ECOR 1010
Lecture 3

Engineering Reporting & Measurements, Dimensions and Units

Engineers – Do We Have to Write?

Ing Lishmajor

"The Gender Stereotypes of Petruchio and Bianca in Shakespeare's The Taming of the Shrew"

Term Essay for ENGL 2109 - Gender, Sexuality and Literature

Essays – No … But … *Reports* – Yes

J. Beddoes, H. Lagacé

"Calorimetric and Microstructural Study of an Al-Zn-Mg-Si Alloy"

Alcan International Ltd., KR-83/049, 2 Aug. 1983 (proprietary)

Introduction – Engineering Reporting

- You Will Be Judged By Ability To Write Well
  - $\Rightarrow$ In this engineering program and throughout your career
- Career Advancement Depends Partly On Writing Ability
- Not Literary Writing
  - $\Rightarrow$ Communications Skills In A Technical & Business Environment
- Never Too Soon to Refine Your Written Skills
  - $\Rightarrow$ You will never have adequate writing skill !

Reporting Topics - Formats

- Current Work:
  - Assignments
  - Laboratory Reports (for ECOR 1010 or other courses)
  - Resumé
  - Job Applications

- Early Career
  - Internal Memos
  - Progress Reports
  - Internal Technical Reports
  - Contribute To External Reports

- Later Career
  - Proposal Preparation
  - Technical Reports
  - Patents
  - Budget / Staffing Forecasts
  - Business Letters

Before Writing – Think About …

- Who Is The Reader ? — The "asker" / Your boss
- What Does Reader Already Know ? — That you work for her/him / The answer
- What Does Reader Want To Know ? — Whether you know the answer / Are you working?
- What Do You Want Reader To Know ? — That you know the answer / That you are working hard

When Writing Remember …

- What is the message you are trying to convey?
  - Purpose of report
  - Scope of work
  - Technical detail
- Who is your audience?
- Start by sketching out a table of contents
- Be consistent in your formatting
  - Style and references

Universal Rules

- Date and Sign Everything Written
- Be Clear and Concise $\Rightarrow$
- Avoid Jargon and Fancy Words
- Plan Content – Outline – Several Drafts
- Spell Checkers Are Only An Aid $\Rightarrow$
- Do NOT Leave Writing to the Last Minute
- **PROOF READ OVER AND OVER**

Be Concise and Clear

- Minimize Number Of Words $\Rightarrow$
- Avoid Verbs Turned Into Nouns

“Determination of procedure occurs at the committee level.”

“The committee determines procedure.”

- Use Strong Subjects

“The decision was made by the supervising engineer.”

“The supervising engineer made the decision.”

- Useless Adverbs

“The project was completed really well.”

“The project was completed well.”

Minimize Number of Words

"Objective consideration of contemporary phenomena compels the conclusions that success or failure in competitive activities exhibits no tendency to be commensurate with innate capacity, but that a considerable element of the unpredictable must inevitably be taken into account."

"The race is not to the swift,
nor the battle to the strong,
neither bread to the wise,
nor riches to those of understanding,
or favour to those of skill;
but time and fate happens to all."

Ecclesiates, chap. 9, verse 11.

You have to be lucky!

Spell Checkers

I have a spell checker

It came with my PC

It plainly checks *four* my *revue*

Mistakes I cannot *sea.*

I've run this poem *threw* it,

I'm sure *your please too no*

Its letter perfect in *it's weigh*,

My checker *tolled* me *sew*.

- Vigorous writing is concise. A sentence should contain no unnecessary words [and] a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts. This requires not that the writer make all his sentences short, or that he avoid all detail and treat his subjects only in outline, but that every word tell.

Elements of Style, William Strunk, Jr. - 1918

Qualities of a Good Engineering Report

- Clear statement of purpose
- Concise presentation of detail
- Logical development of data and ideas
  - Analyze, explain, conclude, recommend
- Objective separation of fact and opinion
- Organized layout
  - Well-spaced headings and visuals
- Has adequate references
  - No plagiarism or “forgotten” references
- Has no spelling or grammatical errors
  - No slang or jargon

Comprehensive Engineering Report

- Title Page
- Executive Summary, Abstract
- Table of Contents, List of Figures, List of Tables
- Introduction
  - Any necessary background information
  - Reasons for writing the report
  - Concise statement of the objective of the laboratory
- Method
  - Detail the method used to fulfil the objective of the laboratory
  - What steps were taken?
  - What tools were used to solve the problem?

Comprehensive Engineering Report

- Results and Discussion
  - Present the findings of your work
  - Tables, graphs, and drawings can support this section, but must be accompanied by descriptive text (caption)
  - Only describe results that relate to the objective
  - Discuss any difficulties/anomalies that were encountered
  - Significance of your results
- Conclusions
  - Was the objective achieved?
  - Either paragraph or organized in point form

Comprehensive Engineering Report

- Acknowledgements
- References
- Appendices
  - Data tables
  - Graphs
  - Drawings

Not required to directly understand Results, Analysis, Discussion or Conclusions

Resumé

- Purpose $\rightarrow$ To Get Interview
- Content
  - Who Are You / Where Are You
  - Your Education
  - Your Work Experience
  - Technical Interests & Achievements
  - Volunteer & Community Activities - Leadership
- Personal Details Not Necessary (Age, Gender, Birthplace, Photograph)
- Academic Marks & Standing
- References - Available On Request
- Customize For Different Jobs

Covering Letter

- Concise, Formal, Respectful But Confident

- Confined To Specific Job
  - Indicate Knowledge of Job / Company
  - Why Hire Me ?

- Contact Details On Letter

- **PROOF READ OVER AND OVER**

Internal Memos

- Rapid Transfer Of Information
- Variety of Formats → Organization Specific
- Often Formal & Archival
- Usually Internal → Immediate Supervisor + Distribution
- Concise, But Not Necessarily Short
- Proper Grammar → Even In E-mail
  - Technical Information
  - Meeting / Trip Report
  - Production Summaries
  - Monthly, Quarterly Progress Reports

PRATT & WHITNEY AIRCRAFT OF CANADA LTD.

MEMO

2780-80-80-30600

12 March 1980

To: Mr. W. Abdel Messeh

From: J.C. Beddoes, Dept. 2788, Ext. 7611

Re: PT7A-1 Low Pressure Shroud Housing

cc: Messrs. D.L. Cook
F.C. Desrochers
H.B. Dunthorne
N. Khemchandani
H. Lavery
I. McCormick
U. Okapuu
A.D. Strelshik
K. Wilson/C. Briggs/ B.Plitz

C.F. #S-3373
S.S.F. #S-3168
S.S.F. #S-3168T

Distribution Including archival files

Ref: 1) Memo from J. Beddoes to W. Abdel Messeh, "PT7A-1, HPT Shroud Housing", dated 14 February 1980.

Introduction

The PT7 low pressure shroud housing was analysed to determine its acceptability from a stress point of view. Additionally, tip clearance for three operating conditions (ground idle, cruise, take-off) was determined. This memo summarizes the analysis and results thus obtained.

Clear statement of content

Conclusions & Recommendations

1) Steady-state cruise tip clearance is 0.015", based on an initial clearance of 0.033" and a pinch point of 0.006", see Figure 1.

2) The variation in tip clearance from leading to trailing edge is less than 0.001".

3) Shroud ring stress levels are well below the 0.2% yield stress of IN-718, the recommended material.

4) Shroud segment stress levels are high, but at no location exceeding the 0.2% yield stress of IN-792 MOD 5A, the recommended material.

Outcome of work

Shroud Housing Design

Details

The LPT shroud housing consists of two parts, the shroud segments and the shroud housing ring. Both these parts are cooled by T_3 air, bled from the cooling duct around the combustion chamber liner. A schematic of the cooling scheme is shown in Figure 2. A total of 0.5% cooling air is bled for the shroud housing. After air impinges on the shroud segment, it will join the hot gas by leakage between the shroud segments. The design and analysis of the LPT shroud segment is similar to that for the HP shroud segment. The HP shroud design is summarized in another memo (Ref. 1).

Project Proposals

- Development of Future Work
  - Marketing Proposal
  - Production Capability
  - Product Development
  - New Design
- Compete For Internal Capital Funds
- Compete For External Work
- Proposal Can Be Costly To Produce
- Contains:
  - Rationale For Expenditure
  - What Is To Be Done
  - Schedule
  - Risks
  - Capability Of Project Group
  - How Will It Be Done
  - Budget
  - Major Potential Problems
- REMEMBER - You May Have To Do What You Propose !

Technical Research Papers

- Concise Summary of a Significant Technical Advance
- Structured Format:

  Abstract, Introduction, Procedural Details, Results, Discussion
  Conclusions, Acknowledgements, References

- Information Becomes Public
  - Free Of Commercialism
  - Cannot Directly Criticize Competitors Product or Process
- Corporate Policy For Release Of Information
  - Internal Technical Reports
  - Frequently Confidentiality Agreements

JOURNAL OF MATERIALS SCIENCE: MATERIALS IN MEDICINE **10** (1999) 389–394

The influence of surface condition on the localized corrosion of 316L stainless steel orthopaedic implants

J. BEDDOES, K. BUCCI
Department of Mechanical and Aerospace Engineering, Carleton University, 1125 Colonel By Drive, Ottawa, K1S 5B6, Canada

Abstract
< 200 words.
Statement of contents
and significance.

The localized corrosion of austenitic stainless steel 316L intended for use as orthopaedic implants is determined as a function of the surface condition and metallurgical state. From the examination of samples exposed to a ferric chloride solution, at both 22 and 37 °C, the independent contribution of crevice and pitting corrosion to localized corrosion is determined. Both forms of localized corrosion occur to a greater extent at the higher temperature. The results indicate that weight loss measurements may not be sufficient to determine the extent of crevice corrosion separately from the influence of pitting corrosion. More importantly, the surface conditions required for the best resistance to crevice or pitting corrosion differ. Electropolished surfaces provide the best resistance to crevice corrosion, while ''bead blasted'' surfaces provide the best resistance to pitting corrosion. The implication of this result in terms of the serviceability as orthopaedic implants is discussed. The current results indicate the cold-worked state exhibits improved resistance to pitting corrosion. However, the influence of the metallurgical state could not be separated from a possible compositional effect.

Background information
to put report into
context

1. Introduction

Type 316L stainless steel is the most popular metal for use as osteosynthesis plates for orthopaedic applications. This popularity stems from a satisfactory combination of good mechanical properties and reasonable cost. However, during exposure to physiological environments the protective surface oxide inherent to 316L is not stable [1], causing both crevice and pitting corrosion to occur [1–3]. Analysis of retrieved implants reveals that even after exposure times as short as 2 months crevice corrosion is evident [4]. While it is uncommon for the pitting and crevice corrosion to be sufficiently extensive that mechanical failure occurs, corrosion releases metallic ions into surrounding tissue leading to inflammation and possible loosening of the implant [5]. Furthermore, there is concern regarding the accumulation of metallic ions, released by corrosion, within internal organs [6]. Pitting and crevice corrosion have resulted in the premature removal of 316L implants [4].

In light of the foregoing, the localized corrosion of 316L for orthopaedic applications has been extensively studied. It is well established that the initiation of both pitting and crevice corrosion is associated with the presence of sulfides [7, 8]. As a consequence the maximum sulfur content of 316L for implant applications is 0.01 wt % [9]. The surface condition of the implant also has a major influence on the resistance to localized corrosion. Generally, reducing the average crevice gap increases the susceptibility to crevice corrosion [10]. However, surface grinding may be detrimental to crevice initiation [11], since it produces residual surface stresses, while electropolishing improves corrosion due to the reduced surface area, removal of the disturbed layer left by grinding, removal of imbedded contaminants, and development of a protective surface film [1, 2, 11].

Type 316L bone fixture plates can be implanted in either the cold-worked or annealed condition. The former provides higher strength, but during surgical procedures the latter is more easily formed to bone contours. Previous investigations suggest that the cold-worked condition is more susceptible to crevice corrosion [2, 12], probably due to an increase in the internal stress.

Clear statement
of purpose

The purpose of the work presented in this paper is to determine the susceptibility to pitting and crevice corrosion at 22 and 37 °C of 316L surfaces prepared according to industrial practices for bone fixture plates. Accordingly, the results for five surface conditions are presented for both the cold-worked and annealed states. A limited number of samples of 304 are included for comparison.

2. Materials and experimental procedure

Approximately 50 316L samples with dimensions of 25 × 50 × 5.5 mm were supplied by a manufacturer of orthopaedic bone fixture plates. The samples were prepared from either annealed or cold-worked stock,

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Long term creep of TiAl + W + Si with polycrystalline and columnar grain structures

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Received 5 September 2004; received in revised form 2 December 2004; accepted 13 December 2004

Abstract
< 50 words.
Statement of contents and significance.

Abstract

The long term creep properties at 207 MPa and 760 °C of TiAl + W + Si with a fully lamellar microstructure and either polycrystalline grains or a columnar grain structure are compared. The results indicate that the columnar grain structure reduces the primary creep strain and delays the onset of tertiary creep, with only 1.2% creep strain after 10,000 h.

Keywords: Bridgman technique; Directional solidification; Titanium aluminides; Creep

Background Information to put report into context

1. Introduction

Compositions based on the TiAl intermetallic exhibit a desirable combination of strength, oxidation resistance, density and creep properties. This combination of properties makes them potential candidates for several elevated temperature applications in reciprocating and gas turbine engines. All of the envisaged applications are within a temperature and stress domain in which creep can be expected to occur and, therefore, the creep resistance of TiAl has been the subject of considerable attention. It is well established that maximum creep resistance of TiAl compositions is developed through heat treatment to the fully lamellar structure of alternating plates of the α_2 and γ phases [1]. Further, if the α_2 and γ lamellae are aligned with the loading direction an improved combination of mechanical properties can result [2,3]. The creep properties of nickel base superalloys can be improved through directional solidification that eliminates grain boundaries transverse to the loading direction [4,5]. Therefore, directional solidification of TiAl to produce a columnar grain structure combined with heat treatment to the fully lamellar microstructural condition may serve to maximize creep resistance, particularly if lamellae are aligned in the load direction. By comparing the long term creep properties of polycrystalline and columnar grained fully lamellar TiAl + W + Si structures this paper refines the definition of the microstructural characteristics necessary for maximum creep resistance and further elucidates the microstructural factors controlling creep of TiAl intermetallics.

Clear statement of purpose

The addition of W to TiAl can improve creep performance [6–8], however creep properties are sensitive to the presence of the W-rich β phase. In W containing TiAl compositions aging the fully lamellar structure in the $\alpha_2 + \gamma$ binary phase field (approximately 850–950 °C) causes β precipitates/particles to form along lamellar interfaces/grain boundaries. Comparison of the creep properties of aged and unaged fully lamellar structures demonstrates that β phase formation lowers the primary creep strain, but reduces the creep rupture life

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Patents

- Legal Document - Significant Initial and Ongoing Costs
- Provides Protection of Intellectual Property
  - Do You Need Or Want Protection ?
  - Usually Strict Corporate Policies In Place
- Must Divulge Technical Details
  - Product Patents More Common - WHAT
  - Process Patents Less Useful & Desirable - HOW
- Structured Format

  Field of Invention, Background of Invention, Summary of Invention, Description of Invention, Examples of Use, Claims
- Usual To Enlist Advice of Patent Attorney
- Lengthy Process - about 2 years from application to patent

United States Patent [19]

Saxena et al.

[11] **Patent Number: 5,897,922**

[45] **Date of Patent: Apr. 27, 1999**

[54] **METHOD TO MANUFACTURE REINFORCED AXI-SYMMETRIC METAL MATRIX COMPOSITE SHAPES**

[75] Inventors: **Pawan Saxena**, Gloucester; **Jonathan C. Beddoes**, Ottawa; **Ashok K. Koul**, Gloucester, all of Canada

[73] Assignee: **National Research Council of Canada**, Ottawa, Canada

[21] Appl. No.: **08/826,672**

[22] Filed: **Apr. 7, 1997**

[51] **Int. Cl.**[6] **C23C 4/08**; B22D 11/00

[52] **U.S. Cl.** **427/455**; 164/465; 427/422; 427/425; 427/427; 427/576; 427/177; 427/178

[58] **Field of Search** 427/576, 422, 427/455, 425, 427, 199, 200, 203, 205, 206, 180, 177, 178; 164/465

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,401,539 3/1995 Coombs et al. 427/422

5,480,676 1/1996 Sonoparlak et al. 427/180

Primary Examiner—Janyce Bell

Attorney, Agent, or Firm—Juliusz Szereszewski

[57] **ABSTRACT**

A composite part consisting of a metallic matrix and reinforcing fibers is fabricated by the simultaneous winding of the fiber and plasma spraying of the matrix onto a rotating mandrel, wherein an axi-symmetric part is produced with multiple layers of the fibers aligned in the circumferential direction. Single or multiple fiber strands are wound onto a mandrel and simultaneously sprayed with the heated powder matrix material using a thermal spray process. Rotation and translation of the mandrel produces an axi-symmetric composite part. The content of the fiber material in the plasma sprayed matrix is typically up to 40% by volume. The light-weight composite part is produced in a single processing step. The part may be used either directly, or as an insert in other components with or without further densification.

11 Claims, 4 Drawing Sheets

ECOR 1010 Lab Reports

- One page of text, plus front (title page) and back matter (appendices)
- Typed and neatly formatted
- Use Course Template: 12 point font size with fixed margins all around
- Drawings, tables, and graphs should be attached to the report as Appendices
- Drawings, tables and graphs should be supported by a short statement describing purpose and content (i.e., a caption)

Title Page

ECOR 1010 – INTRODUCTION TO ENGINEERING

FULL AUTHOR'S NAME

ASSIGNMENT #1

Assignment Title: ...

TO:

Marking TA Name: ...

Marking TA Email: ...

Lab Section: A1

Room: ME2556 – Carleton University

FROM:

Author's Email: ...

Student Number: ...

Word Count*: 278

Number of Figures and Tables: ...

Last Date and Time of Revision: DD/MM/YYYY @ HH:MM (AM/PM)

* Word Count is of all pages, including Title Page, Figures and Tables if applicable (it shows on the left-bottom corner of the MS Word status bar as "Words: ..."). It is just for the part of assignment prepared in MS WORD.

One Page of Text

- Introduction
  - background information, concise statement of technical objective
- Method
  - procedure to investigate objective
- Results & Discussion
  - present results related to objective clearly, refer to graphs, tables or drawing as required
  - details in Appendix
  - discuss difficulties or anomalies and significance of results
- Conclusions
  - list specific significant conclusions
  - state if objective achieved

Figures and Tables

- All Figures and Tables referred to in one page of text must be numbered and have a caption
- Immediately follow text (they are not part of Appendix)

Figure 1: Carleton engineering students at CFB Trenton.

Table 1: 1st Year Full-time Engineering Enrolment 2012

Program	Enrolment
Aerospace	131
Architectural C & S	50
Biomedical & Electrical	35
Biomedical & Mechanical	47
Civil	167
Communications	40
Computer Systems	64
Electrical	144
Engineering Physics	2
Environmental	56
Mechanical	156
Sustainable & Renewable Energy (A&B)	22 & 23
Software	57
Total	994

Appendices

- Sketches, drawings, tables, calculations, etc. and supporting text that provide additional detail to results.
- Each Appendix referred to individually in Results section
- But, each sketch, drawing, table, etc. in the Appendix does not have to be referred to individually in Results section.

Laboratory Reports – Other Courses

- PHYS 1004, CHEM 1101, CHEM 1000
- Make sure you are familiar with reporting requirements

A Couple of Web Resources

- Writing Guidelines for Engineering and Science Students: http://www.writing.engr.psu.edu/
  - Lots of links and examples
- Engineering Communication Centre (UofT): http://www.ecf.utoronto.ca/~writing/handbook.html

Summary

- Poor writing & reporting skills <u>will</u> impede your advancement at university & in your career
- Good writing & reporting requires practice
- **PROOF READ OVER AND OVER**
- There are many forms of technical writing, but always
  - Clarity
  - Conciseness
  - Accuracy
  - Courtesy
- Pay attention in CCDP 2100 - Communication Skills for Engineering Students

Measurements

- Physical quantity that has been observed.
  - Measurement compared to a standard quantity.
    - Standard quantity is called a unit.
    - Example: 1 kg is a standard unit.
      - e.g., mass of an object is 5 times greater than the standard unit, thus its mass is 5 kg.
  - A measurement consists of two parts:
    - A numerical magnitude and
    - A name, symbol, or combination of symbols that define the reference standard.

Measurements, Dimensions, and Units

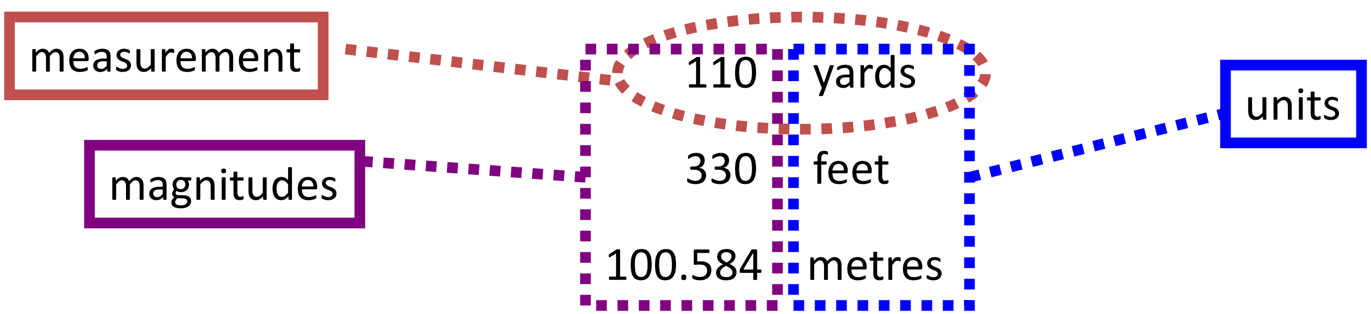
To explain these definitions, consider a CFL Football Field:

Dimension

The physical length of a CFL football field. The actual length of the field is constant, and does not change.

Measurements, Dimensions, and Units

The length of the field can be represented by various measurements:



Changing the unit changes the magnitude of a measurement, not the physical dimension!

Base and Derived Units

- Derived Unit
  - Derived in terms of base units
    - e.g. 1 Newton = 1 kilogram times metre per second squared
      - (N = Kg m/s^2)
- Base Units
  - Fundamental units from which all other units are derived.

Système International d'Unités (SI)

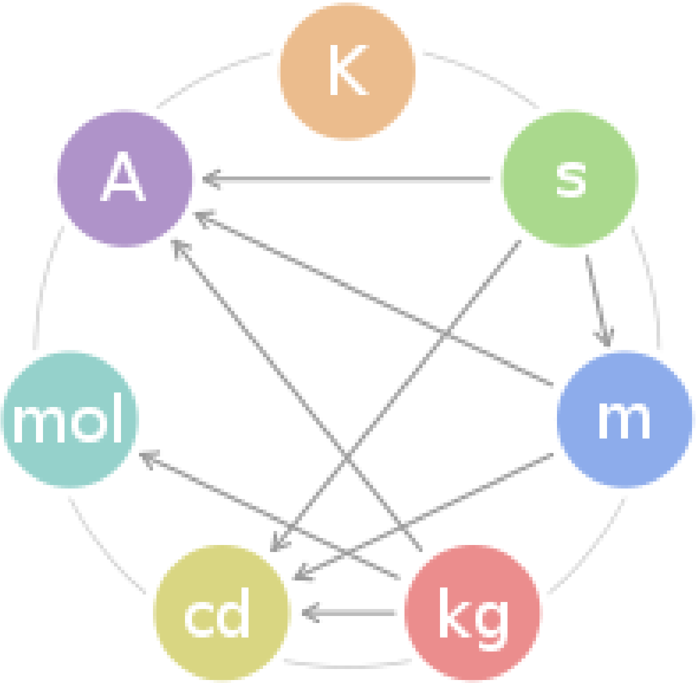
- Adopted by almost all countries
  - United States is a notable exception.
- Metric system introduced as measurement system "for all people, for all time".
- Metre was originally chosen to be one ten millionth of distance between north pole and equator.

Since 1983 the metre is the length of the path travelled by light in vacuum during a time interval of 1⁄299,792,458 of a second.

7 Base Units in SI

The International System of Units (SI) defines seven units of measure as a base set from which all other SI units are derived:

- metre for length
- kilogram for mass
- second for time
- Ampere for electric current
- Kelvin for temperature
- candela for luminous intensity
- mole for the amount of substance.



1 metre is practically = 1,579,800.762042(33) wavelengths of helium-neon laser light in a vacuum

Base and Derived SI Units - 1

TABLE 10.1 Base and derived SI units

Symbol	Unit Name	Quantity	Definition
~~M~~ → m	metre, meter	length	base unit
kg	kilogram	mass	base unit
s	second	time	base unit
K	kelvin	temperature	base unit
°C	degree Celsius	temperature	(kelvin temperature) − 273.15
N	Newton	force	$m \cdot kg \cdot s^{-2}$
J	joule	energy	$N \cdot m = m^2 \cdot kg \cdot s^{-2}$
W	watt	power	$J/s = m^2 \cdot kg \cdot s^{-3}$
Pa	pascal	pressure	$N/m^2 = m^{-1} \cdot kg \cdot s^{-2}$
Hz	hertz	frequency	s^{-1}

Base and Derived SI Units - 2

Electrical and Electromagnetic Units

A	ampere	current	base unit
C	coulomb	charge	$A \cdot s$
V	volt	potential	$J/C = m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
Ω	ohm	resistance	$V/A = m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
S	siemens	conductance	$1/\Omega = m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
F	farad	capacitance	$C/V = m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
Wb	weber	magnetic flux	$V \cdot s = m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
T	tesla	flux density	$Wb/m^2 = kg \cdot s^{-2} \cdot A^{-1}$
H	henry	inductance	$Wb/A = m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$

Base and Derived SI Units - 3

Dimensionless Quantities

rad	radian	plane angle	$m/m = 1$; $1/(2\pi)$ of a circle
sr	steradian	solid angle	$m^2/m^2 = 1$; $1/(4\pi)$ of a sphere
mol	mole	particle count	base unit ($\simeq 6.02 \times 10^{23}$)

Light

cd	candela	intensity	base unit
lm	lumen	flux	$cd \cdot sr$
lx	lux	illuminance	lm/m^2

Absolute and Gravitational Unit Systems

- SI unit system
  - *Absolute* system
    - Mass is a fundamental unit
    - Newton's second law (force = mass × acceleration) is invoked to derive force due to gravity.
- FPS unit system
  - *Gravitational* system
    - Force is a fundamental unit
    - Mass is derived from Newton's second law.
    - Distance, force, and time are fundamental dimensions, measured in units of <u>**feet, pounds, and seconds**</u>.

Comparison of Unit Systems

Table 10.2 Comparison of unit systems

	Dimensions	Absolute		Gravitational	Hybrid
		SI	CGS	FPS	American
Fundamental	Force [F]	–	–	lb	lbf
	Length [L]	m	cm	ft	ft
	Time [T]	s	sec	sec	sec
	Mass [M]	kg	g	–	lbm
Derived	Force [F]	newton ($kg \cdot m/s^2$)	dyn ($g \cdot cm/sec^2$)	–	–
	Mass [M]	–	–	slug ($lb \cdot sec^2/ft$)	–
	Energy [LF]	joule ($N \cdot m$)	erg ($cm \cdot dyne$)	$ft \cdot lb$	$ft \cdot lbf$
	Power [LF/T]	watt ($N \cdot m/s$)	erg/sec	$ft \cdot lb/sec$	$ft \cdot lbf/sec$
	Pressure [F/L^2]	pascal (N/m^2)	$dyne/cm^2$	lb/ft^2	lbf/ft^2

Forces and Gravity

- The application of gravity in Newton's Second Law (F = ma) presents several problems
- It is treated differently in each system of units

Comparison of Unit Systems

- Newton's Second Law: $F = ma$
- SI: $1\ \text{N} = 1\ \text{kg} \cdot 1\ \text{m/s}^2$
- American: $1\ \text{lbf} \neq 1\ \text{lbm} \cdot 1\ \text{ft/sec}^2$ → Does not work!

Re-write Newton's 2nd Law:

$$F = \frac{ma}{g_c} \qquad \text{where } g_c = 32.17\,\frac{\text{ft} \cdot \text{lbm}}{\text{lbf} \cdot \text{sec}^2}$$

Comparison of Unit Systems

Example:

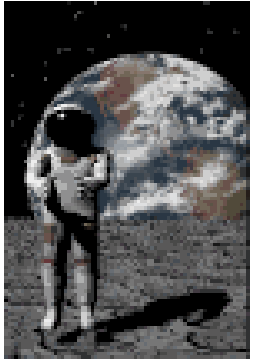
- Your mass is 120 lbm (54 kg). You jump off a cliff. What force pulls you to earth?
  - American:

$$F = \frac{ma}{g_c} = \frac{120\ \text{lbm} \cdot 32.17\ \text{ft/sec}^2}{32.17\ \dfrac{\text{ft} \cdot \text{lbm}}{\text{lbf} \cdot \text{sec}^2}} = 120\ \text{lbf}$$

  - SI:

$$F = ma = 54\ \text{kg} \cdot 9.81\ \text{m/s}^2 = 530\ \text{N}$$

Comparison of Unit Systems



- What about on the moon ? (Acceleration due to gravity is 0.2 that on earth)
  - American:

$$F = \frac{ma}{g_c} = \frac{120\ \text{lbm} \cdot (0.2) \cdot 32.17\ \text{ft/sec}^2}{32.17\ \dfrac{\text{ft} \cdot \text{lbm}}{\text{lbf} \cdot \text{sec}^2}} = 24\ \text{lbf}$$

  - SI:

$$F = ma = 54\ \text{kg} \cdot (0.2) \cdot 9.81\ \text{m/s}^2 = 106\ \text{N}$$

A metric lunch: 1 N = 0.2248 lbf

From *Introduction to Engineering Analysis* by K. D. Hagen, p. 30, 3rd Edition, 2008. Artwork by Kathryn Hagen.

Units !

- Your mass is: 77 kg = 170 lbm = 5.28 slugs = 12 stones & 2 pounds
- You weigh: 755 N = 170 lbf
- Just A <u>Few</u> Other Units !!

- 1 ton = 2 000 pounds (except in UK where it is 2240 lb, because a *hundred weight* is 112 pounds and 1 ton = 20 hwt !!)
- 1 tonne = 1 000 kg (or 1 Mg)
- 1 mile = 0.868 nautical miles = 8 furlongs = 80 chains = 860 fathoms = 1 720 yards = 5280 ft = 15 840 hands = 63 360 inch
- 1 BTU (British Thermal Unit = heat 1 pound of water from 60 to 61°F) = 778 ft·lbf
- 1 ton of cooling = 12,000 BTU/h (power to melt 1 ton of ice in 1 hour)
- 1 acre = 4 480 square yards
- Canadian tablespoon (teaspoon) ≠ US tablespoon ≠ Imperial tablespoon ≠ metric tablespoon
- 1 gallon US ≠ 1 Imp. gallon = 4 quarts = 8 pints = 160 fluid ounces = 153 shots = 102 jiggers
- 1 horsepower = 550 ft·lbf/sec = 2544 BTU/h = 746 W
- bushels, pecks, ångström, mil, rods, drop, dash, pinch, troy once, beer gallon (1.016 gallon), barrel, carrot, kip, fortnight, erg, dyne, bar, torr, calorie, etc., etc.

- Get Good Conversion Tables !!

How to Convert Units

Adding Apples and Oranges:

- You can only add things if they have the same units
- You cannot add 5 apples and 3 oranges
  - (unless you are making fruit salad)
- You must convert to common units

How to Convert Units

For arguments sake:

- 1 apple = 1 PoF   and 1 orange = 1 PoF
- So, you can write the first conversion as:

$$1 = \frac{1\text{PoF}}{1\text{apple}}$$

- Multiplying something by 1 does not change it, so number of apples times 1 PoF/apple gives the equivalent Pofs for the number of apples
- In the same way, oranges can be converted to PoFs

How to Convert Units

$$5\ \text{apples} \times \frac{1\text{PoF}}{1\text{apple}} + 3\ \text{oranges} \times \frac{1\text{PoF}}{1\ \text{orange}} = 8\ \text{PoF}$$

- Be a fanatic about units
- Take the time to write out and cancel units
- It is a very good habit to have
- If the units do not work out then you know you are doing something wrong
- Students who do not know how to convert units typically get 10% fewer marks on exams

Learn to be careful and neat

- Mistakes are easy to make if you are sloppy
- Engineering students can make mistakes, but engineers cannot
- Engineers work in teams in which they review each other’s work
- If your work is a mess and difficult to follow, people will not want to work with you
- If your work is difficult to follow, then people who assess your work might not see how brilliant you really are!

Reading Assignment

- Read Chapter 10