

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING

2.671 Measurement and Instrumentation

Instructions for Using Your Laboratory Notebook

Please read before coming to Lab 3. You will receive a lab notebook at that time.

Why is it Important to Keep a Good Laboratory Notebook?

Keeping a complete and accurate record of experimental methods and data is a vital part of science and engineering. Your laboratory notebook is a permanent record of what you did and what you observed in the laboratory. Learning to keep a good notebook now will establish good habits that will serve you throughout your career. Your notebook should be like a diary, recording what you do, and why you did it. You should feel free to record your mistakes and difficulties performing the experiment - you will frequently learn more from these failures, and your attempts to correct them, than from an experiment that works perfectly the first time. It is extremely important that your notebook accurately record everything you did. A good test of your work is the following question: could someone else, with an equivalent technical background to your own, use your notebook to repeat your work, and obtain the same results? For that matter, **could you come back six months later, read your notes, and make sense of them?** If you can answer yes to these two questions, you are keeping a good notebook.

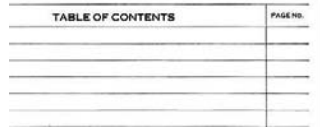
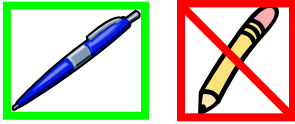


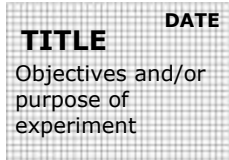
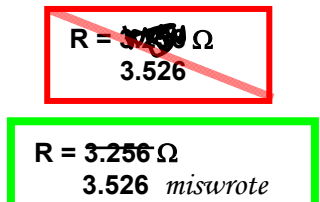


It is also important to maintain a good laboratory notebook in order to protect your intellectual property (e.g. patents). An appropriately maintained laboratory notebook can often mean the difference between gaining or not gaining recognition for a discovery. U.S. patent law states that inventorship is determined by the "first to invent," not the "first to file." The laboratory notebook can be the key piece of evidence in helping to make that determination.


<http://www.auburn.edu/research/vpr/communications/resnews/nov01.html>

The laboratory notebook forms a permanent record that can be referred to while completing a disclosure report (often the first step in patent preparation) and later, provides accurate documentation of the work done. When an investigator makes an invention during the course of a research project, the dates of the conception and reduction to practice (turning an idea into a reality) become very important. Generally, a sketch and a brief written description are sufficient to establish conception. Reduction to practice is accomplished by actually constructing and successfully testing a material or device incorporating the invention.

During prosecution of a patent application before the U.S. Patent Office, or even after issuance of a patent, the filing of another patent application may initiate an interference proceeding to determine which party was the first to invent. Each party has an opportunity to submit documentary proof of his or her dates of conception and reduction to practice. A laboratory notebook may be, and in several high-profile cases *has been* the crucial piece of evidence in this procedure.

Rules for Maintaining your Laboratory Notebook

 <p>TABLE OF CONTENTS</p> <p>PAGE NO.</p>	<p>Leave several pages blank at the beginning for a Table of Contents and update it when you start each new experiment or topic</p>
	<p>Always use pen and write neatly and clearly</p>
	<p>Date <u>every</u> page on the top <u>outside</u> corner</p>
	<p>Start each new topic (experiment, notes, calculation, etc.) on a right-side (odd numbered) page</p>
	<p>Record the TITLE and OBJECTIVES of each experiment (or notes or calculations) at the top of the first page of the notebook dedicated to this topic.</p>
	<p>If you make a mistake, <u>don't obliterate it!</u> You may need to read your mistake later – perhaps you were right the first time! Use a single cross out and EXPLAIN why it was an error.</p>
	<p>Data typed into the computer must be printed and <u>taped into your lab notebook</u>. Plots of data made in lab should also be printed and taped in your lab notebook.</p>
	<p>When you record an observation in your notebook, include an explanation of what you were doing at the time. If appropriate, you may just record the step number in the instructions followed by your observation.</p>

	<p>You must have your lab notebook <u>signed</u> by Dr. Hughey or your lab professor before you leave lab each day. Any pages not signed on the day the experiment was performed will adversely affect your lab notebook grade</p>
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Metric	Requirements	Worth
Pen	Write in pen, not pencil	10%
Date	Date every page at the top	10%
Right Side	Begin each experiment on odd page	10%
Printouts	Attach printouts and plots of data as needed	10%
Legible	Obvious care taken to make it readable, even if you have bad handwriting	10%
Mistakes	Mistakes crossed out with one line and explained	10%
Organized	<ul style="list-style-type: none"> ▪ table of contents ▪ title of experiment on 1st page ▪ objectives of experiment ▪ clear from notebook what you were doing when 	20%
Informative	<ul style="list-style-type: none"> ▪ all required data and information ▪ descriptive comments of your observations 	20%

Example: Complete Experiment

Do not copy the words from this example into your notebook – some of the experimental procedure has changed!

First Page:

Experiment starts on an odd page

Date at top outer corner

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Experiment #3
Estimation of Internal Pressure within an Aluminum Soda Can

The purpose of this experiment is to measure the pressure inside an unopened soda can using strain gauges.

Procedure

The directions were read and a question selected.
e) How does an axial strain measurement compare to a hoop strain measurement for a given type of soda?

CEA-13-240UZ-120
CEA-13-240UZ-120
Stress Type
120.0 \pm 0.3%
Resilience to stress at 20°C
2.085 \pm 0.5%
Stress Factor at 30°C
(+0.3 \pm 0.2)%
Thermal Sensitivity at 30°C

Options
R-A59AF628
Lot Number
121716-6836
Date

MEME
Micro-Measurements
Division
MEASUREMENTS
GROUP, INC.
P.O. Box 27777
Raleigh, North Carolina 27611
(919) 365-3696

GENERAL INFORMATION
SERIES CEA STRAIN GAGES

GENERAL DESCRIPTION: CEA-Series Student Gages are in a general-purpose family of constantan alloy strain gages widely used in experimental stress analysis. Extremely thin and flexible (0.0022 in (0.056mm)), CEA-Series gages feature polyimide-encapsulated grids and exposed copper-coated integral solder tabs to which leadwires may be soldered directly. See Tech Note TN-508 for assistance in gage selection.

TEMPERATURE RANGE: Normal use temperature range for static strain measurement is -100°F to +350°F (-73°C to +175°C). For special or short-term exposure, an expanded range of -320°F to +400°F (-195°C to +205°C) may be used.

STRAIN LIMITS: Approximately 5% for 0.240 in (6 mm) gage length and approximately 2% for 0.120 in (3 mm) and 0.060 in (1.5 mm) gage lengths for single cycle use. See Tech Tip TT-605 for high elongation measurements.

FATIGUE LIFE: Dependent on gage length and method of cycling. 10⁷ cycles at \pm 2000 μ in, 10⁶ cycles at \pm 1500 μ in. Derives 10% for non-zero mean strains of same absolute (peak-to-peak) values. See Tech Note TN-508 for additional data.

ADHESIVES: M-Bond 200 is an excellent, general purpose adhesive for those learning to bond strain gages (see Instruction Bulletin B-127). M-Bond AC-10 may be used when a wider range of bonding properties is needed (see Instruction Bulletin B-127). Refer to Instruction Bulletin B-129 for proper surface preparation and to Catalog A-110 for other bonding agents.

SOLDER: M-Line solder type 361 is recommended for leadwire attachment when operating temperatures do not exceed +500°F (+260°C). See Catalog A-110 for higher temperature solders.

PROTECTIVE COATINGS: Because they have fully encapsulated grids, CEA-Series Student Gages require no further protection under most laboratory conditions. When further protection is required, refer to Catalog A-110 for M-Coat protective coatings information.

NOTE: The backing of Student Gages has been specifically treated for optimum bond formation with all appropriate gage adhesives. No further cleaning is necessary. If contamination of the prepared surface is avoided during handling, should contamination occur, clean with a cotton swab slightly moistened with a low residue solvent such as isopropyl alcohol. Allow the gage to dry for several minutes before bonding.

SELF-TEMPERATURE COMPENSATION: These gages have been manufactured with self-temperature compensation (STC) characteristic to minimize thermal output (see Tech Note TN-504). Thermal output data given below are valid only for the indicated test material, since thermal output is a function of the thermal expansion properties of the test specimen.

Two cans of soda were selected (Seagram's Ginger Ale at room temperature).
The strain gauge was attached to the soda can as described in the lab handout.

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Spec sheet taped into lab notebook

Notebook signed on same day as experiment performed

Second page for Example 1

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Date at top outer corner

However one of the cans was dropped during preparation and was dented. In order to perform the experiment accurately two new cans were selected (Diet Pepsi at room temperature)

Description of something that went wrong in the experiment and what was done to correct the problem

The strain gauges were then attached to these cans. I did the axial and Sam did the hoop

Identification of which member of the team did which task.

While the glue adhered to the strain gauge, the lab amplifier was calibrated.

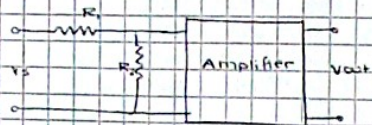
Serial Number of Lab Amplifier: NA 7

Value of each resistor in the voltage divider constructed on the protoboard.

$$R_1 = 5.03 \text{ M}\Omega$$

$$R_2 = 1.203 \text{ k}\Omega$$

Schematic drawing makes clear to what the measured resistances R_1 and R_2 refer.



Used HP E3616A as the power supply and set to 5V

$$V_s = 5.00 \text{ volts}$$

$$V_{out} = 0.161 \text{ Volts}$$

Model number of the power supply specified

$$V_{in} (\text{voltage across } R_2) = 1.20 \text{ mV}$$

$$V_{in} = \left(\frac{R_2}{R_1 + R_2} \right) V_s = \left(\frac{1.203 \times 10^3}{1.203 \times 10^3 + 5.03 \times 10^6} \right) 5.00 \text{ V} = 1.1955 \times 10^{-3} \text{ V}$$

$$\text{Percent error} = \frac{1.1955 - 1.20}{1.1955} = 0.373 \%$$

$$\text{Amplifier gain} = G = \frac{V_{out}}{V_{in}} = \frac{0.161 \text{ V}}{1.20 \times 10^{-3} \text{ V}} = 134.1 \quad 552.85 \quad 550.8$$

$$G = \frac{V_{out}}{V_{in}} = \frac{0.161}{1.1955 \times 10^{-3}} = 134.65 \quad 552.85$$

2/1/02 PLH

Computation:

1. Intermediate steps shown
2. Errors crossed out with a single line and an explanation ("calculator error").

$$V_{in} = \left(\frac{R_2}{R_1 + R_2} \right) V_s = \left(\frac{1.203 \times 10^3}{1.203 \times 10^3 + 5.03 \times 10^6} \right) 5.00 \text{ V} = 1.1955 \times 10^{-3} \text{ V}$$

$$\text{Percent error} = \frac{1.1955 - 1.20}{1.1955} = 0.373 \%$$

$$\text{Amplifier gain} = G = \frac{V_{out}}{V_{in}} = \frac{0.161 \text{ V}}{1.20 \times 10^{-3} \text{ V}} = 134.1 \quad 552.85 \quad 550.8$$

$$G = \frac{V_{out}}{V_{in}} = \frac{0.161}{1.1955 \times 10^{-3}} = 134.65 \quad 552.85$$

Remaining pages for Example 1:

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hoop strain can wall thickness: 0.105 mm
0.104 mm
0.121 mm (sanded)
0.119 mm
nonsanded average = 0.104 mm

axial strain can wall thickness: 0.129 mm
0.104 mm
0.109 mm

Analysis:
hoop strain: $P = \left(\frac{4EL}{D} \right) \frac{f_s}{2 \cdot V} = \left(\frac{4(4.49 \times 10^9)(1.04 \times 10^{-4})}{4.5313 \times 10^{-2}} \right) \left(\frac{0.00223}{2 \cdot 0.35} \right) = 3.31 \times 10^5 \text{ Pa}$

$V_{out} = - \left(\frac{R_s}{R_g} \right) V_s = f_g f_s V_s$ Wrong formula

$V_{out} = - \left(\frac{f_g f_s}{f_g V_s G} \right) V_s = - \frac{f_s}{G}$ $V_s = 10$ $f_g = 2.095$
 $G = \frac{-4 V_{out}}{f_g V_s G} = \frac{-4(0.495)}{2.095(10)} = -0.001168 \text{ Pa}$
 $G = 552.9$

axial strain: $P = \left(\frac{4EL}{D} \right) \frac{f_a}{1.2 \cdot V} = \left(\frac{4(4.49 \times 10^9)(1.04 \times 10^{-4})}{0.5412 \times 10^{-2}} \right) \left(\frac{0.00345}{1.2(0.35)} \right) = 2.49 \times 10^5 \text{ Pa}$

$G = \frac{-4 V_{out}}{f_g V_s G} = \frac{-4(0.495)}{2.095(10)} = -0.001168 \text{ Pa}$
 $G = 552.9$

axial stress accurate!

Error crossed off with explanation

Answer to the question posed by the experiment

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axial resistance b/w leads: 120.9 Ω
hoop resistance b/w leads: 120.3 Ω
the resistance b/w all leads and the can infinite

hoop strain:
calibration resistance: 120.9 Ω
measured output voltage: -7.03 V
expected output voltage:
 $V_{out} = \left(1 - \frac{R_o}{R_g} \right) V_s = - \left(\frac{R_o}{R_g} \right) V_s = - \left(\frac{120.9 - 120.3}{120.3} \right) 10 = -0.994$
K_g strain gauge resistance

diameter: 45.94 mm
45.42 mm
45.46 mm
average diameter: 45.313

After all the connections were checked the amplified output voltage was recorded and the can opened.
 $V_{out} \text{ (before)} = -5.72 \text{ mV}$
 $V_{out} \text{ (after)} = 3.54 \text{ V}$

axial strain:
calibration resistance: 120.9 Ω
measured output voltage: -7.91 V
expected output voltage: $- \left(\frac{R_o}{R_g} \right) V_s = - \left(\frac{120.9 - 120.2}{120.2} \right) 10 =$

diameter: 45.73 mm
45.69 mm
45.72 mm
length: 121.86 mm
121.73 mm
average diameter: 45.313 mm

popped the can:
 $V_{out} \text{ (before)} = -0.04065 \text{ V} = -5.33 \text{ mV}$
 $V_{out} \text{ (after)} = 0.435 \text{ V}$

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Key points in this example:

1. Neat and legible handwriting
2. Experiment title and purpose clearly stated
3. Procedure described clearly and succinctly, including errors and the steps taken to correct them
4. Computations performed neatly showing intermediate steps
5. Errors crossed out with a single line and explained
6. All pages dated at the top and signed by lab professor on the same date