SIMON FRASER UNIVERSITY
THINKING OF THE WORLD

ENSC387: Introduction to Electromechanical Sensors and Actuators

LAB 3: USING STRAIN GAUGES TO FIND POISSON'S RATIO AND YOUNG'S MODULUS

1 Introduction

In this laboratory experiment, you are required to find Poisson's Ratio and Young's Modulus for the aluminum bar supplied with two strain gauges to test specimen in the appropriate configuration and measuring the strains with a Wheatstone bridge. Our Wheatstone bridge uses a professional strain gauge amplifier, the Vishay Measurements Group 2100 system. The company supplying the strain gauges we use has extensive documentation on their products, its history, and background of strain gauges.

Although the gauges you will use have been pre-selected for this application, be sure to read the information on selection and use of strain gauges in the "Strain Gauge Info" section of the **"Strain Gauge Lab"** binder located with the experimental apparatus in Lab 1 on Bench 9.

Familiarize yourself with the concept of the Wheatstone bridge as mentioned in the "Wheatstone Bridges" section of the **"Strain Gauge Lab"** binder. In the same section, read up on use of the 3-wire configuration method and use it to compensate for lead length. You will also find a section in the binder marked "Strain gauge measurements" which provides an overview of our system and how it is used to make measurements. Read this section before using the equipment.

2 Objective

Using 2 single-axis strain gauges, each in ¼ bridge configuration, measure the strain in an aluminum beam loaded in cantilever bending. There are 2 channels available on the Vishay Instruments strain gauge box, so each of the 2 strain gauges can be connected in a separate channel and the readings taken "simultaneously". In the ¼ bridge configuration, there is only 1 active strain gauge on each channel and since we are ignoring temperature variations associated with each strain gauge, we have 3 precision fixed resistors in our bridge circuit (within the Vishay Instrument box).

3 Supplies

1. Aluminium beam with two strain gauges attached.
2. DMM.
3. Vishay strain gauge bridge with cables.
4. Weight basket.
5. Set of weights.

4 Theory

4.1 Poisson's ratio

When a test specimen of an isotropic material is subjected to uni-axial stress, the specimen deforms in the direction of the stress as well as in the perpendicular direction but with an opposite sign. For example, in the illustration shown in Figure 1 below, when a force P is applied to the free end of the beam, the beam stretches on the longitudinal axis while bulging laterally so as to maintain a constant cross-sectional area. Poisson's ratio is the absolute value of the ratio of transverse strain ε_y to the axial strain ε_x (both measured in m/m or in/in):

$$\nu = \left|\frac{\varepsilon_y}{\varepsilon_x}\right| \tag{3.1}$$

For most metals, Poisson's ratio, (ν) is very close to 0.3

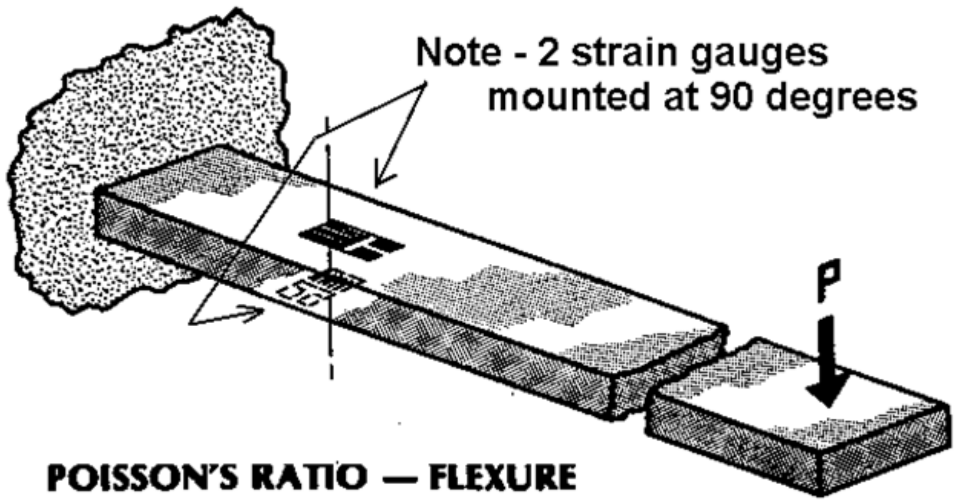


Figure 1: Experiment setup to measure Poisson's ratio of an aluminum beam.

Poisson's ratio can be measured readily with 2 strain gauges bonded on a uni-axially stressed member. One gauge is aligned in the direction of the applied stress, and the second gauge perpendicular to the first. The gauges are commonly mounted adjacent to each other in the form of a "T" if both are mounted on the same side of the sample, or in a "cross" configuration if mounted on opposite sides of the sample (as in Figure 1). When mounted in the "cross" configuration, the centre-points of each gauge must lie on the axis of a single line passing through the beam, perpendicular to the length and width axes of the beam.

4.2 Young's Modulus

We can also use the Vishay strain gauge equipment to calculate Young's Modulus for aluminum. Refer to Figure 2 and Appendix A for details. Measure the dimensions of the aluminum cantilever, the applied weight, and use the follow formula to calculate E, Young's modulus.

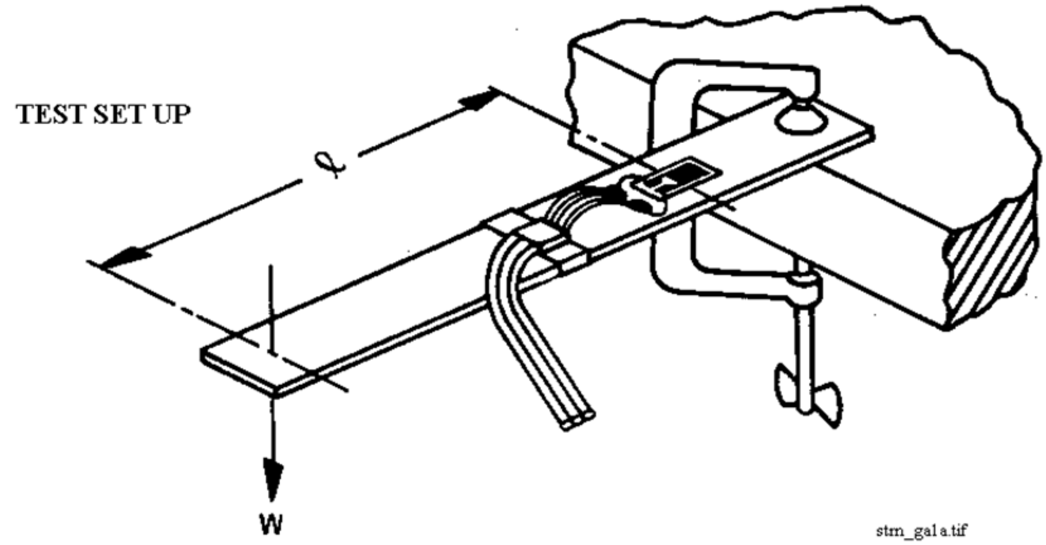


Figure 2: Test setup to determine Young's modulus of an aluminum beam.

$$E = \frac{\sigma}{\varepsilon} = \frac{M_c}{I\varepsilon} = \frac{6mgl}{\varepsilon b h^2} \quad (3.2)$$

E	Young's modulus in [N/m^2]
m	mass [kg]
g	gravitational acceleration [ms^{-2}]
l	length of the cantilever beam (center of gauge to load)
E	Strain
H	thickness of the cantilever [m]
B	width of the cantilever [m]
L	length of the gauge [m]
I	moment of inertia (m^3)
M_c	bending moment at gauge centerline (N.m)

5 Test Assembly

The strain gauge provided for your experiment - part number "CEA-06-240UZ-120" is a Student Gauge (preface CEA, as outlined in the binder). The "240" indicates that the gauge is .240 inches (6.1 mm) long and the "120" indicates that the gauge resistance is 120Ω.

The strain gauge is installed on the aluminum beam as presented in Figure 3. It is equipped with a DE9M connector (male) with a mating connector on the back of the Wheatstone bridge amplifier. When clamping the beam, please direct the sensor cable behind the wingnuts to provide a stress relief and not load the beam with the cable and connector assembly. The pinout of the connector is provided in Table 1. Additionally, a complete connection diagram is provided in Appendix C.

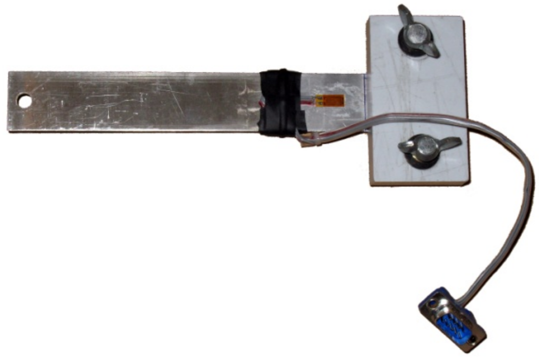


Figure 3: Aluminum beam with a strain gauge.

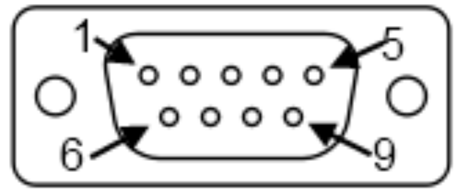


Figure 4: Pin locations on the DE9M connector.

Table 1: Pinout of the DE9 connector on the beam.

Pin No	Function
2	**Transversal strain gauge GY**
3	**Longitudinal strain gauge RD**
4	**Longitudinal strain gauge GY**
6	**Transversal strain gauge RD**
8	**Longitudinal strain gauge RD**
9	**Longitudinal strain gauge GY**

6 Measurement Procedure

1. Fix the supplied aluminum beam into the clamping device on the bench top. Pay careful attention to align it square to the edge of the bench top (this step may already be done).
2. Use a digital multimeter (DMM) to measure the gauge resistances when the beam is unloaded. Repeat your measurements with the gauges when the beam is loaded with a different mass of up to 500 grams and note the changes in resistance under different loading conditions.
3. Connect gauge wires to the amplifier unit using the connectors at the back of the unit.
4. Read the short summary on how to set up the strain gauge amplifier to make strain measurements in appendix A and null the display output to zero with the excitation voltage turned off.
5. Balance the bridges with the weight basket suspended from the beam. Make up a data chart for the readings which you will take as instructed below.
6. Using at least 4 different weights not exceeding a 500 gram load on the beam, take output readings from each gauge for each weight (leave a blank column for step 7).
7. Repeat steps 5 using an excitation voltage of 4.0 Volts.
8. Correct for transverse sensitivity as described in excerpt from the Vishay documentation (appendix B) and insert corrected values in data chart.
9. Use the data which you have collected to calculate at least 8 values for Poisson's ratio.

10. Compare your calculated value to that from literature (cite source) and comment on your results.
11. Use the data gathered to calculate at least 4 values for Young's Modulus using 3.2 supplied above.
12. Compare the value for Young's Modulus to a value from the literature (cite the source used) and comment on the results.
13. Show all data you collected and the numbers you used in your calculations in your report.
14. We have ignored temperature compensation in this experiment – comment on whether this is justifiable or not with our experimental setup.

Appendix A: Summary on strain gauge amplifier set up and strain measurement

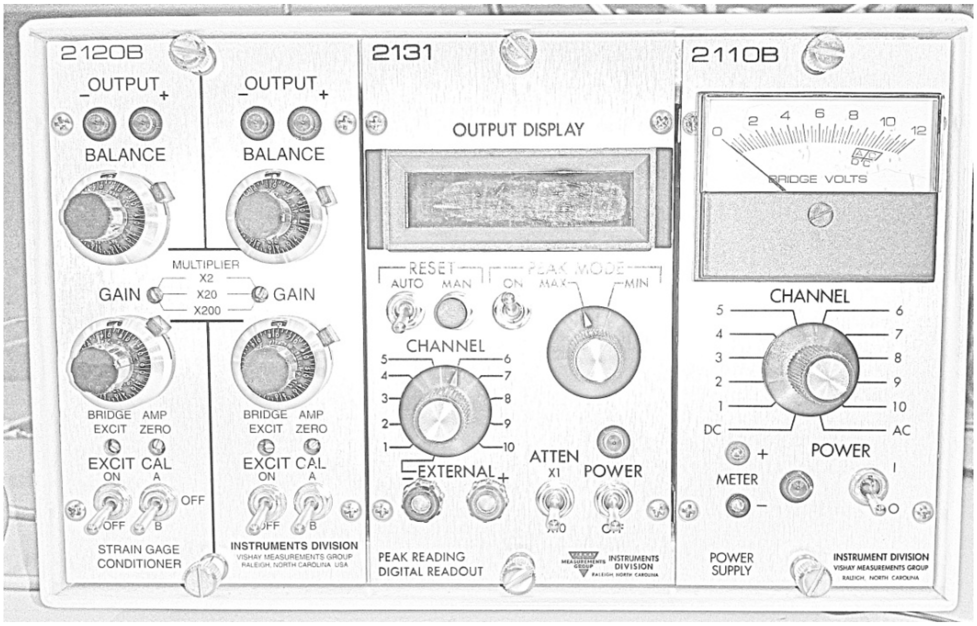


Figure 5: Front panel of the Wheatstone bridge amplifier.

Setup

1. Clamp the beam, with the hollow side of the beam facing towards you.
2. Note that the Wheatstone bridge readout device (Figure 5) has three modules:
   - **2120b** – contains the two channels, the left is channel 1 and the right is channel 2. This lab involves using 2V and 4V excitation for the Wheatstone bridge measurement. Use the channels accordingly:
     channel 1 – 2V excitation
     channel 2 – 4V excitation
   - **2131** – contains the output display – Wheatstone bridge voltage readout (values are in μV). The input of the voltage display is chosen from the channel selector below. (Only channels 1 and 2 are active).
   - **2110B** – displays excitation voltage and houses the power button. The excitation voltage is chosen from the channel selector below. (Only channel 1 and 2 are active)
3. Turn the power button on under the 2110B section to power the Wheatstone bridge machine. Turn the power button on under the 2131 section to power the output display panel.

   Set the following accordingly (**2131**)

   Atten – X1 Channel – 1 Peak Mode – Off Reset – Auto
4. In section **2120B**, for both channels, make sure that the gain multipliers are **200** and that the fine gain adjust right beneath the multiplier are set to **5.0**.

Gauge measurement

You have to take readings for multiple weights for both the axial and the transversal strain gauge, at both 2 volt and 4 volt excitation.

For one strain gauge (axial or transversal) perform steps 5 to 8 as in the followings.

5. Connect the leads from the strain gauge (the DB9 connector) via the channel 1 (2V) with cables that are brought out from the back of the Wheatstone bridge (Appendix C).
6. Turn the EXCIT button off and check if the output display shows value close to zero; if not, turn the "amp zero" pot using a small flat screwdriver.
7. Turn the EXCIT button on and tweak the balance knob so that output display says zero (or close to zero) with the hanging basket attached.
8. Hang weights onto the beam (less than 500g) and record the measurements from the output display. Pick 3 or 4 weights and record the measurements.

Then, perform the following steps.

9. Repeat steps 5 to 8 for the other strain gauge.
10. Repeat 5 to 9 for the channel 2 (4V excitation). Remember to switch the channels to 2 for the output display in section 2131.

Appendix B: Excerpt from Vishay documentation – Analysis and Presentation of Data

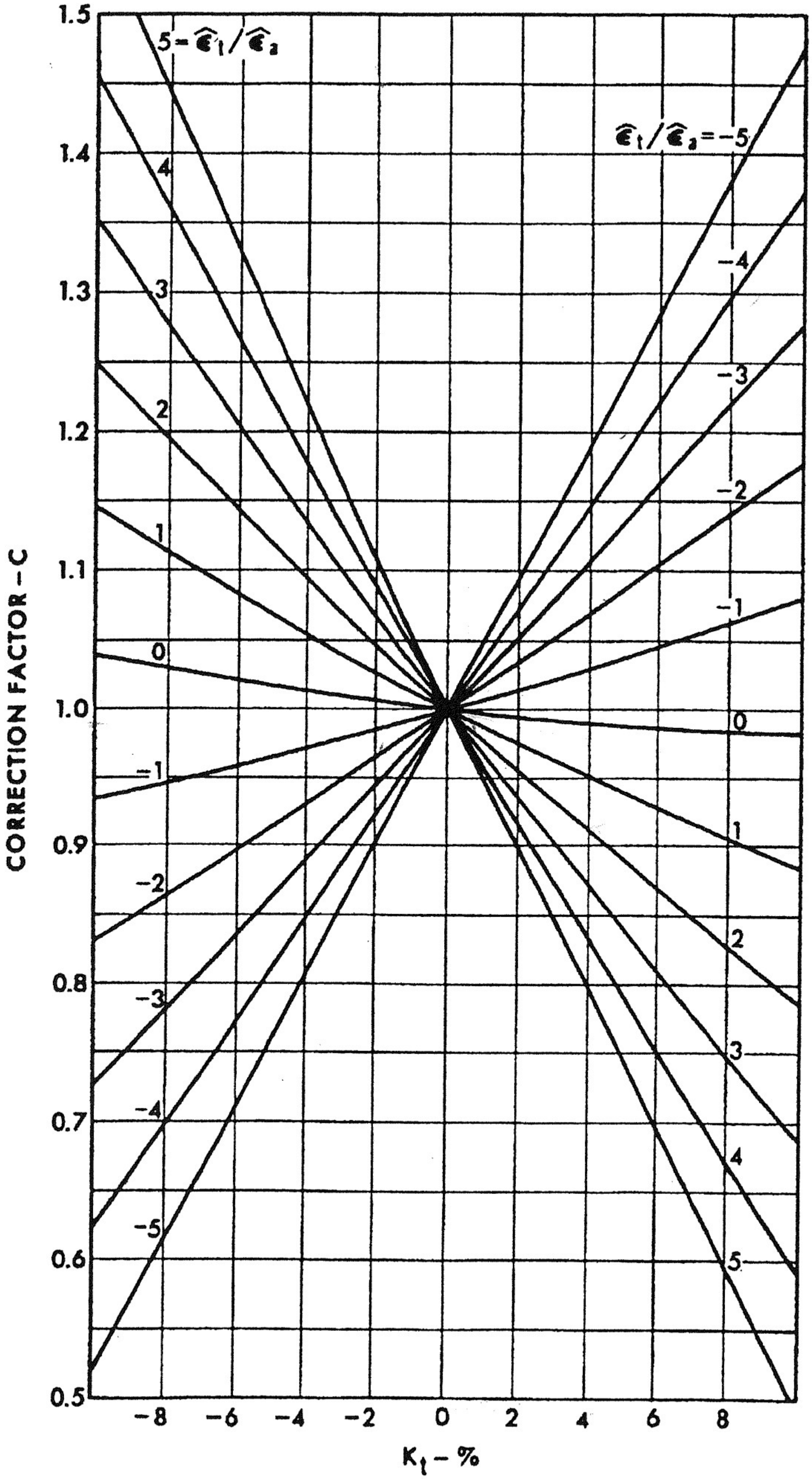
Before calculating Poisson's ratio from the indicated longitudinal and lateral strains, the indicated lateral strain should be corrected for transverse sensitivity. Because the longitudinal strain in the beam is several times as large as the lateral strain, the lateral gauge is subjected to a much larger strain in a direction transverse to its primary sensing axis than along that axis. As a result of the finite width of the grid lines in the gauges, and the presence of end loops connecting the grid lines, strain gauges are generally sensitive not only to the strain parallel to the grid direction, but also (to a much lesser degree) to the strain perpendicular to the grid direction. This property of strain gauges is referred to as "transverse sensitivity", and symbolized by K_t. For the gauge you use for this lab, K_t = 0.4% and the gauge sensitivity S_s = 2.075.

The correction for transverse sensitivity can be made easily from the attached graph provided below. To use the graph, two quantities are needed:

- the ratio of the longitudinal strain to the indicated lateral strain (which is the ratio of the transverse to the indicated axial strain for the lateral gauge)
- the transverse sensitivity, K_t, of the lateral strain gauge (given on the data sheet enclosed in the strain gauge package).

Enter the graph on the abscissa at the value of K_t for the gauges used in this experiment. Project a line upward to the sloped line representing the ratio of the strains transverse to and parallel to the axis of the lateral strain gauge (note that the ratio is actually negative in this instance). From the intersection of these lines, project horizontally to the correction-factor scale on the ordinate to find "C". Multiply the indicated lateral strain by "C" to obtain the corrected lateral strain. The indicated longitudinal strain need not be corrected for transverse sensitivity because the transverse strain sensed by the longitudinal gauge is small to begin with, and similar in magnitude to the transverse strain in the calibration environment used to measure the gauge factor of the strain gauge (the gauge aligned with the applied stress axis in a uniaxial stress field, with a Poisson's Ratio of 0.285).

CORRECTION FOR TRANSVERSE SENSITIVITY



Appendix C: Connectivity Diagram