Battery Buggy

Introduction:
Hi, I am MadCow2357. This is a guide based on my experiences, and other competitors may have different opinions or think differently. Hopefully this guide can provide a good starting point for beginners to this event.

Overview:
Battery Buggy is a Division B vehicle event for the 2019 season. It requires participants to design and build a moving, battery-powered vehicle capable of traveling a certain distance and stopping as close to the ending dot at that distance as possible. The device must meet several parameters regarding size, total power used, types of power used (power must be electrical), and safety restrictions.

Planning:
There are several ways that you can design/build your buggy, each way with advantages and disadvantages. Here are some of the most common approaches that teams take:

Official Battery Buggy Kit:
Designed by Ward’s Science in partnership with the Science Olympiad, this kit is arguably the simplest way to build your Battery Buggy. While rather expensive, teams often take this approach if they want to skip the risks and troubles of buying/ordering parts by themselves (more on this in a minute or two). In other words, this kit comes with everything you need to build a basic battery buggy. However, there are significant downsides to taking this option. First and foremost, this kit will only take you so far. The description on the website says that the kit is not “intended to be an "out of the box solution" for competition. Students and competitors should practice innovation and creativity to make their design their own competition-ready device.” That is, buggies that are built from this kit will, in general, lag behind other buggies built from scratch in terms of performance capability, reliability, etc. Additional downsides include the substantial cost, and the overall quality of the parts.

Commercially Available (Toy) Construction/Assembly Systems:
This method of building is way simpler than the confusing title implies. Basically, you construct your buggy out of pieces/parts from toy construction/assembly systems like Lego and K’nex (Figures 1 & 2), just to name two of the most popular. While you may have to modify a few parts (e.g. by widening an axle hole with a drill), or use a bunch of aesthetically unappealing adhesives (e.g. hot glue), this method is definitely the least time consuming and the cheapest of all the options. That is, assuming that you already have a large collection of either Legos or K’nex (or Lincoln Logs, though it’s hard to imagine how you would turn those into a buggy…) you are willing to “sacrifice”, and that you know your way around them. It is important to know, however, that like building from the Official Battery Buggy Kit, the performance capabilities of a buggy built in this way will likely not be able to match buggies built from scratch.

Modifying an RC Vehicle
This section needs work.
Obviously, the biggest issue with modifying an RC vehicle is implementing automatic braking, and replacing the motor if it does not meet construction parameters. Assuming that you use a wingnut braking system, you must replace at least one axle with a threaded rod. That can be a hassle, since you would likely have to widen the axle holes and wheel mounts. The steps that you have to take to modify an RC vehicle are risky, and usually result in inprecise angles (then bad accuracy).

**Building from Scratch:**

Considered to be the best method, hands down, by pretty much any wheeled vehicle veteran. If you want to achieve the highest level of competitiveness in Battery Buggy, or in any wheeled vehicle event, this is method for you. But keep in mind, this is the hardest, most expensive, and most time consuming of all three most well-known methods. The total cost to build your buggy, if you choose this method, will likely skyrocket over $200, and perhaps even top $400. Additionally, buggies built from scratch usually take much more time to build than buggies built in other ways. See Figure 3.

![Figure 1](A LEGO battery buggy. Note: it does not meet current buggy construction parameters.) ![Figure 2](A K'nex set. Unfortunately, I could not obtain a K'nex battery buggy picture.) ![Figure 3](A buggy built from scratch. Built by students from Walter S. Parker Middle School.)

**Basic Design/Construction:**

*From this point on, this guide can only assist the readers who have chosen to build from scratch.*

**Chassis Material:**

Each material has its advantages and disadvantages. Think very carefully about the material you want to use.

**Overview:**

*Note that this chart only covers basic chassis materials.*

<table>
<thead>
<tr>
<th>Material</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Wood</td>
<td>● Cheap (depending on what species of wood) ● Common</td>
<td>● Prone to warping ● Highest level of precision is hard to achieve</td>
</tr>
<tr>
<td>Material</td>
<td>Easy to work with</td>
<td>Versatile</td>
</tr>
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</tr>
<tr>
<td>Metal</td>
<td>Common (found at most hardware stores)</td>
<td>Stiff and very hard</td>
</tr>
<tr>
<td>Plastic (most specifically ABS and PLA)</td>
<td>3D printing ensures top-notch precision</td>
<td>Many colors!</td>
</tr>
</tbody>
</table>

**Wood:**

Wood is by far the most common chassis material, and not without good reason. It is cheap, common, easy to work with, and relatively durable. You can get wood at pretty much any Home Depot or Lowe’s for a low price, and many dads have prior woodworking experience that will help a lot. People usually either form a “simple box frame” (Figure 4) by connecting four pieces of wood, or place bearing mount blocks on a thin rectangular sheet of plywood (Figure 5). Keep in mind, however, that wooden buggies are rather susceptible to drifting/curving, most often caused by natural imperfections in the wood.

![Figure 4](image1.png)

![Figure 5](image2.png)

MadCow2357’s slightly modified box frame buggy.

Green bearing mounts screwed onto a plywood board..

*Note: This is not a Battery Buggy, though it may seem similar.*

**Metal:**

Metal is hands down, the hardest, most durable, and most rigid chassis material out there (except for possibly carbon fiber, but that's for later). It is found in most hardware stores, and actually much cheaper than you would expect. Your best bet is to connect square aluminum tubes into a box frame, like Nestor Tkachenko did with his Electric Vehicle (link in resources section). Solid bars are too heavy, and will thus slow down your buggy, so hollow tubes are a must. The biggest downside to metal is how difficult it is to work with. You may
require the use of expensive power tools, and those are usually quite dangerous. Thus, seeking help from a professional is definitely recommended. Otherwise, you could waste a bunch of time (and money) trying to get the lengths and angles just right. Or, even worse, get a nasty cut from the power tools involved. Just gonna point that out...

Figure 6

Figure 7

Aluminum buggy by builder83.

Nestor Tkachenko’s impressive aluminum electric vehicle.

Note: This is a device for the Electric Vehicle event in Division C. The rules for EV differ from battery Buggy, so some components shown may not be legal for Battery Buggy.

Plastic (3D Printing):

Plastic is probably not what comes to mind when you hear the words, “Battery Buggy chassis material”. To be honest, that’s completely understandable. ABS plastic is prone to warping (you basically need a heated build plate to accurately print this stuff), and PLA is known to be somewhat brittle. Nylon is very durable, but most 3D printers can’t print in nylon. And all of the above listed materials cost a ton of money, not to mention the meaty price tags for the 3D printers themselves. All in all, 3D printing is most expensive and least durable (depending on the compared materials) way to go among the basic options (material choices). However, by 3D printing, you can achieve levels of accuracy that you can never get by working with wood or metal (with traditional methods; laser cutters can level the field though) by 3D printing your chassis/parts. That is a serious advantage.

It is recommended that you only 3D print smaller pieces, though, with dowels of some sort to connect them. This method results in a light, strong, and aesthetically pleasing battery buggy that can have a significant edge in terms of both speed and accuracy.
windu34’s Electric Vehicle, second place at 2016 National Tournament. Composed of PLA plastic and carbon fiber.

MadCow2357’s 3D printed battery buggy (ABS plastic and carbon fiber). 4th at RI State competition.

Other Materials:
The below listed materials are not commonly used. Not too much is known about them (in this specific context), so the descriptions are sometimes based entirely on speculation. Please use this information at your own risk.

- **Carbon Fiber** - CF is quite possibly the material with the best weight to strength ratio of all. It is light and strong (rigid, durable, etc.), but very expensive. A meter long rod (about 8mm square) could easily cost you over $10. That price might not sound scary, but it is much more expensive than (common) wood or metal. Anyways, sheets are hard to work with, so CF tubes are the way to go (both square tubes and round tubes work fine). 3D print connector pieces to create a frame. Essentially, the carbon fiber rods act as the main structural members, while the connectors, well, connect the rods. See Figures 8, 9, and 10.

- **Foam** - Using foam for your chassis is definitely not recommended. Foam is extremely light and easy to work with (in a crude manner, of course), but it has terrible durability and rigidity. It is also virtually impossible to accurately work it, meaning that the hole Johnny drills for his axle will most likely result in a “zigzag” or a “slant”. More rigid and durable foams are out there, of course, but they are (probably) woefully expensive. A foam chassis would be a feasible solution, maybe, if you need to build a buggy in, say, half an hour. Simply drill roughly parallel holes for the axles in a large foam board. See Figure 11.

- **Cardboard or Corrugated Plastic Board** - You build in the same way with either of these materials as you might do with a piece of plywood. To give a quick recap, you put bearing mounts on top (or on the bottom, whatever you prefer) of the board, and place the other components on another section of board. Or, if you have a corrugated plastic board (Figure 12), you can simply thread the axles through
the gaps in the plastic (though this depends on the cross-sectional diameter of the axle and the space between each support in the corrugated plastic board). But like foam, cardboard and corrugated plastic both lack in durability and rigidness in comparison to plywood. Thus, it is pretty clear that plywood is preferable to cardboard or any similar material.

<table>
<thead>
<tr>
<th>Figure 10</th>
<th>Figure 11</th>
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Cheese’s carbon fiber battery buggy, which earned a sixth place medal at the 2018 National Tournament.

<table>
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<th>Figure 12</th>
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Corrugated plastic board.

**Wheels:**

Wheels are very important, if you didn’t already figure that out. They are the things that allow your buggy to move. Some factors that you may want to consider when choosing wheels:

- Price
- Traction
- Rigidity
- Durability
- Compatibility

**Banebots Wheels:**

The choice wheels for most serious wheeled vehicle competitors, Banebots wheels have good grip, durability, and aesthetic appeal - basically all the qualities you want in your buggy's wheels. But these wheels,
while very functional, can cut deeply into your budget. T81 and T40 wheels are $2.50 to $5.00 per wheel, and the wheel hubs (they are required) range from $4.00 to $5.00 a pop. As mentioned before: not cheap. But arguably the best.

**Figure 13**

Find the perfect wheel for your mobile robot

**CD Wheels:**

CD wheels have lost much of their previous popularity in wheeled vehicle events. Nowadays, most of the more serious competitors choose to spend more on better quality wheels (and other parts), such as Banebots, Lite Flite, Colson, and Fingertech wheels (just to name a few). But CDs were not popular for no reason, you know. In addition to being cheap and common, CDs are light and relatively rigid. The largest problems with CD wheels, are obviously attachment and lack of traction. You can buy CD wheel inserts to mount your CDs for a couple of bucks, and balloons can be used to add traction. Overall, CDs are extremely practical wheels for all wheeled vehicle events. See figures 14 and 15.
Gears:
Gears are essential for the transferring of rotational energy from your motor to your axle, which then turn your wheels. Alternatively, belts and pulleys can be used, but gears are more widely used. When getting gears, you may want consider the price, the number of teeth, the material, the mounting methods, the size, and most importantly, compatibility. It is essential that the gears must be compatible with each other, the motor’s output shaft, and the axle. That means that you have to worry about pitch angles, bore sizes, and mounting methods! But don’t worry, gears that are from the same manufacturer or series are usually compatible with one another. Finding gears with bore sizes that match your motor output shaft and axle diameters can be tricky, though.

Brake System:
Since other methods have been proven to be much less effective, this section will only cover the wingnut braking system.

The wingnut braking system consists of several components, including the threaded rod, the microswitch, the restraining bar/rod, and of course, the system’s namesake, the wingnut. When the axle (threaded rod) rotates, the stopping mechanism, the wingnut, which is restrained by the wingnut restraining rod (duh!), travels linearly along the rod and down the axle. Eventually, the wingnut will lock into place when it hits the stopping mechanism (which is most often a hex nut). It will also activate the micro switch, which cuts the circuit. The vehicle will stop, and the motor will not continue to run. A simple yet effective braking system.
Electrical Components:

Motor:
No motor? No battery buggy. The motor is perhaps the most important of the essential pieces in a battery buggy. Your motor’s rpm should depend on your gearing ratio and the diameter of your wheel, and both should depend on your target time. For example: if your buggy had 3.875 inch wheels (diameter) and a 990 rpm motor geared to a ratio of 1:1, you would get a time between 2 and 3 seconds. There are motor recommendations in the resources section.

Batteries:
According to 2018 rules, you can use up to 8 AA batteries in your battery buggy. It is strongly recommended that you buy a battery pack to hold the batteries.

Resources:
Here are some helpful links and resources that can be of assistance to you in building your buggy.

Scioly.org Pages:
- Battery Buggy Wiki
- Electric Vehicle Wiki
- Battery Buggy Forum - 2018 Season

Videos:
Note: These videos are only for inspiration. Please do not directly copy the designs shown. 4 of the 5 videos show devices built for the Electric Vehicle Event (Division C), so some components exhibited may not be legal for the Battery Buggy Event.

<table>
<thead>
<tr>
<th>Video Owner</th>
<th>Video Title and Link</th>
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<tbody>
<tr>
<td>Michael Laffin</td>
<td>Electric Vehicle Science Olympiad 2015 - Building and Competition</td>
</tr>
<tr>
<td>Kevin Hao</td>
<td>2nd place Electric Vehicle 2016 Science Olympiad National Tournament</td>
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<td>CD Wheel Inserts by Pitsco Education</td>
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