Basic Rocket Knowledge

1. What is rocketry?
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1. What is rocketry?

Rockets have a simple job: they are built to lift a certain weight (the payload) to a certain height, usually as high as possible. The power to do this is almost always accomplished by a *rocket motor or rocket engine*. Rocket motors work by burning some kind of fuel very fast and using the recoil from the ‘ash’ to push the rocket forward.

Ideally the payload is supposed to survive the trip; all rockets should be built with a recovery system of some kind so that both the rocket and payload can return to the ground safely.

The story of the beginning of amateur and model rocketry is well documented in the book “Rocket Boys”, by NASA engineer Homer Hickham; a movie was made from the story: *October Sky*. Essentially... the Russians launch Sputnik, the first satellite to orbit around the earth. Because of Sputnik, Americans thought they were behind the Russians in rocket technology, and so there was suddenly a lot of public interest in rockets. Many ‘non-professional’ people experimented with rockets without really knowing anything about them; some people got very badly hurt as a result of this and a few even died.

In 1957 model rocketry was invented, as defined by the NAR Safety Code. Model rocketry allows children and adults to safely experiment with rockets by agreeing to follow a set of rules. The National Association of Rocketry was formed 1958. The NAR tests rocket motors, sponsors regional and national contests, offers insurance, and gives out academic scholarships to young rocket students.

2. Parts of a Rocket – see ‘Parts of a Model Rocket’ diagram

a. Nose cone – ‘cuts through the air’ – caps off top of body tube and streamlines rocket so that it can fly faster and higher. Comes off at motor ejection so that recovery system can return rocket safely to the ground.
b. Body tube or airframe – the main part of the rocket to which all the other parts are attached; houses the recovery system, payload, and motor mount.
c. Recovery system – could be a parachute or a streamer (a long ribbon of some light material) attached to nose cone and body tube with a shock cord. Slows down rocket from the top of its flight so that the rocket and payload are not damaged.
d. Shock cord – a length of elastic material connecting the nose cone and recovery system to the body tube.
e. Fins – keeps the rocket flying straight during flight.
f. Motor mount – hold the rocket engine securely but allows it to be removed easily after use.
g. Launch lug or button – attaches rocket to launch pad and guides it after launch until the rocket is moving fast enough for the fins to hold it straight.

3. Rocket Engines and a typical flight – see ‘Model Rocket Engines’ and ‘Rocket Flight’

Parts of an engine

a. Casing – holds all the parts of the engine together and contains the combustion of the fuel so it can be directed out of the nozzle.
b. Nozzle – steers the exhaust of the burning fuel so that it all moves away from the engine in one direction. The shape of the nozzle’s *throat* determines how well it does this.
c. Propellant or Fuel Grain – the engine burns this fuel to produce power or *thrust*. Model rocket engine fuel is usually compacted black powder (gunpowder), while mid- and high-power motors usually burn ammonium perchlorate (AP).
d. Delay charge/tracking smoke – after the propellant is exhaust, this charge burns for a set period of time to give the rocket time to coast to its maximum height. The delay charge also contains a material that creates smoke so that the rocket is more visible during flight.
e. Ejection charge – an explosive charge that is triggered when the delay charge is done burning. The explosion pushes the nose cone and recovery system out of the rocket so that it can return gently to the ground. Ejection charges are usually made of loose black powder.
f. Igniter – a piece of wire coated with some kind of flammable material, or *pyrogen*. The igniter is placed in contact with the end of the propellant grain by inserting the igniter through the nozzle of the engine. When a battery is connected to the ends of an igniter, the wire gets very hot and sets off the pyrogen, which in turn starts the propellant in the motor burning.

Model Rocket Flight

a. Ignition – the propellant in the rocket’s engine is started using an electric ignition system that connects a battery to an igniter inserted into the engine.
b. Powered flight – while the engines propellant is burning, the rocket accelerates rapidly off the pad and up into the air. The rocket reaches its maximum speed at the moment the propellant is exhausted.
c. Coast phase – the rocket engine is burning the delay charge during this phase; the rocket is slowing down due to air resistance (drag) and gravity as it coasts upward.
d. Ejection – at or near the peak of the flight, the delay charge is exhausted and the ejection bcharge is triggered, pushing out the recovery wadding, recovery system, and nose cone.
e. Recovery – the rocket floats gently down to the ground, slowed by its recovery system. Check the rocket for damage, prep it for launch with a new engine, and fly it again!

4. Safety Code – see the ‘NAR Model Rocket Safety Code’ sheet attached

Just like the guys on “Mythbusters”, model rocket flyers are proud to be ‘professionals’. The Model Rocket Safety Code is a set of rules that we voluntarily follow; no ‘police’ are going to arrest us for violating it. The Code is there to make sure that we don’t hurt ourselves, someone else, or damage someone’s property while flying rockets. Since 1958 at least 600 million model rockets have been flown with NO serious injuries or deaths; this is an average of more than ten million safe flights a year! Since our club will sponsor launch events where the public is invited to observe and participate, it is especially important that we set an example of how rocketry SHOULD be done; and that means doing everything we can to make our hobby as safe as possible for everyone involved.

Actually, the Federal Aviation Administration (FAA) does regulate some model rocket flights; you may have to get permission from the FAA for any activity near an airport or for the flight of any rocket heavy enough or high enough to be dangerous to an airplane. We only need to worry about this with the larger model rockets, though.

All these rules may seem like a big ‘bummer’ but…. If you play video games, you probably know what happens when you start to use ‘cheat codes’; the games aren’t near as much fun to play. In rocketry, there are so many different things you can try that it can be difficult to make up you mind what to do; the Safety Code gives you some limits and helps narrow your choices.

5. Duties of launch officers

Launch officers (advised by adults) are appointed on rotating basis by the club Board of Directors. All launch officers are responsible for making sure safety code is followed during launch events. Launch officers are official witnesses of club record and qualification flights; these flights must be declared ahead of time in order to count. The most important launch officers are:

Launch Control Officer (LCO) – Responsible for monitoring safety in the launch area. Checks in flights, manages pad assignments, supervises flights. Communicates with other launch officers, tracking and recovery crews. Master of ceremonies during rocket flights.

Range Safety Officer (RSO) – Inspects rockets for stability, payload and recovery security, compliance with safety code. Assists flyers with launch preparation. Assists LCO by monitoring launch area for safety problems. Can stop launch operations at any time, and his word is final (overrides the LCO) on any question of safety.

Refer to the club 'Range Safety Rules' document, as well as the 'Range Safety Officer Training' and 'Launch Control Officer Training' manuals for more information about launch operations and the duties of the LCO and RSO.

6. Engine classes and some rocket 'math'

The NAR Model Rocket Safety Code requires that all model rockets use NAR-certified, commercially produced engines. Model, mid-, and high-power engines are organized into alphabetical motor *impulse classes*. Model rockets flyers generally use classes 'A' to 'D' or mid-power classes 'E' thru 'G'. High-power motors are usually 'H'class or larger, up to 'O'. An engine one letter higher in the alphabet is twice as powerful; in other words a 'B' engine is twice as powerful as an 'A' engine. Twice as much power can mean many different things:

twice as much weight can be lifted
the engine burns twice as long
the rocket accelerates twice as fast
…or a combination of all three of the above.

A commonly used model rocket engine, the Estes A8 series, can easily lift a rocket that weighs about 2 ounces; from this fact we can guess that an Estes D12, which is about 8 times as powerful, could lift up to a pound (16 ounces).

Here's a handy table…

Impulse Class		Equivalent number of 'A' engines	Max. Impulse in Newton-seconds
A	'model'	1	2.5
B	'model'	2	5.0
C	'model'	4	10
D	'model'	8	20
E	'model' or 'mid-power'	16	40
F	'model' or 'mid-power'	32	80
G	'model' or 'mid-power'	64	160
H	'high-power', level 1	128	320
I	'high-power', level 1	256	640
J	'high-power', level 2	512	1280
K	'high-power', level 2	1024	2560
L	'high-power', level 2	2048	5120
M	'high-power', level 3	4096	10240
N	'high-power', level 3	8192	20480
O	'high-power', level 3	16384	40960

Engines and rocket math, continued…

All NAR-certified engines are labeled using a common system that tells you some basic things about the engine: the alphabetical motor impulse class, the average thrust of the motor in Newtons, and the length of the delay charge in seconds. A Newton is a metric unit; 4.45 Newtons of thrust equals 1 pound of thrust. The labels are not always accurate but can give you a good idea of how the rocket engine will perform.

What is impulse, you may ask? An engine's power or 'impulse' is a combination of how hard it pushes the rocket (the thrust) and how long it pushes the rocket (the burn time). For any motor in a particular alphabetical 'class' the impulse of the engine will be about the same. For instance, any 'H' motor will produce somewhere between 160 and 320 Newton-seconds.

So, if you know the average thrust and impulse rating of the rocket motor, you can figure out the burn time. If a particular 'H' has an impulse of 300 N-s, this may mean that it can 'push' the rocket with 30 Newtons of thrust for 10 seconds, or 150 Newtons for 2 seconds, etc. Working backwards, you can see that an Estes A8-3 rocket engine produces 8.0 Newtons of thrust for about 0.32 seconds; 8 N times 0.32 sec equals about 2.5 N-s of impulse, which matches the table above.

Example - An Estes B6-4 model rocket engine is:

a. A 'B', so it is about twice as powerful as an 'A' engine. This engine should be able to lift 4 ounces (including itself) into the air safely.
b. The average thrust should be about 6 Newtons. 6 divided by 4.45 = 1.34 so 6 Newtons is about 1.34 lbs. of thrust.
c. The delay charge (how long the rocket will be allowed to coast) is about 4 seconds.
d. The B6 series has about 5 Newton-secs of impulse, so the engine will burn for 5/6 or 0.83 seconds.

Example – An Aerotech G64-10W mid-power engine is:

a. A 'G'. It should have about 64 times the power of an 'A'. While this motor should be able to handle a 4-pound rocket, an Aerotech G64 is a 'wimpy' G (it has less than 160 Newton-seconds of impulse) so it can only lift about 3 lbs. with the engine and motor casing included.
b. The average thrust is 64 Newtons, more than 10 times that of a B6-4; about 15 lbs. of thrust.
c. The delay is about 10 seconds.
d. A G64, being wimpy, is rated at 120 N-s of impulse, so the engine will burn for 120/64, or a little less than 2 seconds.
e. The 'W' on the end tells you that this motor uses a special type of AP propellant called 'White Lightning'. 'W'-fueled motors are very loud and produce lots of white smoke.

The manufacturers of rocket motors can supply you with more detailed numbers for their engines: the exact 'impulse' the engine produces, the amount of time it takes to burn, exactly how much the engine weighs before and after it has been used. You can even get a *thrust curve* for the most popular engines, which tells about how much thrust the engine produces at each point in time between ignition and burnout. Very few real engines burn evenly, so the thrust that a motor produces can change quite a bit from ignition to burnout. See the 'Popular Model Rocket Engines' sheet for more detailed numbers on engines; we will use some of those numbers for some more 'rocket math' below.

7. Common conversion factors for 'rocket math'

Because rocket science uses a lot of metric units instead of the common English ones, the following table might come in handy:

From Unit		To Unit
1 Newton	=	0.225 pounds (force)
1 pound (force)	=	4.45 Newtons
1 ounce	=	28.35 grams
1 kilogram	=	1000 grams
1 kilogram	=	2.204 pounds (weight)
1 pound (wt)	=	16 ounces
1 pound (wt)	=	453.6 grams
1 pound (wt)	=	0.4536 kilograms
1 meter	=	3.28 feet
1 meter	=	39.374 inches
1 meter	=	1000 mm or 100 cm
1 inch	=	25.4 mm or 2.54 cm
1 mile	=	5280 feet
1 mile	=	1610 meters
1 meter per second	=	3.28 feet per second
1 meter per second	=	2.236 miles per hour
1 foot per second	=	0.6818 miles per hour
1 mile per hour	=	0.447 meters per second

And here are some handy 'constants':

Acceleration of gravity = 9.81 meters per second per second (metric)
Acceleration of gravity = 32.2 ft per second per second (English)
Density of air at sea level = 1.225 kilograms per cubic meter