

Material Properties required:

- Water tight
- Must be able to hold decals or printed on
- Must not contaminate product
- Must have minimal weight
- Must have minimal form factor
- Must have minimal cost (material and production)
- Must be recyclable and/or have low energy requirement of producing

Potential materials:

- Plastic shrink wrap

This material ~~has a str~~ is designed for food wrapping and storage, so it will not contaminate the product.

It is light weight and cheap to both acquire (at a price of \$0.03 /sqft) and form with the simple ~~applicat~~ application of heat, and is available in bag and tube forms to fit the product. It can be printed on directly to present information and attractive designs, although this may deform slightly in the packaging process.

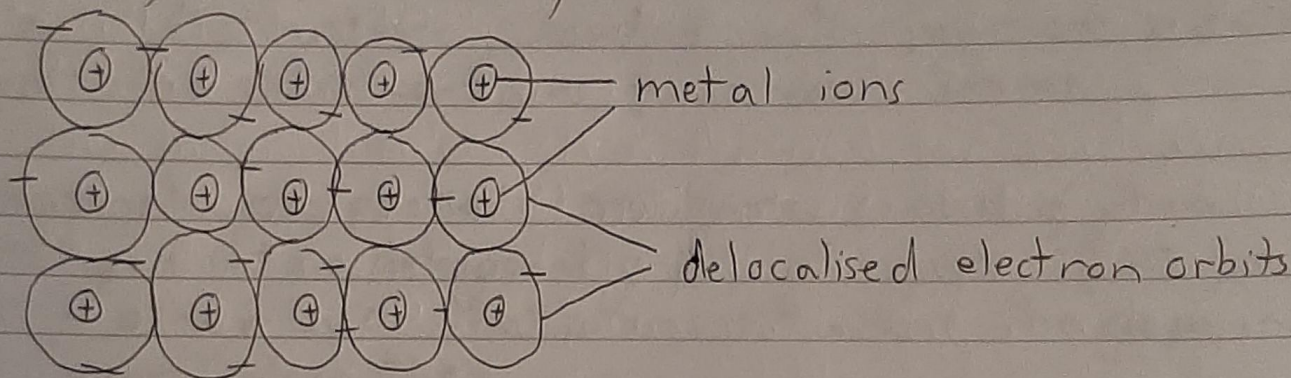
~~Contrary to many~~ Shrink wrap is recyclable on a bulk level, although as a plastic product it is not fully renewable and has a high energy cost and carbon footprint of production

- Card board packaging.

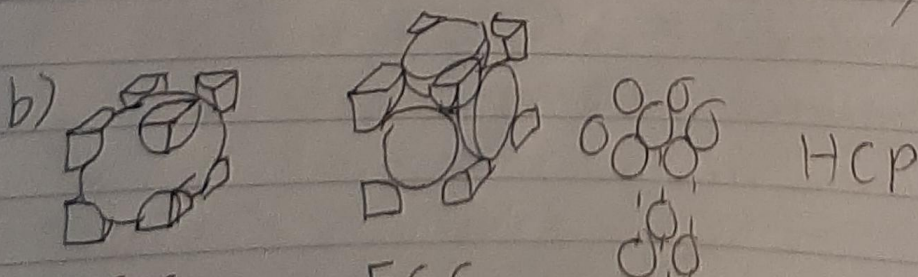
Card board is a renewable material derived from trees. It is both recyclable and biodegradable. It can be printed on very cheaply or in colour for attractive designs.

Cardboard, both printed and bare, is very cheap to produce. However, the energy cost and carbon footprint of its production are both very high relative to plastic, and it is not watertight, mandating a composite packaging with an inner plastic sheet in order to fulfil the requirements.

2. a) In metals, the electrons leave the outer layer of the metal atoms, forming positive metal ions and a sea of delocalised electrons. In a solid metal, these ions form a closely packed and regular metallic lattice:



These delocalised electrons are called valent electrons. Some metals lose one electron from their outer shell and some metals lose two; this is called the valency value of the metal. Metals with a valency of 2 have stronger bonds than valency 1 metals, because the ions and sea are more strongly charged and so attract each other more: this results in a stronger metal.



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A body centred cubic structure consists of atoms arranged in a cube where each corner of the cube shares an atom with one atom positioned at the centre. Each atom in a BCC structure is bonded with eight other atoms. One cube contains two whole atoms.

A face centred cubic structure consists of atoms arranged in a cube where each corner of the cube shares an atom with ~~one~~ three atoms positioned in the centre of each ^{adjacent} face of the cube. Each atom in a FCC structure is bonded with four or six other atoms. One cube contains four whole atoms.

Hexagonal close packed structures consist of atoms arranged into a hexagonal grid, in layers offset from each other such that atoms sit above the gaps in the layer below them.

c) The packing ratio of BCC is 0.68
The packing ratio of HCP is 0.74

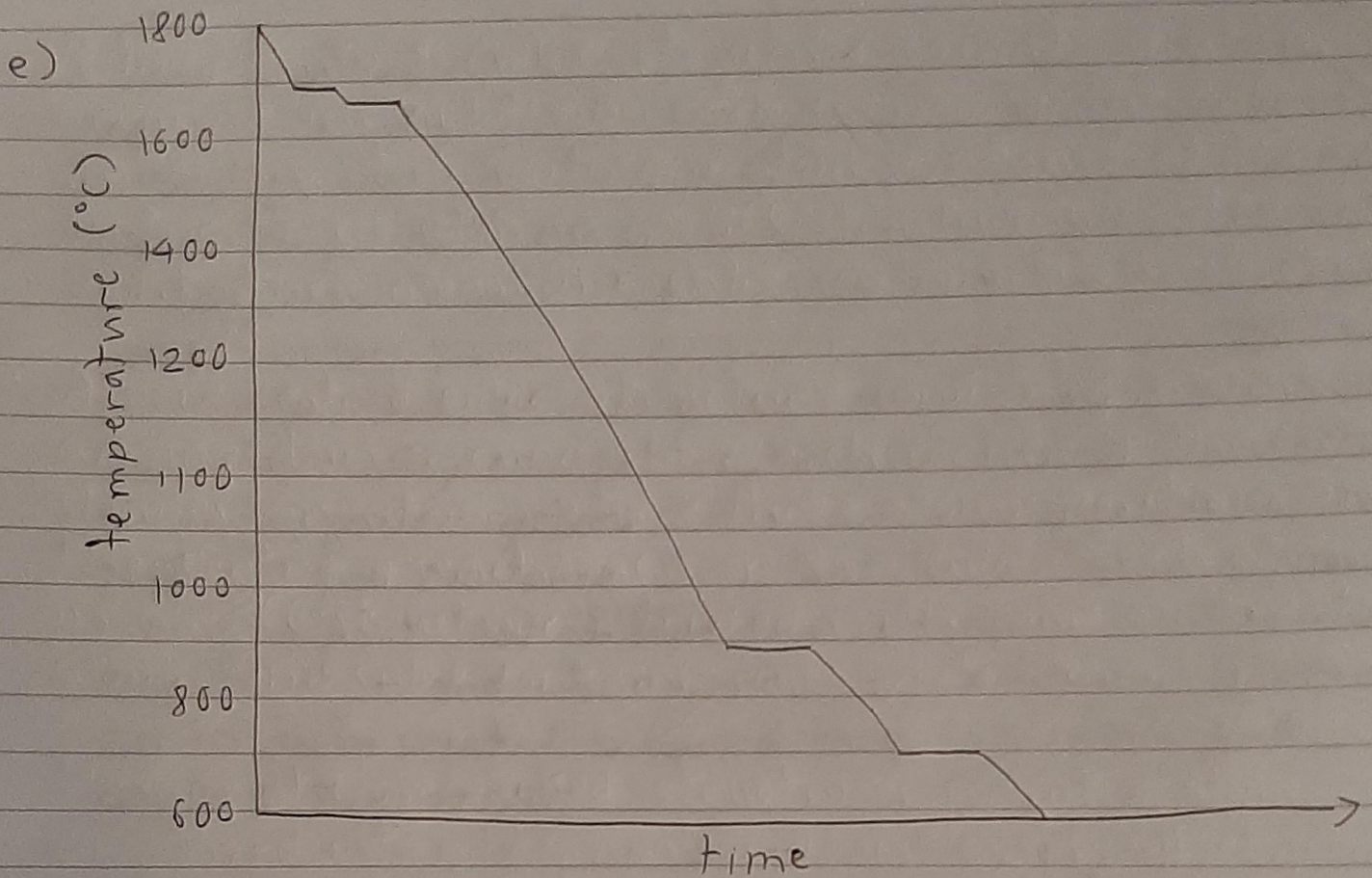
d) The mixture is a liquid at 1800°C
At 1650°C it is a liquid with β titanium structures suspended within it.
At 800°C it is a solid β titanium structure
At 600°C it is a solid α titanium structure

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3. a) ~~Metals~~, Technical ceramics and composites should be considered for this application. This is because they have the lowest density possible for the highest Young's Modulus available: Young's Modulus describes the ratio between stress and strain of a material, so the higher it is the less the chassis will deform under stress.

b) Some woods have a Young's modulus to density ratio comparable to lower-end composites or ceramics allowing them to handle the same

c) The main merit of a carbon-fibre tub is that it provides a very high Young's modulus for as low a weight as possible. Carbon fibre is not very workable mandating the tub design and minimising the amount of additional weight that can be saved with strategic holes. Carbon fibre is, however, corrosion resistant and chemically stable, extending the working life of the chassis. It is electrically conductive, which could be utilised to simplify power systems. It is non-flammable and has good fatigue resistance. It is brittle, which is a flaw - any impact that ~~exceeds~~^{bends} the material will easily break it - and an opportunity, allowing 'shatter zones' to be created to absorb force in a crash and protect the driver.

Steel space frames are, primarily, cheap. They are non-flammable and electrically conductive. They can be manufactured to minimise weight via strategic thinning and holing, and maximise strength where it is needed. It Steel can be alloyed to affect its strength and density and add properties such as corrosion resistance. It is ductile and will bend a lot before breaking; this increases its workability as well as allowing the creation of crumple zones.

d) When welded, a base metal is briefly liquidised and then solidified. This allows reactions with it.

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Brazing is done at lower temperatures and does not melt the base metals, eliminating these weaknesses, as well as lowering energy cost. Providing the correct brazing material is used, it will be just as strong as a weld. It can also be used to link dissimilar metals.

e) The frame could also be bolted together, which is an inexpensive and easy solution but adds weight and creates failure points in the joint.

The frame could also be glued or bonded together, adding little extra weight. Bonding can be a time-intensive process however, and some bonding materials are flammable.

4. a) The material must be airtight, must be of a high Yield Stress to prevent rupture, must be low density to make wearing comfortable, must be machinable to allow the creation of attachment point for valves and hoses, and must not corrode in salt water.

b) Aluminium has a low density, increasing wearer comfort out of the water, and does not corrode in water. However, it has a low Yield strength, making it unsuited for use as a pressurised container. It could be used but is undesirable.

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304 Stainless Steel has a much higher yield strength and will not ~~dis~~ rust in salt water. It is still dense, but the higher yield strength allows the cylinder walls to be thinner, off setting this and increasing the air space.

Pre-pregnated carbon fibre composite has an incredibly high yield strength and a very low density. It is likely expensive but non-corrosive in water given its applications in helicopter blades and wind turbines. This is an ideal material and will be used.

c) The formula indicates the following:

- the higher the yield strength, the thinner the walls can be. This allows for a lighter cylinder carrying more air and would be highly desirable.
- the lower the pressure, the thinner the walls can be. However, the yield strength being high would likely result in less air being stored.

$$d) i) t = \frac{2 * 20 \times 10^6 * 0.1}{1850 \times 10^6} = 0.000216 \text{ m} = 216 \mu\text{m}$$

$$\begin{aligned} ii) m &= 2 + d \ell (A - a) = 2 + d \ell (\pi R^2 - \pi r^2) \\ &= 2 + 1.74 (0.6 (\pi 0.1^2 - \pi (0.1 - 0.000216)^2)) \\ &= 2.000142 \text{ kg} \end{aligned}$$