Glues, Nails, and Screws Handout

There are a variety of methods we have at our disposal to fasten different pieces of wood together. First, we will look at adhesives (glue) then we will examine nails and conclude with screws.

Adhesives

An adhesive, or glue, is a compound that bonds two materials together. Though there are countless materials that can be glued together, we are primarily concerned with bonding wood to wood.

Glues for working with wood come in two basic categories: natural and synthetic.

Natural adhesives, like the name implies come from natural sources like the sap of a tree, bones, egg whites, animal hides. Historically, there have been two sources for natural adhesives; plants and animals.

Plants

From plants, man has gained gums and resins to use as adhesives. In fact, ceramic vessels that dates back 6000 years have been found that had been broken and then repaired using plant resins.

Animals

- As late as the 1800's, Native Americans from (what is now) the eastern United States used the fat of animals mixed with the gum (resin) of the spruce tree as an adhesive. They also used the material as a sealant for their birch-bark canoes. ***Hoof glue***, like the name implies, was/is made from the hooves of animals. Just like adhesives made from plants, hoof glue is ancient. In fact, the oldest known hunting bow was made using hoof glue. So how old is the world's oldest bow you might ask? How about 9600 years! Besides being used to make bows for hunting, ancient peoples used hoof glue for bonding fabric to wood and sealing ceramic vessels. Believe it or not, hoof glue is still used today! Carpenters and woodworkers alike use it to bond materials where the joint must be virtually invisible. Native Americans of the western United States used the hoofs of buffalo in the making of their hoof glue.

- ***Hide glue*** is from what? That's right, animal hides. And, like the adhesives derived from plants and animal hooves, hide glue has been in use for a very, very long time. In fact, the ancient Egyptians were using hide glue approximately 5000 years ago in the construction of furniture. Interestingly, there is evidence that suggests the Sumerians were using hide glue before the Egyptians!

  Traditional hide glue comes as flakes, sheets or granules and must be dissolved in water while being heated. When it reaches 140 degrees, it is ready to use. You must work with it fast though, because after only one minute from application, the hide glue temperature will drop below 120 degrees. At this point it begins to gel, and its bond strength is shot. Traditional hide glue is still available and is used primarily by stringed instrument artisans making things such as violins and cellos. This is because hide glue joints can be taken apart without fear of damaging the wood. This allows Luthiers to periodically disassemble instruments like the violin and perform maintenance on the internal members without ruining the instrument itself. Hide glue is also available in liquid form today, though it has inferior bond strength when compared to hot hide glue. Hide glue was the most commonly used woodworking glue for thousands of years. It was only recently replaced in the early 1900's by synthetic glues like polyvinyl acetate.

Synthetic glues are entirely man made, with no naturally occurring ingredients in them.

- ***Polyvinyl Acetate (PVA)*** is a synthetic polymer (a polymer is a long molecule that is made up of a chain of identical parts known as 'monomers') that is used as the basis for adhesives that are used to bond porous materials such as wood. The two most common glues made from PVA, are "white" glue (think Elmer's) and "yellow" or "carpenter's" glue. PVA glues are the most commonly used wood glues today.

Historical note on Elmer's glue: Have you ever wondered why there is a picture of a bull on the label of Elmer's Glue-All (white glue)? Borden Milk Products' chemical division introduced their first PVA glue called "Cascorez Glue" in 1947. This name was rather short lived however, as the glue was soon renamed. It was renamed for Elmer, the 'husband' of Borden's mascot; "Elsie the Cow."

- ***Polyurethanes*** are a relatively new class of glues that are gaining ground in the woodworking and construction industries. Though they have been used in Europe for several decades, polyurethanes didn't arrive on American shores until the early 1990's. One of the biggest advantages of polyurethane glues is that they are virtually waterproof. This is a distinct advantage over most PVA-based glues that are at best water-resistant. (Although the new Titebond III is claimed to be water-proof, and it is a PVA adhesive) Another distinct advantage to polyurethanes is that they will glue almost anything to anything, and will even fill small gaps (1-2 millimeters or approximately 3/64 to 7/64) if the materials being glued do not match up perfectly. Polyurethane may have only been available as a glue in America since the early 1990's, but skateboarders have been using wheels made of the material since the 1970's. Chemically, polyurethane is similar to PVA glues in that it is a polymer. The difference between PVA's and polyurethane is that in polyurethane, the polymer is a chain of organic units connected by urethane links.

Nails

Imagine the limited aspirations of the first pre-bronze age constructor to join two pieces of wood with a sharp implement. History does not record who it was, but the incredible results of that inspirational moment are all around us - in the houses we live in, the bridges we cross, the furniture we sit on.

Nails have been around for a long time. As soon as man discovered that heating iron ore could form metal, the ideas for shaping it quickly followed.

What is a nail? How does a nail hold two-pieces of wood together? Could a nail be defined as a 'machine.'?

A nail is just that, it is a simple machine known as a wedge. Nails hold two pieces of wood together because they wedge themselves between the fibers of the wood being joined. These fibers react by pushing back against the body (shank) of the nail. This creates a tremendous amount of static friction (stiction). This stiction can be so great that it requires an enormous amount of force to be exerted in order to pull the nail back out once it has been driven. The greater the wedging action, the greater the stiction, the stronger the hold. It is this unique interaction between the nail and wood fibers that allow nails to work. Though there are 'nail' type fasteners used for some other types of materials in construction, nails are not the norm for any other material besides wood.

Today's nails are made of steel wire and are produced by the thousands every minute by fully automated nail-making machines. Nails are so abundant that they are one of (if not the) cheapest components needed to construct a home. In fact, a 50-pound keg of 16-penny sinkers costs only about $35 and contains approximately 3500 nails. That means each nail only costs one cent!

The great nail mysteries of all time: why do we refer to nails by their "penny-size," and why is the term penny abbreviated with a lower case 'd,' instead of a 'p?!'

Nails have been identified by their penny-size for about 400 years. This practice originated in Elizabethan England sometime around 1600. The monetary system used in England at that time was based on the Pound Sterling, which was broken down further into Shillings and Pence. The symbol for pence at the time was a lower case "d." (the lower case "d" goes back to the original Roman "denarius," which over time, came to refer to a penny [penny] in England) Nails were sold for so many pence per 100.

Accordingly, shorter (smaller) nails would be cheaper by the hundred than larger (longer) nails would be. For example; nails that were only 1 ½ inches long were sold for 4 pence (4 penny, or 4d), while 3 ½ inch nails were sold for 16 pence. Nail prices remained unchanged long enough that eventually, the nails price came to refer to its size. Today, no matter how you buy your nails, you by them by the penny-size appropriate for the project or task you wish to accomplish.

Nails in the 21st century are cheap and abundant, but it has not always been this way. There was a time when nails were so rare, they were used as currency. In fact, nails were so valuable when America was expanding westward, that the last thing early settlers would do before striking out would be to burn their house down so they could collect the nails from the ashes. Wherever the settlers went, they took their nails with them. It was also common during this time for people to burn down old, dilapidated structures for the same reason. One might think this was a very wasteful practice but pulling the nails out in order to retrieve them was unacceptable. This was because pulling them out might damage them!

Wrought Handmade Nails

An original 7" (180mm) long Roman nail found in Scotland

(Wrought = beaten into shape by hammer blows)
In the UK, early evidence of large-scale nail making comes from Roman times 2000 years ago. Any sizeable Roman fortress would have its '*fabrica*' or workshop where the blacksmiths would fashion the metal items needed by the army. As the Roman Empire continued to expand during the first century AD, the 20th Roman legion under the command of General Julius Agricola set up camp in Pershire, Scotland. In time they completed construction of the fortress known as "Inchtuthil." In their workshop they produced tons and tons of nails. How do we know these nailors were so productive? Because recent archeological excavations discovered seven tons of Roman nails buried for safe keeping at the sight! Why do you think they buried such a precious commodity and then just left them there? The Romans had been fighting with an indigenous group of people known as the Caledonians for many years. When they were forced to abandon their fortress, seven tons of nails was just too much to take with them. But they didn't want the precious iron the nails contained to fall into their enemy's hands. The Caledonians could turn around and re-forge the nails into weapons. Weapons they could then use against the Romans. This is why the nails were found at the site of the ancient fortress buried six feet down and hidden under a store of 'other' precious items; all in an effort to keep to the Caledonians from finding them. The Roman's plan worked very well, as the nails weren't found until 1961!
For nail making, iron ore was heated with carbon to form a dense spongy mass of metal, which was then fashioned, into the shape of square rods and left to cool. The metal produced was wrought iron. After re-heating the rod in a forge, the blacksmith would cut off a nail length and hammer all four sides of the softened end to form a point. Then the nail maker would insert the hot nail into a hole in a nail header or anvil and with four glancing blows of the hammer would form the rose head (a shallow pyramid shape).

This shape of nail had the benefit of four sharp edges on the shank which cut deep into timber and the tapered shank provided friction down its full length. The wood fibers would often swell if damp and bind round the nail making an extremely strong fixing.
In Tudor times, we have evidence that the nail shape had not changed at all as can be seen by the nails found preserved in a barrel of tar on board the 'Mary Rose' - the Tudor flagship of Henry VIII built in 1509 and recovered from the mud of the Solent in 1982.

A replica of the handmade nails found on board the 'Mary Rose'

Machine Made Nails/Cut Nails

It was not until around 1600 that the first machine for making nails appeared, but that tended really to automate much of the blacksmith's job. The 'Oliver' - a kind of workbench, equipped with a pair of treadle operated hammers - provided a mechanism for beating the metal into various shapes but the nails were still made one at a time.

Eventually, in the USA, towards the late 1700's and early 1800's, a nail machine was devised which helped to automate the process. This machine had essentially three parts. Flat metal strips, of around two feet (600mm) in length and the width slightly larger than the nail length, were presented to the machine. The first lever cut a triangular strip of metal giving the desired width of the nail; the second lever held the nail in place while the third lever formed the head. The strip of metal was then turned through 180° to cut the next equal and opposite nail shape off the strip. These nails are known as cut nails.

Because the nail up until then was handmade, the first machines were naturally designed to re-produce the same shape of product - a square tapered nail with a rose head, but only tapered down two sides of the shank.

Soon nail making really took off, primarily in the USA and the UK with its captive markets of the British Empire. The cut nail was produced in large numbers and various other shapes were devised to suit different purposes.

In the heartlands of the industrial revolution, many nail factories had row upon row of these nail machines and the incessant clatter from them created a deafening sound. But still, the process was labor intensive with a man (or woman) attending each machine.

An interesting historical side note: In 1796, Thomas Jefferson purchased a nail-cutting machine for his blacksmith shop at Monticello. He hoped it would provide a source of cash income while he restored the depleted soil of his farms. Nail rod was shipped from Philadelphia and hammered into nails ranging in size from six-pennies to twenty-pennies. In 1796 Jefferson acquired a nail cutting machine, which made four-penny brads from hoop iron.

In his Farm Book Jefferson wrote: "Children till 10. years old to serve as nurses. From 10. to 16. the boys make nails, the girls spin. At 16. go into the ground or learn trades." Up to fourteen young male slaves, aged ten to twenty-one, worked at the forges of the nailery. From 1794 to 1796, when he was retired to Monticello, Jefferson calculated the efficiency of the nailers, each day weighing their nail rod and the nails they produced. Most of the slaves who began their working lives in the nailery became tradesmen.

Handmade nail (top)
Cut nail (middle)
Wire nail (bottom)

Wire Nails

By the start of the 1900's, the first coils of steel round wire were produced and quickly machines were designed to use this new raw material. The first automatically produced wire nails with no human intervention other than to set up the machine immediately showed that this was the way to produce a cheaper nail.

The fact that the nail had a round parallel shank that had up to four times less holding power didn't matter so much. Thinner timbers were being used in construction and other forms of fastening were becoming available if a strong fixing was needed. The wire nail quickly became the nail of choice as it is today because of its price and the cut nail's day was numbered.

In the 21st century, the nail making process through the ages is now being used by the restoration industry to help to establish when a building was built. Handmade nails suggest the building was built before 1800. Cut nails suggest the building was built between 1800 and the early 1900's. Wire nails will be found in a building put up in the period from then to date.

Screws

Like the nail, screws have a long and interesting history. Theoretically, the invention of the screw is credited to the Greek mathematician Apollonius of Perga (262-190 BC). Sometime around 200 BC he worked out the geometry of the spiral-helix, which is the basis for the screw.

(The application of Apollonius' geometric discovery was carried out by another famous Greek named Archimedes (287-212 BC). He developed the "Archimedes screw" that was used to raise water to different levels for irrigation purposes. He is considered by some to be the greatest scientist ever. By the first century BC, wooden screws were common throughout the Mediterranean. But instead of being used to raise water to fields above the water supply, they were being used in wine and oil presses; in order to squeeze out the precious liquid content of olives and grapes. Metal screws used as fasteners began to show up somewhere between the 1400's, and mid 1500's in Europe. Locksmiths and clockmakers first used them. Though the claimed oldest use of the screw was by goldsmiths for locking bracelets. These early screws were hand-wrought just as nails were, making them expensive and very rare. Due to this, screws as a means of fastening two pieces of wood together would not come into popular use until machines were developed that could produce them quickly and cheaply.

In 1797, this began to happen. An English inventor named Henry Maudslay invented the first thread-cutting lathe that could accurately mass-produce screws of the same size. There was still one drawback to using these screws for joining two pieces of wood together. The screws produced by Maudsley's lathes had blunt ends. It wouldn't be until the 1840's when George Nettlefield began producing screws with pointed ends that their widespread use as a wood fastener began.

Drives

What is a screw without a driver? You must have a driver to install a screw. Screws need to possess a drive that the screwdriver tip fits into or the screw and the driver are worthless. The first screws were "slotted." Meaning that they just had a straight slot cut across their heads for a slotted screwdriver to fit into. This drive works, but the driver easily slips out of the slot. And worse, when too much torque is applied, easily "cams-out." (the screwdriver tip pops out of the drive, usually damaging the drive in the process) In 1908, a Canadian named P.L. Roberson invented the square-drive. Because there is more contact area between the square driver and the square drive, you can apply a lot more torque to the screw without the driver slipping or camming-out.

The original Ford Model-T used over 700 Robertson square-drives in its manufacture. By far the most common screw drive in use today is the Phillips drive. It can be identified by the "cross" formed on the screws head, where two slots drive cross each other at 90 degrees (perpendicular). Like the square drive, it does allow the driver to easily slip out. It does cam-out easier than a square drive under extreme torque but is vastly superior to the slotted drive. The Phillips drive was designed/invented by J.P. Thompson in the early 1930's. Henry F. Phillips bought the design in the hopes of marketing it to the automobile industry. Ironically, what came to be known as the "Phillips Drive", was never manufactured by the Phillips Screw Company, but instead the American Screw Company. Both the square and Phillips drives started out in the auto industry, though neither is used widely in that application anymore. They have been replaced by more modern drives like the TORX (star) and the Allen, or hexagonal drive. Another interesting note in screw-drive history is the tri-wing drive design. It was invented by Nintendo to discourage "home repair" of their Game-Boy system

Screwdriver

In 1744, the first flat or slotted screwdriver bit was invented for use in the carpenter's brace. Eventually, (around the early 1800's) the first purpose-built handheld screwdrivers appeared. Then, about 100 years ago the spiral or "Yankee" screwdriver was invented. This tool has a spiral shaft that turns pushing motion into turning motion. They can also be set to ratchet in one direction, or can be locked, so they behave as typical screwdriver. These were the "power-drivers" of carpenters and tradesmen from days gone by. Though still available, they have almost entirely been replaced by the cordless drill-driver. Invented in 1978 by the Makita Tool Corporation, * the cordless driver-drill is now a vital part of any tradespersons tool repertoire. This was the first cordless power tool designed specifically with driving screws in mind.

Corded drills of the time (as now) tended to be too powerful for driving screws and would easily strip (cam-out) the screws head, and/or break its shank. As well, the cordless drills available at the time were not intended to drive screws and were far from powerful or tough enough to do so at the professional level. The Makita 7.2-volt cordless driver-drill was designed from the outset to stand up to professional use, though this may be hard to believe when it is compared with modern 18, 24, and even 36-volt drivers.

Glues, Nails, and Screws Worksheet

Part 1: Glues

Directions: Fill in the answers to each question as they are discussed or watched.

1. What is an adhesive?
   _____

2. What are the two basic categories of glues?
   _____ and _____

3. Two sources of natural adhesives are:
   _____ and _____

4. What two animal "parts" were/are used to make natural glues?
   _____ and _____

5. Of the two animal-based glues, which one was most commonly used by carpenters, woodworkers and Luthiers until the early 20th century?
   _____

6. One of the most common synthetic glues is known as _____ or PVA.

7. PVA glues are "polymers." A polymer is a _____.

8. The two most common PVA glues are the white and the _____, the latter being commonly referred to as _____.

9. Since the 1990's another synthetic glue has gained in popularity among woodworkers. It is known as_____. Polyurethane in a slightly different form has been the basis for skateboard wheels since the early 1970's.

10. One of the polyurethanes biggest advantages is that it will glue almost
    _____ to _____.

Extra Credit: Who is Elmer?

_____

Part 2: Nails

Directions: Fill in the answers to each question as they are discussed or watched.

11. A nail is a simple machine known as a _____.

12. Nails were at one time so rare, that they were used as_____.

13. What would early American settlers do in order to take their nails with them when they struck out for new territory? _____

14. Nails are among the oldest _____ objects made by humans.

15. What does the word "wrought" mean? _____

16. The first nails were _____ wrought.

17. In the 1700's, machines were finally introduced that cut nails from sheets of iron. Nails produced this way are known as _____ nails.

18. Perhaps the most famous producer of nails in American history was _____ third President of the United States. Both hands wrought and cut nails were produced by his slaves at his home near Charlottesville, Virginia, known as Monticello.

19. During the 1890's the _____ nail was developed. Manufactured from steel rather than iron, it remains the industry standard to this day.

20. What ancient monetary unit does the lower case "d" represent when describing the penny-size of a nail? The _____.

Extra Credit: The two most commonly used nails in home construction today are the _____ penny and the _____ penny _____.

Part 3: Screws

Directions: Fill in the answers to each question as they are discussed or watched.

21. Considered by some to be the greatest scientist of all time, this ancient Greek calculated the value of PI, developed innovative and legendary weaponry that frustrated the efforts of several Roman invasions, and applied the mathematical principle of the screw. His name was _____, and he lived from approximately 287 to 212 BC.

22. Archimedes applied the mathematical principle of the screw by developing a _____ screw that was used to transport water from a lower level to a higher one, allowing for crops to be grown in fields that were higher in elevation than the local water source.

23. By the first century BC, screws made from _____ were common throughout the Mediterranean world.

24. In late Medieval Europe (1400-1550 BC) screws made from _____ were developed.

25. The earliest screw "drive" was the _____. This drive suffered from a tendency to "cam-out" (slip, strip, or pop-out) when under torque.

26. In the early 20th century, the square drive and the _____ driver were developed for use in the auto industry. Both drives resist cam-out under much higher torque loads than slot drives do.

27. When a driver slips, strips, and pops-out of a screw head under torque, it is known as _____ - _____.

28. _____ can be thought of as a rotating force.

29. The most popular/common screw drive today is the _____.