National University FAST

of Computer & Emerging Sciences

Course Title: Physics Lab for Engineers (NL 110)

Course Objective: To implement the concepts of Oscillations and Electricity & Magnetism in Physics & Engineering through different experiments.

CLO	Statement ↓Score →	Exemplary (5)	Proficient (4)	Developing (3)	Beginning (2)	Novice (1)
01	Investigate the relationship between centripetal force with mass, velocity and radial distance for an object in uniform circular motion theoretically from the centripetal force formulae and experimentally from respective slopes in DataStudio generated graphs.	Follow instructions fully and perform experiment with minimum help Calculate percentage error and the error is very less Repeated each step for additional verification All material for lab report is present in the lab report along with post lab questions	Generate graphs F_c vs m, F_c vs v^2 and F_c vs 1/r using the centripetal force formula Calculate slope values by applying linear fit function in DataStudio software from each graphs of: graphs F_c vs m, F_c vs v^2 and F_c vs 1/r Follow all precautions	Utilize Data-Studio Software to run the experiment and to collect the data Correct adjustment of DC source Make tables of force vs. mass, force vs. v^2, force vs. 1/r Calculate slope(s) values theoretically (not from slopes)	Connect overall setup correctly and properly place weights and rotating platform on the rod Utilize the force sensor (CI6746), photogate head (ME9498) into correct channels of 500-interface (CI6760) to perform the experiment. Synchronize sensors with DataStudio software	Attempt to setup the apparatus Incomplete performance of experiment Cannot not Plug force sensor and photo-gate head in correct channels of interface Unable to synchronize sensors with DataStudio software Cannot not generate graphs and slopes for: F_c vs m, F_c vs v^2 and F_c vs 1/r using the centripetal force formula Unable to make tables correctly from the values Cannot calculate percentage error or high percentage error calculation Incomplete lab report with no or few post lab questions mention

02	Calculate coefficient of static friction/kinetic friction of different 500g loaded carts theoretically from the ratio between static frictional force/kinetic frictional force and the normal force and experimentally from respective graph's (force vs. time) in the DataStudio software file.	Follow instructions fully and perform experiment with minimum help Generate tables: Calculate normal force & Static/Kinetic Frictional force(s) in case of three different carts (carpet, wooden & plastic) Calculate percentage error and the error is very less in case of each frictional force from different carts (carpet, wooden & plastic) Repeat each step for additional verification All material for lab report is present in the lab report along with post lab questions	Generate graph(s) [force vs. time] in case of each different frictional force from different carts (carpet, wooden & plastic) and utilize smart tool in DataStudio software to observe min./max. values. Record the slopes (coefficient of static friction/kinetic friction) and vertical intercept from DataStudio software linear fit function. Follow all precautions	Utilize Data-Studio Software to run the experiment and to collect the data Calculate coefficient of friction (static/kinetic) theoretically from formulae $\mu_s = \frac{F_s}{F_N}$ $\mu_k = \frac{F_k}{F_N}$	Connect overall setup correctly and properly place masses (500g - 2000g) into three different carts (carpet, wooden & plastic) Attach force sensor (CI6746) with cart(s) with strings and with 500-interface (CI6760) to perform the experiment. Synchronize sensors with DataStudio software	Attempt to setup the apparatus Incomplete performance of experiment Cannot attach force sensor with loaded cart-mass system Cannot calculate coefficient of friction (static/kinetic) theoretically from formulae Cannot synchronize the force sensor with 500-interface Incomplete data collection in DataStudio software Incomplete or incorrect record of the slopes (coefficient of static friction/kinetic friction) and vertical intercept from DataStudio software via linear fit function. Incomplete or incorrect record of table(s) & graphs (static/kinetic friction vs. normal force) in DataStudio software Cannot calculate percentage error or high percentage error calculation Incomplete lab report with no or few post lab questions mention

03	Find the rotational inertia of a ring and disk from the set up of, mass-set, rotary motion sensor (CI6538), 500-interface (CI6760) and mini-rotational accessory (CI-6691).	Follow instructions fully and perform experiment with minimum help Generate graphs (angular velocity vs. time) in DataStudio software in case of ring and a disk Verify that the experimentally calculated values correspond to the calculated theoretical values calculated from the formulae of rotational inertia Calculate percentage error and the error is very less Repeated each step for additional verification All material for lab report is present in the lab report along with post lab questions	Derive the formulae $[I=(r_p mg/\alpha_1) - m(r_p)^2]$ of rotational inertia by the concept of torque and Newton's second law with free-body diagram the experimental set up Record slope (angular acceleration) and vertical intercept from DataStudio software linear fit function Find acceleration of the ring and disk Follow all precautions	Calculate theoretical values of rotational inertia of a ring and a disk from formulae $I=1/2M(R^2{}_1+R^2{}_2)$ And $I=1/2MR^2$	Connect overall setup correctly and properly place a rotary motion sensor with mini-rotational accessory. Adjust masses with the string passing over rotary motion sensor properly Synchronize the rotary motion sensor with 500-interface	Attempt to setup the apparatus or an incomplete performance of experiment Cannot attach rotary motion sensor with mini-rotational accessory and cannot adjust masses with the string passing over rotary motion sensor Incomplete or wrong derivation of the formulae of rotational inertia by the concept of torque and Newton's second law Cannot synchronize the rotary motion sensor with 500-interface Incomplete data collection in DataStudio software Incomplete or incorrect calculation rotational inertia of a ring and a disk from formulae theoretically Incomplete or incorrect record of the slope (angular acceleration) and vertical intercept from DataStudio software linear fit function Incomplete or incorrect record of graphs (angular velocity vs. time) in DataStudio software Cannot verify that the experimentally calculated values correspond to the calculated theoretical values calculated from the formulae of rotational inertia Incomplete or incorrect calculate percentage error or too high percentage error calculation Incomplete lab report with no or few post lab questions answered

04	Apply Hooke's law to find the spring constant of different springs (shiny, dull or longest) of varying lengths (cm).	Follow instructions fully and perform experiment with minimum help Generate graphs (force vs. extension/compression) using DataStudio software Repeat all procedure for heavy bumper springs as well Calculate percentage error and the error is very less Repeat each step for additional verification All material for lab report is present in the lab report along with post lab questions	Record the slope (spring constant) and vertical intercept from DataStudio software linear fit function both for (a) extension and (b) compression and for each type of spring (shiny, dull or longest) of varying lengths (cm). Follow all precautions	Record data for (a) extension and (b) compression in DataStudio software and repeat steps for each type of spring (shiny, dull or longest) of varying lengths (cm) Calculate theoretical value from formula: $F = k\Delta x$	Connect overall setup correctly and properly place a force sensor with demonstration spring set Adjust masses with the string passing over rotary motion sensor properly Utilize the force sensor (CI6746), demonstration spring set (ME-9866), four-scale meter stick and 500-interface (CI6760) to perform the experiment both for (a) extension and (b) compression Synchronize the rotary motion sensor (CI6538) with 500-interface	Attempt to setup the apparatus Incomplete performance of experiment Cannot attach force sensor with the demonstration spring set and with the table clamp Cannot synchronize force sensor with 500-interface Incomplete data collection in DataStudio software Incomplete creation of graphs (force vs. extension) in DataStudio software. Incomplete or incorrect record of the slope (spring constant) and vertical intercept from DataStudio software linear fit function Incomplete or incorrect calculate percentage error or too high percentage error calculation Incomplete lab report with no or few post lab questions answered

05	Calculate the period of oscillation from a plot of the angular displacement versus time from a torsional pendulum.	Follow instructions fully and perform experiment with minimum help Analyze the slope between torque and angular displacement through the graph Calculate *T* (time period) from the formula of time period for simple harmonic motion: $T=2\pi(I/\kappa)^{1/2}$ Calculate percentage error and the error is very less Repeat each step for additional verification All material for lab report is present in the lab report along with post lab questions	Generate graphs between torque vs angular displacement using the angular displacement relationship in DataStudio Software Calculate rotational inertia of ring and disk by formulae: $I=1/2M(R^2{}_1+R^2{}_2)$ And $I=1/2MR^2$ Follow all precautions	Utilize DataStudio Software to run the experiment and to collect the data Determine the torsional spring constant	Connect overall setup correctly and properly place wires on the clamps of rod. Utilize rotary motion sensor (CI6538) and force sensor (CI6746) in correct channels of 500-interface (CI6760). Synchronize sensors with DataStudio software	Attempt to setup the apparatus Incomplete performance of experiment Cannot not plug in rotary motion sensor and force sensor in correct channels of interface Unable to synchronize sensors with DataStudio software Cannot not generate graphs between torque vs angular displacement using the angular displacement relationship Incomplete or incorrect calculate percentage error or too high percentage error calculation Incomplete lab report with no or few post lab questions answered

06	Identify the dependence of the period of a simple pendulum on the acceleration due to gravity.	Analyze the dependence of g-effective on the time period through the graph Follow instructions fully and perform experiment with minimum help Calculate percentage error and the error is very less Repeat each step for additional verification All material for lab report is present in the lab report along with post lab questions	Utilize DataStudio Software to generate the table of values and make table for the values of g-effective and time period. Make tables correctly from the values of g-effective and time period from the formula: $T=2\pi(L/g_{effective})^{1/2}$ Follow all precautions	Utilize Data-Studio Software to run the experiment and to collect the data Generate graphs between g-effective and time period Start following the procedure/instructions for the following and collection of data (no. of observations)	Connect overall setup correctly and properly place pendulum and angle indicator with the sensors and other accessories Correct clamping of pendulum at correct degrees (0^{o} or 5^{o}) Utilize rotary motion sensor (CI6538) and 750-interface (CI7599) to perform the experiment. Synchronize sensor with DataStudio software	Attempted to setup the apparatus Incomplete performance of experiment Cannot not Plug in rotary motion sensor and use interface correctly Unable to synchronize sensors with DataStudio software Incomplete creation of graphs between g-effective and time period Incomplete or incorrect calculate percentage error or too high percentage error calculation Incomplete lab report with no or few post lab questions answered

07	Calculate ratio of specific heat of air by using period of oscillation from Ruchardt's method and using piston to produce oscillations of air molecules by compression in a cylinder.	Derive an expression (Ruchardt's method) to find out formula of ratio of specific heat of air by utilizing concept of mass-spring system's time period, gas laws and Hooke's law equation Compare value of γ of air experimental vs. theoretical (i.e., 1.4) Follow instructions fully and perform experiment with minimum help Calculate percentage error and the error is very less Repeat each step for additional verification All material for lab report is present in the lab report along with post lab questions	Generate graph height of the piston and square of period of oscillations in DataStudio software and note slope value to put in the formula: $\gamma = \frac{4\pi^2 m(slope)}{AP}$	Utilize Data-Studio Software to run the experiment and to collect the data Write values of required parameters: mass of piston, cross-sectional area of piston, atmospheric pressure Make table (height and period) from adjusting height of air enclosed in cylinder with piston from 9 cm to 1 cm Start following the procedure/instructions for the following and collection of data (no. of observations)	Connect overall setup correctly and properly adjust height of the air enclosed in the cylinder. Connect heat engine/gas law apparatus (TD8572), low pressure sensor (CI6534A) and 750 interface (CI6400). Synchronize sensor with DataStudio software.	Attempted to setup the apparatus Incomplete performance of experiment Cannot not Plug in low pressure sensor, heat engine /gas law apparatus and interface use interface Unable to synchronize sensors with DataStudio software Incomplete or incorrect graph of height of the piston and square of period of oscillations Incomplete or incorrect calculate percentage error or too high percentage error calculation Incomplete lab report with no or few post lab questions answered

08	To verify the inverse-square relationship of Coulomb's law by using charging spheres, Coulomb's torsional balance (ES9070A), charge producers (ES9057B) and basic electrometer (ES9078) and calculate Coulomb's constant from the experimental set up.	Follow instructions fully and perform experiment with minimum help Calculate Coulomb's constant from the experimental set up and using formula: $k = \frac{FR^2}{q_1 q_2}$ Determine the value of the Torsion constant, K_{tor} from the graph of Weight v Twist Angle. Compare experimental value with the accepted value of Coulomb's Constant 8.99x10^9 $\frac{Nm^2}{C^2}$ Calculate percentage error and the error is very less Repeated each step for additional verification All material for lab report is present in the lab report along with post lab questions	Determine the functional relationship between force (which is proportional to the torsion angle (θ) and the distance (R) Generate a graph (twist angle vs. distance) Generate a graph (weight vs. angles) and apply linear fit to find the slope. Follow all precautions	Record the angle in the Data Table: Mass (mg) vs. Twist Angle Calculate the inverse square of the distance values and enter them into the Data Table Twist Angle v 1/(R^2).	Connect overall setup correctly and properly adjust the balance (Zeroing) of Coulomb balance, charged spheres, torsional accessory, charging probe and torsional wire Position spheres on sliding track and incorrect calibration of torsion balance	Attempt to setup the apparatus Incomplete performance of experiment Incorrect adjustment of balance (Zeroing) of Coulomb balance, charged spheres, torsional accessory, charging probe and torsional wire Incorrect positioning of spheres on sliding track and incorrect calibration of torsion balance Incomplete or incorrect record of angle in the Data Table: Mass (mg) vs. Twist Angle Incorrect determination of the Torsion constant, K_{tor} from the graph of Weight v Twist Angle. Incorrect or incomplete graph (twist angle vs. distance). Incorrect or incomplete graph (weight vs. angles) and apply linear fit to find the slope Incomplete or incorrect calculate percentage error or too high percentage error calculation Incomplete lab report with no or few post lab questions answered

09	Determine the charge of the droplet by experimental set up of Millikan's oil drop apparatus (AP8210), DMM (SE9789) and high voltage power supply (SF9585A).	Find the relationship between velocity of oil drop and the electric field by analyzing the forces acting on an oil droplet to get the equation via derivation Determine the charge of electron using derived equation $q = \frac{-smg}{v_o}$ Follow instructions fully and perform experiment with minimum help Repeat each step for additional verification All material for lab report is present in the lab report along with post lab questions	Generate graphs from the values of voltage and change in time and apply linear fit to find the required slope value Calculate the radius of droplet, terminal velocity, mass of droplet and charge of an electron from derived equations Follow all precautions	Find the mass and the charge from the derived equations Make table voltage (V) vs. change in time Calculate the radius of droplet, terminal velocity, mass of droplet and charge of an electron from derived equations Calculate the value of the radius $a = \sqrt{\left(\frac{b}{2p}\right)^2 - \frac{9\eta v_o}{2g\rho}} - \frac{b}{2p}$	Connect overall setup correctly and properly adjust the height of the platform along with its leveling, positioning of atomizer, alignment of optical system, spraying of droplets into the chamber etc.	Attempt to setup the apparatus Incomplete performance of experiment Incorrect adjustment of height of the platform along with its leveling Incorrect measurement of plate separation Incorrect positioning of atomizer Incorrect alignment of optical system Incorrect measurement of voltage Incorrect spraying of droplets into the chamber Incomplete or incorrect determination of mass and the charge from the derived equations Incomplete or incorrect table of voltage (V) vs. change in time. Incomplete or incorrect graphs from the values of voltage and change in time and apply linear fit to find the required slope value Incomplete or incorrect calculation of the radius of droplet, terminal velocity, mass of droplet and charge of an electron from derived equations Incomplete lab report with no or few post lab questions answered

10	Determine the role of resistors and capacitors in electronic circuits on PCB (EM8678) by charging and discharging capacitor.	Observe behavior as charging /discharging of capacitors with different resistances including a bulb Evaluate C=Q/V fully with schematic circuit diagram Analyze how the resistances of different amounts behave in the circuit Follow instructions fully and perform experiment with minimum help Repeat each step for additional verification All material for lab report is present in the lab report along with post lab questions	Observe values of currents and voltages in DataStudio software Generate charging/discharging graphs in DataStudio software Draw a schematic circuit diagram Follow all precautions	Collect data of charging and discharging of capacitors in DataStudio software	Connect overall setup correctly according to circuit diagram layout Utilize DataStudio Software, voltage sensor (CI6503), current sensor (CI6556) in correct channels of 750-interface (CI7599) to perform the experiment Connect batteries Synchronize sensors with DataStudio software	Attempt to setup the apparatus Incomplete performance of experiment Incomplete or incorrect circuit implemented on PCB Cannot not plug in voltage sensor, current sensor and interface 750 in correct ports Unable to synchronize sensors with DataStudio software Cannot not run the set up in DataStudio software Incomplete or incorrect charging/discharging graphs in DataStudio software Incomplete lab report with no or few post lab questions answered

11	Verify Ohm's law by setting up a circuit on PCB (EM8678) and calculate the slope and vertical intercept through each graph to measure resistance value with the help of DataStudio software. .	Compare & verify slope values (Resistance in Ω) with resistances applied Evaluate R=V/I fully with schematic circuit diagram Analyze Ohm's law by generating different linear plots by using 2-3 different resistances Follow instructions fully and perform experiment with minimum help Calculate percentage error and the error is very less Repeat each step for additional verification All material for lab report is present in the lab report along with post lab questions	Generate I-V graphs for different resistances in DataStudio software Calculate the slope through the graphs by applying linear fit function in the DataStudio software Draw a schematic circuit diagram Follow all precautions	Run and collect data of in DataStudio software with following: 10Ω, 33Ω, 100 Ω resistances and light bulb resistance	Connect overall setup correctly according to circuit diagram layout Utilize DataStudio software, voltage sensor (CI6503), current sensor (CI6556) in correct channels of 750-interface (CI7599) to perform the experiment Connect batteries Synchronize sensors with DataStudio software	Attempt to setup the apparatus Incomplete performance of experiment Incomplete or incorrect circuit implemented on PCB Cannot not plug in voltage sensor, current sensor and interface 750 in correct ports Unable to synchronize sensors with DataStudio software Cannot not run the set up in DataStudio software Incomplete or incorrect graphs between V-I Incomplete lab report with no or few post lab questions answered

12	Examine time constant of RC circuit on PCB (EM8678) and generate I/V plot to examine the time constant by applying natural exponent fit in DataStudio software.	Understand time constant formula and its implication on the plot: $V = V_0 e^{\frac{-t}{RC}} \quad \tau = RC$ Follow instructions fully and perform experiment with minimum help Repeated each step for additional verification All material for lab report is present in the lab report along with post lab questions	Generate I-V graphs for different resistances in DataStudio software Calculate the slope through the graphs by applying natural exponent fit function in the DataStudio software Draw a schematic circuit diagram Follow all precautions	Run and collect data of in DataStudio software with following: 10Ω, 33Ω, 100 Ω resistances and light bulb resistance	Connect overall setup correctly according to circuit diagram layout Utilize DataStudio software, voltage sensor (CI6503), current sensor (CI6556) in correct ports of 750-interface (CI7599) Connect batteries Synchronize sensors with DataStudio software	Attempt to setup the apparatus Incomplete performance of experiment Incomplete or incorrect circuit implemented on PCB Cannot not plug in voltage sensor, current sensor and interface 750 in correct ports Unable to synchronize sensors with DataStudio software Cannot not run the set up in DataStudio software Incomplete or incorrect graphs between V-I Cannot understand time constant formula and its implication on the plot

13	Calculate equivalent capacitance in case of parallel or series combination of capacitors (e.g., 0.1-0.3 μF) in circuits on the breadboard of digital logic trainer (EES IT-300) and power supply (MPS-3005LS-3) and measure the voltage and charges across the capacitors by DMM (GDM-360) to verify the behavior in case of parallel or series combination of capacitors in circuits.	Calculate the total capacitance through the series/parallel capacitance formulae $C_{total} = C_1 + C_2 + \ldots C_n$ $C_{total} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \ldots \frac{1}{C_n}}$ Correlate equivalent capacitor with more than one series or parallel combinations Follow instructions fully and perform experiment with minimum help Repeat each step for additional verification All material for lab report is present in the lab report along with post lab questions	Measure the voltage and charges across the capacitors by DMM (GDM-360) to verify the behavior in case of parallel or series combination of capacitors in circuits Calculate the voltage and charge across this equivalent capacitor Follow all precautions	Connect three capacitors on the bread board in the series combination as shown in fig. 1. Connect the power supply of voltage (5V or 12V) through wires.	Connect circuit diagram(s) correctly Make schematic circuit diagram(s) of parallel or series combinations	Attempt to setup the apparatus Incomplete performance of experiment Incorrect set up of capacitors on breadboard Mishandle DMMs and power supply Incomplete schematic circuit diagram(s) of parallel or series combinations Cannot correlated equivalent capacitor with more than one series or parallel combinations Cannot calculate potential difference or amount of charge/current across capacitors Incomplete lab report with no or few post lab questions answered

14	Verify linear relationship between magnetic force with: current carrying wire, length of conductor and magnetic field by using basic current balance (SF8607) with graphs generated in DataStudio software.	Generate graphs of: (force & current), (force & conductor length) and (force & magnetic field) DataStudio software and observe linear relationships Apply formula to the experiment $F_m = IL \times B$ Follow instructions fully and perform experiment with minimum help Calculate percentage error and the error is very less Repeated each step for additional verification All material for lab report is present in the lab report along with post lab questions	Make tables: (current & mass), (length & mass) and (magnetic field-no. of magnets used and mass with changing currents) Learn how to constant respective specific parameter(s) in each part of experiment: 1) force vs. current 2) force vs. length of wire 3) force vs. magnetic field	Run and collect data of in DataStudio software for each part of the experiment: (current & mass), (length & mass) and (magnetic field-no. of magnets used and mass with changing currents)	Connect overall setup and adjust current balance on the current balance accessory (SF6808), magnets with proper handling of AC/DC power supply(SF9584A) and banana plug cords Measurement of mass at zero current	Attempt to setup the apparatus Incomplete performance of experiment Incorrect positioning of current balance, on the current balance accessory, magnets Incorrect handling of AC/DC power supply Incorrect or incomplete tables: (current & mass), (length & mass) and (magnetic field-no. of magnets used and mass with zero current and changing currents). Incorrect or incomplete graphs of: (force & current), (force & conductor length) and (force & magnetic field) DataStudio software and observe linear relationships Incomplete lab report with no or few post lab questions answered

15	Calculate induced emf from the oscillations of induction wand (EM8099) in magnetic field experimentally and compare theoretical and experimental values.	Follow instructions fully and perform experiment with minimum help Compare theoretical and experimental values of induced emf Calculate percentage error and the error is very less Repeated each step for additional verification All material for lab report is present in the lab report along with post lab questions	Observe oscillations of induction wand in magnetic field Generate graph (voltage vs. time) in DataStudio software with a highlight on maximum peak of oscillation to get the value of induced emf	Calculate strength of magnetic field from magnetic field sensor Calculate theoretical value of induced emf from the formula $E = -NA\frac{\Delta B}{\Delta t}$	Connect overall setup and correct position adjustment of induction wand, variable gap magnet etc. Use variable gap magnet (EM8641), voltage sensor (CI6503), magnetic field sensor (CI6520A), rotary motion sensor (CI6538) and 750-interface (CI7599) to perform the experiment. Synchronize sensors with DataStudio software	Attempt to setup the apparatus Incomplete performance of experiment Incorrect positioning of induction wand, variable gap magnet etc. Cannot not plug magnetic field sensor, voltage sensor, and rotary motion sensor in correct channels of 750-interface Unable to synchronize sensors with DataStudio software Cannot calculate strength of magnetic field from magnetic field sensor Incomplete calculation of theoretical value of induced emf from the formula. Incorrect graph (voltage vs. time) in DataStudio software with no highlight of maximum peak of oscillation to get the value of induced emf. Cannot compare theoretical and experimental values of induced emf. Cannot calculate percentage error or high percentage error calculation Incomplete lab report with no or few post lab questions answered

16	Plot the magnetic fields of different coils (single, double, solenoid) versus position by using Helmholtz coil base (EM6715), field coils (EM6711) and primary & secondary coils (SE8653) and analyze each graph that magnetic field strength is inversely proportional to the distance from the coil(s).	Compare theoretical value with experimental values Analyze each graph that magnetic field strength is inversely proportional to the distance from the coil(s) Compare theoretical value with experimental values Understand formulae equations with derivation Follow instructions fully and perform experiment with minimum help Calculate percentage error and the error is very less Repeated each step for additional verification All material for lab report is present in the lab report along with post lab questions	Calculate radii & magnetic fields of single coil, double coil or solenoid coil experimentally from graphs (magnetic field strength vs. distance) by using smart cursor & calculator in DataStudio software Follow all precautions	Calculate magnetic fields of single coil, double coil or solenoid coil theoretically from formulae respectively: $B=\frac{\mu_o NIR^2}{2\left(x^2+R^2\right)^{\frac{3}{2}}}$ $\vec{B}=\vec{B}_1+\vec{B}_2=\frac{\mu_o NIR^2}{\left(\left[\frac{d}{2}-x\right]^2+R^2\right)^{\frac{3}{2}}}\hat{x}+\frac{\mu_o NIR^2}{\left(\left[\frac{d}{2}+x\right]^2+R^2\right)^{\frac{3}{2}}}\hat{x}$ $\vec{B}=\frac{8\mu_o NI}{\sqrt{125R}}\hat{x}$ Calculate radii & magnetic fields of single coil, double coil or solenoid coils	Connect overall setup and correct position adjustment of different coils (single, double, or solenoid/Helmholtz coils) on optical bench and track mount Correct handling of DC power supply, magnetic field sensor and DMMs Use patch cords, optics bench rod clamps (SE9451), DC power supply (SE9720), magnetic field sensor (CI6520A) and rotary motion sensor (CI6538) to perform the experiment.	Attempt to setup the apparatus Incomplete performance of experiment Incorrect positioning of different coils (single, double, or solenoid/Helmholtz coils) on optical bench and track mount Incorrect handling of DC power supply, magnetic field sensor and DMMs Calculate radii & magnetic fields of single coil, double coil or solenoid coil theoretically from formulae Incorrect calculation of magnetic fields of single coil, double coil or solenoid coil experimentally from graphs (magnetic field strength vs. distance) Cannot compare theoretical value with experimental values Cannot analyze each graph that magnetic field strength is inversely proportional to the distance from the coil(s) Incomplete lab report with no or few post lab questions answered