NL-110 Physics Laboratory for Engineers
Lab Manual (Work Book)

DEPARTMENT OF ELECTRICAL ENGINEERING,

FAST-NU, LAHORE

Name: _____ **Roll No.:_____**

Section: _____ **Group: _____**

Table of Contents

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EXPERIMENT # 1:

Centripetal Force

EXPERIMENT 1A – FORCE VS. MASS (Radius and Velocity Must be Constant)

Force (N)	Mass (kg)

Paste the Force VS. Mass Graph below:

Exp. Slop for F/m = _____

Cal. Slop for F/m:

$$\frac{F}{m} = \frac{v\text{^}2}{r}$$

Calculate %error $= \left|\frac{Exp.Slope - Cal.Slope}{\text{Cal.Slope}}\right| \times 100$

EXPERIMENT 1B – FORCE VS. VELOCITY (Radius and Mass Must be Constant)

Force (N)	Velocity (m/s)	Velocity(m^/s^2)

Paste the Force VS. Velocity squared graph below:

Exp. Slope for F/v^2 = _____

Cal. Slope for F/v^2:

$$\frac{F}{v\text{^}2} = \frac{m}{r}$$

$$\textbf{Calculate \%error} = \left|\frac{Exp.Slope - Cal.Slope}{\text{Cal.Slope}}\right| \times 100$$

EXPERIMENT 1C – FORCE VS. RADIUS (Mass and Velocity Must be Constant)

Force (N)	Radius (m)	1/Radius (1/m)

Paste the Force VS. 1/Radius graph below:

Exp. Slope for Fr = _____

Cal. Slope for Fr:

$$Fr = mv\text{^}2$$

$$\textbf{Calculate \% error} = \left|\frac{Exp.Slope - Cal.Slope}{\text{Cal.Slope}}\right| \times 100$$

FINAL ANALYSIS:

1. **Using words and a mathematical expression, describe the relationship between force and mass in uniform circular motion.**

2. **Using words and a mathematical expression, describe the relationship between force and velocity in uniform circular motion.**

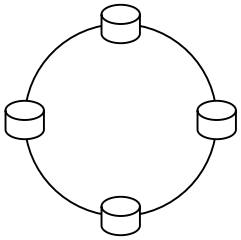
3. **Using words and a mathematical expression, describe the relationship between force and radius in uniform circular motion.**

4. **Combine the three relationships above to create one relationship for force, mass, velocity, and radius.**

5. **How would you convert this expression into an equation?**

6. **What is the constant of proportionality for this equation? Explain.**

7. How could such an equation be used?



8. The figure above is an overhead view of the rotating mass. For each of the 4 points, draw the direction and relative magnitude of the force.

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EXPERIMENT # 2:
To find the coefficient of static friction and the coefficient of kinetic friction for different surfaces

Carpeted tray:

Force (N)	Static friction (N)

Force (N)	Kinetic friction (N)

Exp. Slope for static friction = _____

Exp. Slope for kinetic friction = _____

Cal. Slope static friction:

$$\mu_s = \frac{Fs}{N}$$

Exp. slope for kinetic friction:

$$\mu_k = \frac{Fk}{N}$$

$$\textbf{Calculate \% error} = \left|\frac{Exp.Slope - Cal.Slope}{\text{Cal.Slope}}\right| \times 100$$

Paste Force VS. Time and Friction VS. Normal graph below:

Wooden tray:

Force (N)	Static friction (N)

Force (N)	Kinetic friction(N)

Exp. Slope for static friction = _____

Exp. Slope for kinetic friction = _____

Cal. Slope static friction:

$$\mu_s = \frac{Fs}{N}$$

Exp. slope for kinetic friction:

$$\mu_k = \frac{Fk}{N}$$

$$\textbf{Calculate \% error} = \left|\frac{Exp.Slope - Cal.Slope}{\text{Cal.Slope}}\right| \times 100$$

Paste Force VS. Time and Friction VS. Normal graph below:

Plastic tray:

Force (N)	Static friction (N)

Force (N)	Kinetic friction(N)

Exp. Slope for static friction = _____

Exp. Slope for kinetic friction = _____

Cal. Slope static friction:

$$\mu_s = \frac{Fs}{N}$$

Exp. slope for kinetic friction:

$$\mu_k = \frac{Fk}{N}$$

$$\textbf{Calculate \% error} = \left|\frac{Exp.Slope - Cal.Slope}{\text{Cal.Slope}}\right| \times 100$$

Paste Force VS. Time and Friction VS. Normal graph below:

QUESTIONS:

1. **What specific equation describes this relationship? (Include numbers and units for both the slope and vertical intercept)**

2. **What is the physical meaning of the slope for the static frictional force vs. normal force graph?**

3. **What is the physical meaning of the vertical intercept for the static frictional force vs. normal force graph?**

4. **What relationship exists between the kinetic frictional force and the normal force on an object?**

5. **What specific equation describes this relationship? (Include numbers and units for both the slope and vertical intercept)**

6. **What is the physical meaning of the slope for the kinetic frictional force vs. normal force graph?**

7. **What is the physical meaning of the vertical intercept for the kinetic frictional force vs. normal force graph?**

8. **Did the normal force on the friction tray affect either the coefficient of static friction or the coefficient of kinetic friction? Explain.**

9. **Rank the friction trays from highest coefficients of friction to lowest. What is physically different with the surfaces with high coefficients versus the surfaces with low coefficients? Explain.**

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EXPERIMENT # 3:
To find out rotational inertia of a ring and a disk

Paste the Angular velocity VS. Time graph below:

CALCULATIONS:

$$I = \frac{\tau}{\alpha} \qquad (1)$$

$$\tau = rT \qquad (2)$$

$$\Sigma F = mg - F = ma \qquad (3)$$

1. Derive equation (4), (5) and (6) using equation (1), (2) and (3) to calculate the experimental value of the rotational inertia of the ring, disk, and Rotary Motion Sensor together.

$$I_1=(r_p mg)/\alpha_1 - mr_p^2 \quad (4)$$

$$I_2=(r_p mg)/\alpha_2 - mr_p^2 \quad (5)$$

$$I_3=(r_p mg)/\alpha_3 - mr_p^2 \quad (6)$$

2. Calculate the experimental value of the rotational inertia of the disk and Rotary Motion Sensor together using Equations (1), (2), and (3).
3. Calculate the experimental value of the rotational inertia of the Rotary Motion Sensor alone using Equations (1), (2), and (3).

$(Radius)_{pulley}$ = _____ m

$(Mass)_{disc}$ = _____ g

$(Diameter)_{disc}$ = _____ mm

$(Radius)_{disc}$ = _____ m

$(Mass)_{ring}$ = _____ g

$(Internal\ diameter)_{ring}$ = _____ m

$(External\ diameter)_{ring}$ = _____ m

$(Internal\ radius)_{ring}$ = _____ m

$(External\ radius)_{ring}$ = _____ m

Use following equations to find the rotational inertia of Ring and disc:

$$I = \frac{1}{2} M\left(R_1^2 + R_2^2\right)$$

$$I = \frac{1}{2} MR^2$$

(I)ring =_____

(I)disc = _____

Calculate the experimental value of the rotational inertia of the rotary motion sensors & disc

Exp. Slope = α1 (D+R+P) = _____

Exp. Slope = α2 (D+P) = _____

Exp. Slope = α3 (P) = _____

4. Subtract the rotational inertia of the Rotary Motion Sensor from the rotational inertia of combination of the disk and Rotary Motion Sensor. This will be the rotational inertia of the disk alone.
5. Subtract the rotational inertia of the combination of the disk and Rotary Motion Sensor from the rotational inertia of combination of the ring, disk, and Rotary Motion Sensor. This will be the rotational inertia of the ring alone.

$I_1=(r_p mg)/\alpha_1 - mr_p^2$=_____

$I_2=(r_p mg)/\alpha_2 - mr_p^2$=_____

$I_3=(r_p mg)/\alpha_3 - mr_p 2$=_____

6. Calculate the experimental values of the rotational inertia of the ring and disk.

Rotational Inertia of ring=$I_1 - I_2$=_____

Rotational Inertia of Disc=I_2-I_3=_____

7. Use percent differences to compare the experimental values to the theoretical values.

$$\%difference = \left| \frac{Experimental - Theoretical}{Theoretical} \right| x100$$

%age error for ring=_____

%age error for disc=_____

FINALANALYSIS: (Post-Lab Questions)

1) **Write conclusion of the experiment.**

2) **Name the sensors used in the experiment. And also write the function and characteristics of the sensors.**

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Experiment # 4:
To find the spring constant for several springs

Dull spring

Force (N)	Extension (m)

Longest spring

Force (N)	Extension (m)

Paste Force VS. Extension graph for dull and longest spring below:

CALCULATIONS/QUESTIONS

1. **In general, what pattern do you notice between the force and the displacement/extension of the spring?**

2. **Starting with y = mx + b, write an equation that represents the relationship between force and displacement. Don't forget to include units on all numbers!**

3. **What is the physical meaning of the slope for the force-displacement graph? (Hint: Look at the units!)**

4. **What is the physical meaning of the vertical intercept for the force-displacement graph?**

5. **If you hung the "LONGEST" spring from the ceiling and placed a 50 g mass on it, how far would it extend?**

6. **Some springs are considered non-Hookian. Explain what this term means.**

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EXPERIMENT # 5:

To calculate the period of oscillation is measured from a plot of the angular displacement versus time from a torsional pendulum

Paste the Torque VS. Angle graph below:

Paste the Angle VS. Time graph below:

Calculations:

Exp. Slope = _____

Cal. Slope:

Slop for kappa κ = _____

Find calculated time period using following equation:

$$T = 2\pi \sqrt{\frac{1}{\kappa}}$$

Where I is given by:

$$I = \frac{1}{2} MR\text{^}2$$

$$\text{Calculate \%error} = \left| \frac{Experimental - Calculated}{\text{Calculated}} \right| \times 100$$

QUESTIONS:

1. How does the period depend on the rotational inertia of the object?

2. Was there any other source of rotational inertia that was ignored in this experiment?

3. How could you use a torsional pendulum to determine the rotational inertia of any object that could be mounted on the Rotary Motion Sensor?

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EXPERIMENT# 6:

To explore the dependence of the period of a simple pendulum on the acceleration due to gravity

Angle (deg)	Period (s)

Paste the Angle VS. period graph below:

QUESTIONS

1. **How does the period depend on the acceleration due to gravity?**

2. What do the constants in the curve fit for the Period vs. g data represent? Calculate what they should be theoretically and compare the theoretical value to the curve fit constants.

3. Would the pendulum be longer or shorter on the Moon?

4. What would the period be if the pendulum had been inclined to 90 degrees? What value of g does this correspond to?

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EXPERIMENT # 7

Ratio of Specific Heats of a Gas

Height (m)	Period (s)

Paste the pressure VS. Time graph below:

Calculate γ

$$\gamma = \frac{4\pi\text{^}2m(slope)}{AP}$$

Where

m= mass of piston= _____

A= cross-sectional area of piston =_____

P= atmospheric pressure =_____

Slope from graph of h vs. T^2 =_____

$(\gamma)_{exp}$=

$(\gamma)_{cal.}$=

$$\text{Calculate \%error} = \left|\frac{Experimental - Calculated}{\text{Calculated}}\right| \times 100$$

QUESTIONS

1. **What is the ratio of specific heats of a diatomic gas in theory? Why?**

2. **What is the ratio of specific heats of a monatomic gas in theory? Why?**

3. **Would the slope of the graph for Helium be greater or less than the slope for air?**

4. **Why can we assume air is diatomic? What are the main components of air?**

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EXPERIMENT # 8

To verify the inverse-square relationship of Coulomb's law and find the value of Coulomb's constant from Coulomb torsional balance

Part A FORCE VS. DISTANCE:

Distance (m)	Twist Angle (Degrees)	1/D^2 (1/m^2)	Twist Angle (Degrees)

Paste Twist Angle VS. Distance graph and Twist angle vs. 1/D^2 graph below:

ANALYSIS

1. **Calculate the inverse square of the distance values and enter them into the Data Table "Twist Angle vs 1/(R^2)." Observe the resulting graph. Note: DataStudio automatically corrects the data to resemble two point charges instead of two spheres.**

2. **Determine the functional relationship between force (which is proportional to the torsion angle (θ) and the distance (R).**

Part B FORCE VS. DISTANCE

Voltage (kV)	Twist angle (Degrees)

Paste Twist angle vs. voltage graph below:

ANALYSIS

1. Determine the functional relationship between force (which is proportional to the torsion angle (θ) and the charge (q) (which is proportional to the Voltage).

Part C THE COULOMB CONSTANT

Twist angle (Degrees)	Mass (mg)	Angle (Degrees)	Weight (N)

Paste Mass vs. Twist angle graph below:

Paste weight vs. twist angle graph below:

CALCULATIONS:

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EXPERIMENT # 9

To calculate the charge on an electron with Millikan's oil drop experiment.

Voltage (V)	ΔT(s)

Paste the graph below:

QUESTIONS

1. **Compare your value to the accepted value of the charge of an electron: 1.60×10^{-19} C**

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EXPERIMENT # 10

Determine the role of resistors and capacitors in electronic circuits, verify Ohm's law and calculate time-constant of a capacitor

PART A: CHARGING AND DISCHARGING THE CAPACITOR

Draw schematic diagram below:

Paste the graph below:

POST LAB QUESTIONS

1. **Describe the changes in voltage from the moment the switch is closed until the capacitor is "charged."**

2. **Describe the changes in current from the moment the switch is closed until the capacitor is "charged."**

3. **Describe how your observations of the light bulb correspond to your explanations in questions 1 and 2.**

4. **Make a diagram of the circuit as it is charging. Include the direction of charge flow. Represent positive charges with a "+." Represent negative charges with a "-."**

5. **Describe the changes in voltage from the moment after the capacitor is discharged until the voltage is constant.**

6. **Describe the changes in current from the moment after the capacitor is discharged until the current is constant.**

7. **Describe how your observations of the light bulb correspond to your explanations in questions 5 and 6.**

8. **Make a diagram of the circuit as it is discharging. Include the direction of charge flow. Represent positive charges with a "+." Represent negative charges with a "-."**

9. **Based on the conclusions from the previous questions, what is/are the role(s) of a capacitor in an electronic circuit?**

PART B: OHM'S LAW

Draw schematic diagram below:

Write values of slope of your graph for 10 Ω, 33 Ω resistors and bulb:

Slope for 10 Ω = _____

Slope for 33 Ω = _____

Slope for bulb = _____

Paste the graph below:

POST LAB QUESTIONS

1. **What is the function of the capacitor in this part of the experiment?**

2. **How could this experiment be performed with batteries instead of a capacitor?**

3. **Make a diagram of the circuit . Include the direction of charge flow. Represent positive charges with a "+." Represent negative charges with a "-."**

4. **What is the physical meaning of the slope for the Voltage vs. Current graphs?**

5. **What is the physical meaning of the vertical intercept for the Voltage vs. Current graphs?**

6. **Starting with y = mx + b, write an equation that represents the relationship between Voltage vs. Current for the resistors. Don't forget to include units on all numbers.**

7. **Why is the voltage-current relationship different for a light bulb vs. a resistor?**

PART C: TIME CONSTANT

Draw schematic diagram below:

Paste the graph below:

CONCLUSIONS/QUESTIONS

1. **What is the physical meaning of the "Scale Factor" (A) from the Natural Exponent Fit?**

2. **What is the physical meaning of the "Exponent" (C) from the Natural Exponent Fit?**

3. **Refer to the diagram of the circuit. Describe the role of the capacitor. Specifically, discuss the voltage across the capacitor while the capacitor is charging.**

4. **Further, discuss the current through the circuit while the capacitor is charging.**

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EXPERIMENT # 11

To calculate the equivalent capacitance in Series Combination Circuits and Parallel Combination Circuits

Post Lab Questions:

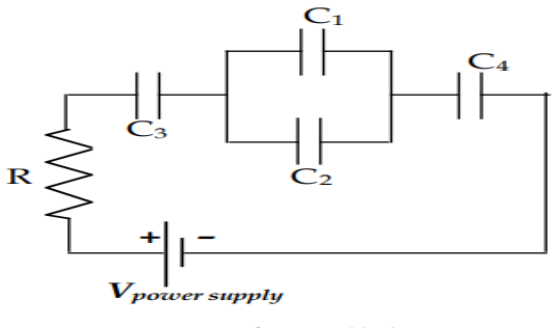
Q1) Calculate the combined capacitance in micro-Farads (µF) of the following capacitors when they are connected together in a parallel combination:

a) **two capacitors each with a capacitance of 47nF**
b) **one capacitor of 470nF connected in parallel to a capacitor of 1µF**

Q2) You have two 42µF and one 39µF all wired in parallel. Draw the schematic and calculate the total capacitance of the system.

Q3) Calculate the total capacitance of the following circuit:

a) **when C1= 5μF, C2= 15μF, C3= 2.1uF, C4= 0.1μF**



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EXPERIMENT # 12

To investigate the magnetic force of a current carrying wire by the effect of current, length of conductor and magnetic field on the magnetic force

Part a FORCE VS. CURRENT

Number of Magnets Used: _____
Current Loop Used: _____

TABLE 1: Calculation of Force

Current (A)	"Mass" (grams)	"Force" (grams)

Slope of Force vs. current graph = _____

Paste the Force vs. current graph below:

QUESTIONS:

1. What relationship exists between the magnetic force and current through the conductor?

2. What is the physical meaning of the slope of the Force vs. Current graph?

3. What is the physical meaning of the vertical intercept of the Force vs. Current graph?

4. Can the vertical intercept be attributed to measurement error? Explain.

5. Write a proportionality expression that represents the relationship between Magnetic Force and Current.

Part B FORCE VS. LENGTH OF WIRE

 # Of magnets used: _____

Current used: _____

"Mass" with I = 0: _____

Length (cm)	Mass (grams)	Force (grams)

Slope of Force vs. length graph = _____

Paste the Force vs. Length graph below:

QUESTIONS:

1. **What relationship exists between the magnetic force and length of conductor in the magnetic field?**

2. **What is the physical meaning of the slope of the Force vs. Length graph?**

3. **What is the physical meaning of the vertical intercept of the Force vs. Length graph?**

4. **Can the vertical intercept be attributed to measurement error? Explain.**

5. **Write a proportionality expression that represents the relationship between Magnetic Force and Length.**

Part C FORCE VS. MAGNETIC FIELD

Current used: _____

Current loop used: _____

Magnetic field (# of magnets)	"Mass" I=0 (grams)	"Mass" I>0 (grams)

Slope of Force vs. magnetic field graph = _____

Paste the Force vs. Magnetic field graph below:

QUESTIONS:

1. What relationship exists between the Magnetic Force and Magnetic Field?

2. What is the physical meaning of the slope of the Force vs. Magnetic Field graph?

3. What is the physical meaning of the vertical intercept of the Force vs. Magnetic Field graph?

4. Can the vertical intercept be attributed to measurement error? Explain.

5. Write a proportionality expression that represents the relationship between Magnetic Force and Magnetic Field.

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EXPERIMENT # 13

To calculate induced e.m.f in a circuit by Faraday's law of induction.

Paste voltage vs. time graph below:

Exp. value of E = _____

Cal. Value of E:

$$\mathbf{E= -NA \frac{\Delta B}{\Delta t}}$$

Where

N= No. of turns of Induction wand = 200

D = Diameter of induction wand = 3.1cm = 0.031 m

A= Area of induction wand = ----------

∆B = Magnetic field =----------

∆t = Change in time period = ----------

$$\textbf{Calculate \%error} = \left|\frac{Experimental - Calculated}{\text{Calculated}}\right| \times 100$$

ANALYSIS

1. Calculate the value of the average emf using Equation (2). Compare this value to the value measured from the graph.

2. Identify on the graph where the coil is entering the magnet and where the coil is leaving the magnet.

3. Is the emf of the first peak positive or negative? Taking into account the direction the wire is wrapped around the coil, does the sign of the emf correspond to the direction expected using Lenz's Law?

4. **Why is the sign of the emf of the second peak opposite to the sign of the first peak?**

5. **Why is the emf zero when the coil is passing through the exact center of the magnet?**

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EXPERIMENT # 14

Magnetic Fields of Coils

SINGLE COIL:

Paste the graph for single coil below:

$$\textbf{Calculate \%error} = \left|\frac{\boldsymbol{Experimental - Calculated}}{\textbf{Calculated}}\right| \times \mathbf{100}$$

CONCLUSION:

HELMHOLTZ COILS:

Paste the Helmholtz graph below:

$$\textbf{Calculate \%error} = \left|\frac{Experimental - Calculated}{\textbf{Calculated}}\right| \times 100$$

Conclusion: