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Engineering Design Concepts 7757C/EA060

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Chapter 1:

The Design Process

1.1 Introduction

This module targets engineering technician students, and is intended for design related studies in Mechanical, Electrical, and Civil engineering.

Engineering Design Concepts will help the student get the gist of designing as an engineer.

This resource package supports the student taking Engineering Design Concepts as an isolated module. In this case the module resource will help to spark ideas and get you interested in engineering design while bringing out the fundamental concepts.

With the help of the resource, Engineering Design Concepts may also be coupled with other project or design tasks, helping to stimulate and guide the design process. You then have the advantage of subjects working together. The module resource will keep you aware of the ‘big picture’ and provide a way of checking the design process.

1.2 Importance of Engineering Design

Competent engineering design is strategic in the success of many ventures. The successful engineering technician may be good at analysis and come up with the right answers, but how do they know they are asking the right questions in the first place?

As an engineering technician you will need to understand some complex principles, and apply analytical methods to find the solution to a problem (Eg. Determine the size of a beam, find the torque on a shaft, calculate the rating of a transistor etc). To get an answer to such problems we may need to know some theoretical principles, apply the right formulae and come up with an answer. To some, this is engineering design, but it can be much more.

The engineering designer may need to;

- Determine the ratings, sizes, quantity, speed etc (Calculate or even ‘feel’ for it)
- Turn an idea into something that works. (Invent, modify similar ideas)
- Consider other issues. (Safety, appearance, environment, market, etc)
- Improve a product to make it easier to make, use, sell etc (Development)
- Prove it will work. (Computer analysis, prototypes and models)
- Accurately specify/record the design (Drawings, diagrams, circuits)
- Check legals (Patents, design codes, safety and litigation risk)
Engineering Design Concepts is one of a new breed of modules presenting a more complete approach to engineering. While it is often necessary in engineering to analyse very specific details, the danger is to get bogged down in the detail and lose sight of the big picture. Generally speaking, mathematical analysis is only a small part of engineering.

**Here are some examples:**

Johny is trying to determine the size of an electric motor needed to drive a conveyor. He applies the equations of mechanics and with the acceleration, velocities and masses in the system comes up with the answer: 4kW. He thinks he might be right but he doesn’t know how much friction is involved - maybe 10%.

A conveyor company does a quote and says you need a 7.5kW motor.

Poor Johny. He used all the right formulas but got the wrong answer! You see, the conveyor company knows about duty cycles, starting torques, typical friction loads, overload capacity, and the (real) cost of replacing the motor. Besides, they never have trouble with the supplier of the 7.5kW motor, and it happens to suit a particular standard gearbox!

* In mathematics, the theory can be more important than the correct answer. In engineering, the theory may give a approximate or minimum solution, but the real answer may depend on some less regular factors -

In Johny’s case, his calculations serve as a guide only, so that at least he knows he shouldn’t be needing a 40kW motor. But looking at a similar system, asking an expert, or getting a ‘gut feeling’ for the job can lead to a reliable design.

*  *  *

And here’s Alison. Her job is to design a 8m steel beam supporting floor joists in a 2 storey building. She has a good understanding of stresses and mechanics of materials, and topped the class in bending moment diagrams and determining design loads. She comes up with an answer.

She knew about Australian Standards and rechecked her answer with tables and standard sections. The beam section was specified on the drawings and everything seemed OK, but the builder has just found out that BHP hasn’t rolled that section for years but needs to place the beam next week.

* A general knowledge of the industry is invaluable. *

*  *  *

Another technician spent endless hours designing an amplifier circuit for a piezo-electric transducer. Excellent analytical and practical skills were demonstrated with the final circuit working perfectly. It turned out to be an overkill however, and much too expensive to implement in the particular product. A far cheaper method was found by using a different sensor.

*  *  *

**Check your options carefully before you launch into the (often arduous) design process.**
1.3 Basic Design Strategies

A definition of Engineering Design

The purpose of engineering design is to work out what is to be made or done. We may be needing to ‘make’ a product, a layout, a process, a program.

Virtually any time something new is to be made, design work is involved. The amount of design work may vary. It depends on the number of choices presented to the designer, the size, difficulty or newness of the job, and the degree of expertise by those carrying out the work.

If it is simple or very familiar to the designer they may just have the design in their head. (Eg a small garden, a shower screen, a mounting bracket, fitting a switch, organising a work area) As the task becomes larger, more complicated or more unusual, more design oriented, the design work can grow from a rough sketch to advanced computer simulation, or expensive trials and prototypes before the final design can be specified.

So ‘designing’ includes any method used to come up with the details (specifications) of something that will do the job.

Design Strategies

There are countless things to design, and many different ways to do the designing. The design process can vary depending on a variety of factors, such as the degree of complexity, scale of the project, experience of the designer, the time available, the designs of competitors etc.

For example, an engineer who is very familiar with a particular sort of job may approach the design in a linear fashion - step by step from beginning to end. This may be thought of as the ‘ideal’ case where the outcome of the design is predictable, or must be analysed carefully to ensure it works first time. Eg: A building, a pump. A more innovative design may require trial and error, and if time allows, a circular or iterative design process might be followed. Eg: An invention, a easily made item.

![Fig 1a: Linear (Ideal)](image1)

- Definition
- Specification
- Concepts
- Analysis
- Refinement
- Detailing
- Proving
- Manufacture

![Fig 1b: Circular (Iterative)](image2)

- Concept (Review)
- Testing (Check)
- Design (Plan)
- Product (Do)
A third option is to develop several ideas in parallel to see which one turns out best in the end - a more expensive but faster method than the circular process, but allowing more room for experiment than the linear method. It is particularly useful for the design things requiring long leadtimes for testing and certification, such as medical equipment, aircraft, drug testing, growing plants, or when you need to shorten the leadtime as much as possible.

**Fig 1c: Parallel (comparative or elimination technique)**

<table>
<thead>
<tr>
<th>Idea 1</th>
<th>Design OK</th>
<th>Product</th>
<th>Fails testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idea 2</td>
<td>Design ideas</td>
<td>Product</td>
<td>Works OK</td>
</tr>
<tr>
<td></td>
<td>combined to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idea 3</td>
<td>give new idea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idea 4</td>
<td>Design OK</td>
<td>2 ways to</td>
<td>Works OK and cheap</td>
</tr>
<tr>
<td></td>
<td></td>
<td>make the</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>product</td>
<td>Poor performance</td>
</tr>
</tbody>
</table>

Here, we are referring only to the design of a particular thing, as distinct from the accumulated design knowledge gained over successive projects. Accumulated design knowledge is circular because it is based on what has or hasn’t worked in the past. A designer who can rely on this for a new design has an obvious advantage and may design linearly. As the level of innovation increases (relative to the designer’s knowledge) then so does the uncertainty of the design outcome, making the circular or parallel design schemes necessary.

In practice, a substantial design project would take a generally linear form with a few parallel and circular trials along the way.

**Product Life Cycle:**

A typical product begins as components and raw materials, is worked on, assembled and tested. It may be packaged and then distributed via transportation and warehousing to the retailers. A customer eventually buys it. Repairs and maintenance might be done during its life until it is finally scrapped. It may be reconditioned, recycled, incinerated, stored or sent to a dump.

The design of a product may be influenced by each of these aspects. The choice of material used in a design relates to virtually every stage, from manufacture to recycling.

A design is really information about a product, not the product itself, so it does not appear as a stage in the product life cycle.
1.4 Design Methods

A design is an answer to a problem, but are many ways to come up with a design. Regardless of whether the design strategy is predominantly linear, circular or parallel, there are 3 main actions involved with a design process - ideas, decisions and refinement.

Ideas: Coming up with the new idea is the beginning of design process. It may be completely new (although this is unusual) or a modification of an existing idea. Conceptualisation means coming up with concepts or initial rough ideas for the design. Concepts may be rough sketches or even just a description. Eg: A concept of an electric skateboard - battery on the rider’s back, motors in the back wheels and hand switch. Brainstorming is one method of inspiring concepts.

Innovation or invention refers to a new ‘thing’ that didn’t exist before. (Machine, process, application or anything that can be patented). Alternatively, the design might be adapted from another design, but still new in its application or execution.

Copying. This is the easy way to come up with a design, this is why people spend lots of money on patents. Ideas do come from other looking at other designs, but there is a limit to how closely you can duplicate it (depending on the patent writer, application etc). Reverse engineering is a term used to describe methods of finding out how something works or how it was made. Some countries get rich that way.

Decisions:

Adaption is another the , adapting other designs, applying new technology, predicting performance by calculation, estimation, modelling or simulation.

Resources for design (Designer: general knowledge and experience, familiarity with products, processes and industry. People: experienced people, specialists in same field, support network, suppliers. Design tools: Computer programs, CAD, simulation and analysis, modelling. Information - data sheets, books, magazines, internet, manufacturer’s catalogues, standards)
1.5 Review Questions

Q1: Consider designing a new house. Would you call the design process primarily linear, circular or parallel? Remember, a circular design process would mean that the design is not finalised until several attempts (builds) had been tried along the way. A parallel design process might see alternative designs trialed together to find the best. You might consider the process of designing a house from scratch (all new design) compared with a project home design.

Q2: Which design scheme is best suited to a product or project that is;
(a) Quick and cheap to make? ...........................................
(b) Similar to a familiar design? ...........................................
(c) Slow to make but not too expensive? ...........................................
(d) Very unpredictable? ...........................................
(e) Carefully analysed by computer before making it? .............................................

Q3: List various products, designs or projects likely to be designed by the three schemes below. Briefly explain why that scheme is suitable. (Eg. Quick and cheap to test)

<table>
<thead>
<tr>
<th>Linear Design Scheme</th>
<th>Circular Design Scheme</th>
<th>Parallel Design Scheme</th>
</tr>
</thead>
</table>

Q4. Describe two designs that you consider to fail in some cases of normal use.

<table>
<thead>
<tr>
<th>Item</th>
<th>Main function</th>
<th>Design Failure</th>
<th>Suggested Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast iron drainage grate</td>
<td>To allow water to enter pit but permit vehicles to pass over</td>
<td>Large lengthwise slots allow bicycle wheel to fall in - for serious accident</td>
<td>* Run slots at 90 degrees  * Narrower or shorter slots  * Use grid instead of slots</td>
</tr>
<tr>
<td>(a)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) 
| | | |

(b) 
| | | |
| | | |
Q5. For the following items, describe its main use (design function), then list other design issues that are more unusual, and ones that cannot be designed for. For example: A schoolbag is designed for carrying books and things and may also need to survive wet weather or hot sun, but not necessarily underwater use or being run over by a car.

<table>
<thead>
<tr>
<th>Item</th>
<th>Main function</th>
<th>Other Design Issues</th>
<th>Impossible Design Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping trolley</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walkman</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telegraph pole</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicycle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Road or (Roadway)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.................
Chapter 2

Regulations

2.1 What is a Standard?

A standard is the recommended way of doing something. Australian Standards (AS) is an organisation that develops and updates standards for almost everything - from Concrete Structures (AS 3600) to Babies Dummies (AS 2432). Many of the Australian Standards are based on standards developed overseas, especially British Standards (BS) and those of the International Standards Organisation (ISO), also DIN.

Each standard has an identification number, sometimes divided into parts. Eg;

```
AS 1100  Part 201  1992  Technical drawing - Mechanical engineering drawing
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This 78 page yellow book (1992 revision) is the Australian Standard (AS) for Mechanical Engineering Drawing. It follows on from the Technical Drawing standard (AS 1100) but goes into more detail about drawing gears, bolts and other mechanical items. Someone who produces an engineering drawing should comply with the standards given in AS 1100 - for example, the choice of scale. The standard shows the preferred way to do technical drawings.

Some standards must be followed exactly, especially where safety is involved. (AS 5848  1992 Code of practice for bungy jumping.) Others are just recommendations that could be applied by the relevant authority if they wanted to. For example, Australia Post might decide to make it easier to put mail in your letterbox (AS 4253  1994  Mailboxes)

Why use standards?

- Standards reduce confusion. Eg: If everyone follows the recommended way of drawing a centreline, it makes it much easier to read a drawing.
- They may be necessary to ensure things are done safely. Eg: Building standards.
- They can also be important for compatibility. Eg Standard mains voltage of 240 Volts AC, 50 Hz.
- They are helpful if you are not sure how to do something. You can learn from them.
- You may need to comply with particular standards for accreditation. Eg Quality standards
2.2 Regulatory Authorities

Not all standards are mandatory. However, there is an increasing level of regulation in areas of manufacture and design. The Australian Standards organisation simply produces the information on what is the ‘proper’ way to do something. It is up to regulatory authorities to decide whether to force people to use a particular standard.

Regulatory authorities include local councils, electricity, water, telephone and other service authorities, environmental protection, roads and traffic, workplace safety, consumer protection, quality accreditors, intellectual property organisations (AIPO) and various State and Federal Government regulatory bodies.

Occupational Health and Safety is one of the first issues to consider in engineering, and the regulatory authority for this is Workcover. They use Australian Standards for workplace safety as well as their own publications. Companies and people who do not comply may receive fines. Refer to OH&S modules or Workcover for more information in this area. The bulk of all design standards for engineering products have some safety aspects involved. Here are some of the more specific safety standards;

Some Australian Standards on SAFETY:

- AS HB9 1994  Occupational personal protection
- AS HB10 1987  Occupational overuse syndrome - Preventive guidelines
- AS 1216 1995  Class labels for dangerous goods
- AS 1219 1994  Power presses - Safety requirements
- AS 1221 1991  Fire hose reels
- AS 1270 1988  Acoustics - Hearing protectors
- AS 1318 1985  SAA industry safety colour code
- AS 1319 1994  Safety signs for the occupational environment
- AS 1473 1991  Guarding and safe use of woodworking machinery
- AS 1485 1983  Safety and health in workrooms of educational establishments
- AS 1558 1973  Protective clothing for welders
- AS 1603 1997  Automatic fire detection and alarm systems
- AS 1647 1992  Children's toys (safety requirements)
- AS 1716 1994  Respiratory protective devices
- AS 1926 1993  Swimming pool safety
- AS 1927 1989  Pedal bicycles for normal road use - Safety requirements
- AS 2211  Laser safety - Equipment classification, and user's guide
- AS 2243 1997  Safety in laboratories
- AS 2261 1990  Rescue buoys
- AS 2476 1981  General fumigation procedures
- AS 2397 1993  Safe use of lasers in the building and construction industry
- AS 2550 1995  Cranes - Safe use
- AS 2726 1995  Chainsaws - Safety requirements
- AS 2809 1985  Road tank vehicles for dangerous goods
- AS 2865 1995  Safe working in a confined space
- AS 2906 1991  Fuel containers - Portable - Plastics and metal
- AS 2939 1987  Industrial robot systems - Safe design and usage
- AS 2958 1988  Earth-moving machinery - Safety
- AS 3175 1994  Approval and test specification - Residual current-operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCB's)
- AS 3200 1994  Approval and test specification - Medical electrical equipment - Particular requirements for safety
- AS 3300 1996  Approval and test specification - General requirements for household and similar electrical appliances
- AS 3574 1988  SAA forest safety code
- AS 3786 1993  Smoke alarms
- AS 4226 1994  Guidelines for safe housing design
- AS 4292 1995  Railway safety management
- AS 4417 1996  Marking of electrical products to indicate compliance with regulations
- AS 4513 1995  Medical electrical equipment - safety standards
- DR 93028  Design for safety in the commercial and service workplace Checklist (Supplement 1)
2.3 Typical Standards used in Engineering Design

ENGINEERING DRAWING
AS HB7 1993 Engineering drawing handbook
AS HB47 1993 Dimensioning and tolerancing to AS 1100.101 & 201
AS 1100 1992 Technical drawing
  Part 201 - Mechanical engineering drawing
  Part 401 - Engineering survey drawing
  Part 501 - Structural engineering drawing
AS 1101 1972 Graphical symbols for general engineering
AS 1102 1986 Graphical symbols for electrotechnical documentation

CIVIL ENGINEERING DESIGN
AS HB2 1986 Australian Standards for civil engineering students
AS HB41 1993 Design checkers' handbook for buildings
AS HB48 1993 Steel structures design handbook
AS HB60 1992 Australian domestic construction manual
AS HB64 1994 Guide to concrete construction
AS HB71 1995 Concrete design handbook
AS HB77 1996 Australian bridge design code
AS 2601 1991 The demolition of structures
AS 1288 1994 Glass in buildings
AS 1554 1995 Structural steel welding
AS 1664 1979 SAA aluminium structures code
AS 1684 1992 National timber framing code
AS 2870 1996 Residential slabs and footings -
  AS 3600 1994 Concrete structures
AS 3700 1988 SAA masonry code
AS 3610 1995 Formwork for concrete
AS 4100 1990 Steel structures

MECHANICAL ENGINEERING DESIGN
AS HB6 1991 Design Standards for mechanical engineering students
AS 1210 1989 SAA unfired pressure vessels code
AS 1228 1990 Boilers - Water-tube
AS 1403 1985 Design of rotating steel shafts
AS 1755 1986 Conveyors
AS 1797 1986 Boilers - Fire-tube, shell, etc
AS 1947 1976 Metric units for use in mechanical engineering and related fields
AS 2671 1983 Fluid power - Hydraulics
AS 2729 1994 Rolling bearings - Dynamic ratings
AS 2784 1985 Endless wedge belt and V-belt drives
AS 2788 1985 Fluid power - Pneumatics
AS 3785 1993 Underground mining - Shaft equipment
AS 1418 1996 Cranes (including hoists and winches)

ELECTRICAL ENGINEERING DESIGN
AS 3000 1991 SAA Wiring Rules
AS 3005 to 3017 Electrical installations; tents, domestic, mines, generators, batteries, electric fences.
AS 3080 1996 Telecommunications installations
AS 3100 to 3350 Approval and test specifications -
  toasters, heaters, portable outlet devices, jugs, isolating transformers, 3112 socket outlets, 3114
  soldering irons, 3115 motor-operated appliances, 3117
  bayonet lampholders, 3120 extension cord sockets,
  3123 industrial plugs, socket-outlets and couplers, 3129
  electric fences, 3137 light fittings, 3139 Switches for
  appliances, 3142 water heaters, 3156 lawnmowers,
  3160 portable electric tools, 3175 & 3190 RCCB's,
  3195 portable arc welding, 3197 portable control
devices, 3200 medical electrical equipment safety, 3250
  mains operated household electronics, 3260 Safety of
  information technology equipment, AS 3300 to 3317
  particular household appliances, 3350 Safety of
  household appliances (vacuum cleaners, irons, spin
diers, washing machines, dishwashers, toasters, grillers, kitchen machines, clocks, sewing machines,
range hoods, air-conditioners, pumps, vending
machines, outdoor barbeques, pressure and steam
cleaners)
AS 4168 1994 Programmable controllers

INFORMATION TECHNOLOGY (COMPUTERS)
AS 3966 I.T. - International standardized profiles
AS 4038 1992 Industrial automation systems -
  Manufacturing message specification
AS 4138 1995 - Telecommunications and information
  exchange between systems
AS 4203 1994 I.T. Open systems interconnection -
  AS (various) Information Processing - discs, tapes, etc
AS (various) Software Eg: AS 3603 Computer graphics
  - Metafiles for picture description information

ERGONOMICS
AS HB10 1987 Occupational overuse syndrome - RSI)
AS HB59 1994 Ergonomics - work systems design
AS 1837 1976 Code of practice for application of
  ergonomics to factory and office work
AS 4442 1997 Office desks

MANAGEMENT
AS 3950 1991 Guide to managing product design
AS 3900 1993 Quality management, assurance
AS 4300 1995 General conditions of contract for design
  and construct
AS 9001 1994 Quality systems
GENERAL DESIGN
AS 2400 1984 SAA packaging code
AS 3500 1995 National plumbing and drainage code
AS HB72 1995 Design vehicles and turning path templates
AS 1366 1992 Rigid cellular plastics for insulation
AS 1428 1993 Design for access and mobility (Buildings, disabled etc)
AS 1657 1992 Fixed platforms, walkways, stairways and ladders - Design, construction and installation
AS 1743 1992 Road signs - Specifications
AS 1745 1989 Outdoor weathering of plastics in the Australian environment -
AS 1892 1996 Portable ladders
AS 1924 1981 Playground equipment for parks, schools and domestic use
AS 2118 1995 Automatic fire sprinkler systems
AS 2153 1997 Tractors and machinery for agriculture and forestry - Technical means for ensuring safety
AS 2231 1980 New tyres for passenger cars

AS 2657 1985 Powered rotary lawnmowers
AS 2693 1993 Vehicle jacks
AS 2845 1995 Water - Backflow prevention devices
AS 2890 1993 Parking facilities
DR 97079 Building in bushfire-prone areas
AS 14001 1996 Environmental management systems -
AS 2070 1992 Plastics materials for food contact use
AS 2320 1979 Metals for surgical implants
AS 2700 1996 Colour Standards for general purposes

INTERESTING / FUNNY
AS 1235 1991 Roof racks for passenger vehicles
AS 1371 1973 Toilet seats of moulded plastics
AS 1535 1975 Moulded plastics garbage cans
AS 2172 1995 Cots for household use - Safety
AS 2432 1991 Babies' dummies
AS 3533 1988 Amusement rides and devices
AS 4253 1994 Mailboxes
AS 5848 1992 Code of practice for bungy jumping

Yes, there is even a standard on plastic toilet seats! (AS 1371)

The above list is only a small sample of standards that might be used by a designer. You will need to search for Australian Standards relevant to your own design study.

Most technical and some larger libraries keep a range of Australian Standards. Few places keep all the books because they go out of date. They may be kept on microfilm or computer.

To look for a standard on a particular subject, refer to the standards index or catalogue. You can look up the subject (listed in alphabetic order) and find the relevant Australian Standards. It also gives a brief description of each standard. This might be also available on computer. (Australian Standards Index is available on CD)
2.4 Intellectual Property

It is much easier to copy an idea than to make it up.

The ideas that are owned by a company are called intellectual property or proprietary knowledge. Care must be taken to prevent this knowledge becoming public, which could nullify the legal right to own the ideas of the product. There are 4 main types of intellectual property;

1. **Patents** are for inventions, improved products or processes that could make good money. A patent prevents others copying the idea by law. They last up to 20 years, but must be applied for at the Patent Office in the Australian Industrial Property Organisation. Patents are examined carefully to see if they are really new and not obvious. If the idea has been demonstrated, sold or publicly discussed before applying for a patent you will lose your right to patent protection. The patent must be carefully written to prevent others modifying the idea slightly without infringing the patent. Patent attorneys specialise in this area.

2. **Registered designs** are used to protect the look of a product, especially if the appearance gives a marketing edge. It must be a new design in terms of shape, configuration, pattern or ornamentation which can be judged by the eye in finished articles. A registered design does not include how it works. Non-industrial artistic designs are protected by copyright. Registration is for 12 months and can be extended up to 16 years.

3. **Trade marks** are for words, symbols, pictures, sounds, smells or a combination of these and they distinguish the goods and services of one trader from those of another. Registration can be renewed indefinitely.

4. **Copyright** is for original material in literary, artistic, dramatic or musical works, films broadcasts, multimedia and computer programs. A special copyright exists for circuit layouts.

In Australia, patents, trade marks, designs and copyright have been Commonwealth functions since Federation. The Australian Industrial Property Organisation (AIPO) administers patents, trade marks and design rights with an examination and registration process. The Attorney-General's Department administers the legislation for automatic rights to copyright and circuit layout rights. Plant Breeder's Rights Australia looks after new plants after examination.

There are also laws about intellectual property such as infringement of trade secrets and confidentiality agreements. These are dealt with under common law - Eg If you sign a confidentiality agreement with someone, they could take you to court if you break it.

**Note on Patents**

The owner of a patent is allowed to make the product or receive royalties from someone who makes it. If a patent infringement does occur, there may be an expensive legal battle to work out who is in the wrong. It may also be necessary to apply for an international patent, or patents in foreign countries where the product may be sold. An Australian patent typically costs around $5000 to $8000 to establish, with a further $7000 or so to maintain it over 20 years.
In a fast moving market it may be better to opt for a petty patent - an easier method which protects you for up to 6 years. A provisional patent sets the date of the invention before anyone else, giving you 12 months to file the real patent (standard, petty or international). A product with a provisional patent may be labelled ‘patent pending’.

A patent may not help if - a country ignores the patent authority, a large company starts making a similar product and you don’t have the money to fight them, the patent is poorly written or is out of date. Some manufacturers in fast moving industries discard the patent process altogether by developing products secretly and marketing them before the opposition can catch up.

AIPO incorporates the Patent, Trade Mark and Designs Offices which administer the Patents Act 1990, the Trade Marks Act 1995, the Designs ACT 1906 and associated regulations as well as the Olympic Insignia Protection Act 1987 and the Scout Association Act 1924.

**Note on Copyright**

Written material automatically comes under copyright. It gives a level of protection, especially against duplication and sale. For example, this document you are reading cannot be photocopied and sold to someone else without agreement from the owner. Also, the diagrams and information contained in it were not taken straight from another book without permission. Educational use of material should always be acknowledged, failure to do this is an infringement of copyright laws - called plagiarism. This applies to journals, research papers and even student assignments!

Software piracy is an infringement of copyright and can be prosecuted in Australia. The high cost of development and the ease of duplication makes computer software vulnerable to duplication. Various other methods are employed to reduce piracy, such as hardware locks (dongles) and software designed for installation on only 1 machine at a time. Software companies can take legal action against unlicensed software users - particularly businesses.

**Resources & Contacts**

- IP Australia, PO Box 200, Woden ACT 2606
- Internet: IP Australia home page:  http://www.ipaustralia.gov.au
- IPAust CD ROM ‘Protecting your Edge with Patents’
- Australian Copyright Council, 3/245 Chalmers St, Redfern NSW 2016
- Circuit layout rights and other copyright issues: Business Law Division, Attorney General’s Dept, National Cct, Barton ACT 2600
- Inventors Associations in most capital cities
2.4 Design Checklist: Standards and Codes

1. **Regulations:** Determine any regulatory authorities that may require approvals, certification, or testing of the design. Eg Approved telephones, vehicle inspections, pressure tests on gas cylinders.

2. **Safety:** Identify possible safety issues relating to the design. Search for information on safe design, use of the equipment: Workcover has various books, pamphlets and other materials on work safety, such as using circular saws or protective footwear.

3. **Design Standards:** Search for Australian Standards relating to the design itself. Make sure you think about all aspects: For example, an electrically heated chair may need to be ergonomic (HB 59) and also comply with AS 3350 Safety of household appliances, as well as furniture construction, materials, paints etc.

4. **Design Process:** Consider standards relating to the design process. For example, engineering drawings to AS 1100, Guide to managing product design, AS 3950 etc.

5. **Standard Parts:** Keep in mind the standards relating to manufacture of the item or components used in it. For example, use standard metric thread sizes rather than your own. Generally, you should try to use standard sizes and methods of manufacture wherever possible.

6. **Quality:** Compliance with quality accreditation requirements where relevant. This may effect documentation of the design as well as manufacturing operations.

7. **Better than Australian Standards.** There may be more stringent standards applied (Eg Financial institutions may set a more demanding building standard - such as increasing the number of wall ties between brick veneer and stud wall by 20%). Local councils may set there own standards beyond the usual ones and these may need to be checked. Companies may also keep their standard of work above the standards. A label like ‘Exceeds AS****’ would indicate this.

8. **Oversea standards.** These may be needed if your design is not covered by Australian Standards, or where the product will be exported. Eg: Manufacturers of biomedical equipment for sale in the US must obtain FDA approval not only for the product but also for the manufacturing processes and records.
### 2.5 Review Questions

**Q1:** Which of the following services is NOT done by the Australian Standards organisation?
(a) Checking and revising information on equipment safety
(b) Ensuring companies comply with the relevant Australian Standard
(c) Selling design standards on different types of machinery
(d) Defining rules for electrical appliances

**Q2:** Select some Australian standards and name any regulatory authority in your area that would become involved if you:

<table>
<thead>
<tr>
<th>If you ...</th>
<th>Regulatory Authorities</th>
<th>Australian Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Designed a new carport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Needed 3 phase power to a factory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) Had doubts about the safety of a machine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) Burnt rubber tyres for an industrial heater.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e) Manufactured concrete railway sleepers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e) Wanted to be a quality accredited supplier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(f) Designed a 240V electric potato peeler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(g) Invented a new type of tap for showers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(h) Built a power boat &amp; trailer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Q3:** State the rules for photocopying of copyright material. (They should be posted at library photocopier)

**Q4:** Define how you might protect the intellectual property for the following; (Patent, trademark, registered design or copyright)

(a) A new shape of soft drink bottle

(b) An new type of electric mousetrap

(c) A symbol used for a logo on a machine

(d) A new herb

(e) A new herbicide

(f) A new herbicide dispensing pump

(g) An electronic control circuit for a herbicide monitoring instrument

(h) A computer program for the control of the herbicide meter

(i) Instructions for the general use of herbicides
Chapter 3

Design Issues

3.1 General Issues

A lawn mower is designed to cut grass. This is the function of the product and drives the whole design. Any successful design must achieve its function, but it may also be influenced to varying degrees by many other issues. Some are listed below;

**Compliance:** Standards, regulations, safety, work and quality practice, patents

**Performance:** Capacity, efficiency, reliability, life, load, power, size

**Economics:** Keep it simple, don’t over-specify, minimise labour, use cheap materials & processes, use standard components, watch out for setup costs & extras.

**Manufacture:** How easy it is to make, use of standard processes

**Modularity:** Standardise to allow easy modification, extension of product.

**Utility:** More than one use of the product or component

**Innovation:** Invention, new application or method

**Appearance:** Aesthetics, image

**Repairs:** Disposable or repairable strategy?

**Commitment:** It gets more difficult to change a design after commitments have been made. Try to get the design right the first time and resist or minimise design changes once production has started. Check all consequences before going ahead with engineering design changes.

**Risk:** Conservative managers prefer smaller, cheaper, or proven methods

**Patents:** Covering yourself or not infringing other patents

**Market:** What else is on the market, who will buy it?

**Analysis:** Analysis tools, knowledge, methods - mathematical, simulation, modelling

**Resources:** How much can you spend on design?

**Timescale:** How much time do you have to design it?
3.2 Functional Performance

Functional performance is simply how well it does the job.

But there is more to it. There might be more than one job - different functions, uses or applications of the product.

There are also various ways of measuring 'how well' something performs. For example: Different people might think a car performs well if - it accelerates quickly, it corners well, it runs economically, it carries a lot of luggage, it goes over rough terrain or it works reliably. But there are many other functions it may have to do, and a level of performance for each. For example; safety (active and passive), replacement parts and servicing expenses, appearance, life, resale value, prestige, legroom, theft risk, comfort, towing, etc. We may also measure the performance of additional systems like air-conditioning, cruise control, sound systems etc)

Functional Performance Factors

**Safety:** Design for health and safety throughout the product life cycle. (See Ch 2: Regulations)

**Ergonomics:** Ease of use, comfort, assists work. (See Ch 5: Ergonomic Concerns)

**Capability:** Power, speed, capacity, compactness, accuracy, repeatability, rating

**Reliability:** Low failure rate, MTBF, failure consequences

**Efficiency:** Energy utilisation, minimal power requirements

**Life:** Time or amount done before thing is scrapped, how long it lasts

**Environmental:** Emissions, manufacture, recycling, fossil fuels, contamination & hazards

Explanations of some Functional Performance Factors

**Efficiency:** Normally defined as output compared to input and expressed as a percentage. You should to use energy measures like work (Joules) or power (Watts). An indicator of lack of efficiency is heat, noise, vibration, deformation, turbulence, incomplete combustion and any energy wastage.

**Rating:** This is the highest level of performance allowed. A safety factor can be used to ensure the rated load is well below the overload level. The safety factor is increased if failure is dangerous, exact loads are estimated or hard to predict, or by regulation.
Reliability: This is the likelihood of the product performing correctly (under normal use). A reliability of 1 (or 100%) means that the item never fails, and a reliability of 0 means it never works. A more complex machine tends to have lower reliability because there are more things to go wrong. Two parallel processes making the same thing increases the reliability. MTBF stands for mean time between failures, which can also be a measure of reliability, (Eg 550 hours of use being average time between failures).

3.3 Market Focus

Price: (See Ch 4: Economic Pressures)
Economy: Combination of operating costs, price, life and resale value.
Maintenance: Ease of repair, spare parts pricing / delivery, servicing requirements
Warranties: Length or measure of warranty, extent of what is included in warranty
Aesthetics: Appearance, perceived image (See Ch 5: Ergonomic Concerns)
Identification: Prestige or ‘in’ thing, well-known brand/company
Marketing: Advertising, packaging, sales strategies

3.4 Design Checklist: Design Issues

PHYSICAL PROPERTIES: Density / Thermal - melting point, softening temperature, conductivity / Electrical - insulation, conduction, / Chemical resistance - oxidation, aging

MECHANICAL PROPERTIES: Strength / Stiffness - rigidity / Flexibility, elasticity / Toughness - resilience, impact resistance, energy absorption / Hardness - wear & abrasion resistance, indentation resistance / Plasticity - ductility, malleability / Creep resistance

GEOMETRIC ATTRIBUTES: Size - length, area, volume, perimeter / Shape - length to diameter ratio, 2nd area moment, proportion / Tolerances - Length, flatness, roundness, parallelism, perpendicularity / Degree or fit / Surface roughness /

DYNAMIC ATTRIBUTES (MECH) - Distance / Velocity / Acceration / Force / Power / Energy - work / Efficiency / Power to weight ratio / Vibration / RPM /

OPERATIONAL ATTRIBUTES - Reliability / Response / Linearity / Fidelity / Precision

INVENTIVE ATTRIBUTES - Innovation / Specialisation / Utility / Modularity / Elegance

ENVIRONMENTAL ATTRIBUTES - Emissions / Material - toxicity, degradation, recyclability, processing detriment / Sustainability / Contamination - hazards
3.4 Review Questions

Q1: List products corresponding to each of the functional performance factors;
(a) Speed  (f) Wear  (k) Efficiency  (m) Wear
(b) Volume  (g) Volume  (l) Efficiency  (n) Wear
(d) Power  (h) Size  (i) Efficiency  (o) Wear
(e) Size  (j) Size  (k) Efficiency  (p) Wear
(f) Wear  (l) Size  (m) Efficiency  (q) Wear
(g) Efficiency  (n) Wear  (o) Efficiency  (r) Wear
(h) Accuracy  (p) Wear  (q) Efficiency  (s) Wear
(i) Quietness  (q) Wear  (r) Efficiency  (t) Wear
(j) Water resistance  (t) Wear  (u) Efficiency  (v) Wear
(k) Clarity  (v) Wear  (w) Efficiency  (x) Wear
(l) Heat resistance  (w) Wear  (x) Efficiency  (y) Wear
(m) Long life  (x) Wear  (y) Efficiency  (z) Wear
(n) Compactness  (z) Wear  (aa) Efficiency
(o) Fidelity
(p) Low vibration
(q) Cleanliness

Q2: List something that needs to resist:
(a) Weather  (f) Discolouration
(b) Cracking  (g) Mixture
(c) Stains  (h) Contamination
(d) Rot  (i) Oxidation
(e) Germs  (j) Conductivity

Q3: What could be used as a performance measurement for the following products?
(a) Computer
(b) Water filter
(c) Battery
(d) Clothes line
(e) Bridge

Q4: A chain saw has a reliability of 98% (assuming it has petrol and that the operator never fails).
If you have 2 chain saws, what is the overall reliability when;
(a) You have a lot of work on (i.e. both must start)?
(b) You have only enough work to keep 1 saw busy?

Repeat the above questions if each operator has a reliability of 95%.
(a)
Chapter 4

Economic Pressures

4.1 Economic Principles in Engineering Design

Money is one of the most powerful influences on a design. You can come up with a great design but the critical questions are...’How much will it cost?’ or ‘How much will it sell for?’

Cost verses price: The actual cost of making a product is always much less than the retail price. The cost is the material and labour expenses in making the item, as well as the use of machinery, electricity, floor space, and everything related to manufacture of the item. Other expenses and overheads need to be paid for like salespeople, advertising, insurances, transport, administration, warranties and sales tax. You still hope to make a profit too!

The mark-up varies from product to product; a builder might make 20% on the cost of a house, but a plastic gismo might cost $5 to make and sell for $19.95. (400%!). However, the injection moulded gismo needs a hardened steel mould (say $20 000), an expensive moulding and some way of getting them sold.

For such a product, small savings in the manufacturing cost can cause substantial reductions in the final price. Cutting $1 in labour might bring the price might go down by several dollars, with a lot more sales. (This is because things are proportional to the value of the item - Eg. Sales tax). This is why manufacturers try to shave every cent off the cost of making something.

High repetition: Making a large number of the same item reduces costs. Materials and components are cheaper as quantities increase (bulk discounting). The quantity of units being made can have a direct bearing on the methods of manufacture, which in turn, may influence materials and design.

![Production Quantity / Cost vs Design Variety](image)

Fig 4a shows the spectrum of manufacturing, from high volume (mass) production of a single design, to one-off manufacture of continuous unique designs. Automation is easier for mass production, whereas customised designs tend to be labour intensive. However, it is easier make sales if you can offer variety. (Maybe this is why people in manufacturing and marketing seem to have different priorities!)
**Economy of Scale:** The size of a business can have a bearing on manufacturing costs. Larger companies might have better production methods (automation), access to world markets, reduced shipping costs, more expertise etc.

**Amortisation:** Many high volume products that need a lot of money before production can begin. (Eg. Tooling, automation setup, programming, circuit design and testing). This cost can be divided into each unit sold (maybe $2.50) to pay for the preparation. Obviously the plan only works if sales are adequate.

For example: Polywantacraka Industries designed a modular plastic bird cage system with a total design and tooling cost of $120 000. How much profit do they need to make on each system to amortise the tooling over 10 000 units?

\[
\frac{120000}{10000} = 12
\]

**Break even:** The break even point is the number of items that need to be sold in order to repay the investment.

For example: Whiz-Bang Pty Ltd makes a circuit for an electronically controlled slow combustion heater. It cost $60 000 to develop ready for production. Each unit costs $7.50. Hotshot Fires Pty Ltd buys them for $25. How many units need to be sold to cover the startup investment?

\[
\frac{60000}{(25.00-7.50)} = 3429 \text{ units}
\]

In reality, break-even analysis can be more complex than this. Eg Not all the profit may go toward amortisation, costs may vary with quantity, there may be other uses for the circuit, cost differences between shifts, cost variations etc.

**4.2 Economic Design Constraints**

**Here are some pointers for keeping the cost of a manufactured product low:**

- Keep the design simple
- Higher volumes are cheaper
- Minimise labour
- Use cheap materials
- Use standard components
- Use cheap manufacturing processes
- Keep to as few processes as possible
- Design for minimal costs after manufacture
- Avoid changes to the design once finalised
4.3 Design Checklist: Economic Factors

The following hints for designing to save money are all competing against the pressure of safety, performance, appearance and reliability. They need to be read as follows:

Without compromising on safety, performance, appearance or reliability ...

Keep the design simple: Fewer parts, less moving parts, less motors or controlled mechanisms, smaller size.

Don’t over-specify: Keep tolerances wide for easier production, trim down (sizes, welds, fasteners, components) minimise ratings, strengths, materials

Higher volumes are cheaper: Aim for higher repetition, one type of design

Minimise labour: Less assembly work, easier assembly, labour content as late as possible in the assembly (avoid having high value-added sub-assemblies sitting around, or scrapped by later mistakes)

Use cheap materials: Design for weaker/softer/cheaper components where possible. Watch out for ‘bargain’ suppliers that can’t always deliver - you should have backup suppliers for key items.

Standardise: Use standard (off-the-shelf) items in the product when you can - try to avoid using customised or special size or designed components. Also aim for using the same thing throughout - material / fasteners / finishes / fittings / sizes / connections

Use cheap manufacturing processes: Low labour, quick and low resources cost. Watch out for hidden costs like glass filled plastics wearing out machines faster, disposing of hazardous by-products.

Keep to as few processes as possible: Avoid re-heating/re-working/ re-clamping/ re-testing etc. Try to do as much as possible in one operation / setup / process. Aim for a minimum number of consecutive processes particularly if the processes require transport or time delays.

Consider setup costs: Check quantity and amortisation costs. Compare high tooling/low part costs (mass production) with low tooling/high part costs (job shop). Consider intermediate methods - flexible manufacture, CNC - lathe, mills, machine centres, turret punch, profile cutting, robotics, surface mount technology, and other flexible production methods.

Watch out for costs after manufacture: Storage (how long does it last, special temperature or pressure, size and shape suitable for packing). Transport (not damaged by normal transport methods, beware of unpressurised aircraft cargo / hot vehicle interiors etc). Designing for point of sale can save on packing & presentation (Eg. mould small plastic components left on sprue, printing a bar code on the product etc)

Avoid design changes once finalised: Try to get design right the first time and resist or minimise design changes once production has started. Changes to a design are very easy to come up with,
but the consequences may involve modifying tooling, production lines, work methods, re-
programming or getting new machines, changing stock, modifying repair manuals & advertising
brochures, and expensive re-work.

**Don’t make it if you can buy it cheaply:** Search for the components carefully before attempting
to design your own, especially if quantities are not very high.

### 4.4 Review Questions

**Q1:** Two inventors came to you asking for 20% of the retail price of a Smoke-Choke, a battery
powered miniature rangehood for ashtrays. They had spent $2000 making a rough but working
prototype. If you were the manufacturer, put forward your case for the costing of the product.

**Q2:** A plastic injection mould for a milk crate cost $100 000. The crate weighs 600g and the
plastic is worth $3 per kg. The total production cost of the moulding operation is $30 per hour.
They sell to the dairy cooperative for $4 each. If the cycle time is 20 seconds, find:
(a) The number of crates made in an hour.

(b) The production cost for each crate.

(c) The break-even point for the amortisation of the tooling

**Q3:** Compare the costs of manufacturing steel and timber house frames.
the person’s hearing. Ergonomics is about making the user comfortable, improving their performance at a machine, or reducing the chance of making errors.

Factors influencing the health or safety of people are treated as safety issues. Ergonomic design comes after the basic safety issues have been addressed. For example, a buzzer should *firstly* not damage the hearing, but *then* should be easy to distinguish from other sounds.

### 5.2 Application of Ergonomic Principles

Ergonomic factors need to be included early in the design process. This is especially true for things designed to be operated by a person (eg A car steering wheel), or used by the public. (eg. A staircase)

Their can be many design factors which relate directly to the design of the machine. There are basic things like size, shape, force, speed, colour and sound. More complex issues might be how easily a latch can be opened, how quickly a dial can be read, how comfortable a seat is.

Think what you are doing right now - reading. How well you can read (and understand) this page might be effected by...

- **Lighting.** (Would you like it brighter or darker, maybe natural lighting and a nice view?)
- **Print** (Quality of print & paper, size and style of letters, page layout, wording)
- **Table** (Would you prefer higher or lower? Sloping? Larger?)
- **Seat** (Seat height, padding, seat length, back support, angles, adjustments?)
- **Noise level** (Can you hear background music or a raging argument going on?)
- **Air** (Too hot, cold, humid, stuffy?)

We probably can’t fix all of these, but some of them might have been improved by the application of ergonomics, like the chair for example.

### 5.3 Ergonomic Factors

Before you design something to suit humans, you may need to find information from relevant Australian Standards. This might tell you how heavy a suitcase can be, how high each step in a staircase, the size and colour of a warning sign, ventilation requirements etc.

The following list is just to start you thinking about ergonomics early in a design process. Later, as the design becomes more detailed the ergonomic issues will become more specific.

A lot of human measurements are given in percentiles. For example, how tall are most men? 173 cm is the 50th percentile, meaning that 50% of people are shorter than this. The 5th percentile is a height of 162 cm, taller than 5% of males. If you are 185 cm or more you would be in the top 5%,
or the 95th percentile. A female who weighs 47 kg is heavier than 5% of females, at 62 kg they are heavier than 50%, and at 90 kg they are in the 95th percentile.

(Based on National Health Survey (US) 1965)

Usually, we can design equipment to suit only a limited range of people. We might have a car that can fit most people, but has trouble with the smallest 1% and those taller than 99%. The added expense of adjusting to fit the rare extremes is not justified by the few extra cars they might sell. In other cases we can make adjustment to suit nearly everyone (eg A backpack).

Other factors have rigid limits, like the maximum weight that should be lifted, or the lowest height of a safety railing. Many of these are safety issues.

**General Ergonomic Considerations:**

**Human Dimensions:** Height, weight, limb lengths and proportions

**Reach:** Seated, standing, left & right hands, feet, fingers, range of motion

**Strength:** Lifting (floor, waist level & overhead), hand grasp, foot pedals,

**Controls:** Size, force, spacing, labelling, arrangement

**Displays:** Size, colours, speed, lighting, symbols

**Warning:** Distinct sound or light, clear lettering, colours

**Environment:** Temperature, lighting level, humidity, vibration, drafts, noise level, pressure

**Others:** Reaction time, convenience, comfort, aesthetics, variety.

**Example.**
If you are making a staircase, how high should each step be?

This is up to the designer to a certain extent, but within limits. People expect steps to be a certain size since they are used to them.

Experience has shown that stairs should be within the dimensions shown.

Why isn’t there a standard step size?

(Eg. 250 x 180 mm)
5.4 Aesthetics

Aesthetic means ‘good looking.’ For a car this might mean smooth and glossy, or for a house brick rugged and rough. Of course, different people have different ideas about what looks good, which is why there are often many different designs of the same thing. (Eg Tap handles)

Designing something to be aesthetic is more an art than a science, but there are a few things worth remembering about appearance.

**Clean and tidy.** (Usually either hide internals, have functional details only, or neat throughout)
**Stick with the one style for object.** (Colour, material, roundedness, proportions, labelling)

For many products, specialists such as industrial designers and artists are used to ensure the product looks ‘right’. For many consumer goods this aspect may decide the sale. Careful study is done even for something like choosing the right colours. Don’t forget, the chosen colour may effect materials, paints, finishes, plastics, packaging design etc, so you can’t just change your mind later on.
5.6 Ergonomic Checklist

The following questions may prompt a machine designer where an operator is involved. It is assumed that safety issues have been dealt with already.

1. What does the person have to do - exactly?
2. Does the person need to see a lot?
   - **Picture:** Look directly or by a window, mirror, video monitor.
   - **Screens:** Watch a computer screen, message display.
   - **Indicators:** Dials- analogue or digital, lights, symbols, words.
3. Does the operator need more information?
   - **Sound:** Listen directly or by microphone, audible indicators
   - **Feel:** Force, vibration, movement, acceleration,
   - **Other:** Smell, temperature,
4. What is the mental side of the job like?
   - **Decisions:** Number of factors, calculation, estimation.
   - **Speed:** Response time.
5. What does the operator do to control it?
   - **Fingers:** Keyboard, mouse, touch-sensitive, switches, knobs.
   - **Hands:** Levers, handwheels, cranks
   - **Other:** Foot pedals, voice activated, complex movements
6. Are the controls arranged logically and work the normal way?
7. Check that all the above processes can be done by all operators. Ensure the dimensions, forces and other measurements are within the user’s capabilities. Check:
   - **Population:** Who will use it? Do you need to fit average, most (say 95%) or all users?
   - **Special cases:** Cold weather clothing, protective shoes, illiterate.
8. Is the working environment well-suited?
   - Check temperature, humidity, air quality, noise, distractions,
9. Is the nature of the work suitable in the longer term?
   - Boring, physically demanding, mentally draining, unsatisfying, frustrating.
10. Is it better to fully automate to remove the need for human interaction?
    - Remember: Machines are good at repetitive processes, but people are better when the job is varied, or when something unexpected happens.
5.5 Review Questions

Q1. List the human factors or measurements you may need to know when designing:
(a) A clothes line
(b) A door
(c) An electric hand drill
(d) An operating console in a lift
(e) A shopping trolley
(f) A balustrade (railing)
(g) A soldering iron

Q2. Give an examples of two products that would require information on;
(a) Human dimensions:
(b) Reach:
(c) Strength:
(d) Controls:
(e) Displays:
(f) Warning:
(g) Environment:
(h) Other:

Q3. Study the design of a small hand operated tool, listing the features that may have required ergonomic design. (Eg: Handle diameter & grip, lever force, weight, visibility of working area, adjustments, labelling)

Q4. Group products that need to suit:
(a) average, (b) most and (c) nearly all people.

Further Resources:
Chapter 6

Design Specifications

6.1 What is a Design Specification?

A specification is the goal a design must meet. It may be very detailed or quite simple. It may be set by the manufacturer or part of a compliance requirement. Constant reference is made to the design specification during the design process since the success of the design will be measured against it. Just as a drawing specifies the outcome of a manufactured component, a design specification determine the outcome of a design.

For example; A sheet of paper used for writing a letter might be specified as A4 and white - and for a simple purpose this might be an adequate specification. But you might need to add more to the specification. If you were in the printing business you might add particular details such as; a moisture content <5%, CIE whiteness of >98%, and a weight of 80gsm. If you were looking for paper to be used for record keeping you may require an archival rating according to ISO 9706. Others may require the paper to be plantation timber only, or even 100% re-cycled. There are many more factors like low water absorbtion, glossy or matt finish, thickness, tear strength etc.

6.2 Common Design Specifications

You can have a specification on just about everything to do with a product - a maintenance spec, an operating spec, a performance spec, a safety spec, a spec for transport and storage, even a spec for disposal. The various specifications that effect a product may need to be known early in the design process.

E.g. You have to design a special lifting arm for the back of a truck. It has to pick up a load of 700kg to a height of 5m. This information is part of a functional performance specification. But a trailer over 2.4m wide becomes a wide load with additional restrictions on its use, so if you were designing a the arm you would try to keep it under 2.4m in width. This is a functional performance specification applied from outside. The safety aspects, operating procedures and maintenance specifications would need to be addressed too.

The Functional Performance Specification

The Safety Specification

6.3: Specification Checklist

6.4 Review Questions
Chapter 7

Sample Procedures

7.1 Sample Mechanical Design: - Improving a Wheelbarrow:

Wheelbarrows come in a range of sizes from the cheap gardening variety to the heavy duty builder’s barrows. Most hardware stores carry a range of barrows, costing as low as $50 up to several hundred dollars!

We are looking for a barrow for the ‘Do It Yourself-er’, which means we are probably looking somewhere in the mid range. Unlike a builder who can write his tools off on tax, the price will be very important here.

**PRICE:**
We check a few shops and get the following information;

<table>
<thead>
<tr>
<th>Barrow Type</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheap garden barrow</td>
<td>$39</td>
</tr>
<tr>
<td>Standard garden barrow</td>
<td>$79</td>
</tr>
<tr>
<td>Light builder’s barrow</td>
<td>$99</td>
</tr>
<tr>
<td>Med builder’s barrow</td>
<td>$139</td>
</tr>
<tr>
<td>Heavy builder’s barrow</td>
<td>$189</td>
</tr>
</tbody>
</table>

The cheap one looks good so far. But the wheel was narrow (it would sink in the mud), the bearing very loose, the tray small, the frame looked frail and the handles were slippery steel tubes. Attempting to do some earthworks with this barrow might prove to be false economy!

**FUNCTIONAL PERFORMANCE SPECIFICATION:**
So in order to choose, we need to ask “What are we going to DO with it?”

Maybe the answer would be; “I want something near the capacity of a builder’s barrow but not necessarily as long lasting (rugged), since I won’t be using it every day - or treating it roughly.

The decision now is between the light and medium builder’s barrows. Is the extra $40 worth it?

Some functional performance factors for a wheelbarrow could include;
* Safety - They should all be safe. Sharp edges and breakage present risks.
* Capacity (tray size in litres / structural capacity in kg)
* Weight and dimensions - (May need to fit in the boot, light weight is less fatiguing)
* Resistance to impact - Tray strength, handles being knocked, dents and abrasion
* Resistance to corrosion - Rust, rot, plastic degradation, paint
* Ergonomics - Handle height and width apart, grip diameter and shape, centre of gravity of load,
* Rolling - Tyre width (soft ground), bearing life and rigidity, pneumatic or solid tyre
* Maintenance - Spares, repairs. (Could you buy a new tube in 5 years time?)
Other factors might arise for more specific use. For example: A plastic tray is good for cleaning cement off, a more rounded tray is less efficient for carrying bricks, timber handles give a better grip in the wet. Other factors - like aesthetics - should be fairly irrelevant here.

We weigh up the barrows, the price and the intended use - and spend the $99.

Fig 7a: The Light Builder’s Barrow

A DESIGN PROBLEM:

It looked nice in the shop. The light builder’s barrow had a capacity of 100 litres, (which is OK), and steel handles in place of timber (good for resisting rot). Apart from a slightly smaller wheel it seemed to be sturdy product.

Until it was fully loaded. Then you get this eerie feeling that the barrow was twisting and buckling. We will investigate this soon, but first of all let’s see what we have to do.

The design brief has 2 parts;

**PART A: Design a method to improve the barrow we have already bought.**

**PART B: Suggest a modified design suitable for high volume manufacture.**
The two handles have little torsional resistance between them. This means that if one handle takes more load, the tray twists and the barrow feels unstable.

![Fig 7b: Balanced Load - Tray square](image)
![Fig 7c: Unbalanced load - Tray skewed](image)

Further investigation shows that the legs of the barrow are also quite unstable when it is loaded. The legs have a parallelogram action if the loaded barrow is pushed from the side.

So the design problem is to get more torsional stiffness between the handles, and to make the legs more rigid. We’ve got about $10 to play with before the cost of the light barrow starts getting to close to the next model up. Production volumes are in the thousands. We don’t want modifications to tray or other high tooling components. Assembly should still be with bolts—preferrably the same size.

(That was a manufacturing specification you just read!)

**DEFINING THE PROBLEM:**

My job as an engineer or designer is to fix the rigidity problem. What’s the first step?

Check to see if it really *is* flexing under load! To do this I must have access to the real thing - put a fair bit of weight in it and try it out. How much weight?

Here are a few ways to *guesstimate*. There is no maximum load stated on the product so we have to make some educated guesses. For example;

**Guesstimate 1:**

Full of sand - say 120 litres (it is usually heaped up)
Density of damp sand - (rang up local sand supplier)
- 1 tonne is approx 0.75 cubic metres (750 litres)
So, 1 litre sand = 1.333 kg
120 litres = 160 kg *(Is this realistic?)*

**Guesstimate 2:**

How many bags of cement would you put in it? .... Say 3
So that weighs 3 x 40kg = **120 kg**
Guesstimate 3: Based on recommended lifting limits. (Phone call to Workcover)
At the time of writing, Workcover does not have a maximum lifting load -
the risk of injury is up to the employer to assess.
Several factors such as the number of times a load is lifted during the day,
the posture, height of the load, distance travelled, nature of the load all
have effect on the injury risk.
Recommendations are; Above 16 to 20 kg the risk increases significantly.
Above 55kg a mechanical lifting device should be used.

So we have to guesstimate again. People pick up bags of cement (40kg)
and these are more awkward to carry than the handles of a wheelbarrow.
We want to stay under the 55 kg level so let’s choose 50kg.

Taking moments about the wheel,
(clockwise moments as positive)

\[ 0 = (Mg \times 0.25) - (50 \times 9.8 \times 1.15) \]

\[ Mg = 2254 \text{ N} \]

\[ M = 230 \text{ kg} \]

(This is the human limit and does not include rough terrain, going
up a slope or tilting the barrow to empty it. This is a high estimation.)

Fig 7d: Free body diagram of forces on the barrow.

So we have 3 guesstimates: 160kg of sand, 120 kg of cement or a maximum recommended lift
giving a load of 230kg. Now we have to use some common sense.

230kg is about 6 bags of cement or 77 extruded bricks (or 58 solid bricks). Its about a quarter of
a tonne, the weight of 3 average men, or it would empty a concrete truck (5 cubic metres at 2.5
tonnes/m3) in 54 loads. This is pretty heavy going for a ‘light’ builder’s barrow.

We will choose 110kg
Note: It seems like a lot of work for a simple thing like estimating how much you can carry in a wheelbarrow. But it shows a very common problem that occurs when engineering meets the real world. We have to make some guesses!
When we do this it is always a good idea to check it will some common sense - or some alternative way to double check your estimates or calculations.

Since we have the product handy, it is a good idea to double check at this point. We load 37 extruded bricks into the barrow. (111kg). It doesn’t look overloaded. Its OK to pick up.

Now we can assess the stability. Figure 7e shows the side and rear views of the barrow. The cross bracing between the legs has a significant effect on lateral (sideways) stability.

![Fig 7e: Orthographic views of side and rear of barrow (3rd angle projection)](image)

Figure 7f shows the loaded barrow under a side load of approx 20kg (196N). The lack of lateral stiffness can now be measured - up to 40mm sway in the legs.

This presents enough of a problem to investigate further. It probably wouldn’t collapse but it may certainly fatigue fairly quickly if it did too much rocking.

![Fig 7f: Rear view the barrow under side loading](image)
CONCEPTUALISATION:

We have two design problems to address, both related to stiffness.

1. The torsional stiffness of the handles

2. The lateral stiffness of the legs.

PART A: Design a method to improve the barrow we have already bought.

The most obvious solution is to copy the bigger wheelbarrow designs. A timber support board is fitted under the tray which stiffens it up and reduces damage to the base of the tray when rocks are thrown in. Diagonal cross bracing is used between the front of the support legs. This keeps the area clear for the user’s feet when they walk.

So we will use 12mm plywood under the tray (the bolts look just long enough to take the extra thickness) and weld (careful - its pretty thin walled tubing!) two 25x3mm steel strips (or flats) onto the front of the legs.

If you don’t have a welder or don’t trust yourself you could just use bolts like the manufacturer did. Five 5/16” zinc passivated bolts, about 1 1/2” long. (An M8 x 40 will do)

![Diagram of components for improving stability of barrow]

That was easy wasn’t it?

It worked too. I couldn’t find any flat steel but a bit of pipe off an old roof rack worked fine. It is noticeably stiffer when loaded. The original cross-brace was removed which makes it easier to walk the barrow too.

Fig 7g: Components for improving the stability of the barrow (1 off)
PART B: Suggest a modified design suitable for high volume manufacture.

High volume design is a different matter. The product is strategically priced (under $100) and must stay that way. Remember - every dollar you add to the manufacturing cost can add several dollars to the final price. Since we have to keep well below the price of the normal builder’s barrow we probably can’t have more than $10 to $20 added to the sale price. This translates to something like $3 to $8 in manufacturing costs.

This is probably not enough to provide the modifications suggested for the one-off design. In fact, the timber base alone may cost this much. So how do we improve the design for a couple of dollars?

We need to come up with some ideas to solve these rigidity problems. It helps not to be too fussy about the ideas at first and be reasonably imaginative. Sometimes a silly idea can help you think of a good solution, so wait till later to get rid of the useless ones. Just get the ideas down.

Ideas:

1. It might be impossible to improve for this sort of money.

2. Perhaps we can re-design the legs to span both along and across. (Leg stiffness)

3. Weld a support bar between the handles and under the tray. (Handles)

4. Curve the handles under the tray to give torsional stiffness. (Handle stiffness)

5. Speaking of bending the handles, maybe the handles could be made by bending the tube around the front of the wheel. This might give enough torsional stiffness and would also do away with an extra bolting operation - as well as increase the strength of the wheel guard. (Handles)

6. Use bolted diagonal bracing as for PART A but ignore the tray support. (Legs)

7. Use sheet steel as bracing and continue it under the handles. (Legs and handles)

Some of these idea may be worth investigating if you had the resources, but we are looking for a minor modification only. There would be too much expense involved in altering the manufacturing processes for ideas 2,3 & 4 - something which is usually justified if the product will be cheaper to make, or sell better.

Idea 5 might be worth looking at, even though it is not a minor change because it may save on assembly costs. If it is technically feasible it might be a longer term improvement.

Ideas 6 is the common way a barrow is braced, making it a technically safe option as well as looking ‘right’ to the customer. Its success would depend on the cost of 3 extra bolts and 1 extra bar, as well as the labour for assembly. Idea 7 is a streamlined version of 6.

The next page shows some concept sketches of the more realistic options 5,6 & 7.
Fig 7h: Concept sketches for leg and handle stability for production barrows.
Idea 7 would definitely be worth prototyping. There may be problems getting the holes to line up with the legs. The thickness of the steel would probably be similar to the tray (0.8mm) but if it’s too light it could be damaged. Added thickness may also help to give more stability to the handles, though this would have to be tested. A powdercoated finish similar to the legs and tray would be the logical choice, or galvanised (zincalume) steel would serve the purpose.

For increased strength, the sheet metal brace may need a folded edge along the bottom. Let’s start with a gut feeling thickness of about 1.2mm.

Fig 7i: Fitting of steel sheet production barrows.

Fig 7j: The final design: A part drawing for the sheet steel leg brace.
7.2 Sample Electrical Design:

7.3 Sample Civil Design:

7.4 Design Study:
Suggested Resources


A thorough text covering design activity in general and the technical side of most of the associated engineering. Intended for students of Design and Technology and related Engineering subjects the book is almost a handbook on design technology. It can move a bit quick through some of the technical stuff (but there’s the non-technical stuff there too). It is an excellent resource, with questions throughout and answers to numeric problems. Up to date!