DEPT. OF ELECTRICAL & ELECTRONICS ENGINEERING
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY, Kattankulathur – 603203.

Title of Experiment	: **9. Displacement measurement using LVDT and pressure measurement using Strain gauge**
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Register Number	: RA2011004010051
Date of Experiment	:13.07.2021
Date of submission	**:** 13.07.2021

Sl. No.	Marks Split up	Maximum marks (50)	Marks obtained
1	Pre Lab questions	5	
2	Preparation of observation	15	
3	Execution of experiment	15	
4	Calculation / Evaluation of Result	10	
5	Post Lab questions	5	
Total		**50**	

Staff Signature

Experiment No. 9 a) Date :	**Displacement measurement using Linear Variable Differential Transformer**

Aim: To measure the displacement and to determine the characteristics of LVDT (Linear Variable Differential Transformer).

Apparatus required: LVDT, Digital displacement indicator, Calibration jig (with micrometre).

THEORY: LVDT (LINEAR VARIABLE DIFFERENTIAL TRANSFORMER)

The most widely used inductive transducer to translate the linear motion into electrical signals is the linear variable differential transformer (LVDT). The basic construction of LVDT is shown in Figure 1.

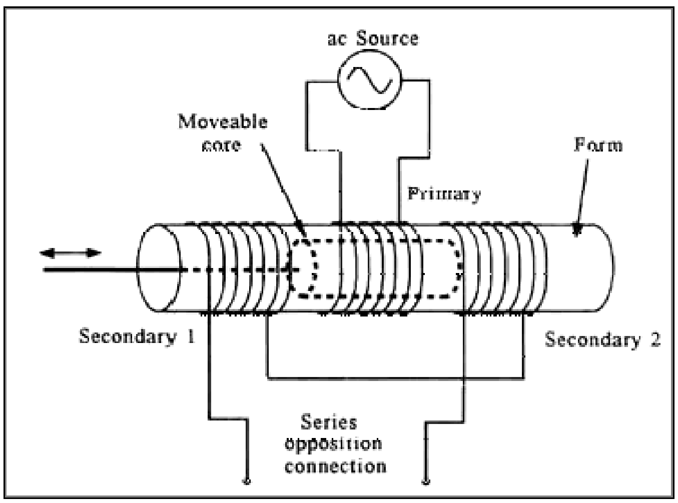


Figure 1. Linear Variable Differential Transformer

The transformer consists of a single primary P and two secondary windings S1 and S2 wound on a cylindrical former. The secondary windings have equal number of turns and are identically placed on either side. A moveable soft iron core is placed inside the transformer. The displacement to be measured is applied to the arm attached to the soft iron core. In practice the arm is made of highly permeability, nickel iron which is hydrogen annealed. This gives low harmonics low null voltage and high sensitivity. This is slotted longitudinally to reduce eddy current losses. The assembly is placed in stainless steel housing and the end leads provides electrostatic and electromagnetic shielding. The frequency of AC applied to primary windings may be between 50 Hz to 20 kHz. Since the primary winding is excited by an alternating source, it produces an alternating magnetic field which in turn induces alternating current voltage in the two secondary windings. Figure 2 depicts a cross-sectional view of an LVDT. The core causes the magnetic field generated by the primary winding to be coupled to the secondary. When the core is centred perfectly between both secondary and the primary as shown, the voltage induced in each secondary is equal in amplitude and 180 degree out of phase. Thus the LVDT output (for the series-opposed connection shown in this case) is zero because the voltage cancels each other. E0 = Es1 - Es2 = 0.

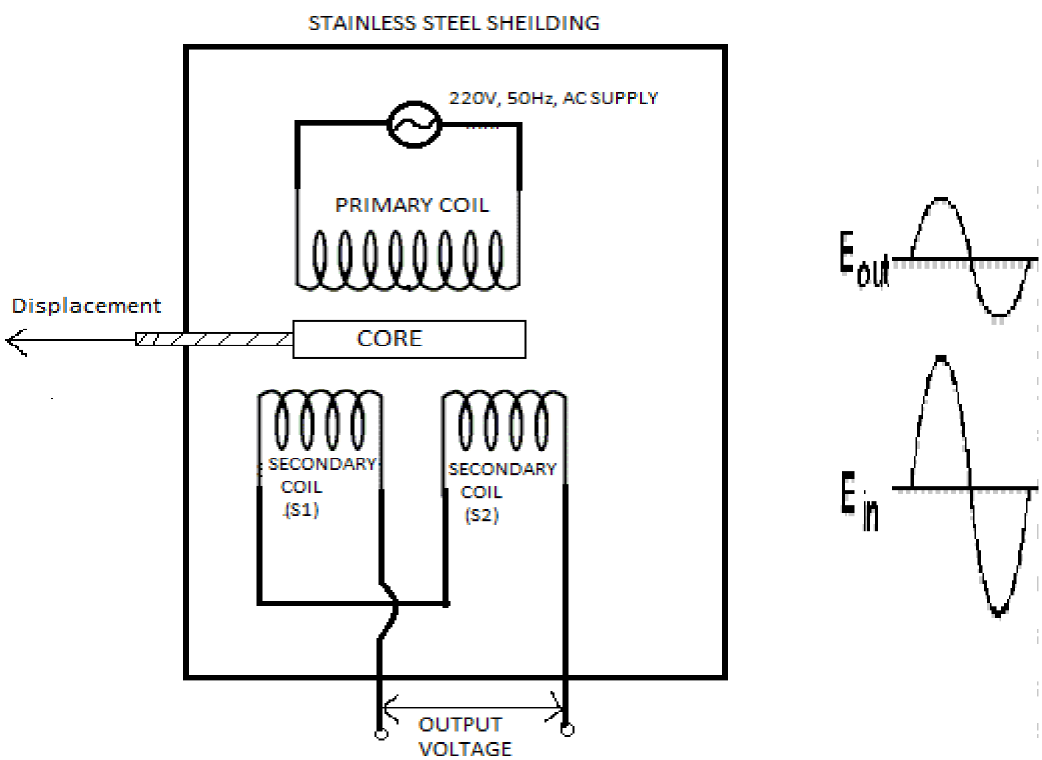


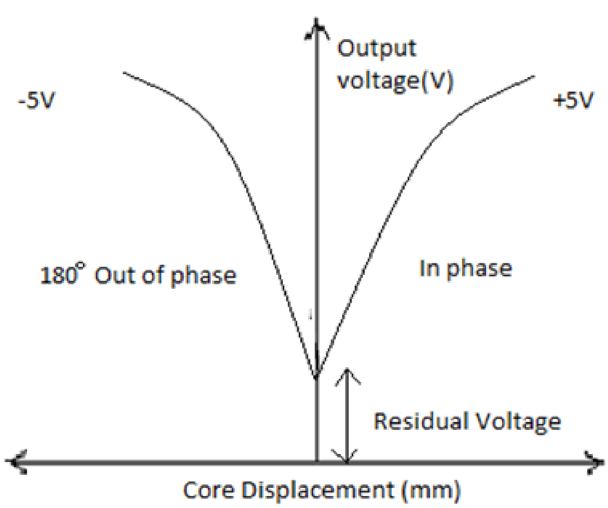
Figure 2. View of LVDT Core and Windings

Displacing the core to the left causes the first secondary to be more strongly coupled to the primary than the second secondary. The resulting higher voltage of the first secondary in relation to the second secondary causes an output voltage that is in phase with the primary voltage. Likewise, displacing the core to the right causes the second secondary to be more strongly coupled to the primary than the first secondary. The greater voltage of the second secondary causes an output voltage to be out of phase with the primary voltage.

Procedure:

1. Plug power chord to AC mains 230 V, 50 Hz and switch on the instrument.
2. Place the READ/CAL switch at READ position.
3. Balance the amplifier with the help of zero knob so that display should read zero without connecting the LVDT to instrument.
4. Replace the READ/CAL switch at CAL position.
5. Adjust the calibration point by rotating CAL knob so display should read 10.00 i.e., maximum calibration range.
6. Again keep the READ/CAL switch at READ position and connect the LVDT cable to instrument.
7. Make mechanical zero by rotating the micrometre. Display will read (00.00) this is null balancing.
8. Give displacement with micrometre and observe the digital readings.
9. Plot the graph of micrometre reading v/s digital reading.

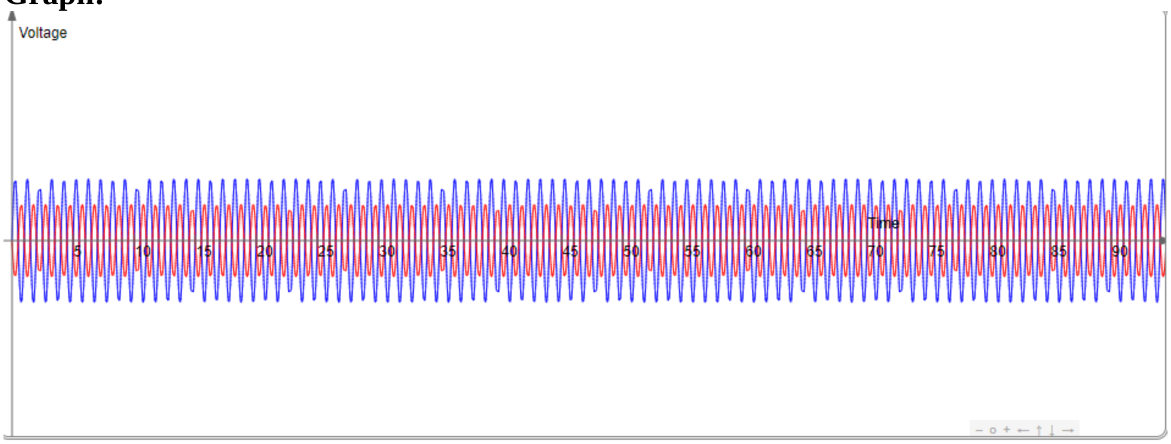
Model Graph:

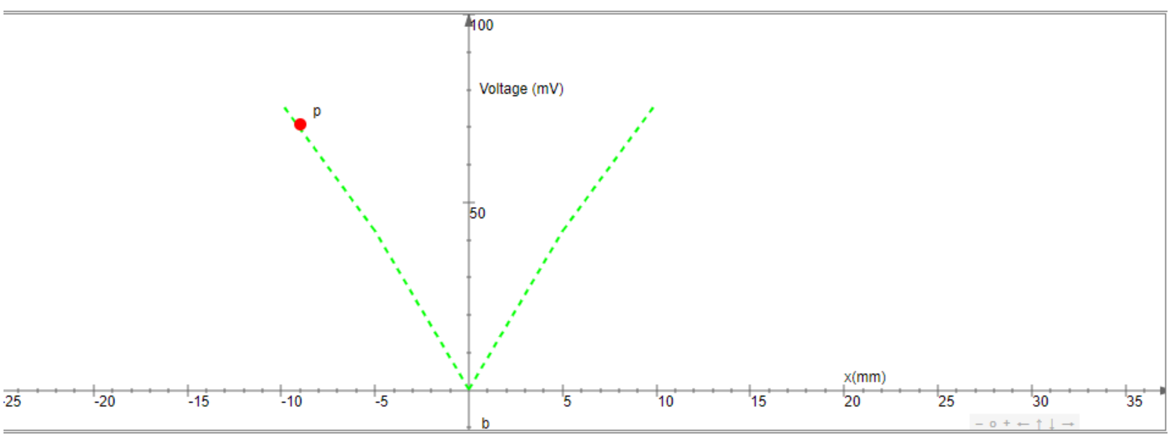


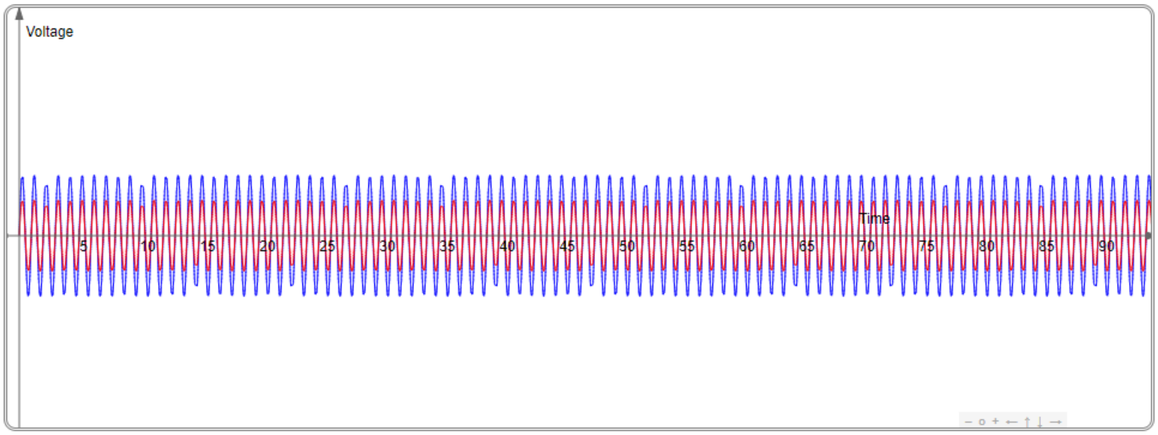
Tabulations:

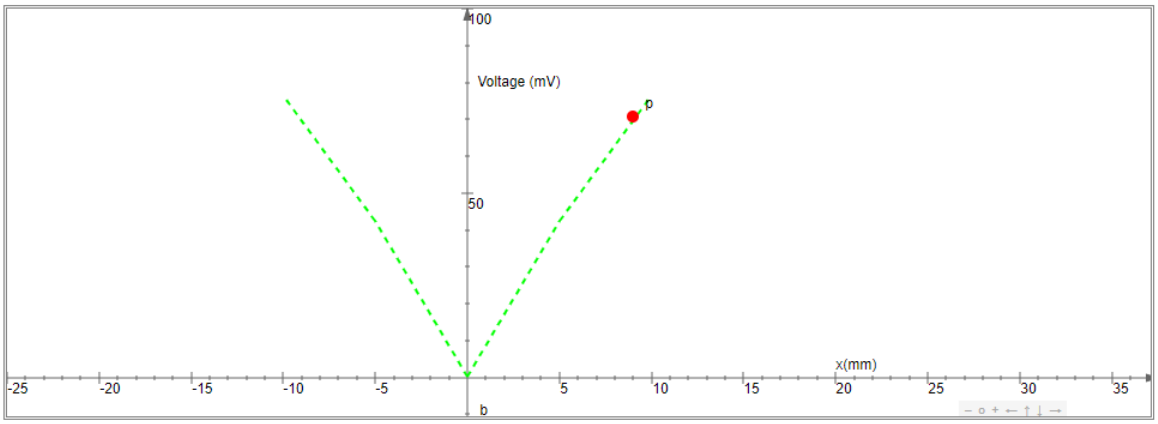
CORE DISPLACEMENT (mm)	SECONDARY OUTPUT VOLTAGE(mV)
0	0
3	**25.91**
6	**50.05**
9	**70.66**
-3	**25.91**
-6	**50.05**
-9	**70.66**

Graph:






Voltage
Time
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90


100
Voltage (mV)
p
50
x(mm)
-25
-20
-15
-10
-5
5
10
15
20
25
30
35
b

Result:

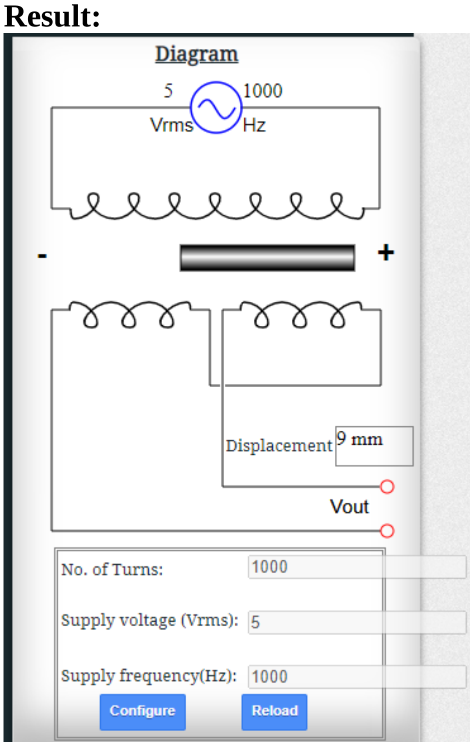


Diagram
5
1000
Vrms
Hz
-
+
Displacement
9 mm
Vout
No. of Turns:
1000
Supply voltage (Vrms):
5
Supply frequency(Hz):
1000
Configure
Reload

POST LAB QUESTIONS:

1. What are the three principles of Inductive transducers?

In Inductive transducers, the basic principle is that self-inductance of a single coil or the mutual inductance between two coils is changed by a quantity to be measured. Usually the measured value could be a rotatory or linear displacement, force, pressure, torque, velocity, acceleration, and vibration.
Inductive transducers work on one of the following principles for its working:

1. Change of self-inductance.
2. Change of Mutual Inductance.
3. Production of eddy current.

2. What are the limitations of LVDT?

1. Large displacement is needed for small output.
2. It is affected due to external magnetic field and hence the entire LVDT circuit needs to be shielded to achieve desired accuracy.
3. Vibrations due to displacement can affect the performance of the LVDT device.
4. The performance of LVDT is affected due to increase in temperature.
5. In order to get DC output, external demodulator is required.
6. It has limited dynamic response.

3. Where LVDT is used?

There are two main ways in which an LVDT can be used;
Main transducer – the LVDT will convert displacement into an electrical signal.
Secondary Transducer – An LVDT can also be used as a secondary transducer where it will measure force, weight or pressure.
Other Applications include:
Power turbines, Hydraulics, Aircrafts, Satellites, Nuclear reactors, Factory automation, Process and control, Materials testing, general industrial application, etc.

4. What are the different types of transducers used for displacement measurement?

A displacement transducer, or DT, is an electrical transducer used in measuring linear position. The output signal of the linear displacement sensor is the measurement of the distance an object has traveled in units of millimeter, or inches and can have negative and positive values.

5. What is the difference between variable resistance & variable inductance displacement transducer?

The variable resistance transducers are one of the most commonly used types of transducers. The variable resistive transducers are used for measuring various physical quantities like temperature, pressure, displacement, force, vibration, etc. These are usually used as the secondary transducers, where the output from the primary mechanical transducer acts as the input for the variable resistance transducer.
Variable Inductance Transducers is a measure that relates electrical flux to current. Inductance is monitored through the resonant frequency of the inductance could to an applied voltage. As inductance changes, the resonant frequency of the coils changes. Electronic circuits that convert frequency to voltage are used to gain a voltage output to inductive transducers.

PRE LAB QUESTIONS (Strain gauge):

1. How does a strain gauges work?

A strain gauge is a sensor whose measured electrical resistance varies with changes in strain. Strain gauges convert the applied force, pressure, torque, ect. Into an electrical signal which can be measured.

2. What is piezo-resistive effect?

It is the change in the electrical resistivity of as semiconductor or metal when mechanical strain is applied. It only causes a change in the electrical resistance, not in electrical potential.

3. What are the types of strain gauge?

a) Linear Strain Gauge.
b) Membrane Rosette Strain Gauges.
c) Double linear strain gauges.
d) Full bridge strain gauges.
e) Shear strain gauge.
f) Half bridge strain gauge.
g) Column strain gauges.
h) 45 – Rosette.

4. Define gauge factor.

Gauge or strain factor of a strain gauge is the ration of relative change in electrical resistance R, to the mechanical strain ε. It is defined as:

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon} = 1 + 2\nu + \frac{\Delta\rho/\rho}{\varepsilon}$$

5. Mention some practical applications of strain gauge.

It is used in the fields of civil engineering and geotechnical monitoring to detect failures in structures like buildings, bridges, and much more.
They are also frequently used for static testing.

Experiment No. 9 b) Date :	**Strain measurement using Strain gauge**

Aim: To measure the strain using strain gauge.

Apparatus Required: Strain gauge, weight, LABVIEW software.

Theory: Strain is the amount of deformation of a body due to an applied force. More specifically, strain (e) is defined as the fractional change in length, Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in./in. or mm/mm. In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as microstrain (me), which is e x 10-6. When a bar is strained with a uniaxial force, as in Figure 1, a phenomenon known as Poisson Strain causes the girth of the bar, D, to contract in the transverse, or perpendicular, direction. The magnitude of this transverse contraction is a material property indicated by its Poisson's Ratio. The Poisson's Ratio n of a material is defined as the negative ratio of the strain in the transverse direction (perpendicular to the force) to the strain in the axial direction (parallel to the force), or n = eT/e. The most widely used gage is the bonded metallic strain gage. The metallic strain gauge consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction (Figure 2). The cross-sectional area of the grid is minimized to reduce the effect of shear strain and Poisson Strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen.

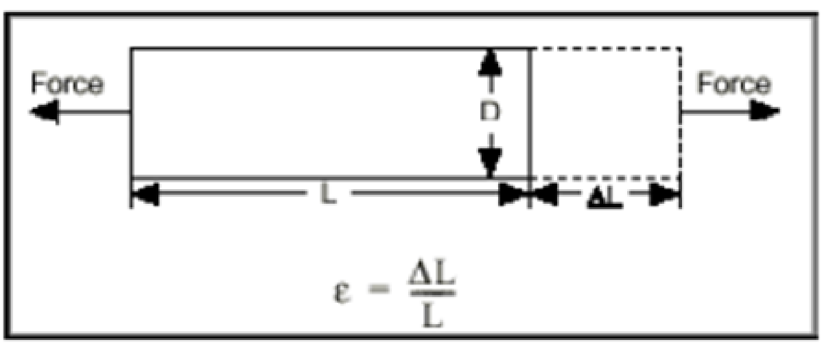


Figure 1. Strain measurement

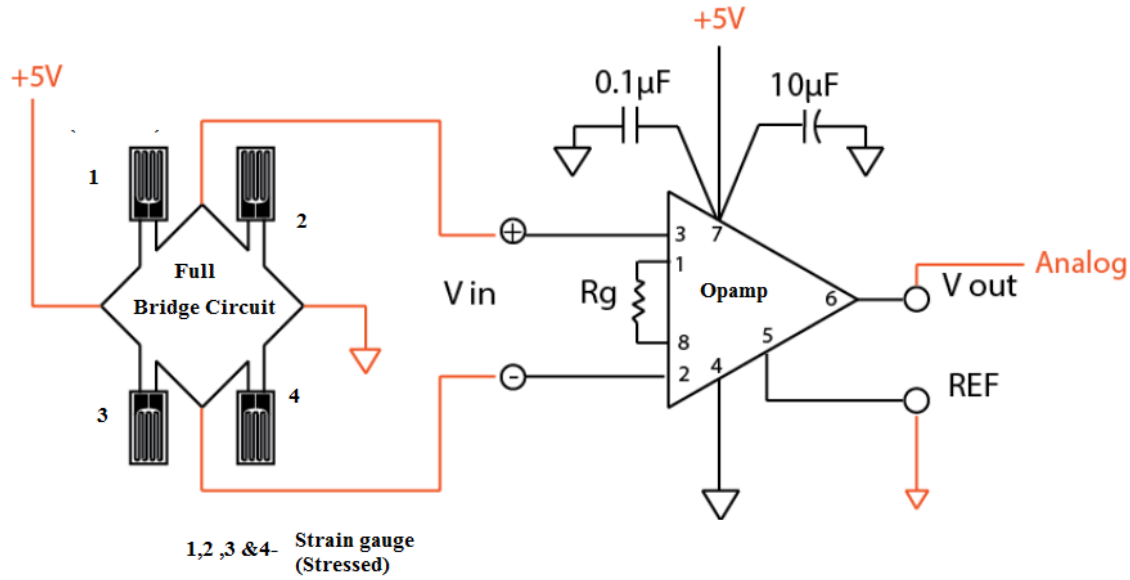


Figure 2. Full- Bridge Strain gauge circuit

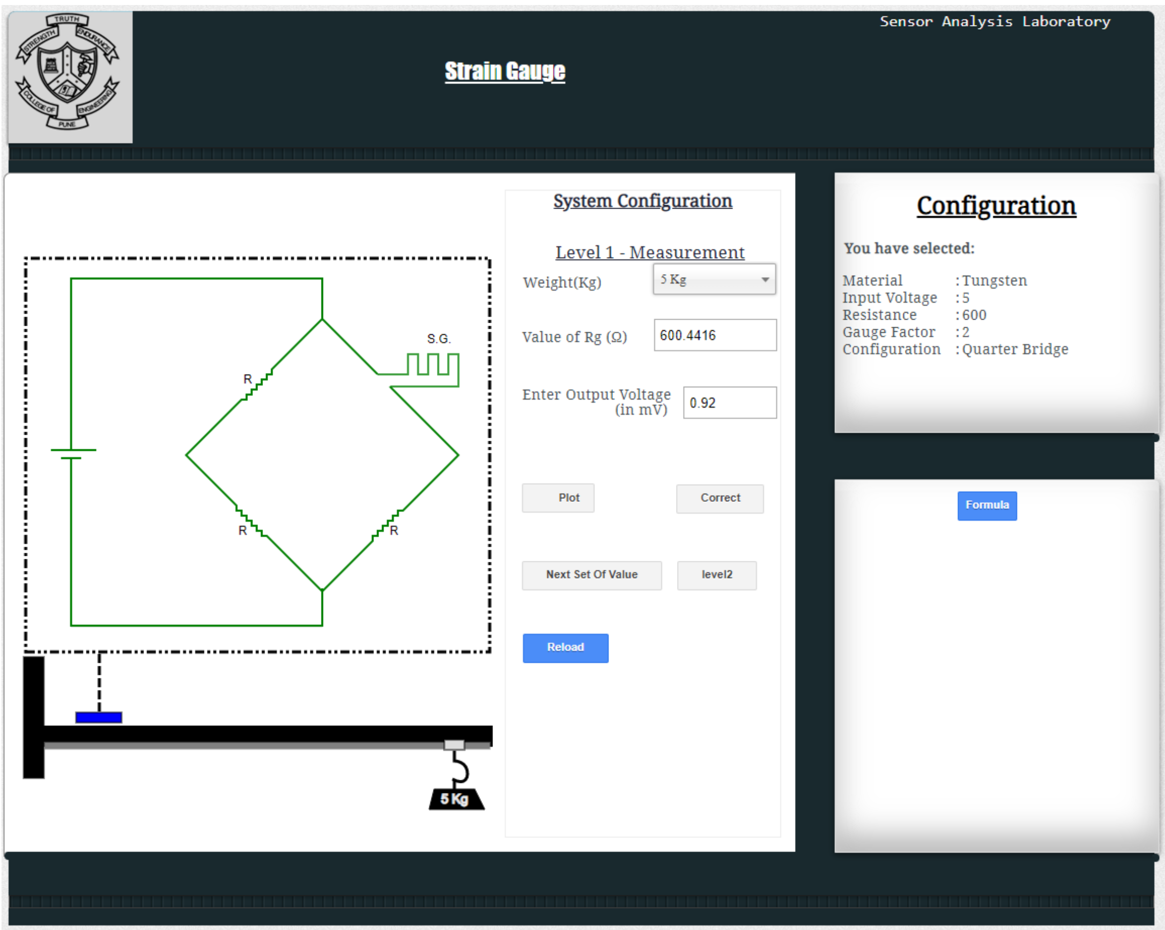
Procedure:

1. Connect the cantilever strain measurement assembly to the main trainer and switch ON the trainer
2. Connect the multi meter at the Instrument output with multimeter in DC VOLTAGE mode and 20 V Range.
3. Connect this STRAIN output also to display section marked Vout.
4. Now without any strain or load in the cantilever beam. So adjust the OFFSET CONTROL to 0 volts at the output.
5. Now place 500 grams weights on the pan suspended n the beam and adjust the gain or call control to read 0.5 volt by multimeter at the strain output terminal.
6. Now remove the weight from the pan and the output must be 0 volt. IF not then readjust OFFSET Control
7. Table the readings for different weight or strain on the load cell as well as display readings.

Tabulation:

S.no	Weight in Pan (grams)	Voltage measured(mv)	Display reading	Calculated value
1	1000	0.18	0.18	0.18
2	2000	0.37	0.37	0.37
3	3000	0.55	0.55	0.55
4	4000	0.74	0.74	0.74
5	5000	0.92	0.92	0.92
6	6000	1.1	1.1	1.1
7	7000	1.29	1.29	1.29
8	8000	1.47	1.47	1.47
9	9000	1.66	1.66	1.66
10	10000	1.8	1.8	1.8

Result:



Strain Gauge Experiment.

Material: Tungsten

Input Voltage (V) = 5V

Resistance (R) = 600 Ω

Gauge Factor (GF) = 2

$$\boxed{\text{Output Voltage in Quarter } (e) = \text{Bridg} \quad \frac{1}{4} \times \frac{dR}{R} \times V.}$$

[dR = GF × dL / L × R].

Rg = R + dR

(New resistance).

GT

For 1000 gram

dR = 0.0883

$$e = \frac{1}{4} \times \frac{0.0883}{600} \times 5$$

$$= 0.18 \times 10^{-3}\ V \text{ (or)}$$

$$= 0.18\ mV.$$

For 5000 gram

$$e = 2.08334 \times 10^{-3} \times 0.4416$$

$$= 0.92\ mV$$

$$e = \frac{5}{4} \times \frac{dR}{600} \times E(S)$$

$$= 2.08334 \times 10^{-3} \times dR.$$

For 10000 gram

$$e = 2.08334 \times 10^{-3} \times 0.8831$$

$$= 1.8\ mV.$$

POST-LAB QUESTIONS:

1. How can you apply the principle of stain gauge?

A Strain gauge is a sensor whose resistance varies with applied force; It converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured. When external forces are applied to a stationary object, stress and strain are the result.

2. What is meant by passive transducer?

Passive transducer is a device which converts the given non-electrical energy into electrical energy by external force. Resistance strain gauge, differential transformer are some examples of passive transducers.

3. What is sensitivity of strain gauge?

A fundamental parameter of the strain gauge is its sensitivity to strain, expressed quantitatively as the gage factor (GF). GF is the ration of the fractional change in electrical resistance to the fractional change in length, or strain:

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$

4. What is a microstrain?

Microstrain is the strain expressed in terms of parts per million.

5. What are the limitations of a strain gauge?

They are not suited for underwater application. They need to be protected with a water tight housing.
Only the surface strain of the component can be measured, but not the integral strain of the component.
It can only measure the strain of a point on the surface of a component in a certain direction, and cannot perform global measurement.