

INDUSTRIAL ECOLOGY – TERM PROJECT

A Design Project and Case Study

For the design project and case study, you are required to form teams of four students. Each group will select one of the following existing products:

- Office chair
- Desk telephone
- Bicycle
- Coffee maker
- Hand mixer
- Underwater disposable camera

and analyze its eco-efficiency using the knowledge and skills you will acquire during this course. The task comprises four key steps:

1. Disassembly;
2. Analysis of materials, energy and consumables used in product and product use;
3. Product redesign;
4. Suggestion for improvements of technical, cost and eco-performance.

Because the term project involves real-world activities, students should expect that there will be gaps in information needed on their topic, and that the criteria used to make recommendations may be ambiguous. Teams are expected to take full account of the uncertainty of their recommendation by highlighting data gaps and the sensitivity of recommendations to assumptions. In actual practice, analyses which highlight gaps in information, identify critical assumptions, and place bounds around a possible answer are often just as useful as analyses which are able to provide clear-cut solutions. Consequently, teams will be evaluated on the thoroughness and creativity of their analyses and recommendations.

Design Project Midterm and Final Report Requirements

In a written report of 15 to 25 pages (At midterm, the report may be shorter and only needs to cover the subjects covered to date) —single spaced, font size Arial or Times New Roman minimum 11pt, figures and tables included, appendix with raw data, eco audit output, *etc.* and references not included in page count—each group of students presents answers to the eco-design questions relevant to their particular case study. Drawings may be hand drawn or computer generated, and should demonstrate good engineering practice. The report should include an abstract, introduction, product and component description, detailed list of assumptions, eco design requirements and materials selection analysis (derivation of selection indices and property charts, *etc.*), a complete eco audit (energy, CO₂, water, *etc.*) a critical discussion, conclusions and references.

A very useful guide for report writing entitled “How to write a paper” can be found on the BBVista site of this course. The section *Examples for Environmentally-conscious Materials Selection Case Studies* may serve as inspiration for the material selection part of the report.

1. TITLE

- **Meaningful and brief**, in 14 pt bold.

2. ATTRIBUTION

- The names of the authors, with all initials;
- The Institute or organisation, with full address;
- The date.

Your name (bold), *your team members' names*,
Thayer School of Engineering, 14 Engineering Drive, Hanover, NH 03755, USA
XX May 2012

3. ABSTRACT

- Try for one sentence each on *motivation, objective, method, key results, discussion, conclusions*.
- Don't exceed 3 sentences on any one of the above points.
- Try not to exceed 100 words. Imagine that you are paying \$1 a word

“The reader of an Abstract has been lured by the title (if it is a good one). He or she now wants to know whether to read on. Tell them, in as few sentences as possible, what they will find. No waffle, no spurious details. Try not to exceed 100 words.” See Ashby's “How to write a paper” for examples.

4. INTRODUCTION

- **What is the problem and why is it interesting?**
- **What novel thing/result will you reveal?**
- **Thorough literature review to support the novelty of your finding.**

“Outline the problem and why it was worth tackling. Review the literature, recording briefly the main contributors and summarising the status of the field when you started the research. Provide any specialised information that the reader might need if he is to understand what follows. State what you will do that has not been done before (new experimental approach? new data? new model? new interpretation?) Keep it as brief as you can whilst still doing all this”.

Start with a good first sentence! See Ashby's “How to write a paper” for examples.

5. DISASSEMBLY

You will start by disassembling the product measuring and carefully documenting:

- Amount of time required for disassembly;
- Ease of disassembly; is it destructive or reversible?
- Tools required;
- Types and amounts (carefully of materials used in product;
- What consumables are required for products function (e.g. energy, water, filters, film)
- Scope for product take back (technical, economic, legal?)

using the CES Edu Pack Materials Selection and Eco Audit tools, taking into account the procedure and criteria outlined in the textbook, lectures and publications such as Lettenmeier et al. (2009), Wimmer et al. (2005) and the Delft University *EcoDesign Checklist* (see below for report grading scheme).

6. ECO AUDITS—ENERGY, CARBON FOOTPRINT, WATER

6.1 ECO AUDIT (ENERGY, CARBON FOOTPRINT) WITH THE CES EduPack

6.1.1 Assumptions and Methods

- **Experimental: materials, methods:**
 - Critically review and compare currently existing design solutions.
 - Show pictures, explosion drawings, etc.
 - What are advantages, disadvantages of existing solutions?
- **Modelling: assumptions, mathematical tools, methods**
- **Computational: inputs, computational tools, methods**
- **Give sufficient detail that the reader can reproduce what you did.**
- **Don't mix Method with Results or Discussion—they come next!**

“This should be an easy section to write: just say what you did, succinctly. Use “we” but do so sparingly: too many “we’s” sounds like a child’s day out: “first we did this, then we did that.” Build up a reference list as you go. See *Reference* Section for the way to deal with references. It is one of the principles of science that a paper should contain sufficient detail to allow the work to be repeated by someone else. Provide this but no more. Keep the results for the next section.”



- 1 litre PET bottle with PP cap
- Blow molded
- Filled in France, transported 550 km to UK
- Refrigerated for 2 days, then drunk

Number	Name	Material	Process	Mass (kg)	End of life
100	Bottles	PET	Molding	0.04	Recycle
100	Caps	Polyprop	Molding	0.001	Recycle
100	Water			1.0	

Transport

Stage 1	14 tonne truck	550 km
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Use - refrigeration

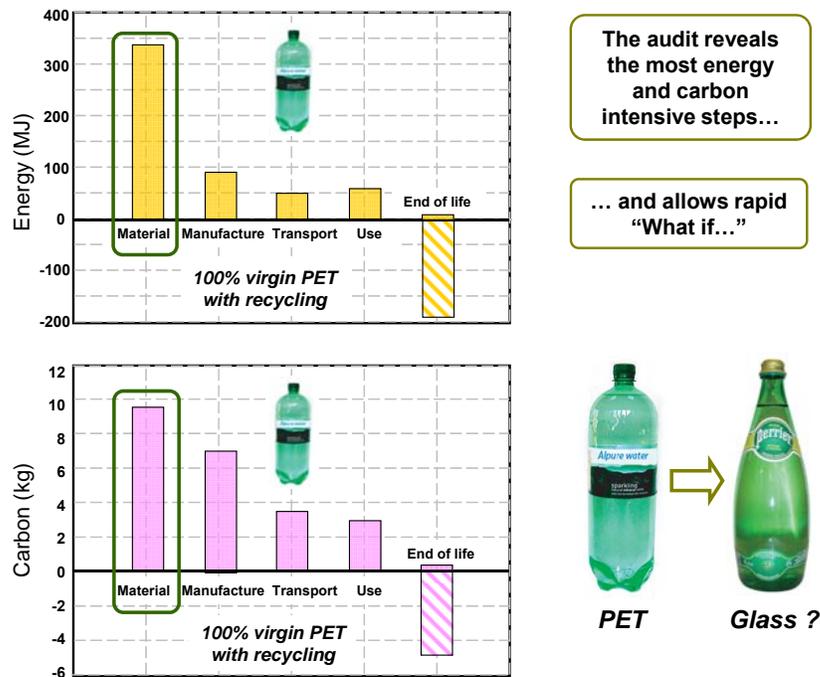
Fossil to electric	0.12 kW	2 days	24 hrs/day
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6.1.2 Results

- **Present the output of the experiments, model or computation.**
- **Don't mix Results with Discussion.**

“This, too, should be an easy section to write. Report your results simply, without opinion or interpretation at this stage. Define all symbols and units. Present data in a form other people can use. Give emphasis in the text the most important aspects of the tables,

graphs or figures. Give error-bars or confidence-limits for numerical or graphical data. Statistics should be meaningful; avoid confidence-eroding statements such as “33.3% of the samples failed: 33.3% survived; the third sample was unfortunately misplaced.” Aim for a concise, economical style. **Poor:** It is clearly shown in Figure 3 that the shear loading had caused the cell-walls to suffer ductile fracture or possibly brittle failure. **Better:** Shear loading fractures cell-walls (Figure 3).”



6.1.3 Discussion

- **Extract principles, relationships, and generalizations.**
- **Present analysis.**
- **Show relationship between the results and analysis.**

“Here you are seeking to extract principles, relationships, or generalisations from the results. Sometimes the results speak for themselves. Most of the research we do aims at why materials behave as they do, and this requires ideas about mechanisms, models and associated theory. The function of the Discussion is to describe the ideas, models and theories and lead the reader through a comparison of these with the experimental or computational data. Bring out the most significant conclusions first; develop subsidiary conclusions after that. *Be clear and concise; a Discussion is not a license to waffle.* See Appendix of Ashby’s “How to write a paper” for examples of waffle and what to do about it.”

6.1.4 Conclusions

- **List any reservations or limitations.**

“The reader scanning your paper will read the Abstract and the Conclusions, glance at the Figures and move on. *Do not duplicate the Abstract as the Conclusions or vice versa.* The Abstract is an overview of the entire paper. The Conclusions are a summing up of

the advances in knowledge that have emerged from it. It is acceptable to present conclusions as a bullet-pointed list.”

5.2 WATER AUDIT USING CES EduPack and/or WUPPERTAL Water Consumption Values

Repeat the above to estimate life-cycle water consumption/footprint of product.

5.2.1 Assumptions and Method (same logic as above)

5.2.2 Results (same logic as above)

5.2.3 Discussion (same logic as above)

5.2.4 Conclusions (same logic as above)

7. ECO-(RE)DESIGN—How can Materials-related Choices Improve the Product’s Eco efficiency?

6.1 DESIGN REQUIREMENTS

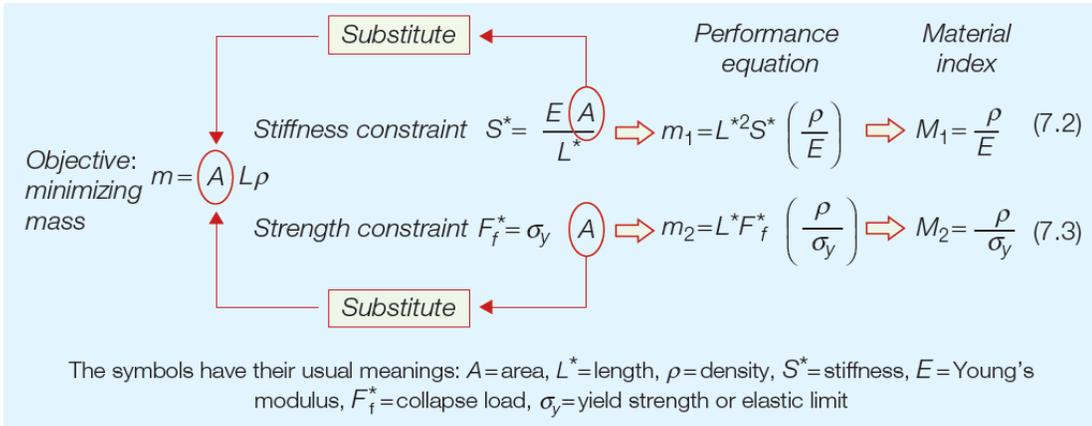
(see lecture notes and case-studies for examples—the below list is NOT complete)

Function	Packaging: Protective material Cutlery: Beam/plate in bending Water filtration device: Filter held in frame; e.g. frame=plate in bending Water bottles: Container, e.g. a pressure vessel
Objectives	Packaging: e.g. Maximize energy absorption per unit weight or per unit volume (depending on application); Minimize cost and eco-impact. Cutlery: Minimize amount of material used, thus mass, per unit of function (e.g. meal served)?; Minimize cost and eco-impact. Water filtration device: Minimize amount of material used, thus mass, per unit of function (e.g. filtration of 1l)?; Minimize cost and eco-impact. Water bottles: Minimize amount of material use, thus mass, per unit of function? Minimize cost and eco-impact.
Objective function	Use “Useful Solutions” to derive the respective functions
Constraints	Packaging: load on packaged article < damaging load; Cutlery: e.g. stiff enough, strong enough. Water filtration device: stiff enough, strong enough. Water bottles: e.g. stiff enough, strong enough
Free variable	Depends on model used: e.g. thickness of packaging material, cutlery, filter frame and bottles. Depends on component shape: e.g. plate (thickness), beam (cross-sectional area), etc.

6.2 THE MODEL—DERIVATION OF MATERIALS INDICES

(see lecture notes, textbook and case-studies for examples)

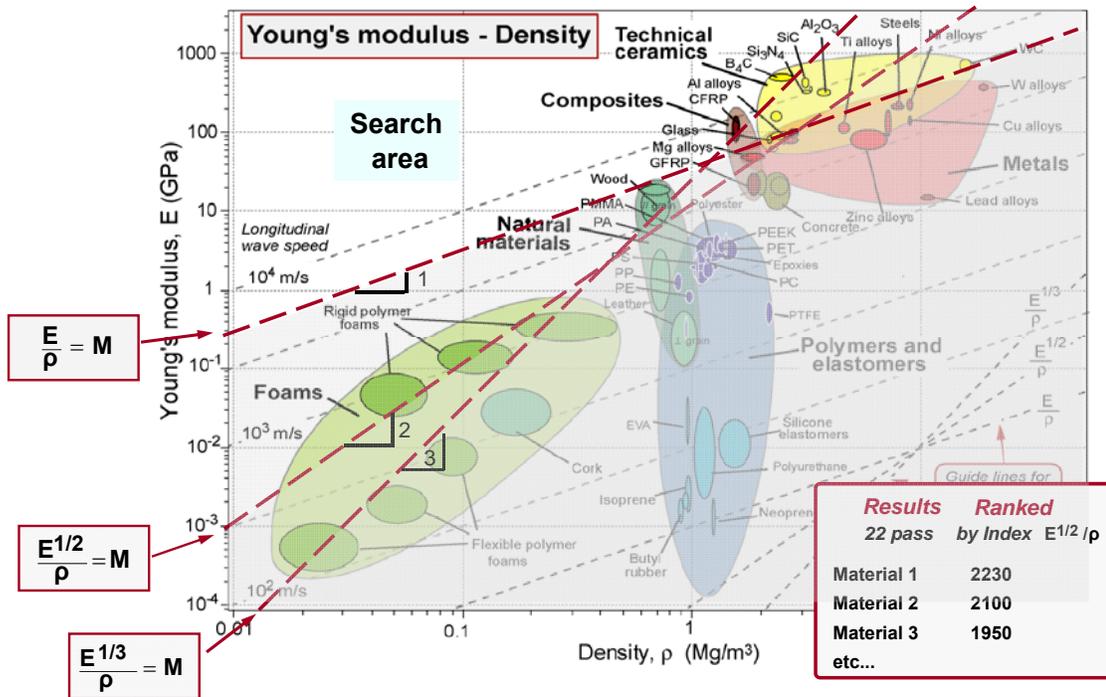
- **One Objective, Multiple Constraints: e.g. stiffness and strength**



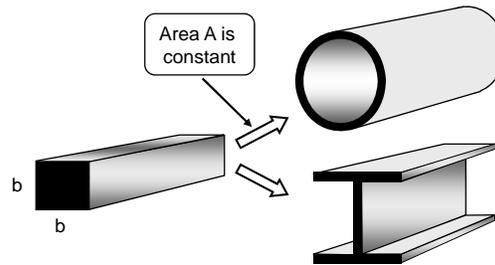
6.3 THE SELECTION—MATERIALS INDICES APPLIED TO MATERIAL PROPERTY CHARTS

(see lecture notes and case-studies for examples for all of the below)

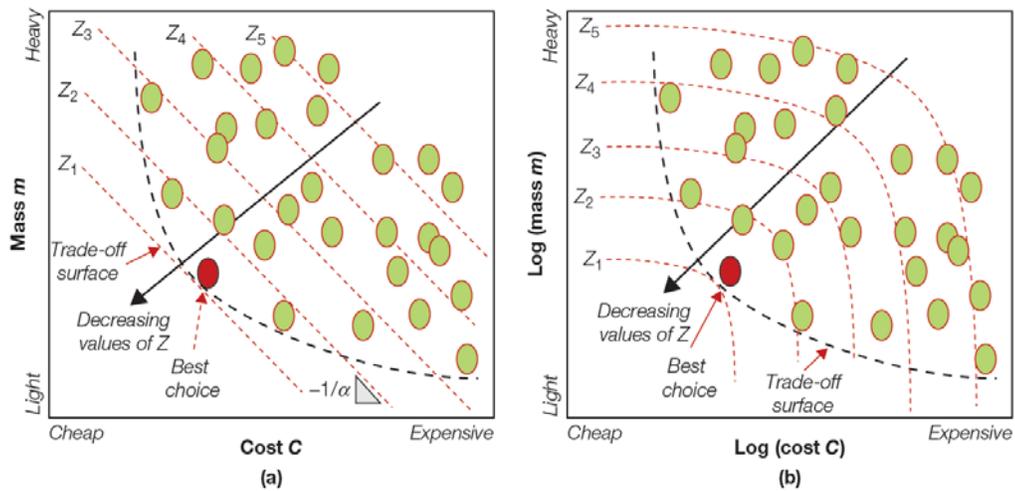
Make sure to calculate Material indices and apply the appropriate selection lines to the appropriate Property Chart!



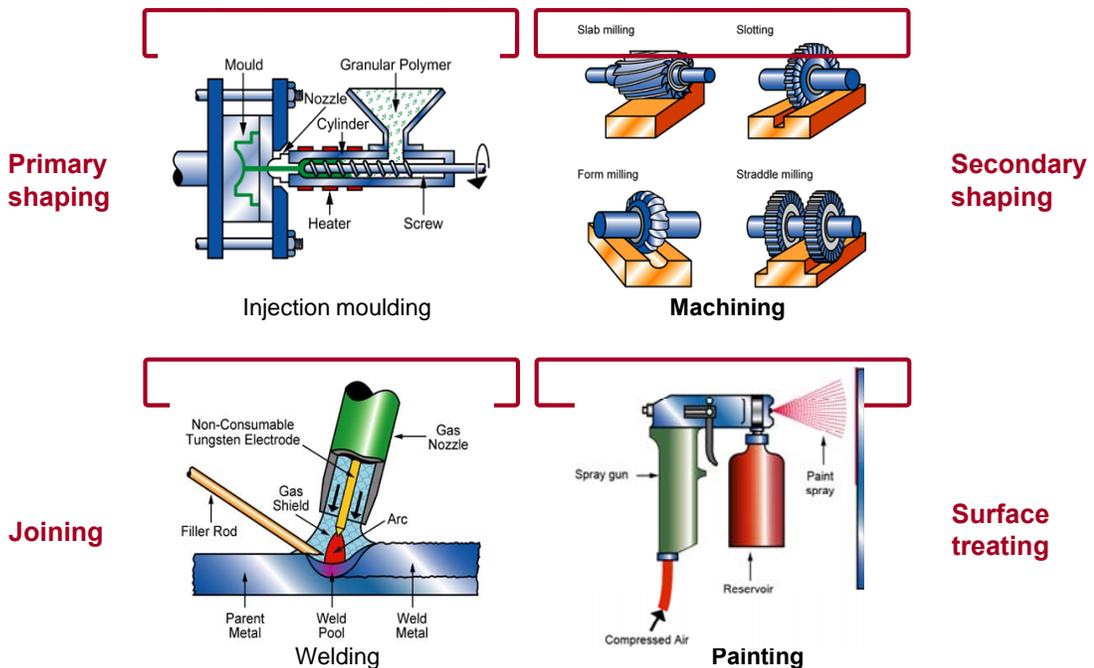
- **Effect of Shape**
(see lecture notes and case-studies for examples)



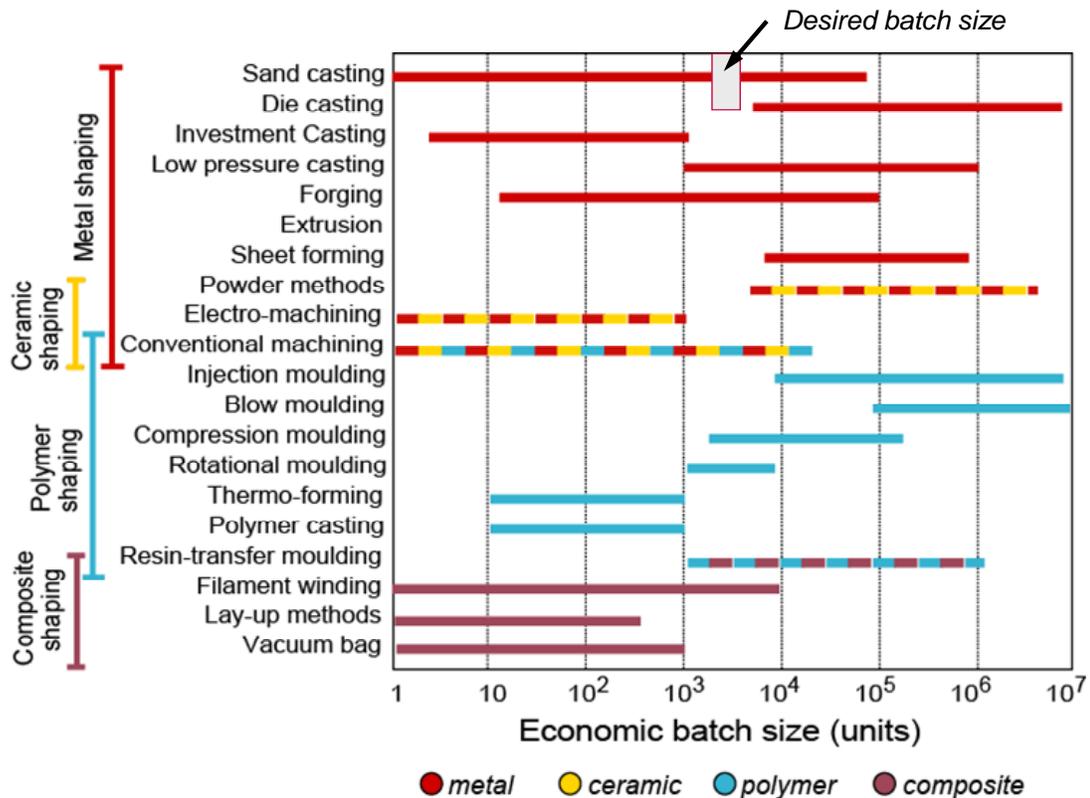
- **Multiple Constraints and Trade-Off Strategies**
- **Multiple (Conflicting) Objectives and Trade-Off Strategies**



- **Processing**



- **Economics**



6.4 RESULTS of materials selection

(see lecture notes and case-studies for examples)

6.5 DISCUSSION of materials selection RESULTS

(see lecture notes and case-studies for examples)

6.6 CONCLUSIONS drawn from materials selection study

(see lecture notes and case-studies for examples)

8. RESULTS of entire CASE STUDY

9. DISCUSSION of entire CASE STUDY

10. CONCLUSIONS drawn from entire CASE STUDY

11. ACKNOWLEDGEMENTS

Thank people who have helped you with ideas, technical assistance, materials or finance.

“Keep it simple, give full names and affiliation, and don’t get sentimental. A formula such as this works well: I wish to thank Prof. L.M. Brown of the Cavendish Laboratory, Cambridge, for suggesting this review, and to acknowledge my debt to the books listed below.”

or:

“The authors wish to thank Professor A. G. Evans of Harvard University for suggesting the approach developed in section 4.3; Mr A. Heaver for his technical assistance throughout the project and Mrs Jo Ladbrooke for proof-reading the manuscript. The research was supported by the EPSRC under grant number EJA S67, by the DARPA-ONR MURI program under contract number N00014-1-96-1028, and by a Research Fellowship from the National Research Council of Canada.”

12. REFERENCES

- **Cite significant previous work.**
- **Cite books, journal papers —not only webpages (see grading scheme)!**
- Take advantage of the literature on the reference shelf in the library, as well as literature posted on BBVista, material distributed during the classes, etc.!
(see reference list in syllabus and book shelves in Hagerty for inspiration)
- **Cite sources of theories, data, or anything else you have taken from elsewhere.**
- **References must be complete: name, initials, year, title, journal, volume, start-page and finish-page.**

“References tell the reader where an idea, prior results and data have come from. It is important that you reference all such sources. It is a conventional courtesy to reference the originators of key ideas or theories or models, even if you modify them. There are almost as many different formats for references as there are journals. If you have ENDDNOTE on your PC it can solve the problem. Best for drafts is the Name/year system (also called the Harvard system):

In text : “Lu (1998)”. If there are two names then “Lu & Chen (1998)”. If there are more than two, then “Lu *et al.* (1998)”. In reference list, ordered alphabetically: “Lu, T.J and Chen, C. (1998) An Analysis of Defects in Metal Foams, *Acta Mater.* 15, 222-226”.

For papers: Name, initials, year, title, journal, volume, start page end page.

For books: Name, initials, year, title, publisher, city and country of publisher, chapter number, start page-end page (if relevant).

All are important. Do not be tempted to make a reference list without all of these. It takes far longer to track down the missing information later than to do it right in the first place.”

13. FIGURES

- **Schematics show how equipment works, or illustrate a mechanism or model.**
- **Drawings and photographs illustrate equipment, microstructures etc.**
- **Flow charts show methods, procedures.**
- **Graphs plot data.**

“Anyone scanning your paper will look at the figures and their captions, **even if they do not read the text.** Make each figure as self-contained as possible, and give it both a title (on the figure itself) and an informative caption (below it). Make sure that the axes are properly labelled, that units are defined and that the figure will tolerate reduction in size without becoming illegible.

Label each curve of graphs. Good figures are reproduced or imitated by others, often without asking—the sincerest of compliments.”

14. APPENDICES

- **Essential material that would interrupt the flow of the main text, such as the complete Eco Audits (CES in and output) and Water Audit.**

“An appendix must have purpose; it is not a bottom drawer for the stuff that you cannot bear to throw away. It is the place for tedious but essential derivations, or for data tables or descriptions of procedures, that would disrupt the flow of ideas in the main text. It should be well structured and stand by itself. Give it a title:

“Appendix A1: The Equation for Toughness” The journal may set it in smaller type than the main text.

When you get this far, you have got a long way. Put the draft on one side for at least 48 hours. Get the graphs plotted, the figures drawn up, micrographs printed and references assembled. Do not tinker with the text yet. It is a good idea to have a check-list like the one on the last page of this manual; it helps you see where you are.”

DELIVERABLES

Students are expected to meet the following requirements during the course of the term project. Written and oral communications are important skills for the successful engineer, and will be taken into account at each project evaluation.

- Environmental performance evaluation of chosen product;
- Recommendations for several improvement options, with engineering and eco analysis, and cost estimates;
- In-class oral presentation near mid-term reporting on progress and outstanding issues;
- Oral presentation of project results at end of term;
- Final 20-25 page written report (including text, figures, and tables).

EVALUATION

The instructors will evaluate the students based on the following criteria:

- (15 points) Appropriateness and application of engineering systems
- (10 points) Quality and reasonableness of recommendations
- (5 points) Mid-term progress presentation
- (10 points) Final presentation and written report.

The project is worth a total of 40 points toward the 100 points for the entire course.

We wish you much fun in researching and writing the Final Report and much success in completing it.