

# SELECTING A MATERIAL

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For any project, the material you choose depends on the answers to a number of questions:

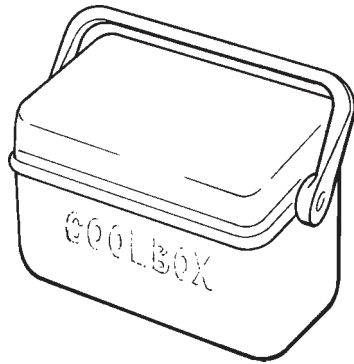
- *What are its thermal properties?*
- *What are its electrical properties?*
- *Is the material available? Is it in sheet, fibre, rod, bar or some other form?*
- *What manufacturing processes or methods will be used?*
- *Does it do the job?*
- *Is it easy to work?*
- *Is it expensive?*
- *What does it look like? Are the colour, surface finish and shape suitable?*
- *What are its mechanical properties, such as strength, hardness, density, stiffness, ductility, malleability, durability etc?*
- *Is the material safe? What are its toxicity and flammability properties?*
- *Is it environmentally friendly? Is it resistant to corrosion? How does temperature affect it? Are there any problems with its disposal? Can it be recycled?*

There are a number of other factors that also come into the decision including your own skills and experience with using different materials.

To select the most effective or appropriate material for a product or component, a designer must know what to expect from a material. Information on the properties of materials is listed in various handbooks that designers consult.

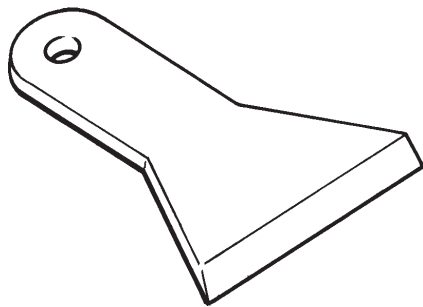
Here are two examples of a design problem and some data on materials that you, as a designer, could look up to help with the design.

**Example 1. The insulated container**



You are designing and making a small container to keep food and drink either hot or cold. What materials might be suitable for insulation? Table 1 lists a number of materials that are especially good insulators. You can cross-check some of these by looking at table 2 which gives figures for thermal conductivity of different materials. A low figure in this table means that a material is a poor conductor of heat. We see, for example, that paper is a very poor conductor of heat and might be suitable as a cheap insulator - as it is for take-home fish and chips! It is especially good in layers because it also traps pockets of air which itself is a good insulator when not moving.

**Example 2. The window scraper**



You are designing and making a small scraper to remove ice or frost from car windows and you want to make it in a single material. What will be strong enough and at the same time not scratch the window or paintwork? Table 3 provides some hardness figures for metals and plastics. If the edge of the scraper is not to be worn away quickly we need a hard material but mild steel (BHN 130) is too hard because it will almost certainly scratch the paintwork. The plastics materials appear to be the most suitable ones on the list, but polythene will probably be too soft (BHN 2). Acrylic or polystyrene seem to be possibilities and you can cross-check these on table 4. Acrylic is the stronger material in terms of tensile strength but it is very poor for impact resistance. It will not stand up to knocks and the edge will probably chip against hard ice. Polystyrene would seem a reasonable choice of material.

**Table 1. Special properties**

<p><b>Some high temperature metals</b></p> <p>Chromium Heat-resisting alloy steels High speed steel Nichrome Nimonic alloys Stainless steel Stellite Tantalum Titanium Tungsten Vanadium</p> <p><b>Corrosion resistant metals</b></p> <p>Cupronickel Lead Monel metal Nickel Pure aluminium Stainless steel Tin Titanium and alloys</p> <p><b>Coating metals</b></p> <p>Brass Bronze Cadmium Chromium Copper Gold Lead Nickel Platinum Silver Tin Zinc</p> <p><b>Good conductors of heat</b></p> <p>Aluminium Bronze Copper Duralumin Silver Zinc</p>	<p><b>Good conductors of electricity</b></p> <p>Aluminium Beryllium copper Brass Copper Gold Magnesium Phosphor bronze Silver</p> <p><b>Good electrical insulators</b></p> <p>Ceramics Ebonite Gases Glass Insulating papers Mica Shellac Silicone rubber Soft natural and synthetic rubber Thermoplastics Thermosetting plastics Tufnol</p> <p><b>Good heat insulators</b></p> <p>Cork Cotton wool Expanded polystyrene Felt Glass fibre and foam Glass wool Hardboard Insulating wallboard Mineral wool Plywood Polyurethane foam Rubber Sawdust Urea formaldehyde foam Wood</p> <p><b>High strength-to-weight ratio materials</b></p> <p>Carbon fibre reinforced plastics Duralumin Glass reinforced plastics Magnesium alloys Nylon Polycarbonate Some aluminium alloys Spruce Titanium Titanium alloys</p>
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**Table 2: Some Physical Properties of Non-Metals**

Material	Mass Density Kg/litre	Melting point °C	Thermal Cond. W/m°C	Coeff of Expn 10 <sup>6</sup> /°C	Elect. Restvty M <sup>2</sup> m	Main uses
Alumina	3.9	2050	21	8	10 <sup>3</sup> -10 <sup>6</sup>	high temperature linings, etc.
Brick	1.4 - 2.2	-	0.4-0.8	3-9	1-2	structure & cladding in buildings
Concrete	2.4	-	1.0-1.5	10-14	-	structure & cladding in buildings
Dry ground	1.6	-	-	-	0.01-0.1	all sorts!
Glass	2.4 - 3.5	1100	0.4-1.1	3-10	5.10 <sup>3</sup> -10 <sup>6</sup>	containers, windows, insulation
Granite	2.7		2.4	6-9	-	decorative cladding, working surfaces
Mica	2.8		0.5		10 <sup>3</sup> -10 <sup>6</sup>	insulation, was used in small windows
Nylon	1.14	200-220	0.25-0.33	80-130	10 <sup>4</sup> -10 <sup>7</sup>	textiles, engineering components
Paper (dry)	1.0	-	0.06		10 <sup>4</sup>	newspapers, magazines, books
Perspex	1.2	85-115	0.19-0.23	50-80	-	models, experimental construction
Polystyrene	1.06	80-105	0.8-0.2	60-80	10 <sup>10</sup>	engineering components, packaging
Polythene	0.93	65-130	0.25-0.5	110-220	10 <sup>5</sup>	engineering components, packaging
PTFE	2.2	-	0.23-0.27	90-130	10 <sup>9</sup>	engineering components, non-stick surfaces
PVC (plasticised)	1.7	70-80	0.16-0.19	50-250	10 <sup>4</sup> -10 <sup>7</sup>	protection of components, clothing
Porcelain	2.4	1550	0.8-1.85	2.2	10 <sup>4</sup> -10 <sup>7</sup>	containers, insulation, heat & electrical
Quartz (crystal)	2.65	-	5-9	7.5-13.7	10 <sup>6</sup> -2x10 <sup>8</sup>	crystal oscillators
Rubber (natural)	1.1-1.2	125	0.15	200	10 <sup>7</sup>	tyres, insulation heat, electrical & vibration
Sandstone	2.4	-	1.1-2.3	5-12	-	structure & cladding in buildings
Timber (along grain)	0.4-0.8	-	0.15	3-5	-	all sorts!

**Table 3. Typical Brinell hardness numbers (BHN) for metals and plastics**

<b>Material</b>	<b>BHN</b>
Soft brass	60
Mild steel	130
Annealed chisel steel	235
White cast iron	415
Nitrided surface	750
PVC rigid	20
Polystyrene	25
Acrylic (Perspex)	34
Polythene (high density)	2
Epoxy resin (glass filled)	38

**Table 4. Physical properties of some plastics**

Properties of plastic	$\rho$ (kg m <sup>-3</sup> )	Tensile strength (N mm <sup>-2</sup> )	Elongation (%)	E (GN m <sup>-2</sup> )	Impact resistance	BHN	Machinability
<b>Thermoplastics</b>							
PVC rigid	1330	48	200	3.4	Good	20	Very good
Polystyrene	1300	48	3	3.4	Average	25	Average
PTFE	2100	13	100	0.3	V.good	-	Very good
Polypropylene	1200	27	200-700	1.3	V.good	10	Very good
Nylon	1160	60	90	2.4	Good	10	Very good
Cellulose nitrate	1350	48	40	1.4	Average	10	Very good
Cellulose acetate	1300	40	10-60	1.4	Average	12	Very good
Acrylic (Perspex)	1190	74	6	3.0	Poor	34	Very good
Polythene (high density)	1450	20-30	20-100	0.7	Average	2	Very good
<b>Thermosetting plastics</b>							
Epoxy resin (glass filled)	1600-2000	68-200	4	20	V.good	38	Good
Melamine formaldehyde (fabric filled)	1800-2000	60-90	-	7	V.good	38	Average
Urea formaldehyde (cellulose filled)	1500	38-90	1	7-10	V.good	51	Average
Phenol formaldehyde (mica filled)	1600-1900	38-50	0.5	17-35	V.good	36	Good
Acetals (glass filled)	1600	58-75	2-7	7	V.good	27	Good

BHN = Brinell hardness number,  $\rho$  = density, E = Young's modulus