3-5 inches down the main line from the shroud lines tie one end of the cone line.

7. Attach another eye screw into the center and bottom of the nose cone. (There should be a predrilled start for the eye screw in the wooden dowel that will be with the cone) Tie the free end of the cone line to the eye screw, and insert the chute into the top of the rocket body and put on the nose cone. (If the nose cone fits tightly sand it down until it fits fairly loose)

8. Insert the rocket engine into the bottom of the rocket. Wrap masking tape around the engine if it does not fit securely.

9. Find at what point on the body that the rocket will balance (horizontally). This point is the rockets center of mass. If this point is behind the center of pressure you can add mass to the front of the rocket or increase the size of the fins until the center of pressure is behind the center of mass.
$A(cp)= D(nose)*A(nose)+D(body)*A(body)+D(fins)*A(fins)$

10. You can use any small diameter metal rod stuck in the ground for launch as long as there are tubes on the side of the rocket that can fit over the rod. There are also launch setups that can be purchased from www.asp-rocketry.com.

11. Safety: When launching stand a safe distance away, base this on the engines possible explosive power.

Figure #1

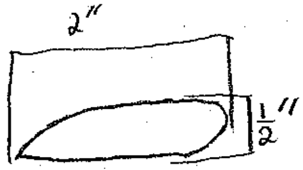
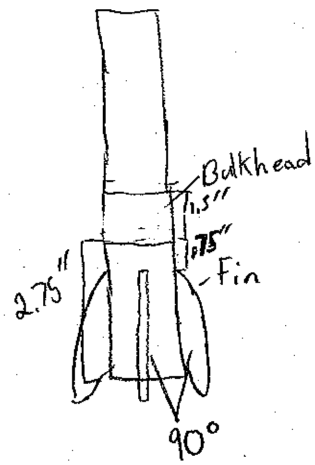


Figure #2



Rueben Hoffman

Model Rocket Body Design

Material List:

1-2 Cardboard Tubes, 12'' long, 1 - 1½'' in diameter

Plastic suitable for recovery shoot (garbage bag, etc.)

Cardboard, straight and capable of being cut

Cardboard/Notecard material for the nosecone

Fishing Line

Carpenter's/Insulator's foam

Duct Tape

Paper Punch Reinforcers (office supply)

Extra Tissue/Cloth/Toilet Paper

Metal Clip (if necessary)

Construction Instructions

For the body: use an appropriately sized cardboard tube

For the fins: cut four stripes of rectangular cardboard, roughly 1'' x 2-3''. remove an equal triangular segment from the "upper" edge of the fin. Apply to the body using Duct Tape and/or glue; must be steady without movement. Secure them to the lower end of the body with a slight tilt parallel to the body. Use the same directional tilt for each fin; this will form rifling.

For the motor attachment: apply carpenter's foam to the bottom of the body, filling it to a depth of 4-5'', after hardened cut out a hole for the placement of the rocket, leaving leeway on either side. Place the motor in the hole, and secure using another application of foam around the motor. Hold the motor straight as it hardens. Optionally, a metal clip may be applied to the hole first, with the purpose of preventing the motor from leaving the rocket in either direction. If it is applied, it will need to be secured to the rocket body either at the base or through the walls, perhaps both. To reuse, the foam may be recut and applied if necessary.

For the recovery: cut a circular sheet of plastic of an appropriate type approximately 6'' in diameter (more may be necessary depending on the amount of foam used earlier). Make 6 holes at least ½ an inch in from the edge at the same radius from the center. Apply a paper punch reinforce to each side of each hole to make them sturdy. Tie a length of fishing line from each hole, which must then be attached to one central line/twine. The resulting lines going to each hole must be the same length, approx. 5''. secure the central line to the inside of the top of the body, at a depth roughly equal to the radius of the shoot using duct tape, and further secure it by application of carpenter's foam. The central line must be long enough to stretch from the securing point to 2'' above the top of the body, so the shoot may deploy. It is acceptable to punch a hole in the side of the body to secure it to if this fails to secure.

For the nosecone: using another length of cardboard tubing or firm paper, cut out, fold, and staple/duct tape together a cone for the nose. This may be of nearly any shape, preferably longer then it is wide, and wider around then the top of the body. Using remaining cardboard tubing, cut a ring off the end, roughly 2-3'' long, and widen it by cutting it to form a strip, then apply duct tape to create a ring slightly wider then the body, wide enough to fit around it snuggly. Cut a circle of cardboard of the same size of the new ring, and secure it to said ring at one end by use of duct tape. Punch a hole in the center of this circle and attach a length of fishing line long enough to stretch from the top of the body to the securing point of the shoot. The ring formed must be smaller in diameter then the cone formed earlier. Attach the new ring to the cone with the circle of cardboard facing upwards by use of carpenter's foam in the tip of the cone and duct tape around the edges of the ring. The resulting nosecone should fit snuggly over the top of the rocket, leaving a lip around it to catch air which will be used to deploy the shoot. The nosecone must point straight upwards when applied to the body for straight flight. Secure the other end of the nose cone line to the base point of the shoot line where the six peripheral shoot lines meet.

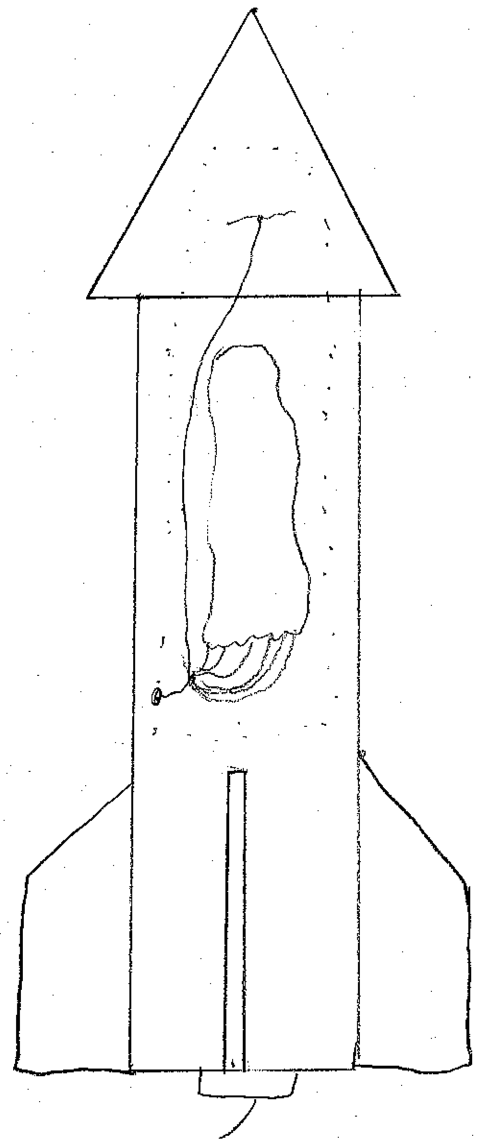
Packing: take hold of the center of the shoot and pull lightly downwards along the shoot and lines, making it able to fit. In this shape, rest the shoot inside the rocket body with the peripheral lengths beneath it and the lead line along side it. Place the nosecone snugly atop the top of the body, with it's line along the same side as the central line. When fired, after reaching maximum altitude, the drag of the air will pull the nosecone off thanks to the lips. When this occurs, the trailing length will draw the shoot up and out, which will deploy and carry the entire structure to the ground.

Cosmetics/Extras: if any holes were punched in the body to secure items, wrap duct tape around them to reduce drag and hold them steady. The entire thing, motor excluded, may be spray painted, and designs added to taste. Stickers etc. may also be applied.

Safety: Be sure the engine, body, and nosecone all point in the same direction to assure a straight flight. Stand away when launching. Clear the surrounding area (don't use in an urban setting, etc.). Use appropriate safety precautions for the type of motor.

Keubeu

Rocket Design



Nosecone

Reuben