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**Polymers and Composites**

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**Acknowledgement**

Mr John Gibson is a highly regarded educator and engineer. John taught Industrial Arts at a number of high schools before taking a position at Sydney Teachers’ College, then University of Sydney. He had an engineering education consultancy and has extensive experiencing working with NESA on Engineering Studies syllabus development and the HSC examination committee. The STEM Industry School Partnerships (SISP) Program asked John for his responses to the iTeachSTEM topic discussion questions. SISP is grateful to John for submitting these example discussion responses.

# Polymers

# Describe the structure of a thermosetting polymer.

Thermosetting polymers have a basic structure of atoms linked together with covalent bonds. These form in long molecular chains, however, the basic unit can also have side branches that bond with side branches of an adjacent chain. The basic unit is called a ‘mer’; when mers link together, the structure is known as a polymer. An example is: epoxy resin. As the structure of the basic mer is three-dimentional, and the covalent bonds are strong, thermosetting polymers tend to be more rigid and stronger than thermo-softening polymers.

1. **Compare the structure of thermo-softening and thermosetting polymers.**

The basic structure of thermo-softening polymers is quite different to that of thermosets. The thermos-softening polymers have a basic core structure, ‘mer’, but the polymer chains are only weakly attached to one another through Van der Waals bonds. This means that tangled chains can be straightened by applying a tensile force; strength is reduced due to weak bonds. Examples –

* polyethylene
* nylon
* polystyrene
* poly vinyl chloride (PVC)

1. **Describe the following:** 
   1. **Hot Compression moulding** is a process for producing polymer mouldings in thermosetting polymers. The powered polymer is compressed in a male/female mould and whilst compressed, is heated to the melting temperature of the polymer. With the pressure held, the polymer will cure and harden. The pressure is released and the product is removed from the mould. An example is: Bakelite.
   2. **Hand lay-up** is a process for producing a skateboard deck in a thermosetting polyester resin. A shaped board is prepared as the mould, is highly polished and, waxed. Three to six layers of glass matt are cut to the plan shape of the board. Resin is applied by brush to the mould surface. The estimated quantity of polyester resin is catalysed with MEKP (Methyl Ethyl Ketone Peroxides). A first layer of glass matt is placed on the wet resin and a firm brush is used to stipple the resin and glass with the aim of removing any trapped air. This process is used for each layer of resin and glass. The job can be trimmed and, left to harden. When cool, the mould can be removed from the pattern and, finished.
   3. **Vacuum lay-up** is the process of using a vacuum source, is much the same as a normal hand lay-up but, instead of stippling the resin/glass to remove air, a vacuum blanket is mounted over the work. When ready, the vacuum is used to squeeze out remaining air prior to the resin curing.
2. **Name 3 thermosetting polymers and an application where they are commonly used.**

* **Polyurethane ~ timber surface finishes**
* **Phenol formaldehyde ~ Bakelite lighting switch plates**
* **Epoxy resins ~ Araldite adhesives**

# Composites

1. **Name reasons why fibre-reinforced polymer (FRP) is a common composite material.**

A typical example of FRP is that of glass-fibre embedded in a polyester resin (liquid) when it is free of air bubbles and completes curing.

Window glass is usually recognised in general terms as being weak and inflexible, however, when glass is drawn into a very thin fibre, its mechanical strength increases significantly and obtains a degree of flexibility.

In the FRP composite, it is recognised that the glass absorbs tensile loads and, the lower-strength resin absorbs compressive loads, thus improving the overall mechanical strength of the material.

1. **Name various fibre types used for reinforcement in thermosetting polymer applications.**

* glass fibres embedded in polyester resin
* carbon fibres embedded in epoxy resin
* boron/epoxy fibres
* hemp fibres
* flax
* Kevlar 49/epoxy

1. **Describe one fibre metal laminate (FML) used in aeronautics.**

The Airbus A380 is made of 25% of composites, including 3% of GLARE in wings, fuselage sections, tail sections and doors. Other materials are 10% steel and titanium and, 61% aluminium.

GLARE is a reinforced glass-fibre metal laminate.

1. **Describe the macrostructure of Kevlar and discuss the material properties.**

Kevlar is a fibre-reinforced polymer, similar in basic form to glass-reinforced polyester polymer, widely used for high performance yacht sails.

A macrostructure of Kevlar would show carbon fibre woven into a pattern, embedded into an amorphous tough resin (having no visible structure).