About Model Rocket Engines

Introduction

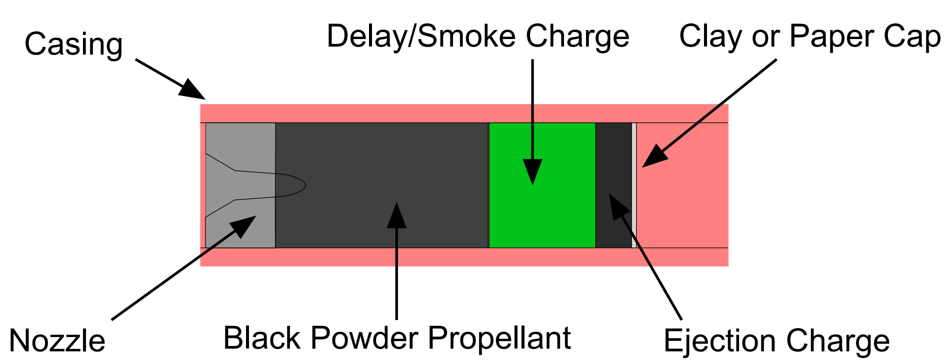
The commercially produced (rather than homemade) model rocket engine is what literally makes your rocket take flight - it is also what has made model rocketry one of the safest hobbies in the world. When used according to some simple instructions and following the safety code model rocket engines are safe and reliable.
Here is a brief introduction to model rocket engines, it's not an exhaustive discussion by any means, but should get you a basic understanding of them and how they work. At the end will be several links that you can pursue for more details and info if you'd like.
As a quick aside before we go further, use of the terms "Engine" vs. "Motor" is a subject often brought up for debate when it comes to model rocketry, and even though there *is* a semantic difference between the two terms (and some would argue that one is correct and the other not), most people use the terms interchangeably.

Types of Model Rocket Engines

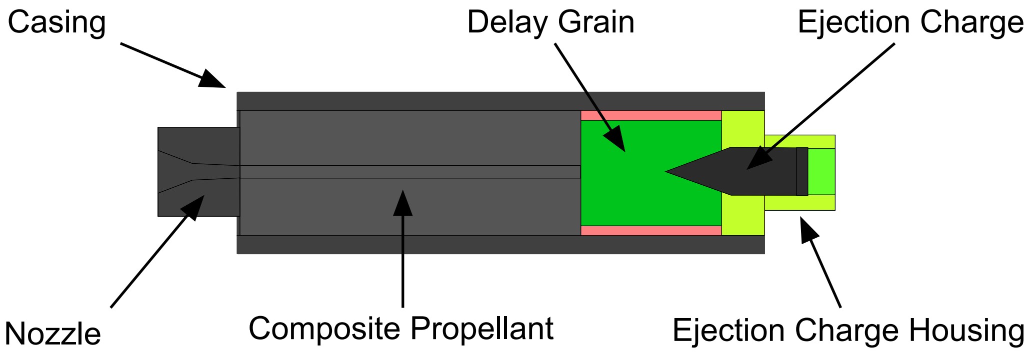
Most model rockets use pre-made solid propellant engines that are designed to be used once and then disposed of, with another engine being used for the next flight of the model. There are also commercially manufactured reloadable engines, but we'll leave the discussion of those for another time.
There are two commonly used types of propellants in model rocketry: black powder and composite. Black powder has been used since the early days of the hobby and is still the most common propellant for smaller sized engines. Composite engines are more recent, but have still been around for many years. They use a propellant similar to what was used in the booster engines of the space shuttle. Composites propellants are more powerful than black powder and are generally used for larger size engines - small composites engines can be made, but as they are generally more expensive than black powder engines to manufacture, most smaller engines stick with black powder.

Parts of A Model Rocket Engine

Typical engines have just a few basic parts: at one end is the nozzle, and behind that the propellant (black powder or composite), a delay and last an ejection charge.



Typical Black Powder Model Rocket Engine

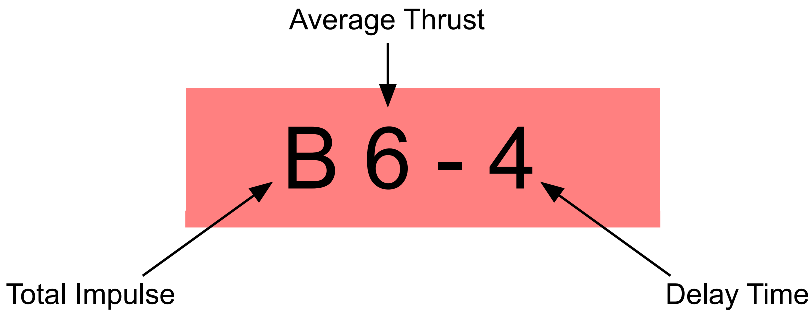


Typical Composite Model Rocket Engine

When it is ignited, the gases produced by the burning propellant are directed out of the nozzle and the thrust from the engine lifts your rocket skyward. As the propellant is used up and it continues upward, the delay charge burns. This delay charge does not provide any additional thrust and let's the rocket coast up towards the top part ("apogee") of it's flight. Most delay charges also product some sort of smoke that makes it easier for you to see and track the rocket as it goes up.
When the delay is used up it ignites the ejection charge which is used to (typically) push out the nose cone and the recovery device (parachute or streamer) for your model.

What Those Letters and Numbers Mean

Rocket engines are usually grouped into power levels that have a letter designation (A, B, C and so on). The thrust that an engine generates is given in *newtons* (a newton is the force required to cause a mass of one kilogram to accelerate at a rate of one meter per second squared). An A engine for example can have a *total impulse* (or more simply *power*) between 1.26 and 2.5 newtons. Each letter value essentially doubles the amount of power in the engine (a B engine can have from 2.6 to 5 newtons, a C from 5.1 to 10, etc.). Even though there is a range, most smaller size engines tend to have the full, or close to the full, impulse. When you get to large engines, say a I, there tends to be more variation within the range (currently there are I engines that range from 330 newtons to just under the maximum range of 640 newtons). For most of you, especially when starting out, it's not terribly important to know all these details, but to remember that in general a B is going to be twice as powerful as an A (and your rocket can go about twice as high), and that a C is twice a B (and it will go higher still!). How high your rocket goes is important to keep in mind depending on the size field you are flying from and the chances of loosing your model if it goes too high and drifts away on recovery.



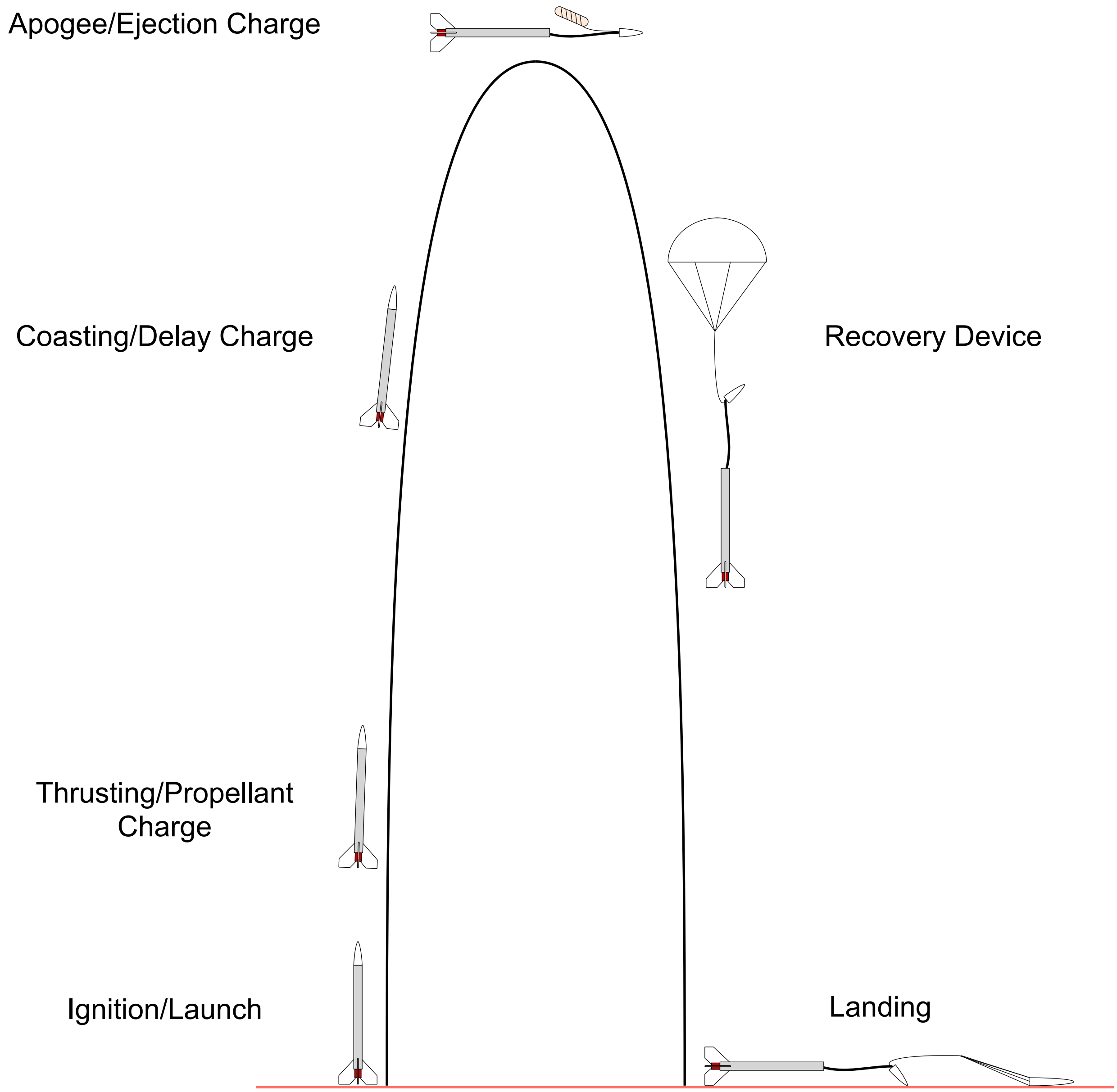
There is a designation printed on the outside of every engine

In addition to the letter on an engine there are also some numbers - let's look at a common engine as an example. The B6-4 engine is, as we know now, an engine that can have between 2.6 and 5 newtons of total thrust due to the "B" designation (an Estes brand B6 actually has 4.9 newtons). The number that follows the letter, 6 in this example, refers to the *average thrust* in newtons. What this can tell you is how fast the propellant burns - a B6 uses up it's propellant in a mere 0.86 seconds! In contrast, a B4 engine burns slower, and takes 1.03 seconds to use up it's propellant. This may not seem like a big difference, but the rate at which an engine delivers it's thrust can effect how your rocket flies (we'll leave that subject for another article at another time). But the easy way to remember is that the smaller the second number, within the same letter designation, the less the average thrust and the slower the rocket will fly.

The last number after the dash, 4 in the case of a B6-4, is the time that the delay charge burns and how long it will allow the model to coast upward after the propellant is burned. At the end of this delay time is when the ejection charge is activated to blow out your recovery device. This number is very important to a safe flight for you model! In most cases you want your rocket to coast up to the maximum height possible (the apogee of the flight, see the drawing of a "Typical Model Rocket Flight" below) and have the ejection charge go off then - it is at this point where there will be the least stresses on the rocket and the best chance of a good flight. If the rocket is still going upward at a high speed when the ejection charge goes off there is a chance the recovery device could be damaged and result in a crash. Likewise of the ejection goes off after the apogee and the rocket is already heading downward the recovery device could be stripped off, or if the rocket is heading downward at a high rate, the ejection charge may not even be powerful enough to push the nose cone off and the model will come down in an unsafe manner.

The same power of engine is often produced with different delay times for flying in different models that will require a longer or shorter delay. The B6 in our example is also available in a two-second delay (B6-2) and a six-second delay (B6-6).

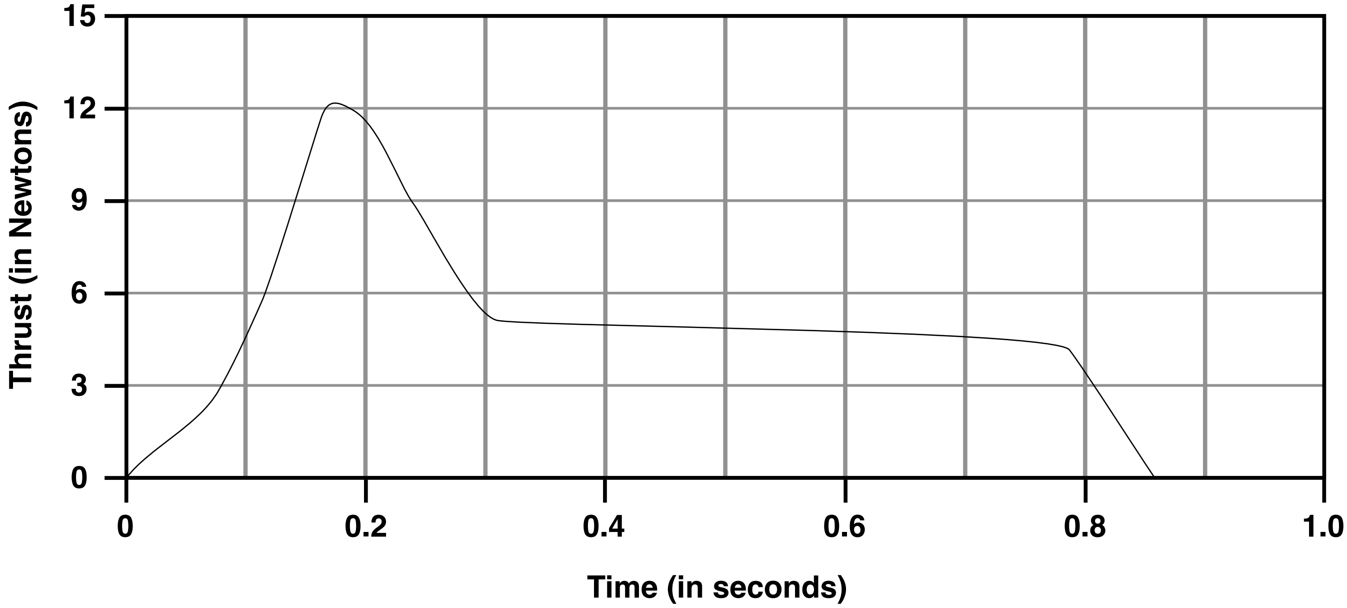
There are also some engines that have a zero at the end (B6-0 for example). These are very specific "booster" engines that do not have a delay or ejection charge. These are for use *only* in the lower stages of two or three stage kits (such as our Two High! and Way Two High! kits).



Typical Model Rocket Flight

What is a Time-Thrust Curve (and why do I need to know about it)?

As noted above, the first number in an engines designation tells you the average thrust for the engine. It's the *average* thrust because most engines do not burn their propellant evenly. Most engines will have a spike of thrust/power when they first ignite to help get the model off the pad rapidly - this gets you model up to speed to allow the fins stabilize it for a safe flight. After this spike has gotten the rocket going, typically the rest of the thrusting phase does not need to be as high to keep it going upward.



Time-Thrust Curve for a B6-4 Engine

Above you see an example of a time-thrust curve for a B6 engine. You'll notice that the thrust spikes just about 0.2 seconds after ignition then declines and levels off for most of the burn time and burns out just after 0.8 seconds (at this time the delay charge would start burning in our example of a B6-4).

The initial spike of thrust (and how much thrust the engine develops) is also a big factor in how heavy your model can be to lift off safely. The length of the delay is also important and the engine manufacturers have determined a "Maximum Liftoff Weight" for each of their engines. This number is very helpful if you are designing your own models, or if you have altered a kit (such as adding a payload section, etc.).

Time-thrust curves and lift-off weight info is usually included with the packages of engines. You can also find the information online (http://www.nar.org/standards-and-testing-committee/nar-certified-motors/ is a good place to start).

Sizes of Model Rocket Engines

The physical size of the engines goes from the tiny MicroMaxx that's a mere 6mm (less than a quarter-inch) in diameter on up to High-Power ones that may be as much as 98mm (nearly four inches!) in diameter.

Probably the most commonly used engines are A, B and C "standard" size engines that are 18mm in diameter and 70mm long (about 0.70" by 2.75"). "Mini" A engines are also common and measure 13mm by 45mm. 24mm diameter engines are typical for most D and E power engines and most are 70mm long but can be longer. Mid and High-Power engines are typically made in 29mm, 38mm and 54mm diameters (and can be larger) with the lengths varying depending on the engine and the manufacturer.

And Just What is "Mid-Power" and "High-Power"?

For many years the "Standard" and "Mini" black powder engine were about all that was available to modelers to propel their rockets. Later on larger black powder D, E and F engines

came along, and then with the introduction of composite propellants even larger engines became available. With this wide range of available engines designations have come up to group them into classes.
"Low-Power" rockets use anything up to an E engine, while models using F and G engines are considered "Mid-Power". Anything flying on H engines and up are designated as "High-Power".

What Engine Do I Use?

If you're just starting out, the best advice is to simply use the engines recommended for the kit you're flying! If your kit is designed so that it can fly on several types of engines (it's typical for a model that can fly on an A engine to also be able to use a B or a C engine, for example) it's best to start with one of the lower powered engines recommended so that you can judge how high it goes and how easily it may be recovered on your field. After that you should be able to judge if it's safe to use more powerful engines.
If/when you progress into designing your own models, it's a good idea to use a computer simulation program (such as OpenRocket or RockSim) to virtually "test fly" you design with different engines and different delays so you can select the best choices for your design.

Restrictions

You have to be 18 years old to purchase engines G power and above. To purchase and use High-Power engines (H and up) you have to go through a certification procedure by either the NAR or Tripoli (you can find details on these certifications on their websites at www.nar.org and http://www.tripoli.org.

There are also some state restrictions when purchasing model rocket engines - here is a brief rundown.
In **California** you must be at least 14 years old to purchase engines up to D power. 18 years old is the minimum age for larger engines. Some cities and counties in California have more restrictive rules - check with the local Fire Marshall if you are unsure of the rules.
In **New Jersey** you must be at least 14 years old to purchase engines up to C power. 18 years old is the minimum age for larger engines.
In **Rhode Island** you must be at least 16 years old to purchase and use engines up to F power.
In **North Dakota** you must be at least 10 years old to purchase engines up to D power. 14 years old is the minimum age for larger engines.

When something goes wrong

While model rocket engines are typically *very* reliable, a small percentage (usually about 0.05%) will malfunction. This may be a delay charge that's longer or shorter than it is supposed to be, or something more dramatic like a catastrophic failure ("Cato" for short). When an engine does malfunction, you need to contact the manufacturer of the engine *directly* about replacements for the engine and any damage it may have caused to your model. Most of the manufacturers are usually pretty good about taking care of issues with defective engines.
If you do have a problem it's also a good idea to fill out a "MESS" (Malfunctioning Engine Statistical Survey) form. The Malfunctioning Engine Statistical Survey is a joint organization program that allows NAR Standards & Testing, Tripoli Motor Testing and the CAR Motor

Certification Committee to track field trends in the reliability of sport rocket motors. You can find the form on the NAR website (http://www.motorcato.org).

For More Info

Here are some pertinent links in addition to the ones noted above:

ThrustCurve.org - Here you will find manufacturer specs, certified performance data and other info on commercial model rocket motors and high-power rocket motors. Most importantly, you can download thrust curves for use with rocket flight simulators (including wRASP, RockSim and SpaceCAD among others).