Format and Style Guide for Technical Reports

prepared by

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Address any comments, suggestions or corrections to this document to *link@usna.navy.mil*

I. The Formal Engineering Report

1. Introduction

The importance of the engineering report as a means of communication cannot be overemphasized. The report reflects directly on you, the writer. A well written report cannot cover up a poorly executed effort; however, a poorly written report can undo an excellent piece of engineering work. Therefore, it behooves all engineering students to master the art and technique of good report writing. Report writing is a skill that can be learned. It is not something that “you have or you don’t.” The sections that follow provide guidelines to help you develop such a skill. The result of a strong personal effort in developing a good report writing ability will serve you well in your professional military career.

Style. A simple but extremely important issue of style is noted. WRITE THE TEXT OMITTING THE USE OF PERSONAL PRONOUNS. Personal pronouns can distract the reader from the purpose of communicating results and conclusions to one of projecting the capability of the author. Remember, authorship is clearly indicated on the title page. Also, use the active sense rather than the passive sense with verbs (e.g. *Passive* - It was determined that the heat transfer was proportional to the temperature difference. *Active* - The heat transfer was proportional to the temperature difference.)

Grading Instructors emphasize different areas in course and report assignments. Though the relative weight may vary, consideration will be given to:

a. Accuracy of work
b. General appearance, grammar, and spelling
c. Quality of laboratory and computer work
d. Clear concise exposition of method and discussion of results
e. Construction of figures and tables
f. Quality and validity of conclusions.

2. Organization

There is no single format for an engineering report although most prescribed formats have many things in common. Normally the organization that is sponsoring the research and the report will prescribe the format. A typical detailed format is given below; however, you should understand that every report does not include each of these sub-topics. Your instructor will specify the required sections.

a. Title page
b. Abstract or Executive Summary
c. Table of Contents and List of Figures
d. Nomenclature
e. Introduction
f. Objectives or Purpose

g. Theory
h. Methodology or Experimental Procedure
I. Results or Summary of Results
j. Discussion
k. Conclusions
l. Recommendations
m. References
n. Appendices
  - Sample Calculations
  - Computer Programs
  - Lengthy Derivations
  - Uncertainty Analysis
  - List of Equipment
  - Apparatus and Procedure
  - Raw Data
  - Specifications (Instructor Handouts)

3. Brief Description of Report Sections

a. Title Page. Give the report a clear descriptive title. List all team members, the date of the report, course and section number, and instructor. Your instructor may specify a more specific format.

b. Abstract. This is a brief, concise summary of what was done, why it was done, and what major results were achieved. It should be no longer than one paragraph. Use terse, accurate wording, not conversational English. The point of the abstract is to give the reader enough information to decide if the report is of interest. It is best to write this section last. You cannot possibly write an acceptable abstract without having a conclusion formulated. The abstract should be a stand-alone document. **Do not make the abstract sound like an introduction or a problem statement!**

Executive Summary. An elaborate project might require, for clarity of presentation, a more detailed explanation than conveniently provided in a single paragraph. In such cases, replace the Abstract with an Executive Summary. An Executive Summary is a concise description of what was done and why, followed by separate sub-sections listing the results, conclusions, and recommendations. The requirement for an Executive Summary section is very common with government reports.

c. Table of Contents and List of Figures. List major topic headings and the page number where each begins. Do the same with the list of figures and number them in sequence. (Figure 1,2,3, etc...) See Appendix A.

d. Nomenclature. This section prepares the reader for a trip through any mathematical development you may have, and any symbols and abbreviations used in tables and graphs. List all the symbols used in the report and their meaning. Be sure to include units. The symbols should be listed in alphabetical order, first the English symbols, then the Greek symbols. Use the common symbols that are used in the current course. Learn how to use your word processor to create Greek letters and other common mathematical symbols.

e. Introduction. Tell the reader what the nature of the work is, what the problem is, why it was investigated, and the general approach to the solution. It should lead the reader from the conception of an idea to the objectives of the work. This section can be used as a more detailed roadmap to guide the reader through the remaining sections by describing each section with one or two sentences. This section deliberately excludes "Results." The objective should be stated in the Introduction, preferably, at the very end. If the objective is clearly stated as a summary ending of this section, the section titled "Objectives" can be omitted.

HINT. Even though the lab handout may state that the objective of the lab is for the student to learn a certain concept, that is not the objective of your report. Put yourself into the situation of being assigned the task of conducting an experiment or investigation in a specific area. Write down an objective that is related to the "work" you are doing.

f. Objectives or Purpose. A brief summarizing statement of what was intended in the study or experiment. The objective can be couched in terms of testing one or more hypotheses. This can be omitted as a specific section if objectives are clearly indicated in the Introduction section (see e. above).

g. Theory. Here, show the derivation of equations used in obtaining results. Number key equations. Equations should be written with your word processor's equation editor. Do not pencil in equations or write them in computer syntax (MathCAD, EES or FORTRAN).

For example:

$$V_i = \Delta L \sqrt{\frac{k\ g_c}{m}}$$

NOT! Vi = L sqrt(k*gc/m)

Note any assumptions made and references used to gain an understanding of the subject. Show derivations of pertinent equations and use free-body diagrams as necessary. Explain how the equations and theory were used to solve or address the objective. Refer to sample calculations in an appendix when appropriate.

h. Methodology or Experimental Procedure. Describe any experimental apparatus with both words and sketches or pictures. Detailed engineering drawings may be referenced but should be included in the appendix. A list of instrumentation should be included here or referenced here and placed in an appendix. If the test procedure is simple it can be listed here. If it is lengthy include an overview of the procedure but put all the exact steps in the appendix.

i. Results or Summary of Results. This is the "end product" of the experiment or analysis. Tables or figures may be used exclusively if there are only a few results in number. If this is the case, state the result and refer to the table or figure with one or two brief sentences.

Be sure each figure has:

(1) A title and legend (if necessary),
(2) Labeled axes with units,
(3) Notes which tell the source of the figure or add explanation,
(4) Indication of experimental uncertainty (if an error analysis has been performed).

Be sure each table has:

(1) A title and legend (if necessary),
(2) Labeled columns or rows with units,
(3) Notes which tell the source of the table or add explanation.

Ensure that the Results section communicates an understanding to the reader. Don't leave the reader the task of digesting a body of numbers and understanding their significance. If numerical results are significant, present them by summarizing and referring to details in an appendix.

j. Discussion of Results. This section constitutes the main body of the report. Interpret the results, qualify them and put them into context. Guide the reader through the thinking process which led to the conclusions. Some specific items that may be addressed are:

(1) How do the results conform to expectations? For example, do the measurements conform to theoretical expectations or to the measurements of other experimenters? What is the explanation of any differences?

(2) If one variable was measured in more than one way, how do the measurements compare and what is the comparison?

(3) How should the graphical presentation of the data be interpreted? For instance, what is the physical significance of the shape, slope, inflection, maximum, minimum, or intercepts of the graph?

(4) What are the sources of error in the analysis or data collection? Do not state: "Results are within experimental error" unless an error analysis supports this.

k. Conclusions. A numerical itemized listing is often useful here. Each conclusion should be one sentence with perhaps one qualifying sentence. The conclusions must be connected to the objectives. Again, project yourself into a realistic engineering situation. The conclusion should not be: "We learned about the relationship between stress and strain." Rather, "The selected samples that were tested have material properties that are within the 2% tolerance limit."

l. Recommendations. What further work should be done to continue the effort? Should the present work be repeated in a different manner. Sometimes the objective was so concise that no recommendations are required; e.g. "The objective was to determine the yield strength of a steel specimen." At other times the objective may lead to a recommendation; e.g. "The objective was to analyze the heat load in a boiler economizer in order to recommend the minimum weight of tubing."

m. References. There are several acceptable ways to cite references, use footnotes properly, and prepare a list of references. Your instructor will tell you the required method. In general, a citation should provide sufficient information to find the source in the library.

n. Appendices. Use the appendices to store important details of the work as well as details which are not necessary for the reader's understanding and which would interrupt the flow of thought if they were put in the discussion. Appendices can be effectively used by referring to them in the Theory and Discussion sections. This is often true of sample calculations. If no reference is made to an appendix in the body of the report, it should not be in the report. Do not store a lot of unexplained junk here (e.g., handwritten notes). Each appendix should be labeled with a letter and caption and should stand alone where the reader's understanding is concerned.

A good rule of thumb is that a person uses the **abstract** to decide whether or not to read the report. Your boss only has the time to read the **executive summary.** The body of the report (**Introduction - Recommendations)** will be read by colleagues who want to know about your work. The **appendices** will be scrutinized by individuals who may want to reproduce all or some of your work.

<u>APPENDIX A</u>: <u>COMMON PLOTTING TECHNIQUES</u>

The following guidelines are presented for the graphical presentation of data. The manner in which test results are presented determines the clarity and importance of findings. In addition to the simple ideas here, remember not to complicate graphs by presenting too much on a single figure.

In general, do not “plot” theoretically determined points, since presumably a theoretical curve is continuous. Show a theoretical curve as a continuous line, and plot the experimental data as single points. Do not draw straight lines between experimental data points. Figure 1 is an example of a poorly planned figure. Even though the figure has a legend, there is no easy way to distinguish which theoretical curve is which. Use distinct line styles to distinguish the curves from one another. Although the use of color printing is becoming more commonplace , it is still a good idea to plan your figures so they can be interpreted if they are copied using a black and white copier. Therefore, do not use color as the only distinguishing feature between lines if it can be avoided. Figure 2 presents the same data as Figure 1, but in a much clearer fashion. Each of the theoretical lines has a distinct style and there are no lines joining the experimental data points. This figure also has a title and a subtitle which may convey additional information. Nevertheless, the figure still has a separate caption. *A graph title is not a caption*!

Most physical phenomena are continuous while most experimental measurements have some error in them. Use some type of curve fitting procedure to demonstrate a trend in the experimental data. Plot the experimental data as points only and plot the trends as lines without the calculated points. Figure 3 is an example of the incorrect way of demonstrating trends and Figure 4 is a good example of illustrating a trend. Even though Figure 3 includes a legend, it is almost useless because of all of the lines on the plot and the small size of the data points. Figure 4 does not have a legend yet it is a much better presentation of the data. The data points are clearly distiguishable, each trend line has a distinct style and labels were added to the graph to identify the individual curves.

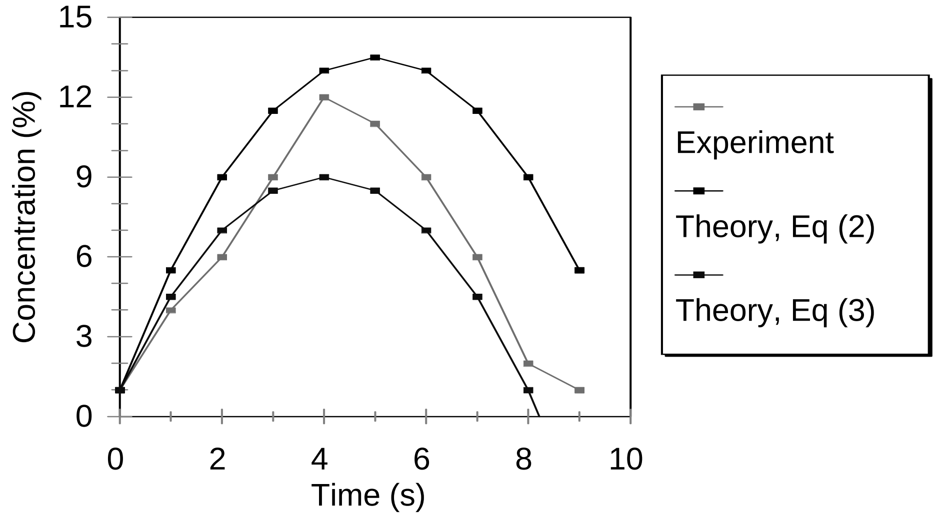


Figure 1 Theoretical predictions and experimental measurements of NaCl concentration as a function of time for Run #23.

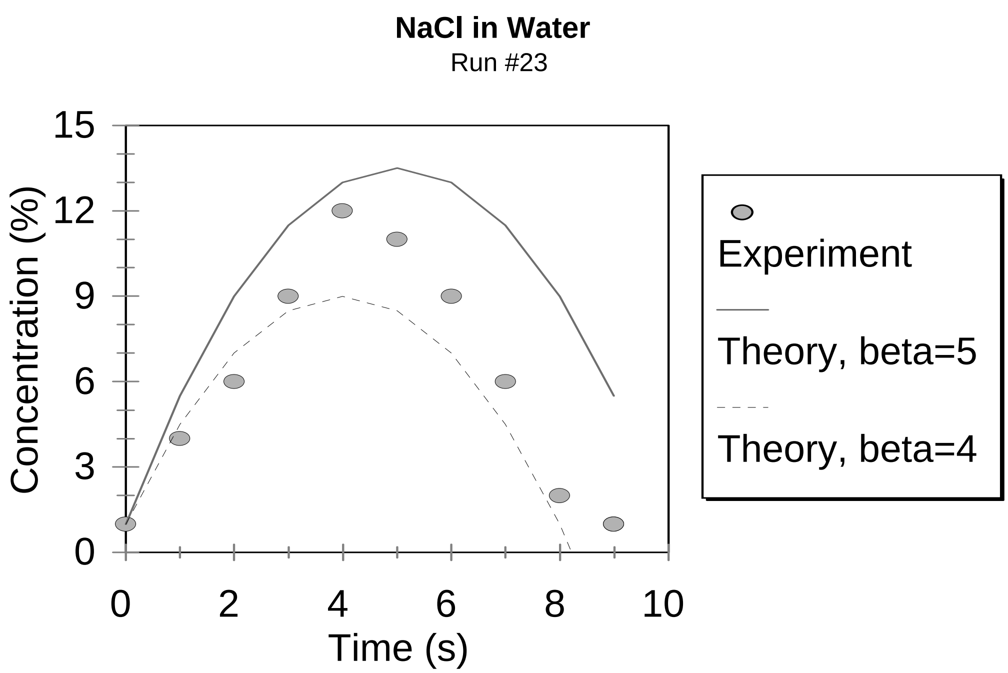


Figure 2 Theoretical predictions and experimental measurements of NaCl concentration as a function of time for Run #23.

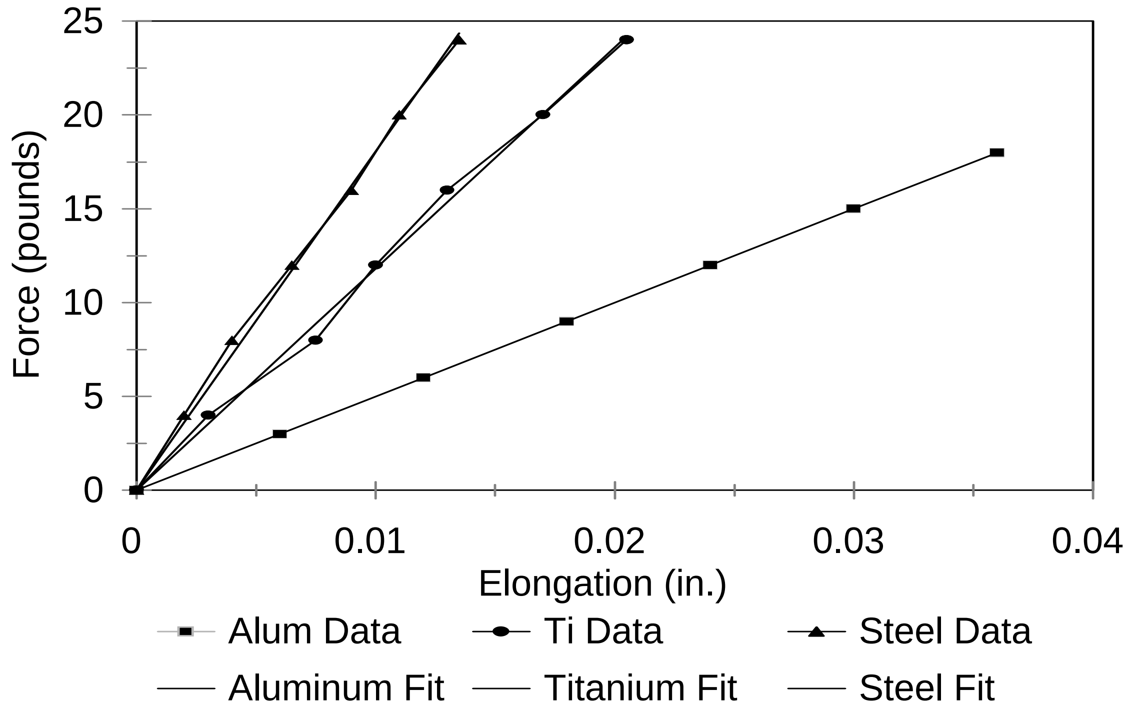


Figure 3 Stiffness plots of steel, titanium and aluminum wires.

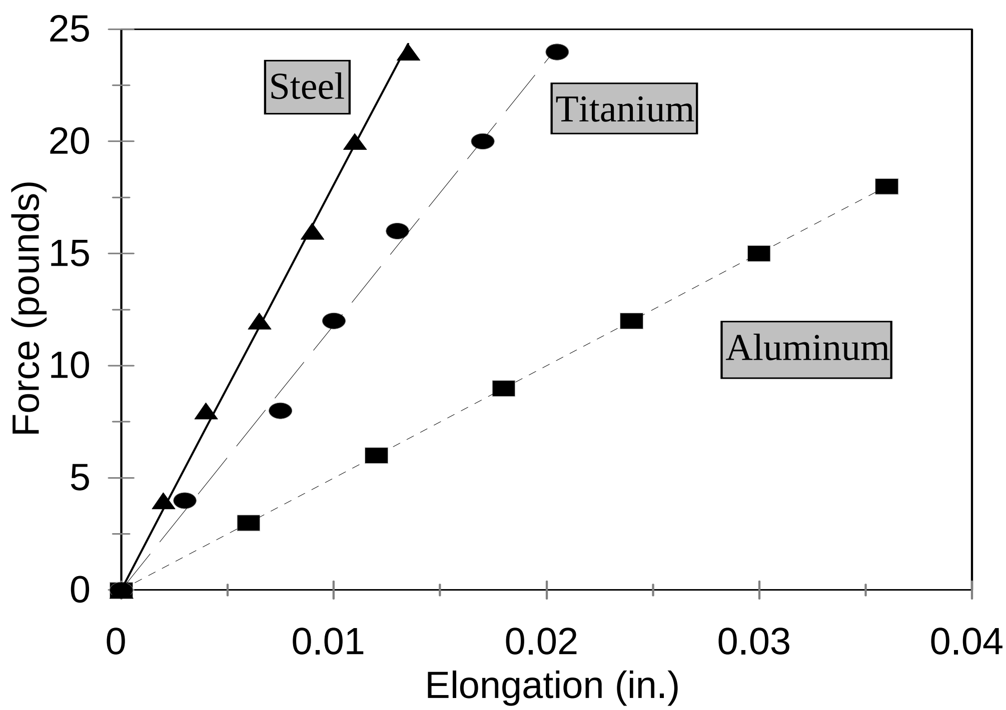


Figure 4 Stiffness plots of steel, titanium and aluminum wires. The lines are least squares fits to the experimental data.

SAMPLE FORMAL LABORATORY REPORT

An Investigation of the Elastic Curve of a Simply-Supported Beam

by

MIDN M.E. Major
20 APRIL 2010

EM217, Sec. 1234

prepared for
Prof. Know-It All

Abstract: The elastic curve for a simply supported beam with a uniform distributed load was determined experimentally and compared with the elastic curve predicted from the moment-curvature relationship. The results demonstrated that the moment-curvature relationship provides an accurate estimate of the elastic curve. The average difference between the experimental results and the predictions was less than 2%.

Theory: A beam subjected to a system of transverse loads and bending moments will deform in response to the applied forces. For an elastic beam in pure bending (no transverse shear forces) the radius of curvature of the beam at any point is related to the internal moment by the relationship:

$$\frac{1}{\rho} = \frac{M_z}{EI_z} \qquad \textbf{(1)}$$

where ρ is the radius of curvature, M_z is the internal moment, E is the elastic modulus and I_z is the moment of inertia about the *z* axis. The curvature of a function, *v(x)*, at any point is 1/ρ and the curvature relationship is:

$$\frac{1}{\rho} = \frac{d^2v/dx^2}{\left[1 + \left(dv/dx\right)^2\right]^{3/2}} \qquad \textbf{(2)}$$

Settting Eq. 1 equal to Eq. 2 to yields:

$$\frac{d^2v/dx^2}{\left[1 + \left(dv/dx\right)^2\right]^{3/2}} = \frac{M_z}{EI_z} \qquad \textbf{(3)}$$

Assuming that the deflections are small compared to the dimensions of the beam and that the elastic curve of the beam is given by the function *v(x)*, then the slope of the beam, *dv/dx*, must be small and, when squared as in the denominator of Eq. 3, becomes vanishingly small so that it may be neglected. This simplifies Eq. 3 to:

$$\frac{d^2v}{dx^2} = \frac{M_z}{EI_z} \qquad \textbf{(4)}$$

which is a linear, second-order, differential equation. This equation can be solved by integrating twice and evaluating the constants of integration from the boundary conditions to yield the function *v(x)* which is the elastic curve of the beam.

The derivation above assumed the beam was subjected to pure bending. In most practical cases the beam is also subjected to transverse shear forces which also causes additional deformation of the beam. The additional deformation due to transverse shear is usually small compared to the deformation due to bending and is often ignored.

Objective: The objective of this experiment was to measure the elastic curve of a simply-supported beam with a distributed load and compare it with the theoretical elastic curve from elementary beam theory.

Experimental Procedure: An aluminum, WF series I-beam, simply-supported with a span of 30 inches was used in this experiment. The beam cross-section is shown in Figure 1.

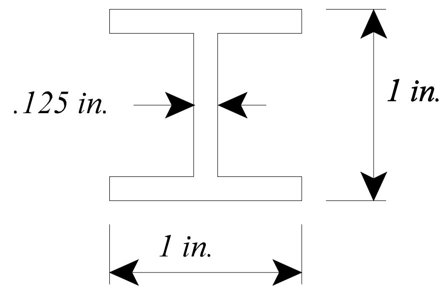


Figure 1 Cross section of the I-beam used in the experiment.

The beam was oriented to produce maximum deflection (i.e. the flanges were oriented vertically instead of on the top and bottom of the web). The moment of inertia for the beam was I=0.02094 in^4 and the elastic modulus for the aluminum beam was assumed to be 9.5 x 10^6 psi. A uniform distributed load over the range 5 in. $\leq x \leq$ 20 in. was simulated by placing a series of 1 in. wide, 1 pound weights on the top of the beam over this region as shown in Figure 2. The deflection of the beam at any position along the length of the beam was determined by using a dial indicator with a resolution of 0.001 in. The dial indicator, adjusted to indicate the vertical motion of the beam, was positioned at a particular point of interest along the unloaded beam and the initial indicator reading was recorded. The distributed load was applied and the new reading of the dial indicator was recorded. The deflection due to the distributed load was the difference between the two readings. This procedure was repeated at stations every two inches along the entire length of the beam.

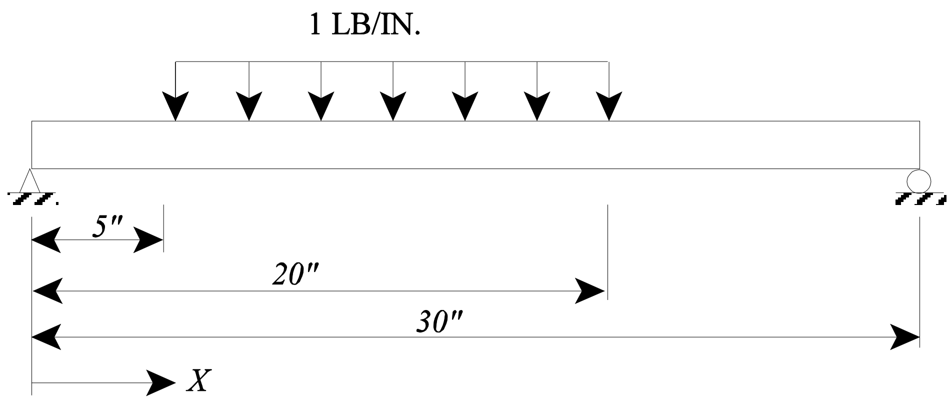


Figure 2 Simply-supported beam with a uniform distributed load acting over the region $5 \le x \le 20$

Results and Discussion: The experimental results for the measured deflection of the beam are listed in Table 1. Also included in this table are the theoretical predictions of the deflections determined from elementary beam theory. The bending moment-curvature relationship, Eq. (4), was integrated to determine the theoretical elastic curve and the constants of integration were evaluated using the boundary conditions, *v(0)=0* and *v(30)=0*. For the beam shown in Figure 2, the elastic curve was given by the expression:

$$v(x) = \frac{1}{EI}\left[\frac{8.75}{6}x^3 - \frac{1}{24}\langle x-5\rangle^4 + \frac{1}{24}\langle x-20\rangle^4 - 783.85x\right] \qquad \textbf{(5)}$$

The expressions within the angled brackets are discontinuity functions. These functions have the property that $\langle x-a\rangle^n = (x-a)^n$ for $x \ge a$ and $\langle x-a\rangle^n = 0$ for $x<a$. The details of this derivation are included in Appendix 1. The theoretical elastic curve and the experimentally measured deflections are plotted and compared in Figure 3.

Discussion: The experimental measurements follow the theoretical prediction of the elastic curve almost identically. The average difference between the theoretical and experimental deflection was 1.9% with a maximum deviation of 11% occurring at the position x=3 in. The large error here was due in part to the resolution of the dial indicator relative to the magnitude of the deflections being measured. An error of 0.001 in. in the deflection was approximately 10% of the value being measured at x=3 in.. It is possible that the dial indicator was bumped or not seated properly when the null reading was taken.

Since the experimental deflections both over and under predicted the theoretical deflections, the errors appeared to be random and could have resulted from small rigid body motion of the beam while adding and removing the weights. Given the uncertainty in the elastic modulus, the agreement between theory and experiment is considered very good. Deformation of the beam due to transverse shear forces does not appear to have a great effect on the results in this case.

Position along beam (in.)	Theoretical Deflection (in.)	Experimental Deflection (in.)	% Difference
0	0	0	0
3	-0.0116	-0.0130	11.8
5	-0.0188	-0.0193	2.7
7	-0.0251	-0.0258	2.9
9	-0.0302	-0.0298	-1.4
11	-0.0339	-0.0350	3.4
13	-0.0360	-0.0360	0.1
15	-0.0365	-0.0373	2.3
17	-0.0353	-0.0351	-0.6
19	-0.0326	-0.0322	-1.3
21	-0.0286	-0.0290	1.5
23	-0.0234	-0.0240	2.5
25	-0.0173	-0.0176	1.5
27	-0.0107	-0.0108	1.3
30	0.0000	0.0000	0.0

Table 1 Theoretical predictions and experimental measurements of the elastic curve for the simply supported beam.

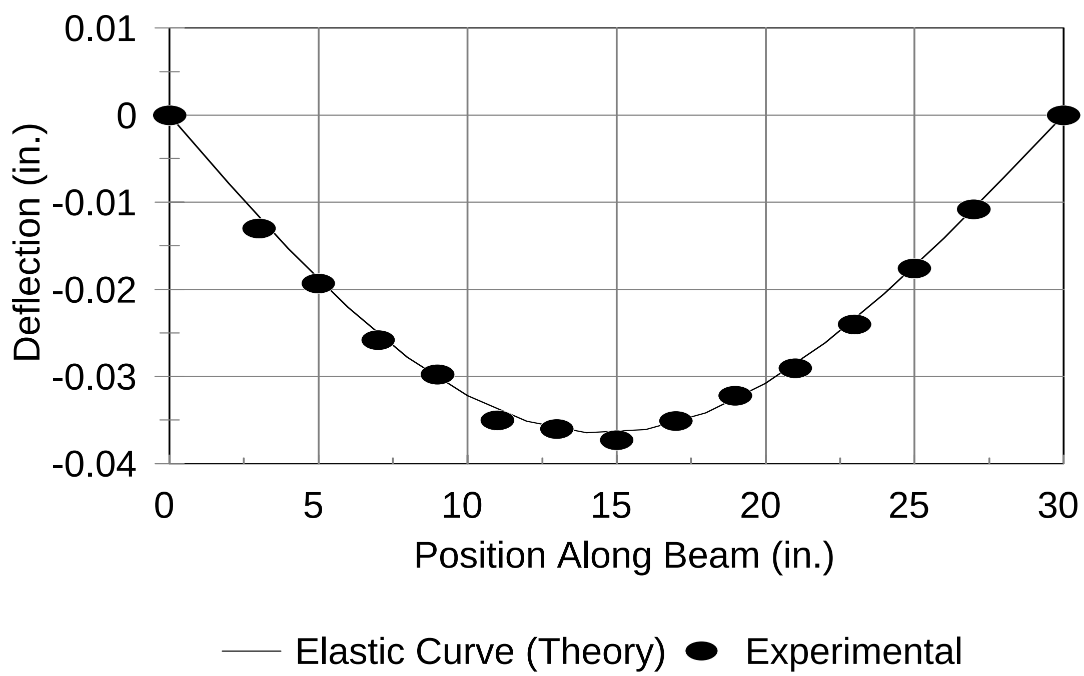


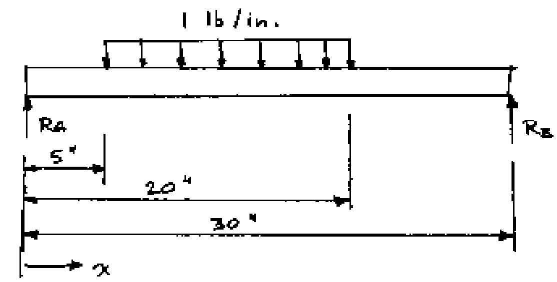
Figure 3 Comparison of theoretical prediction of the elastic curve with the experimentally determined deflections.

The difference between theory and experiment could have been reduced even further by using a more accurate instrument to measure the small deflections of the beam near the supports.

Conclusions: The experimental predictions of the elastic curve agreed with the theoretical predictions with an average difference of less than 2%. It was concluded that elementary beam theory can be used to accurately predict the deformation of a simply-supported beam with a distributed load.

Appendix - Calculation of the Elastic Curve from the Moment-Curvature Relationship

Determination of the Elastic Curve



$\uparrow \sum F_y = 0 = R_A + R_B - 15(1)$

$R_A = 15 - R_B$

$\circlearrowleft \sum M_A = 0 = -15(12.5) + 30R_B$

$R_B = 6.25$ lb

$R_A = 8.75$ lb

Using discontinuity functions,

$$M(x) = 8.75\langle x-0\rangle^1 - \frac{1}{2}\langle x-5\rangle^2 + \frac{1}{2}\langle x-20\rangle^2$$

$$\frac{d^2v}{dx^2} = \frac{M}{EI} = \frac{1}{EI}\left[8.75x - \frac{1}{2}\langle x-5\rangle^2 + \frac{1}{2}\langle x-20\rangle^2\right]$$

$$\frac{dv}{dx} = \int\frac{M\,dx}{EI} = \frac{1}{EI}\left[\frac{8.75}{2}x^2 - \frac{1}{6}\langle x-5\rangle^3 + \frac{1}{6}\langle x-20\rangle^3 + C_1\right]$$

$$v(x) = \iint\left(\frac{M\,dx}{EI}\right)dx = \frac{1}{EI}\left[\frac{8.75}{6}x^3 - \frac{1}{24}\langle x-5\rangle^4 + \frac{1}{24}\langle x-20\rangle^4 + C_1x + C_2\right]$$

$v(0) = 0 \quad \therefore C_2 = 0$

$$v(30) = 0 = \frac{8.75}{6}(30)^3 - \frac{1}{24}(25)^4 + \frac{1}{24}(10)^4 + 30C_1$$

$\therefore C_1 = -783.85$

$$v(x) = \frac{1}{EI}\left[\frac{8.75}{6}x^3 - \frac{1}{24}\langle x-5\rangle^4 + \frac{1}{24}\langle x-20\rangle^4 - 783.85x\right]$$

II. Memorandum Format for a Laboratory Report

1. Introduction

The memorandum style lab report is a brief summary of the objective of the lab exercise, a presentation of the key results and a summary statement of conclusions or findings. Three paragraphs will usually be sufficient for such a report; however, there is no hard and fast rule that restricts you from adding additional information if it is necessary to explain the results. Supporting documentation such as tables, graphs, calculations and lab handouts are included as enclosures to the memorandum. All enclosures and references must be listed on the header of the memorandum and must be referenced in the text of the memorandum.

Even though this format is much more brief than the formal lab report, it is essential that all information be presented accurately and completely. The tables and graphs must contain all of the elements described in the handout on the formal engineering report and all enclosures must have titles.

2. Format

The memorandum should comply with the standards of the *Navy Correspondence Manual,* SECNAVINST 5216.5C. The general format is illustrated below:

MEMORANDUM DATE

⇦ *blank line*

From: *(Your name)*
To: *(Recipient's name and title)*
Via: *(Chain of command, if applicable)*

⇦ *blank line*

Subj: *(A BRIEF descriptive title)*

⇦ *blank line*

Ref: (a) *(as appropriate)*
(b)

⇦ *blank line*

Encl: (1) *(Tables, graphs, related documents, .. etc)*
(2)

⇦ *blank line*

1. (Numbered paragraphs)

2.

Your signature
Your name and rank

3. <u>Example</u>

A sample lab report prepared using this format is included for your reference.

SAMPLE MEMORANDUM REPORT

MEMORANDUM 31 FEB 02

From: MIDN 3/c I.B. Keelhaul
To: Prof. Know-it-All, Mechanical Engineering Department

Subj: EM217 LAB - ELASTIC CURVE OF A SIMPLY SUPPORTED BEAM

Ref: (a) "Elastic Curve of a Beam," EM217 Lab Handout

Encl: (1) Theoretical predictions and experimental measurements of the elastic curve for the simply supported beam.
(2) Determination of the elastic curve.
(3) Comparison of theoretical prediction of the elastic curve with the experimentally determined deflections.

1. The objective of the lab exercise was to measure the elastic curve of a simply supported beam subjected to a distributed load and to compare the measured curve with the theoretical prediction of the elastic curve.

2. The experimental apparatus and procedure were performed in accordance with reference (a). Enclosure (1) lists the experimental results for the measured deflection of the beam and the theoretical predictions of the deflections determined from elementary beam theory. The bending moment-curvature relationship was integrated to determine the theoretical elastic curve and the constants of integration were evaluated using the boundary conditions, $v(0)=0$ and $v(30)=0$. Enclosure (2) contains the details of this derivation. The theoretical elastic curve and the experimentally measured deflections are plotted and compared in enclosure (3). The experimental measurements followed the theoretical prediction of the elastic curve almost identically. The average difference between the theoretical and experimental deflection was 1.9% with a maximum deviation of 11% occurring at the position x=3 in. The large error here was due in part to the resolution of the dial indicator relative to the magnitude of the deflections being measured. An error of 0.001 in. in the deflection is approximately 10% of the value being measured at x=3 in.. It was possible that the dial indicator was bumped or not seated properly when the null reading was taken. Given the uncertainty in the elastic modulus, the agreement between theory and experiment is considered very good.

3. The experimental predictions of the elastic curve agreed with the theoretical predictions with an average difference of less than 2%. It was concluded that elementary beam theory can be used to accurately predict the deformation of a simply-supported beam with a distributed load.

I.B. KEELHAUL
MIDN, USN

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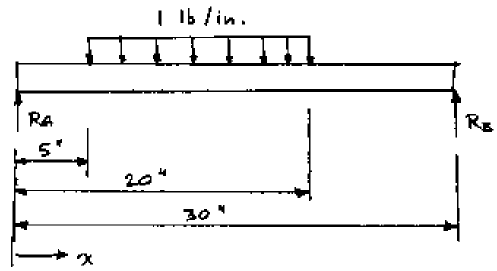
25	-0.0173	-0.0176	1.5
27	-0.0107	-0.0108	1.3
30	0.0000	0.0000	0.0

Enclosure (1) Theoretical predictions and experimental measurements of the elastic curve for the simply supported beam.

Determination of the Elastic Curve



$\uparrow \Sigma F_y = 0 = R_A + R_B - 15(1)$

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Using discontinuity functions,

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$$\frac{dv}{dx} = \int \frac{M\,dx}{EI} = \frac{1}{EI}\left[\frac{8.75x^2}{2} - \frac{1}{6}\langle x-5\rangle^3 + \frac{1}{6}\langle x-20\rangle^3 + C_1\right]$$

$$v(x) = \iint\left(\frac{M\,dx}{EI}\right)dx = \frac{1}{EI}\left[\frac{8.75}{6}x^3 - \frac{1}{24}\langle x-5\rangle^4 + \frac{1}{24}\langle x-20\rangle^4 + C_1x + C_2\right]$$

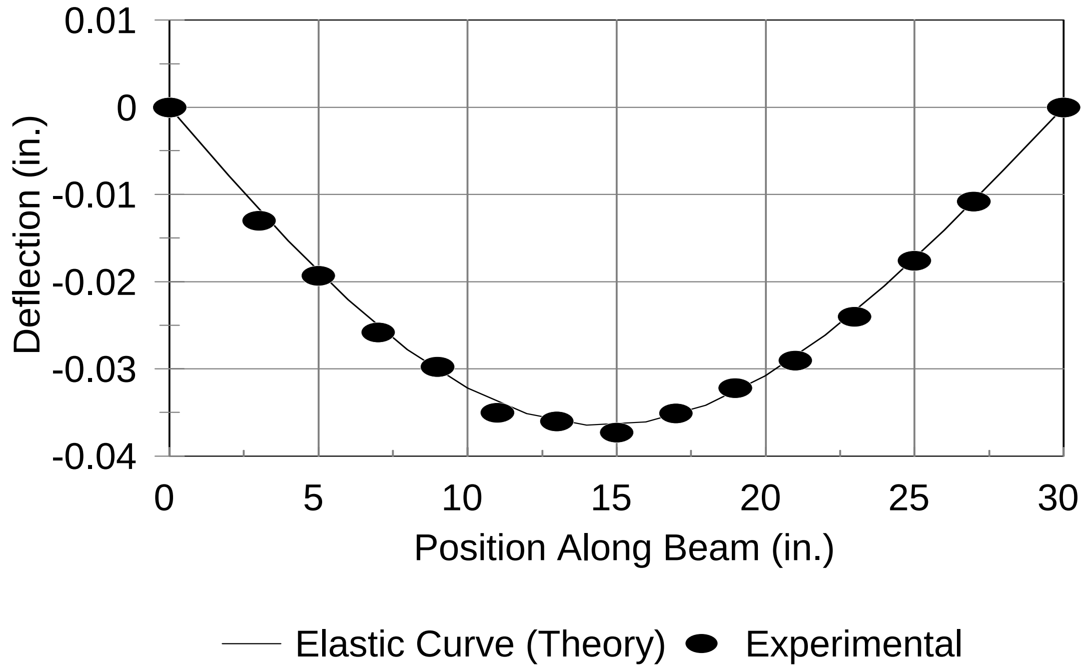
$$v(0) = 0 \qquad \therefore C_2 = 0$$

$$v(30) = 0 = \frac{8.75}{6}(30)^3 - \frac{1}{24}(25)^4 + \frac{1}{24}(10)^4 + 30C_1$$

$$\therefore C_1 = -783.85$$

$$v(x) = \frac{1}{EI}\left[\frac{8.75}{6}x^3 - \frac{1}{24}\langle x-5\rangle^4 + \frac{1}{24}\langle x-20\rangle^4 - 783.85x\right]$$

Enclosure (2) Determination of the elastic curve.



Enclosure (3) Comparison of theoretical prediction of the elastic curve with the experimentally determined deflections.