PRO 204 – Modeling Prototyping

POLYURETHANE AND WOOD

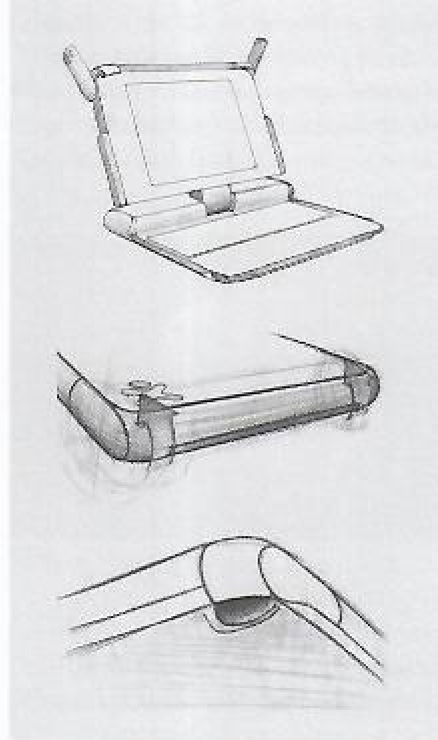
Polyurethane (PU) modelling board is a high-quality material that can be sculpted to a fine level of detail and finish. Specifically developed for applications to replace wood, it is dimensionally stable, does not have a grain structure and will not rot. The density is consistent and available in specific increments. In addition to its use in modelmaking it is used as a coring material in marine and aviation applications. Being a thermoset plastic material, it has strong polymer bonds and is generally not heat formable. Polyurethane boards are distinguished primarily by density. The lower-density materials, often referred to as foam, are easier to shape, but have visible surface porosity. This is not generally an issue for low-fidelity prototypes, where a porous surface texture conveys the correct message that the model is not final. Higher-density modelling boards, sometimes called machining boards, tend to have a density higher than 480kg/m3 (30lb/ft3).

Applications for Polyurethane Board

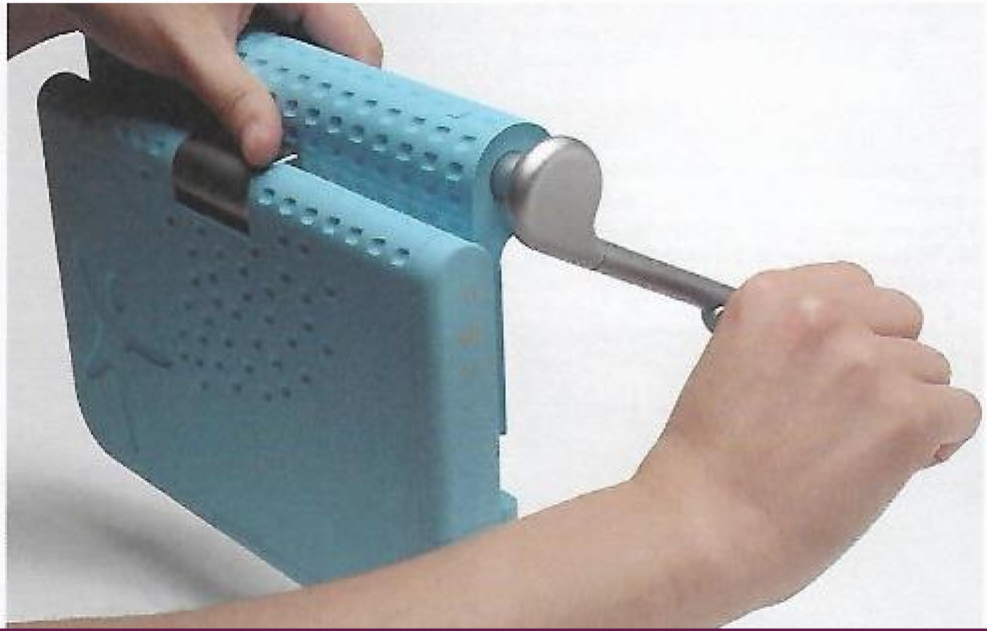
The lower-density materials are good for explorative work, whereas higher-density boards are excellent for highly refined appearance prototypes. The higher-density materials are also useful for making tools for vacuum forming (see page 116).

Product designers use polyurethane modelling board extensively for form development. The speed and efficacy at which the material can be hand-worked or CNC machined means that prototypes can be built quickly and that many different options can be studied in real physical space.

Take, for example, the iconic One Laptop Per Child (OLPC) project. Yves Béhar and his firm Fuseproject were given a demanding brief by Nicholas Negroponte, who initiated the OLPC project at MIT's Media Lab. This low-cost laptop specifically aimed to make computing and Wi-Fi technology available to children in developing countries, demanding ruggedness, portability and the ability to recharge in locations that may have no electricity supply. Fuseproject started by focusing on the experience of the product in terms of an overall product strategy. The product had to be intuitive and friendly-looking. During ensuing ideation, a fluid approach that used sketching, 3D CAD and prototyping concurrently allowed an examination of different options against the design objectives and strategy. In all, more than 40 different prototypes were built. Polyurethane modelling board was a useful and easy-to-use material for looking at a series of formal variations, as shown below.



Fuseproject made more than 40 prototypes, many of them in PU, during the development of the One Laptop Per Child computer project. Sketches and computer work went hand in hand with prototypes to explore and test many alternatives.



Working with PU Modelling Board

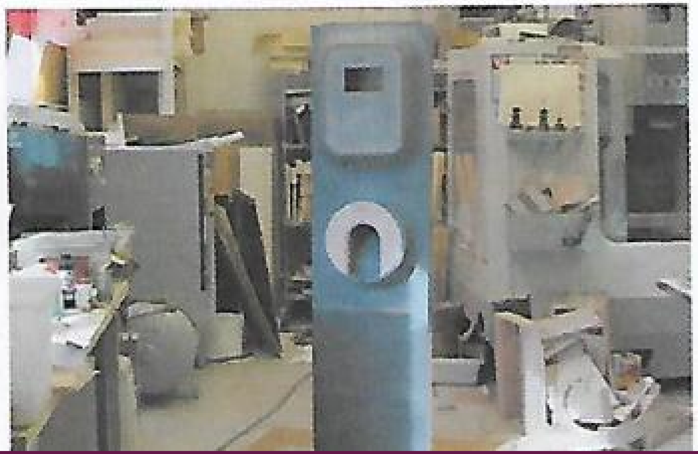
Polyurethane dust is very fine and will easily become airborne, so containment and personal protection against the dust is important. Always wear eye protection and a dust mask, and be careful not to rub your eyes accidentally with dusty hands. Avoid blowing air to clean up: instead rely on vacuuming and containment. The higher-density machining boards are generally formulated to produce less dust, as they have more binders than the low-density foams.

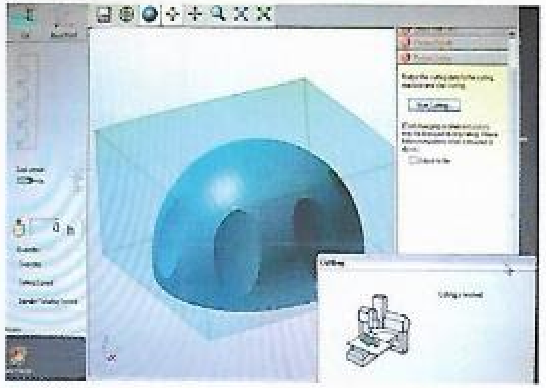
Hand-Shaping PU Modelling Board

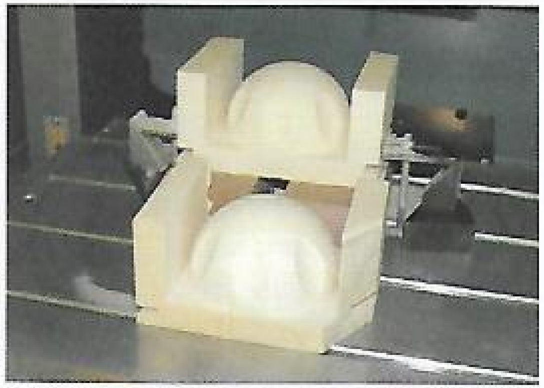
Lower-density PU modelling board (foam) can be cut and shaped easily with hand tools. A three-step process is an effective way to work with different grades of polyurethane foam – this involves cutting, followed by shaping and then finishing. Cutting usually starts with cutting an outline with a bandsaw. Hotwire tools will not work since the material is not a thermoplastic and therefore will not melt. Hand saws, also, are able easily to cut lower-density materials. Shaping is done with a rasp to rough the shape. This saves time and creates far less dust than trying to sand the shape. Some extra material should be left on the part for finishing with sandpaper.

CNC Machining

Polyurethane foams are machined very accurately with a CNC machine. The higher-density machining boards have been specifically developed to be CNC machined and to produce less dust while cutting. Professional modelmaking shops specialize in producing highly realistic appearance prototypes for a range of clients in industry. These shops employ highly trained professional modelmakers who are specialized in creating precision prototypes, including all aspects of final detailing. Professional designers tend to focus on making initial prototypes in-house and subcontract the final high-quality appearance prototypes to a modelmaking service bureau.





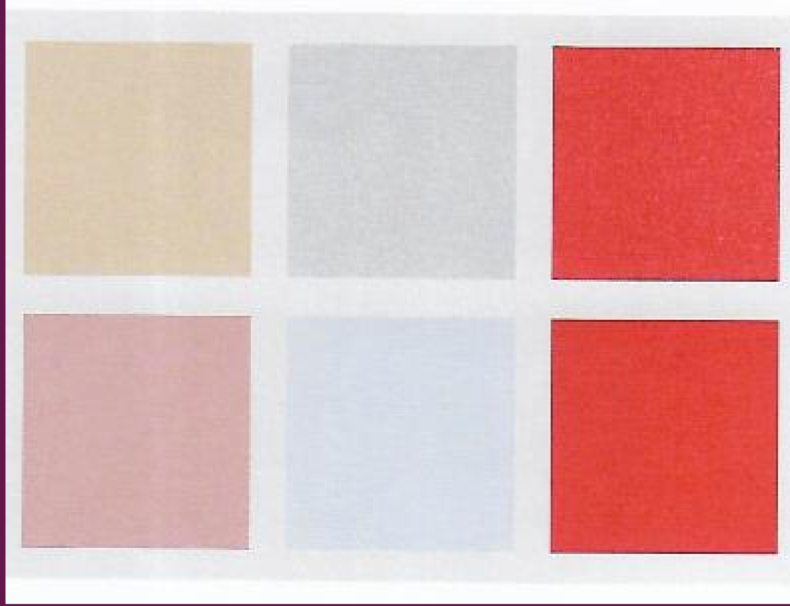


Because the materials are easy to cut, they can also be machined with lighter-weight prototyping mills, which are both easier to operate and less costly to run than larger production machines. These smaller mills are suitable for smaller shops and are often used in schools as well.

Gluing

Glue is used to laminate material and to join different pieces together. Foam will often be combined with other materials, and in such cases the glue needs to be compatible with both materials. Also see Chapter 9 on adhesives (page 79).

Glue	PU to PU	PU to Styrene or Acrylic	PU to Metal
Polyurethane Glue	√		
Epoxy	√	√	√
Cyanoacrylate	√	√	√



Filling, Sealing and Painting

Lower-density foams leave visible pores when painted. Higher-density machining boards (480kg/m3 or 30lb/ft3) have a smooth surface that can be primed and painted smooth. *The higher-density modelling board is therefore used for* high-fidelity appearance models.

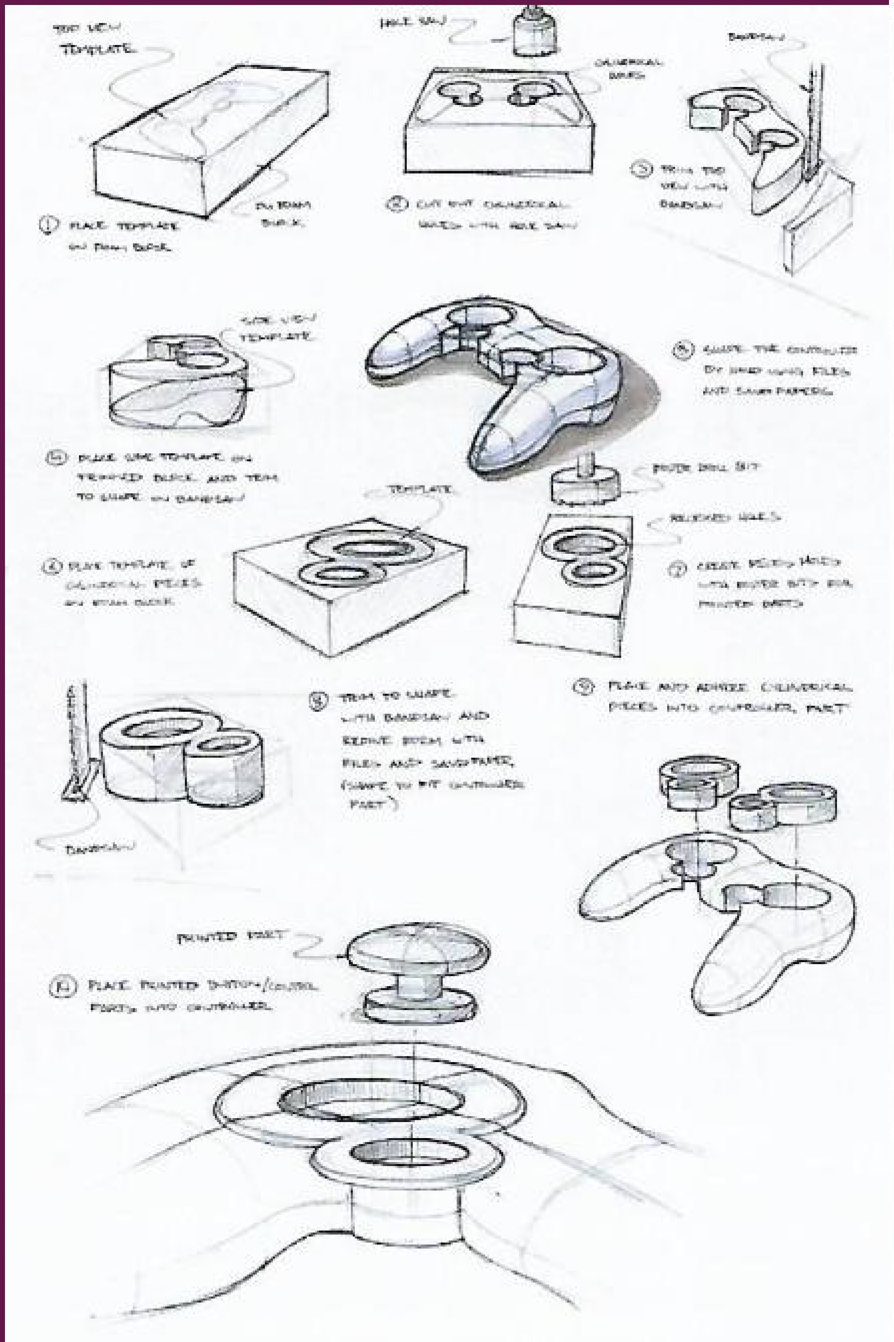
Low-density PU foam shows porosity when primed and painted (top row), whereas high-density PU foam is smooth when painted (bottom row).

Tutorial Game Controller

A complex organic form can be difficult to create in 3D CAD. Sometimes it is better made by hand and then scanned in to the program as a guide for surface creation (see Chapter 7 on workflow, page 53). This tutorial shows how a game controller was shaped by hand in low-density PU foam (240kg/m3 or 15lb/ft3). The interactive elements (buttons and paddles) were designed directly in 3D, since they are simple geometric shapes that are easier to computer-model. These were made separately using the Dimension 3D printer.

Overview: The model consists of a complex organic-shaped main housing. Joysticks and buttons sit in protruding cylindrical housings that are distinct from the main form.

Step 1 The process starts with sketching the form of the product. Scale top and side views will be used as cutting templates. These can be hand-drawn or created in Illustrator®.



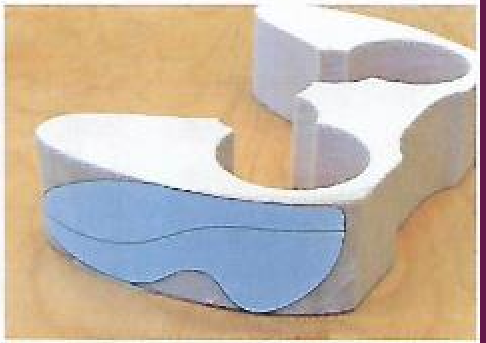
Step 3 The top outline of the game controller is glued on to a piece of PU foam that has been trimmed to the overall thickness. The cylindrical control housing outlines will also be cut from the same piece of foam.

Step 4 Holes are first cut in the main housing to make room for the cylindrical control housings. This can be done with a hole saw mounted on a drill press, or with a scroll saw. Note that power tools require adequate training and supervision.

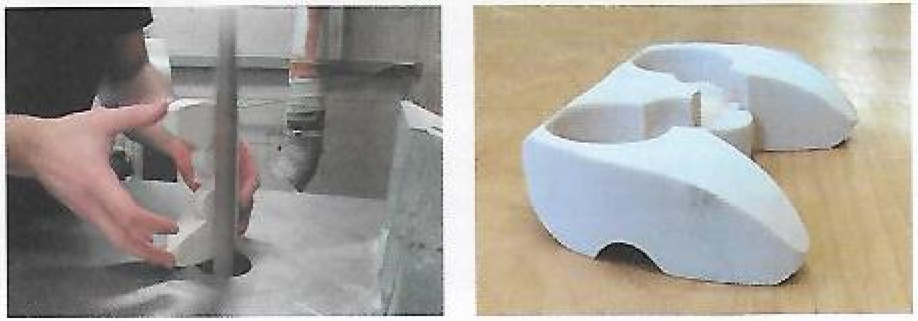
Step 5 The outlines are now cut with the bandsaw (or a scroll saw).

Step 6 The shaped outline is then sanded smooth and a side-profile template attached. In the process of removing material for the cylindrical pieces, the main housing has become weak and risks breaking when the side profile is sanded.

Step 7 The solution is to use a portion of the cylindrical control housings to strengthen the part. The two cylindrical protrusions are cut in half so that the bottom half of each piece can be glued into the main body to create a stronger part. The top halves are saved so that they can be added at the end to create distinct and protruding cylindrical forms.

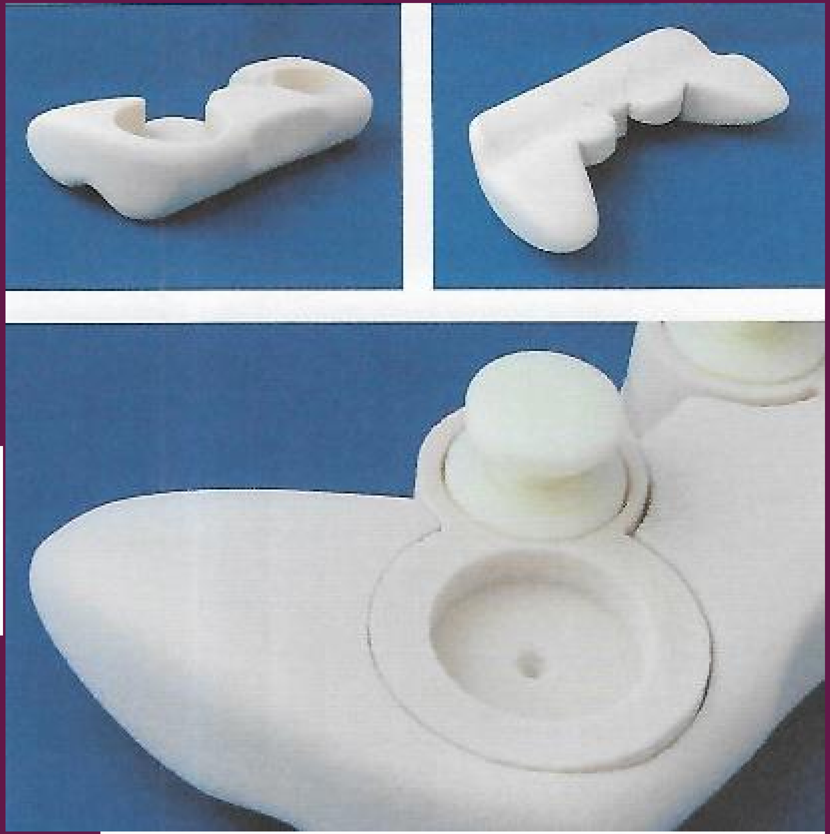


Step 8 The side profile is then sanded to shape on a belt sander. This could have been done with a hand-held rasp instead, in which case the part would be mounted in a vice while being worked on.



Step 9 The finger-rest concave surface is sanded with a post sander. This could also be done with a circular-shaped rasp.

Step 10 The shape is now sanded manually, blending the surfaces into a final desired shape.



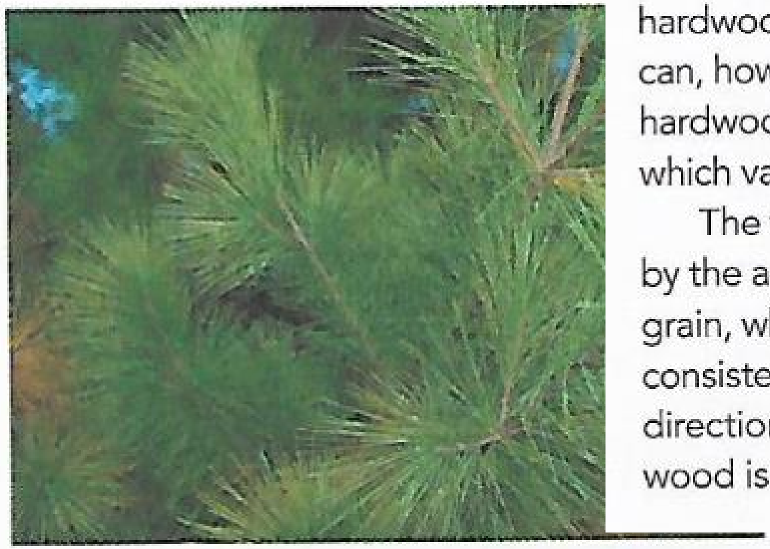
Step 11 The cylindrical protrusions are now glued into place with cyanoacrylate glue. This additive approach shows how important it is to break a form down into its constituent parts and to build each separately.

WOOD

Wood is a common and renewable natural material, a complex and incredibly varied resource that comes in different weights and degrees of stiffness. Trees are confined to their particular climate and environment, but certain varieties of wood are exported widely around the globe for their natural properties. Classified as either softwood or hardwood, wood originates either from evergreen trees, such as spruce, pine and cedar or from deciduous varieties such as cherry, walnut, mahogany and birch. The lightest wood available is Ecuadorian balsawood, widely used to make model aeroplanes.

Softwoods come from needle-bearing evergreen trees (conifers), whereas hardwoods tend to be from broad-leaved deciduous trees. The term hardwood can, however, be misleading; balsa, for example, is very soft, but is technically a hardwood. A more accurate measure of the wood's hardness is therefore density, which varies from 150kg/m3 (10lb/ft3) for balsa to 1,000kg/m3 (60lb/ft3) for ebony.

The term 'wood grain' is often used to describe the colour and texture formed by the annual growth rings of the tree. Oak and walnut have a very noticeable grain, whereas linden (tilia or basswood in North America) has a very fine and consistent light grain. As seen in the pictures below, the grain runs in a vertical direction, alternating between lighter and darker shades. The strength of the wood is also aligned with the fibres that grow in this direction.



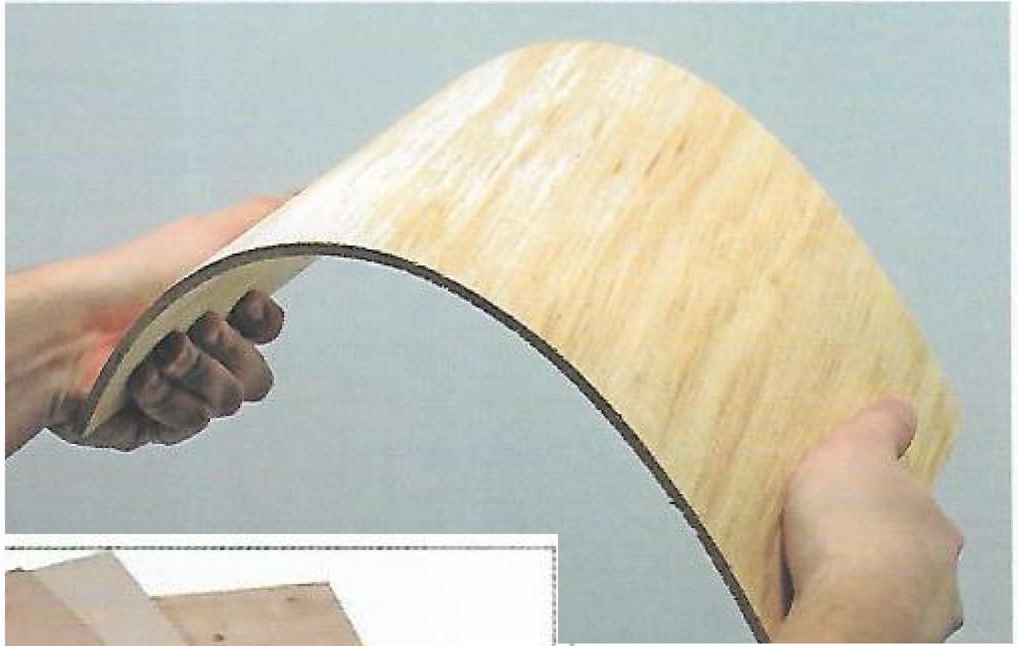
Deciduous trees, such as oak (top), are classified as hardwoods, whereas conifers, such as pine (above), are classifed as softwoods.

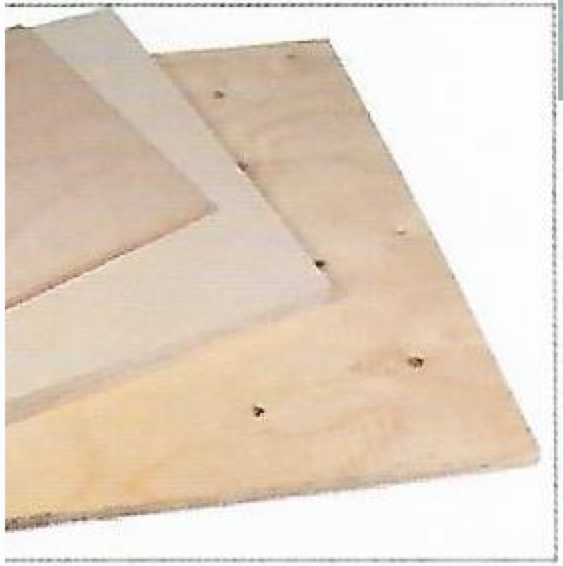
The grain of the wood is shown in its colour and texture. Linden/basswood (left), red oak (middle) and black walnut (right).

Wood is graded for different applications and markets. Construction timber is likely to be fast-growing softwoods, such as spruce, and is likely to have knots and splits. Furniture-grade wood is selected not to have deficiencies and is also kiln-dried, making it resistant to splitting and shrinking. There is an associated trade-off in cost and availability.

Wood is commonly sold as board or sheet. Veneers are very thin sheets of wood sliced from a board and are applied to finish the surfaces of furniture. Mouldings and round dowels are useful for prototyping projects.

Sheet materials include plywood, chipboard, medium-density fibreboard (MDF) and Masonite. Plywood is made by laminating at least three thin sheets of wood veneer at right angles to each other. This cross-lamination of wood fibres gives the material strength in both directions, enabling it to resist bending and warping. Construction-grade plywood has a rough finish and often shows knots. It is primarily structural and is useful for a variety of applications where strength and low cost is important, for example, to hold something during a test, also known as a test jig. Finer furniture-grade plywood is laminated with a top layer of high-quality hardwood, such as cherry, birch or walnut. Aircraft modelmaking plywood is a very strong, thin sheet material most commonly found in hobby or craft shops. The thickness typically varies from 1mm (0.04in) to 5mm (0.2in), making it suitable for fine-detailed projects such as mechanisms. Flexiply or flexi-plywood is another useful plywood material, which has all the layers of veneer running in the same direction, allowing the board to bend along the grain of the wood. Be careful when planning though, as the flexi-plywood will bend only in this one direction.





Plywood (above) is made in different grades for different applications. Bendy or flexi-plywood (left) is a useful material for creating curved planes in wood.

Wood is sold in many forms, including board, sheet, mouldings, dowels and veneer.

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