Composite Materials and Mechanics Lab
Mechanical and Aerospace Engineering Department
Polytechnic Institute of NYU

SMART Project
July 5-August 15, 2011

FINAL PROJECT REPORT

Project: Effect of Fiber Orientation on the Mechanical Properties of Epoxy Based Fiberglass Composites

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Research Objectives:

- To fabricate fiberglass composite materials of three different fiber orientations - 0^0 , 45^0 and 30^0-60^0

- To study the Mechanical properties such as Young's Modulus and Poisson's ratio of all samples using Tensile test

- To calculate the Elastic modulus of these composites using Rule of mixtures

- To draw the calibration curves for 0^0, 45^0 and 30^0-60^0oriented fiberglass samples using the sensitive optical fiber loop sensor

- To compare the results and discuss about the effect of fiber orientation on the mechanical properties of fiberglass composite

COMPOSITE MATERIALS

* These are prepared by combining two or more different natural or artificial materials to maximize desired properties and also to minimize unwanted properties.

Properties:
- Density
- Tensile Strength
- Tensile Modulus
- Thermal properties
- Electrical properties

Advantages:
- High strength
- Light weight
- Design Flexibility

Design Objectives:
- Strength
- Toughness
- Weathering
- Costs

Fiberglass : (Glass-Reinforced Plastic, GRP)

It is a fiber reinforced polymer made of a plastic matrix (epoxy) reinforced by fine fibers of glass.

Uses : Boats, Automobiles, Hot tubs, Water tanks, Roofing, Pipes,

Advantages: Lightweight, Strong, and Robust material.

Low Cost compared to carbon fiber and aramid (Kevlar)

Disadvantages:

- Relatively Low Strength
- High Elongation
- Moderate Strength to weight ratio

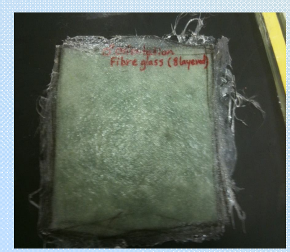
Fabrication:

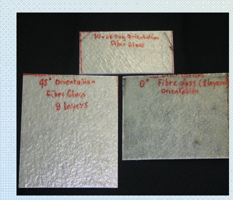
Step 1 : Cutting

Step 2 : Lay-up

Step 3 : Curing

Step 4 : Heating and trimming





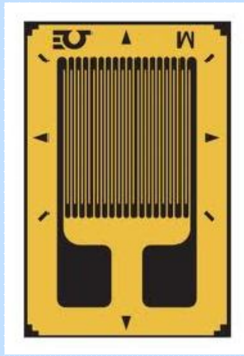
TENSILE TEST:

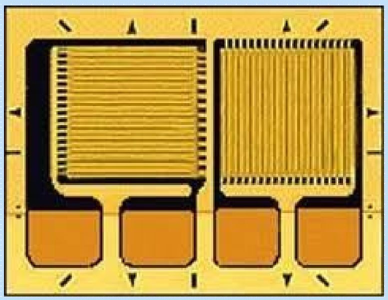
- ✓ **BONDING STRAIN GAUGE TO THE SAMPLE**

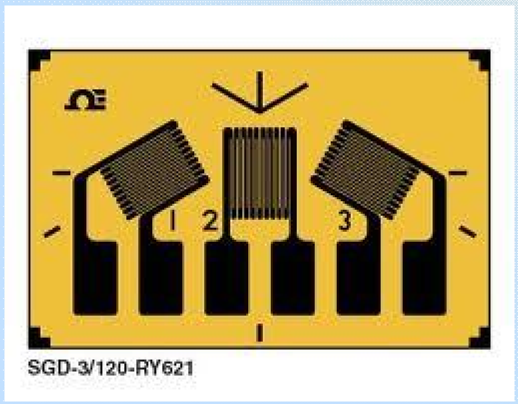
Basis: Resistance of strain gauge varies with the applied pressure

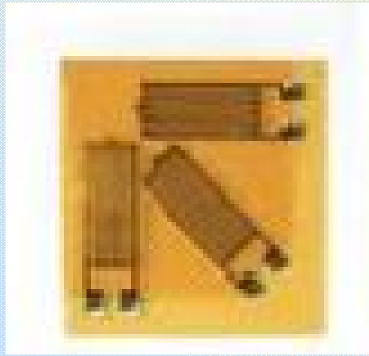
Types of strain gauges:

Uniaxial, bixial , delta 3 element, rectangular 3 element









TENSILE TEST:

- **In the test circuit, strain gauge will act as one of the resistors in the wheatstone bridge.**

- **gives load versus extension data**

- **Both tangential and longitudinal voltages are noted down for a point corresponding to linear region of stress –strain graph**

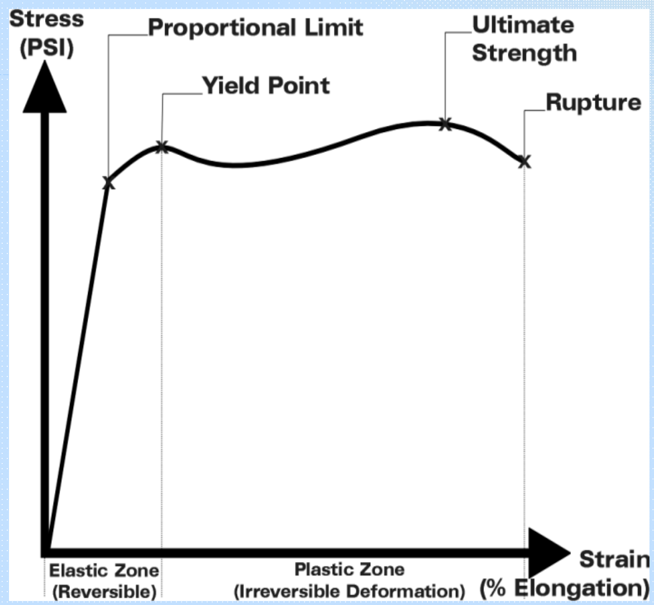


Fig. Sample stress-strain graph

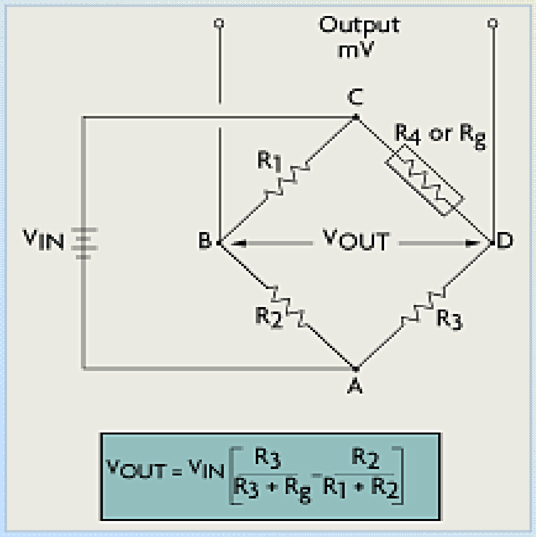


Fig. Schematic of wheatstone bridge circuit

TENSILE TEST:

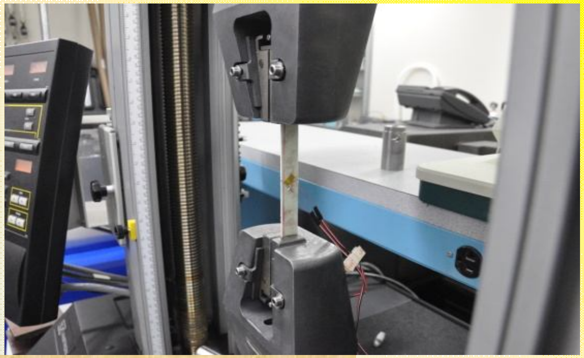


Fig. Specimen mounted on tensile test machine

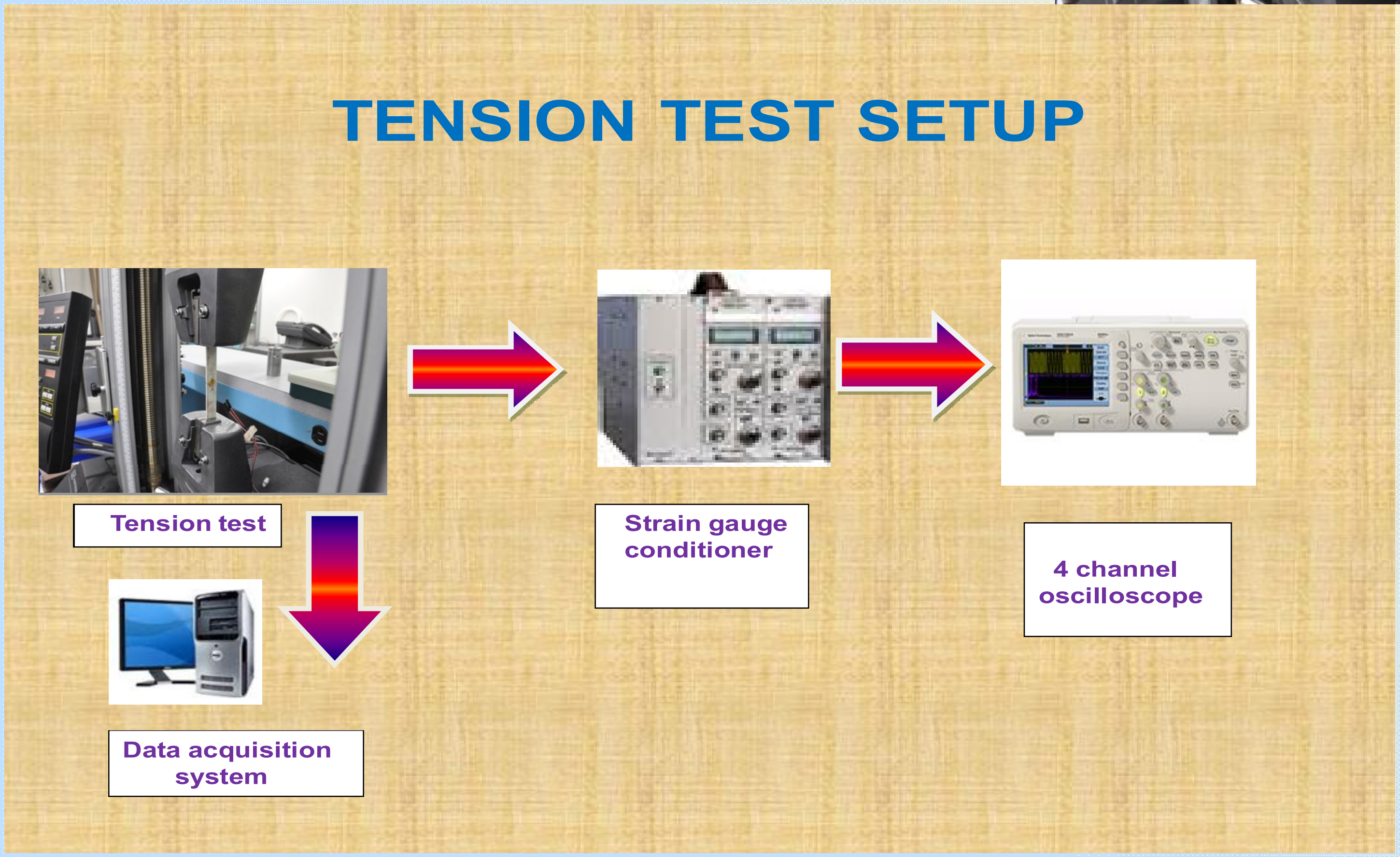


Fig. Flow chart of Tension test setup

TENSILE TEST RESULTS:

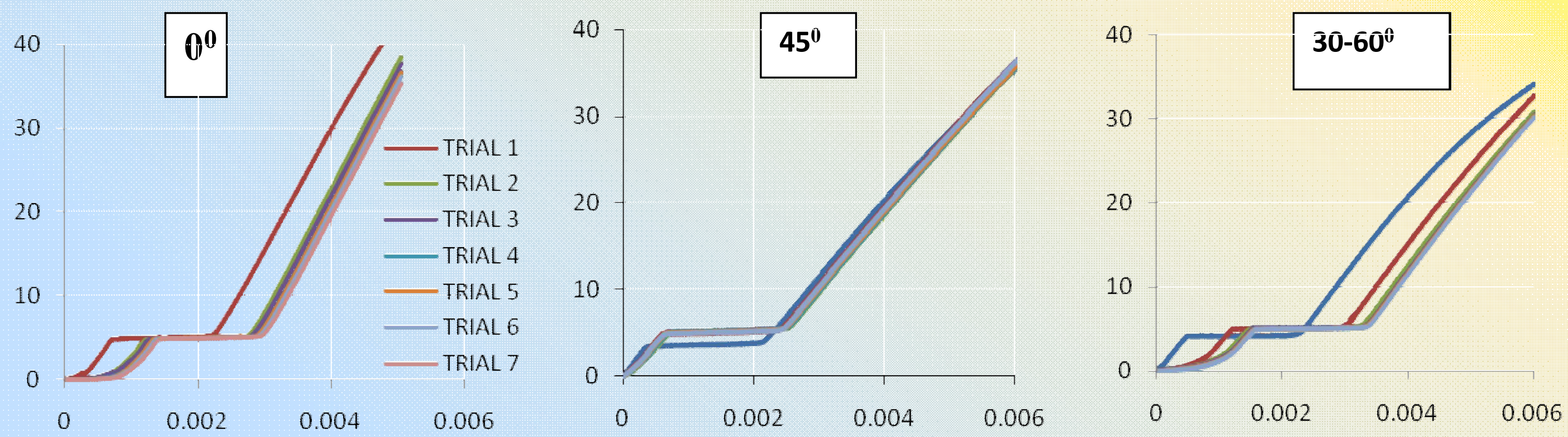


Fig. Stress versus strain plots of all fiberglass composite specimens

- All samples have shown similar behavior with a significant change in the slope of linear region between the range of strain values 0.003 to 0.006

- The plateau region between the range of strain values 0.001 to 0.003 may be due to slip in the grip of clamp fixtures or due to readjustment of matrix particles in between the layers

- The Young's modulus of each curve is calculated by finding the slope of linear region

TENSILE TEST RESULTS:

The data of young's modulus values are given below

	ORIENTATION		
TRIAL	0 DEGREE (Gpa)	45 DEGREE (Gpa)	30-60 DEGREE (Gpa)
1	13.630	8.561	8.216
2	14.764	9.807	8.514
3	14.431	9.926	8.535
4	14.783	9.438	8.622
5	14.897	8.476	8.567
6	14.905	9.483	8.495
7	14.755	9.488	8.985
AVERAGE	14.595	9.311	8.562
st dev	0.454	0.572	0.227
% st dev	3.108	6.140	2.654

- **Young's modulus of zero degree oriented sample is more than other orientations.**
- **A slight variation in young's modulus values between 30^0-60^0 and 45^0 orientations.**
- **Results clearly show the effect of orientation on the young's modulus of the fiberglass composite.**

TENSILE TEST RESULTS:

$$\text{Poisson's ratio} = -\left[\frac{\text{transverse strain}}{\text{longitudinal strain}}\right]$$

- Poisson's ratio varies in between 0 and 0.5.
- Many materials exhibit positive Poisson's ratio
- Negative Poisson's ratio is exhibited by materials which expand laterally when stretched

Ex: Re-entry foam – Discovered by Dept. of Materials science, University of Wisconsin

Poisson's ratio is calculated using the following formula:

$$\text{Poisson's ratio} = \frac{\text{transverse voltage x gauge factor 1}}{\text{logitudinal voltage x gauge factor 2}}$$

TENSILE TEST RESULTS:

TABLE: Poisson's ratios of all samples

TRIAL	0 DEGREE	45 DEGREE	30-60 DEGREE
1	0.11321512	**0.484777518**	0.54054068
2	0.11887588	**0.481038753**	0.45866486
3	0.12035720	**0.519675970**	0.51666599
4	0.09752498	**0.512880562**	0.45638301
5	0.11687586	**0.503436096**	0.44556825
6	0.11614313	**0.505854801**	0.45107223
7	0.11296684	**0.505904866**	0.45183016
AVERAGE	**0.11370843**	**0.501940**	**0.47438931**
STD DEV	**0.00763289**	**0.014135992**	**0.03789912**
% STDEV	**6.71268714**	**2.816280375**	**7.9890342**

- **Poisson's ratio of zero degree oriented sample is low compared to other orientations**

- **The higher values of Poisson's ratios in 30^0-60^0 and 45^0 orientations may be due to mismatch in the orientation between the layers**

Rule of mixtures:

Fig. Burning and recovery of original fiberglass from composite

Rule of mixtures:

- **An analytical method used to calculate the upper limit of modulus of composite.**

E(composite) = E(fiberglass) V(fiberglass) + E(matrix) V(matrix)

Where E : Elastic modulus ; V : volume fraction

- The volume fractions of constituents- fiberglass and matrix are calculated by burning the composite.

- The percentage volumes of constituents are shown in the following table.

Fiber Orientation	Volume of composite cu.mm	Volume of fiberglass Cu.mm	Volume of epoxy Cu.mm	% by volume of fiberglass	% by volume of epoxy
0^0	0.38908	0.20703	0.18205	53.2103	46.79
45^0	0.31717	0.19922	0.11795	62.8118	37.19
30^0-60^0	0.34410	0.20820	0.13596	60.5065	39.49

Rule of mixtures:

The elastic modulus value is calculated by using rule of mixtures.

ORIENTATIONS	E(composite)=E(fiber)xV(fiber)+E(matrix)xV(matrix)
0^0	38.604 = 70 x 0.53 + 3.2 x 0.46
45^0	44.58 = 70 x 0.62 + 3.2 x 0.37
30^0-60^0	43.24 = 70 x 0.60 + 3.2 x 0.39

The Elastic modulus values are well above the Young's modulus values calculated using tensile test

Flexural Test:

- Performed to study the material's ability to withstand the load.
- The most common flexural test conducted on fiberglass composite materials is the 3-point test.

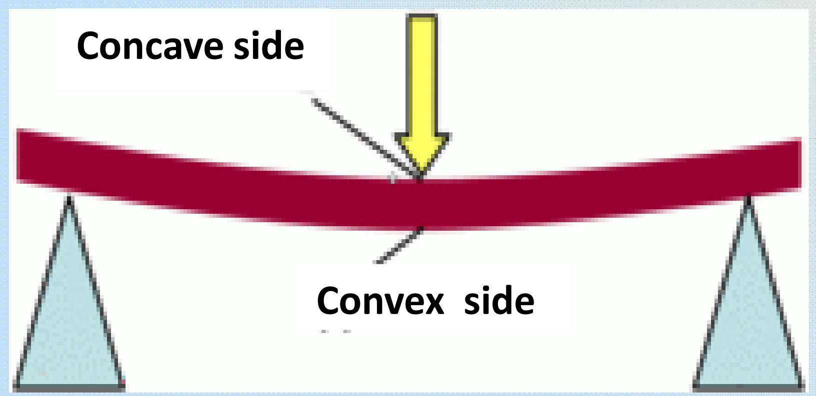


Fig.Three point flexural Test

Flexural Test:

- The optical fiber loop is used as a sensor
- Principle: The intensity of output radiation decreases with a reduction in the diameter of the loop

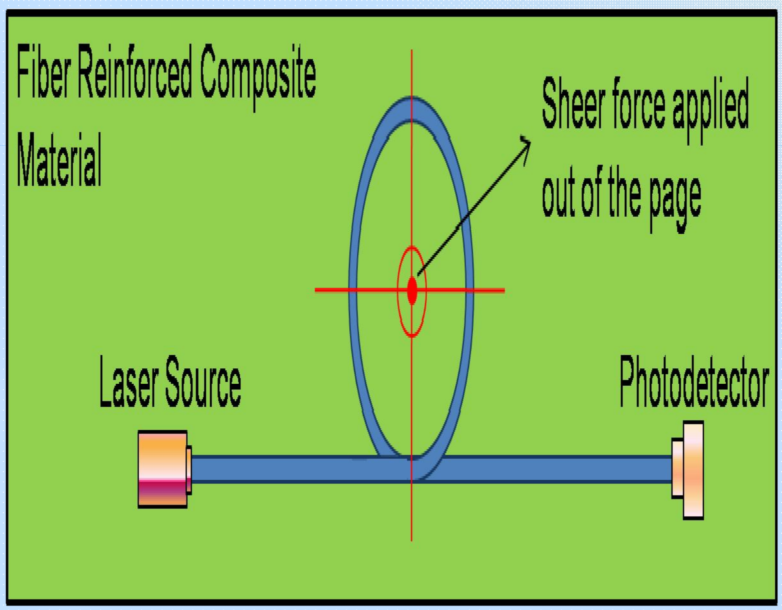


Fig. Optical fiber loop sensor

Fig.Composite bonded with optical fiber loop sensor

Flexural Test:

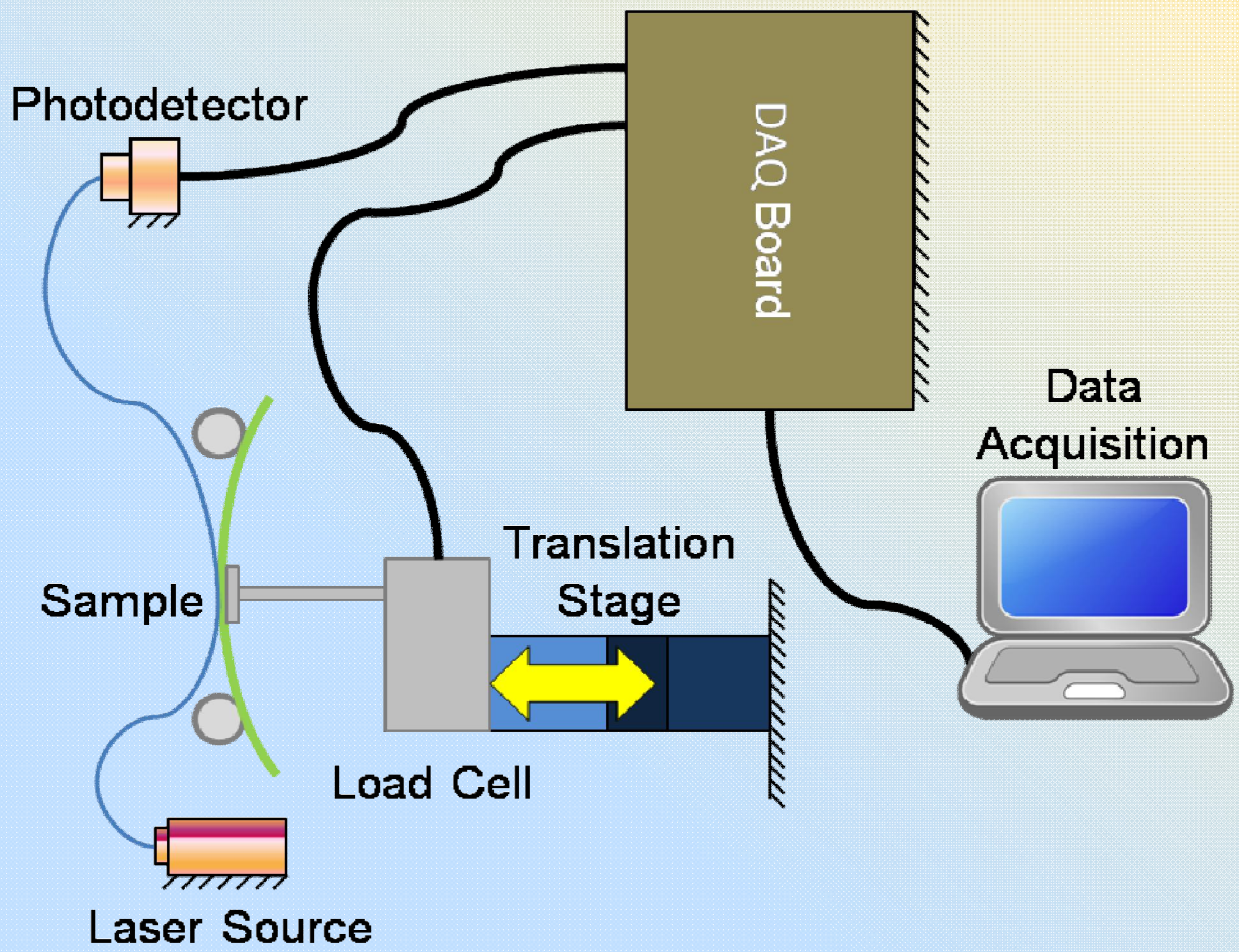


Fig. Schematic diagram of experimental setup for shear stress test

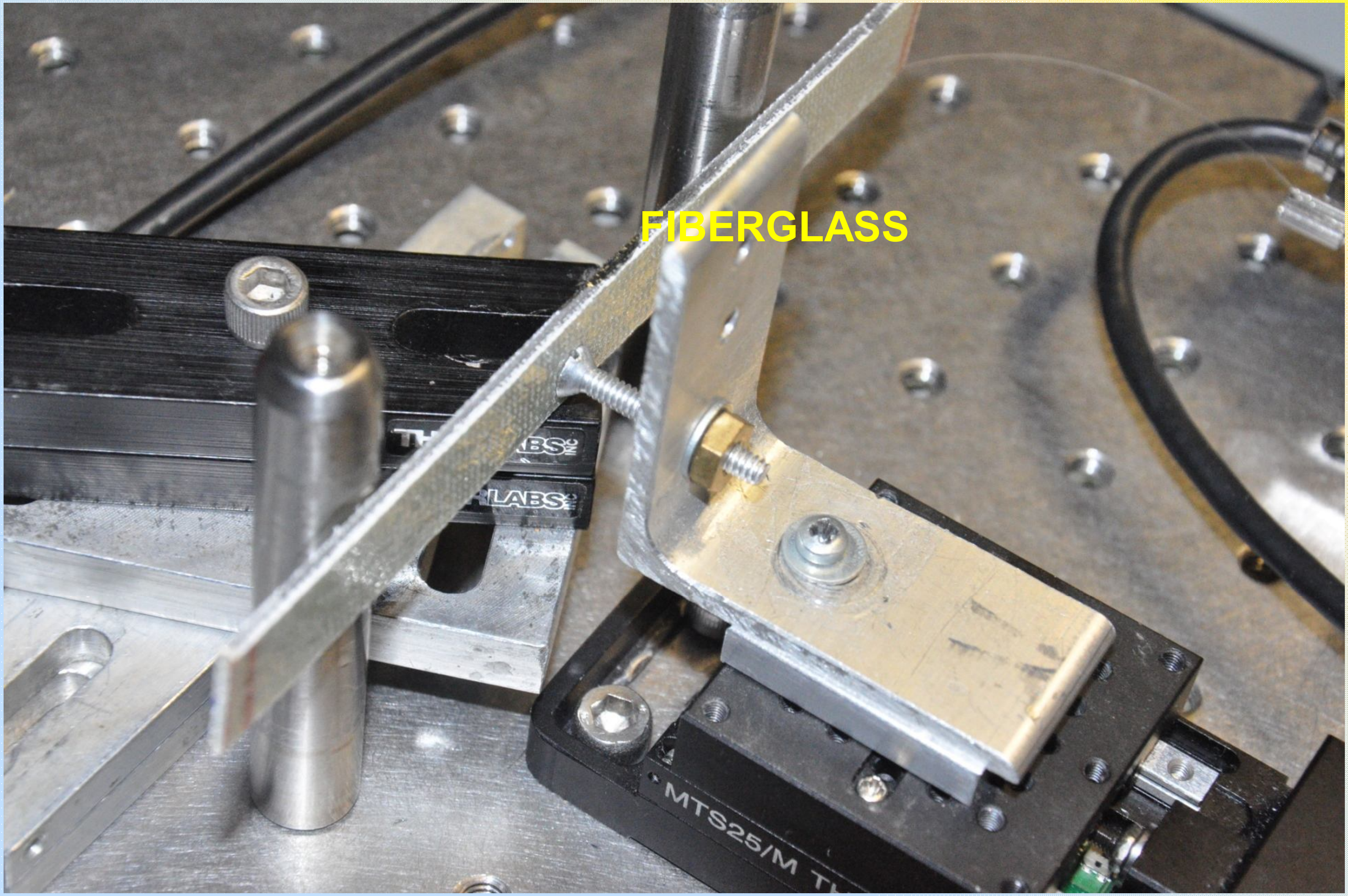


Fig. Composite mounted on a platform for 3-point test

Flexural Test:

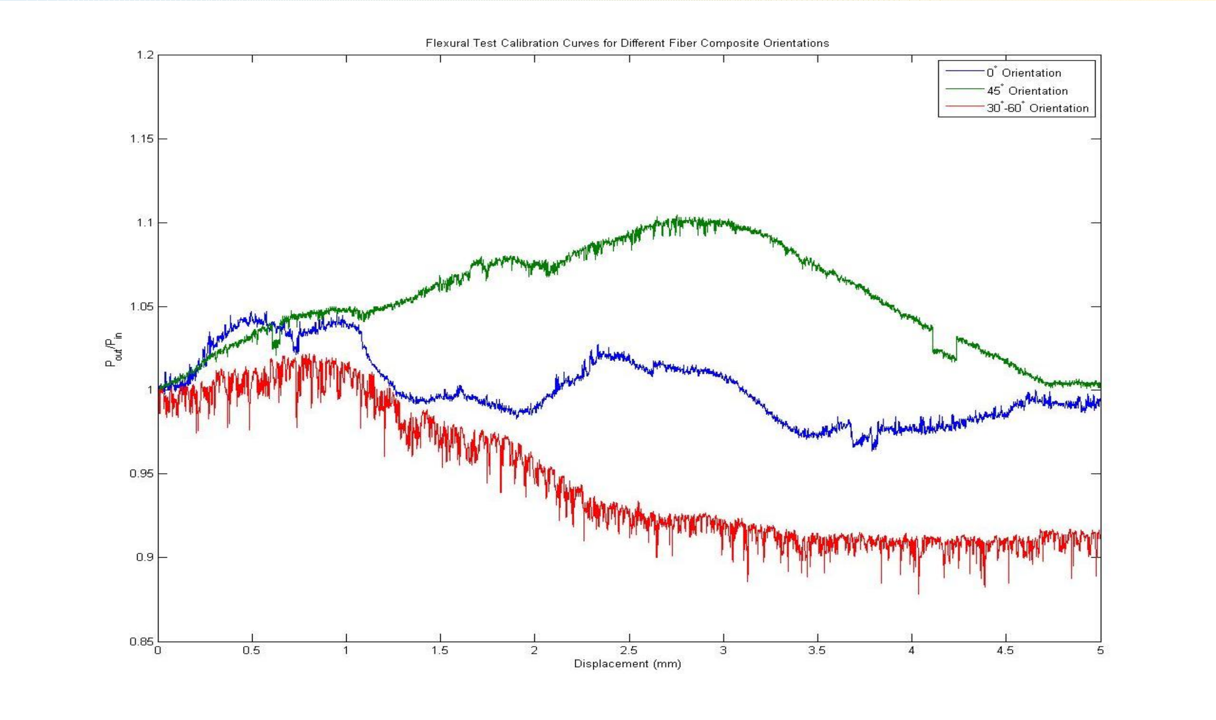


Fig. Flexural test calibration curves of 0^0, 45^0 and 30^0-60^0 orientations

- **The results show clear difference in the power output response among different orientations.**
- **The output response of zero degree oriented samples is greater compared to other samples.**

Conclusions:

•A significant change in the mechanical properties such as Young's modulus and Poisson's ratio have been observed with a change in fiber orientation.

•The mechanical properties calculated using tensile test are well below the upper limit of elastic modulus values calculated using rule of mixtures.

•The consistency in the alignment of successive layers plays a key role on the mechanical properties of multilayer composites.

•A significant difference in the power output response has been observed with fiber orientation.

•Since , the response of optical fiber output is very sensitive to load , Flexural test using the optical fiber loop is a promising technique to be used in the study of shear modulus.

Future work:

- To check the consistency of the values obtained from each measurement, more samples belonging to the same orientation needs to be fabricated and tested.

- To study the systematic variation with the fiber orientation , more number of orientations must be tried instead of three.

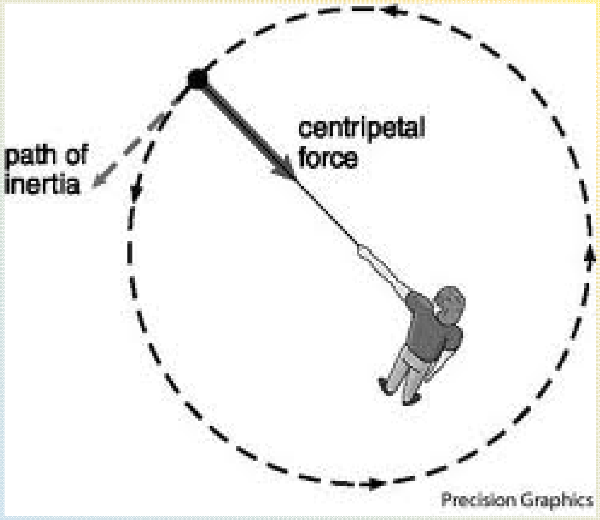
- During the fabrication process, extreme care must be taken at each step starting from fiber cutting to heating the composite in the furnace.

- The effect of fiber orientation in carbon and aramid fiber composites must studied and compared with that of fiberglass.

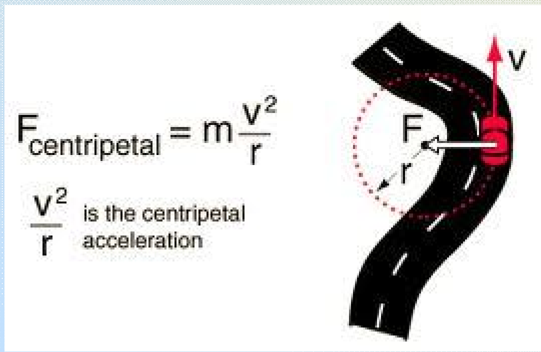
- Impact and thermal studies needs to be performed on these samples.

LESSON PLAN

Topic: **Centripetal Force**



Materials Needed: Basic Stamp2
DC Motor
Diode Laser
Photodiode
Opamp IC -
Kevlar string
Bob



FORMULA

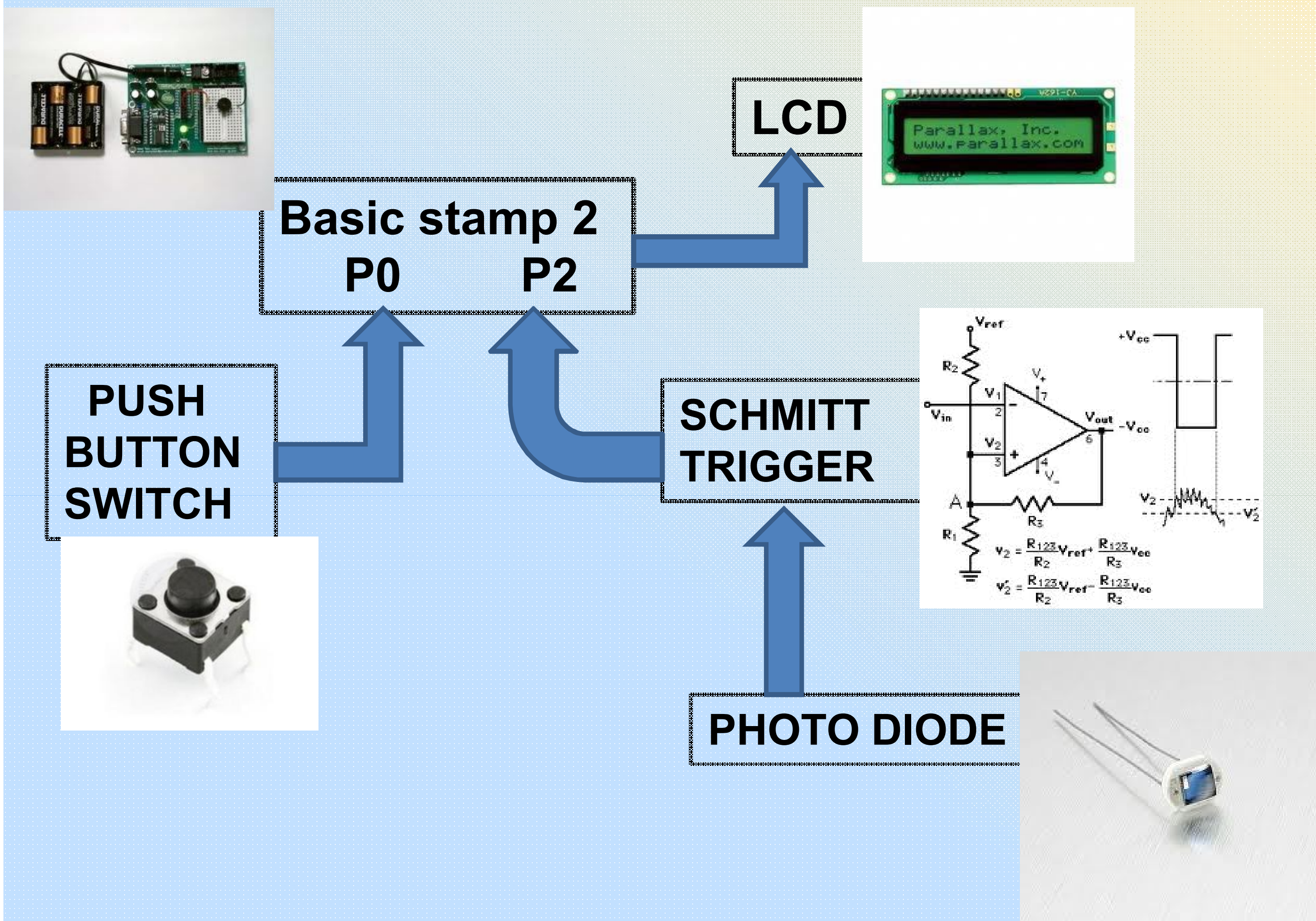
$$F_c = ma_c = \frac{mv^2}{r} = 4\pi^2 mrf^2$$

Where F_C : centripetal force ; v: speed of revolving object ;
m: mass of the object; a_c : centripetal acceleration ;
r: length of the string; f: frequency of revolution

OBJECTIVES:

- **Distinguish between speed and velocity**
- **Differentiate linear and circular motion**
- **Relate Newton's second to centripetal force**
- **Calculate the centripetal force acting on the object**
- **Identify dc motor, basic stamp2 and sensors**
- **Understand the working of Basic stamp2 and sensor setup.**

BLOCK DIAGRAM OF FREQUENCY COUNTER



SCHMITT TRIGGER

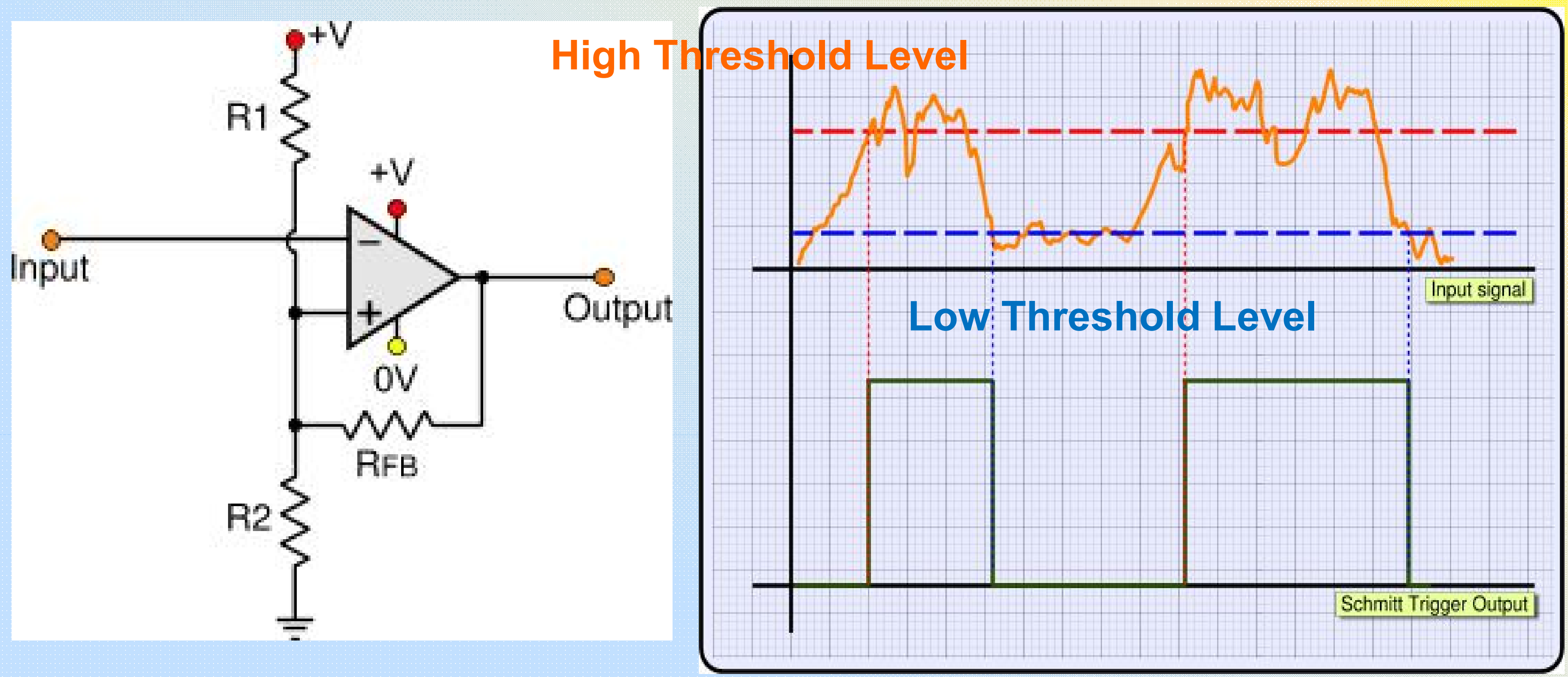


Fig. Schmitt trigger circuit and its response

A SCHMITT TRIGGER CONVERTS SLOWLY VARRYING NOSY INPUT SIGNAL INTO A RECTANGULAR WAVE

High Threshold Level :

$$R_{TOT} = (R1 \times R_{FB}) / (R1 + R_{FB})$$

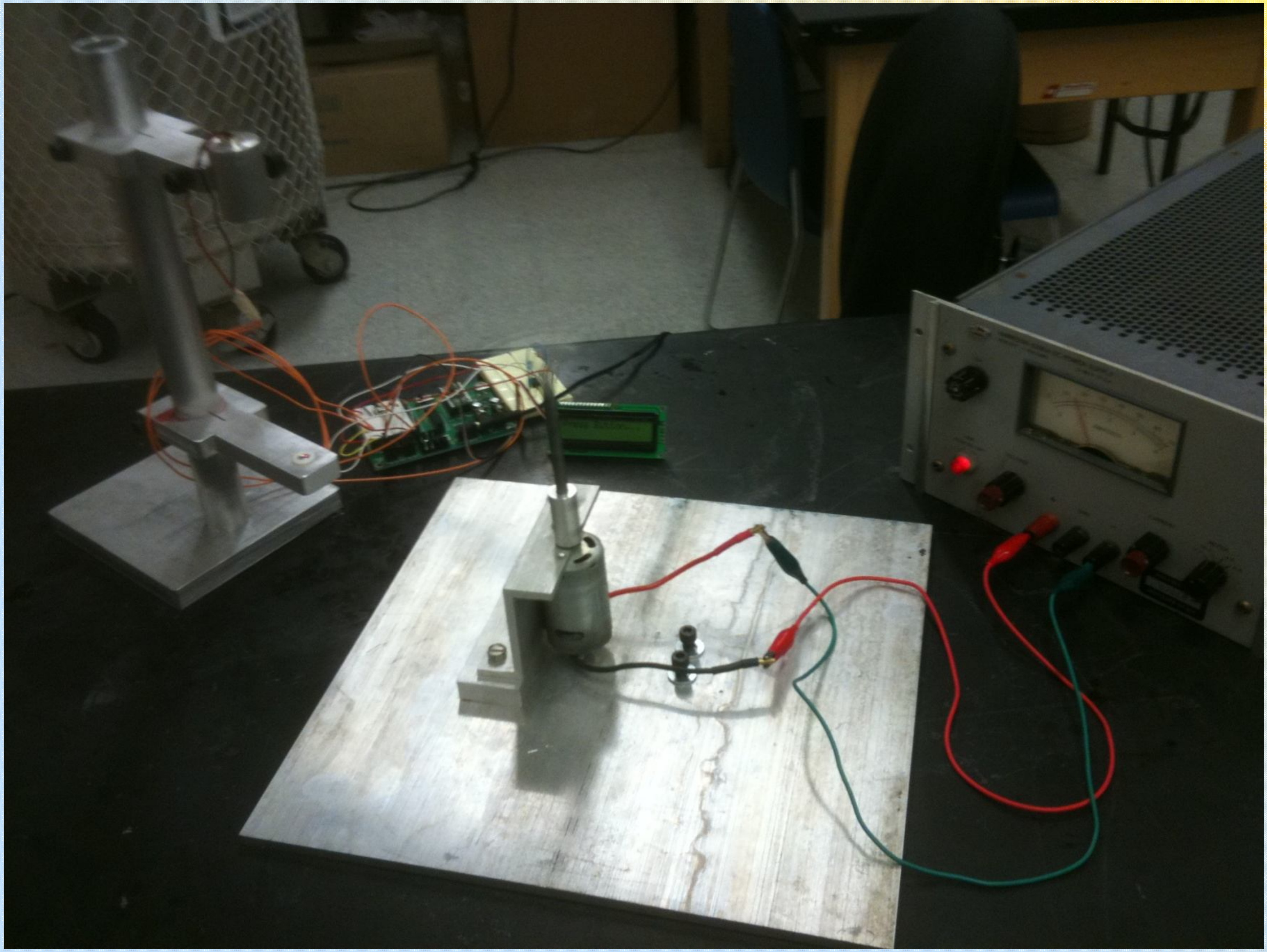
$$V_{THRESHOLD\_HIGH} = V * R2 / (R2 + R_{TOT})$$

Low Threshold Level :

$$R_{TOT} = (R2 \times R_{FB}) / (R2 + R_{FB})$$

$$V_{THRESHOLD\_LOW} = V \times R_{TOT} / (R1 + R_{TOT})$$

CENTRIPETAL FORCE SETUP



CENTRIFUGE : **Used to separate substances of different densities. Denser substances tend to be displaced from the center more than ones that are less dense.** :

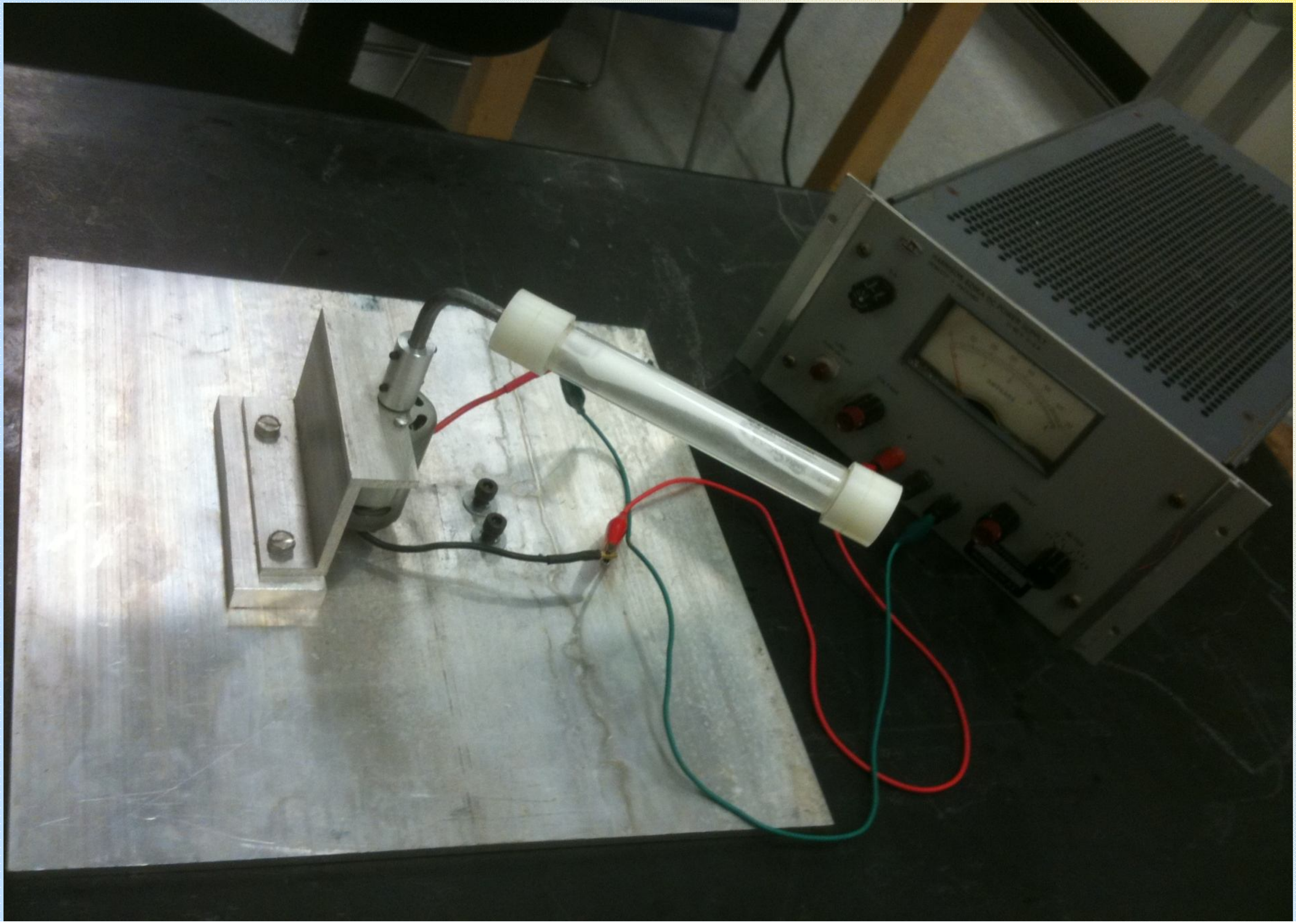


Table : Length of the string (Radius) versus Velocity of the bob

Mass of bob(g), m	Radius (m), r (length of the string)	Time period, T (s)	Velocity, V $V=2\pi r/T$, (m/s)	V^2 (m/s)^2
20	0.15			
20	0.20			
20	0.25			
20	0.30			
20	0.35			

Graph: Draw V^2 versus T plot and find the slope of the curve

Centripetal force $= F_c = ma_c = \dfrac{mv^2}{r}$

Acknowledgements:

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Mr. Gleb Dorogokupets
Mr. Petros Skaliarinis

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Professor Vikram Kapila - Program Dirctor
Mr. Jared Frank - Program Insructor
Mr. David Lopez - fellow
Mr. Xiaoyang Lin - fellow
Mr. Alessandro Betti - Machinist

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Mechanical and Aerospace Engineering Department for organizing the summer research program-2011 and allowing to use their facilities.

```
' {$STAMP BS2}
' {$PBASIC 2.5}
counter VAR Word
counter1 VAR Word
counter1 = 0
t VAR Byte
N VAR Word ' input: numerator ' -6554<N<+6554
D VAR Word ' denominator ' -6554<D<+6554
X VAR Word ' place holder
I VAR Word ' integer part
J VAR Nib ' index
F VAR Word ' fractional part ' .0000 to .9999
SEROUT 12, 84, [22, 12]
PAUSE 5000
DO
DO
SEROUT 12, 84, [128, "Press Button..."]
LOOP UNTIL (IN0 = 0)
FOR t = 1 TO 20   ' number of iterations
COUNT 2, 1000, counter ' frequency = t value x counting duration
'DEBUG CLS, HOME, ? IN2, CR, ? counter
counter1 = counter1 + counter
'DEBUG  " frequency after",  ?t,
'DEBUG HOME,  ? counter1,CR
SEROUT 12, 84, [128,"Time= ", DEC2 t, "s, ",  "C=", DEC counter1]
IF t = 20 THEN
N=counter1
D=20
GOSUB Divide
SEROUT 12, 84, [148,"Freq = ",DEC I,".",DEC F, "Hz"]
PAUSE 500
D=counter1
N=20
GOSUB Divide
SEROUT 12, 84, [128,"Period = ",DEC I,".",DEC F,  "s"]
ENDIF
NEXT
PAUSE 10000
SEROUT 12, 84, [12]
counter1 = 0
LOOP
 divide:
I=1-(N.BIT15^D.BIT15*2)   ' sign of result
N=ABS N                  ' divide absolute values
D=ABS D
I=N/D*I          ' integer part
X=1000                   ' .1,.01,.001,.0001 place holder
F=0                   ' fractional part
FOR J=1 TO 3             ' 4 places
N=N//D*10              ' remainder * 10
```