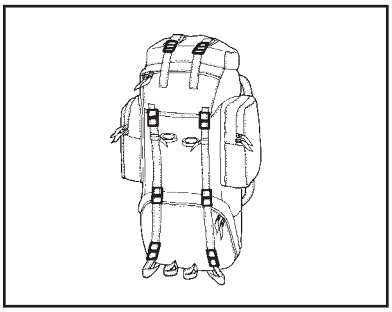
CASE STUDIES



Select one of the following products of which you have an example:

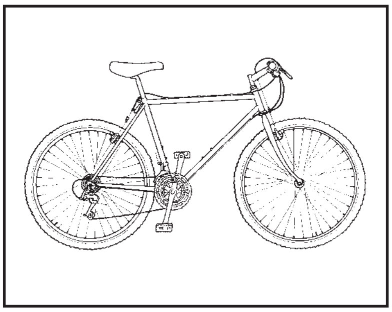
Rucksack

Bicycle

Sports Shoes

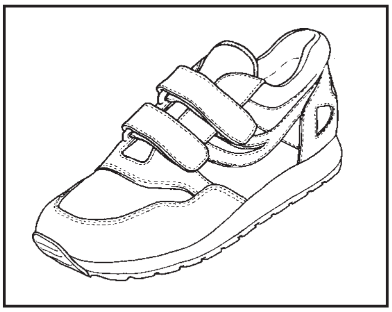
Transformer Toy

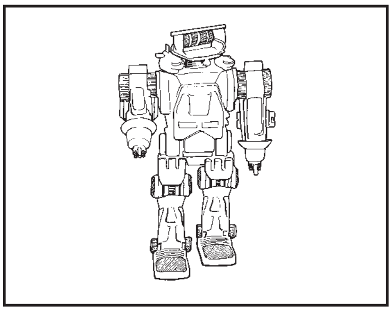
Tennis Racket



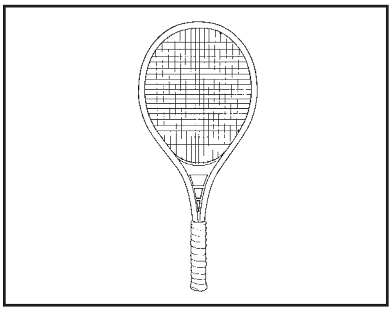
For the one product you choose:

- State the example you have chosen.
- Read the information.
- Identify the materials used.
  Explain why they have been used.
- What manufacturing processes have been used?
  Explain why they have been used.
- What links are there between the materials selected and the manufacturing processes used?
- Identify the features of the product that could result in product success.
- Suggest some quality control checks that could be used to make sure that the product meets its specification.
- Where does your money go?

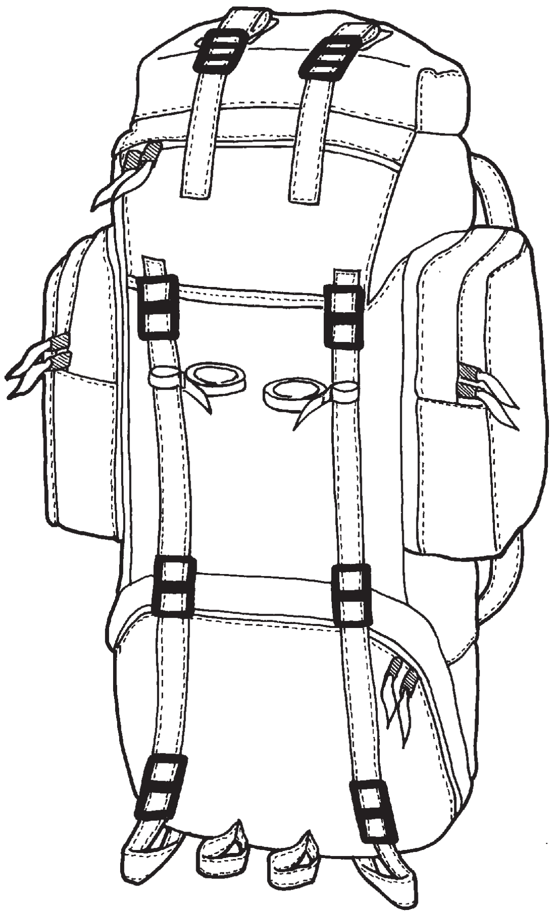




Relate each term to the development of the product you have chosen.



RUCKSACK



Use
Rucksacks are used in many harsh environments: arctic wastes, deserts and high mountain ranges. During major climbing expeditions and extended trips in remote areas, people's lives may depend on them. The design of the rucksack, the materials used and the manufacturing process must all be of high quality.

Requirements
The key requirements of a rucksack are comfort, safety and durability. On difficult terrain comfort and safety are closely related. The designer aims to reduce fatigue and minimise any danger of losing balance with a heavy rucksack weighing up to half the body weight of the individual.

Fatigue can be reduced by redistributing the weight away from the shoulders to the pelvic girdle by the correct use of hipbelts. The optimal distribution of the load varies according to the terrain; for uphill walking the centre of mass should be eased away from the back, while going downhill it should be close in. The centre of mass should be high for level terrain and low for rough terrain.

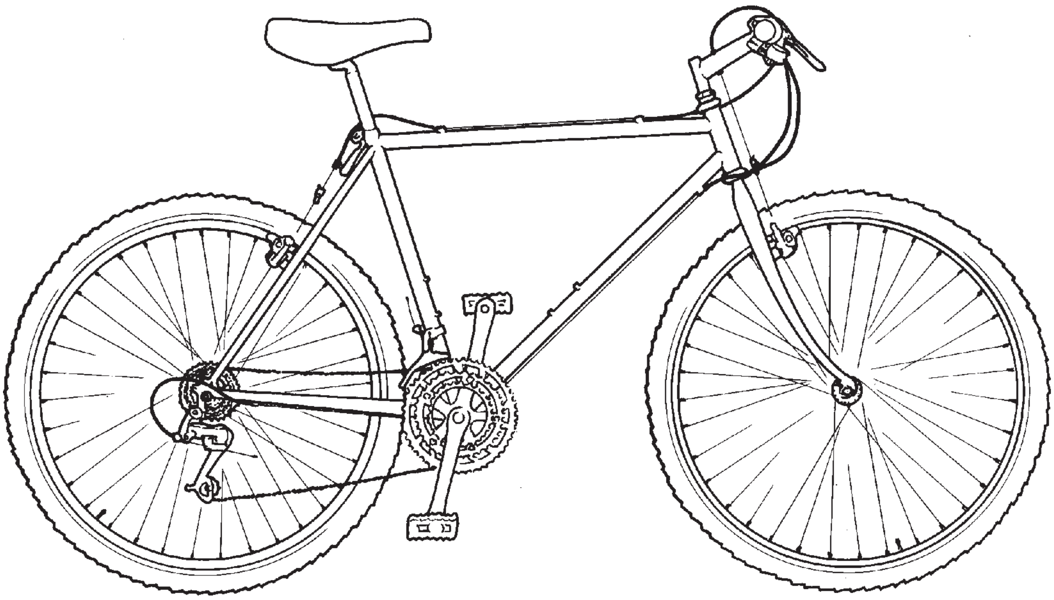
To allow for these variations the Condor rucksack, for example, has a self-adjusting back system which is invaluable when the going is tough and the load is heavy. The system enables easy adjustment on the move to redistribute the weight as the terrain changes or to relieve fatigue.

Selecting materials
Some of the properties required by the materials used in the rucksack construction are common to them all. They must be unaffected by the temperatures encountered in both desert and arctic regions; they need to resist abrasion and degradation from exposure to sunlight, water and perspiration; and be lightweight.

For efficient load transfer through the harness and hipbelt, some rucksacks use polypropylene plates to create a semi-rigid structure. The plates are sufficiently flexible to wrap around the body, stiff enough to provide support and will return to their original shape when released. The polypropylene plates can also be sewn through without cracking, and are easily stamped out into the required shape and satisfy all general requirements.

The ideal rucksack fabric is a textured nylon that is closely woven, stain resistant and proofed against water and snow. Condor rucksacks have been proved on several Everest expeditions and the materials used have successfully withstood the rigours of one of the harshest environments in the world.

BICYCLE



Use
Bicycle frames have to withstand high loads with minimum weight. They also require good corrosion resistance.

Requirement
The material used for a bicycle frame needs good stiffness and good strength to weight ratios. It is an advantage to cast the frame as a complete unit. This eliminates the need to braze or glue separate sections by hand thus simplifying manufacture. This also ensures that each frame is identical and without any weak points.

Selecting the materials
The frames of most cycles are made from steel tubing. This has to be both light and stiff, but the wall thickness of the tubing cannot be too thin otherwise it might buckle as a result of the forces acting on it. (A bicycle can be subjected to very severe dynamic loading when it is ridden.)

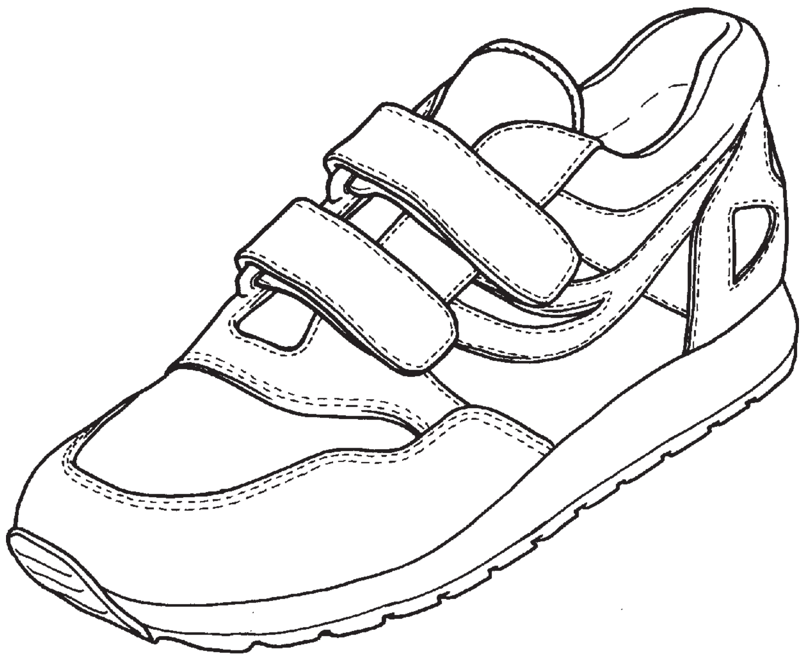
An alternative to the steel fabricated frame is a single casting in a suitably strong and light metal alloy. Where cast frames have been used, the designers have modified the basic frame shape to meet the requirements of stiffness, strength and aerodynamics. Although it is expensive to set up production facilities for a cast frame, these costs can be offset by the opportunities for high volume production. The alloys used for single-part cast frames are based on magnesium which is actually lighter than aluminium. When alloyed or combined with other metals such as zinc, manganese and aluminium, it offers an exceptional strength to weight ratio. A typical weight for a magnesium alloy frame is only 2kg.

In cycles for younger children, plastics are sometimes used throughout for both the frame and wheels. These are very strong fibre-reinforced materials which are given additional strength by clever geometry or shape. (An all-plastic bicycle for adults with a rubber belt drive was once produced but it was unusual and not a commercial success.)

A conventional bicycle wheel is made up from a series of steel spokes which are very strong in tension. The wheel is a remarkable structure since the frame actually ‘hangs’ largely from the spokes at the top of the wheel. All the spokes in tension keep the otherwise very weak rim from flattening out when a bicycle is ridden. In some advanced racing cycles, the wheels are made from a solid but very thin disc of material. This can be lighter than a conventional wheel and aerodynamically superior.

Modern engineering methods have made it possible to produce all the mechanical parts of a bicycle more cheaply and more accurately than was previously possible. It is interesting to note, however, that many of the basic components and principles involved in bicycle design have not changed much in 100 years. (Leonardo da Vinci described the chain drive in the 16th century!)

SPORTS SHOES



Use
Walking with a spring in your step may have more to do with the soles of your shoes than how you feel. Sports shoes have become a major fashion item; they look good, and they feel good. Some people will go to any lengths to own the latest Nike or Reebok.

Requirements
Most sports shoe soles are formed by two components; a midsole providing cushioning and shock absorption, and a tougher outsole providing abrasion resistance and grip. The midsole is the most important component of the sports shoe. It must provide cushioning, flexibility and stability during rapid direction changes. The longer it retains these properties under the demanding conditions of sporting activities the better.

Selecting the materials
The first generation of sports shoes used an elastic material, such as polyurethane elastomer, as a midsole, with a high-density polyurethane or rubber outsole. The dual density soles offered much more scope to design shoes for specific sports, prompting intensive research into the athletic footware.

High performance dual density soles have three main configurations; dual density polyurethane/rubber and EVA/ rubber. Polyurethane offers the best combination of cushioning, elasticity and durability for the midsole but is heavier than the rival EVA (ethylene-vinyl acetate copolymer).

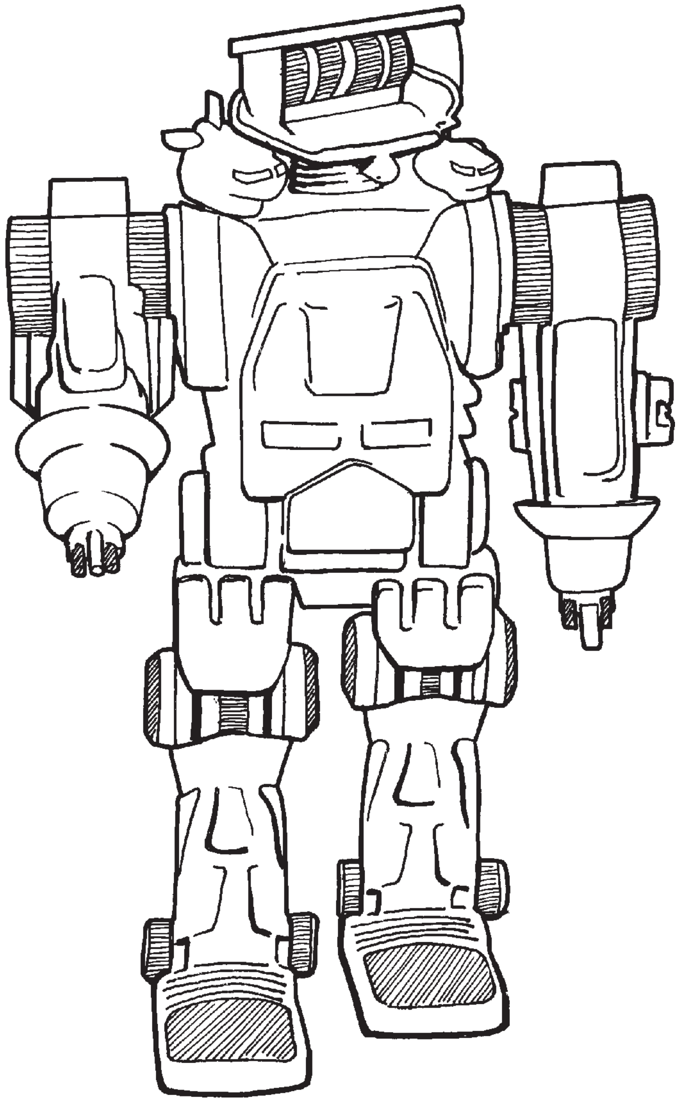
Foam materials break down when repeatedly impacted; the lightweight EVA foams more rapidly than the higher density polyurethane foams. The polyurethane midsoles with moulded 'airbag' inserts, (as found in many modern sports shoes) is generally more durable and achieve a design that reduces the weight of the sole without sacrificing performance.

The latest models feature more highly engineered midsoles which contain inserts such as an 'airbag'. These contain pressurized gases within a thin, flexible membrane.

Polyurethane elastomers, with their durable energy-absorbing and elastic qualities, can be moulded around these positioned inserts, offering the designers a very effective and versatile cushioning system.

The system permits tremendous design freedom to tailor the sole to the exact requirements of specific sports using variations in pressure, shape and positioning of the airbags and sole thickness and shape. It also provides an extra feature to enhance the aesthetic appeal of the shoe.

Transformer Toy



Use
There are many categories of toys on sale. One which has become very popular is the transformer toy - so called because the basic parts can be re-formed to represent different things. A typical transformer toy, for example, can be changed from a car to a robot by turning parts around and locking them into new positions.

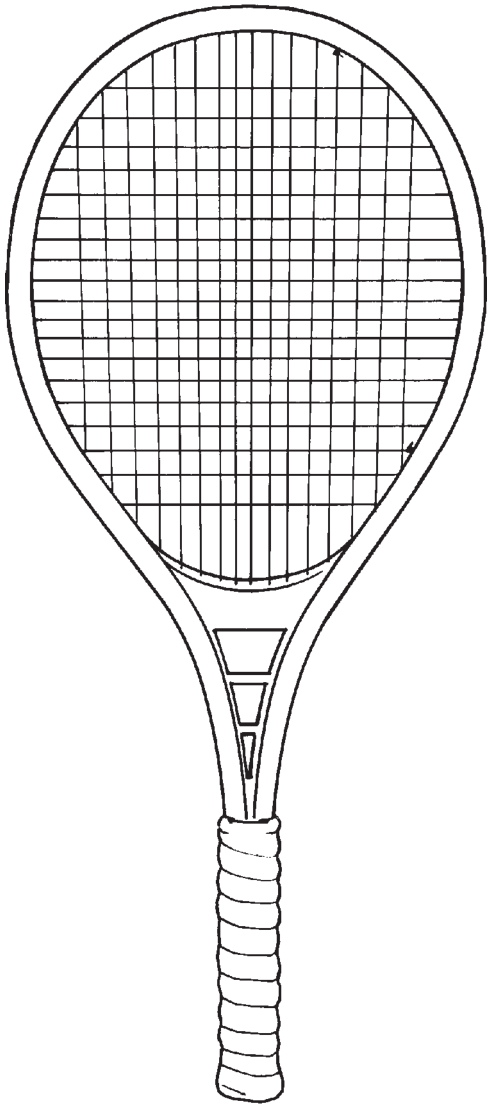
Requirements
These toys are extremely clever in the way they convert in appearance from one thing to another. It is not widely appreciated, however, that they often involve highly advanced mechanical linkage principles to enable the 'transformer' movements to take place - and they use advanced manufacturing methods.

Selecting the materials
Most transformer toys are injection moulded but are examples of high precision injection moulding. This is where very high tolerances are achieved so that the parts which come out from different moulds fit together accurately. (Precision injection moulding of components such as gears and other mechanical parts has eliminated the need for more expensively machined metal parts in products such as cameras and camcorders and has thus contributed to making these goods much more affordable.)

If you examine the joints of transformer toys, it is not always obvious how they 'work'. At a first glance they are as mysterious as the mechanism of a Rubic's cube. Have you ever wondered how all the parts can be turned around but still remain together as a cube? Sometimes, transformer toys can be taken apart for closer examination because the joints are 'popped' together using the same principle as poppet beads. Achieving such close fits between two parts is only possible through moulding to tolerances of less than 0.01 mm!

Some transformer toys are motorised so that they move along as cars or produce mechanical movements as - say - robots. This requires even greater design skill, and compares with the ingenuity that goes into designing other more 'serious' consumer products such as lawnmowers, foodmixers etc.

THE EVOLUTION OF THE TENNIS RACKET



Use

The area where new materials have made rapid inroads is sports equipment. Led by the competitive world of professional sport there is a high premium on performance, and the manufacturers, eager to have their equipment used by top professionals, constantly experiment with new materials.

Requirements

The original tennis rackets were made of laminated wood and strung with natural gut. The wooden frames were limited in stiffness and strength although they had good damping properties. It was not until the late seventies that materials technology had developed sufficiently to offer viable alternatives.

The key requirements are strength and lightness. Other factors such as stiffness and shock absorption also need to be considered.

Selecting the materials

Wooden rackets

Little change in racket design occurred throughout the long period of wooden rackets. As the game itself developed and became more popular racket designers experimented with different types of wood and methods of construction. Most rackets were made from laminates of ash and beech or hickory bonded with phenol formaldehyde adhesive.

Metal frames

Metal frames became feasible with the development of improved light alloys. Aluminium alloys are most common but alloys of magnesium have also been used.

Metal frames are competitively priced but the relatively poor vibration damping properties mean they are not liked by top players. The rackets are made from extruded or drawn tubing appropriately shaped, with a separate throatpiece fitted.

Composite rackets

Most professional players now use rackets with composite materials of which there are many different types. Currently the best performance rackets are the 'graphites' which use carbon fibres. There are two manufacturing methods used, injection moulding and compression moulding. These use different types of materials and produce rackets with different properties.

The injection moulding process at Dunlop uses chopped fibres in a matrix of nylon. This produces a racket with better vibration damping properties than the compression rackets formed by long fibres in an epoxy resin matrix.

Strings
Racket strings have also changed over the years. Initially monofilament nylon strings were introduced as an alternative to natural gut. These were joined by the superior multifilament nylon which is now the most common string but natural gut is still used by most professionals.

DunlopMax series
In the process developed by Dunlop, the composite is moulded around a core of low melting point alloy of bismuth and tin. This core is then melted out through the shaft to leave a hollow and very light frame.

The original version, the Max 150G, was filled with polyurethane foam to improve vibration damping and encapsulate any metal pieces that remained inside the frame. With the advent of the large headed rackets, an internal lining of rubber latex replaced the foam.