Six projects for 1st and 2nd year students that don't use indices.

The six projects summarised briefly below rely on formulating the constraints that a material must meet in order to fill the requirements of a design. Applying these, using some combination of Limit stage, Graph stage and Tree stage leads to sensible results. The first five projects only require the Level 1 database. The last one needs Level 2.

1 Design a CD case that doesn't crack or scratch CDs

The standard CD ("Jewel" case) cracks easily and, if broken, can scratch the CD. Jewel cases are made of injection moulded polystyrene, chosen because it is transparent, cheap and easy to mould. The project: redesign the case and choose a material for it. The redesign might be a minor refinement of the standard 3-part design, a new shape (circular instead of square?) or a single part moulding with a natural hinge linking lid to case.

Material choice. Here the requirements might be

- *Optical properties*: transparent or optically clear.
- *Fracture toughness* better than polystyrene (data for polystyrene can be found in its Level 1 or 2 record).
- *Young's modulus* not too different from polystyrene (to make sure the case is stiff enough)
- Able to be *injection moulded.*
- *Cost* not more than twice that of polystyrene.

Applying these using the Level 1 database gives PMMA (acrylic) and PET as possible, perfectly sensible choices.

2 Materials for knife-edges and pivots

Precision instruments like clocks, watches, gyroscopes, and scientific equipment often contain moving parts located by knife-edges or pivots. The accuracy of location is limited by the deformation of the knife-edge or pivot and the mating surface. Elastic deformation is minimised by choosing materials with high Young's modulus; plastic deformation is limited by choosing materials with high hardness.

Material choice. The requirements

- *Young's modulus*: as large as possible.
- *Hardness:* as large as possible.

The best way to tackle this using the Level 1 database is to make a graph stage of Young' modulus and Hardness and pick the materials with high values of both. The very best are all ceramics: boron carbide, silicon carbide and tungsten carbide. If the selection box is relaxed so that the first metals appear, the selection picks up medium carbon steel, high carbon steel and low alloy steel. All are sensible choices: the ceramics when the ultimate precision is required, the steels when robust design able to deal with shock loading is needed.

3 Find a material for heat sink for a Pentium 4 chip in a compact portable computer

The power density of present day computer chips is such that removing the heat generated in them is a major consideration. The chip is attached to a heat sink that conducts the heat from the chip to a set of fins cooled by fan-driven air flow. The heat sink must conduct heat well, be able to operate continuously at 150 C and be electrically insulating.

Material choice. The requirements:

- *Electrical properties:* good insulator
- *Maximum service temperature* > 150 C (423 K)
- As large a *thermal conductivity* as possible.

Applying this using the Level 1 database, using a graph stage to plot thermal conductivity and selecting materials with the largest value gives aluminium nitride – the favored material for heat sinks.

4 Materials for storage heaters.

A storage heater captures heat over a period of time, then releases it, usually to an air stream, when required. Those for domestic heating store solar energy or energy from off-peak electricity and release it slowly during the cold part of the day. Those for research release the heat to a supersonic air stream to test system behaviour in supersonic flight. What is a good material for the storage material?

Material choice. The requirements:

- *Maximum service temperature* > 150 C (423 K)
- *Low cost*
- *Specific heat:* as high as possible

Applying this using the Level 1 database, using a graph stage to plot specific heat and cost and selecting materials with the large values of the first and low values of the second gives brick, stone and concrete.

5 Encapsulation for an electrical connector

Miniature connectors like the parallel port of a PC allow up to 20 connection to be made simultaneously. The material specification from one manufacturer is listed below. What material would be suitable?.

Material choice. The requirements:

- *Electrical properties:* good insulator
- *Maximum service temperature* > 200 C (473 K)
- *Tensile strength* > 100 MPa.
- *Elongation* > 2%
- Able to be *injection moulded.*
- As *cheap* as possible

Applying this using the Level 1 database, using a Tree stage to meet the requirement of injection moulding and a Limit stage to apply all the constraints except price gives polyamides (Nylons) and polyetherether ketone (PEEK). The records show that the first costs about $3/kg, the second about $95/kg. The recommendation at Level 1 is Nylon.

6 Materials for a fresh-water heat exchanger

Heat exchangers, typically, consist of a set of tubes through which one fluid is pumped, immersed in a chamber through which the other fluid flows; heat passes from one fluid to the other. The material of the tubing must conduct heat well, have an maximum operating temperature above the operating temperature of the device, not corrode in the fluid, and – since the tubes have to be bent – have adequate ductility.

Material choice. Typical requirements:

- *Maximum service temperature* > 150 C (423 K)
- *Elongation* > 20%
- *Corrosion resistance in fresh water*: very good
- As large a *thermal conductivity* as possible.

Applying this using the Level 2 database (necessary because Level 1 doesn't have corrosion resistance), using a graph stage to plot thermal conductivity and selecting materials with the largest value gives copper alloys and aluminium alloys. Both are used for heat exchangers.