CONSTRUCTING WOODEN TOYS

Plans and instructions for making 15 toys, including techniques and jigs for machining small parts safely

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All proceeds are used by the SDFWA to support the toy donation program and other Association activities. For comments, suggestions, or questions about this book, please contact us at ToyBook@SDFWA.org.
In memory of

Helen and Charlie Bierman
Dedicated to Charlie Bierman

We worked with Charlie Bierman for 15 years, sharing many days together building wooden toys for donation through the San Diego Fine Woodworkers Association Toy Program or preparing materials for others to use in toy making.

Charlie was an innovator, perfectionist, and an extraordinary teacher. He was constantly designing new toys and finding better and safer ways to build them. For 20 years he was the leader of a toy building workshop of 15 members that still meets once a week and produces over 500 toys a year for donation.

He organized and instructed a four weekend course at Palomar Community College for many years, and he coordinated the work of other toy building workshops in San Diego County. To our knowledge, no toy left the Toy Program for donation without his stamp of approval for operation and safety.

Some years ago Charlie put together a pamphlet of instructions on the methods that he and others had developed to safely machine small toy parts and to mass produce these parts so that a number of duplicates of a toy could be produced efficiently. This pamphlet was used many times in workshops he gave over the years.

In 2016 he asked us to help him convert the material in this pamphlet into a full-length book, along with step-by-step instructions for building 15 of the most popular wooden toys made by the Toy Program. We met regularly to hash out ideas, review copy, and make decisions regarding content.

Charlie died in August 2017. He was working on this project up to the day he died. This book will serve as one of his many legacies, and we hope the reader enjoys using it as much as we enjoyed working with Charlie.

Steve Naiman
Charlie Pinkus
June, 2018
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The Toy Program of the San Diego Fine Woodworkers Association (SDFWA) takes pride in making quality wooden toys for donation to children throughout San Diego County. Since the inception of the Program about 25 years ago, the Association has given away approximately 35,000 toys to over 50 non-profit organizations that serve children, such as day care centers, health clinics, and pre-schools.

The purpose of this book is two-fold: first, to provide plans and step-by-step instructions for making fifteen of the Program’s most popular toys; second, to share a number of tips, techniques, and jigs unique to toy making that members of the Toy Program have found to be of great use for safely machining small toy parts.

The SDFWA toy workshops make 20 to 50 toys for donation at the same time. Some of the jigs described in this book were designed to make duplicates of toy parts that are interchangeable.

We hope that the information in this book will help you find pleasure in making wooden toys for your children, grandchildren, and friends, as well as for donation.

More information about the SDFWA can be found at: www.sdfwa.org.

Acknowledgements

We are indebted to a number of people who helped with various aspects of this book. This work would not have been possible without the excellent drawings produced by Bill White. In addition, we thank Lynn Rybarczyk and Andy Patterson for taking photographs of the toys included in the book and Sejal Pinkus for designing the covers. We are very grateful to Susan Davis for her thorough editing and suggestions, and Mike Davis for technical support.

Incorporated in this book are the ideas, knowledge and skills of many members of the SDFWA Toy Program. In particular, we thank Bob Dodds, Ed Gladney, Dan McNaughton, and Mark Tally who contributed drafts of several of the chapters. We also appreciate the reviews and comments on this work by Jeff Bratt, Roger Solheid, Dale Stauffer, and the support of the Board of Directors of SDFWA. Finally, we thank Augie and Shikari – our toy testers.
1. Safe Toys and Woodworking Safety

Introduction

This book is divided into two parts. If you are like the authors, you will want to get started constructing toys as soon as possible. Therefore, in Part I (Chapters 2 – 17) we include plans and instructions for making fifteen toys designed to amuse and educate.

Each of Chapters 3 though 17 is devoted to a different toy, and each of these chapters is self-contained. Therefore, it is possible to skip around and work on only the toys you are most interested in making.

Chapter 2, the first chapter of Part I, gives some important instructions and tables used throughout the book. It is suggested that you skim through this chapter to become familiar with the things that will be referred to often in Chapters 3 – 17, before starting to construct toys.

Part II (Chapters 18 – 22) is on toy making techniques and jigs. It is divided into chapters on each aspect of toy making, from shaping the body of a toy to assembly. These chapters include tips that apply to all the toys described in Part I, from machining small parts safely to examples of the jigs that have enabled the SDFWA Toy Program members to efficiently make 20 to 50 toys at a time for donation.

The remainder of this chapter provides some very important information on safety for you and for the child playing with toys, along with observations on how the design of toys influences the ways that children play with them.

Safety

Personal Safety

A number of the woodworking procedures presented in this book require cutting, drilling, and routing operations on small parts. It is essential that these parts are held firmly, either in a vise or with a clamp, in order to safely complete operations on them.\(^1\)

It is also essential that fingers are kept as far away as possible from tools. This can be difficult in making wooden toys, because toys are very small projects as woodworking projects go.

\(^1\) Disclaimer: Neither the authors nor the SDFWA (its directors and officers) assume responsibility for any injuries suffered or damages or losses incurred arising from the use of the information contained in Constructing Wooden Toys.
1. Safe Toys and Woodworking Safety

**Remember to:**

- Take your time - do not rush a procedure.
- Check and double check measurements.
- Avoid shortcuts – look for the safe way to complete every operation.
- Understand plans and instructions before beginning work on a toy.

Be constantly aware of potential dangers associated with using hand and power tools. Always be familiar with the safe procedures for using your tools, and never override safety measures out of laziness, fatigue, anger, impatience, or the desire for speed.

Finally, if you have not already taken a woodworking course during which you have passed a safety test, we strongly advise you do so before embarking on the projects contained in this book.

Woodworking can be very enjoyable, but it can also be dangerous. Don’t let an accident ruin your enjoyment.

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**Safety of Toys**

To insure that the wooden toys you make are safe for children to use, ask yourself the following questions:

1. Does the toy have smooth edges and corners and no rough surfaces?
2. Are all parts securely attached?
3. If it is a toy that has wheels, such as a car, does it roll freely when pushed on a hard surface?
4. If the toy has mechanical parts, does it work properly when pushed across a hard surface?
5. Do all loose, small parts satisfy the United States Consumer Products Safety Commission’s regulations for small parts for toys?

If you cannot say “yes” to all of these questions, repair the toy before letting a child play with it.

**Small Parts Regulation**

The purpose of this regulation is to prevent deaths and injuries to children under three from choking on, inhaling or swallowing small objects.

Figure 1-1 shows the anti-swallow test device developed by the Consumer Product Safety Commission.
Questionable parts are placed in the cavity of the test device. If a small part fits completely into the cylinder, and the toy or product from which it came is intended for use by children under three, the toy or product is banned because it presents a choking hazard.

If the part protrudes above the cavity, it is considered safe. If you plan to design wooden toys, it would be useful to have a copy of this test device. It can be purchased or made.

Following are the steps to make the device (see Figure 1-2 for the plan):

1. Start with a block of wood 2" wide, 3" long, and 2" deep.

2. Drill a 1 ¼" hole centered on one of the 2" x 2" ends through the entire 3" block.

3. Take a 1 ¼" dowel and trim the end at a 45 degree angle.

4. From the end that was cut at 45 degrees, cut off 2" from the longest side of the 45 degree angle. You should now have a piece of 1 ¼" dowel with one end cut at 45 degrees. The short side should measure ¾"; the long side should be 2".

5. Test that the dowel slides into the 1 ¼" hole cut into the 2" x 2" x 3" block of wood so that the flat end is square with the bottom of the cavity as shown in Figure 1-2. It might be necessary to sand the dowel to get it to fit.

6. Remove the dowel, put glue around the lower inside of the cavity, and glue the dowel in place.

7. The test device created should have the same cavity as the device shown in Figure 1-1.

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2 Anti-swallow test devices can be found by searching the internet, for example "Safety 1st Small Objects Tester". The cost is approximately $10.
How Children Play with Toys

There are many different types of toys, and children will find many different ways to play with any given toy. It is, however, important to distinguish between some common types of toys in terms of how children might play with them.

One basic distinction is between toys that are propelled, such as a toy car pushed along a floor, and toys whose pieces are manipulated, such as a puzzle. Furthermore, toys are propelled in one of three ways: either by a push stick, a pull string, or by hand.

The toy building chapters that follow include four push toys and four pull toys, including two toys that can be made as either a push or pull toy. In addition, there are four toys designed to be propelled by hand, and the remaining three toys are manipulated but not propelled, for example, the doll bed/cradle (Chapter 7).

The importance of the distinction between push and pull toys follows.

Push Stick Toys

Push toys are considered better than pull toys for children learning to walk. This is because children want to watch the motion of the toy. If the toy needs to be pulled, the child will have to walk backward to see it. Obviously this can lead to falls and bumps that can be mostly avoided by having the child push the toy.

In addition to allowing the child to watch the toy as he/she walks forward, the push stick also provides greater control over the movement of the toy and teaches directional control.

The push stick is a sub-assembly that is used on four to six of the toys described in this book. Rather than repeat the instructions for each toy, the steps for making a push stick and its grip are given in Chapter 2.

Pull String Toys

There are some toys that can be built with either a push stick or a pull string. The duck (Chapter 6) is an example. However, there are some toys that cannot make use of a push stick, for example, the honey bee (Chapter 8). To propel such toys, a child must either propel it by hand or use a pull string.

A toy with a pull string should only be used by a child who is comfortable walking backward because it is natural that the child will want to look at the toy as it is being pulled.

Since several toys in this book use a pull string, suggestions for making and attaching a pull string are given in Chapter 2.
Part I. Toys
2. Getting Started

This chapter includes information that is used in most of the toy chapters. It is often referred to by the instructions in those chapters, thus avoiding repetition. It is suggested that you skim through this chapter to become familiar with the topics covered here, because you will likely need to refer to it later.

The tools and materials you will need to make the toys in Chapters 3 through 17 are described here. Also included is important information about the dimensions for some commonly used toy parts.

At the end of the chapter are instructions for making subassemblies for push sticks and pull strings used by a number of the toys, and critical information on glued parts and rotational parts.

How to Proceed

In planning this book, the authors had originally intended the toy chapters to be used by beginners as well as experienced woodworkers, and that a limited number of power tools would be required.

It soon became apparent that power tools were going to be essential in order to build many of the toys. However, for the reader with few if any power tools, we suggest beginning by making small cars and trucks (Chapter 3), the weedwacker push toy (Chapter 4), the circle animal puzzle (Chapter 5), or the doll bed/cradle (Chapter 7).

It has already been noted that once you become familiar with the content in this chapter, you can skip around among the 15 toy chapters (3 through 17) to work on only the toys you are most interested in making.

Each of the toy chapters is self-contained. However, in order to make them self-contained we have needed to provide some repetition or reminders in these chapters. To limit the repetition, we make liberal use of boxes throughout the book that refer the reader to more information about an instruction or topic. The boxes are color coded as follows:

**Red Box**

A warning about an important instruction or a reference to a sub-assembly described elsewhere.

**Green Box**

A reference to more information about a topic, including how to make jigs to safely machine small parts.
2. Getting Started

Tools

We all have different woodworking experiences and skills, not to mention different tools. It is assumed, however, that the reader has basic skill and knowledge of woodworking practices and tools.

Although there are occasional exceptions, to build each toy requires the following general steps:

- Create rectangular blocks of wood (called “blanks”) out of which the main part, the body of the toy, and other parts are made.
- Transfer the design of the body and other parts to the blanks. Templates for all the major parts are given in each chapter.
- Drill holes while the blanks are still rectangular.
- Rough cut-out the parts from the blanks.
- Sand the body and other parts to the outline on the blank.
- Round over edges and do finish sanding.
- Seal the parts, apply a top coat of finish, and assemble the toy.

Depending on the tools you have available there are a variety of ways to accomplish these steps.

Below are lists of tools that can be used for the operations described above. In general, for each operation the list is arranged from the most preferred tool to the least preferred. Using the least preferred tools can be a challenge for making most of the toys, but this will depend on your skill and patience.

Cutting Tools Needed

You will generally need one tool from each of the following groups to perform the given operation:

**Cutting straight edges**
- Table saw
- Chop (miter) saw
- Circular saw
- Hand saw

**Cutting curves**
- Bandsaw
- Scroll saw
- Jig (saber) saw
- Coping saw

**Drilling holes**
- Drill press
- Hand power drill
- Hand drill

**Rounding over edges**
- Stationary router (that is, a router attached to a router table)
- Wood rasp
- Block plane
- Sanding block

**Sanding**
- Oscillating spindle sander
- Stationary belt sander
- Stationary disk sander
- Sanding drums
- Sanding block
Other Tools and Supplies

Following are some general tools and supplies that are needed for many of the toy construction projects in this book, along with some measuring instruments that would be useful to have available.

Other tools
- Clamps
- Phillips head screw driver
- Drill bits (see section on Dimensions)
- Center punch or nail
- Roundover bits (⅛” to ¼”)

Supplies
- De-waxed shellac
- Water-based polyurethane
- Wood glue
- Wood molding glue
- Sand paper (80 – 150 grit)
- Foam sanding pad (fine grit)

Measuring instruments
- Metal rulers (6 inches and longer)
- Tape measure
- Metal square
- Caliper (to measure diameters)
- Protractor
- Compass

Tools Needed for Each Toy

Specific tools required to make each toy are generally not indicated by the step-by-step instructions in Chapters 3 - 17. Rather, it is up to the reader to select the best tool at your disposal. Any tools unique to building a given toy will be referred to as “special tools” in each chapter, for example, the size and type of drill bits needed.

Materials

Hardwood is generally preferred for the body of a toy. However, in many cases a toy’s body needs to be made out of wood that is 1 ½ to 2 inches thick. This thickness of hardwood is generally not found at a hardware or do-it-yourself lumber store.

It might be possible to purchase short pieces of thick hardwood such as oak, maple, birch, cherry, walnut, and mahogany, to name a few, from your local lumber mill or woodworkers’ store. Short pieces of hardwood left over from furniture making projects often provide enough wood for making a toy.

We generally avoid softwoods, but some that are of good quality are acceptable. However, fir is not recommended because it contains resin that can clog sandpaper and tools, and construction lumber should be avoided since it presents a challenge in accurately locating and drilling holes into it.
A good alternative to purchasing thick or wide pieces of hardwood is to glue together more accessible \( \frac{3}{4} \)" thick pieces to form the wood blanks needed for a toy.

**Making Thicker and Wider Toy Blanks**

See Chapter 18, pp. 151-2

Often it is necessary to purchase parts like small wheels, axle pegs and wood buttons. Local craft stores might stock these parts, but the variety will be limited. It is best to purchase these parts through suppliers that can be found on the internet, and these parts are generally reasonably priced. The Appendix lists several suppliers of these parts.

Large wheels are used in a number of the toys in Part I. These can be very expensive to purchase, so methods for making them are described in Part II. These methods can also be used to make small wheels, if that is preferred to purchasing them.

You will find the dowels, washers, screws, and eyelets that are used to make some toys at your local hardware store.

**Dimensions**

**THIS IS VERY IMPORTANT!** At the beginning of the instructions for making each toy are two tables listing the parts needed. The first shows the wood parts that need to be machined – called the "Cut List." Most of these parts will be cut from blanks of wood. Some will be cut from purchased parts. The second table gives the list of "Other Parts" usually purchased parts requiring little or no modification.

Both tables give the dimensions of the part or wood blanks for the toy being constructed. However, it is **IMPORTANT** to note that in many cases the main part of the toy, the "body," requires a thickness of wood that can vary.

Often a range of thicknesses is given, allowing some flexibility in using the wood that is available. In such cases the toy can be made regardless of the exact thickness of the body.

This flexibility in thickness for the wood chosen for the body means that the dimensions of other parts used to construct this toy might need to be adjusted in length because they depend on the thickness of the body. For example, this would be the case for the length of an axle that needs to pass through the body of a toy car.

Therefore, when dowels are listed to be used for the axle of a toy, the length given is long enough to be used with whatever thickness is chosen for the body and the phrase "cut-to-fit" will follow the item.

After deciding on the thickness of the toy’s body, it is important to check the dimensions of all the other parts to be certain they will work with the chosen thickness of the body. It might be necessary to adjust the dimensions of these parts.

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\(^3\) "Machined" refers to cutting out, rounding over edges, sanding, and drilling operations.
Cut Lists and Dimensions

Don't be concerned that the dimensions for some parts shown in the Cut List are a bit greater than the dimensions given on a diagram for the part.

This is because the dimensions for a part that need to be shaped from a blank will be given oversize to help in transferring the template for the part to the blank and in cutting out the shape.

Templates

In each chapter there are templates for many of the parts that need to be cut from blanks. The templates are used to draw an outline of the part on the blank. Use tracing paper or a photo copy of the template to do this, being certain to not only draw the outline but also mark any holes that need to be drilled into the part.

Drill Bits and Hole Sizes for Glue Joints and Rotating Axles

Some of the small toy parts used for the toys in Part I are purchased, for example dowel rods, axle pegs, and wooden buttons. It is essential to have the correct size drill bit for creating the holes in which these parts will fit.

In some cases the parts will be glued into the hole; in other cases the part will need to move freely, for example a wheel axle.

Unfortunately, some of the drill bits needed to create the holes for these parts are not in the group of six to 12 drill bits commonly sold as a set. Although individual drill bits of almost any size can be purchased at a store that specializes in woodworking tools, if you plan to make a number of toys, an investment in a large set of drill bits containing fractional sizes, letter sizes, and decimal sizes is very useful. See the Appendix for a complete list of the decimal equivalents of a wide range of drills.

A large selection of drill bit sizes will provide a wider option for making a good glue joint with dowels, axle pegs, and wooden buttons.

The table on the next page shows the commonly used toy parts and the normal drill bit sizes to create a glue joint or to create a hole for a rotating axle. Use this table with caution. It is best to check the size of holes in a piece of scrap wood, especially for holes that are to make a glue joint.

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4 For example, Rockler Woodworking and Hardware.

5 Harbor Freight sells a set of 115 bits that will cover all needs. Look for it on sale!
### Holes for Rotating Axles

**Warning – Rotating Parts**

Holes for rotating parts need to have between $\frac{1}{32}$" and $\frac{1}{16}$" clearance to enable the parts to rotate freely. After drilling the $\frac{9}{32}$" hole for a $\frac{1}{4}$" dowel that will serve as a rotating axle, check that the dowel rotates freely in the hole. Since the diameter of dowels tend to vary slightly from the dimension advertised, it might be necessary to re-drill the hole with a slightly larger drill bit if the fit is tight. The same warning applies to holes for $\frac{5}{32}$" axles.

Applying some paraffin to the center of a dowel will help the wheels spin freely. But it is critical to keep the wax away from the ends of the dowel that will be glued into a wheel or another part.
Glue Joints for Dowels, Axle Pegs and Wood Buttons

**Warning – Glue Joints**

We have found that purchased dowels, wood buttons, and axle pegs might have diameters that vary from their advertised dimensions. This is true not only from parts purchased from different manufacturers but also from the same manufacturer.

For example, it would not be unusual for a ¼” [0.250"] dowel purchased for the axle of a toy to actually have a diameter as small as 0.240” or as large as 0.255”. Since this dowel will need to form a solid glue joint with the ¼” hole in a wheel, the fit should be tested in the wheel or by using a piece of scrap wood before gluing.

Therefore, before gluing a dowel, axle peg, or wood button into a hole, find out if it is necessary to make adjustments for too loose or too tight a fit.

**The Test:** A dowel (axle peg, or wood button) should fit easily into the hole in which it is to be glued without applying force. It should fit snugly and should not fall out when the object in which it is placed is turned over. Test the fit in the center hole of purchased wheels, and test the fit by drilling a hole in a piece of scrap wood before drilling a hole in a toy part.

**Correction for a Loose Fit:** In gluing a dowel into the center hole of a wheel, if the dowel is loose and a small amount undersized, a thicker glue ⁶ should be used. If it is a very loose fit, try to find a larger diameter dowel. When gluing a dowel, axle peg, or wood button into a part for a toy and the fit is loose when tested in a piece of scrap wood, either use thicker glue or use a smaller drill bit to make the hole in the part.

**Correction for a Tight Fit:** On the other hand, if the dowel, axle peg, or wood button is oversized and will not fit into the hole unless forced, a slightly larger drill bit will need to be used to re-drill the hole or to ream it out [see Chapter 19, p. 169], or the end of the part that is to fit into the hole will need to be sanded until a good fit is achieved.

**Another option:** An investment in a few “lettered” size drill bits is a great help in achieving good fits for dowels, axle pegs, and buttons. In the case of ¼” [0.250"] holes, the “C” [0.242”], “D” [0.246”], “F” [0.257”] and “G” [0.261"] lettered drill bits are very useful. For ¾” [0.375"] holes, the “T” [0.358”], “U” [0.368”], “V” [0.377”], and “W” [0.386"] lettered drill bits are very useful.

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⁶ For example, Titebond Molding and Trim Glue can be used to create a glue joint in a slightly oversized hole.
2. Getting Started

Sub-assemblies

*Push Stick and Grip (Figure 2-1)*

1. Cut the push stick from a $\frac{1}{2}$" diameter dowel. Most hardware stores stock these dowels and they are generally 3 feet long. The length should be cut to suit the child that will be using the toy. Without specific knowledge about the user, a common length is $17 \frac{7}{8}$" - enabling two push sticks from one dowel.

2. The design of the handle grip is shown in Figure 2-2. Although the grip is optional, it might make it easier for a child to hold onto the stick when pushing the toy. Cut a piece of hardwood $\frac{3}{4}$" by $\frac{3}{4}$" by 2 1/2" long. Round over all edges of the grip to a $\frac{1}{8}$" radius, then sand the entire grip and the dowel.

3. To safely drill the $\frac{1}{2}$" hole $\frac{3}{4}$" deep into the end of the handle grip, clamp the grip securely in a vice or to fence of a drill press.

4. Test the fit of the dowel in the hole drilled at the end of the grip to determine if it will make a good glue joint with the grip. If the fit is tight, sand $\frac{3}{4}$" of the end of the dowel until a good fit is achieved. See warning on glue joints (p. 19).

*Figure 2-1. Push Stick with Handle Grip Attached*

*Figure 2-2. Handle Grip*
Making a Pull String

2. Cut the string with a hot string cutter, or if such a cutter is not available, melt each end of the string with a match or lighter.
3. Tie a loop at one end for pulling. Put a drop of glue on all knots or they will become loose (see Figure 2-3).
4. If it is desired to attach a ball or piece of dowel to the end of the string, be sure it will pass the anti-swallow test using the device shown in Figure 1-1.
5. The string length should be between 18” and 30”, depending on the toy configuration and the age of the child using the toy. Testing with a child is best.

Figure 2-3. Pull String
On to Toy Building

At the start of each of the toy chapters you will find: the list of materials needed to make the toy, plans including all dimensions, a list of special tools required for that toy, and step-by-step instructions for machining and finishing the parts and assembling the toy. When needed, a template (actual-size drawing) is provided for tracing the outline of the parts on wood blanks.

In most cases several different types of tools could be used to fashion a given part of a toy. For example, in cutting out the body of a toy whose shape is curved, we generally prefer making a rough cut with a band saw, then smoothing out the edges with a drum or oscillating spindle sander. But if you don’t have access to a band saw, a scroll or jigsaw will suffice, or perhaps even a coping saw, and you can always sand by hand.

The list of tools you could use for a given operation, shown earlier in this chapter, are ordered by the generally most preferred tool to the least preferred. There are exceptions, however, and they will be noted in the individual toy chapters.

Finally, it is recommended that you review all the instructions for building a given toy to determine if the tools at your disposal will enable you to accomplish all the cutting operations required.
3. Small Cars and Trucks

Several designs of small toy vehicles are pictured below. These toys vary in length from 3 ½" to 5". The steps to make the green car in Figure 3-1 are given in this chapter. This is an easy toy to make and one that requires very few tools.

![Figure 3-1. Small Green Car](image)

There are an unlimited number of designs for small toy cars and trucks. The procedures presented in this chapter to make the green car can be used to make a variety of vehicles, such as the ones shown in Figure 3-2, or others of your own design. The only change would be the shape of the body. Variations in placing and attaching the wheels are described at the end of this chapter.
Materials and Tools

The wood cut list and other parts needed to make the small green car are given below, followed by the parts explosion (Figure 3-3). An actual size drawing that can be used as a template for making the car is in Figure 3-4.

### Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Any hardwood</td>
<td>¾” to 1 ½” x 2 ½” x 5”</td>
<td>1</td>
</tr>
<tr>
<td>Axles</td>
<td>Dowel</td>
<td>¼” diameter x 3” long (cut-to-fit)</td>
<td>2</td>
</tr>
</tbody>
</table>

### Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Dimensions</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheels</td>
<td>Any hardwood</td>
<td>1” diameter with ¼” center hole</td>
<td>4</td>
</tr>
<tr>
<td>Washers</td>
<td>Plastic or steel</td>
<td>¼”</td>
<td>4</td>
</tr>
</tbody>
</table>

### Tools Required

- Basic tools and supplies (see Chapter 2, pp. 14-15)
- 9/32” drill bit

![Figure 3-3. Car Parts Explosion](image-url)
**Car Body**

1 – **Wood block.** Begin with a rectangular block of wood 2 ½" wide by 5" in length. The block should be at least ¾" thick. If available, thicker stock (up to 1 ½" thick) will make the car more realistic.

The width and length dimensions of the block of wood are a bit greater than the final dimensions of the car to facilitate the transfer of the outline of the car onto the block.

Draw the outline of the car on the block using Figure 3-4 as a template by placing the bottom of the template along one straight edge of the block. Using a nail or center punch, mark the location of the two holes for the wheel axles, located 5/16" above the bottom of the car.

2 – **Axle holes.** Drill holes for the axles using a 9/32" drill bit. For best results, drill from one side completely through the body to make the two holes (one on each side) for the front wheels. Then repeat for the rear wheels.

**This is a critical step.** It is important that the drill bit be perpendicular to the side of the car body. Clamping the bottom of the car against a fence will help to insure accuracy. The ¼" axles should rotate freely in these holes.

3 – **Shape.** Rough cut out the car’s body within 1/32" to 1/16" from the outline on the blank. Sand to the outline, then round over the edges to a 3/16" to ¼" radius, using a wood rasp and sandpaper, or router.

**Router Safety**

**DO NOT USE** a router to round over edges of toy parts **UNLESS** the router is stationary, that is, attached to a router table. See Ch. 18., p. 158.

4 – **Sand.** Next sand the entire shape, using progressively finer sandpaper up to 150 grit sandpaper.

5 – **Seal, paint (optional), and clear finish.** Finishes should be applied to the body and the wheels before assembly. First seal all parts except the dowel axle with de-waxed shellac. When dry, lightly sand with a foam sanding pad to remove any raised grain.

Next apply paint and one or two coats of water-based polyurethane. Or skip the paint and just use polyurethane, letting the car be the natural color of the wood. Lightly sand between coats of polyurethane.

**More on Finishing**

See Chapter 21, p. 183

6 – **Ream out holes if necessary.** Finish often gets into the ¼” center holes of wheels. It might be necessary to use a ¼” drill bit to ream out the wheel holes before gluing the dowel (axle) into the hole.

**Reaming Out Holes**

See Chapter 19, p. 169.
Assemble

1 – Glue one wheel. Test that the 3” dowel being used for the wheel axle is a good fit in one of the car wheels.

Glue Joints
See Chapter 2 (p. 19) on testing and adjusting holes for good glue joints between dowels and wheels.

Put glue in the hole of the wheel using a toothpick or nail. Smear the glue around the inside of the hole. Don’t use too much glue and wipe off any glue that has gotten on the inside surface of the wheel.

Insert the 3” dowel into the wheel, pushing it through until it is flush with the outside edge of the ¼” hole in the wheel. Wipe off any excess glue pushed to the outside of the wheel.

Repeat this step using the second axle (dowel) and another wheel.

Wheels have now been attached to one side of the front and rear axles of the car. Allow the glue in these wheel-axle assemblies to set for about 15 minutes.

2 – Dry assemble7. On one of the wheel-axle assemblies put a washer on the dowel up against the wheel and insert the dowel into one of the axle holes in the car.

Between the washer and the body of the car insert a spacer that is about $\frac{1}{32}$” thick.8

On the other side of the car put a washer on the ¼” axle and a spacer, then slide a second wheel onto the axle so that the wheel, washer, and spacer are up against the second side of the car.

Place a mark where the dowel is flush with the outside of the second wheel that has yet to be glued to the axle. This will show how much needs to be trimmed off this dowel.

Repeat this step with the other wheel-axle assembly.

Before disassembling for gluing, test that the axles with wheels attached rotate freely. If not, ream out or increase the size of the axle holes in the car.

3 – Glue second wheel. Remove the second wheel, washers and spacers from one of the wheel-axle assemblies. Trim the dowel to the location marked. Reassemble, making sure to have a washer and spacer on each side of the car’s body.

Put glue in the center hole of the second wheel, wiping off any glue that has gotten on the inside of the wheel, and push it onto the axle until the end of the axle is flush with the outside edge of the hole in the center of the second wheel. Wipe off the glue pushed to the outside of the wheel, remove the spacers, and test once again that the axle with two wheels attached rotates freely. (If not, disassemble quickly before the glue dries and make corrections.)

Repeat this step with the second wheel-axle assembly. Allow the glue to set for 15 minutes. The car is ready to drive.

7 To “dry assemble” means to assemble parts without glue to test that the parts fit properly.

8 The plastic clip used to seal the bag of a loaf of bread makes an ideal spacer. A piece of cardboard from a cereal box will also work.
3. Small Cars and Trucks

**Figure 3-4.** Car Template

**Figure 3-5.** Fenders and Axle Pegs for Axles
3. Small Cars and Trucks

Variation 1

A slight variation to the design and procedure given above is to drill holes for the wheels in the side of the vehicle to create fenders. See for example the tow truck and minivan in Figure 3-5. This will only work if the body of the car or truck is at least 1 ½" thick. To drill the holes for the fenders, use the following steps:

1. Instead of creating the axle hole with a 9/32" drill bit, use the smallest diameter drill bit that is long enough to drill a “centering” hole through the body for the front wheels and the rear wheels of the vehicle. Try to make this hole no greater than ⅛" in diameter.

2. Using the centering hole as a guide, drill a 1 ¼" hole on each side of the front and rear of the car. A Forstner bit is best for this operation. This hole should be ¼" to 5/16" deep, depending on the thickness of the wheel.

Types of Drill Bits


Variation 2

An axle peg can be glued into the vehicle body instead of using a through ¼" dowel for an axle. See for example the tow truck in Figure 3-5 or two of the convertibles in Figure 3-2.

The procedure follows:

1. Use a 15/64" bit to drill the front and rear through axle holes for wheels with a ¼" center hole.

2. Now, instead of using a ¼" dowel for the axle, use a 7/32" or 15/64" axle peg. The tenon might need to be sanded to make a good glue joint.

3. Depending on the thickness of the car body, the axle peg tenon may need to be shortened. The length of the tenon should be no greater than half the sum of the thickness of the car body and the two wheels.

4. Each of the four wheels will be glued into the body separately with an axle peg. Use the following procedure:

Put glue into a hole in the car body, making sure to wipe off any excess glue that comes out of the hole onto the side of the car.

Next insert the axle peg with the wheel, washer, and spacer into the hole up against the car body. Repeat with the other three wheels. Do not use too much glue. Be careful to avoid glue squeezing out of the hole in the car body and sticking to the spacer, washer, or wheel.

5. For wheels with a ⅜" center hole, drill an 11/32" hole in the vehicle body, use an 11/32" axle peg, and follow the procedure described in steps 1 – 4.
4. Weedwacker

As this toy is pushed forward, its blades turn, and the multi-colored wing tips add excitement. It’s a perfect toy for the toddler learning to walk.

![Figure 4-1. Weedwacker](image)

Materials, Tools, and Plans

The Wood Cut List and Other Parts for this project are given on the next page. Figure 4-2 is the parts explosion and Figure 4-3 provides drawings of some of the individual parts.

Each part should be finished prior to assembly, since it is not possible to apply sealer, paint, or polyurethane to this toy once it is assembled.

The tools needed conclude this section.
### Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blade base</td>
<td>Hardwood</td>
<td>1&quot; x 3 ½&quot; x 3 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Blades</td>
<td>Hardwood</td>
<td>¼” to ½” x 1 ¼” x 7 3/4”</td>
<td>2</td>
</tr>
<tr>
<td>Blade head</td>
<td>Hardwood</td>
<td>1&quot; x 1 ½” x 1 ½”</td>
<td>1</td>
</tr>
<tr>
<td>Wheel block</td>
<td>Hardwood</td>
<td>1” x 1” x 1 ¾”</td>
<td>1</td>
</tr>
<tr>
<td>Spacer block</td>
<td>Hardwood</td>
<td>¼” to ½” x 1 ¼” x 1 ¼”</td>
<td>2</td>
</tr>
<tr>
<td>Blade axle</td>
<td>Dowel</td>
<td>3/8” diameter x 3” to 3 ½” (cut-to-fit)</td>
<td>1</td>
</tr>
<tr>
<td>Push stick</td>
<td>Dowel</td>
<td>½” diameter x 18” (cut-to-fit)</td>
<td>1</td>
</tr>
<tr>
<td>Handle grip</td>
<td>Hardwood</td>
<td>¾” x ¾” x 2 ½”</td>
<td>1</td>
</tr>
</tbody>
</table>

### Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive wheel</td>
<td>Any wood</td>
<td>1 ¾&quot; diameter with ¼&quot; center hole</td>
<td>1</td>
</tr>
<tr>
<td>Idler wheel</td>
<td>Any wood</td>
<td>1 ½” diameter with ¼&quot; center hole</td>
<td>1</td>
</tr>
<tr>
<td>Wheel axle</td>
<td>Axle peg</td>
<td>7/32”</td>
<td>2</td>
</tr>
<tr>
<td>Washer</td>
<td>Nylon or steel</td>
<td>¼”</td>
<td>2</td>
</tr>
</tbody>
</table>

---

Figure 4-2. Weedwacker Parts Explosion

---

9 The spacer blocks need to be the same thickness as the blades.
Figure 4-3. The Individual Parts Except Wheel Block (not actual size)

**Tools Required**

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools for this toy:
  - Fractional twist drill bits: $3/8"$, $13/32"$, $15/64"$, $1/2"$
4. Weedwacker

Steps

**Blade Base**

1 – **Forming the base.** Begin with a piece of hardwood 1” thick by 3 ½” square.

2 – **Create octagon shape.** Make a 45-degree angle cut at each corner to turn the square base into an octagon. Starting the angle cuts 7/8” from the edge at each corner will result in an irregular octagon with opposite sides parallel and equal in length. Four sides will be 1 ¼” long; the other four sides will be 1 ¾” long (see Figure 4-3).

3 – **Round over the edges.** This is best done using a 1/8” roundover bit in a router attached to a router table. If a router is not available, a wood file and/or 150 grit sandpaper will work.

**Router Safety**

**DO NOT USE** a router to round over edges of toy parts **UNLESS** the router is stationary, that is, attached to a router table. See Ch. 18, p. 158.

3 – **Drill hole in base.** Drill a hole in the exact middle of the base with a 3/32” drill bit. This hole will need to accept the blade axle, a 3/16” dowel, with free movement.

**Rotating axles**


**Blade, Spacers and Base Assembly**

1 – **Prepare blades.** The blades need to be made from wood that is ¼” to ½” thick. Thin stock can be purchased or cut from a thicker piece. Obtain or prepare enough of this thin stock (about 19”) to make the blades and the spacers described below. Cut two blades, 1 ¼” wide and 7 ¾” long.

2 – **Chamfer ends.** At about ¼” from the end on each side make a 45-degree cut (See Figure 4-3).

3 – **Form blade assembly.** Glue one blade on top of the other at 90 degrees to form a plus (+) sign with equal length arms. Clamp and allow glue to dry.

4 – **Cut spacers.** To support the upper blade of the blade assembly, spacers are required between the blade and the blade base. Cut two square spacers 1 ¼” x 1 ¼” from the same material used to make the blades.

5 – **Glue spacers to blade.** Choose one blade as the "upper" blade and glue the two spaces underneath that blade and up against the "lower" blade (see Figures 4-1 and 4-2). Clamp and allow glue to dry.

6 – **Glue blades and spaces to base.** Once the glue has dried on the blade-spacer assembly (Step 5), glue the side with the spacers and lower blade to the base. The blades need to be lined up with the 1 ¼” sides of the irregular octagon and centered on the base (see Figure 4-1). Clamp and allow the glue to dry. Do not be concerned that the blade-spacer assembly covers the center hole on the base. This will be corrected in the next step.

---

10 Small pieces of ¼” hardwood are available at the “big box” do-it-yourself stores.
7 – **Center hole.** Once the glue is dry on the blades and spacers attached to the base, use a \( \frac{3}{32} \)" drill bit to continue the center hole in the base through both blades now attached to the base. Check that the \( \frac{3}{8} \)" blade axle dowel rotates freely in this hole.

---

**Blade Head**

1 – **Prepare blank.** Cut a piece of 1" thick hardwood into a square 1 ½" x 1 ½".

2 – **Shape.** Across one of the 1 ½" x 1 ½" sides cut off the face at 35 degrees. Start the cut about \( \frac{3}{4} \)" from the bottom of the block (see Figure 4-3).

3 – **Drill hole for push stick.** Place the blade head in a clamp, vice or other holding device positioned such that the 35-degree angled face is horizontal. Drill a ½" diameter hole \( \frac{3}{4} \)" deep centered in this face.

4 – **Drill hole for blade axle.** On the 1" x 1 ½" bottom edge measure \( \frac{5}{16} \)" from the front of the blade head and drill a \( \frac{3}{8} \)" hole \( \frac{5}{8} \)" deep. See Figure 4-3 for the correct position and location of this hole.

---

**Wheel Block**

1 – **Blank.** Cut a piece of 1" x 1" hardwood 1 ¾" long.

2 – **Drill hole for blade axle.** In the center of one of the 1" x 1 ¾" sides, drill a \( \frac{3}{8} \)" hole \( \frac{5}{8} \)" deep. (See Figure 4-4). This will be referred to as the “top side.” In this hole the \( \frac{3}{8} \)" blade axle will be glued during assembly.

3 – **Drill holes for axle pegs.** In opposite 1" x 1" sides, drill \( \frac{15}{64} \)" holes \( \frac{5}{8} \)" deep for the wheel axle pegs. See Figure 4-4. The exact location of these holes is **very important** to assure the correct operation of the weedwacker blades.

One hole needs to be located \( \frac{3}{4} \)" from the “top side” and centered horizontally on the 1" x 1" side. On the other end of the block, drill the axle peg hole \( \frac{5}{8} \)" from the “top side” and centered horizontally on that 1" x 1" side. See Figure 4-4.

---

**Glue joints**

Follow the instructions in Chapter 2 (pp. 18-19) for making good glue joints for the \( \frac{1}{2} \)" and \( \frac{3}{8} \)" holes in blade head and wheel block and the \( \frac{15}{64} \)" holes for the axle pegs in the wheel block.

---

**Handle Grip and Push Stick**

**Make Push Stick and Grip Sub-assembly**

4. Weedwacker

Figure 4-4. Wheel Block Construction
(Note: blades are not shown glued on top of the blade base in this drawing.)

Finish

1 – Sand. Use 150 grit sandpaper to sand the surfaces and edges of all the parts prepared above. Using a sanding block helps to round over edges. The parts for this toy are too small to safely round over using a router, unless a fixture designed to hold small parts is used. Check to be certain all sharp spots or splinters that could hurt a little hand have been removed.

2 – Shellac. Except for the blade axle, seal all other parts, including the two wheels and the heads of the two axle pegs with de-waxed shellac. Cover the bottom 3/4” of the push stick with painter’s tape before applying any finish to the push stick assembly to prevent problems in gluing it into the blade head. After the shellac dries, lightly sand the parts with a fine sanding pad to remove any raised grain.

3 – Paint tips of blades (optional). Any color combination of stripes can be painted on the tips of the blades to add color to the toy and amusement for the user.

4 – Clear finish. Apply one or two coats of water-based polyurethane or another child safe clear finish to all the parts, except the blade axle and the tenons of axle pegs. If applying more than one coat of clear finish, lightly sand between coats.
Wheel Block Assembly

1 – **Attach idler wheel.** Put glue into the hole on the end of the wheel block that is ¾” from the top. See Figure 4-4. Wipe off any excess glue from the surface of the wheel block.

Slide the 1 ½” diameter wheel onto one of the 7/32” axle pegs followed by a washer and push the axle peg into the hole in the wheel block, using a spacer approximately 1/32” thick to provide a small gap between the washer and the wheel block. Make sure the wheel rotates freely on the wheel block. Allow the glue to set.

2 – **Attach drive wheel.** Put glue into the hole on the other end of the wheel block that is ⅝” from the top of the block. In this hole glue the 1 ¾” drive wheel, using a 7/32” axle peg, washer and spacer. Make sure the wheel rotates freely on the wheel block. Allow the glue to set.

Final Assembly

1 – **Attach push stick to blade head.** Glue the push stick into the face of the blade head that has been cut at a 35-degree angle. Allow the glue to set.

2 – **Dry fit blade axle.** Insert a piece of 3/8” dowel about 3 ½” long, into the top of the wheel block. Put the blade-base assembly on the dowel (see Figure 4-2). Next attach the bottom of the blade head to the top of the blade axle.

The blade-base assembly rests on the drive wheel. As the toy is pushed, rotation of the drive wheel should cause the blade-base unit to rotate. Push the toy along the floor to determine that the blades rotate freely. If not, a longer piece of 3/8” dowel might be needed or the 13/32” hole through the blade base might need to be enlarged. If there is too much 3/8” axle between the top of the blade-base assembly and the blade head, trim the 3/8” dowel.

3 – **Glue.** If the dry fit is acceptable, glue the blade axle into the wheel block at the bottom and into the blade head at the top.

---

11 The plastic clip used to seal a loaf of bread makes an ideal spacer. A piece of cardboard from a cereal box also works.
5. Circle Animal Puzzle

This toy allows children to develop their creative abilities by making a variety of animals from puzzle pieces. Drawings of some of the animals that can be created are shown in Figure 5-3.

Children should be encouraged to create their own designs. Figure 5-1 is an example of what can be made with the wooden animal puzzle pieces.

Figure 5-1. A Goose Made with Animal Puzzle Pieces
Plan, Materials, and Tools

Figure 5-2 is the plan for making the circle animal puzzle pieces. Note that this drawing is not actual size. The material, tools and steps needed to make this toy follow:

![Circle Animal Puzzle Plan (not actual size)](image)

**Wood Cut List**

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puzzle pieces</td>
<td>Plywood (3/16&quot; to 3/8&quot; thick)&lt;sup&gt;12&lt;/sup&gt;</td>
<td>9&quot; x 9&quot;</td>
<td>1</td>
</tr>
</tbody>
</table>

**Tools Required**

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools for this toy:
  - ½" brad point drill bit (optional). See Chapter 19 (pp. 166-7) on types of drill bits.

---

<sup>12</sup> Any plywood can be used, but Baltic birch is best because it contains the fewest voids.
Figure 5-3. Example Animals Created from Circle Animal Puzzle Pieces
(not actual size)
Steps

1 – Prepare plywood. Sand both sides of the plywood square.

2 – Seal plywood. Use de-waxed shellac to seal both sides of the plywood. Once the seal coat is dry, lightly sand both sides of the square, then clean off the sawdust using a tack cloth\(^\text{13}\) or vacuum.

3 – Clear finish. Apply one or two coats of water-based polyurethane to both sides of the plywood. This is a clear finish that dries quickly.

4 – Draw pattern onto plywood. Locate the center of the plywood square, then center punch the center. Using a square, compass, and ruler, draw to scale the two concentric circles, the horizontal and vertical lines, and the 45-degree line as shown in the plan (Figure 5-2).

5 – Create eye. Drill a ½” eye hole with a brad point drill bit in the location shown in Figure 5-2 or paint the eye on both sides of the square (see painted eye in Figure 5-1).

6 – Cut plywood into puzzle pieces. Cut on the lines carefully to maintain the straight sides and the curved sides. Do NOT use a table saw.

7 – Sand edges of pieces. Use a sanding block to sand all edges except the inner radii, where a piece of handheld sandpaper works best.

8 – Finish. Use the shellac sealer on the raw edges of the pieces. When dry sand lightly, then apply polyurethane to the edges.

More on Finishing

See Chapter 21, p. 183

Circle Cutting and Sanding Jigs

The circle cutting and sanding jigs described in Ch. 18 (pp. 155-58) and Ch. 20 (pp. 178-79) could be used to cut out the circle before cutting the diagonal lines.

Figure 5-4. Frame to Hold Puzzle Pieces

The piece of 9" x 9" plywood left over after cutting out the 8 ½" circle can be used to store the puzzle pieces. See Figure 5-4.

To make the frame, glue the remainder of the 9" x 9" plywood from which the circle was cut to a square piece of 9" x 9" plywood to form the frame. Although it is not clear in the photograph (Figure 5-4), in order to cut out the circle there is a cut into the edge of the square frame.

---

\(^{13}\) A cloth treated with tacky material and used to remove saw dust.
6. Duck (Push or Pull)

As the duck moves its wings flap, making this a very entertaining toy for a toddler. It can be made to push along the floor (see Figure 6-1) or as a pull toy.

This chapter describes making the duck as a push toy. Eliminating the push stick and screwing a screw eye in the duck's nose with a pull string attached easily turns it into a pull toy (see Chapter 2, p. 21).

![Figure 6-1. Push Duck](image)
Materials and Tools

The wood cut list, other parts, tools needed for this toy and a drawing showing the parts explosion (Figure 6-2) follow.

### Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duck body</td>
<td>Any wood</td>
<td>¾” to 1 ½” x 6 ⅛” x 9”</td>
<td>1</td>
</tr>
<tr>
<td>Wings</td>
<td>Any wood</td>
<td>½” x 2 ¾” x 4 ½”</td>
<td>2</td>
</tr>
<tr>
<td>Handle grip</td>
<td>Any wood</td>
<td>¾” x ¾” x 2”</td>
<td>1</td>
</tr>
<tr>
<td>Axles</td>
<td>Dowel</td>
<td>3/8” diameter x 4”</td>
<td>2</td>
</tr>
<tr>
<td>Wing lifts</td>
<td>Dowel</td>
<td>¼” diameter x 7/8”</td>
<td>4</td>
</tr>
<tr>
<td>Push stick</td>
<td>Dowel</td>
<td>½” diameter x 18”</td>
<td>1</td>
</tr>
</tbody>
</table>

### Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheels</td>
<td>Any wood</td>
<td>5/8” x 2” with 3/8” center holes</td>
<td>4</td>
</tr>
<tr>
<td>Wing pivots</td>
<td>Axle peg</td>
<td>7/32”</td>
<td>2</td>
</tr>
<tr>
<td>Decoration</td>
<td>Craft paint</td>
<td>Yellow and color for eyes</td>
<td></td>
</tr>
<tr>
<td>Washers</td>
<td>Metal or plastic</td>
<td>⅛”</td>
<td>2</td>
</tr>
<tr>
<td>Washers</td>
<td>Metal or plastic</td>
<td>3/8”</td>
<td>4</td>
</tr>
<tr>
<td>Eyes</td>
<td>Axle peg</td>
<td>7/32”</td>
<td>2</td>
</tr>
</tbody>
</table>

### Tools Required

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools for this toy:
  - 13/32", 15/64", 1/2", and 1/4” twist drill bits
6. Duck (Push or Pull)

Figure 6-2. Parts Explosion

Plans and Steps

1 – Transfer outline. Start with a rectangular block of wood at least 6 ¼" by 9". Adjacent sides should be square (at right angles to each other) to facilitate lining up the holes to be drilled in the body. The thickness of the body can vary to suit the material available.

Using tracing paper or a photo copy of the template (Figure 6-6), draw the outline of the duck’s body onto the block. Mark the locations of the two #1 holes and the holes #2 and #3, as shown on Figure 6-3.

2 – Drilling holes. Holes #1, #2, and #3 are drilled through the body. (Hole #3 is not drilled if the eye is to be painted.) The hole for the push stick (#4) will be drilled on top of the body below the head, after the body is cut out of the block.

With a center punch or a nail, mark the holes to be drilled on the face of the block. The two holes marked #1 are made by using a 13/32" size drill bit. Hole #2 requires a 15/64" size drill bit, as does #3 if using an axle peg for the eye.
6. Duck (Push or Pull)

3 – **Cut out and round over edges.** Cut out the body to within $\frac{1}{32}$" - $\frac{1}{16}$" of the outline. Sand to the outline, removing any uneven bumps or hollows. If rounding over edges by hand, start with 80 grit sandpaper and approximately sand to a $\frac{3}{16}$" radius, or use a router with a $\frac{3}{16}$" or $\frac{1}{4}$" round over bit.

**Router Safety**

**DO NOT USE** a router to round over edges of toy parts **UNLESS** the router is stationary, that is, attached to a router table. See Ch. 18, p. 158.

4 – **Sand.** Completely sand all surfaces using 120 – 150 grit sandpaper.

5 – **Drill hole for push stick.** Hole #4 is drilled at a 45-degree angle on the back of the duck below the head. Use a $\frac{1}{2}$" drill bit and make the hole 1" deep. The $\frac{1}{2}$" dowel might need to be sanded to fit properly. Use a jig or clamp to hold the body to drill the 45-degree angle.

**Jig for Drilling Hole for Push Stick**

See Chapter 19, p. 172.

![Body of Push Duck Dimensions](image)

**Figure 6-3.** Body of Push Duck Dimensions (not actual size)
Wings and Wheels

1 – **Shape wings.** Start with two blocks of wood, at least 2 ½” by 4 ¼”. The sides should be square to one another to facilitate drilling the hole in the wing. The thickness of the blocks is not critical. Wood that is 3/8” or ½” thick will work.

Copy the pattern of the wing (Figure 6-6) onto each block and mark the hole location. The wing outline and hole location are critical in order for the wings to flap properly.

Drill the ¼” hole in each wing at the location shown. Next cut out the two wings. Sand the edges to the outline, making sure in particular that the bottom edge of the wing (the part that will rub against the wing lift) is smooth. Round over the edges by hand or with a 1/8” round over bit using a router attached to a table.

Sand all surfaces using 120 – 150 grit sandpaper.

2 – **Wheels and drive pegs.** Review the suggestions in Chapter 2, p. 19 for obtaining a proper fit for dowels glued into holes. Check whether the 3/8” dowels (axles) fit into the 3/8” hole in the 2” wheels. These dowels will need to be glued into the wheels, so the fit should not be too loose or too tight.

Once a proper fit is achieved, the 3/8” dowels should **not** be glued or cut to length until the duck parts are assembled.

3 – **Wing lifts.** Drill the two rear wheels to accommodate the wing lift dowels. This can be a difficult operation. These wheels need to be secured firmly before drilling.

On the back of the wheels drill the two ¼” holes for the wing lifts at the locations shown in Figure 6-4. Make these holes about ½” deep, but do not drill through the wheel.

The ¼” wing lift dowels should be 7/8” long and extend ¾” from the surface of the wheel. Test the drill size and depth on a piece of scrap wood and be certain to obtain a good fit for gluing. If sanding the dowels, do so before cutting them to length.

---

**Push Stick and Grip** [see sub-assembly instructions in Chapter 2, p. 20]

1 – **Make Push Stick and Grip.** Follow the sub-assembly instruction given in Chapter 2.

2 – **Glue.** Glue the grip to the push stick.

3 – **Prepare for Finishing.** Apply masking tape to 1” of the end of the push stick that will be glued into the body of the duck to avoid getting finish where glue is to be applied.
If necessary, enlarge hole to fit 3/8" diameter dowel

2" diameter wheel 5/8" thick

1/4" wing lift dowels

3/8" axle pegs - see instructions for length

Install wheels with wing lift dowels 90 degrees apart as shown.

Figure 6-4. Push Duck Back Wheel Assembly
*not actual size*
Paint and Clear Finish

1 – Paint. Prime all parts to be painted. Paint the body and wings yellow, using craft paint or spray paint.

Seal all other parts, including the push stick and grip, with shellac.

If ¼” axle pegs are used for the eyes, the heads can be painted any color other than yellow, or colored with a permanent marking pen. If using craft paint, it is best to seal the heads first, then sand lightly before painting.

Avoid getting paint into the holes that will be used for moving or glued parts, or on the tenon of axle pegs used for the eyes.

2 – Clear finish. Put a clear finish on the push stick and grip. Also put a clear finish on the wheels and all the painted parts, but keep finish out of the holes. For a clear finish, satin or semigloss water-based polyurethane is recommended. If using a second coat of polyurethane, sand lightly with a fine sanding pad between coats.

Finishing Tips

See Chapter 21, p. 183.

Assemble

1 – Front axle. The length of the 3/8” dowel for this axle should be at least the sum of the thickness of the body plus the thickness of the two front wheels plus ¼” to allow for the washers and spacers.

Dry assemble this 3/8” dowel in hole #1 in the front of the duck. On each side of the body place a washer, then a wheel. Insert a spacer (0.02 to 0.04 inches thick) between each of the washers and the body of the duck. Check that the axle rotates freely. Align the end of the dowel to the outside edge of one wheel and place a mark where the dowel protrudes from the outside face of the other wheel.

Then take apart what has been assembled, cut the dowel at the mark and sand the ends. Next glue the front wheels onto the axle (with washers and spacers) in place. Put glue in the holes of the wheels, wiping off any glue from the inside of the wheels. Push the wheels onto the axles, lining up the end of the axle to the outside edge of the wheels. Finally, wipe off any excess glue that has been pushed to the outside of the wheels.

Tips for Assembling Wheels

See Chapter 22, p. 189-91.

2 – Rear axle and wing lift dowels. First glue the 7/8” x ¼” wing lift dowels into the inner surfaces of the rear wheels (see Figure 6-4). The dowels must protrude 3/8” from the wheels.

Next size the 3/8” rear axle. The length of this axle will be the sum of the thickness of the two wheels, the thickness of the duck body, plus 1 1/8” (the thickness of two ½” thick wings plus 1/8” clearance). If the wings are thicker than ½”, adjust the length of the rear axle accordingly.

16 The plastic clip used to seal the bag of a loaf of bread or a piece of cardboard from a cereal box make ideal spacers.

17 If the wings are thicker than ½”, adjust the length of the rear axle accordingly.
3 – Glue rear axle. The gluing procedure is similar to the front axle assembly except the wheels pegged with the wing lift dowels are offset 90 degrees to each other and no washers are used. The offset causes the wings to alternately lift and fall. Now glue the rear axle and wheels into rear hole #1 in the duck body as was done for the front wheels and axle. Be certain to allow for an \( \frac{1}{8} \)" clearance between the lift dowels and the body of the duck.

4 – Wing assembly. Axle pegs and washers are used to glue the wings into hole #2 of the body of the duck. It might be necessary to shorten the length of the axle peg tenons. They should be no longer than the thickness of the wing plus half the thickness of the duck's body. Be certain to use a spacer between the washers and the body to allow a clearance gap of approximately \( \frac{1}{32} \)" for the wings to move freely. Figure 6-5 is a rear view of the duck that shows the operation of the wing lifts.

5 – Eyes. If using axle pegs for the eyes, cut the tenons of the two axle pegs to a length of \( \frac{1}{4} \)". Apply a small amount of glue in hole #3 (on each side of duck) and glue the shortened axle pegs into each side.

There are alternatives to using axle pegs for the eyes. One is to paint the eyes directly on the body, in which case there is no need for hole #3. Another alternative is to purchase plastic eyes. A third is to use painted wooden buttons for eyes.

Creating Eyes

Chapter 21 [pp. 184-5] describes various approaches for creating eyes.

6 – Push stick. Put glue into hole #4 in the body of the duck with a toothpick or nail. Wipe off glue from the flat surface around hole, then insert the push stick sub-assembly into hole #4.
6. Duck (Push or Pull)
7. Doll Bed/Cradle

The doll bed is shown in Figure 7-1. The pillow and blanket add a nice touch to this toy but are not a part of the instructions that follow. The bottom (base) of the bed slides on the three spacers (dowels) between each pair of side rails. When the bed is turned over, the bottom slides to convert the bed into a cradle as shown in Figure 7-2.
Materials and Tools

Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headboard</td>
<td>Baltic birch or hardwood</td>
<td>$3/8&quot;$ to $3/4&quot;$ x $6 1/2&quot;$ x $9 1/4&quot;$</td>
<td>1</td>
</tr>
<tr>
<td>Footboard</td>
<td>Baltic birch or hardwood</td>
<td>$3/8&quot;$ to $3/4&quot;$ x $6 1/2&quot;$ x $9 1/4&quot;$</td>
<td>1</td>
</tr>
<tr>
<td>Rails</td>
<td>Any hardwood</td>
<td>$5/8&quot;$ x $3 3/4&quot;$ x $14&quot;$</td>
<td>4</td>
</tr>
<tr>
<td>Base</td>
<td>Plywood</td>
<td>$1/8&quot;$ to $1/4&quot;$ x $7 3/4&quot;$ x $13&quot;$</td>
<td>1</td>
</tr>
<tr>
<td>Rail spacers</td>
<td>Dowel</td>
<td>$1/4&quot;$ x $3&quot;$</td>
<td>6</td>
</tr>
</tbody>
</table>

Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screws</td>
<td>Steel Phillips head</td>
<td>$#6 \times 1 5/8&quot;$</td>
<td>8</td>
</tr>
</tbody>
</table>

Tools Required

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools for this toy:
  - Twist drill bits: $11/64", 9/32",$ and $1/8"$
  - Forstner or brad point bit (preferred): $1/2"$
  - Countersink drill bit

Plans and Steps

The drawings for building and assembling various parts of the bed are shown in Figures 7-3, 7-4 and 7-5. These drawings are not actual size. At the end of this chapter (Figure 7-6) is an actual size pattern for making the headboard and footboard.
**Headboard and Footboard**

1 – **Shape.** Use the template (Figure 7-6) as a pattern to draw these parts on the rectangular blanks. Mark the locations of the four holes. Since the headboard and footboard are identical, the same template is used for both.

The preferred material for making these parts is Baltic birch plywood, but any hardwood will do. The thickness is not critical. Material from $\frac{3}{8}”$ to $\frac{9}{16}”$ thick can be used. A band saw is ideal for obtaining a rough cutout of these parts. Otherwise use a jig saw or coping saw.

2 – **Sand and Round Over.** Next sand the edges to obtain the shape shown in Figure 7-3, then round over the edges either by hand or using a $\frac{1}{8}”$ roundover router bit. Sand the rounded over edges of the headboard and footboard to 150 grit sandpaper.

[Router Safety]

**DO NOT USE** a router to round over edges of toy parts **UNLESS** the router is stationary, that is, attached to a router table. See Ch. 18, p 158.

3 – **Drill.** The final step in preparing the headboard and footboard is to drill $\frac{11}{64}”$ clearance holes (four holes each) for screws to attach the rails (see Figure 7-3 or 7-5). Then countersink these holes.

**Figure 7-3.** Headboard (Footboard) – *not actual size*
Tip for Making Multiple Doll Beds

The doll bed/cradle is a very popular toy. Once you make one you could be inundated with requests for more. A jig that makes it easy to accurately drill the holes in the rails and base is described in Chapter 19, pp. 173-6.

The method of template routing, shown in Chapter 20 (pp. 162-3), can be used to make identical headboards and footboards, and helps to avoid a lot of sanding after these parts are cut out on a band saw or jig saw.

Rails and Base

1 – Prepare the rails. The rails should be cut from a piece of ¾” hardwood, 14” long. The plans given here call for 5/8” thick rails, however, ¾” x ¾” stock will also work. A table saw is ideal for this cut, but if one is not available a handsaw can be used.

2 – Prepare the base. Cut the base from a piece of ⅛” to ¼” plywood. Sand all edges and round the corners to a ½” radius.

3 – Drill holes in rails and base. Drill three 9/32” diameter holes ½” deep in one 5/8” wide side of each rail, at the locations shown in Figure 7-4.

Drill ½” diameter holes through the plywood base centered at the locations shown in Figure 7-4. If available, a ½” diameter Forstner bit or brad point bit should be used for these holes. Use a backup board to minimize tear-out.

4 – Round over and sand rails. Next round over the edges of the 5/8” wide side opposite the side in which the rail spacer holes were drilled (see Figure 7-4.)

The round overs can be done with a ½” or 3/16” round-over bit in a stationary router. If this is not available, a rasp, hand plane, or 80 grit sandpaper can be used. Finally, sand by hand all surfaces of the rails to remove any rough or sharp edges. Use 120 – 150 grit sandpaper.

5 – Cut rail spacers. Sand the ¼” dowel rod purchased for this toy, then cut six 3” lengths from it. Sand the ends of the dowels to break the edges.
Figure 7-4. Bed Rails and Bed Base
(These drawings are to scale but not actual size)
1 – Seal, stain or paint (optional), and clear finish. Seal all parts except the dowels with de-waxed shellac, then apply a child safe clear finish such as water-based polyurethane to all the sealed parts.

Before applying the polyurethane finish, the faces of the headboard and footboard can be decorated (see for example, Figure 7-1). Because the bed is designed to be turned upside down, depending on whether it is being used as a bed or cradle, when decorating the headboard or footboard try to use a design that looks good in both directions.

To personalize the bed, paint the child’s name on the headboard or footboard or both.

2 – Assemble. See Figure 7-5 for top and side views of assembled doll bed. Begin to assemble the bed by drilling 1/8” pilot holes centered in the ends of each of the four rails (see Figure 7-4).

The bed/cradle should be assembled as if it were to be used as a bed (not a cradle) in order to have a flat surface on which to rest the headboard and footboard. Next, attach the bottom rails using 1 ½“ screws from the outside of the headboard and footboard. These screws should be countersunk.

Now place the bed on a flat surface and insert the six rail spacer dowels (three on each side) into the holes in the bottom rails. Next place the base on the bottom rails having passed the rail spacers through the holes in the base. Do not glue the spacers into the rails.

With the spacers in the bottom rails and the base installed on the spacers and resting on the bottom rails, attach the top rails by inserting the spacers into the holes of the top rails. Finally, attach the headboard and footboard to the top rails by using 1 ½“ screws. Countersink the screws.

3 – Check that the base slides. Turn the bed over (as a cradle) to be certain that the base slides freely on the rail spacers. If there is a problem, determine what is preventing the base from sliding. It might be necessary to re-drill the holes in the base, if they were not located correctly.

4 – Test for wobble. Rest the completed doll bed on a flat surface (as a bed, not a cradle). If the bed wobbles, that is, it does not rest flat on the surface, have someone hold the footboard end while you hold and slightly twist the headboard end to achieve a flat resting bed. This process might need to be repeated by trial and error to correct the wobble.

Addition to Bed

The finished doll bed shown in Figure 7-1 includes a blanket and pillow. These items make the bed more realistic and can be created from scraps of fabric. Including a small doll with the bed makes this a complete toy.
Figure 7-5. Assembling the Bed
(These drawings are to scale but are not actual size)

Figure 7-6. Headboard/Footboard Template (next page)
7. Doll Bed/Cradle
8. Honey Bee

Even though this honey bee is not designed to fly, it entertains young children by “flapping” its wings as it is pushed or pulled across the floor.

Figure 8-1. Honey Bee

Materials, Tools and Plans

Tables giving the materials required to construct the honey bee are given on the next page, followed by a parts explosion (Figure 8-2) and the special tools required. Drawings of all the parts can be seen in Figure 8-3.
### Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Any wood</td>
<td>1 ⅛&quot; – 1 ½&quot; x 3 ¼&quot; x 6 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Wings</td>
<td>Plywood</td>
<td>⅛&quot; x 2&quot; x 2 ½&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Wheel axle</td>
<td>Dowel</td>
<td>¼&quot; diameter x 3&quot; (cut-to-fit)</td>
<td>1</td>
</tr>
<tr>
<td>Wing hub</td>
<td>Dowel</td>
<td>½&quot; diameter x 12&quot; (cut-to-fit)</td>
<td>1</td>
</tr>
<tr>
<td>Wing axle</td>
<td>Dowel</td>
<td>¼&quot; diameter x 4&quot; (cut-to-fit)</td>
<td>1</td>
</tr>
</tbody>
</table>

### Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel</td>
<td>Any wood</td>
<td>1 ½&quot; with ¼&quot; center hole</td>
<td>2</td>
</tr>
<tr>
<td>Antenna</td>
<td>Axle peg</td>
<td>⅞/32&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Decoration</td>
<td>Paint, Sharpie pen</td>
<td>Yellow, blue, black, red</td>
<td></td>
</tr>
<tr>
<td>Washers</td>
<td>Metal or plastic</td>
<td>¼&quot;</td>
<td>4</td>
</tr>
<tr>
<td>Screw eye</td>
<td>Steel</td>
<td>Small</td>
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</tr>
<tr>
<td>Pull string</td>
<td>Nylon</td>
<td>30&quot;</td>
<td>1</td>
</tr>
</tbody>
</table>

![Figure 8-2. Parts Explosion](image.png)

---

18 A slab wheel, available from most wooden toy parts suppliers, could be used.

19 These are optional. They are used to make the bee a pull toy.
Tools Required

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools for this toy:
  - Drill bits: 9/32", 5/64", 15/64", ¼", or 17/64", ½" (optional for jig, p. 65)

**Figure 8-3. Honey Bee Parts**
8. Honey Bee

**Steps**

The step-by-step instructions for making the parts and assembling the honey bee follow. Actual size templates for the body and wings are given in Figures 8-4 and 8-5, and a front view of the finished toy is shown in Figure 8-6.

---

**Body**

1 – **Transfer pattern.** Use a block of wood at least 1 ⅛” thick by 3 ⅜” wide and 6 ½” long. The block can be thicker - up to 1 ½” thick. Transfer (trace) the pattern for the body (Figure 8-4) onto the block.

2 – **Mark holes.** Using a scratch awl or nail, mark the hole locations on one side. There will be one location for the wheel axle and one for the wing axle.

3 – **Drill holes.** Use a drill press if possible. If not keep hand drill bit square to the wood. The wheel axle hole is 9/32”. The wing axle hole is 5/16”.

4 – **Shape.** Cut out the shape of the body 1/32” to 1/16” outside the outline.

5 – **Sand.** Either by hand or with power equipment, sand all the edges to the outline.

6 – **Round over edges.** If a router is not available, round over the edges with a rasp, file, and sandpaper. If available, use a router with a 3/16” or ¼” round over bit, to round over all the edges.

7 – **Finish sanding.** Hand sand all surfaces, finishing with 150-grit sandpaper.

8 – **Drill two holes for antennas.** On either side of the head of the bee, drill holes ½” deep for the axle peg antennas. From the side view (see Figure 8-4), these holes should be at an angle of approximately 45 degrees to the bottom of the body. From the front, they should point at a slight angle (10 to 15 degrees) outward (see Figure 8-6).

---

**Jig for Drilling Antenna Holes**

See Chapter 19, p. 173

To drill these holes, use a 15/64” bit. The axle peg tenons will probably need to be sanded to create a proper glue joint. This operation can be done using a hand drill. The exact angle is not critical. Experiment in a piece of scrap wood and hold the body securely with a clamp or in a vice.

Set the body aside for now.

---

**Router Safety**

**DO NOT USE** a router to round over edges of toy parts **UNLESS** the router is stationary, that is attached to a router table. See Ch. 18, p. 158.
Wings and Wheels

1 – Shape wings. Cut two ovals out of a piece of ⅛" plywood using the pattern provided (Figure 8-5). Sand the edges to smooth out the wings.

2 – Prepare hubs. Using a piece of ½" dowel at least 12" long (for safety) cut a notch on each end of the dowel to accept the wings. Center the ⅛" wide cuts on each end of the dowel. One way to do this is to make a ⅛" deep cut on a band saw, then nibble away to widen the space. Check the fit frequently.

3 – Holes for wing axle. After both notches fit the wing, cut a 1 ¼" piece from each end of the 12" dowel. These 1 ¼" pieces will become the hubs that connect the wings to the wing axle. Make the cuts as square as possible.

Next sand, file, or cut a 45° angle on each side where the wings attach. Each end of the 12" dowel should look as follows:

4 – Attach wings to hubs. Glue the wings into the hubs as shown in the diagram below, ending with what look like two small ping-pong paddles. Hereafter called a "hub-wing."

5 – Flatten wheel treads. To make the wings turn as the bee is moved across the floor, the edges of the wheels must be flat. If the 1 ½" wheels purchased for this toy have a rounded tread, it will be necessary to flatten the tread. (It is, however, possible to purchase slab wheels that have a flat tread.) Rounded wheels can be flattened on a stationary belt or disk sanding machine, or by hand. Be careful. The wheels still need to be round but just have flat edges.
8. Honey Bee

Finish

1 – **Sand.** Use 150 grit sandpaper to sand all parts for finishing.

2 – **Prime.** Before painting, prime the body, hub-wings, wheels and antenna. Use an acrylic primer or shellac. If shellac is used, lightly sand the finish to remove the raised grain. Allow to dry completely.

3 – **Paint.** Use yellow for the body and hub-wings, blue and red (or colors of your choice) for the wheels and antennas, respectively. Cover the last ½” of the antenna tenons with tape so no paint gets on the ends.

Avoid getting paint in the axle holes of the wheels and wing hubs. This will allow better glue adhesion. Don’t paint the axles. To paint the black stripes on the body, use a brush, rag, or sponge. Draw the eyes and a mouth on the bee using a Sharpie pen.

Once the paint is dry, one or two coats of water-based polyurethane will help to preserve the finish and make it easier to clean the toy.

Assemble

1 – **Wheel axle.** Cut the ¼” dowel for the wheel axle about ¼” longer than the sum of the thickness of both wheels plus the thickness of the body and two washers. This will allow a loose fit for the wheels.

2 – **Wing-hub axle.** Cut the ¼” dowel for this axle ⅛” longer than the depth of both holes in the hubs plus the thickness of the body and two washers.

3 – **Dry assemble.** Assemble without glue to check that the wings turn while the bee is rolled along the work bench. The hubs should rest lightly on the wheels. If the wings do not turn, enlarge the hole for the wing-hub axle slightly and test again.

4 – **Glue wheels and wing-hubs.** After checking that the wings turn with the wheels, glue parts together. When gluing axles or axle pegs in holes, put glue into the hole using a toothpick or nail. Do not put glue on the axle or shaft of the axle peg.

Glue one wheel onto the wheel axle up to the outside edge of the wheel. Allow glue to set, then place a ¼” washer on the axle, slide the axle through the body, and place a second washer on the other side. Now glue the second wheel in place.

Glue one wing-hub onto the wing-hub axle. After glue sets, place a ¼” washer on the axle, put the axle through the body, place a second washer on the other side, and glue second wing-hub onto the axle.

5 – **Glue antennas.** Glue the antennas in place. Since the antenna holes tend to become enlarged when drilling them at an angle, it is suggested that thicker wood molding glue be used.

6 – **Finishing touch (optional).** Once the glue has thoroughly dried, paint the ends of the wheel axles the same color as the wheels.

7 – **Pull string (optional).** If honey bee is intended to be a pull toy, attach a screw eye and pull string. (See Figure 8-1 and "Making a Pull String, p. 21.")
Figure 8-4. Body Template

Figure 8-5. Wing Template
Figure 8-6. Front View
One way to drill the hole in the end of the 1 ¼" hub is to first drill two ½" holes through a piece of scrap, then place the hubs in the holes as shown in view #1, Figure 8-7.

To keep the hubs from spinning put a narrow piece of ⅛" plywood through both notches previously cut on the wings (see view #2). It will be necessary to place feet under the piece of scrap to keep it from wobbling.

Finally, clamp the jig in place after lining the center of one of the hubs under a ¼" drill bit in a drill press (see view #3). Drill the ½" deep hole. Repeat with the other hub.

This jig can also be used with a hand drill, but care must be taken to keep the drill bit perpendicular to the hub.

Another way to drill the holes in the wing hubs is to place the hubs into the piece of scrap wood as shown Figure 8-7, then wrap the exposed hubs with a rubber band and hold with a pair of pliers. The rubber band will prevent marring of the hubs as the holes are drilled.
9. School Bus

This is a popular toy with both girls and boys. It's lots of fun loading the students and driver into the bus, driving them around, and then unloading them.

![Figure 9-1. School Bus](image)

Materials and Tools

Following are the materials required to build the school bus. Included is information on selecting the wood for this project and the list of drill bits needed.
Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Any wood</td>
<td>1 ½&quot; x 3 ½&quot; x 8 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Roof</td>
<td>Any wood</td>
<td>¾&quot; x 3 ½&quot; x 3 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Bumper</td>
<td>Any wood</td>
<td>¼&quot; x ⅝&quot; x 3 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Wheels</td>
<td>Any wood</td>
<td>1 ½&quot; diameter with ¼&quot; center hole</td>
<td>4</td>
</tr>
<tr>
<td>Roof supports</td>
<td>Dowel</td>
<td>⅜&quot; diameter x 3 ¾&quot;</td>
<td>6</td>
</tr>
<tr>
<td>Handle</td>
<td>Dowel</td>
<td>⅜&quot; diameter x 6&quot;</td>
<td>1</td>
</tr>
</tbody>
</table>

Selecting the Wood

The body of the school bus can be made from a piece of 2 x 4 construction lumber. However, this type of wood is not recommended because it can have very coarse grain, making it difficult to accurately locate holes and obtain a smooth finish. If construction lumber is used select the piece carefully.

A better choice would be several pieces of clear pine glued together to obtain a block thick enough for the body of the bus. Poplar or perhaps mahogany will also work very well for the body. It is suggested that the same type of wood be used for the roof that is used for the body of the bus.

Making Thicker and Wider Toy Blanks

See Chapter 18, p. 151-2.

Since the finished toy will be painted, it is not necessary to use a good piece of hardwood.

Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel axles</td>
<td>Axle peg</td>
<td>7/32&quot;</td>
<td>4</td>
</tr>
<tr>
<td>Washers</td>
<td>Metal or plastic</td>
<td>⅛&quot;</td>
<td>4</td>
</tr>
<tr>
<td>Little people</td>
<td>Any wood</td>
<td>⅞&quot; diameter x 2 ½&quot;</td>
<td>7</td>
</tr>
<tr>
<td>Headlights</td>
<td>Wood buttons</td>
<td>½&quot; mushroom head</td>
<td>2</td>
</tr>
<tr>
<td>Warning lights</td>
<td>Wood buttons</td>
<td>½&quot; mushroom head</td>
<td>7</td>
</tr>
<tr>
<td>Body</td>
<td>Paint</td>
<td>School bus yellow</td>
<td></td>
</tr>
<tr>
<td>Little people</td>
<td>Craft paint</td>
<td>A variety of colors</td>
<td></td>
</tr>
<tr>
<td>Lights</td>
<td>Craft paint</td>
<td>Red and white</td>
<td></td>
</tr>
</tbody>
</table>

20 These are purchased. See the list of wooden toy part suppliers in the Appendix.
Tools Required

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools needed for this toy:
  - 25/64", 15/64", ¼", ⅜" twist drill bits
  - 1" Forstner bit

Plans and Steps

| Body |

1 – Blank. Prepare a piece of wood 1 ½" thick, 3 ½" wide and 8 ¼" long. If using 2" by 4" construction lumber, the thickness can vary a bit from 1 ½" without changing the plans, but the width and length should be as given.

2 – Round the four corners. Draw a ¼" radius on the top of the bus body at the corners. Use a sanding block, stationary belt sander or disk sander to round the four corners as shown in Figure 9-2 – top view.

3 – Round over edges. Select the side that will be the bottom and round over the two side edges and rear edge of the bottom of the body to a radius of ¼". This could be done using a sanding block, although a router with a ¼" roundover bit is preferred. If using a router, go slowly at the corners to avoid splintering. Put a slight round over on the edges on the top of the body either by sanding or using a ⅛" router roundover bit.

4 – Lay out hole locations. Use a square and ruler to locate the centers of the holes for the six ⅜" dowel roof supports and seven little people, following the top view plan given in Figure 9-2. Use a punch to mark these holes for drilling. The location of the holes for the roof supports must be very accurate to align with the corresponding holes in the roof. The locations of the holes for the little people are not as critical.

Template for Locating Holes

See Chapter 19 (pp. 171-2) for a template that can be made to locate holes in the body and roof of the school bus. This template can be very useful if making several school buses.

5 – Drill holes in body. Drill the six holes for the roof supports ½" deep using a 25/64" drill bit. These holes need to provide a loose fit for the ⅜" dowel supports to align easily with the roof.

The seven 1" holes should be drilled 11/16" deep. Clamping the body against a fence is suggested to safely and accurately drill these holes.
6 – **Drill axle holes.** Use a square and ruler to locate the centers of the four holes for the wheel axle pegs, two on each side of the body, following the plan given in the side view of Figure 9-2. With a punch mark these holes for drilling, then drill the holes 1" deep using a $\frac{15}{64}$" diameter drill bit. Accuracy is very important in locating these holes. Each needs to be the same distance (½") from the bottom of the body to prevent the bus from “rocking” when the wheels are assembled.
7 – **Drill holes for lights.** Locate the centers of the holes for the two headlights on the front and the two warning lights on the rear of the body (see Figure 9-2). Mark with a punch these holes for drilling. Drill the two headlight and warning light holes $5/16$" deep using a $25/64"$ diameter twist bit or brad point bit.

The wooden buttons used for the lights have a head that is $1/2$" in diameter and a tenon that is $3/64$" in diameter. It is usually necessary to use a $25/64"$, bit to drill holes for the tenons because they are tapered. To verify using the correct size drill bit for the buttons purchased for this project, drill a test hole in a piece of scrap wood.

If wood buttons are not available, substitute with $11/32"$ axle pegs, which have heads that are close in size to the $1/2"$ buttons. Use a $11/32"$ diameter drill bit to drill the holes for these axle pegs and shorten their tenons to suit the hole depth.

8 – **Optional) Cut recess for bumper.** Use a table saw or hand saw to cut the recess for the bumper. See the plan (Figure 9-2 – side view) to determine the location of this recess. The recess is optional. The bumper can be glued directly to the front of the body.

9 – **Sand body.** Sand the entire body, starting with 100 grit sandpaper and finishing with 150 grit sandpaper. Break all sharp edges.

---

**Glue Joints**

See Chapter 2 [pp. 18-9] for ways to achieve good glue joints for axle pegs and wood buttons and suggestions for overcoming problems with a poor fit.

---

**Roof**

1 – **Prepare wood.** Figure 9-3 is the plan for the roof. Begin by cutting a single piece of wood $3/4$" thick, $3 1/2$" wide and $3 1/2$" long. This piece will eventually be divided into two pieces, as shown in Figure 9-3, after all the holes are drilled and the top edges are rounded over.

2 – **Locate roof support holes.** Use a square and ruler to locate the centers of the $25/64"$ holes for the six dowel roof supports. The location of these holes must be very accurate to align with the corresponding holes in the body of the bus.

Do not be concerned that the two rear support holes do not appear to be over the rear holes in the body. This piece of wood will eventually be divided into two pieces. Then the rear holes will line up.

It is also very important to pay attention to the direction of the grain of the wood used for the roof in relation to the holes for the roof supports. The grain must be at a right angle to the handle that will be used to connect the front and rear roof pieces, to avoid any weakness in the roof. The proper grain direction is shown in Figure 9-3. Use a punch to mark the location of the six holes.

3 – **Round over corners and edges.** Draw a $1/4$" radius on the top of the bus roof at the corners. Use a sanding block, belt sander or disk sander to round the four corners as shown in Figure 9-3. If using a router to round over the top edges, go slowly at the corners to avoid splintering.

4 – **Locate handle and light holes.** On the rear edge of the bus roof (see Figure 9-3) locate the holes for the three warning lights. On the front edge of the bus roof locate the holes for the two warning lights. Use a punch to mark these holes for drilling.
**5 – Drill holes in roof.** Use a \( \frac{55}{64} \)" bit to drill the six roof support holes for the \( \frac{3}{8} \)" dowel supports. These holes should be \( \frac{1}{2} \)" deep.

Using a \( \frac{55}{64} \)" bit, drill the center warning light hole 2" deep on the rear edge of the roof, then use it to drill the remaining warning light holes \( \frac{5}{16} \)" deep.

**6 – Cut roof and sand.** At the location 7\( \frac{8}{16} \)" from the rear edge, saw roof into two pieces as shown in Figure 9-3. Then sand both pieces.

---

**Painting Body, Roof and Accessories**

**1 – Shellac and paint body and roof.** Put masking tape over the spot on the front of the bus where the bumper will be glued. Apply dewaxed shellac to all surfaces of the body and roof, avoiding the holes where glue will be applied – the holes for the roof supports and the holes on the sides for the axle pegs and lights. Allow the shellac to dry, then sand lightly and apply yellow paint. More than one coat of yellow paint may be required to achieve a bright yellow school bus finish.

**2 – Little people.** Applying a coat of shellac to seal the surfaces of the little people will avoid “bleeding” along grain lines when they are painted. Allow the shellac to dry, then sand lightly. Use acrylic paints to “dress” the people.

The small jars of acrylic paint sold at craft stores are ideal for this purpose. A fine point permanent ink pen is useful for painting facial features.

**3 – Paint accessory items.** Paint the heads of the two wooden buttons (the headlights) white or silver; paint the heads of the seven remaining wooden buttons red (the warning lights); paint the heads of the four axle pegs silver, white, or yellow (the hubcaps); paint the four wheels black; and paint the front and edges of the bumper black or silver.

**4 – Finish coat.** Once all the painted parts are dry, apply one or two coats of water-based polyurethane.
This is the bottom view of the roof (looking up from the body). The roof is cut into two parts along the line shown above after all the holes are drilled, the corners and top edges are rounded over, and the entire piece is sanded.

Figure 9-3. School Bus Roof (actual size)
1 – **Dry assemble.** Ream out all holes into which parts are to be glued.

**Reaming Out Holes**

See Chapter 19, p. 169.

Before gluing the parts in place, assemble them “dry”, including the handle that connects the two pieces of roof. Cut the ¾” dowels used for the roof supports to size, making sure when dry assembled to hold up the roof that there is a 2 ¼” space from the top of the body to the roof to enable the “little people” to easily fit into the bus.

Correct any part fitting issues at this point. See Figure 9-4 for a side view of the assembled roof and bus body. When checking the fit of the handle, make sure it is recessed ¼” in the hole through the back-roof piece so that there will be room to glue the middle warning light.

2 – **Glue body, roof, lights and bumper.** Begin by gluing the six roof supports into the body. While the glue is still wet, glue and assemble the handle connecting the two pieces of roof while also gluing the roof assembly to roof supports that have already been placed in the body.

Next glue in place the lights and bumper. Use a clamp or masking tape to hold the bumper in place until the glue dries.

3 – **Attach wheels.** Put glue into the holes on the body, not on the axle pegs. When gluing the wheels in place, insert a washer between each wheel and the body, and leave a 1/32” to 1/16” gap between the wheels and the body.

4 – **Place the people.** Load the “little people” onto the bus and they are ready to go to school.

---

21 To assemble “dry” means to assemble the parts without glue.

22 The plastic clip used to seal a loaf bread or a piece of cardboard from a cereal box will serve as ideal spacers between the washer and the bus body.
10. Counting 1 - 2 - 3 - 4

Toys like Counting 1 - 2 - 3 - 4 have been around for many years in one form or another. This type of toy is used to help toddlers and young children learn a few numbers and some basic shapes. It helps develop fine motor control at the same time.

Figure 10-1. Counting 1-2-3-4
Materials, Tools, and Plan

Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Thickness, width, length</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>Hardwood</td>
<td>¾&quot; x 6&quot; x 6&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Pieces</td>
<td>Baltic birch plywood</td>
<td>¼&quot; x 3 ½&quot; x 3 ½&quot;</td>
<td>10</td>
</tr>
<tr>
<td>Pegs</td>
<td>Dowel</td>
<td>5/16” diameter x 1 5/8”</td>
<td>10</td>
</tr>
</tbody>
</table>

Tools Required

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools for this toy:
  - Square with 60-degree angle
  - Compass
  - Drill bits: ½” drill bit (brad point bit preferred); 5/16” twist bit

Figure 10-2. 1-2-3-4 Board and Pieces
Figure 10-3. Counting 1 - 2 - 3 - 4 Base (not actual size)
Steps

**Base and Pegs**

1 – **Base.** Cut ¾” stock into a 6” by 6” square.

2 – **Mark peg holes.** Use a pencil to locate the centers of the 10 holes for the pegs, following the dimensions given in Figure 10-3, or by using the template for the base given in Figure 10-4. Accuracy is important here to ensure that the pieces will slide easily onto the dowels. Use a punch to increase the size of the marks.

3 – **Round corners.** Using a sanding block, stationary belt or disk sander, round the corners to an approximate ¼” radius.

4 – **Round over edges.** Using a sanding block or a router, round over the edges (top and bottom) to a ⅛” to 3/16” radius.

5 – **Drill holes for pegs.** Use a piece of scrap wood to drill test holes with a 5/16” drill bit. Test that the 5/16” dowel purchased for this project forms a good glue joint in the test holes. If not, select a different drill bit or sand the dowels.

6 – **Sand.** Use 150 grit sandpaper on all surfaces of the base.

7 – **Cut pegs.** Before cutting, sand the entire 5/16” dowel using a sanding pad. Cut 10 pieces from the dowel, each exactly 1 ⅝”. Check that the pegs form a proper glue joint in the holes drilled in the base. Chamfer the edges of one end of each peg.

8 – **Attach pegs.** Use a nail or toothpick to smear glue into the 10 holes in the base, and then insert a peg into each hole. Wipe off any glue that squeezes out of the holes.

**Glue Joints**

See Chapter 2 (pp. 18-9) on drilling and testing good glue joints for dowels.

**Router Safety**

DO NOT USE a router to round over edges of toy parts **UNLESS** the router is stationary, that is, attached to a router table. See Ch. 18, p. 158.

**Chamfering**

See Chapter 20 (pp. 180-1) for a simple jig used to safely sand, round over, or chamfer the end of a dowel using a stationary belt or disk sander.
Circle, Rectangles, Triangles, and Squares

1 – Circle. Use a compass to draw a 2 7/8” diameter circle on one of the 3 1/2” square pieces of Baltic birch. Cut out the circle within 1/16” of the outline, then sand to the outline. Mark the center of the circle with a punch.

Circle Cutting and Sanding Jigs
See Chapters 18 (155-8) and 20 (178-9) for jigs to cut out and sand circles.

2 – Rectangles, triangles and squares. Following the dimensions given in Figure 10-3, or using the templates (Figure 10-4), cut out 2 rectangles, 3 triangles and 4 squares from the remaining Baltic birch 3 1/2” x 3 1/2” blanks.

Using a chop saw is the easiest way to cut out these pieces. Of course, other methods can be used, and if rough cuts are made the pieces can be sanded to achieve the correct sizes. Mark the exact locations with a punch where holes are to be drilled.

Drilling and Drill Bits
See Chapter 19, pp. 165-7.

3 – Drill holes. Holes need to be drilled in each of the toy pieces using a 1/2” drill bit. The accuracy of the location of these holes is very important for the pieces to fit properly on the pegs. It is possible to drill two or three of the pieces at a time if they are held together tightly with clamps while drilling. Be certain to use a backup board for clean exit holes when drilling.

4 – Sand. Using a sanding block, sand the top and bottom of each piece and all edges, including around the 1/2” holes. Round the corners of the rectangles, triangles, and squares.

Finish

1 – Seal. Apply a coat of de-waxed shellac to the entire base, including the pegs, and to all the pieces. When dry, sand lightly with a foam sanding pad to remove any raised grain. Let dry for about one hour.

2 – Polyurethane. Apply one or two coats of water-based polyurethane to the base, pegs, and pieces. Lightly sand between coats with a fine sanding pad.
Figure 10-4. Counting 1 – 2 – 3 – 4 Templates
11. Hopping Frogs

As the frogs (Figure 11-1) are moved along the floor, they alternately “hop” up and down. Young children have fun pushing the frogs. As a bonus, older children can learn from this toy how a cam and camshaft work.

Figure 11-1. Hopping Frogs Push Toy
Materials and Tools

Following are the lists of parts with their dimensions and the tools required to make this toy. The parts explosion (Figure 11-2) shows how the parts will fit together.

Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>Hardwood</td>
<td>¾&quot; x 4&quot; x 3 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Platform</td>
<td>Hardwood</td>
<td>¾&quot; x 1 ½&quot; x 4 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Lifter base</td>
<td>Hardwood</td>
<td>½&quot; x ¾&quot; x 3 ¾&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Frogs</td>
<td>Hardwood</td>
<td>¾&quot; x 3 ¼&quot; x 4&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Legs</td>
<td>Hardwood</td>
<td>¾&quot; x ¾&quot; x 2 ¼&quot;</td>
<td>8</td>
</tr>
<tr>
<td>Leg connectors</td>
<td>Axle peg</td>
<td>7/32&quot;</td>
<td>12</td>
</tr>
<tr>
<td>Wheel blank</td>
<td>Baltic birch</td>
<td>1 ½&quot; x 4 1/2 &quot; x 4 ½&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Cams</td>
<td>Dowel</td>
<td>1&quot; diameter x ¾&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Axle</td>
<td>Dowel</td>
<td>¾&quot; diameter x 5 ½&quot; (cut-to-fit)</td>
<td>1</td>
</tr>
<tr>
<td>Lifters</td>
<td>Dowel</td>
<td>¾&quot; diameter x 3 ¾&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Push stick</td>
<td>Dowel</td>
<td>1 ½&quot; diameter x 16&quot; to 22&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Handle grip</td>
<td>Hardwood</td>
<td>¾&quot; x ¾&quot; x 2 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Eyes</td>
<td>Axle peg (optional)</td>
<td>7/32&quot;</td>
<td>4</td>
</tr>
</tbody>
</table>

Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paint</td>
<td>Acrylic</td>
<td>Green</td>
<td></td>
</tr>
<tr>
<td>Pen marker</td>
<td>Permanent</td>
<td>Black</td>
<td></td>
</tr>
<tr>
<td>Screw</td>
<td>Dry wall</td>
<td>1 ⅝&quot;</td>
<td>1</td>
</tr>
</tbody>
</table>

Tools required

- Woodworking tools and supplies (see Chapter 2, pp. 14-5)
- Special tools for this toy:
  - Drill bits: "1/64", "3/16", "1/4", "15/64", "3/8", "13/32", and ½"
11. Hopping Frogs

Figure 11-2. Parts Explosion

**Plans and Steps**

**Base**

1 – **Wood block.** Start with a block of wood at least $\frac{3}{4}$" x 4" x 3 $\frac{1}{2}$". This is larger than the template (Figure 11-3) to allow room to draw the outline of the pattern on the block using the template. The dimensions of the base are given in Figure 11-6.
Before drilling holes in the base, platform, legs and wheels, review the information in Chapter 2 (pp. 18-9) concerning holes for glue joints and holes for rotating axles.

2 – Axle hole. Drill the $\frac{13}{32}$" axle hole using a drill press if possible. If not keep your drill bit square to the wood.

3 – Shape. Cut the shape slightly proud of the outline. Sand all the edges to the outline, preferably with a stationary power sander.

Round over all the edges except the top with a file and sandpaper to about a $\frac{1}{8}$" radius. Or use a stationary router with a $\frac{1}{8}$"round over bit.

4 – Holes on edges. See Figure 11-6 for the locations of these holes. Drill a $\frac{1}{8}$" diameter hole $\frac{3}{4}$" from the front edge, centered on the thickness. This is a pilot hole for a screw. Drill a $\frac{1}{2}$" hole 1" deep centered on the thickness of the 45° angled cut for the push stick. Figure 11-4 shows a simple jig that can be constructed for holding the base when drilling the push stick hole.

5 – Sand. Hand sand all surfaces, finishing with 150 grit sandpaper.
Figure 11-4. Jig for Holding Base and Frogs when Drilling
1 – **Wood blank.** Start with a rectangular blank 3/4" x 1 1/2" x 4 1/2". Mark the holes as indicated in Figure 11-5 using a scratch awl or small nail. There are three holes on the top and four on the long edges.

2 – **Edges.** Round over the edges to a 1/8" radius.

3 – **Holes.** Drill the two 3/32" holes on the top of the platform. These holes go all the way through and become the guide for the lifters. Drill the four 15/64" holes on the edges 5/8" deep. A 7/32" axle peg will be glued into these holes, so take care the holes form proper glue joints.

4 – **Dado.** Cut a 3/4" dado 1/8" deep on the bottom side 1 7/8" from each end. This can be done with a dovetail saw and chisel or a table saw. If cutting on the table saw use an extension board screwed to your miter guide or push it through using a piece of 1" x 6" scrap wood. See Figure 11-5.

5 – **Sand.** Hand sand all surfaces, finishing with 150 grit sandpaper.
11. Hopping Frogs

Figure 11-6. Frog and Base Dimensions (not actual size)
11. Hopping Frogs

Frogs

1 – Wood block. Start with two blocks of wood, each at least ¾” x 3” x 4”. These are larger than needed to allow room to place the pattern on the block and cut out a frog from each block. Transfer the pattern to each block from the template (Figure 11-7). The dimensions for the frog are given in Figure 11-6. Using a scratch awl or nail, mark the hole locations for the axle pegs on each block.

The lower hole is for attaching a leg with a leg connector (axle peg). The upper hole is for an axle peg that will serve as an eye. The hole for the eye is optional – depending on how you choose to create the eye.

Creating Eyes

Chapter 21 (pp. 184-5) describes various approaches for creating eyes.

2 – Drill. Using a 15/64” twist drill bit, drill through holes for the axle pegs that will attach the legs on each side of the frogs and for the eyes (if using axle pegs for eyes).

These holes are best done with a drill press. If using a hand drill, keep your drill bit square to the wood. These holes need to form a glue joint with axle pegs, so take care in getting a proper fit.

3 – Shape. Using a band saw or a scroll saw, cut the shape to within ⅛” to ⅛” of the outline. Then sand the frogs to the outline.

4 – Edges. Round over the edges to a ⅛” radius.

5 – Lifter hole. Drill a ⅜” hole ¾” deep in the bottom of each frog to accept the lifter. The hole should be about a 3° to 5° angle to the back of the frog. This keeps the frogs from hitting each other as they move up and down. Use the jig shown in Figure 11-4 for drilling these holes.

6 – Sand. Hand sand all surfaces, finishing with 150 grit sandpaper.

Frog Legs

1 – Shape. Rip a 20” piece of ¾” stock to ⅜” wide on a table saw or bandsaw. If a bandsaw is used be sure to sand the cut edge smooth and flat. Cut the strip into eight 2 ¼” lengths.

2 – Drill glue holes. On one end of four of the legs mark a point ⅜” from the end and ⅜” from the edge. Use a 15/64” twist bit to drill a hole through these legs, as shown in Figure 11-5. These four legs will be “upper” legs, and a “lower” leg will be attached to each of them with an axle peg. Mark these four holes so they are easy to identify later. One way to do this is to place a mark with a felt pen inside the hole.

3 – Drill other holes. On each of the other ends of the legs (there should be 12 more ends) mark a point ⅜” from the end and ⅜” from the edge. Use a ¼” twist bit to drill these 12 through holes.

4 – Round over. Use a file or disk sander to round each end of the legs to an approximate ⅛” radius.

5 – Sand. The edges of legs should be sanded to an approximate ⅛”round over. Finally, sand all surfaces of the legs to 150 grit sandpaper.
11. Hopping Frogs

**Wheels, Cams, and Lifter Bases**

**1 – Shape wheels.** From Baltic birch plywood or hardwood cut out two 4” diameter wheels, each with a 3/8” center hole. Sand the faces and sand and round over the edges to a 1/8” radius.

**Jig to Make large Wheels**

See Chapters 18 (pp. 155-58) and 20 (pp. 178-9) for ways to make and sand large wheels.

**2 – Cut cams.** From a longer piece of 1” dowel, cut two 3/4” long pieces. Sand the ends flat. These will become the cams that lift the frogs.

**3 – Glue cams.** Glue one cam to each wheel 3/8” from the edge. Since the face of the cam being glued to the wheel is end grain, it is best to use Titebond Molding glue.

**4 – Lifter bases.** From 1/2” thick wood cut out two lifter bases 3/4” wide x 3 3/8” long. On each of the lifter bases drill a 3/8” hole 3/8” deep in the center of one of the 3/4” sides (See Figure 11-5).

**Push Stick**

See instructions in Chapter 2 (p. 20) for building the push stick and grip sub-assembly.
1. **Sand and prime.** Sand all cut parts to 150 grit sandpaper, then seal all parts and sub-assemblies except the wheel axle, axle peg tenons, and lifters with de-waxed shellac.

Avoid getting sealer, paint and clear finish in holes in which axle pegs or dowels will be glued. One way to do this is to wrap the axle peg tenons and the end of dowels with painter’s tape and insert them in the holes, thus keeping the holes clear of finish.

Once dry, lightly sand all sealed parts with a fine sanding pad to remove the raised grain.

2. **Paint.** Use green paint on the frogs, legs, and axle peg heads.

3. **Clear coat.** Apply one or two coats of water-based polyurethane to all painted and sealed parts (but not to the wheel axle, axle peg tenons, or lifters).

4. **Eyes.** Use a permanent marker (black) to draw eyes on the frogs. If using axle pegs shorten the tenons to glue the pegs into the holes for the eyes.

---

### Assemble

1. **Wheel axle.** Put glue into the center hole of one of the wheels. Insert the \( \frac{3}{8} '' \) diameter 5 1/2'' long wheel axle (dowel) into the hole from the inside (the side with the cam) so that it is flush with the outside of the wheel. Wipe off any glue pushed to the outside.

2. **Lifters.** The lifters should be sanded with 220 grit sandpaper then waxed (any paste wax) to reduce friction. However, do not wax the last 1'' on each end where they will be glued into the bottom of each frog and the lifter base.

3. **Glue lifters.** Glue a lifter (\( \frac{3}{8} '' \) dowel, 3 3/4'' long) in the center hole of each lifter base. When the glue sets, insert the lifters through the platform and glue one lifter into the hole in the bottom of each frog.

4. **Attach platform.** Use a 1 5/8'' drywall screw to attach the platform to the base. The front edge of both base and platform should align.

5. **Dry assemble the second wheel.** Insert the wheel axle with one wheel attached through the \( \frac{13}{32} '' \) axle hole in the base. Put the second wheel on the other end of the axle, adjusting it's position so that both wheels clear the lifters by \( \frac{1}{6} '' \). Place a mark where the axle is flush with the outside of the second wheel. Take the second wheel off and trim the axle to the mark. Re-assemble the wheels without glue. The cams should be off-set from each other by 180 degrees.

6. **Assemble remaining parts.** Assemble the frog legs **without** glue to check that everything works smoothly.

The tenons of the 12 axle pegs (leg connectors) will need to be shortened at this time to approximately \( \frac{3}{4} '' \) in length. Cut them to fit as follows. The ends of the tenons of the four axle pegs that connect a lower leg to an upper leg should be flush with the back of the upper leg when inserted through the lower leg, allowing
for a gap of \(\frac{1}{32}\)" to \(\frac{1}{16}\)" between the legs. Use a spacer to create this gap.\(^{23}\)

The tenons of the 8 axle pegs used to connect the legs to the frog body or platform should also be about \(\frac{3}{4}\)" long and allow for a spacer between the legs and the parts into which they are glued.

In doing the dry assembly, the axle pegs may be loose. To temporarily keep them in the holes, wrap painter’s or masking tape on the tenon.

If assembled correctly, the frogs should alternately move up and down as the toy is rolled along the workbench. The finished toy should appear as shown in Figure 11-8. After checking that everything works, glue parts together including removing the drywall screw, gluing the platform to the base, and replacing the screw.

When gluing the leg connectors (axle pegs), be sure to use a spacer between the pieces to allow for movement. If these connections are too tight the toy will not work.

**6 – Push stick.** Glue the push stick into the \(\frac{1}{2}\)" hole on the base.

---

\(^{23}\) The plastic clip used to seal a loaf bread or a piece of cardboard from a cereal box will serve as ideal spacers between the legs.
12. Car Transporter

This toy consists of a truck and trailer carrying three cars. The cars are arranged on the trailer to conserve space.

Kids view this toy as a neat way to transport cars and usually have no trouble fitting the cars on the trailer. Parents, however, seem to get a bit frustrated trying to arrange the cars on the trailer and often need to ask a child for help, like asking a kid for help with your computer or cell phone.

Figure 12-1 shows two finished car transporters, one with the cars on the trailer like a puzzle.

![Figure 12-1. Car Transporter](image)

*Figure 12-1. Car Transporter*

---

24 This toy is based on a design by Steve Baldwin and illustration by Mike Henry.
## Materials and Tools

### Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Thickness, width, length</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trailer &amp; 3 cars</td>
<td>Hardwood (1)</td>
<td>1 ¼&quot; to 1 ½&quot; x 3&quot; x 11 3/4&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Cab</td>
<td>Hardwood (2)</td>
<td>1 ½&quot; x 1 7/8&quot; x 2 1/4&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Cab base</td>
<td>Hardwood (3)</td>
<td>3/4&quot; x 2&quot; x 5 1/4&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Pivot block</td>
<td>Hardwood (3)</td>
<td>3/4&quot; x 1 1/2&quot; x 1 7/8&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Trailer wheel mount</td>
<td>Hardwood (1)</td>
<td>3/4&quot; x 1 1/4&quot; to 1 1/2&quot; x 2&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Hitch pin</td>
<td>Dowel</td>
<td>3/8&quot; diameter x 1 1/2&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Car axles</td>
<td>Dowel</td>
<td>1/4&quot; diameter x 3&quot; cut-to-fit</td>
<td>6</td>
</tr>
<tr>
<td>Cab axle (front)</td>
<td>Dowel</td>
<td>1/4&quot; diameter x 3 1/2&quot; cut-to-fit</td>
<td>1</td>
</tr>
<tr>
<td>Exhaust pipe (4)</td>
<td>Dowel</td>
<td>1/4&quot; diameter x 3&quot; cut-to-fit</td>
<td>1</td>
</tr>
</tbody>
</table>

1. The trailer/cars and the rear mount should be made from the same type of wood and same thickness.
2. The cab can be made from a different type of wood than the trailer/cars.
3. The cab base and pivot block should be made from the same type of wood, but they do not need to be the same wood as the cab or trailer/cars.
4. The exhaust pipe is optional. It is an example of any number of ways that the car transporter can be decorated. Other additions, not shown in the cut list or other parts, are putting headlights on the cab. These would be made from ½" wood buttons and are shown on Figure 12-2.

### Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Thickness, width, length</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car wheels</td>
<td>Hardwood</td>
<td>1 ¾&quot; diameter with ¼&quot; hole</td>
<td>12</td>
</tr>
<tr>
<td>Truck wheels (front)</td>
<td>Hardwood</td>
<td>1 ½&quot; diameter with ¼&quot; hole</td>
<td>2</td>
</tr>
<tr>
<td>Truck wheels (rear)</td>
<td>Treaded</td>
<td>1 ½&quot; diameter with ¼&quot; hole</td>
<td>2</td>
</tr>
<tr>
<td>Trailer wheels</td>
<td>Treaded</td>
<td>1 ½&quot; diameter with ¼&quot; hole</td>
<td>2</td>
</tr>
<tr>
<td>Trailer and truck axles</td>
<td>Axle peg</td>
<td>7/32&quot;</td>
<td>4</td>
</tr>
<tr>
<td>Washers</td>
<td>Plastic or metal</td>
<td>1/4&quot;</td>
<td>18</td>
</tr>
<tr>
<td>Exhaust pipe cap (4)</td>
<td>Axle cap</td>
<td>½&quot; with ¼&quot; hole</td>
<td>1</td>
</tr>
</tbody>
</table>

### Tools Required

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools for this toy:
  - Brad point drill bit: 5/8"
  - Twist drill bits: 9/32", 15/64", 3/32" and 5/32".
Plans and Steps

The parts explosion is given in Figure 12-2. The trailer and cars are cut from one piece of wood (See Figure 12-3). Figure 12-4 is the template for the trailer and cars.

Individual parts that comprise the truck cab, and their dimensions, along with the trailer wheel mount, are in Figures 12-5 and 12-6.

Figure 12-2. Parts Explosion
1 – **Wood blank.** Begin with a squared-off piece of wood that is 3” wide by 11 ¾” long. It should be 1 ¼” to 1 ½” thick. The exact thickness is not critical and will have little bearing on the other parts of this toy, except the length of wheel axles. The following steps assume that the wood blank chosen is 1 ¼” thick. A greater thickness will require longer wheel axles.

Figure 12-4 is the full-size template to be used with the 3” x 11 ¾” blank. It has been cut in half to fit on the page. Use carbon paper to transfer the pattern to the wood blank, being certain to clearly show the outline of the cars on the trailer and the centers of the holes in each car.

Figure 12-3 shows the side view dimensions and how the cars will fit on the trailer after this blank is cut apart. This figure also shows the location of the trailer wheel mount which is not cut from this blank (see step 5).

2 – **Drill holes in cars.** Use a punch or nail to mark the centers of the holes for the car side windows and for the axles. Drill these holes while the wood blank is rectangular.

The windows are made by using a ⅝” brad point bit and the hole is drilled through the car. Go slowly and use a back-up board.

Use a 9/32” drill bit to make the six holes for the wheel axles. These holes are drilled through the cars and should be located 5/16” above the bottom of each car. It is very important to keep the drill perpendicular when drilling these holes. Otherwise the cars will be off balance when the wheels are attached.

3 – **Shape.** Either a bandsaw or a scroll saw should be used to cut the cars from the blank and trim the blank for the hitch. Although it might be possible to use a coping saw to make these cuts by hand, it is not recommended. Be particularly careful in sawing the horizontal cut along the bed of the trailer. This cut will produce the bottom of the middle car and the top of the car in front of it, and when sanded they should be parallel to the opposite side of each car, respectively.

4 – **Sand.** Once the cars have been cut from the trailer, smooth out all the edges to remove saw marks. Do not be too aggressive in sanding. The objective is to make the edges as smooth and free of saw marks as possible on the cars and the trailer, without removing too much wood, so that the cars will fit closely together when carried on the trailer.

5 – **Trailer wheel mount blank.** Prepare a piece of wood ¾” thick by 2” long to be attached to the trailer’s bottom. This piece of wood should be the same width as the thickness used for the trailer (and cars). Although not necessary, it looks best if the same type of wood is used.

6 – **Glue wheel mount.** The trailer wheel mount holds the wheels for the trailer. It is glued onto the bottom of the trailer 1 ¼” from the rear. Allow glue to set before continuing.

7 – **Round over.** The edges of the cars and trailer should be rounded over to about a ⅛” radius. This can be done by hand with a sanding block or by using a router. If using a router, there are several edges that cannot be rounded over because there is no square side to run the bearing against. These edges will need to be rounded over by hand.

**Router Safety**

*DO NOT USE a router to round over edges of toy parts UNLESS the router is stationary, that is, attached to a router table.* See Ch. 18, p. 158.
8 – Sand and round over windows. Take a small piece of sand paper and run it around the edges of the windows to round them over to about $\frac{1}{8}"$ radius. If the drilled holes to make the windows are rough, they will need to be sanded. To sand these holes, use a piece of sandpaper rolled around a pencil or short piece of dowel.

9 – Drill holes in trailer. The rear treded wheels will be attached to the trailer with axle pegs. Use a punch or nail to mark the center of the trailer wheel mount (see Figure 12-6). Use a $\frac{15}{64}"$ bit to drill this through hole, again being careful to keep the drill perpendicular to the side of the trailer.

Use a $\frac{3}{8}"$ bit to drill the hole in the bottom of the trailer for the hitch pin. The center of this hole is located $\frac{5}{8}"$ from the front of the trailer (see template Figure 12-4) and centered on the bottom. It should be $\frac{1}{2}"$ deep.

10 – Attach hitch pin. Cut a piece of $\frac{3}{8}"$ dowel $1\frac{1}{8}"$ long. Chamfer (round over) one end, then glue the other end into the hole in the bottom of the trailer.

Chamfering

See Chapter 20 [pp. 180-1] for a simple jig used to safely chamfer the end of a dowel using a belt or disk sander.
Figure 12-4. Template for Trailer and Cars
1 – Cab. Start with a piece of wood 1 7/8" high by 2 1/4" long. It should be about 1 1/2" thick, but this is not a critical dimension and a slightly narrower thickness can be used.

Mark the location of the center of the side window (See Figure 12-5). Use a pen or pencil to mark the side that will be the bottom of the cab. Cut the front of the cab as shown on the drawing to represent the front windshield. The angle of this cut should be approximately 35-degrees from the vertical front of the cab.

Next, using a router or a sanding block, round over selected edges of the cab to a 1/8" radius. All edges should be rounded over except for the four bottom edges because the bottom will be glued to the base. Also, the two edges above and below the windshield should not be rounded over. Finally, as was done with the cars, use a 5/64" brad point drill to make the window in the side of the cab.

2 – Base. Prepare a piece of 3/4" thick wood 2" wide by 5 1/4" long. Round over all edges to a 1/8" radius. Next, holes for two sets of wheels need to be drilled through the base from one side. Once again, it is important that the drill bit is held perpendicular to the side of the base when making these holes.

Select one end as the rear of the base. A 15/64" through hole is drilled 1/2" from the rear in the center of the edge of the base (see Figure 12-5). On each side at the rear of the base a 9/32" axle peg will be used to attach a 1 1/2" treads wheel to the base.

The front wheels are ordinary (rounded) wheels 1 1/2" in diameter. The hole for these wheels is drilled 1" from the front of the base, centered on the edge. This is also a through hole. It needs to be made using a 9/32" drill bit since the front wheels will be attached to a 1/4" dowel (axle) which must rotate in this hole.

3 – Pivot block. Cut the end of the piece of wood being used for the pivot block at a 45-degree angle as shown in Figure 12-5. The top of the block should now be a rectangle approximately 1 1/2" x 1 1/8". Clamping the pivot block securely, drill a 13/32" hole through the center of the top. Use a sanding block to break any rough edges on the pivot block.

4 – Sand and assemble truck body. Sand the three pieces that make up the truck body (cab, base, and pivot block) to remove all saw marks, using progressively finer sandpaper up to 150 grit sandpaper. Glue and clamp the cab to the base. It should be centered on the base and located about 1/8" from the front of the base. Glue and clamp the pivot block to the rear of the base. Its sloped edge can come right up to the rear edge of the base.

5 – Assemble exhaust pipe (optional). Glue the axle cap with the 1/4" hole onto a 1/4" dowel 3" long to form the exhaust pipe (see Figure 12-6). When the glue attaching the cab and pivot block to the base has set, drill a 1/4" hole 3/6" to 1/2" deep for the exhaust pipe at the location shown in Figure 12-5.
12. Car Transporter

Figure 12-5. Truck (not actual size)

Figure 12-6. Wheel Mount and Exhaust
12. Car Transporter

---

**Finish**

1 – **Seal coat.** The car hauler parts to be sealed include: the truck, trailer, three cars, four 1½" diameter treaded wheels, heads of four axle pegs, two 1 ½" diameter wheels for the cab, twelve 1 ¼" diameter car wheels, and the exhaust pipe assembly (optional).

After checking that all surfaces and edges are smooth (all saw marks have been removed), seal each of these parts with de-waxed shellac, except the tenons of the axle pegs. After the shellac dries, lightly sand all parts with a fine foam sanding pad.

2 – **Paint (optional).** If you choose to paint some of the parts, for example, the wheels (black), the exhaust pipe (silver), or the body of the cars, truck and trailer, it should be done now before the next step.

3 – **Clear finish.** Apply a coat of water-based polyurethane to all parts except the axles and tenons of the axle pegs. If a second coat of polyurethane is applied, lightly sand between coats.

---

**Assemble**

1 – **Ream out holes.** It is very likely that some shellac and polyurethane have gotten into the axle holes in the wheels and the body of the truck and trailer. Before the wheels can be assembled, it is usually necessary to ream out these axle holes using the drill bits that originally created the holes.

---

**Glue Joints**

Chapter 2, p. 19, gives a way to test whether the holes in the truck and trailer for the axle pegs and the holes in the wheels in which a ¼” dowel (axle) are glued will form good glue joints. If the holes fail the test, follow the suggestions to correct the problem.

25 The plastic clip used to seal the bag of a loaf of bread makes an ideal spacer

3 – **Attach wheels with treads.** From the outside put an axle peg through the center hole of a treaded wheel and place a washer and spacer on the axle peg next to the inside of the wheel. The spacer should allow a small gap of about ¼" between the washer and the side of the wheel mount.25

Put glue into one of the holes in the trailer wheel mount. Wipe off any excess glue, then insert into the hole the tenon of the axle peg with the wheel, washer, and spacer.

Repeat with the wheel on the other side of the trailer wheel mount and with the two treaded wheels on the rear of the truck.

---

2 – **Dry assemble.** Assemble without glue the wheels with treads into their locations on the trailer and rear of the truck using axle pegs to test if the axle peg and hole will make a good glue joint. Do the same test for all the wheels in which a ¼" dowel (axle) will be glued. Make any corrections to the holes before continuing.
4 – Prepare car wheel axles. Carefully measure the length and then cut the six axles needed for the car wheels. In measuring the length, consider the following: the thickness of a car body, plus the thicknesses of the two wheels, two washers, and two spaces. Also consider how you want the ends of the axles to appear.

The axles can be cut so that their ends are squared off with the outside of the wheels or rounded over to appear like a hubcap. If the latter choice is made, add an extra ¼" to the axle (⅛" on each side) for rounding over.

Examples of squared off axles can be seen in Figure 22-1, p. 190, along with an example of a wheel with axles that are rounded over.

5 – Attach first wheel. Put glue into the hole of one wheel using a toothpick or nail. Smear the glue around the inside of the hole. Don’t use too much glue. Wipe off any glue on the back of the wheel.

Insert an axle into the wheel, pushing it through from the inside until it is flush with the outside edge of the ¼" hole in the wheel or slightly protruding, depending on whether you want to achieve a squared off or hubcap look. Wipe off any excess glue from the outside of the wheel.

Repeat this step with five more car wheels and axles. Wheels have now been attached to one side of the front and rear axles of each car. Allow the glue to set for about 15 minutes.

6 – Attach the second wheel. On one of the car wheel-axle assemblies prepared in step 5, put a washer and spacer on the axle up against the wheel and insert the axle into one of the axle holes of a car body. Push this assembly up against the car body.

On the other side of the car put a washer and spacer on the axle. Put glue into the center hole of the second wheel, wiping off glue from the inside of the wheel. Finally, slide this wheel onto the axle pushing it up against the car body, with washer and spacer between it and the car body. Wipe off excess glue pushed to the outside of this wheel. Repeat with the other five wheel-axle assemblies. Allow the glue to set for 15 minutes. Remove the spacers and the wheels should turn freely.

7 – Front truck wheels. Repeat steps 4 through 6 for the 1 ½" truck wheels and longer axle to attach the wheels to the front of the truck.

8 – Exhaust pipe (optional). If an exhaust pipe was made, it should be glued into the hole behind the cab. Any other decorations, for example headlights, should also be glued in place. When the glue is dry, the car transporter is ready for use.

Variations

In addition to the exhaust pipe and headlights, there are a few of other additions or changes that can be made to the cars, truck and trailer. For example:

- Use axle pegs instead of dowels for the front truck wheels and the car wheel axles.
- Put a front and rear bumper on the truck and trailer and add tail lights (see Chapter 9).
- Cut fenders for the wheels in the cars and/or truck, as described at the end of Chapter 3.
13. Grasshopper

This grasshopper doesn’t hop, but its legs move up and down as it is pushed or pulled along the floor. It is an entertaining toy for all ages – especially toddlers.

Shown below is the grasshopper as a pull toy. The steps that follow describe making it as either a pull or a push toy. If a pull toy is preferred, do not drill the hole in the top of the grasshopper or make the push stick; rather attach a string to the front as shown below.

Figure 13-1. The Grasshopper as a Pull Toy
## Materials and Tools

### Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Any Wood</td>
<td>1 ⅛&quot; to 1 ½&quot; x 3 ⅓&quot; x 10 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Large Leg</td>
<td>Hardwood</td>
<td>¾&quot; x 2&quot; x 6&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Small Leg</td>
<td>Hardwood</td>
<td>⅝&quot; x ⅝&quot; x 5 ⅝&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Wheel axles</td>
<td>Dowel</td>
<td>⅝&quot; x 3½&quot; (cut-to-fit)</td>
<td>2</td>
</tr>
</tbody>
</table>

### Additional Items for Wood Cut List to Make a Push Toy

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handle grip</td>
<td>Hardwood</td>
<td>¾&quot; x ¾&quot; x 2 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Push stick</td>
<td>Dowel</td>
<td>½&quot; x 17 ½&quot; to 18&quot; (or cut-to-fit)</td>
<td>1</td>
</tr>
</tbody>
</table>

### Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Dimensions</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel</td>
<td>Hardwood</td>
<td>2 ¼&quot; diameter (⅜&quot; center hole)</td>
<td>4</td>
</tr>
<tr>
<td>Small leg connectors</td>
<td>Axle peg</td>
<td>⁷/₃₂&quot;</td>
<td>4</td>
</tr>
<tr>
<td>Large leg connectors</td>
<td>Axle peg</td>
<td>¹¹/₃₂&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Washers</td>
<td>Steel or Plastic</td>
<td>¼&quot;</td>
<td>4</td>
</tr>
<tr>
<td>Washers</td>
<td>Steel or Plastic</td>
<td>⅜&quot;</td>
<td>6</td>
</tr>
<tr>
<td>Eyes</td>
<td>Axle peg</td>
<td>⁷/₃₂&quot; (or 5/16&quot; button)</td>
<td>2</td>
</tr>
<tr>
<td>Paint</td>
<td>Acrylic</td>
<td>Green and red</td>
<td></td>
</tr>
<tr>
<td>Pull String</td>
<td>Nylon</td>
<td>30&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Screw eye</td>
<td>Steel</td>
<td>Small</td>
<td>1</td>
</tr>
</tbody>
</table>

### Tools

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools for this toy:
  - Twist drill Bits: ⁹/₁₆", ¹¹/₃₂", ¹³/₃₂", and ¹⁵/₆₄"
  - ½" brad point or Forstner bit (optional)
Plan and Templates

Figure 13-2 is the parts explosion for the grasshopper. Dimensions for the body and legs are given in Figure 13-3.

Step-by-step instructions for constructing the toy follow Figure 13-3. Figure 13-6 (at the end of the chapter) has actual size templates for the body and large legs.

Figure 13-2. Grasshopper Parts Explosion
(Ignore the push stick and hole on top of the grasshopper if making a pull toy. Not shown are the round overs for the body and legs – see the step-by-step instructions.)
Figure 13-3. Dimensions for Grasshopper Body and Legs (not actual size)
Steps

1 – **Transfer pattern.** Start with an oversized block of wood at least 1 $\frac{3}{4}$" x 3 1/2" x 10 1/2”).

The block can be thicker (up to 1 ½”). Transfer the pattern for the body using carbon paper or drawing an outline around a copy of the pattern (Figure 13-6).

2 – **Mark the holes.** Use an awl or nail to mark the holes on one side. There are two holes for the wheels, one for the eye and one for the large leg.

### Warning – Glue Joints and Rotating Holes

Before proceeding to drilling holes in the body or the legs [see next section], review instructions in Chapter 2 (pp. 18 – 19) concerning holes for glue joints and holes for rotating axles.

3 – **Drill holes.** A drill press is preferred for drilling the holes since they must be parallel to each other and perpendicular to the side of the body for proper operation of the toy. It is much easier to mark and drill all the holes before shaping the body, because a square block of wood is easier to hold and drill on the drill press.

All the holes in the body are through holes. Use a $\frac{13}{32}$” drill bit for the wheel axle holes. These will be holes for rotating parts. Use a $\frac{11}{32}$” bit for the hole in which the large leg connector ($\frac{1}{32}$” axle peg) will be glued.

If axle pegs are going to be used for the eyes, drill a $\frac{15}{64}$” through hole in which $\frac{7}{32}$” axle pegs will be glued. Do not drill the hole for the eyes if an alternative method for creating the eyes is going to be used (see Chapter 21 on Finishing for alternatives).

4 – **Shape.** Cut out the body within $\frac{1}{32}$” to $\frac{1}{16}$” from the outline.

5 – **Sand.** Using a power sander or simply by hand, sand to the outline.

6 – **Push or pull.** There is an option when building this toy. It can be a push toy or a pull toy (see Chapter 1, p. 11). If making a push toy a ½” hole, 1” deep is drilled at a 45-degree angle as indicated in Figure 13-3. A drill press is preferred for this operation. The body needs to be secured at a 45-degree angle and drilled with a ½” Forstner or Brad point bit. If the grasshopper is to be a pull toy, then omit this step.

7 – **Round over the edges.** Create a $\frac{3}{16}$” to $\frac{1}{4}$” round over on all outside edges of the body. If available, use a router fixed in a table. Otherwise, use a rasp and sandpaper to round over the edges.

### Router Safety

**DO NOT USE** a router to round over edges of toy parts **UNLESS** the router is stationary, that is, attached to a router table. See Ch. 18, p. 158.

8 – **Finish sanding.** Hand sand all surfaces and edges with 150 grit sandpaper.
### Legs and Wheels

1. **Large legs.** Cut two slightly oversized blocks of wood \( \frac{3}{4}" \times 1 \frac{3}{4}" \times 5 \frac{3}{4}" \). Trace the pattern for the large leg given in Figure 13-6 on each block. Mark the hole positions using an awl or nail. The distance between the holes is critical for proper operation.

2. **Small legs.** Cut two blocks of wood \( \frac{5}{8}" \times \frac{5}{8}" \times 5 \frac{3}{8}" \). Mark the hole positions (see the design for the small leg given in Figure 13-3). Once again, the distance between holes is critical for proper operation.

3. **Drill holes in large legs.** Before shaping the large legs, drill the two holes in each leg marked for the leg connectors (axle pegs). The hole at the large end of these legs is for an \( \frac{11}{32}" \) axle peg that will rotate in the hole. Use a \( \frac{13}{32}" \) drill bit for this hole and check for proper rotation. Increase the size of the hole if the fit is tight. The hole at the narrow end of the large leg will form a glue joint with a \( \frac{7}{32}" \) axle peg from the small leg. This hole should be made with a \( \frac{15}{64}" \) drill bit and should be tested in a piece of scrap wood to achieve a good fit. Again, adjust the size of the hole if the fit is not proper for a glue joint.

4. **Drill holes in small legs.** Drill the two holes in each small leg marked for the leg connectors (axle pegs). Both holes in each leg should allow rotation for a \( \frac{7}{32}" \) axle peg. Therefore, use a \( \frac{1}{4}" \) drill bit for these holes. Check for proper rotation in a piece of scrap before drilling holes in these legs.

5. **Shape the legs.** Cut out the large legs to within \( \frac{1}{32}" \) to \( \frac{1}{16}" \) of the outline. Sand the legs to the outline. Sand the ends of the small legs to a \( \frac{1}{4}" \) radius.

6. **Round over edges.** Round over the edges of each of the legs by sanding to a \( \frac{1}{8}" \) radius or using a round over bit in a router fixed in a router table.

7. **Sand.** Sand all surfaces to remove any sharp edges.

8. **Wheels.** Wheels for the grasshopper are \( \frac{3}{4}" \) thick by \( 2 \frac{1}{4}" \) in diameter with a \( \frac{3}{8}" \) center hole. These are readily available for purchase, but can also be made from hardwood or Baltic birch plywood.

### Making Wheels

Chapters 18, 19, and 20 describe techniques and jigs for making, sanding, and rounding over wheels.

It is important to drill the hole for attaching the small leg to the rear wheels at the same spot on both rear wheels. Otherwise the grasshopper will not “hop” correctly.

To drill these holes, it is recommended a jig be used for holding the wheels on the table of a drill press. A simple jig for doing this is shown in Figure 13-4. The jig consists of a short \( \frac{3}{8}" \) dowel glued into a small block of wood with a square edge. The wheel is placed on the dowel and the wood is clamped up against the fence of the drill press.

Drill the hole for attaching the small leg on the flat side of the wheel. Use a \( \frac{15}{64}" \) drill bit and test the hole in a piece of scrap wood to determine that the \( \frac{7}{32}" \) axle peg used to hold the small leg to the wheel will form a good glue joint. Stop short of drilling all the way through the wheel.

---

26 See Appendix for a list of suppliers.
1 – Seal. Brush or wipe de-waxed shellac on all the parts except the axle and tenons of the axle pegs. When dry lightly sand to remove any raised grain.

2 – Paint. There are several options for painting the grasshopper. One is to use a green water-based, child safe paint for the body (see Figure 13-1). Another is to leave the body the natural color of the wood and only paint the wheels and the heads of the axle pegs (see Figure 13-5).

3 – Eyes. If the eyes are made from 7/32" axle pegs, the heads are usually painted red, but they can be any color. The tenon of the axle pegs may need to be shortened to glue the eyes in from each side. These are small parts and you don’t want them to become loose, so test and possibly adjust the hole before gluing the eyes in place.

4 – Clear finish. After all the painted surfaces have dried, apply one or two coats of water-based polyurethane to all parts except the axles and the tenons of the axle pegs. Lightly sand between coats.

5 – Dry assemble wheels and legs. Once all the finish is dry, the parts can be assembled. If the holes were not covered when finishing the parts, ream out the holes in the body, legs and wheels with the same drill bit used to make the hole.

Next attach the wheels and legs to the body without glue to check the movement of the parts. As the grasshopper is pushed along the workbench, the legs of the grasshopper should alternatively move forward and backward as the wheels are moved. When the right-side legs go forward the left side legs should move backwards and vice versa.
This is accomplished by setting the rear wheels such that the holes for the axle pegs on the outside of these wheels are positioned 180 degrees from each other. That is, when the hole on the outside of the left rear wheel is at the bottom of the wheel, the hole on the outside of the right rear wheel is at the top of that wheel. Make any necessary adjustments before proceeding.

6 – Attach wheels. Put glue in the center hole of one of the rear wheels (the wheels with the 15/64” hole on the outside). Insert one of the 3/8” wheel axle into the center hole so that it is flush with the outside of this wheel. Make certain that the 15/64” axle peg hole is on the outside (see Figure 13-2).

Glue one of the front wheels to the other ⅜” wheel axle. Wipe off the excess glue that is pushed to the outside of the wheels. Allow 15 minutes to set.

Next dry assemble the front wheels, as follows: put a washer on the axle next to the wheel, insert the wheel, washer and axle through the hole in the body of the grasshopper, placing a spacer that is approximately 1/32” thick between the washer and body of the grasshopper.27

Applying some paraffin wax to the center of the dowel between the wheels will assure the wheels will spin freely, but do not get wax on the ends of the axle where it will be glued to a wheel.

On the other side of the body place a washer and spacer, then the second wheel. Place a mark where the axle meets the outside of the second wheel. This is where the axle will be cut off.

Remove the second front wheel and the axle with wheel attached. Trim the axle where it was marked, then re-assemble with the washers and spacers in place. Put glue in the ⅜” hole of the second wheel, then push the axle from the inside of the wheel until it is flush with the outside. Wipe off excess glue pushed to the outside of the second wheel and remove the spacers.

Repeat the wheel assembly process with the two rear wheels, being certain that the rear wheels with the 15/64” axle peg holes are opposed at 180 degrees (see Figure 13-2). Also, be certain these holes face the outside of the body. Allow the glue to set in the rear wheels before attaching the legs.

7 – Assemble legs. Attach one end of a small leg to each rear wheel as follows. Use a toothpick or nail to put glue into the 15/64” hole on the side of one of the rear wheels. Wipe off any excess glue.

Put a 7/32” axle peg through one end of a small leg and a washer on the other side. Put a spacer between the washer and the leg, then insert the axle peg into the hole in the rear wheel. Repeat with the other small leg on the other rear wheel.

Next attach the large end of the large legs to the body with 11/32” axle pegs, using the same procedure (glue in hole in body, washer, and spacer) used for attaching the small legs to the rear wheels.

Finally, attach the small legs to the large legs with 7/32” axle pegs, gluing the axle pegs into the large leg using the same procedure (with a washer and spacer) as above.

---

27The plastic clip used to seal the bag of a loaf of bread or a piece of cardboard from a cereal box make ideal spacers.
1 – **Pull string.** If this is to be a pull toy, attach the screw eye to the front of the grasshopper, as shown in Figure 13-1, then attach the pull string.

2 – **Push stick.** If this is to be a push toy (Figure 13-5), a ½” diameter hole for the stick was drilled into the top of the body at a 45-degree angle after the body was shaped.

---

**Pull String**

Chapter 2 (p. 21) gives suggestions for attaching a pull string.

**Push Stick Sub-assembly**

See Chapter 2 (p. 20) for instructions.

Cover the bottom 1” of the stick with painter’s tape, then seal the entire push stick with shellac. Once the shellac is dry, use a sanding pad to lightly sand the handle and stick, then apply one or two coats of water-based polyurethane. Sand between coats.

When the finish is dry, remove the painter’s tape from the end and glue the stick into the ½” hole in the body, using a toothpick or nail to put the glue in the hole.

---

**Figure 13-5.** The Grasshopper as a Push Toy

**Figure 13-6.** Templates (next page)
13. Grasshopper
14. Mouse

Toddlers can get a lot of practice walking and running with this push toy mouse (Figure 14-1). And the mouse has been known to squeak as the wheel axle rubs against the hole in the mouse's body.
Materials and Tools

Below are the materials and tools required, followed by a parts explosion (Figure 14-2) and side view (Figure 14-3).

Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Hardwood</td>
<td>¾&quot; to 1&quot; x 7&quot; x 9&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Wheels</td>
<td>Hardwood or plywood</td>
<td>¾&quot; x 4&quot; x 4&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Ears</td>
<td>Plywood</td>
<td>¼&quot; to ⅜&quot; x 3 ¼&quot; x 6&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Grip</td>
<td>Hardwood</td>
<td>¾&quot; x ¾&quot; x 2 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Axle</td>
<td>Dowel</td>
<td>⅜&quot; diameter x 4 ½&quot; (cut-to-fit)</td>
<td>1</td>
</tr>
<tr>
<td>Wheel spacers</td>
<td>Dowel</td>
<td>¾&quot; diameter x 1&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Push stick</td>
<td>Dowel</td>
<td>½&quot; diameter x 17 ⅞&quot;</td>
<td>28</td>
</tr>
<tr>
<td>Nose connector</td>
<td>Glue dowel</td>
<td>¼&quot; diameter x 1&quot;</td>
<td>1</td>
</tr>
</tbody>
</table>

Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes</td>
<td>Options</td>
<td>See ways to create eyes (Chapter 21)</td>
<td>2</td>
</tr>
<tr>
<td>Nose</td>
<td>Hardwood ball</td>
<td>¾&quot; with ¼&quot; diameter</td>
<td>1</td>
</tr>
<tr>
<td>Feet</td>
<td>Leather, plastic or rubber</td>
<td>⅛&quot; x 2&quot; x 4&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Feet fasteners</td>
<td>Brads</td>
<td>1&quot;</td>
<td>4</td>
</tr>
</tbody>
</table>

Tools Required

- Woodworking tools and supplies (see Chapter 2, pp. 14-5)
- Special tools for this toy
  - Twist drill bits: ⅜", 25/64", and ⅛/32""""""""""""
  - 1" Forstner bit
  - Pliers

28 Cut length to fit size of child.

29 A piece of inner tube works well. The material must be flexible enough to curve with the wheel as it turns.
14. Mouse

Figure 14-2. Mouse Parts Explosion

Figure 14-3. Mouse Side View
14. Mouse

Plans and Steps

**Body**

1 – **Design.** Figure 14-4 gives the dimensions for the mouse body. The template for the body is at the end of this chapter (Figures 14-8). Copy the outline of the template onto the rectangular blank for the body and mark the holes that need to be drilled in the face of the blank.

2 – **Hole for wheels.** Drill the through hole for the ¾” axle using a ⅛/32” drill bit. Since the axle must rotate in the hole, a drill bit larger than ¾” must be used. Drill a test hole and check that the ¾” dowel being used for this project rotates freely.

3 – **Eyes.** Use the template to mark the location of the eyes. There are several choices for the mouse eyes. See step number 6, in the next section. The size of the holes for the eyes will depend on the option chosen. No holes will be needed if the eyes are painted or plastic eyes are glued on.

4 – **Shape.** Cut out the body to within ⅛” to ¼” of the outline. Do not cut the slot for the ears now. That will be done in step 3 of the section (on the next page) on "Holes and Slot in Edge of Body." Sand the body to the outline.

5 – **Edges.** Round over edges to a ⅛” to ¼” radius, either using a rasp and sandpaper or a router.

### Router Safety

**DO NOT USE** a router to round over edges of toy parts **UNLESS** the router is stationary, that is, attached to a router table. See Ch. 18, p. 158.

6 – **Sand.** Progressively sand all surfaces and edges up to a 150-grit sandpaper.

**Wheels, Ears, Feet, Eyes, Push Stick and Grip**

1 – **Wheels.** The 3 ¾” diameter wheels need to be made from plywood or hardwood. The center hole should be ¾” in diameter. Adjust the size of this hole to the dowel purchased for this project, allowing for a proper glue joint.

2 – **Wheel spacers.** Cut the 1” spacers from a ¾” diameter dowel. Locate the center of the ¾” diameter and drill a ⅛/32” hole through each spacer. These small spacers need to be held firmly when drilling the hole, and the ¾” dowel needs to rotate freely in this hole. Sand the corners of the spacers to break any rough edges.

### Making Wheels

See Chapters 18 and 19 for ways to make large wheels. There is also a jig described in Chapter 20 for sanding the edges of wheels, and another jig in Chapter 18 for rounding over wheels using a router.

### Jig to Hold Spacers for Drilling

See Chapter 19 (p. 170) for an easy to make jig for holding a spacer while drilling the center hole.
14. Mouse

3 – Feet. Use the template (Figure 14-7) to cut out two feet from the material chosen (leather, plastic, or rubber).

4 – Slot for Feet. Draw slots in the wheels for the feet, as shown in Figure 14-2 (or 14-3). Cut a slot in each wheel about 1" long perpendicular to the edge. The feet will be inserted in this slot during the assembly process. The width of the slot needs to match the material used for the feet.

The feet should not fit loosely in these slots. Try to make the width such that a small amount of force is required to pull the feet into the slot.

5 – Ears. Using the template (Figure 14-6), draw an outline of the ears onto the 3 ¼" x 6" blank. Make the width of the cut-out on the bottom of the ears fit the width of the mouse body. Cut out the ears, sand to the outline, round over the edges (except the edges of the cut-out) to a ⅛" radius, and sand all surfaces and edges to 150 grit sandpaper.

6 – Eyes (optional). Axle pegs with either ½" or ⅜" heads or wood buttons with ½" or ⅜" heads can be used for the eyes. If axle pegs are used, their tenons will need to be shortened. Other choices are to purchase plastic eyes or paint them directly on the body.

Creating Eyes

Different ways to create eyes are described in Chapter 21, pp. 184-5.

7 – Push stick. Make the push stick and grip as described Chapter 2. Adjust the length for the child that will be using the toy.

Holes and Slot in Edge of Body (see Figure 14-4)

1 – Push stick. Drill a ½" hole 1" deep in the body for the ½" diameter dowel.

2 – Nose. Drill a ¼" hole ½" deep for the glue dowel that holds the ball nose.

3 – Ears. In the body cut the slot for the ears ⅝" deep. The width of this slot should suit the thickness of the blank out of which the ears were made.

Glue Joints


Finish

1 – Sealer. Mask off all parts that will be glued. Seal all wooden parts with de-waxed shellac, except the axle that is used to attach the wheels and the dowel used to attach the nose. Allow to dry, then lightly sand with a super fine sanding pad.

2 – Paint (optional). Any painting of parts should be done before the mouse is assembled. Paint the eyes directly on the face of the body, if that option for eyes is chosen.

3 – Finish coat. Continue to mask all parts that will be glued. Apply water-based gloss or semi-gloss polyurethane or another child safe clear finish to all the sealed parts. Two coats are recommended.
Figure 14-4. Mouse dimensions (not actual size)

Figure 14-5. Mouse Ears Dimensions (not actual size)
14. Mouse

Assemble

1 – Feet. Pull the feet into the slots in the wheels. Since the slots are narrow, the best way to insert the feet is to clamp the wheel in a vice and use two pliers to pull the feet into the slot.

Nail two brads into the edge of each wheel to secure the feet. The brads should go from the edge of the wheel into the feet. Countersink the brads and fill the holes with wood filler.

2 – Glue axle. Sand the end of the axle. Put glue into the center hole of one of the wheels using a toothpick or nail. Wipe off any glue from the faces of the wheel, then insert the axle so its end is flush with the outside of the wheel. Wipe off the glue that is pushed to the outside. Allow the glue to set for 15 minutes.

3 – Dry assemble wheels. Put one of the ¾" wheel spacers onto the axle. Slide the axle with the wheel attached into the axle hole in the body of the mouse. On the other side of the body put the second ¾" spacer and the second wheel. Allowing a gap of about 1/32" between the spacers and the body, place a mark where the axle is flush with the outside of the second wheel – the one not yet glued to the axle.

4 – Trim axle and glue second wheel. Disassemble the wheels and axle (step 3) and trim the axle at the mark. Reassemble the axle, spacers, and wheels. Glue the second wheel to the axle and remove the ¼" spacers.

Using Wood Buttons to Cover Axle Hole

An alternative to the method described above for attaching the wheels is shown in Figure 14-1. Here a ½” wood mushroom button is glued into the axle hole. The wheel is wide enough to allow space for the tenon of the button to be glued into the axle hole, and still have enough space to glue the axle to the wheel.

4 – Nose. Glue one end of the ¼" connector dowel into the ball and the other end into the body.

5 – Ears. Glue the ears to the slot in the top of the head.

6 – Eyes. If using axle pegs, wooden buttons, or purchased plastic eyes with tenons, holes should have already been drilled for the tenons. Glue the eyes into the holes on either side of the body.

30 The plastic clip used to seal a loaf of bread or a piece of cardboard from a cereal box make ideal spacers for this gap.
14. Mouse

Figure 14-6. Template for Ears

Figure 14-7. Template for feet

Figure 14-8. Template for body (next page)
14. Mouse
15. Hippo

This toy is designed to be moved along the floor by hand rather than pulled by a string or pushed by a stick. The mouth of the hippo opens and closes as it is pushed. This movement is created by alternating dowels on the wheels that lift the head up, then let it fall.

![Hippo Toy]

**Figure 15 – 1. Hippo**

**Materials and Tools**

The following tables give the wood cut list and other parts. Figure 15-2 shows the parts explosion and Figure 5-5 gives the dimensions of the body and head sides. Special tools needed to construct this toy are noted below, followed by the step-by-step instructions for building the hippo.
Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Hardwood (1), (2)</td>
<td>1¼&quot; x 4&quot; x 9 ¾&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Head (sides)</td>
<td>Hardwood (2)</td>
<td>¾&quot; x 3 ½&quot; x 5&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Upper head spacer block</td>
<td>Hardwood (2), (5)</td>
<td>¾&quot; x 1 7/16&quot; x 3 ¼&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Lower head spacer block</td>
<td>Hardwood (2), (5)</td>
<td>¾&quot; x 1 7/16&quot; x 1 ¼&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Wheel blanks</td>
<td>Baltic birch (3), (4)</td>
<td>½&quot; x 3&quot; x 3&quot;</td>
<td>4</td>
</tr>
<tr>
<td>Teeth</td>
<td>Dowel</td>
<td>¾&quot; x ¾&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Axles</td>
<td>Dowel</td>
<td>¾&quot; x 3 ¾&quot; (cut-to-fit)</td>
<td>2</td>
</tr>
<tr>
<td>Drive pegs</td>
<td>Dowel</td>
<td>¾&quot; x ¾&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Rear wheel spacers</td>
<td>Dowel</td>
<td>¾&quot; diameter x ½&quot;</td>
<td>2</td>
</tr>
</tbody>
</table>

(1) If using wood thicker than 1 ¼" for the body, the thickness of the two head spacers will need to be adjusted.
(2) Use the same type of wood for all these parts. Mahogany or walnut will look good.
(3) Use Baltic birch plywood or any hardwood.
(4) These square blanks will be used to make a wheel 2 ½" in diameter. Alternatively, these wheels can be purchased. Several toy part suppliers offer them as 2 ½" flat slab wheels (¾" thick) with a ⅜" center hole. (See Appendix for list of suppliers.)
(5) The width of the spacers needs to be ⅜/16" greater than the thickness of the body.

Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes (head pivot)</td>
<td>Axle peg</td>
<td>7/32&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Washers</td>
<td>Plastic or steel</td>
<td>⅛&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Tail</td>
<td>Twisted nylon rope</td>
<td>¼&quot; diameter x 1 ½&quot; long</td>
<td>1</td>
</tr>
</tbody>
</table>

Tools Required

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools for this toy:
  - Twist drill bits: ⅛/32", ⅛/64", ⅛", and 3/8"
**Figure 15-2.** Parts Explosion

### Plans and Steps

**Body**

1. **Design.** Use the template at the end of this chapter (Figure 15-6) to transfer the outline of the hippo’s body onto the wood blank. Mark the holes on the body with a center punch or a nail.

2. **Holes.** Drill the three holes in the side of the body. Each is a through hole. The two axle holes are made by using a $\frac{13}{32}$” drill bit and the hole for the eye axle peg (jaw pivot hole) is made using a $\frac{15}{64}$” drill bit.

3. **Shape.** Cut out the body to within $\frac{1}{32}$” to $\frac{1}{16}$” of the outline. Sand to the outline. Round over the edges to a generous radius, either by sanding or using a $\frac{1}{4}$” roundover bit. Then sand all surfaces and edges up to 150 grit sandpaper.

**Router Safety**

**DO NOT USE** a router to round over edges of toy parts **UNLESS** the router is stationary, that is, attached to a router table. See Ch. 18, p. 158.

4. **Attach tail.** Drill a $\frac{1}{4}$” diameter hole $\frac{1}{2}$” deep on the back rear of the hippo for the tail. Cut a piece of $\frac{1}{4}$” twisted nylon rope $1 \frac{1}{2}$” long and cauterize the ends so that they do not unravel. Glue the tail into the hole.
1 – Make or purchase. The hippo uses wheels that are 2 ½" in diameter with a ⅜" center hole. These wheels can be purchased or made. The following steps assume the reader has made and rounded over the wheels.

Making Wheels

See Chapters 18, 19, and 20 for techniques and jigs to cut out, sand, and roundover wheels.

If the wheels have been purchased, the following instructions might need to be slightly modified, depending on the size and type of wheels purchased.

2 – Front wheels. Drill an off-set ⅜" hole on the inside of each of the two front wheels for the dowel that activates the head/mouth. The center of this hole should be ⅝" from the center of the wheel (see Figure 15-3), and it should be ⅜" deep. Be certain to clamp each wheel securely before drilling.

3 – Drive peg. Cut two ¾" lengths from a ⅜" diameter dowel. Put glue into each of the off-set holes drilled into the front wheels and insert a drive peg into each hole. Wipe off any excess glue. The drive pegs should extend out of the hole ⅜".

4 – Front axle. Assuming the body of the hippo is 1 ¼" thick (if thicker or thinner adjust the following accordingly), cut a piece of ⅜" diameter axle 3 ½" long. Put glue into the ⅜" center hole of one of the front wheels and insert the axle from the inside of this wheel (the side that has the drive peg) until it is flush with the outside. Wipe off any excess glue from the outside of the wheel and let the glue set.

5 – Dry assemble front axle. Insert the wheel and axle that has been assembled into the hole in the front of the hippo’s body and put the second front wheel onto the axle extended through the body. Adjust the position of the second wheel such that there is about ⅛” space between each drive peg and the body of the hippo. Place a mark where the axle extends past the outside of the second wheel. Take the second wheel off and trim the axle at the mark. Set aside these two wheels, one with the axle attached. Finish will be applied to them before final assembly.

6 – Rear axle spacers. To keep the rear wheels the same distance from the hippo’s body as the front wheels, it will be necessary to put spacers on the rear axle. Cut two spacers ½" in length from a piece of ⅜" dowel. Drill a 13/32” hole through the center of each spacer.

Jig to Safely Hold the Spacers for Drilling

See Chapter 19, p. 170.
7 – Rear axle. Once again, assuming the body of the hippo is 1¼" thick (if thicker or thinner adjust the following accordingly), cut a piece of ¾" diameter axle 3½" long. Put glue into the ¾" center hole of one of the rear wheels and insert the axle through this hole until it is flush with the outside. Wipe off any excess glue from the outside of the wheel and let the glue set.

8 – Dry assemble rear axle. Put one of the ¾" diameter spacers onto the rear axle up against the wheel that has been glued to the axle. Insert the axle with wheel and spacer into the hole in the rear of the hippo’s body.

Place the second ¾" diameter spacer onto the axle that has extended through the body of the hippo, then put the second rear wheel onto the axle.

Adjust the position of the second wheel such that there is about ¼" space between each spacer and the body of the hippo. Place a mark where the axle is flush with the outside of the second wheel.

Remove the second wheel and trim the axle at the mark. Set aside these two rear wheels, one with the axle attached. Finish will be applied to them before final assembly.

Head

1 – Sides. Using the template in Figure 15-6, transfer the outline of the head sides onto each of the two ¼" thick blanks with the grain running lengthwise. Mark the location of the axle peg eye which is also the pivot hole.

2 – Drill and shape. Drill the eye/pivot hole through each blank using a ¼" drill bit. Cut out the two sides for the head within 1/16" of the outline, but do not sand them to the outline just yet. The distance from the eye/pivot hole to the bottom of the jaw is critical to the proper opening of the mouth, so be careful in drilling and cutting out these pieces.

3 – Spacer assembly. The head is formed from the two spacer pieces and the two head sides. Cut the end of the upper head spacer at a 45-degree angle as shown in Figure 15-4a. Glue the lower head spacer to the other end of the upper head spacer as shown in Figure 15-4a. This will be referred to as the “spacer assembly.” Allow the glue to dry before continuing to the next step.

4 – Head construction. The spacer assembly has one squared off end which will become the nose and one end cut at a 45-degree angle. After the sides are glued to the spacer assembly, it will be shaped to conform to the shape of the sides. For now, leave the spacer assembly squared off at the nose end.

5 – Teeth. To drill the holes for the teeth, place the spacer assembly upside down on a piece of scrap wood. Drill a ¾" hole in a piece of scrap wood to determine if the ¾" pieces of dowel being used for the teeth will make a good glue joint in a ¾" hole. If not, adjust accordingly. Drill the holes for the teeth under the nose of the head in the locations shown in Figure 15-4b, then glue the teeth in place.

Figure 15-4a. Spacer Assembly
15. Hippo

6 – Glue spacer assembly to head sides.
Begin by assembling but not gluing the front and rear wheels onto the body of the hippo. Adjust the front wheels so that the drive pegs are at the top of the wheel and opposite each other.

Next secure the hippo’s body to your workbench with a clamp or vice, keeping the wheels in the position described above. Use an axle peg to dry assemble (assemble without glue) one of the head side pieces to one side of the hippo’s body, inserting a ¼” washer between the side and the body. Allow this side piece to rest on the drive peg on that side. Repeat with the other head side piece and other side of the hippo.

Next apply glue to the sides of the spacer assembly and place it between the two head sides as shown in Figure 15-2. Be certain to orient the spacer assembly such that the squared off double thickness is at the nose end and the cut-off 45-degree angle is at the roof of the mouth. Press this assembly together, making sure the head side pieces are within the edges of the spacer assembly and are lined up exactly opposite each other. Any excess of the spacer assembly will be removed later. Now clamp the head sides to the spacer assembly. The newly formed “head assembly” should rotate freely on the axle pegs. Allow the glue to dry completely.

7 – Shape. Once the glue that created the “head assembly” is dry, remove the axle pegs and the head assembly from the body of the hippo. Cut and then sand the squared off end of the spacer assembly now attached to head sides, so it matches the shape of the head side pieces. Sand the head assembly to the outline drawn on the two head sides.

Next, sand the edges to a generous radius. Then sand all surfaces and edges up to 150 grit sandpaper. Be careful around the lower end of the jaw. Do not remove too much wood in order not to reduce the amount of open/close action of the mouth.

Finish

1 – Sand. All surfaces should be sanded with 150 grit sand paper. If the wheels have been made, sand a slight round over on the edges to remove any rough spots.

2 – Seal coat. Apply de-waxed shellac to all surfaces except the wheel axles and tenons of the head pivot axle pegs. Lightly sand after the shellac dries, then remove any dust.

3 – Paint eyes and teeth. The heads of the head pivot axle pegs that are the hippo’s eyes. Put painter’s tape on the tenons of the axle pegs to protect them from paint, then paint the heads a dark color (say blue or black). Paint the teeth white.

4 – Top coat. Apply water-based polyurethane to all surfaces except the wheel axles and axle peg tenons. Once dry, lightly sand again if applying a second coat of polyurethane.
1 – Ream out holes. If finish has gotten into the axle peg eye pivot hole or the axle holes, it might be necessary to ream out these holes before assembling the hippo.

Reaming out Holes

See Chapter 19, p. 169.

2 – Rear wheels. Place one of the ¾” diameter spacers onto the rear wheel glued to the rear axle, then insert this axle through the rear of the hippo. Place the other ¾” diameter spacer on the axle protruding out the other side of the body. Next place glue into the center hole of the second wheel from the side that will be on the inside and insert this wheel onto the axle such that the axle is flush with the outside surface of the wheel. Wipe off the excess glue.

Warning

For each of the instructions that involve gluing a dowel into a hole, be certain to get a good glue joint. For instructions to check the glue joint, see Chapter 2, p. 19.

3 – Dry assemble front wheels. The positioning of the front wheels is critical. The drive pegs on the two front wheels are located towards the body and at 180 degrees from each other to assure proper movement of the head and mouth.

It is suggested that the front wheels be assembled dry to test the movement of the head and mouth in the next step.

4 – Attach head and mouth. Place the head assembly onto the body. When doing this it is necessary to slip a washer between the body and the side of the head before inserting the axle peg. This is done on each side. With the front wheels in position (step 3), test that the drive pins are set to cause the mouth to move up and down as the front wheels turn. Once satisfied with the movement of the head, remove the axle pegs and head assembly.

Put a small amount of glue into each side of the 15/64” holes in the head using a nail or toothpick. Lightly coat the inside of the hole, then wipe off any glue on the outside surface. Next place the head on the body, slip the washers between the body and the side of the head, and insert the axle pegs into the holes. Move the head up and down to be certain there is no glue stuck to it.

5 – Attach front wheels. Insert the front axle with one wheel already glued to it into the hole in the front of the hippo. On the wheel not yet glued to the front axle, put glue into the center hole from the inside of the wheel, then put this wheel onto the axle so that it is flush with the outside face.

Be certain to align this wheel so that its drive peg is at 180 degrees to the opposite front wheel drive peg. Wipe the excess glue off the outside of the wheel that was just glued. Let the glue set.
Figure 15-5. Dimensions

Figure 15-6. Templates (next page)
15. Hippo
16. Rolling Rattle

Pictured below is the rolling rattle – a push toy particularly good for toddlers learning to walk, but also enjoyed by older children. As it is pushed along, the “clackers” make a clicking sound. As a side benefit, parents can hear what the user is doing and where she/he has gone.

Figure 16-1. Rolling rattle
## Materials and Tools

### Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yoke</td>
<td>Hardwood</td>
<td>¾” x 6” x 6 ¾”</td>
<td>1</td>
</tr>
<tr>
<td>Wheel</td>
<td>Hardwood or BB</td>
<td>½” to ¾” x ¾” x 4” x 4”</td>
<td>2</td>
</tr>
<tr>
<td>Clacker</td>
<td>Hardwood</td>
<td>½” x 1” x 10 ½” (to be cut into 3 parts)</td>
<td>1</td>
</tr>
<tr>
<td>Push stick</td>
<td>Dowel</td>
<td>18” to 24” to suit size of child</td>
<td>1</td>
</tr>
<tr>
<td>Handle grip</td>
<td>Hardwood</td>
<td>¾” x ¾” x 2 ½”</td>
<td>1</td>
</tr>
<tr>
<td>Clacker supports</td>
<td>Dowel</td>
<td>¼”x 3 ¾” (cut-to-fit)</td>
<td>3</td>
</tr>
</tbody>
</table>

### Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Dimensions</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axle</td>
<td>Axle peg</td>
<td>⅛”, (overall length should be 1 ¾/16”)</td>
<td>2</td>
</tr>
<tr>
<td>Washers</td>
<td>Plastic or steel</td>
<td>¾”</td>
<td>2</td>
</tr>
</tbody>
</table>

### Tools Required

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Additional tools for this toy:
  - twist or brad point drill bits: ¼”, ⅜”, ½” and ⅞/16”
  - 1” spade drill bit

---

31 BB = Baltic birch plywood
Plans and Steps

Figure 16-2 shows the parts explosion for the rolling rattle. Dimensions for the main parts (clackers, wheels, and yoke) are in Figures 16-3, 16-4, and 16-5. Templates for these parts are in Figures 16-6 through 16-8.
**Yoke**

1 – **Design.** Transfer the pattern to the face of the ¾" x 5 5/8" x 6 ¼" blank as shown on the template Figure 16-7. Mark the locations for drilling the two 1" diameter holes shown on Figure 16-4.

2 – **Drill holes.** Using a 1" spade drill bit, drill each hole a little more than half way through the block from one face – far enough that the pointed tip of the drill just pokes through to the other side of the block. Turn the block over and finish drilling the two holes from the other side.

3 – **Mark cut out.** Draw lines tangent to the holes that mark the rectangle to be cut out of the bottom of the yoke, as shown in Figure 16-4.

4 – **Shape.** Using a band saw or scroll saw, cut along the tangent lines to remove the inside of the yoke, then cut within 1/32" to 1/16" of the outline to shape the top and bottom of the yoke.

5 – **Sand.** Smooth out the edges where the inside of the yoke was cut out.

6 – **Round ends.** Using a hand sanding block or a power stationary sander, round the ends of the yoke at the bottom and the top.

7 – **Round over edges.** Use a router with a 3/16" round over bit, or a file and/or sanding block to ease all the edges.

**Router Safety**

**DO NOT USE** a router to round over edges of toy parts UNLESS the router is stationary, that is, attached to a router table. See Ch. 18, p. 158.

8 – **Hole for push stick.** Drill a ½" hole 1" deep, centered on the top of the yoke.

9 – **Axle holes.** Centered on each side of the yoke, ¾" from the ends, drill a hole for the axle pegs that hold the wheel and clacker assembly to the yoke. Use a 11/32" or 23/64" drill bit for these holes.

**Glue Joints**

Check that the holes drilled for the push stick and axle pegs, and for the wheels (in next section) will make a proper glue joint. See Chapter 2 (p. 19) for ways to test or make corrections if necessary.

**Wheels**

1 – **Make wheels.** This toy requires two 3 ½" diameter wheels with a ⅜" center hole. Figure 16-6 is the template for the wheels. The dimensions are shown in Figure 16-5.

2 – **Drilling holes in wheels.** To begin, tape the wheels together with painter's tape. They will be drilled at the same time. Mark three equidistant hole locations ½" from the edge of the wheels (see Figure 16-5). They should be approximately 2 ¼" center to center.

Drill all the way through both wheels with a ¼" twist or brad point drill bit. Using a drill press is preferred to maintain alignment. Use a scrap backup board to avoid tear out. If using a hand-held power drill, take care to keep the drill bit perpendicular to the wheels.

Making Wheels

See Chapters 18, 19, and 20 for techniques and jigs to cut out, sand, and roundover wheels.
Drill a hole through the center of the wheels using a \( \frac{3}{8} \)" drill bit. Afterwards, remove the tape but temporarily maintain the position of the wheels. When the clacker cage is assembled the wheels will need to be aligned the same way they were drilled.

To remember this alignment, place a small mark on the inside of each wheel at one pair of opposite dowel holes. Make it light and on the inside because this mark cannot be removed before finish is applied.

### Clackers

1. **Prepare blank.** Begin with a piece of hardwood \( \frac{1}{2} \)" thick, 1" wide and at least 10" long. Using a sanding block, round over all edges to an approximate \( \frac{1}{8} \)" radius.

2. **Cut individual clackers.** Using a bandsaw, scroll saw, or handsaw cut the blank into three 3 ¼" lengths.

3. **Put hole in clacker.** At one end of each piece drill a \( \frac{7}{16} \)" diameter hole. Locate the center of this hole \( \frac{1}{2} \)" from the end, centered on the face of the clacker (see Figure 16-3).

4. **Shape opposite end.** Narrow the end of each clacker opposite the end in which the hole was drilled, using Figure 16-8 as a template. This can be done using a bandsaw, wood file, and/or power sander. Round over both ends using a sanding block or power sander.

![Figure 16-3. Clacker Dimensions (not actual size)](image-url)
16. Rolling Rattle

**Figure 16-4.** Yoke Dimensions (not actual size)

**Figure 16-5.** Wheel Dimensions (not actual size)
Rolling Rattle

Refer to Chapter 2 (p. 20) for steps to construct the push stick and grip.

Push Stick

Refer to Chapter 2 (p. 20) for steps to construct the push stick and grip.

Finish

1 – Sand. If not already done, sand all cut parts with 150 grit sand paper.

2 – Seal. Cover 1” of the bottom of the push stick with painter’s tape where it will be glued into the yoke.

Apply a coat of shellac to all parts prepared to this point. Once dry, lightly sand with a sanding pad to remove any raised grain.

3 – Paint clackers. Using distinct colors for each, paint the clackers with a child-safe paint.

4 – Clear finish. Paint all pieces with a clear child-safe finish, for example, water-based polyurethane. When dry, repeat if necessary, lightly sanding with a fine foam sanding pad between coats.

More on Finishes and Finishing Methods

See Chapter 21, p. 183.

Assemble

1 – Construct cage. Cut the clacker supports - three pieces of ¼” dowel 3 ¼” long. Dry assemble the dowels and wheels, paying attention to the alignment marks previous put on the inside of the wheels by placing the dowels through from the inside. Check that the wheels are 3 ¼” apart (outside to outside) with the dowels inserted. Disassemble the cage.

2 – Glue supports in one wheel. Putting glue into the three dowel holes of one wheel, glue the clacker support dowels into the wheel. Wipe off glue that squeezes to the outside of the wheel. When the glue is set, place a clacker on one dowel. Be sure it rests between the other two dowels. Repeat for the remaining two clackers.

3 – Glue second wheel. Line up the pencil marks made earlier and glue the second wheel in place on the dowels, being certain that the dowels are glued into the inside of the second wheel. Let glue set.

4 – Attach cage to yoke. Attaching the clacker cage to the yoke can be tricky. It is wise to do a dry assembly of the following step before using glue. This will also enable you to test that the clackers are working properly when the wheels turn.

The upper part of the tenon of the 11/32” axle peg will be glued to the yoke and the lower part will serve as the axle on which the cage turns. This axle peg has an overall length of 1 3/16” with a tenon length of 1 5/8”.
Place the clacker cage inside the yoke and as the axle pegs are pressed through from the outside of the yoke insert a washer on each axle peg between the yoke and the cage. Run the yoke along a flat surface to determine that the clackers in the cage work properly. As the wheels turn, the clackers should make a clacking sound as they slide on the clacker supports.

Once satisfied that the clackers work, disassemble the cage from the yoke and prepare to glue the axle pegs into the yokes. This is more easily done if the yoke is held vertically in a vice. Apply glue to one of the axle pegs along the top ¾” of the tenon (from the head down). Remember to insert a washer between the yoke and the wheel as the axle peg is being inserted from the outside of the yoke. Also remember that the axle peg is to be glued only to the yoke, not to the wheels of the clacker cage.

After installing the axle peg on one side, turn the yoke over and glue the other axle peg with washer into the wheel on the other side. Spin the cage to make sure there is no glue hindering its movement.

5 – Attach push stick. Remove the tape from the end of the push stick, put glue into the hole at the top of the yoke, and glue the stick into the yoke.

![Figure 16-6. Wheel Template](image-url)
Figure 16-7. Yoke Template

Figure 16-8. Clacker Template
17. Helicopter

This is a challenging but rewarding toy to build. The main rotor (the blades on top of the helicopter) rotates as the body of the helicopter is pulled or pushed across the floor.

This toy can be propelled by hand (the version below), or a pull string can be attached to the nose. The finished helicopter is shown in Figure 17-1. An x-ray view below the photo shows the rotor drive mechanism – one of the more difficult parts of this toy to construct.
Materials and Tools

This section includes the wood cut list, other parts, and tools needed to construct the helicopter, followed by a parts explosion (Figure 17-2).

Wood Cut List

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size (thickness, width, length)</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Hardwood</td>
<td>1 ¾&quot; x 3 ½&quot; x 6&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Tail boom</td>
<td>Hardwood</td>
<td>⅞&quot; x ⅞&quot; x 6&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Tail rotor</td>
<td>Hardwood or BB</td>
<td>1/4&quot; x ¾&quot; x 2 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Main rotor</td>
<td>BB or Hardwood</td>
<td>⅛&quot; x 9&quot; x 9&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Main rotor hub</td>
<td>Wood slab wheel</td>
<td>½&quot; x 1 ½&quot; diameter (TWF150)</td>
<td>1</td>
</tr>
<tr>
<td>Vertical drive wheel</td>
<td>Treaded wheel</td>
<td>½&quot; x 1 ¼&quot; diameter (TWT125)</td>
<td>1</td>
</tr>
<tr>
<td>Horizontal drive wheel</td>
<td>Wood slab wheel</td>
<td>⅛&quot; x 1&quot; diameter (TWF100)</td>
<td>1</td>
</tr>
<tr>
<td>Vertical rotor shaft</td>
<td>Dowel</td>
<td>⅛&quot; x 3 ¼&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Glue dowel</td>
<td>Dowel</td>
<td>⅛&quot; x 2&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Wheel axle</td>
<td>Dowel</td>
<td>⅛&quot; x 5 ¼&quot; (cut-to-fit)</td>
<td>1</td>
</tr>
<tr>
<td>Wheel spacers</td>
<td>Dowel</td>
<td>¾&quot; x 1 ½&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Drive wheel locking pin</td>
<td>Dowel</td>
<td>¾/₁₆&quot; x 1 ½&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Tail wheel strut</td>
<td>Dowel</td>
<td>½&quot; x 1 3¼&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Tail rotor support arm</td>
<td>Dowel</td>
<td>½&quot; x 2 ¾&quot;</td>
<td>1</td>
</tr>
</tbody>
</table>

Other Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Size</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheels</td>
<td>Hardwood</td>
<td>9/₁₆&quot; x 1 ¾&quot; diameter (TW1750)</td>
<td>2</td>
</tr>
<tr>
<td>Tail wheel</td>
<td>Hardwood</td>
<td>⅞&quot; x 1&quot; diameter (TW1000)</td>
<td>1</td>
</tr>
<tr>
<td>Tail wheel axle</td>
<td>Axle peg</td>
<td>7/₃₂&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Tail rotor axle</td>
<td>Axle peg</td>
<td>7/₃₂&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Washers</td>
<td>Steel or plastic</td>
<td>¼&quot;</td>
<td>2</td>
</tr>
<tr>
<td>Screw eye (optional)</td>
<td>Steel</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>String (optional)</td>
<td>Nylon</td>
<td>22&quot;</td>
<td>1</td>
</tr>
</tbody>
</table>

32 Part numbers listed in parenthesis after the description of certain parts are from Woodworks, Ltd. Other suppliers will have similar parts.
33 BB = Baltic birch
34 This wood slab wheel can be made rather than purchased. See Chapter 18 on the making of wheels.
Figure 17-2. Helicopter Parts Explosion

Tools Required

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools for this toy:
  - Twist drill bits: $\frac{13}{32}$", $\frac{3}{8}$", $\frac{15}{64}$", $\frac{1}{4}$"
  - 1" spade or brad point bit
  - 1 $\frac{3}{4}$" Forstner bit
  - 3/8" Forstner bit
  - 1/2" brad point bit
  - Chisel
  - Pliers

Drill Bits

See Chapter 19 (pp. 166-7) on the types of drill bits used in toy building.
**Plans and Steps**

### Body

**1 – Prepare blank.** Cut out a piece of hardwood 1 ¾" thick, 3 ½" wide and 6" long, larger than needed to allow for shaping the body.

Side, back and bottom views of the body are shown in Figure 17-3. This drawing is not actual size. A template for the body that is to scale is given in Figure 17-4. Using this template, mark the outline of the body on the rectangular blank and locate all the holes to be drilled into the side, back, and bottom of the body, as shown in Figure 17-3. Indent the center of the holes with a punch or nail, but do not cut out the blank just yet.

Using a router, round over the bottom only with a ¼" roundover bit.

### Router Safety

**DO NOT USE** a router to round over edges of toy parts **UNLESS** the router is stationary, that is, attached to a router table. See Ch. 18, p 158.

**2 – Drilling sequence.** It is easier to drill all the holes in the body while it is still a rectangular block. Before beginning, place a piece of scrap wood under the body to prevent tear out when drilling through holes.

When drilling through holes, drill more than halfway through until the point of the bit comes out the other side. Then turn the piece over to finish drilling the hole.

**Hole #1.** On the side drill the through hole for the wheel axle using a 13/32" diameter bit.

**Hole #2.** On the side drill the 1" diameter through hole to represent the cockpit.

**Hole #3.** On the back edge drill a hole 1 ⅛" deep using a ¾" size drill bit. This hole is for the dowel that attaches the tail boom.

**Holes #4.** On the bottom drill two ½" diameter holes 1 ¾" deep. These holes are used to prepare the cavity for the rotor turning mechanism.

**Hole #5.** On the bottom use a 1 ¼" Forstner bit to enlarge the cavity to a depth of 1 ¾". This hole is for the rotor turning mechanism.

**Hole #6.** With a 13/32" bit placed in the center of the 1 ¼" hole #5, drill all the way through the body.

**3 – Chisel out the cavity.** Following the outline given on the bottom view of the body in Figure 17-3, use a hand chisel to enlarge the parts of the cavity for the rotor turning mechanism that were not cut out by drilling holes #4 and #5. The entire cavity depth should be 1 ¾". Use a chisel to smooth out the bottom of the cavity.
Figure 17-3. Helicopter Body (not actual size)

Figure 17-4. Helicopter Body Template (actual size)
**Shaping Body**

1 – **Trim the rectangular blank.** Cut out the body of the helicopter following the outline of the body previously drawn on the rectangular blank. When cutting the block, stay just outside the outline.

2 – **Sanding.** Finish shaping the body by sanding to the outline.

3 – **Round over edges.** All the remaining edges of the body should be rounded over to an approximate ¼” radius. Do this by hand since the drilled holes will prevent a router bearing from running smoothly around the body.

4 – **Finish sanding.** Sand all surfaces and the rounded over edges to 150 grit sandpaper.

**Wheel Assembly Parts**

1 – **Wheel axle and wheels.** Cut a ¾” diameter dowel to a length of 5 ¼”.

The 1 ¾” diameter helicopter wheels have a ¼” center hole that needs to be enlarged to fit the ¾” dowel, which will be glued into this hole. Before enlarging this hole, it is advised to drill a test hole in a piece of scrap wood to determine the best size drill bit to use to get a good glue joint for the piece of ¾” dowel used for this project.

Many ¾” diameter dowels are not exactly ¾”. A 25/64” diameter bit will often work better than a ¾” drill bit. Whichever bit is used, it should be a twist bit. Such a bit will automatically center in the ¼” hole.

2 – **Wheel spacers.** Cut two ¾” diameter dowels 1 ½” long. See Figure 17-2. Mark the center of one end of each dowel, then center punch the center as accurately as possible. Drill a 13/32” hole through each dowel to form a spacer. Use the jig referred to above to hold the dowels for drilling these center holes.

**Jig to Drill Circular Parts**

Use the drilling jig described in Chapter 19 [p. 170] to hold the wheels to enlarge their center holes.

**Rotor Shaft Assembly Parts**

1 – **Vertical rotor shaft.** Cut a ¾” dowel 3 ¼” long.

2 – **Horizontal drive wheel.** This wheel should be purchased. It is too small to make safely. To purchase this wheel, see the list of part numbers in the cut list.

The wheel should be 1” in diameter and 5/16” to ¾” thick. Drill a hole in the center in which the ¾” rotor shaft will be glued. Use the jig for drilling circular parts to hold this wheel for drilling. Select the proper size drill bit as described in the previous section. The wheel will already have a ¼” center hole. Use an appropriate size twist bit to enlarge this hole.

3 – **Vertical drive wheel.** Use a purchased wheel for this part - a 1 ¼” diameter treaded wheel, ½” thick. This wheel comes with a ½” center hole.
Enlarge the center hole using an appropriate size twist bit that will enable the hole to accommodate the \( \frac{3}{8} " \) axle. Next drill a \( \frac{3}{16} " \) hole halfway through the side to the center of the wheel for the drive wheel locking pin (see Figure 17-2).

Set aside these rotor shaft parts for now.

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**Tail Boom Assembly**

1 - **Tail boom.** Cut a piece of hardwood \( \frac{7}{8} " \) square by 6" long (see Figure 17-5). Round over the four 6" long edges to a \( \frac{1}{4} " \) radius.

2 - **Shaping the boom.** Make the 30-degree angle cut on the end of the boom (30 degrees from the horizontal). The cut should begin midway up the back side of the boom at about \( \frac{3}{8} " \) from the bottom.

A straight-forward way to do this is to first mark the cut as shown in Figure 17-5, then bandsaw or hand saw the cut just outside the line. Finish with sanding to the line with a stationary disk or belt sander, or sanding block.

3 - **Drill holes in boom.** Use a punch to mark the hole locations. The following holes should be drilled with a brad point bit to achieve a square bottom and a good fit for the dowels that will be glued into the holes.

Drill two \( \frac{1}{2} " \) diameter holes in the boom \( \frac{1}{2} " \) deep – one for the tail wheel strut centered on the underside of the boom \( \frac{1}{2} " \) from the end where the 30-degree cut was made, the other for the tail rotor support arm centered on the 30-degree cut and drilled perpendicular to this cut.

Next mark the center of the end of the boom that attaches to the body. Drill this hole for the glue dowel \( \frac{1}{8} " \) deep with a \( \frac{3}{8} " \) bit (see Figure 17-5).

The dowels might need to be sanded to achieve a good fit in the holes drilled above. An alternative drill bit to achieve a better fit for the \( \frac{3}{8} " \) hole is a \( \frac{25}{64} " \) diameter bit.

4 - **Tail rotor support arm.** Cut a \( \frac{1}{2} " \) diameter dowel 2 \( \frac{3}{4} " \) long. Round over one end, then use a \( \frac{15}{64} " \) bit to drill a through hole \( \frac{1}{2} " \) from the rounded end. This hole is for the axle peg that attaches the tail rotor.

5 - **Tail rotor.** Cut out the tail rotor from a piece of hardwood stock or Baltic birch that is \( \frac{1}{4} " \) thick. The width and length are \( \frac{5}{8} " \) and 2 \( \frac{1}{2} " \) respectively. Round the ends of the rotor as shown in Figure 17-2. Drill a \( \frac{1}{4} " \) hole in the center of the tail rotor.

6 - **Tail wheel strut.** Cut a \( \frac{1}{2} " \) diameter dowel 1 \( \frac{3}{4} " \) long. Round over one end, then use a \( \frac{15}{64} " \) bit to drill a through hole \( \frac{5}{16} " \) from the rounded end. This hole is for the axle peg that attaches the tail wheel to the strut.

7 - **Partial assembly.** Use a toothpick or nail to put glue into the two \( \frac{1}{2} " \) holes in the tail boom. Wipe off any excess glue. Insert the tail rotor support arm and the tail wheel strut into their respective holes, making certain that the \( \frac{15}{64} " \) holes drilled near the ends of these pieces face the side of the tail boom, that is, the holes are perpendicular to the side (see Figure 17-5). Allow glue to set for about 15 minutes before the next step.

Set aside the tail boom assembly until finish is applied to all parts.
17. Helicopter

Figure 17-5. Tail Boom

Main Rotor (Propeller Blade) Assembly

1 – Main rotor (propeller). On a piece of ⅜” Baltic birch plywood 9” square draw the pattern for the propeller blades using Figure 17-7 as the template.

Cut out the blades along the outline drawn leaving ⅛” to ⅛”, then sand to the outline. Round over all edges to a ⅛” radius, either by hand or with a router. Sand both sides and edges with 150 grit sandpaper.

2 – Main rotor hub. Mark the center of the propeller as shown in Figure 17-7 and draw lightly a ⅜” diameter circle at the center. Cut out the ⅜” diameter main rotor hub from ½” thick Baltic birch plywood or hardwood using a hole saw or bandsaw and jig.

Alternatively, purchase a 1 ½” wood slab wheel (see cut list for the part number). Sand the rotor hub with 150 grit sand paper, then mark the center of the hub.

3 – Assemble. Glue and clamp the rotor hub to the propeller on the spot where the 1 ½” circle was drawn on the main rotor.

Once the glue has set, use a twist bit to drill a hole in the center of the hub for the ⅜” vertical rotor shaft. Test whether a ⅜” diameter bit or one slightly larger or smaller is best to provide a good glue joint in this hole. Drill almost through the hub, but not all the way (see sectional detail, Figure 17-7).

Whether made or purchased, the hub will likely already have a ¼” center hole. The twist bit used to enlarge it will automatically center in this hole.
Finish

1 – Seal. Apply de-waxed shellac to the outside surfaces of the body.

Also apply shellac to the following parts: the helicopter wheels and spacers, the tail boom sub-assembly (tail boom plus tail rotor support arm and tail wheel strut), the tail wheel, the head of the tail wheel axle, the tail rotor, the head of the tail rotor axle, and the main rotor assembly.

Do not apply shellac to the vertical rotor shaft, the horizontal and vertical drive wheels, or the wheel axle.

To prevent getting finish on the tenons of the two axe pegs, wrap them with painter’s tape. Once the shellac is dry, use a fine sanding pad to remove any raised grain by lightly sanding all the parts that have been sealed with shellac.

2 – Clear coat. Apply one or two coats of a semi-gloss or gloss clear finish such as water-based polyurethane or another child-safe clear finish to all the parts sealed with shellac.

3 – Ream out holes. Once the finish is dry, ream out holes to clean out any sealer or clear coat that has gotten into them. This will help to assure good glue joints or clean holes for rotating parts.

Reaming out Holes

See Chapter 19, p. 169.

Assemble

1 – Complete tail boom sub-assembly.

Attach the tail wheel to the tail wheel strut. To do this put glue into the 15/64” hole in the strut, wiping off any excess glue from the surface of the hole.

Next place the tail wheel on the tail wheel axle (the 7/32” axe peg). Put a washer and spacer between the wheel and strut to allow for easy rotation of the wheel, then insert the tail wheel axle into the hole in the strut.

In a similar way, attach the tail rotor to the tail rotor support arm by gluing the tail rotor axle (the 7/32” axe peg) into the support arm. As with the tail wheel, use a washer and spacer.

Finally, glue the 3/8” glue dowel into the end of the tail boom, allowing it to protrude about 1”. The tail boom sub-assembly is now complete.

2 – Drive mechanism assembly. Verify that the vertical rotor shaft fits into the hole in the center of the horizontal drive wheel to make a good glue joint. If not, adjust the hole or sand the end of the shaft.

Next cut a piece of 100 grit sandpaper into a 1” circle and glue this circle to one side of the horizontal drive wheel.

Put glue into the center hole of the horizontal drive wheel opposite the side on which the sandpaper was glued. Then insert the vertical rotor shaft so it is flush with the sandpaper.

37 The plastic clip used to close the plastic bag of a loaf of bread or a piece of cardboard from a cereal box make ideal spacers.
Once the glue has set, install the $\frac{3}{8}$" vertical rotor shaft with drive wheel attached through the $\frac{13}{32}$" vertical hole in the body of the helicopter. Verify that the horizontal drive wheel clears the cavity walls by at least $\frac{1}{16}$" in all positions when in the bottom of the body. If this is not the case, chisel out more of the cavity.

**3 – Trial wheel assembly.** Assemble but do not glue the wheel axle, two spacers, and two wheels through the body of the helicopter. Check the amount of extra axle length. The goal is to have a $\frac{1}{16}$" gap between the spacers and the helicopter body. If the gap is more than $\frac{3}{16}$", trim the axle. If the gap is less than $\frac{1}{16}$" shorten the spacers.

**4 – Attach one wheel.** Disassemble the wheel assembly, and glue one wheel onto one end of the axle. To do this put glue into the hole in the wheel and push the axle through the hole from the back of the wheel until it is flush with the front of the wheel. Wipe off the excess glue.

**5 – Attach drive wheel.** Once the glue has set, slide the vertical rotor shaft with the horizontal drive wheel attached into the cavity and through the $\frac{13}{32}$" in the helicopter body. See Figure 17-6.

Next put a spacer onto the wheel axle and slide the axle with wheel and spacer through one side of the body, while holding the vertical drive wheel so that the axle passes through it. Adjust the vertical drive wheel so that there is a $\frac{1}{16}$" gap between it and the side of the cavity and the $\frac{3}{16}$" hole in the edge of the vertical drive wheel is perpendicular to the bottom of the helicopter body.

Using a $\frac{3}{16}$" drill bit in a hand drill, and the $\frac{3}{16}$" hole in the drive wheel as a guide, drill through the wheel axle and through the other side of the vertical drive wheel.

**6 – Test main rotor assembly.** Cut the $\frac{3}{16}$" diameter drive wheel locking pin to a length of 1 $\frac{1}{8}$" – slightly shorter than the diameter of the vertical drive wheel. Insert the locking pin through the hole in the vertical drive wheel, into the wheel axle, then into the other side of the vertical drive wheel. **Do not glue it in place** at this time.

Place the main rotor assembly onto the vertical rotor shaft extending above the top of the helicopter body.

Test that the main rotor turns as the helicopter wheels turn. If not successful, identify what prevents the main rotor from turning and make corrections.

If the test is successful, remove the locking pin by using a drift punch or the head of a finishing nail to push it out of the hole in the vertical drive wheel and pliers to pull it out.

**7 – Attach sub-assemblies to body.**

Put a small amount of glue on the locking pin and insert it into the vertical drive wheel, through the wheel axle, and into the other side of the vertical drive wheel, thus attaching the vertical drive wheel to the axle. **Note:** Once the locking pin is glued into place it is very difficult to make corrections to the movement of the main rotor, so it is critical you are satisfied with the test performed in step 6.

Insert the second spacer onto the other side of the wheel axle and glue the second 1 $\frac{3}{4}$" helicopter wheel in place.

Next, attach the finished tail boom sub-assembly to the helicopter body by putting glue into the $\frac{3}{8}$" hole in the rear of the helicopter body and attaching the sub-assembly.

Finally, put glue into the hole in the main rotor hub and attach it to the vertical rotor shaft protruding from the top of the helicopter.
As wheels rotate the vertical drive wheel turns, causing horizontal drive wheel to rotate, which in turn causes vertical rotor shaft to turn main rotor.

Vertical rotor shaft (3/8" dowel, 3 1/4" long) glued into horizontal drive wheel.

Horizontal drive wheel with 3/8" hole in center to accept vertical rotor shaft. A circle of sandpaper is glued to bottom to improve friction between horizontal and vertical drive wheels.

Vertical drive wheel with 3/8" hole in center to accept axle. Drill 3/16" hole from edge through wheel axle to accept drive wheel locking pin.

Wheel axle (3/8" dowel approximately 5 1/4" long). Adjust length during assembly. Caution: Drill 3/16" hole for drive pin only during assembly.

Drive wheel locking pin - a 3/16" dowel cut to length to fit hole through vertical drive wheel and axle.

**Figure 17-6.** Drive Mechanism
Figure 17-7. Main Rotor Template
Part II. Jigs and Techniques
18. Shaping Parts

Most of the toys described in Section I of this book have a main part, called the “body” of the toy. If the toy has moving parts, they are usually attached to the body. Making the body or any other part of the toy starts with a square or rectangular block of wood – the wood blank.

If a template is going to be used in cutting out a part, the dimensions of the wood blank in the Cut List will be slightly greater than the part to allow for transferring the design from the template to the blank and cutting out the part.

Forming the Wood Blank

The first challenge in beginning a toy building project is to obtain the size of wood needed for the parts.

Although it might be possible to obtain a rectangular block of wood with the length required, it might not be possible to find the width or thickness needed. Many of the toys described in Section I required parts to be made out of wood that is thicker than ¾” – the standard thickness of most readily available lumber.

Unless you have made furniture requiring wood that is 1” to 2 ½” thick and have scraps left over, it is unlikely you will have the lumber out of which the wood blank for the body and other toy parts can be obtained. In addition to the thickness, finding the proper width can also be a challenge.

There is a simple solution to these problems - gluing together two or more pieces of wood to form the thickness and/or width needed.

Wide Blanks

Gluing two or more pieces of wood together to form a wider block of wood is a fairly easy process. In addition to the wood, the supplies and tools needed include wood glue and clamps.

The process is known as edge gluing, that is, gluing the individual pieces of wood edge-to-edge. If you have never done this before, we suggest searching the internet for “edge gluing” videos that will demonstrate the procedure.38

Here is a brief summary of edge gluing. Critical to the process is making certain the edges are perfectly straight and square to each other. Then apply glue to both edges and clamp the pieces together every 12”.

Let the glue set for about 30 minutes, then scrape off any glue that has squeezed out from the edges. Clean up the surfaces by sanding or passing through a planer. Repeat with a third piece of wood, if necessary.

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38 See for example, “3 steps to great glue ups: edge joints” produced by the FineWoodworking magazine.
18. Shaping Parts

**Thick Blanks**

Creating a thick blank from two or more pieces of wood is known as face gluing, that is, gluing together the faces of two or more pieces. The procedure is similar to edge gluing. Searching the internet for “face gluing” will provide videos that offer tips on this process.

**Steps for Making the Body of a Toy**

The normal steps for making the body of a wooden toy are:

1. Work out the machining and sanding sequence.

2. Start with a square or rectangular wood blank. Sand all surfaces to remove saw and/or milling marks. If the wood blank has been created by edge or face gluing together two or more pieces of wood, it is necessary to check the blank to see that all surfaces and edges are clear of glue and are square. Sand with the direction of the grain.

3. Do any accessible straight saw cuts.

4. If the body has a curved shape, transfer the shape of the body from a template to the block of wood, creating an outline on the wood. Mark hole locations using the plan or template.

5. Drill holes in the body while the blank is still rectangular. The square edge of the blank makes it easier to clamp the blank against the fence of a drill press in order to align the holes. This is especially important if making duplicate copies of the toy.

6. Cut the contour of the body to within $\frac{1}{32}$" to $\frac{1}{16}$" of the outline. (There are cases where contouring will precede some drilling and straight cuts.)
18. Shaping Parts

Body Cut from Blank

7. Sand the body contour to the outline on the block of wood.

8. Do any necessary round over of edges. (Sometimes rounding over edges, if done on a router, will need to be completed before drilling some of the holes. Holes in the edge can prevent the round over bit bearing from running smoothly along an edge.)

9. Sand out any saw or milling marks or burn marks from cuts and rounding over, and then sand all surfaces and edges.

View the body in strong light. If surfaces are not well prepared, a clear finish will emphasize defects. If necessary, sand some more.

Band Sawing

Bandsaw Safety

This is not intended to cover all the safety aspects in using the band saw, but just a few key issues in cutting parts for toys:

1. Always keep the upper blade guide about ¼" above the work piece. This not only reduces the chance of getting your fingers near the blade teeth, but also provides better blade support for truer, smoother cuts.

2. When cutting small parts, keep your fingers out of the danger zone – the area 1 ¼" from the blade teeth or the area of the table insert.

3. Use the correct blade for the job: ½" or wider hook blades for re-sawing; standard and skip tooth blades for scrolling. Match the blade width to the smallest radius required.

4. When cutting dowels, grip them securely to prevent rotation.

5. While the blade is moving, do not back up the wood on long cuts or curves. Shut off the bandsaw before backing up.

Remember: be alert and safety conscious at all times.

Router Safety

DO NOT USE a router to round over edges of toy parts UNLESS the router is station-ary, that is, attached to a router table. See p. 158.
18. Shaping Parts

Key Bandsaw Set-up Procedures and Adjustment

1. Guide blocks for the blade must be smooth, true, flat and properly adjusted. Regularly remove and re-grind them. Even metal guides become “grooved,” allowing the blade to move around no matter how well adjusted.

2. Follow the band saw manual for the correct guide block adjustment gap. It is usually 0.003 – 0.005”.

3. Make sure the blade has not been “pushed” out of its true path with the band saw blade wheels.

4. When all adjustments have been made, check that the blade is square to the bandsaw table.

5. Check that there is proper tension on the blade. One way to do this is to raise the upper guide 6” with the power off. Then push the blade sideways with your finger. The blade should not deflect more than ¼” if under proper tension.39

Making Wheels

Wheels up to 2” in diameter can be purchased at economical prices. This is not true for the larger wheels needed on some of the toys described in Part I. If only a few large wheels are needed, it still might pay to purchase them.

Wheels that resemble car or truck tires are best purchased. However, there are ways to make wheels of any size if you have access to a drill press or a band saw. These wheels will have flat surfaces. See, for example, the hippo (Chapter 15) or rolling rattle (Chapter 16).

Chapter 19 describes a simple way to make wheels using a drill press and hole saw.

Following are are two methods to make large wheels using a bandsaw – freehand and using a special purpose jig.

Freehand Method

This method takes considerable practice and patience.

1. Use a compass to draw the wheel on a square blank of wood that is slightly larger than the desired wheel.

2. Drill the center hole, usually either ¼” or ⅜” in diameter.

3. Follow the pattern as closely as possible as you cut out the wheel. It is best to do this with a bandsaw or scroll saw. Try to cut out the wheel to within 1/32” to ¼” of the pencil outline on the blank.

4. Sand to the outline. A stationary belt or disk sander works best for this operation, in conjunction with the circle sanding jig described in Chapter 20. If this equipment is not available, sanding can be also be done using a hand sanding block.

5. Round over the edges to a ⅛” or 3/16” radius, either by hand or using a router installed in a router table in conjunction with the jig described later in this chapter.

39 Finewoodworking.com/2012/11/09/
6. Sand all surfaces of the wheel with 150 grit sandpaper.

An easier way to make wheels on a bandsaw requires the use of a jig. Searching the internet will provide many different examples and demonstrations of bandsaw circle cutting jigs. The simple jig described here is designed for making wheels for toys.

**Circle Cutting Jig**

### Making the Jig

1. Cut a strip of hardwood to fit the miter slot on your bandsaw. It should be snug but also able to easily slide back and forth without binding. Cut the thickness to be less than the depth of the slot.

2. Cut a piece of ¾” plywood approximately the size of your bandsaw table to serve as the base of the jig. It must extend at least 1” to the left of the blade and at least 3” to the right of the miter slot, and it must be long enough to cover the depth of the table.

3. Place the base on the bandsaw table to mark the location of the miter slot, then glue the strip from Step 1 to the bottom of the base, making sure it is square to the front edge of the plywood.

Reinforce the strip by drilling and countersinking a few ¾” screws or using ¾” brads through the strip and into the base.

4. Make a stop block - a piece of wood approximately ¾” x 1” x 4” long. On the bottom of the base glue this block along the back edge. Reinforce it by drilling and countersinking several drywall screws through it into the base. Figure 18-1 shows the jig to this point.

5. After the glue dries, place the base on your bandsaw table with the guide strip in the miter slot, turn on the bandsaw, and push the base toward the blade until the base stops because the stop block has engaged the front of the bandsaw table.

6. After turning off the bandsaw, remove the base and draw a line perpendicular to the cut at the point where the cut ended.

Measure from the cut along this line the radius of the circle desired. In Figure 18-2, marks have been put at $\frac{1}{16}$”, $\frac{2}{16}$”, and $\frac{3}{16}$” from the cut. These will be the center holes for making circles that are 2”, 4”, and 6” in diameter. The $\frac{1}{16}$” added to each radius above allows room for sanding. (To sand circles, see the jig described in Chapter 20.)

Attaching a screw on the face of the stop block will help to fine tune the jig (see Figure 18-2).
7. Use a punch to indent the marks made in step 6, then drill a ¼” or ⅜” hole, depending on the size of the center hole of the circle to be cut.

8. To continue the instructions for making and using the jig, it will now be assumed that a 2” diameter wheel with a ¼” diameter center hole is to be made. At the 1 ⅛” mark from the saw cut, drill a ¼” hole into but not entirely through the base of the jig.

9. Cut a ¼” diameter dowel about 1” long to serve as a pivot dowel. Insert this dowel into the ¼” hole drilled in the base of the jig. See Figure 18-3.

**Using the Jig**

1. Prepare a blank of wood out of which a 2” diameter wheel with a ¼” center hole will be cut. The blank should be a rectangle or square piece of wood with its shortest side at least 2 ¼” long. It should be the thickness of the desired wheel.

2. Locate the center of the blank and at that point drill a ¼” through hole.

3. Press the blank on the top of the pivot dowel and put the jig on the bandsaw table with the guide strip engaged in the miter slot. See Figure 18-4.

4. Turn on the bandsaw and push the jig forward while holding the blank on top of the pivot dowel. The jig will stop moving forward when the stop block comes up against the front of the bandsaw table. See Figure 18-5.
18. Shaping Parts

Figure 18-4.

(Note: the upper blade guide is higher than the recommended ¼" above the work piece in Figure 18-4 and the following photographs in order to better show the use of the jig. In practice it should be lower.)

Figure 18-5.

5. Keep the jig pressed against the front of the bandsaw table as you slowly turn the blank on the pivot dowel into the moving bandsaw blade. See Figure 18-6.

Figure 18-6.

6. When a complete circle has been cut out, stop the bandsaw blade and slide the jig off the blade through the original cut made in the blank.

Fine Tuning Jig

Keep an eye on the bandsaw blade as the blank is turned into it. The blade bending off a vertical position is an indication that the jig is out of adjustment. If this happens, stop the bandsaw and check that the center of the pivot hole is lined up with the front of the blade teeth.

Adjusting the screw in the front edge of the stop block, where it engages with the front of the bandsaw table, can help to make fine adjustments to the location of the jig.

Making More Pivot Dowel Locations

The jig described above has a row of ¼" pivot dowel holes for different size circles. There is a simple way to add more pivot hole locations or holes for circles that need a ⅜" center hole and thus need a ⅜" pivot dowel.

Simply screw a second stop block onto the original one (see Figure 18-7). This will pull the jig back the width of the added stop block, enabling another row of pivot dowel holes. To do this, it will be necessary to either remove the fine tuning screw on the original stop block or drill a hole in the back side of the additional stop block to cover this screw.

After adding the second stop block, put the jig on the bandsaw table and push it forward through the saw cut made earlier until the added stop block is stopped by the front of the bandsaw table. Now draw the new line perpendicular to the end of the bandsaw blade. Along this new line drill additional holes for pivot dowels to make the desired circle diameters and center holes. Alternatively, it is easy enough to make another one of these jigs.
18. Shaping Parts

Using a Router

In toy making, the router is used primarily for rounding over edges of toy parts. This helps to create smooth edges and child safe toys. The router is also used to shape parts when making duplicate parts, using the technique of template routing.

Since toy parts are small and hard to clamp to a work bench, using a router is not recommended unless it is stationary (attached to a router table).

**Router Table**

Rounding over edges or shaping parts are techniques that should be done using a router table.

To obtain the best results:

1. The router table must be flat and the insert must be flat and flush with the table. A sagging table or table insert will give uneven round overs. This will result in excessive sanding to repair the “step” created or partial round over.

2. The roundover bit must be precisely adjusted relative to the table surface to give a full round over, but without creating a “step” in the bottom surface (see Figure 18-8).

3. The router bit must be sharp and the guide roller (bearing) free turning.

**Making a Router Table**

Instructions for making a simple router table can be found on the internet by searching “building a router table.”
To achieve a smooth finish with few or no burn marks (some woods like cherry and maple burn easily), the following procedures will help:

1. The work piece must be moved **against** the rotational direction of the cutter (see Figure 18-9). It is very dangerous to move the piece with the direction of the cutter, since this may cause your work piece and your hand to be pulled into the cutter.

2. When routing small parts, it is best to use a clamp, jig, or push stick to keep your fingers a safe distance from the router bit.

3. Use only enough pressure on the work piece to maintain contact with the router bit.

4. Keep firm downward pressure on the part against the table.

5. Never stop the work piece movement against the cutter. Do the cutting in a series of overlapping sweeps.

6. The feed rate is not really critical, but too slow a rate can produce burn marks, and too fast a rate is likely to cause the finish to be rough. Reducing cutter RPM is an alternative technique.

7. When using a roundover bit, initially set the bit slightly low. After the first cut, the bit should be raised to the correct setting and the roundover re-cut. This second pass will remove a small amount of material, resulting in a cleaner cut.
To add realism to animals, cars, etc. the edges of nearly all toy parts are rounded over. Also, the round over provides a safer edge for children who handle the toys, or who might fall on them.

The roundover size (size of roundover bit) for the toys in Part I is specified in the instructions for each toy and was chosen to suit the type of toy.

In rounding over edges, sharp router bits are a necessity to minimize sanding. Sanding out burn marks is not fun! Burn marks may be avoided by using a variable speed router. If burn marks occur, reduce router RPM up to one half. Reduce feed rate also.

Plan ahead regarding the drilling of holes in a part and the rounding over of edges. It has been recommended to drill holes before the part has been cut out from a rectangular blank, in order to have a square edge on which to register the part for drilling. However, there are cases in which the holes might interfere with the router bearing when doing round overs. In such cases, it is recommended to round over before drilling those holes, or round over by hand sanding.
Router Jigs

Methods for making large wheels have been described earlier in this chapter. This section begins by showing how to make and use a simple jig for rounding over the edges of those wheels. It concludes with illustrations showing the technique of template routing.

Wheel Roundover Jig

This jig is used on a router attached to a router table and installed with a roundover bit. It should be used after the edges of the wheel have been sanded, either by hand or using the jig for sanding wheels described in the Chapter 20, pp. 178-9.

The jig is made as follows: At the end of a piece of scrap wood about 2” wide, ¾” thick and 6” to 8” long drill a hole for a dowel which has the same size diameter as the center hole of the wheel whose edges need to be rounded over.

The dowel should be located close enough to the end of the wood such that the wheel will hang over the edge at least ¼” (see Figure 18-10). It should be no longer than the thickness of the wheel to be rounded over.

Place the wheel on the dowel (Figure 18-11). Now turn the jig over with the wheel on the dowel, turn on the router, and move the jig clockwise around the spinning roundover bit, as shown in Figure 18-12.
18. Shaping Parts

Template Routing

The technique of template routing is very useful if you want to make multiple copies of the same toy or where a toy, such as the Doll Bed (Chapter 7) requires two identical parts – the headboard and the footboard. Making a headboard is used to illustrate the procedure:

1. Begin by making a template of the part. Any wood can be used for a template, but MDF is particularly user friendly because of the ease in which it can be shaped. It pays to take the time to make a very accurate template, since the parts that will be produced will be exactly like it.

2. Next, use the template to create an outline of the part on the blank of wood from which the part will be cut.

3. Now cut out the part about 1/32” outside of the outline. This is usually done on a bandsaw or scroll saw.

4. Next attach the template to the rough cut-out part. There are several ways to do this. In the case of the doll bed headboard, the template is screwed to the blank using two screws. This is possible since the headboard will eventually have four screw holes on it’s surface.
If screwing the template to the blank is not possible, either use double sided tape to attach the template to the blank or a special purpose jig.\(^4\)

5. Finally, use a flush trim router bit with a bearing that runs against the template to trim the approximate excess \(\frac{1}{32}\)" from the rough cut-out of the part (Figure 18-13).

![Figure 18-13. Trimming the Part](image)

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\(^4\) See “Pattern Routing Jig,” Fine Woodworking (6/2/14) or video by Matt Kenney.

\(^{41}\) “Template Routing Basics,” Fine Woodworking (9/20/13) or video by Tim Rousseau.
Other Cutting Jigs

Because of safety concerns, toy builders often create jigs as they are building a toy. Following is an example of one such jig used to machine the small hubs of the Honey Bee wings (Chapter 8).

These hubs are made from 1 ¼" pieces of ½" dowel. They require a hole drilled in one end and a slot cut in the other end. Chapter 8 has described ways of doing these two operations. Figure 18-14 shows a jig that provides another way to cut the slots.

Making the Jig

The jig is made from a piece of wood 3" wide, 9" long and at least 1 ¼" thick. The width and length dimensions are not critical.

Along the length of one face of the board (call this the top) draw a center line. Along this line drill ½" diameter holes about 1" apart. These holes should be 1" deep and be drilled with a brad point bit to create a flat bottom.

Next drill two ¼" holes from one side through the width. These holes should be located ½" down from the top toward each end of the jig, and counter sunk on one side.

Finally, saw the board in half, lengthwise, along the exact center of the holes and re-assemble it with two ¼" machine bolts, placing the head of the bolts in the countersunk holes.

Using the Jig

Place the 1 ¼" pieces of ½" dowel for the wing hubs of the honey bee toy into the holes, pushing them down to the bottom of the holes. Then tighten the machine bolts. Next adjust the table saw blade to a height of about ¾". **Warning:** Make sure the bolts are well above the saw blade.

Adjust the table saw fence so that the blade will cut through the middle of each hub, and make a cut as shown in Figure 18-14. The height of the blade might need to be adjusted by experimenting with the jig.

The end product will be hubs cut as shown in Figure 18-15.
19. Drilling

This chapter begins with a review of drilling methods, the types of drill bits used to make wooden toys, and the drill bit sizes to use. It also includes how to cut out and sand large wheels using a drill press, and some useful jigs for locating drill holes and holding small round parts for drilling.

Drilling Methods

Toy making requires smooth bores and clean entry and exits for holes, especially holes used for rotating axles. The following guidelines should help to achieve the desired results:

1. If available, use a drill press for all holes. The part to be drilled should rest on a back-up board, and one of the straight edges of the part should be held or clamped against a fence. The fence, in turn, should be clamped to the drill press table.

Figure 19-1 shows a typical set-up. In this example the drill press is fitted with a jig that includes the table and the fence.

2. Try to drill holes while the wood blank is still rectangular. This will require fewer set-ups on the drill press when drilling a number of holes that are the same distance from the edge of the blank and will also speed up drilling multiple copies of the same toy.

The wood blank for the Car Transporter (Figure 19-2) is a good example of this. All the holes have been drilled before the cars and trailer are cut out of the blank.

3. Make certain drills are sharp.

4. Tighten all three jaws on the drill chuck.

5. Use moderate feed rates and correct RPM for smooth bores (see Delta Drill Press Chart available on line).

6. Use a back-up board to eliminate splinters that are pushed out of the bottom of the drill hole as the drill exits the wood. This is known as “blowout”. Move the back up board frequently.

7. Start with a slow feed rate at entry and use a slow feed rate at exit to minimize shredding and “blowout”.

8. Clear chips often, especially in deep holes, by removing the drill bit from the hole so the chips fall out.

9. Clamp toy parts when using large drills (⅜" diameter and larger). The biggest danger is losing control when retracting the drill from the hole.

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42 With the possible exception of screw pilot holes.
19. Drilling

Figure 19-2. Wood Blank for Car Transporter

Types of Drill Bits

Figure 19-3 shows the common drill bits used in toy making:

![Image of drill bits]

Twist Drill Bits. The twist drill bit is the most common “household” bit, but it is not ideal for drilling wood. Its advantages are that it comes in a large variety of sizes, is the least expensive drill bit, is easily sharpened, and if used correctly gives very acceptable results.

Using the right speed (revolutions per minute - RPM) will help get smooth bores. Often twist bits are run too slowly. HSS (high-speed steel) bits can take lots of RPM in wood.

Sharp drills and moderate feed rates are especially important when using twist bits to achieve the smooth bores needed for axle holes.

Brad Point Drill Bits. Brad point drills are preferred over twist drills because they give smoother, more accurate bores. However, they are not available in the variety of sizes needed for all toy making operations.

Follow RPM charts when using brad point drills. Do not use brad point drills with drill bushings. Bushings will ruin the cutting edges of these bits. If a brad point drill is being used to drill through a piece of wood, start on one side and drill deep enough so the point of the bit just comes out the other side. Then turn the wood over and finish the hole by drilling from the other side.

Forstner Drill Bits. These drill bits are especially useful for larger diameter holes. They are the only drills that can be used for drilling on a slant surface (see Figure 19-4) or creating flat bottom holes.
When using a Forstner bit, keep the RPM down, especially for larger size drills. These bits get overheated very easily due to their design. With some kinds of wood, especially plywood, chips jam up. It is usually necessary to clear chips more frequently when using these bits.

Forstner bits can also be used for drilling an interrupted surface, as shown in Figure 19-5. This illustration shows a large hole being drilled next to and partially over a smaller hole. This was used in cutting out the cavity for the helicopter drive mechanism (Chapter 17, p. 141).

**Hole Saw.** If bore smoothness is not critical, large drill holes can be achieved using a hole saw. Hole saws are especially useful in toy making for cutting out large wheels. They come in a variety of sizes, from ½” to over 8” in diameter.

When a hole saw is being used to cut out a wheel, start on one side and drill almost through the wood. Then turn the wood over and finish the hole by drilling from the other side. Keep in mind that the diameter given for a hole saw is the saw’s outside diameter. Therefore, use a hole saw with a diameter that is at least ⅛” larger than the diameter of the wheel you want to make.

**Spade Drill Bit.** These bits are used mostly in construction, for example, for putting holes through studs. They drill deep holes quickly.

Although seldom used in toy making because they tend to leave a ragged hole, there are occasions where they are useful. One such case occurred in cutting out the yoke for the Rolling Rattle (Chapter 16). A spade drill with spurs is preferred.

If a spade drill bit is being used to drill a through hole in a piece of wood, start on one side and drill more than half way through so the point of the drill just comes out the other side. Then turn the wood over and finish the hole by drilling from the other side.
What Size Drill to Use?

In toy making, drilled holes are usually for one of two purposes: as a way to glue one part (a dowel, wood button, or axle peg) to another; or to receive an axle (dowel or axle peg), which needs to move freely in the drilled hole.

Clearly the use of the hole is one important issue in determining the size of the hole to be drilled. Another important issue stems from the fact that dowels of a given diameter actually are seldom the exact diameter stated by the manufacturer. A given size dowel can vary enough to cause a problem in obtaining a good glue joint, even dowels from the same manufacturer as well as from one manufacturer to another.

Therefore, before drilling a hole for a glue joint or moveable axle, be certain to obtain an accurate measurement of the diameter of the dowel or the diameter of the tenon being used. (This is why it is recommend to have a caliper as one of your basic measuring instruments.) To the diameter add the following clearances:

- A hole made for a movable ¼" or ⅜" diameter dowel or an axle peg should be at least ¹/₃₂" (about 0.032 inches) larger in diameter than the dowel or tenon that is to be moveable in the hole. Larger diameter dowels require more clearance.

- A hole made for a glue joint should be slightly loose – approximately 0.005 inches Larger in diameter than the dowel or tenon being glued into it.⁴⁴

Once a drill bit has been chosen for the hole, it is recommended that a test hole be drilled in a piece of scrap wood to see how the dowel, axle peg or wood button being used fits the hole. If the hole does not seem to be satisfactory, try a different size drill bit until the fit works.

Achieving proper glue joints for parts to be glued into a hole is particularly important in order to avoid parts becoming loose and causing a potential choking hazard. Using the test for proper fits given in Chapter 2 (pp. 19) or the spacing given above to determine if a hole has a proper glue joint is strongly recommended.

The table in Chapter 2 (p. 18) gives the normal drill bits to be used with different size dowels, wheels, axle pegs and wood buttons. It is provided as a starting point in selecting the correct size drill to be used, keeping in mind the purpose for the hole (glue joint or moveable part) and the actual size of the dowel, axle peg, or wood button to be used.

The drill size suggestions provided in this table apply whether using manufactured wheels or custom made wheels. Certain “lettered” drills are particularly useful for creating good glue joints for ¼" dowels. They are D (.246” in diameter), F (.257”), and G (.261”). For gluing ⅜” dowels, the following “lettered” drills are useful: U (.358” in diameter), V (.377”) and W (.386”). See Appendix A for decimal equivalents of fractional, lettered, and millimeter-sized drills.

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⁴⁴ 0.005 inches is approximately the thickness of two pieces of newspaper.
Reaming Out Holes

Holes might need to be reamed out by hand for two reasons. First, to clean out any fuzz or finish (shellac, etc.) that has gotten into the hole. Second, to adjust the size of the hole in order to achieve a good glue joint or to enable an axle to rotate freely in it.

The easiest way to ream out holes is to use the drill bit that originally made the hole fastened in a drill chuck (see Figure 19-6). The drill chuck provides a grip for turning the bit in the hole, and gives much better leverage than trying to ream out the hole by holding a drill bit in your hand.\[^{45}\]

![Figure 19-6.](image)

Cutting Out and Sanding Wheels

Making Wheels on a Drill Press

To cut out a wheel from a wood blank using a hole saw, drill almost all the way through the wood from one side. Then flip the blank over and drill from the other side. The wheel that has been cut out of the blank will have a ¼" center hole. If it needs to be enlarged to ⅜", re-drill the center hole with a ⅜" twist drill. Be sure to have the wheel securely held in a clamp because the drill will tend to grab and spin the wheel. A useful jig to hold a wheel for drilling is shown on page 170.

Sanding Wheels on a Drill Press

After a wheel has been cut out of a blank, its edges need to be sanded and rounded over. One way to sand the edges of a wheel with a ¼" center hole is to secure a ¼" threaded rod (bolt with the head cut off) into the drill press chuck and put the wheel on the bolt secured with a nut and washer. One side can be up against the chuck. Depending on the length of the bolt, more than one wheel can be put on the bolt and sanded at the same time.

Turn on the drill press, holding sandpaper against the edge of the wheel(s). Start with very coarse sandpaper and work to very fine, always holding the sandpaper on the left side - the side turning away from you. This will prevent having your hand forced back.

If the wheel has a ¾" center hole, use a ¾" bolt with the head cut off.

\[^{45}\] Inexpensive drill chucks can be found for less than $10. Look for Jacobs and Yakamoz brands, and check online or stores like Harbor Freight.
Drilling Holes in Small Round Objects

At times a hole must be drilled in a circular piece of wood, such as a wheel or a dowel to be used as a spacer.

This is necessary when making several of the toys in Section I. See, for example, making the spacers for the Mouse (Chapter 14) and Helicopter (Chapter 17), and enlarging the center hole of a wheel for the Helicopter.

Small round objects cannot be held by hand while drilling, and they are usually too small to clamp securely. A simple solution is to make a "wooden pliers."

Take a piece of scrap wood and drill a hole in one end the size of the object (wheel or dowel) that needs to be drilled. Using a bandsaw or a scroll saw, cut a “V” wedge from the hole to the end of the piece of wood. See Figure 19-7.

The wedge forms a handle that can be gripped or clamped to hold the object that needs to be drilled.

The wheel in Figure 19-6 has a ¼" center hole that needs to be enlarged for a ⅜" axle. Place the wheel in the pliers, grip the ends to hold the wheel securely, then drill the larger center hole, as shown in Figure 19-8.

Figure 19-7. Wood Pliers to Hold Round Objects

If the end of the pliers shows signs of breaking when gripped or clamped too tightly on the object, a bolt can be placed through the end to hold it securely.

Round over the edges of the handle to make the pliers more comfortable to hold.

Figure 19-8. Wood Pliers in Action
Other Jigs to Assist in Drilling

Drilling jigs are useful for several reasons. They safely hold small toy pieces for drilling, they can make the location of holes more accurate and they can speed up the construction process.

When making duplicates of the same toy, a jig can help to assure that parts are interchangeable. Woodworkers tend to develop jigs as needed when working on a project. Sometimes they are never used again. However, here are some examples of toy making jigs created by members of the SDFWA Toy Program that have been used for many years.

Templates for Marking Holes

If many of the same toy are going to be made, either now or in the future, it will be helpful to have a template for marking the location of holes to be drilled in the body or parts of the toy, especially if there are a number of holes to be drilled.

One such template is shown in Figure 19-9. This template is used to locate the 10 holes that need to be drilled in the wood blank for the trailer and cars of the Car Transporter toy (Chapter 12).

The template was made from a piece of scrap wood the same width and length as the car hauler blank. The thickness is not critical – ¼” to ¾” will do. The centers of the 10 holes are located on the template and holes are drilled for screws at those locations. The screws need to be longer than the thickness of the template so that they poke through to serve like a nail punch for locating the holes to be drilled in a wood blank.

To use the template, place it on a wood blank for this toy and press or lightly hammer the template to mark the holes on the blank. Then drill the holes.

Another example of a template to mark the holes to be drilled into a toy is shown in Figure 19-10. Here two templates were used for the School Bus (Chapter 9) – one for the body (marking 10 holes) and one for the roof (6 holes).

Figure 19-9. Template for Marking Holes in Car Transporter Blank
A number of the toys described in Part I required a ½" hole for a push stick. Often this hole needs to be drilled at an angle on an odd shape on the top of the toy’s body.

Unlike other holes that are drilled in the body of a toy when it is a rectangular blank, this hole cannot be drilled until the body has been cut out of the blank, making it very difficult to hold the toy for drilling the push stick hole into the edge.

What is needed is a special purpose jig that can hold the toy’s body at the correct angle for the push stick hole. An example of such a jig follows (Figure 19-11).

This jig is used to drill the hole behind the head of the Duck (Chapter 6). Such jigs are simple to make. They require a vertical stand to which is attached a piece of wood in the shape of the bottom of the toy. This piece is rotated in the desired direction for drilling the push stick hole and attached to the stand. The stand can then be clamped to the drill press table and the toy placed on it for drilling.
Push sticks are not the only holes drilled at an odd angle. Another example are the holes for the antenna of the Honey Bee (Chapter 8). Like the push stick, these holes need to be drilled into the edge of the toy after the body is cut out.

A further complication is that these holes are not perpendicular to the edge. A special purpose jig used to hold the body of the bee and to achieve the correct angle is shown in Figure 19-12.

The sides of the jig are at a 10-degree angle to the base, tilting outward from each side (See Figure 19-12A).

The body of the honey bee is placed in the jig and wedged up against one side (Figure 19-12B). The jig is put up against the fence of a drill press (Figure 19-12C) and the antenna hole is drilled into that side.

Then the wedge is removed and the body is wedged against the opposite side of the jig and that hole is drilled.

A further complication is that these holes are not perpendicular to the edge. A special purpose jig used to hold the body of the bee and to achieve the correct angle is shown in Figure 19-12.

The sides of the jig are at a 10-degree angle to the base, tilting outward from each side (See Figure 19-12A).

The body of the honey bee is placed in the jig and wedged up against one side (Figure 19-12B). The jig is put up against the fence of a drill press (Figure 19-12C) and the antenna hole is drilled into that side.

Then the wedge is removed and the body is wedged against the opposite side of the jig and that hole is drilled.

When a toy has multiple similar parts, it is useful to have a jig that can help to make the parts interchangeable and to achieve accurate hole locations.

The final example of a special purpose drilling jig is one that is used to make the three 9/32” holes in each of the four bed rails and the six 1/2” holes in the bed bottom of the Doll Bed (see Chapter 7).

The jig is shown in Figure 19-13. Instructions for making and using it follow.
Making the Doll Bed Drilling Jig

The jig, shown in Figure 19-13, is made as follows:

1. Use a ½" to ¾" thick piece of plywood or MDF that is at least 8" wide and 14" long for a base.

2. On one of the long (14") edges attach a fence that comes approximately 1" above the base. It can be made out of the same material used for the base or any scrap wood and can be attached to the edge of the base using drywall screws.

3. With the base and fence away from you, attach another fence on the right (short) side of the base. It should also rise about 1" above the base and should be about 6" long. Attach this side fence to the edge of the base and to the end of the longer side fence with drywall screws.

4. Attach a piece ½" thick wood of any type to the inside of the short side fence to serve as a spacer. Make the spacer about 4" long and 2" high so that it can be easily screwed to the short side fence on the inside of the base. It needs to be positioned exactly ¾" from the long side fence so that a ½" wide bed rail can fit between its edge and the long side fence.

5. Measuring from the side fence (not the ½" spacer), place three marks on the long fence, each 3 ½" apart.

6. Cut a 3 ½" spacer from one of the pieces of wood used to make the rails. The dimensions of this spacer need to be 3 ½" long, ½" wide, and ¾" thick. Cut a second spacer that is 3 ½" wide with any length and thickness.

Using the Jig

Following are instructions for using the Doll Bed rail and base drilling jig:

1. After putting a 7/32" drill bit into the chuck of the drill press, clamp the jig on the drill press table such that the tip of the drill bit is lined up with the third 3 ½" mark on the base (from the right side) and is 5/16" from the long side fence (see left side photo in Figure 19-14).

The dark line on the base in Figure 19-13 is the line along which the drill is to be located. Once the jig is properly lined up and clamped, it will remain in that location until all three holes are drilled into all the bed rails.
2. A bed rail is placed along the long side fence as shown in the right photo of Figure 19-14, slipping its end in the slot between the ½” spacer attached to the short side fence and the long side fence.

3. Drill a 9/32” hole ½” deep (the left hole on the rail). Next rotate the rail 180 degrees to drill the 9/32” hole on what was the right end. The jig should remain clamped in place. Only the bed rail is moved for drilling each successive hole.

4. Remove the rail and replace it with the 3 ½” spacer. Then put the rail up against the spacer and drill the 9/32” hole in the center of the rail (Figure 19-15). This completes drilling three holes on one side of the rail.

Figure 19-14. Drilling Three Holes for the Bed Rail Spacers

Figure 19-15. Drilling Center Hole in Rail
19. Drilling

5. Repeat for all the rails that need to be drilled. Recall that each bed uses four rails.

6. Replace the $9/32"$ drill bit with a $1/2"$ brad point or Forstner drill bit. Clamp the jig on the drill press table such that the tip of the drill bit is once again lined up with the third $3\frac{1}{2}"$ mark on the base of the jig and is $1/2"$ from the long side fence.

7. Place a bed base on the jig with its narrow end against the $1/2"$ spacer on the right side, as show in the left photo of Figure 19-16.

8. If more than one bed is being made, place a second base on top of the first. It is possible to drill the $1/2"$ holes in three or four bases at one time, but do not drill through the bottom base. It serves as a back-up board to prevent splintering.

9. As with the rails, flip the board 180 degrees to drill the hole on the other end, then place the $3\frac{1}{2}" x 3\frac{1}{2}"$ spacer up against the right side and place the bed base against it to drill the center $1/2"$ hole. See the right photo in Figure 19-16.

10. Flip the bed base over and repeat the $1/2"$ holes on the other side of the base.

Figure 19-16. Drilling the Doll Bed Base
20. Sanding

At this point all the parts of a toy have been made. The next step is to be certain these parts are ready to have paint or a clear finish applied. Rough edges, saw marks, and any defects must be addressed by sanding and perhaps patching before finishing can begin.

In addition, if edges have not been rounded over using a router, sanding the edges to create roundovers will be necessary. Proper sanding is key to a quality looking toy. Like most woodworking projects, sanding, finishing and assembly take about one half the total time in producing the project.

Patching and Sanding

Patch defects prior to sanding. This way patch overruns will be removed for a uniform finish. Match the wood color to a reasonable degree if using a clear finish coat.

Sanding begins with coarse sand paper (60 to 80 grit) used to sand out saw and other machining marks. Employ power sanding as much as possible for eliminating machine marks (surface roughness) and for “fine tuning” (smoothing out) contours that were cut on the band saw.

Sand with the grain. Use disk sanding sparingly because circular marks are hard to remove. Belt, random orbit and oscillating spindle sanders all work very well.

As a final step before applying finish, hand sand all parts including rounded over edges with 120 to 150 grit sandpaper. Remove all tool burn marks if not already removed. Break any sharp edges or corners not rounded.

Between Coats of Finish

A fine or extra fine foam pad works well to smooth the first coat (sealer coat) of finish. Shellac is usually used for this first coat, and it has the tendency to raise the wood grain. However, the grain can be easily smoothed with a foam sanding pad.

Sand very lightly on edges and corners. If the shellac sealer is removed, the final coat of water-based polyurethane will leave blotchy light-colored areas.

Sanding Jigs

There are several jigs that are very useful in sanding small parts. The first, referred to in Chapter 18, is used to sand wheels cut out freehand, on a bandsaw, or by a hole saw. The second is used to round over or chamfer the ends of dowels.

Sometimes a special purpose jig needs to be created for sanding a very small toy part. An example is given at the end of this chapter.
A way to sand wheels using the drill press was described in Chapter 19. Another approach to sanding the edges of wheels and making sure they are round is to use a jig resting in front of a belt or disk sander. Figure 20-1 shows the set-up.

Following are the steps to make this jig. It is assumed that there is a table or platform with a miter slot in front of the vertical belt or disk sander. It is also assumed that the slot is parallel to the sander.

**Making the Jig**

1. The base of the jig consists of a piece of ¾” plywood or MDF a little larger than the platform in front of belt or disk sander.

2. Cut a dado perpendicular to the sander in the center of the base about 3/8” deep. This will be the top of the base.

3. Cut a strip of wood the length of the base to fit the miter slot in the platform. Glue and screw the strip to the bottom of the base such that the base is located close to but not touching the sandpaper on the belt or disk sander.

4. Cut another piece of plywood 3” wide by 10” long. This will serve as “slider” holding the wheel to be sanded. At one end of the slider drill two holes for posts, one ¼” in diameter and the other ⅜”. Initially drill these holes about ½” from the end of the slider. More holes might need to be added later, depending on the size of wheels being sanded.

5. At the other end of the slider drill a centered ¼” hole ¾” from the end. Drill another centered ¼” hole 3 ¾” from the same end. On a bandsaw or scroll saw connect the holes cutting out a slot ¼” wide. A ¼” carriage bolt will be put through this slot. The slider should now look as follows:

6. Next cut a strip of wood to fit the dado in the base that is perpendicular to the sander. Its thickness should be less than the depth of the dado. Glue this strip to the bottom of the slider from the end where the two post holes were drilled. Its length should extend to the groove cut in step 5 and it should be centered and parallel to the long side of the slider. The bottom of the slider should now look as follows:
7. Cut another piece of plywood 2" x 3" and drill a ¼" hole at its center. This serves as a stop block and will be used to adjust the length of the slider.

8. Insert a ¼" carriage through the stop block and into the ¼" slot in the slider. Place a washer and wing nut on the other end. The bolt needs to be about 1" longer than the sum of the thicknesses of the slider and the stop block.

9. Cut a dowel to serve as a post (either ¼" or ⅜" in diameter, depending on the center hole of the circle to be sanded). The post should be long enough to protrude about an 1" above the slider after it is put into the hole at the end of the slider.

Using the Jig

1. With the power off, place the wheel to be sanded on the post and set the stop block against the base so the wheel just touches the sander. Tighten the wing nut to set the position of the wheel. Now move the slider with wheel back from the sander, turn on the power, and slowly slide the wheel forward, rotating the wheel as it comes in contact with the sander (see Figure 20-1).

2. If all edges of the wheel are not being sanded, turn the power off, loosen the wing nut and set the stop block so the wheel is closer to the sander.

3. **Important Note:** Be sure to keep the end of the slider within ½" of the sander to keep the wheel from tipping. This can be done by drilling other holes for the "post dowel" along the length of the slider. Just remove the post from one hole and insert it into another.

**Figure 20 – 1. Wheel Sanding Jig**
There are times when the end of a dowel will have to be sanded square if the end is rough or was poorly cut off from a long piece of dowel, or it might need to be rounded or chamfered for a wheel axle.

When using a dowel as an axle for a car or truck wheel, rounding over or chamfering the end before gluing into the wheel gives a more finished look (Figure 20-2) and might make the wheel appear to have a hub cap.

**Dowel Sanding and Chamfering Jig**

Making the Jig

This jig is made from two pieces of wood. The horizontal base is about 9" long, 1 ½" wide, and at least ½" thick. The exact dimensions are not critical. The vertical piece attached to the end should be about 2 ½" x 2 ½", with a thickness of at least ¾".

On the top of the vertical piece are notches in which a dowel will rest. The notches can be cut with a round or triangular file, or using a bandsaw set at 45 degrees.

The jig in Figure 20-3 has three notches. The center notch is parallel to the sides. The notches on either side are at a 45-degree angle to the side. The notch on the right is large enough to hold ⅜"dowel, the one on the left is a bit narrower for a ¼" dowel. These notches can be modified to suit your needs.

Once the two pieces of wood have been prepared, attach the vertical notched piece to the end of the horizontal base using two screws through the bottom of the base.
Using the Jig

Clamp the jig to the table in front of a belt or disk sander with the notched end almost touching the sandpaper (see Figure 20-4).

A dowel whose end is to be sanded square is placed in the center notch perpendicular to the sandpaper. Rest a finger of one hand on top of the dowel to keep it horizontal. Turn the sander on and with the other hand gently push the end of the dowel while turning it toward the sander to achieve a smooth, squared-off end.

To chamfer or round over the end of a dowel, place the dowel in either the left or right side notch again holding it with a finger from one hand and pushing the dowel toward the sander with the other hand while slowly turning the dowel. See Figure 20-5.
This jig puts a chamfer on a very small part – the 1¼" long by ½" diameter dowels used to make the wing hubs of the Honey Bee (Chapter 8).

### Making the Jig

1. Start with a piece of 1" thick scrap wood about 5" x 5". One way to get this thickness is to surface glue together two pieces of ½" plywood.

2. Toward the top of one edge draw two parallel lines, ½" apart, and at a 45-degree angle to the edge. The upper line should be 1½" long; the lower line should be ⅞" long.

3. Chisel out a ½" deep hole between the two lines. Next hammer a finishing nail as close to the edge as possible.

4. Repeat with a second set of parallel lines about 1" below the first set (Figure 20-6).

### Using the Jig

1. Place the 1¼" wing hub dowels in the jig (Figure 20-7). The notches in the end of the dowels will already have been cut. (See Chapter 8 or the special purpose jig at the end of Chapter 18 on ways to cut this notch.)

2. Put the jig on the platform in front of a belt sander, turn on the sander, and gradually bring the jig up against the sandpaper to chamfer one side of the dowel (Figure 20-8).

3. Remove the jig from the platform, turn the dowel over and repeat the chamfer on the other side of the notch.

---

Figure 20-6.

Figure 20-7.

Figure 20-8.
21. Finishing

All finishes used in toy making must be nontoxic when dry. Shellac for sealing, acrylic craft paint, and water-based polyurethane for a hard clear finish are safe to use on toys. Some spray paints and oil based finishes are also safe – check the labels.

Applying finish to a toy is not essential, but it will add to the attractiveness of the toy and make it easier to keep it clean. There are, of course, many different types of finishes that could be used. This chapter describes the ones we have used for many years that have been found to provide very good results.

Thorough sanding is required before finishing. Then mask off any ends of parts that will be glued, for example the end of an axle peg. Parts of a toy are usually finished separately before the toy is assembled. There are exceptions, however, when the toy or some parts are assembled before finishing.

Clear Finishes

Most toys are made out of hardwoods, so they deserve a clear finish to show off their beauty. One of the attractions of wooden toys is seeing the interesting wood grain from which they are made. Although children enjoy playing with colorful toys, the interesting shades of natural wood grain can also be appealing.

Shellac

Shellac is recommended as the first coat of finish. It serves to seal the wood. It will also bring out the color and grain of wood. This is particularly important if the next coat is a clear finish. Shellac can be wiped on or brushed on.

However, shellac tends to raise the grain of wood, that is, cause the surface of the wood to feel rough. Once dry, the piece will need to be lightly sanded with 320 grit sandpaper or a fine sanding pad before applying the next coat of finish. Don't forget to clean off the dust after sanding.

The foam pad minimizes cutting through the shellac at the edges. In addition to removing raised wood grain, sanding also helps bond the next coat of finish (polyurethane or paint).

In using shellac apply a two-pound cut of de-waxed shellac with a rag, brush, or spray gun. The purpose for using a de-waxed shellac is to assure that the final coat will create a good bond with the sealer.46

If the plan is to use a stain on the toy, do not use shellac.

Polyurethane47

The preferred final coat is water-based gloss or semi-gloss polyurethane, applied by brush or spray gun. Water-based polyurethane gives a shiny, hardwearing finish to toys. It also dries quickly, and a second coat can often be applied without sanding again, if done within several hours of the first coat.

Both shellac and water-based polyurethane are environmentally friendly coatings. If the toy or part of the toy is to be painted, it is still recommended that it first be sealed with shellac. It is also a good idea to apply a coat of water-based polyurethane after the paint has dried, especially if an acrylic craft paint or flat paint has been used.

46 Zinsser makes a shellac called Seal Coat which is 100% wax free. It is available at most paint stores.

47 Many companies make water-based polyurethane. If you prefer an oil-based finish, the Salad Bowl Finish by General Finishes is non-toxic when cured.
Color on Toys

Toys don't need to be painted. Most of the toys described in Part I were made out of good quality hardwoods. The natural variations in the grains of the wood from which they were made can be very attractive.

However, it is also true that toys are appealing to children when they are painted, stained, or decorated in bright colors. See for example Small Cars and Trucks (Figures 3-1 and 3-4), Push Duck (Figure 6-1), Honey Bee (Figure 8-1), School Bus (Figure 9-1), Hopping Frogs (Figure 11-1), Grasshopper (Figure 13-1), and Mouse (Figure 14-1).

Following are some things to consider when painting toys:

1. Mask off surfaces to be glued.
2. If using quick drying spray paint, do so from several angles for good coverage. As soon as the part sprayed is dry, flip it over and spray the reverse side.
3. If a second coat is required, sand lightly with super fine sanding pads or 320 grit sandpaper.
4. Acrylic craft paint usually takes longer to dry than paint from a spray can. Be certain the part painted is thoroughly dry before turning over to paint the reverse side.
5. Unless the spray paint is high gloss, a final clear coat of water-based polyurethane is recommended. To obtain a good clear finish with polyurethane, hand painting works well and is quick.

Creating Eyes

There are seven toys in Part I that needed eyes. The instructions for those toys gave four methods to create eyes: painting the eye directly on the toy, leaving a hole for the eye, using a painted axle peg or wood button for the eye, or using a plastic (purchased) eye. In some cases only one method could be used. In other cases there are choices.

Eyes Painted Directly on the Toy

The Circle Animal Puzzle, Figure 5-1, has an eye that is painted directly on one of the puzzle pieces. It was also suggested in the instructions that this eye could simply be represented by a hole drilled through one of the pieces. The Honey Bee (Figure 8-1) is another example of an eye painted directly on the face of the toy.

Painted Axle Peg or Wood Button

The head of a 7/32” axle peg is approximately 3/8” in diameter. It makes an ideal small eye. This type of eye was used for the Hopping Frogs (Figure 11-1). In this case the axle peg was painted yellow. Once dry a black cross, representing the pupil, was drawn on the yellow eye using a permanent marker.
Another example is the Grasshopper shown in Figure 13-1. It has a $7/32$" axle peg eye painted red. For slightly larger eyes, use a $11/32$" axle peg. It's head is approximately $1/2$" in diameter. This is the type of eye used by the Grasshopper in Figure 13-5. The $1/2$" wood mushroom button can also be used to create this larger size eye.

**Plastic (Purchased) Eyes**

The Push Duck (Figure 6-1) and the Mouse (Figure 14-1) show the use of a plastic eye. These type of eyes, purchased from craft suppliers, often come with a tenon and can be glued to the toy the same way an axle peg eye would be glued. Without a tenon they would be glued directly to body.

**Choices for Eyes**

Most of the examples sited thus far allow for choices in how to create eyes for the toy. However, this was not the case for the Hippo (Figure 15-1) which uses an eye that must be an axle peg. Here the axle peg serves to allow the jaw to rotate, as well as being the eye.

**Painted Decorations**

The entire toy does not need to be painted to make it attractive. In many cases a small amount of decoration will suffice. Examples of this are the Weedwacker (Figure 4-1), where only the tips of the blades have color, and the Rolling Rattle (Figure 16-1), where only the rattles are painted.

In the case of the Hippo (Figure 15-1), just the eyes and teeth were painted, and this small amount of paint makes the color stand out even more.

The Doll bed/cradle presents a unique situation for decorating. We like to have some color on the headboard or footboard or both, but not all designs will work. If you paint a decoration on the headboard or footboard when the toy is a bed, it might look very strange when the toy is turned over to become a cradle. For this reason we have found that flowers work very well, or some abstract design.

In painting a child’s name on the bed, we have found it works best to paint the name twice, first in a curve that follows the curve of the headboard when the toy is a bed, then as a similar curve when the bed is turned over to become a cradle (see Figure 7-1). This way the name can be read in each direction.
Jigs Used in Finishing

The remainder of this chapter shows some simple jigs that can be useful when finishing toys.

Whether wiping, brushing, or spraying on the finish, lay the parts on triangular strips of wood (Figure 21-1). This technique maximizes air circulation during drying, and minimizes contact with the surface of the part.

The triangular strips can be ripped out of ¾" square stock. Sand the strips enough to eliminate shreds and splinters of wood.

![Figure 21-1.]

Finishing Wheels

There are some easy to make jigs to help with the finishing of wheels. Wheels that have not been glued in place can be strung on undersized dowels and suspended across a notched cardboard box to hold them in place (Figure 21-2), or placed on small pieces of tapered dowels inserted in holes in a piece of scrap wood (Figure 21-3). A pencil sharpener is an easy way to taper the dowels.
The notched cardboard box will also work for the body of a toy that has more than one through hole, for example, a car. In this case use two undersized dowels to support the car, one in each axle.

For wheels that have been glued to an axle, drill holes in a piece of scrap wood slightly larger than the diameter of the axle and stand the axles with wheels attached in the holes (Figure 21-4).

When sealing or painting the heads of axle pegs, it is important to keep the tenon clear of finish. First, cut the tenons of the pegs to the required length, if this is necessary. Then smooth or break the edges that were cut off.

Use a painting board (Figure 21-5) when applying the finish. The painting board is simply a piece of Masonite or scrap wood. Drill 5/16” diameter or 7/32” diameter holes into the board, depending on the size of axle pegs.
Insert the pegs into the holes. Their heads should be flush with the top of the board. Then set the board on supports on top of a drop cloth, or attach it to two supports.

Apply the finish to the heads of the pegs. During the drying process, push the pegs upward a couple of times to avoid the heads adhering to the board. When dry, simply place the board on a clean surface, turn it over, and the pegs will all pop out for retrieval.

Figure 21-5.
22. Assemble

With all construction, including sub-assemblies, and finishing completed, it is time to assemble the parts. Some parts are glued in place, for example the mouse ears to the mouse head. In such cases this could be done before or after finish is applied, depending on how the parts are being finished.

In practically all cases, however, assembly involves dowels, wood buttons, or axle pegs being glued into wheels, legs, or the body of the toy. These final steps are most important because they will assure the toy is fully functional, that is, the movement of the wheels and other parts work as intended. If they don’t, see the trouble shooting suggestions and corrective measures at the end of this chapter.

Wheels on Dowels

Wheels glued to dowels are designed to rotate in a hole in the body of a toy. The following description assumes wheels are being attached to the axles of a car, but the same procedure would apply to any toy with wheels:

1. Sand the whole dowel being used for this project with 220 or 320 grit sandpaper before cutting it into axles.

2. Ream holes by hand to remove paint and fuzz. When reaming out wheel center holes, select a drill bit that will create a hole that makes a good glue joint with the axle being used. Don’t forget to ream out the holes in the body of the car in which axles must freely rotate.

3. Cut the dowel over-size that is being used for the axle. Sand one end either squared-off or chamfered. Figure 22-1 shows examples of these two ways to finish the ends of axles. The axles of the two wheels from the left are squared-off; the one on the right is chamfered to look like a hubcap.

4. Dry assemble one wheel on the end of the axle that was sanded. Size the axle length by inserting the axle with wheel attached through the axle hole with a washer and a spacer on the side of the axle where the wheel is attached.

The spacers should be about \( \frac{1}{32} \)" thick (.02 -.04`). The plastic clip that is used to seal the outer bag of a loaf of bread makes a good spacer or A piece of cardboard from a cereal box will also work.

See Chapter 2 (p. 19) on testing and achieving good glue joints.

See Chapter 19, p. 169.

See Chapter 20 [pp. 180-1] describes a jig that can be used to sand the ends of axles to give them a squared off or rounded look.
5. On the other side of the car insert on the axle the second wheel up against a washer, spacer, and the body of the car. Mark the location where the axle is to be trimmed (Figure 22-2). If the end is to be chamfered, place the mark about \( \frac{1}{8} \)” from the edge of the wheel; if squared-off place the mark at the edge of the wheel.

6. Disassemble the wheels and axle from the car and trim the axle where marked. Sand the end and break (round over) the corners or chamfer the end.

7. Glue one wheel to one end of the axle. (See gluing suggestions in the next section). Allow the glue to set.

8. Re-assemble the axle with one wheel attached (Figure 22-3), making sure to put a washer and spacer on each side of the body. Use the instructions given in the next section for attaching the second wheel. Let the glue set. When dry remove the spacers and test the rotation of the wheels.

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**Figure 22-1.** Squared off and Chamfered Axles

**Figure 22-2.**

**Figure 22-3.**

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**Another Approach to Sizing Axles**

Rather than cutting the axle oversize, then cutting it to fit the vehicle once one wheel has been dry assembled to the axle, another approach is to cut the axle to length before assembling the wheels. (This was done in Chapter 12, Car Transporter.)

This approach requires careful measurements that must include the width of the vehicle, and the width of two wheels, two washers, and two spacers. To this length add \( \frac{1}{4} \)” if the ends of the axles are to be chamfered to make them look like hubcaps.
Gluing Wheels onto Axles

The following procedure assumes that paint or a clear finish has already been applied to the wheel and the center hole of the wheel has been reamed out to remove paint and fuzz.

1. Put glue in wheel hole using a toothpick, nail, or piece of \( \frac{1}{8} \)" dowel.

2. Wipe off excess glue from the inside of the wheel.

3. Insert axle (dowel) from the inside of the wheel.

4. Wipe off excess glue pushed to the outside of wheel.
22. Assemble

**Affixing Toy Parts with Axle Pegs**

The following steps assume the body and wheels (or other part) are already finished. It is also assumed that a proper size hole has been drilled into the body, the hole has been reamed out after painting, and the axle peg has been tested in the hole to assure it will make a good glue joint in the hole.

1. Put glue in the hole with a nail, toothpick, or small $\frac{1}{8}$" dowel. Smear the glue around the inside of the hole.

2. Wipe off excess glue from the outside of the hole.

3. Assemble by placing the part (usually a wheel) along with a washer and spacer (if called for) onto the axle peg. Insert the axle peg with the wheel, washer, and spacer into the hole. See Figure 22-4).

4. Allow glue to set for at least 15 minutes.

5. Test that glued part moves properly.

**Note:** Axle peg tenons may need to be shortened, depending on the width of the part in which they will be placed.

*Figure 22-4.*
Trouble Shooting and Corrective Actions

Attention to the gluing and assembling steps in this chapter will help to assure good results. However, if the assembly of parts is not going well, such as an axle not moving freely when fitting in the body of a toy, it will be necessary to take corrective action (not a hammer!). Following are some general guidelines for preventing or solving problems in assembling toys:

1. If there is a problem with a part, analyze it and search for ways to enable the part to correctly function before proceeding to assemble additional parts or additional units. This might involve:
   a. Checking that the part’s dimensions are correct,
   b. Looking for rough spots which could be hanging up the part,
   c. Seeing if there are proper clearances for moving parts, or
   d. Re-visiting the instructions to determine that they have been followed.

2. The best approach we can advise is to assemble as much of the toy as possible without gluing, that is, dry assemble the toy. This approach has been suggested in most of the toy building chapters. If the parts that are to be glued are fitting properly, the toy should hold together without glue in order to test that its moving parts are working properly.

3. Take precautions before assembling, such as, reaming out holes that might have gotten sealer, paint, or clear finish in them.

4. If making multiple copies of a toy, test any jigs that are being used after making two or three toys to determine that you are getting good results, before making a large batch of the same toy.

In putting together the instructions for making the 15 toys in Chapters 3 – 17, we have tried to insert warnings or suggestions that will prevent problems from occurring. We hope these have helped and that you find success in constructing wooden toys.
Appendix

Some Suppliers of Wooden Toy Parts

A search of the internet will provide a number of suppliers of wooden toy parts. Following are few that appear to have a wide range of parts. Check the web pages of these and others firms to compare costs and sizes of the parts you need.

- American Woodcrafters Supply
- Armor Crafts
- California Dowels and Turnings, Inc.
- Casey's Wood Products, Inc.
- Woodworks Ltd.

Some Other Books on Making Wooden Toys

Here is a small selection of the many books on toy building that have been produced over the years. Noted are special features of these books.

  Features transportation toys (cars, trains, trolleys, planes and boats).

  Includes a wide variety of toys made years ago that can still delight children of all ages today.

  Contains lots of good tips for making animals that move.
## Decimal Sizes of Selected Drill Bits

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The Authors and Illustrator

**Charlie Bierman.** After serving in the Army during World War II, Bierman earned a degree in engineering. He was employed in the aerospace industry and worked for many years on the launches of the Atlas rockets. After retiring he took up woodworking, and this led to toy building. He was the leader of the El Cajon, California toy making group for over 20 years.

**Charlie Pinkus.** An undergraduate degree in industrial engineering led Pinkus to pursue graduate degrees in operations research. On completing his studies, he taught in departments of engineering, mathematics, and technology and operations management for 35 years. On retiring he took some woodworking courses, one of which was on toy building taught by Charlie Bierman.

**Steve Naiman.** Naiman spent over 25 years teaching woodshop to junior high school students in El Cajon. After retiring it was natural for him to continue woodworking and he joined the toy making group in El Cajon. He is now leader of the group and once again teaching woodworking, but this time to seniors.

**Bill White.** White had a 22-year career in the Navy, from which he retired as a Lieutenant Commander. He always had an interest in woodworking, so after retirement he became head carpenter in the La Mesa/Spring Valley School District. On retiring from his second career he joined the El Cajon toy making group.