MECHANICAL ENGINEERING TECHNOLOGY
ESSENTIALS FOR LABORATORY REPORTS

The laboratory report should be **clear and concise**. A well written laboratory report should have an acceptable form, and **free of any grammatical and spelling error** and **written in your own words. Plagiarism is not acceptable.** The report must be prepared on a word processor with **double line spacing**. Subscript, superscript, Greek letters should be used where applicable.

The formal lab-reports must contain the following sections in the order shown.

- Cover page: Download the cover page and fill out the necessary fields
- Abstract
- Main body of the report:
  - Objective
  - Introduction/Theory
  - Procedure (including diagrams, list of equipment, sketches etc)
  - Results (including data table and sample calculations)
  - Interpretation of results
  - Conclusion
  - References

Abstract: The abstract is a synopsis of an entire technical report and should not exceed one page. This section should be written in a separate page in paragraph form and should provide answers to the following three questions:

1. What was done
2. How was it done, and
3. What were the significant results and conclusions?

One to two sentences should be devoted to answer the first two questions**, and the last question should be more elaborated with highlights of the results, supported by numerical figures**. Do not include any table, figure or sketches in the abstract. **The abstract is a summary of the whole report and it is easier to compose the abstract after the whole report has been written.**

The main body of the report

It should contain the following sections:

Objective: The main body of the report will start with this section. State in few sentences what was attempted in the experiment. After reading the objective, the reader should have a very clear idea of what is being attempted.

Introduction/Theory

The introduction and theory can be two separate sections or combined in one section. The introduction contains a review of the previous work on the same topic. The introduction should also make a case for doing the work by answering the following questions. Why is this work necessary? What knowledge can be gained from this work? Why is this knowledge necessary? What is the justification for spending the time and money to conduct this work? **You can do a bit of Google search on the topic to find material for introduction.** If you cite other's work in your report, you must include the source of the material in the reference list at the end of the report.

The theory section should develop the theoretical background for the work. The derivations (if necessary) of pertinent theoretical relations should be presented in this section. The following questions are answered in this section. Based on the theory, what are the expected results? What are the limitations of the theory? If the work duplicates previous work that has universally accepted results, what are the "acceptable" results? This sets up a basis of comparison for your results in the discussion section of the report.

Procedure

This section is important for the reader to understand how the work was done. It allows the reader to duplicate the work if necessary. Under this section a list of equipment and a schematic should be provided. The equipment list should include every piece of equipment used. Major equipment, that is crucial to the work, should be listed with the make and model number. The schematic is not supposed to be a 3D multicolored work of art. It is a simple line drawing that shows the layout of the project, with the major details included. From the equipment list and schematic, the reader should be able to duplicate the project.

The procedure should be a complete description of the method used to accomplish the experiment. **The procedure must be in the past tense and should describe what has been done**.

Results

In this section the results of the work are presented. Present the data and the results in a neat tabular form, and **explain in the text what is being presented**. All tables should be numbered sequentially and have their own titles explaining what they are presenting, complete with units of measures used for each measurement. The graphs and tables should be able to stand alone, separate from the report, and still be understandable.

Interpretation of results

This is the section where the results of the work are analyzed, compared to theory or expected results, and interpreted. Graphs can be used to compare the results of various settings or to present the trend that is important. In this section you get to explain what the results all mean. How does the results compare to the expected or theoretical values? Have any trends being established and if so, what is their significance? Did the experiment stay within the theoretical limitations? Try to perceive any question that the reader might have about the results and then answer it. What if the experimental results appear to be incorrect? Point out where the results are incorrect and give probable reasons for such errors. Are there obviously bad data points? Does the result look better after eliminating the bad points? What are your suggestions for correcting the experiment? Get as much out of a failed project as possible. Almost as much can be learned from a failed project as from a successful project if the discussion is presented correctly. The next time the experiment is run, the reader will have learned from your mistakes.

Conclusion

In this section summarize what has been learned from this project. Present briefly the highlight of the results. Indicate if there is any future scope of study.

References: This is a list the reference of cited works in your report. Follow the style of reference provided at the end of chapters in your text book.

MET 301
EXPERIMENT # 1
WHEATSTONE BRIDGE

Introduction

The Wheatstone bridge is an electrical circuit used to compare an unknown resistance with a known resistance. It is commonly used in control circuits. For example, a temperature sensor in an oven often consists of a resistor with a resistance that increases with temperature. This temperature-dependent resistor is compared with a known resistor (outside the oven) to control a heater and maintain a set temperature.

A schematic of a Wheatstone bridge, shown in Figure 1: Let R_1 is an unknown resistor, the resistor R_3 is known and adjustable, and the resistors R_2 and R_4 have a known ratio of R_2/R_4, although their individual values may not be known. When a voltage V_i is impressed upon the circuit at points C and D, a galvanometer G indicates the voltage difference V_{AB} between points A and B.

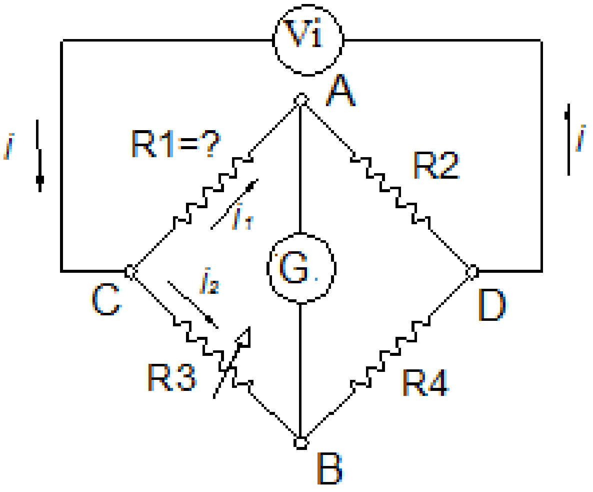

Figure 1 Wheatstone bridge circuit

Either the known resistor R_3 is adjusted, or the ratio R_2/R_4 is adjusted until the voltage difference V_{AB} is zero and no current flows through the galvanometer and $V_{AB}=0$. When the $V_{AB}=0$, the bridge is said to be balanced.

Since $V_{AB}=0$, the voltage drop from C to A must be equal to the voltage drop from C to B, ie. $V_{CA}=V_{CB}$. Likewise, we must have $V_{AD}=V_{BD}$. Thus, from ohms law, we can write,

(1) $i_1 R_1 = i_2 R_3$

(2) $i_1 R_2 = i_2 R_4$

Dividing (2) by (1), we have

(3) $R_1/R_2 = R_3/R_4, \quad R_1= R_3*R_2/R_4.$

Thus the unknown resistance R_1 can be computed from the known resistance R_3 and the known ratio of R_2/R_4. Notice that the computed R_1 does not depend on V_i, the impressed voltage;

hence V_i need not be very stable or well-known. Another advantage of Wheatstone bridge is that, it uses a *null measurement,* (V_{AB}=0), the galvanometer does not have to be calibrated.

In practice, the Wheatstone bridge is seldom used merely to determine the value of a resistor in the manner just described. Instead, it is used to measure small changes in R_1 due to, for example, change in mechanical strain or change in temperature. For example, suppose $R_1 = 10^6\ \Omega$ and we wanted to measure a change in R_1 of $1\ \Omega$ resulting from a change in mechanical strain. There is no ohmmeter which can accurately measure a change in resistance of 1 part in a million. However, the bridge can be set up so that V_{AB}=0 when $R_1 = 10^6\ \Omega$. Then any change in R_1, ΔR_1, would result a non-zero V_{AB}, which can be shown, is proportional to ΔR_1. You would not weigh a cat by weighing a boat with or without a cat on board. Likewise, you would not want to measure very small changes in R_1 by measuring with and without the change. We will apply this principle in our laboratory #2, to measure minute changes in resistance strain gages due to application of mechanical load.

Experiment

The experimental setup for this lab is shown in Figure 2, which includes a digital multi-meter (DMM), two decade resistance boxes, a power supply unit, a Wheatstone bridge circuit panel, and two panel mounted unknown resistors AB and CD. In this experiment we will measure resistances by using the DMM, and then by using the Wheatstone bridge, and compare the accuracy of the two measuring systems.

Figure 2 Experimental set up for Wheatstone bridge lab.

We will measure the resistance of AB and CD separately. Then we will measure the equivalent resistance when the two resistors are connected in series, and again measure the equivalent resistance when they are connected in parallel (see Figure 3). Based on the measured values of R_{AB} and R_{CD}, we will expect a resistance value $R_{AB} + R_{CD}$ when the two are connected in series, and $(R_{AB} * R_{CD})/ (R_{AB} + R_{CD})$ when the two are connected in parallel. The comparison of these expected values with the respective measured values by two measuring systems will give us estimates of the measurement accuracy of the two systems.

Series

Parallel

Figure 3 Panel mounted resistors AB and CD, when connected in series and parallel

First we will use the DMM (Figure 4) to measure the resistance values. Set the DMM in resistance mode by pressing the kΩ function button, connect resistors using two cables and measure the resistor AB, CD, AB and CD in series, and AB and CD in parallel. For each measurement, push the appropriate range selecting button to get the maximum possible precision level. Notice that for smaller resistance values, precision level is 0.001 kΩ and for the larger ones 0.01 kΩ .

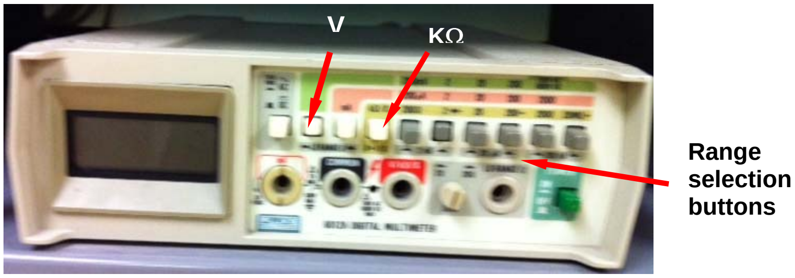

Figure 4 Digital Multi-meter (DMM)

Next, we will measure the above resistances using the Wheatstone bridge circuit panel (Figure 5). The unknown resistance is connected to “R=?” position of the bridge, and the adjustable resistance is connected to “R ADJ” position. The total current flowing through the bridge is shown in the ammeter to the left of the bridge. Notice that on the right side of the bridge, the two arms have equal resistance, 10K and 10K, that is the ratio of these two resistance values is one. Then according the equation (3), when the adjustable resistance will be exactly equal to the unknown resistance, the bridge will be balanced.

Figure 5 Wheatstone bridge circuit panel

Two decade boxes (Figure 6), connected in series, will act as the adjustable resistance. The decade resistance boxes allow a convenient way of selecting and quickly changing the resistance by setting the dials to appropriate decade numbers. The top box can adjust the resistance from 0 to 1000 kΩ, in .01 kΩ steps. The bottom box can adjust between 0 to 100 Ω, in .01 Ω steps. When the two boxes are connected in series, they will allow us to adjust resistance from 0 Ω to 1000 kΩ, with 0.01Ω steps. Before connecting to the bridge, check the change in resistance as the dials are turned, by connecting them to the DMM in resistance mode.

Figure 6 Two decade boxes connected in series

An adjustable power supply unit (Figure 7) will be used to power the bridge. Switch on the power supply; adjust the coarse and fine voltage knobs to set the voltage to 5 volts. If necessary, turn the current knob slightly until the green lamp (CV) lights up. Too much voltage might blow the fuse of the Wheatstone bridge circuit. Use the DMM in voltage mode, to check the voltage output from the power supply. Connect the red and black terminals of the power supply unit to the red and black terminal of the bridge.

Figure 7 Adjustable power supply unit

Connect the DMM in voltage mode to the “BRIDGE OUT” terminals of the Wheatstone bridge (Figure 5). The DMM will serve as the galvanometer G to measure the bridge output V_{AB}, as shown in Figure 1.

Balance by bridge by adjusting the decade resistance boxes until the bridge output voltage V_{AB} registered by the DMM is decreased as nearly as possible to zero. Since you already know the resistance values, start by dialing in those values in the decade boxes, and then adjust it until the bridge output is zero. Start out with the 20 volt scale of the DMM, and refine your readings as you approach balance condition to take the readout on the 200 mv scale. When the bridge is balanced, record decade resistance in kΩ, bridge unbalance (if any), bridge input voltage, and bridge current in the data sheet. Repeat the above steps for the resistor CD, AB and CD connected in series, and AB and CD connected in parallel, and record all data in the data sheet.

Results

1. Tabulate R_{AB} and R_{CD} as measured by the digital multi-meter, and Wheatstone bridge. Calculate the theoretical resistance values when R_{AB} and R_{CD} are in series and in parallel combinations. Include these computed values in the data table together with the measured series and parallel values. Calculate percentage of error with respect to the theoretical values.

2. Use the digital multi-meter readings of the four resistances as standards and calculate the percentage of error for each of the measured data by Wheatstone bridge circuit.

Names ________________________
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WHEATSTONE BRIDGE
DATA SHEET

Digital Multi-meter readings and theoretical values

	Resistor values from multimeter	Theoretical values	% of error from theoretical value
R_{AB}		Not applicable	Not applicable
R_{CD}		Not applicable	Not applicable
R_{AB} and R_{CD} in series		$R_{AB} + R_{CD}=$	
R_{AB} || R_{CD} in parallel		$(R_{AB} \times R_{CD})/(R_{AB} + R_{CD})=$	

Wheatstone bridge: values from the decade resistance box and theoretical values

	Resistor values from decade box	Theoretical values	% of error from theoretical value
R_{AB}		Not applicable	Not applicable
R_{CD}		Not applicable	Not applicable
R_{AB} and R_{CD} in series		$R_{AB} + R_{CD}=$	
R_{AB} || R_{CD} in parallel		$(R_{AB} \times R_{CD})/(R_{AB} + R_{CD})=$	

Comparison of the resistance values obtained from multimeter and bridge

	Resistor values from multimeter (R_M)	Resistance values from bridge (R_W)	% of difference $(R_M-R_W)*100/R_M$
R_{AB}			
R_{CD}			
R_{AB} and R_{CD} in series			
R_{AB} || R_{CD} in parallel			

Additional information for Wheatstone bridge

	Bridge unbalance, V_o (mv)	Impressed voltage V_i (mv)	Bridge current (mA)
R_{AB}			
R_{CD}			
$R_{AB} + R_{CD}$			
R_{AB} || R_{CD} in parallel			

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Instructor's signature / Date