Click to prove you're human

All great planes used to be named after great women. My nod to that tradition was naming my world-record paper airplane design after my wife.Suzanne represents a number of firsts. Its the first glider to hold the record for distance, thrown by Joe Ayoob in 2012. Its the first time a thrower/designer team has held the record. (Predictably, the old world record holder hated the idea, but Guinness liked it.) Its also the first paper airplane to use a variable dihedral angle to optimize lift-to-drag over a range of speeds.We know the plane goes well beyond the current record of 226 feet 10 inches; Joe has thrown the plane more than 240 feet.We hope youll build and fly the Suzanne glider. Wed love to know just how far the plane can go.Glider or Dart?Figure AFigure BPrevious record holders were very small-winged darts. The wings were more like the fins on an arrow; simply for directional stability and not providing lift. It didnt matter if the plane rolled, which they frequently do. The throw was a simple 45 launch, like any ballistic projectile.For that reason, those kinds of planes were called ballistic darts (Figure B). The old record holder, a ballistic dart, took only 3 seconds to go 207 4.My plane is a glider (Figure A). It takes 9 seconds to fly 226 10. My plane gets launched level, climbs on its own by generating lift, and really flies the last third of the flight. It gently touches down and skids to a stop. The old kind of plane simply crashes into the finish line. The folding is easy (throwing for a world record is not), but the taping will take some time. All folds are valley folds ( ) except for the mountain fold ( ) in Step 9. This tutorial is excerpted from my book The World Record Paper Airplane and International Award-Winning Designs which you can find at thepaperairplaneguy.com/shop.1. Make a diagonal fold. Line up the top with the left side.2. Unfold Step 1.3. Make a diagonal fold the other way.4. Unfold Step 3.5. Line up the left edge with the diagonal crease.6. Line up the right edge with the other diagonal crease.7. Fold the top down, across the point where the diagonal creases cross.8. Fold the top corners down to meet at the centerline. The top layer creases should line up with the bottom layer. Follow the existing creases.9. Fold the plane in half. The mountain fold means you flip it over first, then fold in half.10. Rotate the plane turn so that the center crease is on the bottom.11. Make the wing fold. Start by positioning the creased edge of the wing against the center crease, but dont fold yet. Keep pulling the wing down until the little white triangle is gone. Now fold. Then make the other wing match.12. Cut the tape into strips 30mm long: 3 strips about 2.25mm wide, and 7 narrow strips about 1.5mm wide.13. Apply tape strips in the numbered order shown here. Note that strips 3, 4, 5, 15, and 16 are wider strips. Strips 3, 4, and 5 are all cut from one wide strip. Strips 10, 11, and 12 are all cut from one narrow strip.FrontBack14. Use your dihedral gauges to set the angle at the nose at 165, and at mid-wing 155.Going the DistanceWorld record throw by Joe Ayoob as the author (left)looks on.To throw your world record plane, hold it where the most layers meet (at the thickest part). Keep the wings level. Strive for smooth acceleration.Get the plane flying straight, and then work up to a fast throw. For turns at regular gliding speeds, youll adjust the trailing edge of the plane normally. See The Flight Stuff below for tips on adjusting your planes control surfaces.But keep in mind that the faster this plane flies, the closer to the nose your adjustments will be made. At our highest throwing speeds, if the plane veered right on launch, I would bend the leading edge on the left down a little, at the nose.$1,000 Reward!Use this design and officially break the world record for distance, and a $1,000 reward is yours. You must be named by Guinness as the world record holder.[Update: the record has been broken!]John Collins teaches the Bluprint class Plane Games: Make & Fly Paper Airplanes where he shows how to fold and fly five of his best designs, including this world-record plane, and tests each one for distance, speed, and more. I had the opportunity to bring back together members of the first team who helped develop Make: magazine, taking an idea I had and turning it into something real and tangible. I am grateful for all that they did.Dale Dougherty Mark Frauenfelder:Mark was the first editor for Make: magazine. He had worked at Wired and was a founder of Boing Boing.Today, hes research director at a nonprofit think tank called Institute for the Future, and theyre in Palo Alto, California. David Albertson:David came up with the design and format for Make: magazine. He is a graphic designer who has his own firm, Albertson Design in San Francisco. Shawn Connally: Shawn was the managing editor for Make:, working with Mark as well as copy editors and designers to produce the magazine. Today, she divides her time between Occidental, California, and New Mexico. She is a master gardener. Paul Spinrad: Paul was an early contributor to Make: and then joined the team as an editor. Today, hes a technical writer at Broadcom. Keith Hammond: Keith is the editor-in-chief of Make:. He started as a copy editor on early issues of Make: before managing the projects section. Here on Make:cast is the original interview with Mark, David, Shawn, Paul and Keith. DNA of Make:, est. 2005: Delightful makers, DIY projects, open source technology, hacks and how-to skills. Dale: Mark, when I first talked to you about a new magazine I wanted to start, you were in Rarotonga in the Cook Islands. Mark: I was there with my two young daughters and [wife] Carla. You had been doing the Hacks series of books at OReilly and you wanted to do a general-interest recreational technology magazine. Dale: I had no experience publishing a magazine, but I had connected to John Battelle. He knew you from Wired. Mark: About four months later, I came back from Rarotonga and I flew out to meet you with John. I was really excited about it. You asked about a designer and I had always been a huge admirer of David Alberstons work. So then, Dale and David and I met, and you said, lets make a prototype. So that was several weekends and weeks up at Davids in his studio, putting stuff on the wall. We didnt have a name for the magazine and I was pushing foolishly for the name Geek. You of course came up with the great name Make, which was perfect. And then adding the colon to it was just, like, the brilliance of that what are you going to make? Dale: My original idea was Hacks magazine. I told my kids, and they didnt get the word hack. It meant nothing to them. As an editor at OReilly, I recalled a book we had published about a Unix utility, Managing Projects with GNU Make. I wanted the magazine to be about projects, how to build things. The make utility was used to run a bunch of commands to compile a program. I didnt care if anyone knew that connection, but I loved the word make because it was a verb for doing something. David: Mark, I remember when we were here in my little office, just how much fun it was. Dale, you had shared with me old Popular Mechanics magazines. I loved those. Theyre so beautifully done and they were so sincere. And so when we talked about this being like a shop manual, I really got excited about that. Shawn: I had a 3-year-old at home. Dale said, come in, I have this crazy idea. He would never call it crazy; I called it crazy to do this stuff. But I thought it was a pretty interesting idea. Dale: Your role, Shawn, was managing editor, which is really bringing all the different pieces together. Paul, you came on after the first issue. Paul: I used to work at Wired but not at the same time that Mark did; yet we knew a lot of folks in common. Id taken some time off to write a book about VJing, about live video performance, which I was super into. I pinged Mark looking for work and he said Im starting this magazine. Do you want to write these two short pieces? There was one about this guy in Fremont who had built in his backyard a monorail. I love that stuff. Dale: We have a photo of a puppy in the monorail that captures your interest immediately. Paul: Totally. The puppy monorail! Dale: Keith is our current editor-in-chief. Keith: I had just moved to Sebastopol like, why is there a magazine in this little town? And so I came in and met the magazine team that had been pulled together, right after the first issue succeeded. You guys were like, Oh, we have to really do this now! Its fussy work, scientific notations and abbreviations, conventions and nomenclature and dimensions its really fussy. David: It was a big part of selecting the typeface for the magazine. We had character sets that allowed for inline fractions and that had all the mathematical symbols, so we could keep them uniform with the whole look of the magazine. Keith: On top of that, it has to actually work! The part number has to be the right part number; the length of the screw has to be right, or it wont fit. Paul: And its in print! Worth 1,000 photos: Infographics, exploded illustrations, and cutaway diagrams show you how it really works. Dale: David, one of the things Im really proud of is the design of Make: and it has stood the test of time. Weve had other designers follow David but he laid the foundation. We took a category that often didnt have much design, either it was grungy or just plain, the equivalent of Courier font. David: I didnt have to pitch it too hard; it was great to have you guys as collaborators to push things along. It was really worth the effort because we wanted those pages to look great. Dale: David, you had a particular vision, and I trusted that. We didnt do a hundred variations. You were pretty close from the beginning. David: I really wanted this to stand out, to not look like a typical techie manual, and I wanted your vision, Dale, of this thing being for, like, dads and kids, that kind of age range I wanted kids to look at it and say, this is exciting. Its not just the gear. Dale: A lot of the computer magazines were based on classes of gear, mobile phones or laptops or PCs or Macs. They were overly business focused plain, straightforward. I wanted making to be fun and playful. Thats one of the reasons people do it. Mark, you have a great sense of whats cool. I think its honed in Boing Boing, and I dont mean affected cool but authentic and genuine, something original that you havent seen before like, someone actually did that! Mark: Thats always been my thing. Like when Wired hired me to do their review section, and also they had a section called Fetish, which was new gadgets and things like that, and it was just tapping into my natural interest for interesting new things out there that intrigued me. Dale: But Mark, you actually have a degree in mechanical engineering. Mark: I do. Dale: I think the secret touch you had, and I see it in places like Japan, like our Maker Faire Tokyo, its combining pop culture or the sense of whats popular or cool with technology. David: I remember when Mark said, OK, we got a scoop! The big scoop was that there are a bunch of students in Hong Kong who were going to like the local Pizza Hut. They had architected the salad bar so that they could maximize a single bowl by building platforms out of carrot sticks. I love that Mark was like, We got it! Were going to be the first ones to get that out there. Dale: One of the things that we tried to do was have illustrations for the projects. Keith: The exploded diagram or cutaway for that big opening illustration for major projects it sets this context for how the whole thing works. It was not a boring diagram, it was beautifully illustrated with a lot of character. Dale: Again, thats a connection to those old Popular Mechanics that had wonderful line art. It did something that photographs dont do the same way. It was clear and easy to understand. Mark: We made a connection to Roy Doty who was the fantastic Wordless Workshop illustrator for Popular Science and Popular Mechanics. He was in his mid-80s doing illustrations for us. He was such a great bridge, and a thrill to work with. Show and tell: Overview illustrations, materials lists, and step-by-step instructions lead to a successful build. Dale: The first issue had four major projects. I think they were a pretty good reflection of what Make: wanted to be. One was the mag stripe reader by Billy Hoffman, which was a hack. How do you know whats on that mag stripe on a credit card or a hotel room key? And then Johnny Lees $14 Steadicam. It had a weight at the bottom of a pipe and a bracket to hold a camera. We had a challenge to figure out what was going to be on the cover. What would be the most different and inspiring project we could find? We found Cris Benton, a professor of architecture at UC Berkeley who was putting cameras up in the air hanging from a kite. He was flying them at 200 feet so he could get different views of buildings. Our goal was to share the instructions of how to build something and not hand-wave over the process. Cris had many different camera rigs but the one he made for the magazine was a harness made with popsicle sticks and it was designed for a disposable camera. Mark: It had the Silly Putty viscous timer. Cris made this project for us especially, because we said: Your rigs are expensive. Can you do a low-cost version? The shutter mechanism was a little film canister with Silly Putty inside and a rubber band. You wound it up in the Silly Putty, but it was super viscous. So the little lever that pressed the shutter button David: It was a toothpick with rubber bands. Mark: It took 3 minutes to finally hit the shutter, but it was enough time to deploy that kite and get it up to altitude. Dale: It was a Rube Goldberg kind of contraption. Mark: That first project makes you realize how long ago this was. Now theres just so many other options with Bluetooth and all that stuff. Dale: Cris was also using a Canon camera and he was able to hack the firmware in to do the same kind of thing, getting a delay. Ive found it fascinating that we covered hacking consumer technology to make it do something that you want it to do, but it wasnt really made to do. Paul: Theres something very subversive about DIY and doing things youre not supposed to. The design of Make: was very approachable and appealing. It was not anti-establishment in any way. It was very direct and clear. Thats what made it so subversive. Cris Benton, Berkeley, California, writes: Like Make: I find myself 20 years older and this places me in the state of contented retirement. I continue to play around with KAP, using low level photographs in sustained, longitudinal projects to document and understand landscapes of interest. My South Bay Salt Pond work led to exhibits at the Exploratorium and to Saltscapes, a book with Heyday Press. Another KAP project documents the coastal defenses of San Francisco Bay. These days I am splitting my time between grandkids, camping, and travel but still get a kite up now and then. flickr.com/photos/kap_cris Johnny Lee, Redmond, Washington, writes: I am working on AI experiences for wearable devices like AR glasses. Very buzzwordy, I know. Previously, I developed spatial computing technology for Google, and did a short stint in robotics. The $14 camera stabilizer was my first real exposure to the power of the maker community. Being included in the premier issue of Make: is still a badge of honor I even got to ride the coattails of the magazine when it was included in the Cooper Hewitt Smithsonian Design Museum Triennial in 2006. It definitely encouraged me to continue making other projects accessible to the community such as my Wii-remote hacks and funding the Adafruit OpenKinect prize. Mike Ossman, Evergreen, Colorado: Mike writes and designs open source products at GreatScottGadgets.com, which he calls an effort to put exciting, new tools into the hands of innovative people notably the HackRF One software defined radio (SDR) transceiver featured in Make: Volumes 84 and 87. Billy Hoffman, Atlanta, Georgia, writes: Writing for that first issue of Make: was not only rewarding but also very validating: there existed other people, like me, that were obsessively curious with how things worked, and with building things. In early 2005, I was about to graduate from college. I had been active in the hacking/2600 scene, but working with Make: and OReilly helped me see there was a much broader appeal. Since Make:, Ive made a career of figuring out how things work, as a researcher, founder, and then CTO at a series of computer security and web performance startups. Nowadays I do my making with my daughter, who loves to download, modify, and print models on her 3D printer. In her eyes, hackers are people who know how to mod Minecraft! Dale: One of the questions I got early on was, why are you doing a print magazine? There was something about it being tangible that really appealed to me. This was a magazine about objects and we wanted to create the magazine as an object about those objects. I hoped people would want to collect them and hold on to them. David: I think we were all aware that it was comfort food for some people too, like the people who would have a subscription to Martha Stewart Living and they never make a recipe. They just felt really good about going through the pages and looking at the pictures and the elaborateness of some of these little projects. We heard from some readers: I comb through every issue, I make maybe one project a year. Dale: I also heard from people who said I grew up reading magazines like Popular Electronics and thats how I learned about technology. I read it under the covers at night with a flashlight. Were filling peoples head with ideas for things, and then their own ideas emerge and they then know how to do it because they saw someone else do something like it. Keith: Now thats all in your bag of tricks. And it demystifies technology, whats under the hood. Its not a magic black box from some big company. Its just technology you can figure out how it works and you can point it in a new direction. Paul: I remember it was like the peak period for magazines going out of business. It was so funny, working for Make: while reading that so-and-so is going out of business. I kept thinking, there is an exception here. Keith: We somehow started a magazine right when all the other magazines were going off a cliff. And it only got worse. But we were like Wile E. Coyote. We just went out over the cliff and just kept going. Were still going. Dale: I like that image. I didnt know if wed get any advertising. So we had a higher cover price than most magazines. Tim OReilly said, when people pay for something, they value it. Keith: I think reader-supported publications are the ones that have kept bumping along steadily. Dale: Mark, you mentioned our first project, kite aerial photography, was long, over 30 pages in print. We had to back up the release of the first issue because of the complexity of it. One thing that distinguishes Make: is how we provided detailed step-by-step instructions for projects. David: Its recipe building. We really worked on that and kept trying to hone it so that we had a templated way to lay out projects in a sequence. I worried that the material would come across as extraordinarily dense and impenetrable. What we wanted was something that people can look at and go, OK, I can handle this. It gives them the confidence that they can understand it all. All of us worked really hard to make sure the instructions were really as simple as they can be. Dale: Editors had two challenges. One was working with some authors who are not naturally writers. Second, often theyre not very good at describing their own work in a way that other people can follow the instructions, without knowing the same background information. They had to think how someone else would be able to do what they do. Keith: This is what led to the Make Labs engineering interns building and testing projects to see if this stuff would really work. Especially mechanical contraptions like the Stirling engine confused. And thats the editorial back-and-forth with the author. We started improving the projects also for photography. David: And we built a guide for authors for taking their own photographs. We tried to make that into its own how-to to make it really easy for them. Dale: Theres such authenticity to a photo that a maker takes of their project, often its in their workshop or their garage. I always preferred that to our own studio shoots. Paul: Another part of Davids design was the photo of the materials at the very beginning, a sort of establishing shot of all the materials.You see how it makes the project so tangible and less intimidating. Youre setting the stage: This is what you start with. You can do it: Howtoons presented kid-friendly DIY projects in a comic-book format. Dale: Mark, I really enjoyed meeting the makers as people. They didnt fit into the traditional categories of artists or even technologists and or scientists and others. It was fun to find out, often this is a side project or something that they just did. You never asked a maker, whyd you do that? It was more like, were happy that they did it. David: There was such a folk art kind of component to a lot of these things the makers and how unique they were. Dale: These encounters with people led me to thinking about Maker Faire as an event to bring all these makers together for the public to meet them and talk to them about their projects. Shawn: I still remember the first time I saw an ad that used the word maker after we started the magazine. Dale pretty much created this word and this movement and now I get every week, an ad or an email about makers. I think we created a word and a movement, as you say. Dale: The word maker served a purpose of connecting people that had different interests and different things they like to do but they were all makers. Maker Faire was just an umbrella for all kinds of different people who make things and they can all talk about their projects and regardless, they can say Im a maker. Shawn: The word maker, like you said, you put it in the first issue and now 20 years later, everyone just uses it as a noun in a way that really no one did 20 years ago. I find that fascinating and really something for all of us to be proud of. This article appeared in Make: Volume 92. Ive been collecting clever ways of slotting flat stock together since I first read Nomadic Furniture back in 1999, well before the advent of the accessible hobby-class CNC tools that today make manufacturing parts like these pretty easy. Now, the world is full of people designing models, project enclosures, sculpture, furniture, and all kinds of other cool stuff to be assembled from parts made on laser cutters and CNC routers. I keep expecting a definitive book or website to emerge that covers the bag of tricks in an organized way, but so far, I havent found it. Maybe this article can serve as a jumping-off point. In any case, I think its time to share my notebook of CNC panel joinery. In presenting this material, I want to first acknowledge my respect for the worlds established and ancient traditions of joinery. I do not for a moment imagine that any of this is fundamentally new. But I do see a need to organize this information to address the needs of the the small CNC tool operator who wants to make interlocking, self-aligning and/or demountable joints in flat stock, for instance plywood or sheet plastic. Or just to inspire her.I may abuse some terms, without meaning to, and I am glad to be corrected by those who are in the know about traditional joinery. Generally, I have tried to use descriptive terms instead of proper names to avoid confusion, but here and there I may have slipped up and called a rose by some other name.To simplify things, at first, Im only considering joints between two panels. Also, again for the sake of simplicity, Ive limited myself to techniques that use all-the-way-through cuts, orthogonal to the plane of the stock. For a taste of how complex this subject can become, without these limitations, and how quickly, check out Jochen Gross 50 Digital Wood Joints project. Heres a montage of teaser thumbnails to whet your appetite:For this article, though, Im deliberately considering a very limited case: Two (or even just one) cut parts, no partial-depth cuts, and a cutting axis always at 90 degrees to the surface of the stock. Even with these limitations, the possibilities are rich.Laser vs. Rotary Cutters The Inside Corner ProblemHobby class laser cutters and CNC routers each have advantages and disadvantages. Laser cutters can cut much finer details because they have very small kerf. On the other hand, theyre more expensive and cant do partial-depth cutting or pocketing like a CNC router can. They also use heat, which can burn the substrate and/or generate nasty off-gassing. On the other hand, the burning effect can be used decoratively. A CNC router can change bits and cut complex relieved surfaces, or make cuts with mitered or otherwise profiled edges. I dont think either tool can be described as simply better, and, with one minor caveat, all of the techniques presented here can be used equally well with either a laser cutter or a router.Because of its very small cutting channel, a laser cutter can produce an inside corner with a sharp angle, whereas a rotary cutter using a physical tool is limited to inside corners rounded at the cutting tools radius:The laser-cut version, with its sharp 90 corners, is suitable for use in a simple edge-lap joint:The router-cut version, however, doesnt work. The radiused corners bump into each other and the part edges dont line up. You can cut each slot a bit deeper, of course, and in some applications this may be OK, but doing so leaves a void in the center of the joint and concentrates stress on the radiused corners. A better solution is this:Now the inside faces of the edge laps mate cleanly. On the other hand, the round divots are visible in the assembled joint. If that bothers you, of course, you can also do it this way, if your cutter is narrow enough:On average, this method offers the best compromise, IMHO: The flat areas between the divots seat against each other firmly and the divots themselves are concealed inside the joint.To simplify presentation, the joints below are presented with ideal laser cut inside corners. But all of them should be readily adapted to rotary cutting by using the divot method shown above.BiasingMany of these joints are symmetrical, and can be assembled in more than one way. The joint above, for instance, can be assembled in two different ways (four if approaches from below are allowed). Which is correct?Often it is possible to deliberately break this symmetry so that the parts can only be assembled in one way, or at least in fewer or more obviously correct ways. Now the joint can still be assembled incorrectly, but the disfavored orientations are more obviously wrong, because the part edges no longer align.This trick can be very handy in complex structures, particularly for kit parts, to keep end users from putting the joint together backwards. I call a joint that has its symmetry deliberately broken in this way biased.Cross (X) JointsHeres a version of the basic slotted edge lap joint in which one side has an integral snap-lock feature. The snap hooks are accessible from the end of the joint. Insert a small flat-blade screwdriver, pry a bit, and they can be popped loose and the joint opened again.But move the hook and the catch away from the edges of the stock, and the snap-lock action becomes irreversible.Note that both pieces of stockcouldinclude both hooks and catches. Im only showing one sided snapping joints for clarity.Replace the hook with a bulge and the snap becomes a detent: The part will stick in place but can be removed with sufficient force.The detent could catch in one position, or many.Heres a more unusual X joint that uses a radial interlocking motion to seal the deal.A biased version is also possible. Heres a similar joint with the symmetry broken shown disassembled (left), assembled in favored orientation (middle), and assembled in its disfavored orientation (right).Locks or detents can be added to the stationary member, as shown aboveand/or to the rotated member, as shown here. Note, in this case, that it doesnt matter if the profile of the catch is hooked or rounded: Once the catch pops into the slot, itll be very hard to get out. For the reversible version, move the slot and the catch out to the edge of the stock.Finally, in the case of X joints, if one member is narrower than the other, a full-width slotted arrangement becomes possible:Such joints may be useful especially for shelves or other upright applications where gravity can be exploited to keep the pieces engaged, and may be biased or otherwise modified like the T joints described below.Tee (T) JointsHere is a simple mortise and tenon type joint. We can split the mortise and tenon into two slots and tabs (or into as many slots and tabs as we like). If we break the symmetry of the slots and tabs, the joint becomes biased. And if we extend the tab a small distance past the thickness of the stock, we can add easily add snaps or detents that catch on the far side of the slotted part.Fasteners in the plane of one of the pieces can now be introduced. This captive square nut joint is seen on a number of commercial products featuring CNC-cut parts, for instance the Phlatformer vacuum former kit and several popular 3D printer kits:This particular configuration was the subject of a nomenclature debate here on the blog not too long ago, though I dont think any sort of consensus was achieved. Interesting possibilities includecaptive nut joint, bedframe joint, and Pettis joint (which ismy personal favorite, because it observesStiglers Law).There are almost certainly other clever ways to incorporate metal fasteners or other bits of common hardware in this type of joinery that I havent seen, and/or that have not been invented, yet.Corner (L) JointsThis arrangement of interlocking tabs and slots at a ninety degree angle is, of course, ancient and rudimentary. Most people call it a box joint. It, too, can be biased by breaking symmetry.And it is just as amenable to the bolted captive-nut arrangement.Oblique (V) JointsThough the captive-nut joint doesnt really work unless the two parts are at right angles to one another, generally the L joints can be pressed into service for acute or obtuse angles, as well.The bottoms of the slots no longer index closely against the surface of the stock, but if the members are held in alignment by some other means, for example by glue or the introduction of a third panel (as shown to right), it may not matter.An interesting variation on this method, in which the fingers are rounded, has been used by Sebastien Wierinck in his Chair model 01, as shown:Sebastien is using pins, I believe, running longways through both sets of fingers, along the axis of each joint, which requires an out-of-plane drilling operation that is technically disallowed under our rules. But these joints could certainly be glued. If using glue, however, the rounded fingers, through they may look better , will limit the surface area available to the adhesive.Coplanar (I) JointsHere, for instance, is the classic finger joint, used to join members in the same plane for gluing.This interlocking bulbed version doesnt depend on glue for its strength in tension. If left unglued, of course, these flat joints require some means to keep the two pieces in the same plane when the joint is in use. Here is a variation of the bulb joint that allows for in-plane hinging action:I want to call this a Kanelba hinge, for George S. Kanelba, of New York, whose Cube Desk project in the 1984 Popular Science book 67 Prizewinning Plywood Projects is the only place Ive ever seen it.Kanelba hinges can be daisy-chained to make snakes. The individual hinges, of course, can be set to stop at angles other than 90.FlexuresThough not strictly joints, there is a class of clever CNC tricks that meet our criteria for inclusion here (two or fewer members, all-the-way-through cuts at 90 degrees) that are designed to exploit the natural elasticity of the panel material itself to create living hinges, springs, and other dynamic flexing elements. We have already broached the subject of integral flexures with our discussion of catches and detents, above.This is an in-plane spring or living hinge element that is kind of like kerf-bending, but with thru cuts. If not constrained to motion in the plane, such a feature will be pretty unstable. Heres a version more suitable for out-of-plane bending:This is the somewhat famous Snijlab living hinge technique (which I continue to believe should be called a sninge), an accordion-cut pattern that allows for stable out-of-plane flexing. It is most commonly executed in laser-cut plywood, but theres no reason it couldnt be cut with a CNC mill and/or in other materials, though a router-cut sninge will have to be longer to achieve the same degree of flexibility as a laser-cut version, because the router slots will have to be considerably wider.Finally, heres an oddball free-hanging spiral technique, courtesy of the good folks at PlasmaCAM. The spiral is cut out of a piece of steel using a CNC plasma cutter, but the same idea could work with a laser cutter or a mill, in a different material.Final ThoughtsThis is obviously a huge area, and this postunwieldy as it isonly just scratches the surface. Compiling it, new variations and ideas kept occurring to me, as I suspect they will to you. The rules to the game, again, are simple: all-the-way-through cuts, 90 degrees to the surface of the stock, only one or two cut parts involved. What clever tricks have I missed? Let me know, below. Liberate the rear hubs and axles from some old bike wheels by cutting the spokes off with a Dremel (seen in the first picture). Youll use these as the drive hubs, mounted in the drills.First, you need to lock the axles to the hubs. The easiest way is to jam the axle bearings mechanically. Unscrew the axle nuts and remove the ball bearings (second picture), then overtighten the axle nuts back down as hard as you can. The axle should now be frozen.If the axle works loose, fix it permanently by drilling and pinning the hub through the axle (third picture), using 6-32 machine screws and jam nuts (or nylon insert nuts). We used 3 screws per hub to prevent them shearing off. You could also weld the axle to the hub.The drills face opposite directions on the kart, but you have your choice of how to align the drive hubs in the drills. If you align both hubs in the same direction, you wont need to do this next modification. But we aligned our hubs in opposite directions, because that way the drills line up much better for sitting between them. If you do this, then one of your drive hubs must be drivable backward, so that it doesnt just coast against its drill. This means youll need to freeze one freewheel entirely by welding the gears to the hub, making it a fixed hub.To avoid doing this fixie modification, you could also substitute a real fixed rear hub (popular with road racers and bike hipsters), or buy a drive sprocket like we did in the Drill Rod scooter and engineer your own axle to mount it in the drill.Put the axles in the drill chucks and tighten them well.First, look over the anatomy of the spur gear pair in this figure and the vocab below.Number of Teeth (N)Pitch Diameter (D): The circle on which two gears effectively mesh, about halfway through the tooth. The pitch diameters of two gears will be tangent when the centers are spaced correctly.Diametral Pitch (P): The number of teeth per inch of the circumference of the pitch diameter. Think of it as the density of teeth the higher the number, the smaller and more closely spaced the teeth on a gear. Common diametral pitches for hobby-size projects are 24, 32, and 48. The diametral pitch of all meshing gears must be the same.Circular Pitch (p) = pi / P: The length of the arc between the center of one tooth and the center of a tooth next to it. This is just pi (= 3.14) divided by the diametral pitch (P). Although rarely used to identify off-the-shelf gears, you may need this parameter when modeling gears in 2D and 3D software like were doing here. As with diametral pitch, the circular pitch of all meshing gears must be the same.Outside Diameter (Do): The biggest circle that touches the edges of the gear teeth. You can measure this using a caliper like Sparkfun.coms # TOL-00067. Note: Gears with an even number of teeth are easiest to measure, since each tooth has another tooth directly across the gear. On a gear with an odd number of teeth, if you draw a line from the center of one tooth straight through the center across the gear, the line will fall between two teeth. So, just be careful using outside diameter in your calculations if you estimated it from a gear with an odd number of teeth.Center Distance (C): Half the pitch diameter of the first gear plus half the pitch diameter of the second gear will equal the correct center distance. This spacing is critical for creating smooth-running gears.Pressure Angle: The angle between the line of action (how the contact point between gear teeth travels as they rotate) and the line tangent to the pitch circle. Standard pressure angles are, for some reason, 14.5 and 20. A pressure angle of 20 is better for small gears (and gears with few teeth), but it doesnt make much difference. Its not important to understand this parameter, just to know that the pressure angle of all meshing gears must be the same. Heres a good tutorial on making your own PCBs (Printed circuit boards). And below is our round up with the many other methods Creating Printed Circuit Boards (PCBs) is easy and fun for the whole family! But read the disclaimer heat and corrosive chemicals are dangerous ;-) After youve prototyped and tested your circuit design, creating a PCB will provide a sturdy and reliable backbone for your circuit and will give your project a professional finished quality.Using PCBs can even help reduce the time you spend building circuits, especially if you are producing multiple units, as you only need to follow a parts placement diagram (theres no longer any need to worry about specific interconnections).As is usually the case, there is more than one way to do it: there are numerous ways to create PCBs. They range from the time-consumming and difficult to the fully automated and expensive. Here we will attempt to describe a method weve found ideal for small production runs (say, a few prototypes to a couple of dozenwhen you reach the hundreds, it will probably be easier, quicker and cheaper to outsource) of single- or double-sided boards.HOW TO Make Printed circuit boards An illustrated guide Link.Related:HOW TO Direct to PCB ink jet resist printing Link.PCB etching Link.Two sided PCB using toner method Link.HOW TO Turn your EAGLE schematic into a PCB Link.PCB making Link.Open source PCB design tools Link.PCB creation process Link.$30 High-speed PCB drill press Link.DIY Ultraviolet light source for PCB exposure Link.HOW TO Make PCBs with a laser printer Link.HOW TO Build a PCB router Link.Cheap and easy toner transfer for PCB making Link.PCB pictures with a scanner Link.Making a hand drawn PCB (printed circuit board) Link.HOW TO Create your own PCBs Link.Make Volume 02 Primer: Printed Circuit Boards (Page 166) Link (free MAKE preview, if you like it pick up a copy and/or subscribe!). Download the candlelight code file, candlelight_pixels.ino, from the GitHub repository. This code is a modified version of Neopixel Flames by Simon Cleveland. Using the Arduino IDE, open the file and select Adafruit Gemma 8MHz as the board, and USBtinyISP as the programmer. Gemma does not use a port.Connect the Gemma board with the USB cable, then upload the code to the board.NOTE: Not all USB v3 ports recognize the Gemma bootloader. Use a USB hub or USB v2 port if the Gemma will not enter bootloader mode. If you see the error A programmer is required to upload, navigate to Sketch Upload Using Programmer and use this option to upload instead of the IDE button.The code is formatted for GRB pixels instead of RGB pixels. If you end up with green flames, switch the g and r variables in the code. Play with the following variables to affect the code in the following ways:brightness (0-255): a higher value will be more visible, but will drain the battery faster.r, g, b (0-255): these are the base color values that your flame will flicker away from.color_delta: the degree to which a flickering flame strays from its base color. A bigger delta will have a more pronounced effect, but could stray into non-fire-toned colors.Judge your candle flickering effect on the whole LED strip, not just one. What looks good on one LED looks chaotic across an entire strip. Is your robot grinding to a halt? Have a door that makes an annoying SQUEEEAK every time you open it? Dont reach for the WD-40 yet! In general, the most common application of a lubricant is to reduce friction between surfaces, but not all lubricants are equal. In this handy guide, well go over a few of the most common lubricants, how they work, and when to use them.Photography by Hep SvadjaOilsRead articles from the magazine right here on Make:. Dont have a subscription yet? Get one today.Oils are thin liquids made of long polymer chains, with additives for various extra properties. Common additives include antioxidants to keep the oil from oxidizing, corrosion inhibitors to prevent parts from corroding, and detergents to keep deposits from forming. These long chains are hard to squeeze out from between surfaces, making oils useful as a slippery barrier between them. Oils come in different weights (such as 5W or 10W), which correspond to viscosity. The lower the number, the thinner the oil, and the more easily it will flow.Uses: Hinges, bearings, tool maintenance, sharpening bladesTypes: Motor oil, 3-in-1 oil, sewing machine oil, bar and chain oilUse When: You want to lubricate something without the resistance inherent in using grease You need lubrication to wick into a small space, without having to take anything apartDont Use When: The surfaces being lubricated are exposed to dust or dirt, which can eventually gum up and cause more friction You need to keep things around the surfaces clean, because oils are low in viscosity and thus tend to drip and run The surfaces are exposed to water or anything that can wash the oil away. It wont last long! (While oil can help make things water resistant, it can also absorb water over time. The more water that absorbs into the oil, the lower its adhesion will be, causing it to wash off of the very parts that need lubrication.)GreasesGreases are made by using oil (typically mineral oil) and mixing it with thickeners (such as lithium-based soaps). They may also contain additional lubricating particles, such as graphite, molybdenum disulfide, or polytetrafluoroethylene (PTFE, aka teflon). Greases combine the lubricating properties of oils with added stickiness, allowing the lubricant to adhere to the surfaces better. Greases can even act as a barrier, protecting the surfaces from contaminants that can corrode or damage them. Like oils, greases come in a range of consistencies, from ketchup-thin to thick like cheddar cheese. One downside to grease is that because its so thick and sticky, it can cause resistance in small or fast-moving mechanisms.Uses: Gears, bearings, chains, linkagesTypes: White lithium grease, marine grease, silicone grease Use When: You need lubrication to stay put and stick to surfaces for a long time You want to seal out contaminants such as water or dust You use a machine so infrequently that you may forget to oil itDont Use When: You have fine or fast-moving mechanisms where thick grease would create too much resistance You dont want a mess. When parts move, they can fling grease all around, so it may not be the best option for keeping things cleanPenetrating Lubricants Any shade-tree mechanic would agree that these types of lubricants deserve their own special section. Penetrating lubricants are the saviors of many stuck-bolt combatants, loosening years of rust and debris in minutes. Contrary to the other substances covered here, penetrating oils are not designed for long-lasting lubrication. Instead, they are low-viscosity oils with additives that are specifically designed for one purpose: to infiltrate the tiny cracks between surfaces (such as screw threads), add lubrication, and break up rust.There are a lot of different penetrating oils out there, but did you know that you can make your own low-cost penetrating oil that outperforms almost all of them? In an experiment conducted by Drexel University engineering students, they found that a mixture of vegetable oil and acetone works as well (or better) than WD-40 at loosening stuck bolts.Its easy to make! Just mix up a solution thats 90% vegetable oil and 10% acetone, and squirt it wherever necessary. Be careful when mixing, as acetone is flammable, and will melt many plastic containers. If possible, use a glass or metal container to mix it, or buy an oil can to make things even easier. Also, be sure to shake the mixture before each use, as acetone and vegetable oil tend to separate over time.Why Shouldnt I Use WD-40 on Everything?WD-40 actually stands for Water Displacement formula 40, and while it can help loosen rusty bolts, the film of oil left behind isnt nearly enough for good, long-lasting lubrication. You might find that the troublesome squeak subsides for a little while, but soon enough youll have to go spray it away again. Using the right lubricant the first time will ensure that the problem is solved long enough for you to forget all about it. Save the WD-40 for what it does best: light lubrication, cleaning, and freeing stuck-together Lego bricks.Dry LubricantsDry lubricants are made up of lubricating particles such as graphite, molybdenum disulfide, silicone, or PTFE. At the molecular level, these particles are super slippery, so they reduce the friction between surfaces in contact with one another. Its common to find these lubricants in spray form, where they are mixed with water, alcohol, or some other solvent that will evaporate away after application, leaving behind a thin film.Uses: 3D printer rails, threaded rods, locks, hingesTypes: Graphite powder or spray, molybdenum disulfide spray, (dry) silicone spray, PTFE sprayPowdered graphiteUse When: You have tiny parts that shouldnt be gunked up by grease or oil that will attract dust You need to keep surrounding surfaces clean Your surfaces are exposed to extremely high heat or pressure, which would typically oxidize oilsDont Use When: Your surfaces are exposed to solvents or other liquids that can wash them away Tagged make53 Skill Builders Workshop Discuss this article with the rest of the community on our Discord server! ADVERTISEMENT

How to make a five-year plan. How to make a five year plan template. How to make a 5-year plan. How to create a 5-year plan.