Materials: engineering, science, properties, and design
3e Solution manual

Chapter 1: Exercises with worked solutions

Exercise E1.1 Use a search engine such as Google to research the history and uses of one of the following materials:

- Tin
- Glass
- Cement
- Titanium
- Carbon fiber

Present the result as a short report of about 100 - 200 words (roughly half a page).

Specimen answer: Tin. Tin (symbol Sn), a silver-white metal, has a long history. It was traded in the civilizations of the Mediterranean as early as 1500 BC (the Old Testament of the Christian bible contains many references to it). Its importance at that time lay in its ability to harden copper to give *bronze* (copper containing about 10% tin), the key material for weapons, tools and statuary of the Bronze age (1500 BC – 500 BC). Today tin is still used to make bronze, for solders and as a corrosion resistant coating on steel sheet ("tin plate") for food and drink containers – a "tinnie", to an Australian, is a can of beer. Plate glass is made by floating molten glass on a bed of liquid tin (the Pilkington process). Thin deposits of tin compounds on glass give transparent, electrically conducting coatings used for frost-free windshields and for panel lighting.

Exercise E1.2 What is meant by the *design-limiting properties* of a material in a given application?

Answer. A design-limiting property in a given application is one that limits the performance of the application. To meet a required level of performance, the design-limiting properties must meet or exceed target values.

Exercise E1.3 There have been many attempts to manufacture and market plastic bicycles. All have been too flexible. Which design-limiting property is insufficiently large?

Answer. Flexibility is lack of stiffness. The stiffness of a structure depends on its shape and size, and on the value of Young's modulus E of the material of which it is made. In design for stiffness E is a design-limiting property. In bicycle design the values of E offered by plastics are insufficiently large. However if the plastic is reinforced with carbon or glass fiber the stiffness can be increased to a useful level – high performance bicycles are made of carbon-reinforced plastic.

Exercise E1.4 What, in your judgment, are the design-limiting properties for the material for the blade of a knife that will be used to gut fish?

Answer. Hardness (to give a wear resistant, sharp edge); ability to be shaped to a blade; resistance to corrosion in fresh and salt water; stiffness (meaning modulus) to ensure that the thin blade does not bend or buckle during use.

Exercise E1.5 What, in your judgment, are the design-limiting properties for the material of an oven glove?

Answer. Flexibility (to allow weaving or shaping, and motion in use); low thermal conductivity (to insulate); maximum operating temperature > 200C (high oven setting); and ability to be washed, meaning tolerance of water.

Exercise E1.6 What, in your judgment, are the design-limiting properties for the material of an electric lamp filament?

Answer. The filament must be a good electrical conductor; maximum operating temperature > 2000°C (or a temperature of that order); ductility to enable it to be drawn to fine wire.

Exercise E1.7 A material is needed for a tube to carry fuel from the fuel tank to the carburetor of a motor-powered mower. The design requires that the tube be flexible, and that the fuel be visible. List what you think would be the design-limiting properties.

Answer. Flexible (meaning low modulus E); transparency (to allow fuel to be visible); very good resistance to organic solvents (gasoline and oil); ability to be formed into tube.

Exercise E1.8 A material is required as the magnet for a magnetic soap holder. Soap is mildly alkaline. List what you would judge to be the design-limiting properties.

Answer. Ferromagnetic; very good resistance to fresh water and mild alkali.

Exercise E1.9 The cases in which most CDs are sold have an irritating way of cracking and breaking. Which design-limiting property has been neglected in selecting the material of which they are made?

Answer. Fracture toughness

Exercise E1.10 List three applications that, in your judgment, need high stiffness and low weight. Think of things that must be light (as they are moved, perhaps rapidly) but must not be too 'bendy'.

Possible answers. Racing bicycle frames; aircraft wing spars; car wheels; sports equipment; precision machine tools; radio-telescope dishes; high-speed printing presses.

Exercise E1.11 List three applications that, in your judgment, need optical quality glass. Think of products that rely on distortion-free imaging.

Possible answers. Binoculars; cameras; contact lenses; microscopes; telescopes; fiber-optic cables.

Exercise E1.12 List three applications that you think would require high thermal conductivity. Think of things that you have to get heat into or out of.

Possible answers. Cooking utensils; heat exchangers (car radiators, air-conditioning units); heat sinks (like those that conduct the heat from the processor in your PC); thermal sensors and thermally activated safety equipment.

Exercise E1.13 List three applications that you think would require low thermal expansion. Think of things that you that will lose accuracy or won't work if they distort.

Possible answers. Optical benches; precision watches; gyroscopes such as those in inertial guidance systems; precision equipment generally.