ELECTRIC BICYCLES

TRAINING MODULES

Student Course

e-VETBike

Sustainable Life Sustainable Vocational Education

Dear Students and Trainees,

Developments in the field of technology have become more and more effective in our lives every day. In parallel with this, the working time of today's people and the time they spend on the roads are increasing rapidly. The current state of traffic is becoming increasingly complex for every country and city. As a result of population growth, migration and the increase in job opportunities in big cities, the time spent on the roads is increasing even more. People who want to find a solution to the disadvantages caused by this situation have searched for more practical methods and have had to develop bicycle technology, which has been used for years, as a savior.

Today, bicycle technology has developed remarkably and is on its way to becoming today's favorite means of transportation, both mechanically and electrically. This rapid development in bicycle technology has brought along both technological and maintenance needs.

In this context, this project has been implemented with the aim of improving the skills and qualifications of instructors and students in Vocational Education and Training on electric bicycles, bringing the content of vocational education closer to the development of contemporary electric vehicles and training the intermediate staff needed by electric bicycles. For this purpose in this student book, our project partner General Directorate of EGO produced first chapter of History of Electric Bikes, our partner Eu&Pro centrum vzdělávání a praxe, s.r.o. produced second chapter of Electrical Theory and its Components, our partner Liceul Tehnologic de Transporturi Auto Targoviste produced third chapter of Direct Current Principles, our partner ACADEMIA, izobrazevanje in druge storitve d.o.o. produced fourth chapter of Battery Technologies in Electric Vehicles, our partner Güvercinlik Şehit Hasan Gülhan Vocational and Technical Anatolian High School produced fifth and sixth chapters of Electric Motors Used in Bicycles and Structural Features of Electric Bicycles and the project coordinator Hacettepe University produced seventh and eighth chapters of Legal Regulations a bout Electric Bicycles and Periodic Maintenance and Service of Electric Bicycles.

When the e-VETBike Sustainable Life Sustainable Vocational Education project prepared by experts in the field is completed, our students will have all the information about electric bicycle systems and will be trained in maintenance and repair as a result of the relevant training, exams and evaluations.

We hope that this book will be useful to all interested students.

Prof. Dr. Şefika Şule ERÇETİN
Hacettepe University/Project Coordinator

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MODULE 1. HISTORY OF ELECTRIC CYCLING

MODULE 1. OBJECTIVES

To know the history of electric bicycles, to be able to describe their types, to have knowledge of the principles of operation.

MODULE 1. TOPICS

1.1. Historical development of electric bicycles and today's standards of use
1.2. Types of electric bicycles
1.3. Advantages and disadvantages of electric bicycles
1.4. The principle of operation of electric bicycles

MODULE 1. APPLICATIONS

Application 1.1. The Development of Electric Bicycles
Application 1.2. Standards for the Use of Electric Bicycles
Application 1.3. The Place of the Electric Bicycle in Electric Vehicles

Application 1.1.	The Development of Electric Bicycles

a) Purpose of Application: To investigate and report on the historical development of the electric bicycle.

b) Duration of Application: 90 minutes

c) Requirements:

1. Describe the invention of the first electric bicycle in 1880. Who was the inventor, and what components were used in this early electric bicycle?
2. Explain the patent application filed by Ogden Bolton in 1895. What was unique about his invention, and how did it differ from earlier electric bicycles?
3. Discuss Charles Theryc's invention in 1896. What was the key feature of his electric bicycle, and how did it contribute to the development of electric bicycles?
4. Describe Hosea W. Libbey's electric bicycle invention in 1897. What were the innovations he introduced, especially regarding the power source?
5. Explain Mathew J. Steffens' patent in 1898 and the belt drive system used in his electric bicycle. How did this system work, and what advantages did it offer?
6. Discuss Gordon John Scott's electric bicycle design in 1898. What was unique about his invention, particularly in terms of power generation and usage?
7. Describe John Schnepf's bicycle invention in 1899 that utilized a pulley system. How did this system transfer power to the wheel, and what were its advantages?
8. Explain Heinzmann's contribution to the development of electric bicycles in 1920. What role did this German company play in popularizing electric motors for bicycles?
9. Discuss the production of the "Electrocyclette" in France in 1927. What were the specifications of this electric bicycle, and what impact did it have on the market?
10. Describe the advancements in electric bicycle technology during and after World War II. How did designers like Ben Bowden and innovations like the "Bicycle of the Future" contribute to this progress?
11. Summarize the current usage standards for electric bicycles and briefly highlight the differences from past usage standards. Also, provide a brief overview of the most significant improvement in terms of energy efficiency.

d) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Research has been done and sources have been identified	20p
2	Discussion of key inventions or innovations between 1896 and 1927 in the electric bicycle development	20p
3	Discussion of the innovations in electric bicycle technology	30p
4	Summary of current usage standards for electric bicycles, highlighting differences from past standards, and overview of the most significant energy efficiency improvement	30p
	Out of 100 points in total ... scored.	100 p

e) Questions: Please answer the questions given below.

1. Who is credited with inventing the first electric bicycle in 1880, and what key components were used in its construction?
2. What unique feature did Ogden Bolton introduce in his 1895 patent application for an electric bicycle, and what was the power source for his invention?
3. Describe the 1897 invention by Hosea W. Libbey, including the location of the electric motors and how they were powered during different road conditions.
4. Explain the significance of Mathew J. Steffens' 1898 patent for an electric bicycle, particularly the belt drive system. How did this system work?
5. How did Charles P.D. Davidson and Peter W. Leighton contribute to the development of electric bicycles in 1977, and what problem did their innovation aim to solve in electric bicycle design?
6. List the restrictions on electric bicycles in Turkey.

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You can switch to the other application.

Application 1.2.	Standards for the Use of Electric Bicycles

a) Purpose of Application: To investigate and report the usage standards of electric bicycles according to different countries.

b) Duration of Application: 30 minutes

c) Requirements:

1. Discuss the differences between the current usage standards for electric bicycles and those in the past.
2. Describe the three main components of electric bicycles
3. Compare and contrast the common motor placement options for electric bicycles: front hub, rear hub, and mid-drive. Discuss the advantages and disadvantages of each placement method.
4. Explain the importance of seals and secure covers for protecting electronic components in electric bicycles. Discuss the potential risks of liquid damage and how these protective measures contribute to the longevity of electric bicycle systems.
5. Discuss the characteristics and limitations of S-Pedelecs. Under what conditions is their use necessary?
6. Discuss on the power-on-demand and pedal assist system. What are the advantages of electric bicycles equipped with these systems?
7. Provide information about kits used to convert standard bicycles into electric bicycles
8. Discuss the importance of adjustable assistance levels and their impact on the electric bicycle's performance.
9. Explain how the control unit manages the interaction between the rider's input and the motor's assistance level
10. Classify electric bicycles according to their motor powers

d) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Research has been done and sources have been identified	20p
2	Understanding of Electric Bicycle Components and analysis of motor placement options	20p
3	Accurate description of how the power-on-demand and pedal assist systems function.	10p
4	Provide information about kits used to convert standard bicycles into electric bicycles	10p
5	Discussion of protective measures	10p
6	Clear presentation of the different categories and their characteristics	30p
	Out of 100 points in total ... scored.	100 p

e) Questions: Please answer the questions given below.

1. What is an S-Pedelec, and how does it differ from a Pedelec? In which regions is the use of S-Pedelecs subject to different regulations?
2. How do electric bicycles with a power-on-demand system operate and in which situations can this type of bicycle be particularly beneficial?
3. Technically, what is the most important feature that distinguishes today's electric bicycles from their ancestors?
4. Why is it crucial to protect electronic components in electric bicycles, and what risks are associated with liquid damage?
5. Explain the specific circumstances or areas where the use of electric bicycles might be restricted or subject to special rules in your locality.

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You can switch to the other application.

Application 1.3.	The Place of the Electric Bicycle in Electric Vehicles

a) Purpose of the Application: To investigate and compare and report the effects, advantages and disadvantages of the electric bicycle compared to other electric vehicles.

b) Duration of Application: 45 minutes.

c) Requirements:

1. Explore and report on the environmental, health, and societal effects of electric bicycles and other electric vehicles.
2. Identify and compare the advantages of electric bicycles over other electric vehicles. Discuss aspects like cost-effectiveness, ease of use, accessibility, and their role in sustainable urban transportation and how do these effects contribute to their popularity?
3. Similarly, identify and compare the disadvantages of electric bicycles in contrast to other electric vehicles. Consider factors like range limitations, speed, infrastructure, and safety concerns.
4. Analyse and report on the specific use cases or scenarios where electric bicycles excel or fall short compared to other electric vehicles. Discuss scenarios such as commuting, leisure, last-mile transportation, and environmental impact.
5. Investigate recent technological advances in electric bicycles and other electric vehicles. Examine innovations in batteries, motors, control systems, and safety features.
6. Discuss the existing regulations and policies governing electric bicycles and other electric vehicles in your region. Explain how these regulations impact their usage, safety, and integration into transportation systems.
7. Based on your research and analysis, provide recommendations for individuals, communities, or policymakers regarding the adoption and integration of electric bicycles compared to other electric vehicles.
8. Predict whether electric bicycles are likely to become more or less popular in the future and briefly explain why.

d) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Research has been done and sources have been identified	20p
2	Advantage comparison	10p
3	Disadvantage comparison	10p
4	Use case analysis	10p
5	Technological advances investigation	10p
6	Discussion of regulations and policies	20p
7	Recommendations and future popularity prediction	20p
	Out of 100 points in total ... scored.	100 p

e) Questions: Please answer the questions given below.

1. What are some of the key environmental benefits associated with the use of electric bicycles when compared to other electric vehicles?
2. List three advantages of electric bicycles in terms of cost-effectiveness and ease of use for urban transportation.
3. Name one societal effect of electric bicycles that was discussed in the assignment.
4. Mention one technological advancement in electric bicycles or other electric vehicles that you found notable.
5. Name one or two specific disadvantage of electric bicycles compared to other electric vehicles, focusing on either range limitations or safety concerns.
6. Describe a hypothetical situation where electric bicycles could address transportation challenges, using a few sentences.

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MODULE 2. ELECTRICAL THEORY AND COMPONENTS

MODULE 2. OBJECTIVES

To be able to define the definition of electricity and to understand its usage areas.

MODULE 2. TOPICS

2.1. Definition and use of electricity
2.2. Use of electricity in transport
2.3. Electricity storage and charging systems
2.4. High voltage battery charge, discharge and balancing procedures

MODULE 2. APPLICATIONS

Application 2.1. Stages of Generation, Transmission and Distribution of Electricity
Application 2.2. DC Electricity Generation Test with Dynamo
Application 2.3. AC Electricity Generation Test with Alternator
Application 2.4. Application of Charge and Discharge Processes with Capacitor
Application 2.5. Charging and Discharging Processes in Batteries and Batteries

Application 2.1.	Stages of Generation, Transmission and Distribution of Electricity

a) Purpose of Application:

The purpose of this application is for students to practice the Stages of Generation, Transmission and Distribution of Electricity and to improve their skills in designing electrical circuits.

b) Duration of Application: 2 - 3 hours

c) List of Materials and Equipment Used:

No.	Properties of Materials and Equipment	Explanation
1	Resistors	2-3 different values of resistor for each student (for example, 220-ohm, 470 ohm, and 1K ohm). 6-9 resistors in total for each student.
2	Capacitors	1-2 capacitors of different capacities (e.g., 10uF and 100uF) for each student 2-4 capacitors in total for each student.
3	Transistors	At least 2 NPN type transistors (for example, 2N3904) for each student 4 transistors in total for each student.
4	LEDs	3-4 LEDs (in different colours) for each student 12-16 LEDs for each student in total.
5	Connecting wires	It is important to provide sufficient connecting wires for each student.
6	Multimeter	Providing one multimeter per student will help them take measurements and test their circuits. However, this equipment can be costly, so 1 multimeter can be used shared.
7	Breadboard (Testing board)	1 breadboard for each student
8	Power supply	1 power supply for each student

d) Process Steps:

This application is designed to teach students step by step how to design electrical circuits.

1. **Basic Circuit Design:** Students are shown a basic circuit design. To power an LED, a resistor is connected.
2. **Use of Resistors and Capacitors:** Students add resistors and capacitors to the circuit and observe how it works.
3. **Use of Transistors:** Students learn the process by integrating transistors into their circuits. This is the basis for more complex circuits.
4. **Power Supply and Transmission:** Students simulate the electricity production stage by connecting the circuits they designed to a power source.
5. **Transmission and Distribution:** Students simulate the process of distributing electricity by connecting the circuits they designed to a transmission line.
6. After each step, students are given small practice assignments and their progress is evaluated.

e) Scoring:

No.	Scoring Criteria	Score
1	Circuit design skills	20p
2	Correct selection of components used	20p
3	Implementation of security measures	20p
4	Correct operation of circuits	20p
5	Successful execution of transmission and distribution processes	20p
	Out of 100 points in total ... scored.	100 p

f) Questions:

1. In electrical circuits, what is resistance measured in?
   A) Ohms
   B) Volts
   C) Amperes
   D) Watts

2. What is the primary function of a capacitor?
   A) Generate electrical energy
   B) Store electrical energy
   C) Interrupt an electrical circuit
   D) Transmit electrical energy

3. What is the operating principle of an NPN transistor?
A) Conveys positively charged electrons
B) Conveys negatively charged electrons
C) Cuts off current flow
D) Amplifies current

4. What is the purpose of a parallel connection in electrical circuits?
A) Interrupts current flow
B) Combines resistances
C) Increases voltage
D) Distributes current

5. What is an electrical transmission line?
A) A device that generates electrical energy
B) A pathway for transmitting electrical energy
C) A device that stores electrical energy
D) A power generation facility

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You can switch to the other application.

Application 2.2.	DC Electricity Generation Test with Dynamo

a) Purpose of Application:

The purpose of this application is to teach students DC Electricity Generation Test with Dynamo and to give them practical experience. Students will get to know the components of Dynamo, observe the electricity production process and understand this subject better by analysing the data they obtain.

b) Duration of Application: 2 - 3 hours

c) List of Materials and Equipment Used:

No.	Properties of Materials and Equipment	Explanation
1	Dynamo	1 dynamo for each student
2	Turbine or rotatable mechanism	1 turbine or rotatable mechanism for each student
3	Multimeter or measuring device	Providing one multimeter per student will help them take measurements and test their circuits. However, this equipment can be costly, so 1 multimeter can be used shared.
4	Connection wires	It is important to provide sufficient connecting wires for each student.
5	Magnet to create a magnetic field	1 magnet for each student
6	Instruction materials and safety equipment (goggles, gloves, etc.)	Sufficient guidance materials and safety equipment for each student

d) Process Steps:

1. **Dynamo Assembly:** As the first step, demonstrate to the students how to assemble the Dynamo. Introduce its components and ensure they put them together correctly.
2. **Turbine Preparation:** Teach the preparation of the turbine or rotatable mechanism. This will be used to rotate the Dynamo and generate electricity.
3. **Connections and Measurements:** Instruct the students on how to make connections between the Dynamo, turbine, and measuring devices. Correct connections are essential to initiate electricity generation.

4. **Rotating the Turbine:** Assign the task of rotating the turbine to the students. During this process, have them observe electricity generation using a multimeter or measuring devices.
5. **Data Collection and Analysis:** Teach the students to measure and record the data they obtain and analyse the results. Work on the quantity of electricity produced, voltage, and other relevant data.
6. **Progress Steps:**
    - Dynamo assembly
    - Preparation of the turbine
    - Making connections
    - Rotating the turbine
    - Data collection and analysis

e) Scoring:

No.	Scoring Criteria	Score
1	Dynamo assembly	20p
2	Preparation of the turbine	20p
3	Making connections	20p
4	Rotating the turbine	20p
5	Data collection and analysis	20p
	Out of 100 points in total ... scored.	100 p

f) Questions:

1. What are the main components of a Dynamo?
   A) Coil, magnetic field, accumulator
   B) Magnetic field, generator, motor
   C) Magnetic field, rotating arm, output wire
   D) Magnetic field, magnetic material, pin

2. To increase electricity production, which of the following should be done?
   A) Reduce the magnetic field
   B) Decrease turbine speed
   C) Increase rotation speed
   D) Reduce the number of coils

3. What safety precautions should be taken during Dynamo-based DC electricity production?

A) Use goggles and gloves
B) Maintain silence
C) Avoid mixing up devices
D) No safety precautions are necessary

4. What is the role of the magnetic field in electricity production?

A) Stores electric current
B) Generates electric current
C) Performs the rotation work
D) Facilitates the transmission of electric current

5. Which component is used to rotate the turbine during the Dynamo-based DC electricity production experiment?

A) Magnet
B) Magnetic field
C) Coil
D) Electric cable

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You can switch to the other application.

Application 2.3.	AC Electricity Generation Test with Alternator

a) Purpose of Application:

The purpose of this application is to provide students with practical skills in electrical energy production by providing them with the opportunity to practically perform the basic assembly and testing of alternators.

b) Duration of Application: 3 - 4 hours

c) List of Materials and Equipment Used:

No.	Properties of Materials and Equipment	Explanation
1	Alternators	1 alternator for each student
2	Connection wires	It is important to provide sufficient connecting wires for each student.
3	Multimeter	Providing one multimeter per student will help them take measurements and test their circuits. However, this equipment can be costly, so 1 multimeter can be used shared.
4	Hand tools (screwdriver, pliers, etc.)	Basic hand tools that each student can use during alternator assembly
5	Assembly bench or workbench	Enough study space for each student
6	Safety goggles and gloves	Adequate safety glasses and gloves for each student

d) Process Steps:

1. **Preparation Phase:**
   - Give students a brief theoretical information about the working principles of the alternator.
   - Give students time to examine alternator parts and understand the functions of the components.
2. **Assembly Process:**
   - Show students the step-by-step process of assembling the alternator.
   - Be careful when assembling the rotor and ensure that the rotor is positioned correctly.

- Instruct students on the assembly of the stator and the correct connection of the wires.

3. **Electrical Connections and Controls:**
   - Teach students how to connect the electrical wires from the alternator's output.
   - Have them measure the electric current, voltage and frequency produced using a multimeter.
4. **Performance Test:**
   - Ask students to measure the voltage and current at the output of the alternator and check the frequency.
   - Have them record the measurements in a data table and evaluate the operating condition of the alternator.
5. **Troubleshooting:**
   - Teach students how to troubleshoot if they detect any problems.
   - For example, the wires may be misconnected or the magnetic field must be corrected.
6. **Progress steps:**
   - Theoretical information presentation and part inspection
   - Alternator installation
   - Electrical connections and measurements
   - Performance testing and data recording
   - Troubleshooting applications

e) Scoring:

No.	Scoring Criteria	Score
1	Accuracy and order of alternator installation	20p
2	Correct electrical connections	20p
3	Multimeter use and measurement accuracy	20p
4	Data collection and analysis capabilities	20p
5	Troubleshooting and error correction skills	20p
	Out of 100 points in total ... scored.	100 p

f) Questions:

1. What are the basic components of an alternator?
   A) Battery and spark plug
   B) Rotor and stator
   C) Clutch and brake
   D) Filter and radiator

2. What factor determines how the rotor should be positioned during alternator assembly?
A) Weight of the rotor
B) Colour code of the rotor
C) Orientation of the magnetic field
D) Length of the wires

3. Which device is used to measure the electrical current coming from the output of an alternator?
A) Voltmeter
B) Ammeter
C) Ohmmeter
D) Thermometer

4. What is the relationship between the voltage and current at the output of an alternator?
A) Direct proportion
B) Inverse proportion
C) No relationship between them
D) Mixed proportion

5. Which of the following measures can be taken to increase the efficiency of an alternator?
A) Keep the rotor stationary
B) Remove the stator
C) Weaken the magnetic field
D) Increase the rotor speed

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You can switch to the other application.

Application 2.4.	Application of Charge and Discharge Processes with Capacitor

a) Purpose of Application:

The purpose of this application is to explain to students the basic functioning of capacitors and to help them understand the charging/discharging processes by putting them into practice.

b) Duration of Application: 2 - 3 hours

c) List of Materials and Equipment Used:

No.	Properties of Materials and Equipment	Explanation
1	Capacitor	1 capacitor for each student
2	Resistor	1 resistor per student
3	Ammeter	1 ammeter for each student
4	Voltmeter	1 voltmeter for each student
5	Switches	1 switches for each student
6	Circuit board or breadboard	1 circuit board or breadboard for each student
7	Connection wires	It is important to provide sufficient connecting wires for each student.
8	Battery or power supply	1 battery or power supply for each student

d) Process Steps:

1. Give students a brief theoretical explanation about the basic working principles of capacitors. Emphasize basic concepts such as how capacitors work and their energy storage capacity.
2. Create a circuit to show students the processes of charging and discharging:
   - Connect the capacitor to the breadboard or breadboard.
   - Add the resistor to the circuit and add a switch that will be used to charge or discharge the capacitor.
   - Complete the circuit with ammeter and voltmeter. Ammeter is used to measure electric current while voltmeter is used to measure voltage.
3. Tell students to follow these steps to observe the charging and discharging processes of the capacitor:
   - To charge the capacitor, turn on the switch and record the ammeter and voltmeter readings.
   - Ask how they can tell when the capacitor is fully charged.

- To discharge the charged capacitor, turn off the switch and record the ammeter and voltmeter readings again.
- Ask how they can tell if the capacitor is fully discharged.

4. Encourage students to observe how charging and discharging processes change using different resistor values.

5. Progress steps:

- Presentation of theoretical information about the working principles of capacitors
- Creating a circuit for students to charge and discharge capacitors.
- Observing charging and discharging processes and collecting data
- Repeating the experiment using different resistor values
- Discuss the results.

e) Scoring:

No.	Scoring Criteria	Score
1	Creating a circuit and making its connections correctly	20p
2	Accurately observe and record the charging and discharging processes of the capacitor	20p
3	Comparing results by repeating the experiment using different resistor values	20p
4	Interpreting experiment results and explaining the use of capacitors in daily life	20p
5	Safe working and equipment use	20p
	Out of 100 points in total ... scored.	100 p

f) Questions:

1. What is the fundamental operation of capacitors?

A) Convert electrical energy into magnetic energy
B) Convert electrical energy into chemical energy
C) Convert electrical energy into mechanical energy
D) Convert electrical energy into electrical potential energy

2. What is the key difference between the charging and discharging processes?

A) Energy is lost during the charging process, and energy is gained during the discharging process.

B) Energy is gained during the charging process, and energy is lost during the discharging process.

C) There is no energy change between the charging and discharging processes.

D) Energy is stored during the charging process and erased during the discharging process.

3. What is the purpose of an ammeter, and how is it used?

A) Measures electric potential difference, controls components in parallel.

B) Measures electric current, controls components in series.

C) Measures resistance values, checks capacitance.

D) Measures electrical power, monitors magnetic fields.

4. How can you tell that a fully charged capacitor is completely discharged?

A) The voltmeter reading reaches its maximum value.

B) The voltmeter reading reaches its minimum value.

C) The ammeter reading reaches its maximum value.

D) The ammeter reading reaches its minimum value.

5. When you repeat the experiment using different resistance values, what happens as the resistance in the circuit increases?

A) The charging time increases, and the discharging time decreases.

B) The charging time decreases, and the discharging time increases.

C) Both the charging time and the discharging time decrease.

D) Both the charging time and the discharging time increase.

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You can switch to the other application.

Application 2.5.	Charging and Discharging Processes in Batteries

a) Purpose of Application:

The purpose of this application is to teach students the Charging and Discharging Processes in Batteries practically in the real world and to help them understand how different types of batteries work.

b) Duration of Application: 2 - 3 hours

c) List of Materials and Equipment Used:

No.	Properties of Materials and Equipment	Explanation
1	Lead-acid or lithium-ion batteries (in compliance with safety measures)	1 battery for each student
2	Battery charger (compatible with the type of batteries)	1 battery charger for each student
3	Voltmeter	1 voltmeter for each student
4	Ammeter	1 ammeter for each student
5	Crocodile clips	1 set of crocodile clips for each student
6	Safety goggles and gloves	Adequate safety glasses and gloves for each student

d) Process Steps:

1. **Safety Preparations:** Inform students about safety rules and have them wear necessary protective equipment (glasses, gloves).
2. **Introduction of Batteries:** Explain to students the features and usage instructions of different types of batteries. Identify which batteries are lead-acid and which are lithium-ion.
3. **Charging Experiment:**
   - Give each student a battery and ask them to measure the current voltage and amperage of the battery.
   - Have them charge the battery with the charger and follow the process.
   - Ask them to record changes in voltage and amperage when charging is complete.
4. **Discharge Test:**
   - Make sure they discharge the charged battery safely and follow the process.
   - Ask them to record changes in voltage and amperage when the discharge process is complete.

5. **Discuss Results:** Have students discuss how charging and discharging processes differ for both types of batteries and what safety precautions should be taken.
6. **Process Steps:**
    - Correctly connecting the battery and connecting it to the charger
    - Making voltage and amperage measurements
    - Accurately determine the start and end of the charging process
    - Discharging the battery safely
    - Making voltage and amperage measurements
    - Correctly determine the beginning and end of the discharge process
    - Recording experiment results correctly
    - Analyse the test results and explain the differences between the batteries

e) Scoring:

No.	Scoring Criteria	Score
1	Battery charging process	20p
2	Battery discharge process	20p
3	Complying with safety precautions	20p
4	Making accurate voltage and amperage measurements	20p
5	Analysing test results and explaining the differences between batteries	20p
	Out of 100 points in total ... scored.	100 p

f) Questions:

1. What are the fundamental differences between lead-acid batteries and lithium-ion batteries?
A) Rechargeability
B) Weight
C) Charging speed
D) Charge capacity

2. During the battery charging process, which parameters change?
A) Only voltage
B) Only current
C) Both voltage and current
D) Only temperature

3. When is the battery discharge process necessary?
A) When the battery is brand new
B) When the battery is completely discharged
C) When the battery overheats
D) When the battery is being charged

4. What are the advantages of lithium-ion batteries?
A) Low energy density
B) Low charging rate
C) High energy density and lightweight
D) Rapid discharge rate

5. What safety precautions should be taken during the battery charging process?
A) Protective gloves should be used.
B) Voltmeter and ammeter should not be used.
C) It should be done in a closed room.
D) Doors and windows should be left open.

THE PRACTITIONER:		**IMPLEMENTED BY:**	
Name-Surname:		**Name-Surname:**	
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MODULE 3. PRINCIPLES OF DIRECT CURRENT

MODULE 3. OBJECTIVES

Knows the principles of direct current.

MODULE 3. TOPICS

3.1. Direct Current (DC) Circuit Measurements and Calculations
3.2. Direct Current Source Connections
3.3. Direct Current Motor Connections

MODULE 3. APPLICATIONS

Application 3.1. OHM Law Practice
Application 3.2. Serial, Parallel and Mixed Circuit Connections and Applications
Application 3.3. Application of Environmental Currents Method
Application 3.4. Battery Connection Tests
Application 3.5. DC Motor Tests

Application 3.1.	OHM Law Practice

a) Purpose of Implementation: To apply the OHM law.

Ohm's Law is a fundamental principle in electrical circuits, and it describes the relationship between voltage, current, and resistance.

The statement of Ohm's Law is as follows: *"The current passing through a conductor between two points is directly proportional to the voltage across the two points and inversely proportional to the resistance of the conductor."*

Mathematically, Ohm's Law is represented as:

U = I * R

b) Duration of Application: 60 minutes

c) Visuals and Circuit Diagrams:

A multimeter is a versatile tool that combines various measurement functions, including measuring voltage, current, and resistance. It is indispensable for diagnosing electrical issues in an e-bike.

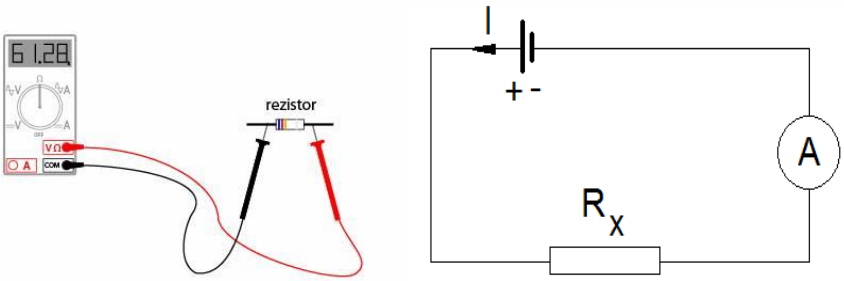

Figure 3.1

d) List of Materials and Equipment Used: Provide the materials and equipment in the table given below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	multimeter	1pcs
2	cables black	1pcs
3	cables red	1pcs
4	resistance	3 Ω
5	battery	36V

e) Requirements: When working with a multimeter, it's essential to follow a sequence of operations to ensure accurate measurements and your safety.

f) Process Steps: Perform the following process steps in order.

1. Turn on the multimeter and set it to the appropriate mode for the measurement you want to make. Common modes include DC voltage (V), AC voltage (V), DC current (A), AC current (A), resistance (Ω), and others.

2. Ensure that the range setting is appropriate for the expected value of the measurement. Start with the highest range and decrease as needed for better accuracy,

3.Before making any connections, check that the multimeter's probes are in good condition, with no exposed wires or damaged insulation.

4.If the multimeter has fuses, make sure they are intact and compatible with the measurement you are about to make.

5.When measuring voltage or current, always start with the highest range to avoid damage to the multimeter and yourself in case of unexpected high values.

6.If you are measuring resistance, make sure the circuit or component is not powered, as measuring resistance with power applied can lead to inaccurate readings.

7.For voltage and resistance measurements, insert the black probe into the common (COM) jack and the red probe into the appropriate jack for the measurement mode you selected (e.g., VΩmA for voltage and resistance).

8.For current measurements, move the red probe to the current (A) jack.

9.Place the probes across the circuit or component being measured. Ensure a secure connection for accurate readings.

10.Read the measurement on the multimeter's display. Pay attention to the unit and range setting to interpret the value correctly.

g) Measurement and Evaluation: The tables related to the study are given below.

Table 3.1: Table of Measurements

No	Voltage	resistance	current	power
	U(V)	R(Ω)	I(A)	P(W)

h) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The circuit diagram is drawn and its descriptions are written	20p
2	The circuit was built and connected on the experimental set.	20p
3	The experiment was run and the necessary measurements were made.	20p
4	The formula to calculate power in a DC	20p
5	The obtained results were evaluated and interpreted.	20p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

1. What is the main characteristic of a DC circuit?
2. The motor of an e-bike operates at a voltage of 36 volts (V) and draws a current of 10 amperes (A). Calculate the power consumed by the motor using Ohm's Law formula: Power (P) = Voltage (V) * Current (I). What is the power consumption of the motor?
3. If an e-bike's motor is connected to a 48-volt (V) battery and draws a current of 20 amperes (A), and you want to know the effective resistance of the motor, you can rearrange Ohm's.

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Number:		**Number:**	
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You can switch to the other application.

Application 3.2.	Serial, Parallel and Mixed Circuit Connections and Applications

a) Purpose of Application: To make applications related to various circuit connections and to evaluate the measurement results.

b) Duration of Application: 60 minutes

c) Visuals and Circuit Diagrams:

1. resistors grouped in series (serial circuit connections- applications),

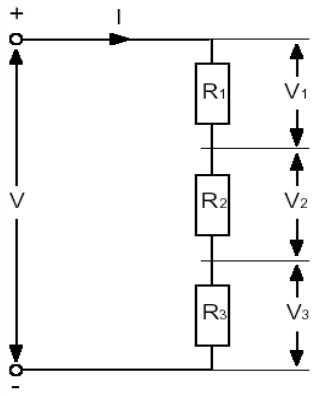


Figure 3.2.1

Rt is equal to the sum of the three resistances connected in series R1, R2, R3: Rt = R1 + R2 + R3. The total resistance of two or more resistors connected in series is equal to the sum individual resistances.

2. resistors grouped in series (parallel circuit connections-applications),

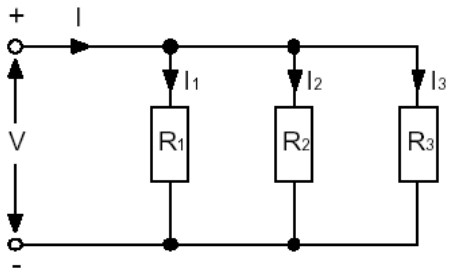


Figure 3.2.2

The total resistance of two or more resistances connected in parallel is equal to the inverse the sum of the inverses of the individual resistances.

$$Rt=\frac{1}{\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3}}$$

3. mixed group resistors (mixed connections-applications).

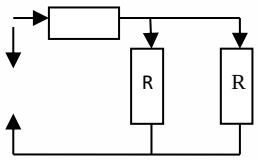


Figure 3.2.3

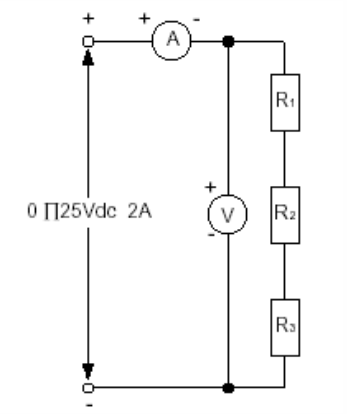
$$Rt=R1+\frac{R2R3}{R2+R3}$$

d) List of Materials and Equipment Used: Provide the materials and equipment in the table given below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	A-ammeter	1pcs
2	V- voltmeter	
3	R1-resistors 120 Ω /5W	1pcs
4	R2- resistors 220 Ω /5W	1pcs
5	R3- resistors 330 Ω /5W	1pcs
6	Power supply 0.25V DC,2A	1pcs

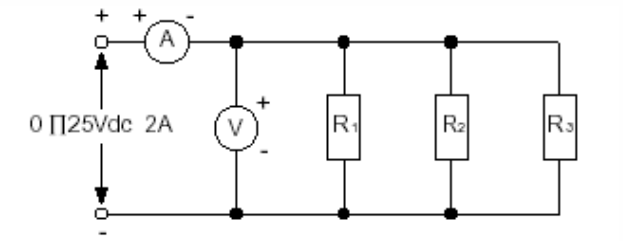
e) Requirements:

1.Build the following circuit:



a. Turn the handle of the variable transformer clockwise to the maximum.
b. Check that the voltage/current ratio that gives the total resistance of the circuit is equal to R1 + R2 + R3 (resistors connected in series).
c. Reset the DC output to zero and disassemble the circuit.

2.Build the following circuit:

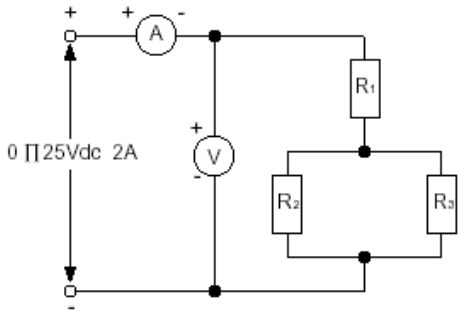


a. Turn the handle of the variable transformer clockwise to the maximum.
b. Check that the voltage/current ratio that gives the total resistance of the circuit is equal to

$$Rt=\frac{1}{\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3}}$$

(resistors connected in parallel).
c. Reset the DC output to zero and disassemble the circuit.

3. Build the following circuit:



a. Turn the handle of the variable transformer clockwise to the maximum.
b. Check that the voltage/current ratio that gives the total resistance of the circuit is equal to

$$Rt=R1+\frac{R2R3}{R2+R3}$$

c. Reset the DC output to zero and disassemble the circuit.

f) Process Steps: Perform the following process steps in order.

1. Build the circuit.
2. Turn the handle of the variable transformer clockwise to the maximum.
3. Check that the voltage/current ratio that gives the total resistance of the circuit
4 Reset the DC output to zero and disassemble the circuit.

g) Measurement and Evaluation: The tables related to the study are given below.

Table 3.2: Table of Measurements

No	Voltage U(V)	Current I(A)	rezistance R1(Ω)	rezistance R2(Ω)	rezistance R3(Ω)	rezistance Rt(Ω)

h) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The circuit diagram is drawn and its descriptions are written	20p
2	The circuit was built and connected on the experimental set.	20p
3	The experiment was run and the necessary measurements were made.	20p
4	Does the formula for calculating resistance in a DC obey Ohm's law?	20p
5	The obtained results were evaluated and interpreted.	20p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

1. Does the ratio between the voltage applied to the circuit and the total resistance follow Ohm's Law?
2. In the series circuit, if all the resistors are equal, how is the total resistance determined?
3. In the mixed circuit, if the resistors are equal, how is the total resistance determined?

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Name-Surname:		**Name-Surname:**	
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Date-Duration:		**Date-Duration:**	
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You can switch to the other application.

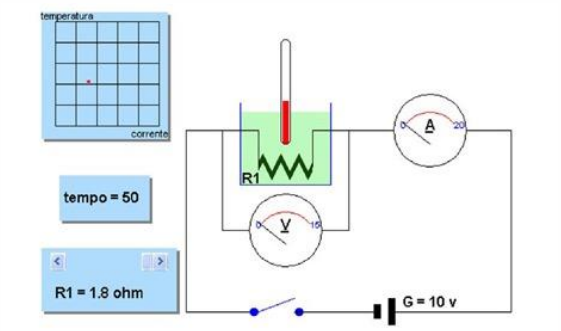
Application 3.3.	Application of Environmental Currents Method

a) Purpose of Application: To determine the circuit components using the method of environmental currents in the electrical circuit and to compare them with the measurements.

The electrothermal effect (the thermal effect of the electric current) consists in the heating of a conductor when the electric current passes through it.
The fuse protects electrical devices in electrical installations against over currents that occur in the network, especially when a short circuit occurs. It plays the role of an electric switch when currents with very high intensities appear in the circuit. Being made of a very thin silver or copper wire, it has a high resistance compared to the rest of the devices (the resistance of a conductor is inversely proportional to its thickness). When over currents pass through the electrical network, the fuse wire melts and interrupts their passage through devices (which would otherwise burn them). The blown fuse is replaced with a new one (purchased commercially), after the cause of the short circuit has been removed.

b) Duration of Application: 60 minutes

c) Visuals and Circuit Diagrams:



d) List of Materials and Equipment Used: Provide the materials and equipment in the table given below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	Calorimeter with thermometer	1pcs
2	voltmeter	1pcs
3	ammeter	1pcs
4	direct current source	1pcs
5	swich	1pcs
6	connection conductors	1set

e) Requirements: To determine the temperature, the amount of heat released by the resistance in the calorimeter, for 10 minutes.

f) Process Steps: Perform the following process steps in order.

- the choice of circuit materials,
- making the electric circuit

- recording the values of measured quantities: voltage, current, temperature
- calculation of the amount of heat released.

g) Measurement and Evaluation: The tables related to the study are given below.

No	voltage	current	resistance	temperature	time	heat
	U(V)	I(A)	R(Ω)	$t(C^0)$	Δt(s)	Q(J)

h) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The circuit diagram is drawn and its descriptions are written	20p
2	The circuit was built and connected on the experimental set.	20p
3	The experiment was run and the necessary measurements were made.	20p
4	Determine the Joule power in the experiment	20p
5	The obtained results were evaluated and interpreted.	20p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

1.Define the effects of electric current.

2.Define Joule's law.

3.What other applications of the thermal effect do you know?

THE PRACTITIONER:		**IMPLEMENTED BY:**	
Name-Surname:		**Name-Surname:**	
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Date-Duration:		**Date-Duration:**	
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You can switch to the other application.

Application 3.4.	Battery Connection Tests

a) Purpose of the Application: To examine the voltage-current relations by connecting the batteries in series, parallel and mixed and to compare them with the measurements.

Direct current batteries can be connected in series, parallel and mixed.

When batteries are connected in series, the voltage of the battery system increases, while the capacity remains the same.

For the serial, parallel connection of the batteries, since they are not equal, it is necessary to use a voltage equalizer, “battery balancing”.

Before connecting the elements together in a parallel battery, it is necessary to measure the voltage on each of them with a voltmeter to make sure that the future operation is safe.

b) Duration of Application: 60 minutes

c) Visuals and Circuit Diagrams:

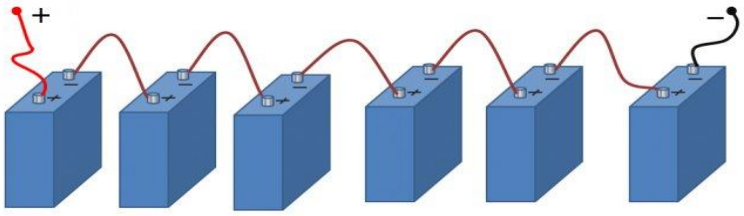


Figure 3.4.1 serial connection

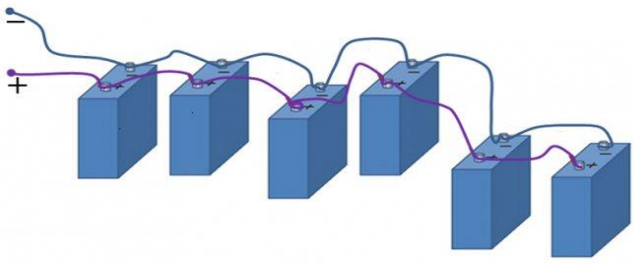


Figure 3.4.2 parallel connection

Figure 3.4.3 digital multimeter

Figure 3.4.4 Tester

d) List of Materials and Equipment Used: Provide the materials and equipment in the table given below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	Battery 2,14Vx6pcs	6pcs
2	Multimeter	1pcs
3	tester	1pcs

e) Requirements: To examine the voltage-current relations by connecting the batteries in series, parallel and mixed and to compare them with the measurements.

f) Process Steps: Perform the following process steps in order.

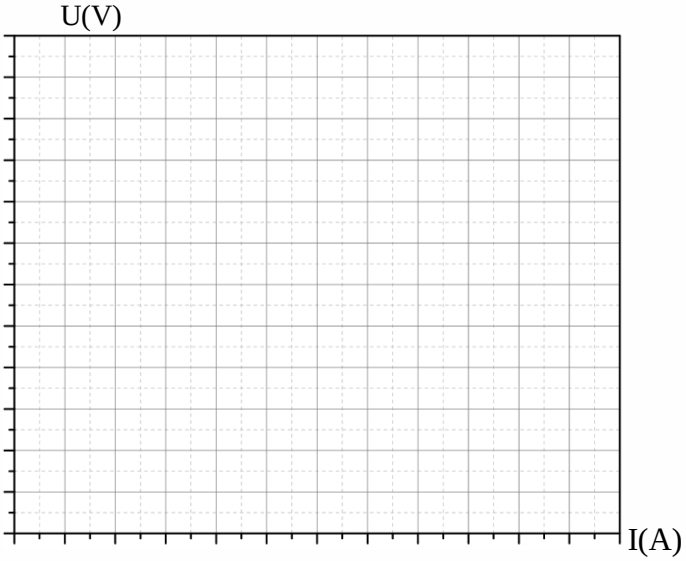
• use dielectric gloves.
• do not touch the terminals with bare hands.
• the batteries must be disconnected from the loads.
• use tools with insulated handles.
• check the terminals and connection pins before connection.
• do not use batteries with different parameters and degree of wear.
• be careful with the polarity.
• use suitable wires for the connection.
• isolate the assembly from moisture.
• before using the voltage tester, wear appropriate personal protective equipment (PPE), such as safety glasses and gloves, especially when dealing with high-voltage batteries.
•ensure the battery is disconnected or turned off before proceeding with the measurement to avoid accidental electrical contact.
•turn on the voltage tester and check its battery level or ensure it has sufficient power for the measurement.

g) Measurement and Evaluation: The tables related to the study are given below.

Table 3.2: Table of Measurements

	serial connection			parallel connection		
No	Voltage	Current	measured value	Voltage	Current	Measured value
	U(V)	I(A)	U(V)	U(V)	I(A)	U(V)

Chart voltaje-current



h) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The circuit diagram is drawn and its descriptions are written	20p
2	The circuit was built and connected on the experimental set.	20p
3	The experiment was run and the necessary measurements were made.	20p
4	What are switching errors?	20p
5	The obtained results were evaluated and interpreted.	20p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

1.How to classify storage batteries from a constructive point of view?

2.What are the advantages and disadvantages of the serial connection?

3.What are the advantages and disadvantages of the parallel connection?

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Name-Surname:		**Name-Surname:**	
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Date-Duration:		**Date-Duration:**	
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You can switch to the other application.

Application 3.5.	DC Motor Tests

a) Purpose of Application: To conduct various experiments on DC motors.

The direct current motor is powered by direct current.
The direct current machine consists of a stator (inductor) and a rotor (induced)
The stator consists of a cast iron or steel casing in the core in which the poles (main and auxiliary) are fixed with the respective windings (inductors) or without windings in the case of permanent magnets. The two shields that carry the bearings are located on the sides of the case.
The rotor is made of sheets of electrotechnical steel, fixed on the shaft, having peripheral notches where the active sides of the inductor coils are located. The rotor has a cylindrical collector of insulated copper laminations mounted dovetail on a shaft hub.
The ends of the rotor coils are connected to the collector blades which make contact, during rotation, successively with the brushes located in the brush holders which are fixed with insulating material to the stator. Carbon, copper or graphite bronze brushes are connected by flexible copper links to the machine terminals. They are fixed in the "neutral axis", which leads to improved commutation.
According to the type of excitation we distinguish machines with derivation (parallel), series or mixed (compound) excitation.

b) Duration of Application: 60 minutes

c) Visuals and Circuit Diagrams:
Consider the circuit diagram for the DC motor with shunt excitation.

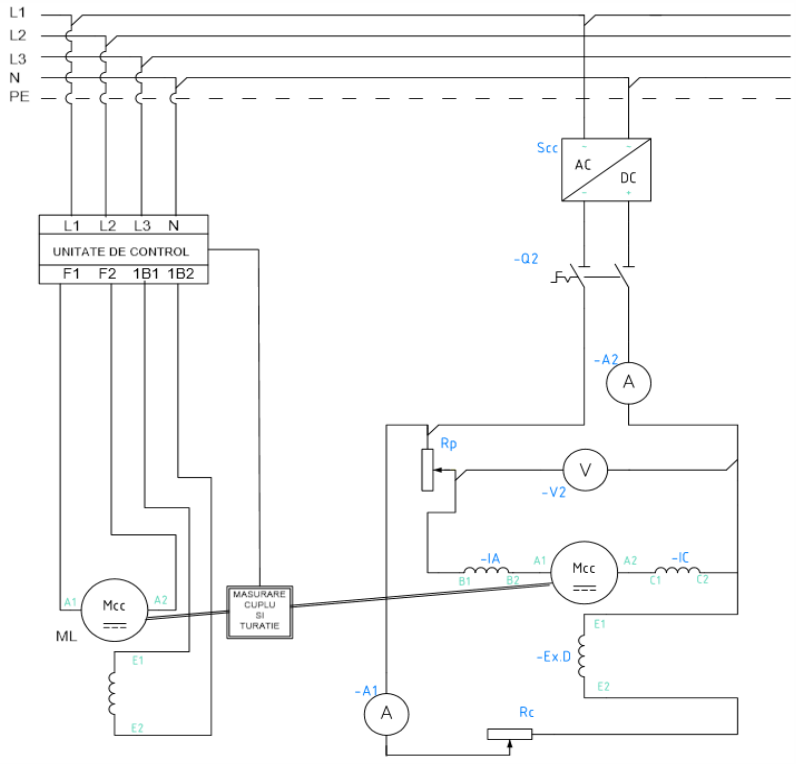


Figure 3.5

d) List of Materials and Equipment Used: Provide the materials and equipment in the table given below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	Control unit n=3000rot/min; M=10Nm	1pcs
2	Mcc n=2040 rot/min, U=220V, I=5,5A, Ie=0,24A	1pcs
3	Scc U=220V, Imax=10A	1pcs
4	Q2-switch	1pcs
5	Rc- field rheostat	1pcs
6	Rs- load rheostat	1pcs
7	A1-ammeter 1A	1pcs
8	A2-ammeter 10A	1pcs
9	V2-voltmeter 300V	1pcs

e) Requirements: In the following, several experimental trials will be carried out to trace the natural characteristic and the artificial characteristics of the shunt-excited DC.
In 60 minutes, the idling characteristic is drawn - n=f(Ie) - it is drawn keeping constant the motor supply voltage and the load applied to the shaft having the value M=0.

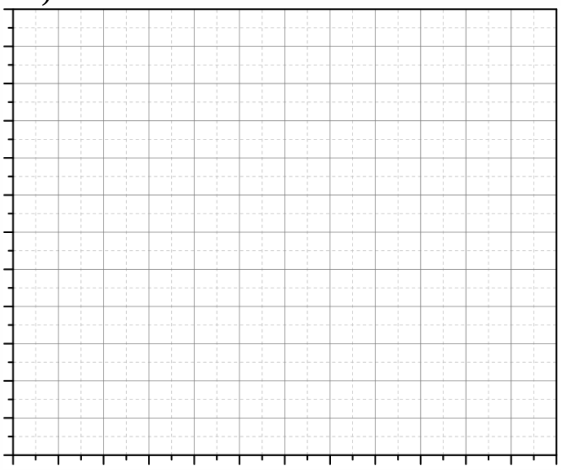
f) Process Steps: Perform the following process steps in order.
The load rheostat and the field rheostat are set to maximum value.
1- Switch Q2 closes.
2- The starting rheostat Rp is varied until the value of the armature supply voltage, measured by the voltmeter V2, is the nominal one, indicated on the indicator plate.
3- The excitation current, measured by the amperage A1, is varied in an increasing direction by decreasing the value of the field rheostat and the motor speed is read.
This completes table.

g) Measurement and Evaluation: The tables related to the study are given below.

Ie(A)									
n(rot/min)									

Plot the idle characteristic with the resulting values.

n(rot/min)



Ie(A)

h) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The circuit diagram is drawn and its descriptions are written	20p
2	The circuit was built and connected on the experimental set.	20p
3	The experiment was run and the necessary measurements were made.	20p
4	Draw the diagram n=f(Ie)	20p
5	The obtained results were evaluated and interpreted.	20p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

1. Define the direct current motor.
2. What are the constructive elements of the direct current motor
3. Which represents the idle characteristic?

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Name-Surname:		**Name-Surname:**	
Number:		**Number:**	
Date-Duration:		**Date-Duration:**	
Signature:		**Signature:**	

You can switch to the other application.

MODULE 4. BATTERY TECHNOLOGIES IN ELECTRIC VEHICLES

MODULE 4. OBJECTIVES

To be able to define battery technologies used in electric vehicles.

MODULE 4. TOPICS

4.1. The need for electrical energy storage
4.2. Structure, functions and working principles of batteries.
4.3. Lead-Acid (Pb-acid) Batteries
4.4. Nickel Cadmium (NiCd) Batteries
4.5. Nickel Metal Hydrate (NiMH) Batteries
4.6. Lithium-Ion (Li-ion) Batteries
4.7. Lithium-Ion Polymer (LiPo) Batteries
4.8. Lithium Iron Phosphate (LiFePO4) Batteries
4.9. Lithium Sulfide (Li-S) Batteries
4.10. Battery Management System
4.11. Battery Modelling Methods

MODULE 4. APPLICATIONS

Application 4.1. Structural Properties and Types of Batteries and Batteries
Application 4.2. Comparison of Batteries
Application 4.3. Photovoltaic Panel-Battery Application
Application 4.4. Checking Batteries

Application 4.1.	Structural Properties and Types of Batteries and Batteries

a) Purpose of the Application: To guide vocational high school learners through a hands-on exploration of various battery types, focusing on their internal structures, components, and the relationship between their structure and functionality.

b) Duration of Application:
3 sessions, each session lasting 2 hours (6 hours total).

c) Requirements:

- Assorted battery samples (preferably expired or unused) including Alkaline, Lithium-ion, Lead-acid, Nickel-Cadmium, and Nickel-metal hydride.
- Safety equipment: Safety goggles, gloves, lab coats, and aprons.
- Dissection tools: Scalpels, tweezers, and dissecting trays.
- Digital microscope or magnifying glasses.
- Plastic bags or containers for safe disposal.
- Data recording sheets for each student.

d) Process Steps: Perform the following process steps in order.

Safety Briefing:

- Always wear safety goggles, gloves, lab coats, and aprons during the entire process.
- Handle dissection tools with caution.
- Avoid puncturing or causing damage to the batteries that might lead to leaks or reactions.

Battery Classification:

- Label and categorize each battery type on the workstation.

External Observation:

- Before opening, observe and note the external characteristics of each battery type: size, shape, terminal design, markings, etc.

Dissection:

- Under the instructor's guidance, carefully open each battery type using the dissection tools.
- Observe and identify the internal components such as the anode, cathode, separator, and electrolyte.

Microscopic Observation (if tools available):

- Examine a sample of each component under a digital microscope or magnifying glass.
- Note the visible differences in structure and texture.

Recording Observations:

- Fill in the provided data sheets with observations, drawings, or notes.

Group Discussion:

- Discuss findings with peers. Share insights on how structural differences might affect battery performance and usage.

Clean-Up:

- Ensure all dissected battery parts are safely stored in containers or plastic bags.
- Dispose of them as per safety guidelines.
- Clean the workstation and return all tools to their designated places.

e) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	External Observation - Depth and accuracy of observations made on external battery features.	15p
2	Dissection Skills - Care and accuracy during the battery dissection process.	25p
3	Internal Components Identification - Correctly identifying and describing the internal components of each battery.	25p
4	Safety and Procedure Adherence - Following safety guidelines and the outlined process meticulously.	20p
5	Participation in Discussion - Quality of insights and active participation in the group discussion.	15p
	Out of 100 points in total ... scored.	100 p

f) Questions: Please answer the questions given below.

- Describe the structural differences you observed between the various battery types.
- How does the internal structure of a battery relate to its voltage, capacity, and overall performance?
- Why might certain materials be used as anodes or cathodes in different battery types?
- Were there any unexpected findings during your dissection? If so, describe them.
- How can understanding the internal structure of batteries aid in making informed decisions about their use in specific applications?

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You can switch to the other application.

Application 4.2.	Comparison of Batteries

a) Purpose of Application:

To enable vocational high school learners to practically investigate and compare the characteristics of different battery types, fostering a deeper understanding of their suitability for various applications.

b) Duration of Application:

3 sessions, each session lasting 2 hours (6 hours total).

c) Requirements:

- Assorted battery samples: Alkaline, Lithium-ion, Lead-acid, Nickel-Cadmium, and Nickel-metal hydride
- Digital multimeters
- Load resistors
- Stopwatch or digital timer
- Battery holders and connectors
- Protective equipment: Safety goggles, gloves
- Data recording sheets for each student

d) Process Steps:

Safety First:

- Always wear protective gloves and safety goggles.
- Do not attempt to open or puncture the batteries.
- Ensure the working area is well-ventilated.

Battery Identification:

- Label and arrange each battery type on the workstation.

Voltage Measurement:

- Use the multimeter to measure and record the voltage of each battery type. Ensure that the positive (red) lead is connected to the positive terminal and the negative (black) lead to the negative terminal of the battery.

Discharge Test:

- Connect each battery to a suitable load resistor.
- Monitor and record the time taken for each battery to discharge significantly (e.g., voltage drop by 50%).

Discussion and Reflection:

- After testing, regroup and discuss observations with peers and instructors.
- Reflect on which battery types seemed most effective for high-drain applications versus those that may be better for longer, low-drain uses.

Clean-Up:

- Disconnect all batteries from their loads.
- Return all equipment to its designated place.
- Properly dispose of or store the batteries following instructor guidelines.

e) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Battery Identification - Correctly labelling and identifying each battery type.	10p
2	Voltage Measurement Accuracy - Correct use of the multimeter and accurate recording of values.	20p
3	Discharge Test - Successful execution of the discharge test and accurate time recording.	20p
4	Safety and Procedure Adherence - Properly following all safety guidelines and steps.	30p
5	Discussion and Reflection - Quality of engagement, insights, and participation in the post-test discussion.	20p
	Out of 100 points in total ... scored.	100 p

f) Questions: Please answer the questions given below.

- Based on your voltage measurements, which battery provided the highest initial voltage?
- Which battery type maintained its voltage the longest during the discharge test?
- Are there any discernible relationships between the physical size of a battery and its discharge time?
- Why might some batteries be more suited for certain applications over others?
- If cost and environment factors were introduced, how might your battery choice for a particular application change?

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You can switch to the other application.

Application 4.3.	Photovoltaic Panel-Battery Application

a) Purpose of Application: To teach vocational high school learners the principles of harnessing solar energy using photovoltaic (PV) panels, converting it to usable electrical power, and storing it in batteries for subsequent use.

b) Duration of Application:
4 sessions, each session lasting 2 hours (8 hours total).

c) Visuals and Circuit Diagrams:
A simple circuit diagram showing:

- PV panel connected to a charge controller.
- Charge controller connected to a battery.
- Battery connected to a load (e.g., LED lamp)

[Note: In this format, actual visual representations can't be displayed, but they should be straightforward, schematic-style diagrams that students can easily follow.]

d) List of Materials and Equipment Used: Provide the materials and equipment in the table given below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	Small-scale photovoltaic (PV) panels	1-2
2	Charge controllers	1-2
3	Batteries: preferably Lead-acid or Lithium-ion	1-2
4	Digital multimeters	1-2
5	Load devices: LED lamps or small motors	1-2
6	Connecting wires and terminals	1-2
7	Sunlight or a high-intensity light source (if testing indoors)	1

e) Requirements:
Students should come prepared with:

- Laboratory notebooks for recording observations and data
- Safety goggles and gloves
- Basic understanding of electrical circuits

f) Process Steps: Perform the following process steps in order.
Setup:

- Place the PV panel under sunlight or the light source.
- Connect the PV panel to the charge controller using the provided terminals.

Battery Connection:

- Connect the battery to the charge controller, ensuring correct polarity.
- The charge controller acts as a mediator, ensuring the battery isn't overcharged.

Load Connection:

- Connect the load device (LED lamp/motor) to the battery.

Measurements:

- Using the multimeter, measure the voltage output from the PV panel, the voltage at the battery, and the current flowing to the load.
- Record these measurements.

Observations:

- Observe and record how the load device behaves as the battery discharges.
- Note any changes in brightness (for LEDs) or speed (for motors).

Battery Recharging:

- Disconnect the load and allow the PV panel to recharge the battery.
- Measure and record the time taken for the battery to recharge fully.

g) Measurement and Evaluation:

- Compare the voltage output from the PV panel to the voltage stored in the battery.
- Evaluate the efficiency of energy transfer from the panel to the battery and from the battery to the load.

h) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Setup Accuracy - Properly setting up the PV panel, charge controller, and battery connections.	20p
2	Measurement Precision - Accurate use of the multimeter and precise recording of measurements.	30p
3	Observational Skills - Depth and accuracy of recorded observations regarding load device behavior and battery recharging.	20p
4	Safety Practices - Adherence to safety guidelines during the experiment.	20p
5	Data Interpretation - Drawing meaningful conclusions from the collected data.	10p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

- How does the voltage output from the PV panel compare to the stored voltage in the battery?
- Why is a charge controller necessary in this setup?
- Based on your observations, how does the efficiency of energy transfer affect the performance of the load device?
- If you were to scale this setup for real-world applications, what considerations might you need to consider?
- How does the angle and intensity of sunlight affect the efficiency of the PV panel?

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You can switch to the other application.

Application 4.4.	Checking Batteries

a) Purpose of the Application: To teach vocational high school learners how to evaluate and determine the health, voltage, and current output of various types of batteries.

b) Duration of Application:
2 sessions, each lasting 1.5 hours (3 hours total).

c) Requirements:
Students should come prepared with:

- Laboratory notebooks for recording observations and data.
- Safety goggles and gloves.
- Basic understanding of electrical circuits and measurements.

d) Process Steps: Perform the following process steps in order.

Safety Briefing:

- Ensure all students wear safety goggles and gloves throughout the experiment.
- Emphasize handling batteries with care, especially if they show signs of damage or leaking.

Battery Categorization:

- Label and categorize provided batteries based on their types, e.g., Alkaline, Lithium-ion, Nickel-Cadmium.

Visual Examination:

- Before testing, visually inspect each battery. Look for any signs of physical damage, corrosion, or leaks. Record observations.

Voltage Measurement:

- Using a digital multimeter, set it to the voltage (V) setting.
- Connect the positive (red) probe to the positive terminal of the battery and the negative (black) probe to the negative terminal.
- Record the voltage reading for each battery.

Current Measurement (for rechargeable batteries):

- Set the multimeter to the current (A) setting.
- Connect the battery in series with a known resistor and measure the current output.
- Record the current readings.

Comparative Analysis:

- Compare the measured voltage to the battery's rated voltage (usually printed on the battery).
- Note any significant deviations and what they might indicate about the battery's health.

Discussion:

- Discuss the findings among groups. Share insights on battery health, potential applications based on their output, and safe disposal methods for batteries that are no longer functional.

e) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Visual Examination - Accuracy in identifying and recording visible signs of damage or wear.	15p
2	Voltage Measurement - Correct use of the multimeter and precise recording of voltage measurements.	25p
3	Current Measurement - Correct setup for measuring current and accurate recording.	25p
4	Comparative Analysis - Depth and accuracy in comparing recorded data with expected results.	20p
5	Participation in Discussion - Quality of insights and active participation in group discussions.	15p
	Out of 100 points in total ... scored.	100 p

f) Questions: Please answer the questions given below.

- Why might the measured voltage of a battery differ from its rated voltage?
- What signs or measurements might indicate a battery is nearing the end of its useful life?
- How can visual inspection help in determining a battery's health?
- What are the potential hazards associated with damaged or leaking batteries?
- Why is it important to regularly check and evaluate the health of batteries in practical applications?

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MODULE 5. ELECTRIC MOTORS USED IN THE BICYCLE

MODULE 5. OBJECTIVES

To be able to define the electric motors used in electric bicycles.

MODULE 5. TOPICS

5.1. The operating logic of electric motors
5.2. Parts of electric motors
5.3. Power transmission and control in electric motors
5.4. Direct current motor connections
5.5. Speed of direct current motors

MODULE 5. APPLICATIONS

Application 5.1. Working Test of Foreign Excitation DC Motor
Application 5.2. Working Test of DC Series Motor
Application 5.3. Working Test of DC Shunt Motor
Application 5.4. DC Series Motor Speed Adjustment and Speed Direction Change
Application 5.5. DC Shunt Motor Speed Adjustment and Speed Direction Change
Application 5.6. Test of Electric Bike Motor Control Card

Application 5.1.	Working Test of Foreign Excitation DC Motor

a) Purpose of Application: To conduct the operating experiment of the foreign excited DC motor and to evaluate the results.

b) Duration of Application: 60 minutes.

c) Visuals and Circuit Diagrams: Figure 5.1 shows the test connection diagram of the foreign-excited DC motor.

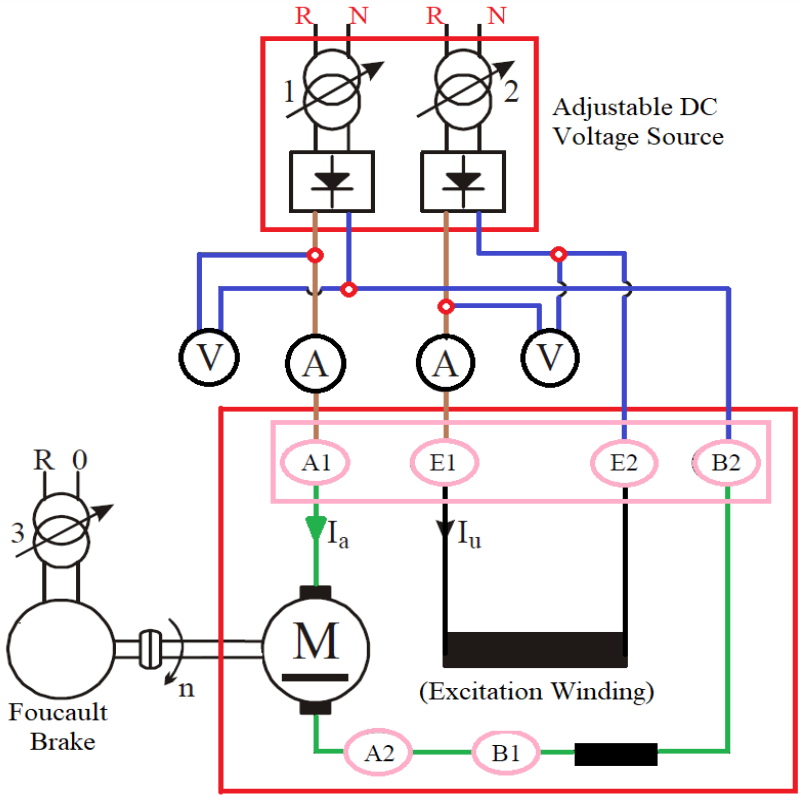

Figure 5.1: Foreign excited DC motor test

d) List of Materials and Equipment Used: Provide the materials and equipment in the table given below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	DC motor (foreign excited)	1 pcs
2	Fuko brake mechanism	1 pcs
3	Excitation wrap	1 pcs
4	DC Voltmeter	2 pcs
5	DC Ammeter	2 pcs
6	Regulated DC power supply (one for fuko brake)	3 pcs
7	Control cables (1.5-2.5 mm2 NYA)	Enough
8	Experimental set	1 pcs
9	Hand tools (pliers, echo chisel, screwdriver, etc.)	-
10	Multimeter	1 pcs
11	Tachometer	1 pcs

e) Process Steps: Perform the following process steps in order.

1. Draw the wiring diagram given in Figure 5.1 in accordance with the drawing rules and note the explanations.

2. Take the necessary precautions regarding occupational safety and wear the work coat.

3. Before starting the test, determine what the Ra and Ru resistors are related to the structure of the DC motor with a multimeter measuring instrument. Note these values.

4. Record the label values of the DC motor.

5. Make the connection given in Figure 5.1.

6. Energize the circuit under teacher supervision. Measure the speed of the motor in each operating situation with the tachometer.

7. Set the DC source to 2 no.lu to bring the excitation current to its nominal value.

8. Increase the inductive voltage from zero until you see the first rotational movement of the rotor and record the values. Adjust until you see the rated inductor voltage from the 1 no.lu DC regulated source. Write each data in Table 5.1.

9. Load the engine by gradually increasing the voltage of the brake mechanism. Write each data in Table 5.1.

10. To allow the DC motor to operate at rated load, reduce the excitation current in small steps to 0.4 A. Write each data in Table 5.1.

11. Cut the circuit power and deliver the circuit by disassembling it.

f) Assessment and Evaluation: The table related to the study is given below.

Table 5.1: Table of Measurements

No.	Inductive Voltage	Inductive Current	Inductor Current	Revolutions	Shaft Moment	Exit Power
	Ea (V)	Ia (A)	Iu (A)	n (rpm)	Tm (N.m)	Pout (W)

g) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The circuit diagram is drawn and its descriptions are written.	20p
2	The circuit was built and connected on the experimental set.	20p
3	The label information of the DC motor was written, and the resistances were measured.	20p
4	The experiment was run and the necessary measurements were made.	20p
5	The obtained results were evaluated and interpreted.	20p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

1. Describe the operation of the circuit.
2. Why was the Fuko brake used? Explain.
3. What is the task of the stimulation dressing? Explain.

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You can switch to the other application.

Application 5.2.	Working Test of DC Series Motor

a) Purpose of Application: To conduct the DC series motor test and to evaluate the results.

b) Duration of Application: 60 minutes.

c) Visuals and Circuit Diagrams: Figure 5.2 shows the test connection diagram of the DC series motor.

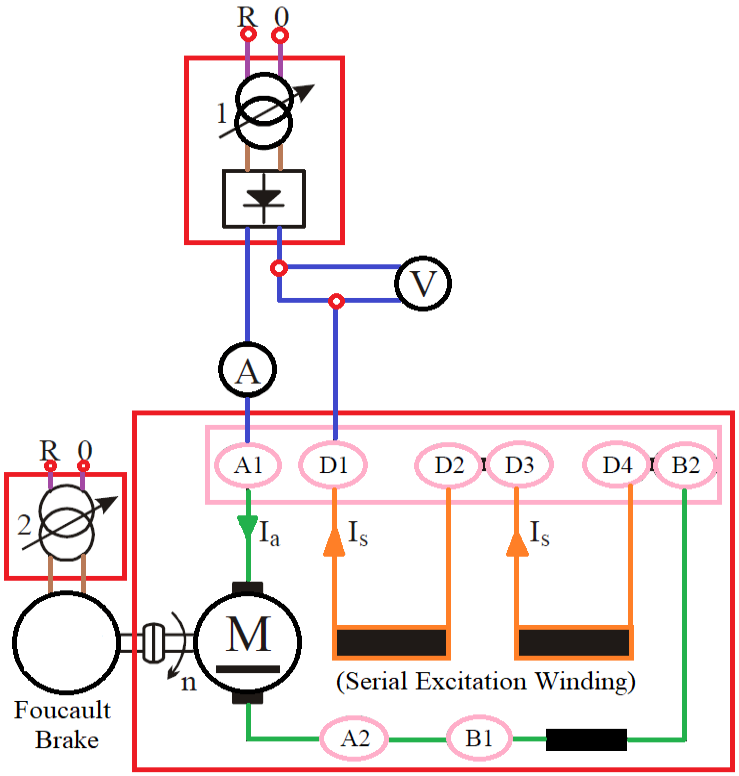

Figure 5.2: DC series motor test

d) List of Materials and Equipment Used: Provide the materials and equipment in the table given below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	DC series motor	1 pcs
2	Fuko brake mechanism	1 pcs
3	Excitation wrap	1 pcs
4	DC Voltmeter	1 pcs
5	DC Ammeter	1 pcs
6	Regulated DC power supply (one for fuko brake)	2 pcs
7	Control cables (1.5-2.5 mm2 NYA)	Enough
8	Experimental set	1 pcs
9	Hand tools (pliers, echo chisel, screwdriver, etc.)	-
10	Multimeter	1 pcs
11	Tachometer	1 pcs

e) Process Steps: Perform the following process steps in order.

1. Draw the wiring diagram given in Figure 5.2 in accordance with the drawing rules and note the explanations.

2. Take the necessary precautions regarding occupational safety and wear the work coat.

3. Before starting the test, determine what the Ra and Ru resistors are related to the structure of the DC series motor with a multimeter measuring instrument. Note these values.

4. Record the label values of the DC series motor.

5. Make the connection given in Figure 5.2.

6. Energize the circuit under teacher supervision. Measure the speed of the motor in each operating situation with the tachometer.

7. Increase the inductive voltage from zero until you see the first rotational movement of the rotor and record the values. Adjust until you see the rated inductive voltage from the 1 no.lu DC regulated source. Write each data in Table 5.2.

8. Load the engine by gradually increasing the voltage of the brake mechanism. Write each data in Table 5.2.

9. To allow the DC series motor to operate at rated load, reduce the excitation current in small steps to 0.4 A. Write each data in Table 5.2.

10. Cut the circuit power and deliver the circuit by disassembling it.

f) Assessment and Evaluation: The table related to the study is given below.

Table 5.2: Table of Measurements

No.	Inductive Voltage	Inductive Current	Inductor Current	Revolutions	Shaft Moment	Exit Power
	Ea (V)	Ia (A)	Iu (A)	n (rpm)	Tm (N.m)	Pout (W)

g) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The circuit diagram is drawn and its descriptions are written.	20p
2	The circuit was built and connected on the experimental set.	20p
3	The label information of the DC motor was written and the resistances were measured.	20p
4	The experiment was run and the necessary measurements were made.	20p
5	The obtained results were evaluated and interpreted.	20p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

1. Describe the operation of the circuit.
2. How does DC series motor work? Explain.

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You can switch to the other application.

Application 5.3.	Working Test of DC Shunt Motor

a) Purpose of Application: To conduct the DC shunt motor test and evaluate the results.

b) Duration of Application: 60 minutes.

c) Visuals and Circuit Diagrams: Figure 5.3 shows the test connection diagram of the DC shunt motor.

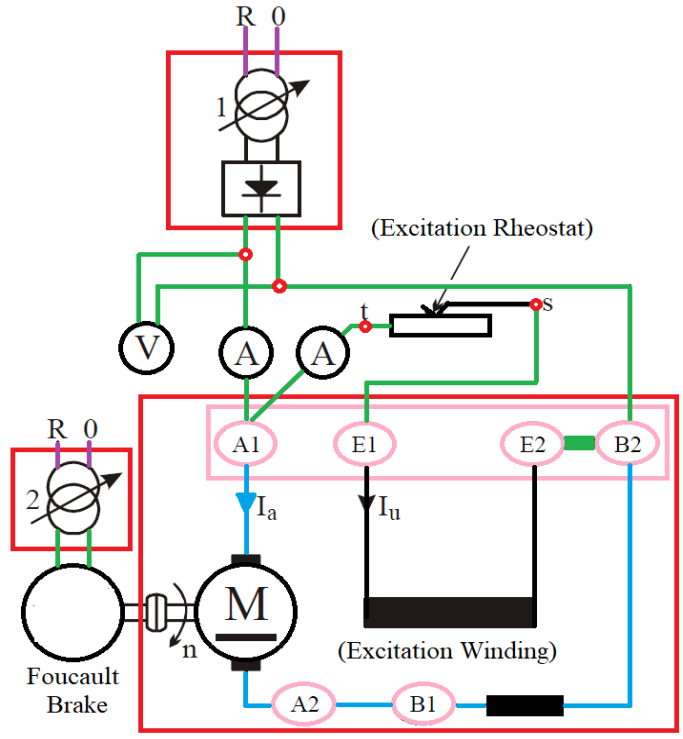

Figure 5.3: DC shunt motor test

d) List of Materials and Equipment Used: Provide the materials and equipment in the table given below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	DC shunt motor	1 pcs
2	Fuko brake mechanism	1 pcs
3	Excitation wrap	1 pcs
4	Excitation rheostat	1 pcs
5	DC Voltmeter	2 pcs
6	DC Ammeter	2 pcs
7	Regulated DC power supply (one for fuko brake)	2 pcs
8	Control cables (1.5-2.5 mm2 NYA)	Enough
9	Experimental set	1 pcs
10	Hand tools (pliers, echo chisel, screwdriver, etc.)	-
11	Multimeter	1 pcs
12	Tachometer	1 pcs

e) Process Steps: Perform the following process steps in order.

1. Draw the wiring diagram given in Figure 5.3 in accordance with the drawing rules and note the explanations.

2. Take the necessary precautions regarding occupational safety and wear the work coat.

3. Before starting the test, determine with a multimeter measuring instrument what the Ra and Ru resistors are related to the structure of the DC shunt motor. Note these values.

4. Record the label values of the DC shunt motor.

5. Make the connection given in Figure 5.3.

6. Energize the circuit under teacher supervision. Measure the speed of the motor in each operating situation with the tachometer.

7. Increase the inductive voltage from zero until you see the first rotational movement of the rotor and record the values. Adjust until you see the rated inductive voltage from the 1 no.lu DC regulated source. Write each data in Table 5.3.

8. Load the engine by gradually increasing the voltage of the brake mechanism. Write each data in Table 5.3.

9. Play the resistance in stimulation rheostat and write the results in Table 5.3.

10. To allow the DC shunt motor to operate at rated load, reduce the excitation current in small steps to 0.4 A. Write each data in Table 5.3.

11. Cut the circuit power and deliver the circuit by disassembling it.

f) Assessment and Evaluation: The table related to the study is given below.

Table 5.3: Table of Measurements

No.	Stimulated rheosta	Inductive Voltage	Inductive Current	Inductor Current	Revolutions	Shaft Moment	Exit Power
	R (Ω)	Ea (V)	Ia (A)	Iu (A)	n (rpm)	Tm (N.m)	Pout (W)

g) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The circuit diagram is drawn and its descriptions are written.	20p
2	The circuit was built and connected on the experimental set.	20p
3	The label information of the DC motor was written and the resistances were measured.	20p
4	The experiment was run and the necessary measurements were made.	20p
5	The obtained results were evaluated and interpreted.	20p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

1. Describe the operation of the circuit.
2. How does DC shunt motor work? Explain.
3. What is the difference between DC series motor and shunt motor? Explain.

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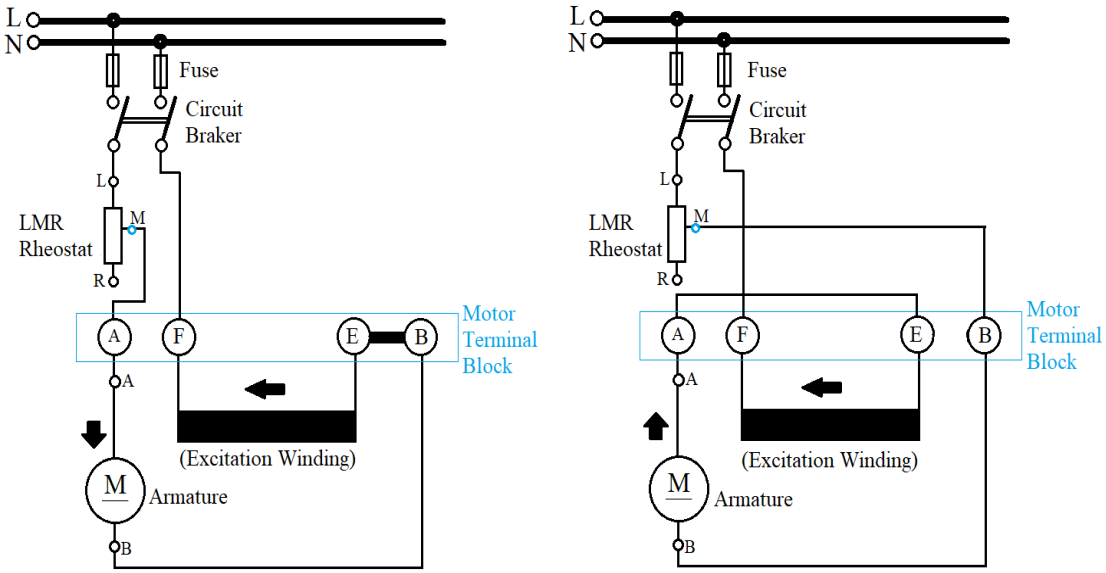
You can switch to the other application.

Application 5.4.	DC Series Motor Speed Adjustment and Speed Direction Change

a) Purpose of Application: To carry out the speed adjustment and speed direction change test of the DC series motor and to evaluate the results.

b) Duration of Application: 60 minutes

c) Visuals and Circuit Diagrams: In Figure 5.4 (a, b), the speed adjustment and speed direction change test links of the DC series motor are given. The speed of both connections is adjustable; However, in circuit (a) the motor shall be operated in the forward direction and in circuit (b) the motor shall be operated in the reverse direction.



(a) Operating in the forward direction (b) Operation in the reverse direction

Figure 5.4: Speed adjustment and speed direction change connections of the DC series motor.

d) List of Materials and Equipment Used: Provide the materials and equipment in the table given below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	DC series motor	1 pcs
2	Rheosta	2 pcs
3	DC Voltmeter	1 pcs
4	DC Ammeter	1 pcs
5	Multimeter	1 pcs
6	Regulated DC power supply	1 pcs
7	Control cables (1.5-2.5 mm2 NYA)	Enough
8	Experimental set	1 pcs
9	Hand tools (pliers, echo chisel, screwdriver, etc.)	-
10	Switch	1 pcs
11	Auto insurance	1 pcs
12	Tachometer	1 pcs

e) Process Steps: Perform the following process steps in order.

1. Draw the wiring diagrams given in Figure 5.4 in accordance with the drawing rules and note the explanations.

2. Take the necessary precautions regarding occupational safety and wear the work coat.

3. Before starting the test, determine what the Ra and Ru resistors are related to the structure of the DC series motor with a multimeter measuring instrument. Note these values.

4. Record the label values of the DC series motor.

5. Make the connection given in Figure 5.4 (a). Pay attention to the connections of the inductor and inductor tips and the connections of the ends of the LMR and qst rheostats.

6. Energize the circuit under teacher supervision. Measure the speed of the motor in each operating situation with the tachometer.

7. Gradually change the resistance of the LMR and qst rheostats. Observe that the DC motor rotates at different speeds in the forward direction. Write each result read on the measuring instruments in Table 5.4.

8. Cut off the energy.

9. Perform the connection given in Figure 5.4 (b).

10. Energize the circuit under teacher supervision.

11. Gradually change the resistance of the LMR and qst rheostats. Observe that the DC motor rotates at different speeds in the reverse direction. Write each result read on the measuring instruments in Table 5.4.

12. Cut off the energy and dismantle the materials.

f) Assessment and Evaluation: The tables related to the study are given below.

Table 5.4: Measurement Table

Circuit Connection	LMR Rheosta (Ω)	QST Rheosta (Ω)	U (Volts)	I (Amps)	RPM (rpm)
(a)	Miscarriage	Miscarriage			
	Middle	Miscarriage			
	High	Miscarriage			
	Miscarriage	Middle			
	Middle	Middle			
	High	Middle			
	Miscarriage	High			
	Middle	High			
	High	High			
(b)	Miscarriage	Miscarriage			
	Middle	Miscarriage			
	High	Miscarriage			
	Miscarriage	Middle			
	Middle	Middle			
	High	Middle			
	Miscarriage	High			
	Middle	High			
	High	High			

g) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The circuit diagram is drawn and its descriptions are written.	20p
2	The circuit was built and connected on the experimental set.	20p
3	The label information of the DC motor was written and the resistances were measured.	20p
4	Experiments were run and the necessary measurements were made.	20p
5	The obtained results were evaluated and interpreted.	20p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

1. What needs to be done to change the speed of the DC series motor? Describe it on the figure.

2. What needs to be done to change the speed direction of the DC series motor? Describe it on the figure.

3. What is the task of rheostats in the circuit?

THE PRACTITIONER:		**IMPLEMENTED BY:**	
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Signature:		**Signature:**	

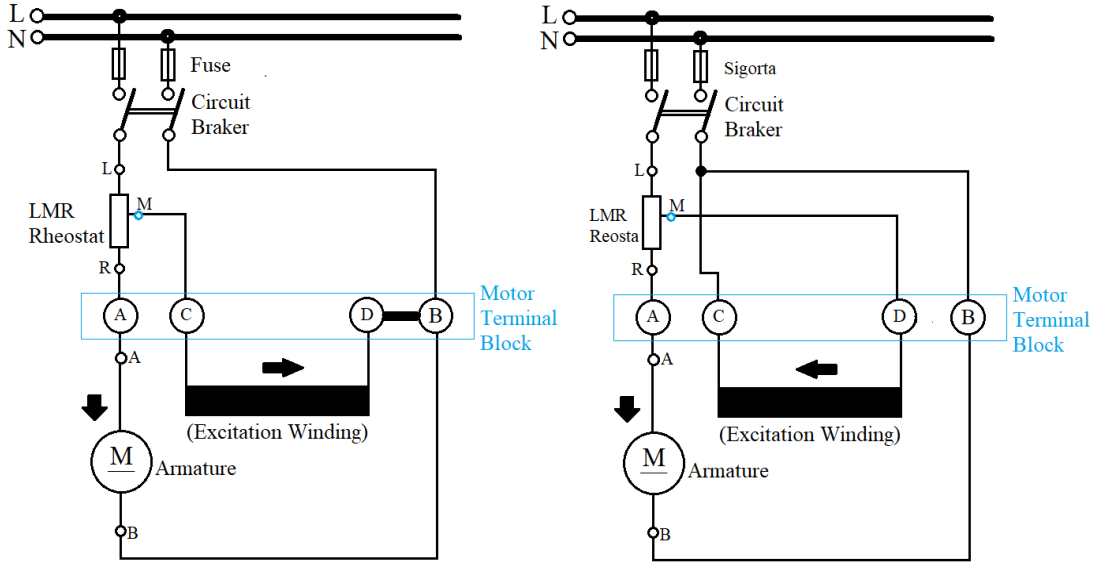
You can switch to the other application.

Application 5.5.	DC Shunt Motor Speed Adjustment and Speed Direction Change

a) Purpose of Application: To carry out the speed adjustment and speed direction change test of the DC shunt motor and to evaluate the results.

b) Duration of Application: 60 minutes

c) Visuals and Circuit Diagrams: In Figure 5.5 (a, b), the test links of the DC shunt motor speed adjustment and speed direction change are given. The speed of both connections is adjustable; However, in circuit (a) the motor shall be operated in the forward direction and in circuit (b) the motor shall be operated in the reverse direction.



(a) Operating in the forward direction (b) Operation in the reverse direction

Figure 5.5: Connections for speed adjustment and change of speed direction of DC shunt motor

d) List of Materials and Equipment Used: Provide the materials and equipment in the table given below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	DC shunt motor	1 pcs
2	Rheosta	2 pcs
3	DC Voltmeter	1 pcs
4	DC Ammeter	1 pcs
5	Multimeter	1 pcs
6	Regulated DC power supply	1 pcs
7	Control cables (1.5-2.5 mm2 NYA)	Enough
8	Experimental set	1 pcs
9	Hand tools (pliers, echo chisel, screwdriver, etc.)	-
10	Switch	1 pcs
11	Auto insurance	1 pcs
12	Tachometer	1 pcs

e) Process Steps: Perform the following process steps in order.

1. Draw the wiring diagrams given in Figure 5.5 in accordance with the drawing rules and note the explanations.

2. Take the necessary precautions regarding occupational safety and wear the work coat.

3. Before starting the test, determine with a multimeter measuring instrument what the Ra and Ru resistors are related to the structure of the DC shunt motor. Note these values.

4. Record the label values of the DC shunt motor.

5. Perform the connection given in Figure 5.5 (a). Pay attention to the connections of the inductor and inductor tips and the connections of the ends of the LMR and qst rheostats.

6. Energize the circuit under teacher supervision. Measure the speed of the motor in each operating situation with the tachometer.

7. Gradually change the resistance of the LMR and qst rheostats. Observe that the DC motor rotates at different speeds in the forward direction. Write down each result read on the measuring instruments in Table 5.5.

8. Cut off the energy.

9. Make the connection given in Figure 5.5 (b).

10. Energize the circuit under teacher supervision.

11. Gradually change the resistance of the LMR and qst rheostats. Observe that the DC motor rotates at different speeds in the reverse direction. Write down each result read on the measuring instruments in Table 5.5.

12. Cut off the energy and dismantle the materials.

f) Assessment and Evaluation: The tables related to the study are given below.

Table 5.5: Table of Measurements

Circuit Connection	LMR Rheosta (Ω)	QST Reosta (Ω)	U (Volts)	I (Amps)	RPM (rpm)
(a)	Miscarriage	Miscarriage			
	Middle	Miscarriage			
	High	Miscarriage			
	Miscarriage	Middle			
	Middle	Middle			
	High	Middle			
	Miscarriage	High			
	Middle	High			
	High	High			
(b)	Miscarriage	Miscarriage			
	Middle	Miscarriage			
	High	Miscarriage			
	Miscarriage	Middle			
	Middle	Middle			
	High	Middle			
	Miscarriage	High			
	Middle	High			
	High	High			

g) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The circuit diagram is drawn and its descriptions are written.	20p
2	The circuit was built and connected on the experimental set.	20p
3	The label information of the DC motor was written and the resistances were measured.	20p
4	Experiments were run and the necessary measurements were made.	20p
5	The obtained results were evaluated and interpreted.	20p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

1. What needs to be done to change the speed of the DC shunt motor? Describe it on the figure.

2. What needs to be done to change the speed direction of the DC shunt motor? Describe it on the figure.

3. What is the task of rheostats in the circuit?

4. What are the differences between the DC series motor test and this experiment? Please comment.

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You can switch to the other unit application.

Application 5.6.	Test of Electric Bike Motor Control Card

a) Purpose of Application: To Examine the Operation of Brushless DC Motors and evaluate the results.

b) Duration of Application: 60 minutes

c) Visuals and Circuit Diagrams:

The electric bike controller is one of the main parts of the electric bike, it is the brain of the e-bike, which controls the speed, running, stopping of the motor. The battery is connected to all other electronic components, such as the engine, throttle (accelerator), gauge (speedometer), PAS (Gear) or other speed sensors if available.

A controller consists of the main chips (microcontrollers) and peripheral components (resistors, sensors, MOSFET, etc.). In general, the controller includes PWM generator circuit, AD circuit, power circuit, power device driver circuit, signal acquisition and processing circuit, overcurrent and low voltage protection circuit.

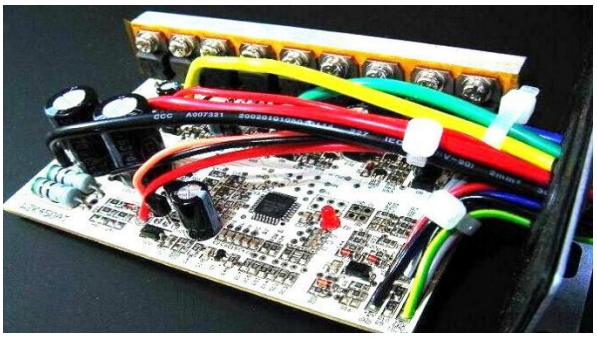

Fig.5.6 Example is a Brushless Motor controller.

5.6.1 How does the electric bike controller work?

Fig.5.7 A sample set of Brushless Motors and Controllers.

5.6.2. Usage

After connecting the battery, the controller provides operating voltage to the external device through the power circuit, such as switch +5V, headlight +5V, etc.

PWM outputs a pulse waveform corresponding to the MOSFET driver circuit depending on the throttling or PAS input. The MOSFET driver circuit controls the opening and closing of the MOSFET circuit to control the motor speed.

The low-voltage circuit is to prevent the battery from draining when the voltage is lower than the controller's set value, at which time the PWM circuit stops the output.

The overcurrent protection circuit limits the operation of the controller, battery, motor at extremely high current.

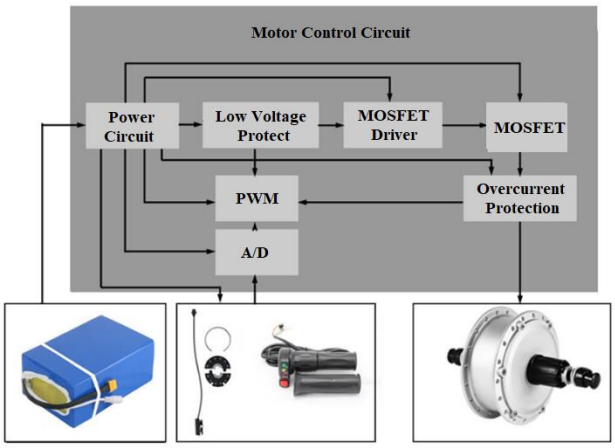

Fig.5.8 Brushless Motor Controller.

5.6.3. What is the function of the electric bike controller?

The main function of an electric bicycle controller is to display the information it receives from all electrical components (throttle, speed sensor, display, battery, motor, etc.).

Other multiple protection functions of the controller perform the following functions in relation to the design of the controller.

a. *Overvoltage protection*: The controller monitors the battery voltage and shuts down the motor when the battery voltage is too high. This protects the battery from overcharging.

b. *Low-voltage protection*: The controller monitors the battery voltage and shuts down the motor when the battery voltage is too low. This protects the battery from excessive discharge.

c. *Over-temperature protection*: The controller monitors the temperature of the FET (field-effect transistor) and shuts down the motor if it gets too hot. This protects FET power transistors.

d. *Overcurrent protection*: Reduces the current to the motor if too much current is supplied. This protects both the motor and the FET power transistors.

e. *Brake protection*: The engine turns off when braking despite other signals received by the controller at the same time. For example, if the user applies brakes and throttle at the same time, the brake function acquires.

In general, if a motor has hall sensors, these sensors will detect the rotation of the motor and the controller will give the corresponding voltage to the motor based on the sensor signals. This will result in lower power consumption and greater starting torque, resulting in more stable operation.

c) Process Steps: Perform the following process steps in order.

1- See the connection kit given in Figure 5.8.
2- Take the necessary precautions regarding occupational safety and wear the work coat.
3- Check that the terminals of the control unit are correct.
4- Make the connections in order.
5- Check the battery one last time before connecting it.
6- Connect the battery and energize the circuit under teacher supervision.
7- Check the energy status on the display.
8- Check the operation of the engine speed by checking the throttle.
9- Check for a conflict between brake control and braking.
10- Check the operation of the torque control.
11- Cut off the energy and dismantle the materials.

f) Assessment and Evaluation: The tables related to the study are given below.

Table 5.5: Work Table

Circuit Connection	Process	Tried	Didn't work
(a)	On-Off		
	Display		
	Motor Speed Control		
	Brake Control		
	Torque Control		

g) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The wiring diagram is drawn and descriptions are written.	20p
2	The connection has been established and the connections have been made.	20p
3	The functions of the materials are measured and noted.	20p
4	The circuit was operated and the necessary measurements were made.	20p
5	The obtained results were evaluated and interpreted.	20p
	Out of 100 points in total ... scored.	100 p

h) Questions: Please answer the questions given below.

1. Describe the operating system of the engine.
2. Explain the operating logic of the engine speed control.
3. Describe the task of the Torque control in the circuit.
4. Explain the operation of the brake system.
5. Describe the technical characteristics of the battery.

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MODULE 6. STRUCTURAL FEATURES OF THE ELECTRIC BICYCLE

MODULE 6. OBJECTIVES

To know the structural features of electric bicycles.

MODULE 6. TOPICS

6.1. Body designs
6.2. Mechanical connection designs
6.3. Powertrain and pedal assemblies
6.4. Types of braking / regenerative brakes
6.5. Lighting and warning systems
6.6. Display circuits

MODULE 6. APPLICATIONS

Application 6.1. Electric Bicycle Equipment Research
Application 6.2. Transforming Bicycles into Electric Bikes Project

Application 6.1.	Electric Bicycle Equipment Research

a) Purpose of Implementation: To investigate and report the equipment of electric bicycles in a comprehensive manner in technical and economic aspects.

b) Duration of Application: 3-5 weeks

c) Requirements: It is requested that comprehensive research including the technical and economic aspects of electric bicycles be carried out and that this research be submitted as a report. Prepare the study report in line with the information given below and print it out and submit it.

- Describe in detail the structure and parts of the electric bike. Detail the sections of each element with pictures.
- Explain the types of electric bicycles. Compare each of them in terms of technical and economic aspects.
- Interpret the use of electric bicycles in the world and in Turkey with numerical data. Evaluate the predictions for the future.
- Comment on the advantages and disadvantages of the electric bicycle compared to other electric vehicles.
- Evaluate the effects of the motor on the electric bike.
- Evaluate the effects of the battery on the electric bike.
- Prepare the report output in color not to exceed 100 pages.
- Place the report in the blue file with attention to the page number.
- In the report, use the Arial font 11 pt in the headings and 10 pt in normal texts as justified. Please leave a space between the title and texts.
- List the sources used in the report in the "Bibliography" section and write the number citations of each of them in the text.
- Make all the text written in the report according to individual interpretation and do not place any text directly into the report.
- Create the cover section of the report file according to your information.

d) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Research has been done and sources have been identified.	20p
2	The file design has been created and the articles have been written in accordance with the rules.	20p
3	The determined research has been made and explained in the relevant titles.	20p
4	The research was supported by photographs.	20p
5	In the study, references were cited and pages were numbered.	20p
	Out of 100 points in total ... scored.	100 p

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You can switch to the other application.

Application 6.2.	Conversion of Bicycle to Electric Bicycle Project

a) Purpose of Application: To make and test various application projects that convert normal bicycles into electric bicycles with different conversion kits.

b) Duration of Application: 3-5 weeks

c) Visuals: Visuals showing the transformation of the normal bicycle into an electric bicycle are seen with different conversion kits in the figures. These images vary with the use of different apparatus for each conversion kit.

6.2. Conversion kit-1: Conversion using Swytch Bike e-bike conversion kit.

Figure 6.2.1: Swytch Bike e-bike conversion kit

Figure 6.2.2: Bicycle and electric bicycle (e-bike)

e) Requirements: A normal bike will be converted into an electric bike using the Swytch Bike e-bike conversion kit. Do the necessary research on the internet about this subject and review all the information. Provide this material and equipment, make a sample application and test the work by making the connections. Photograph each process step and record it by taking a video. Evaluate the study and interpret the differences of the study from the normal electric bike. Deliver the obtained information and visual materials on DVD.

f) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Research was conducted and a report was generated.	20p
2	The materials and equipment to be used have been determined and supplied.	20p
3	Materials and equipment are mounted on the bicycle.	20p
4	All stages were photographed and videotaped and recorded.	20p
5	The obtained study was analysed and evaluated.	20p
	Out of 100 points in total ... scored.	100 p

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6.3. Conversion kit-2: Conversion using medium hub motor e-bike conversion kit.

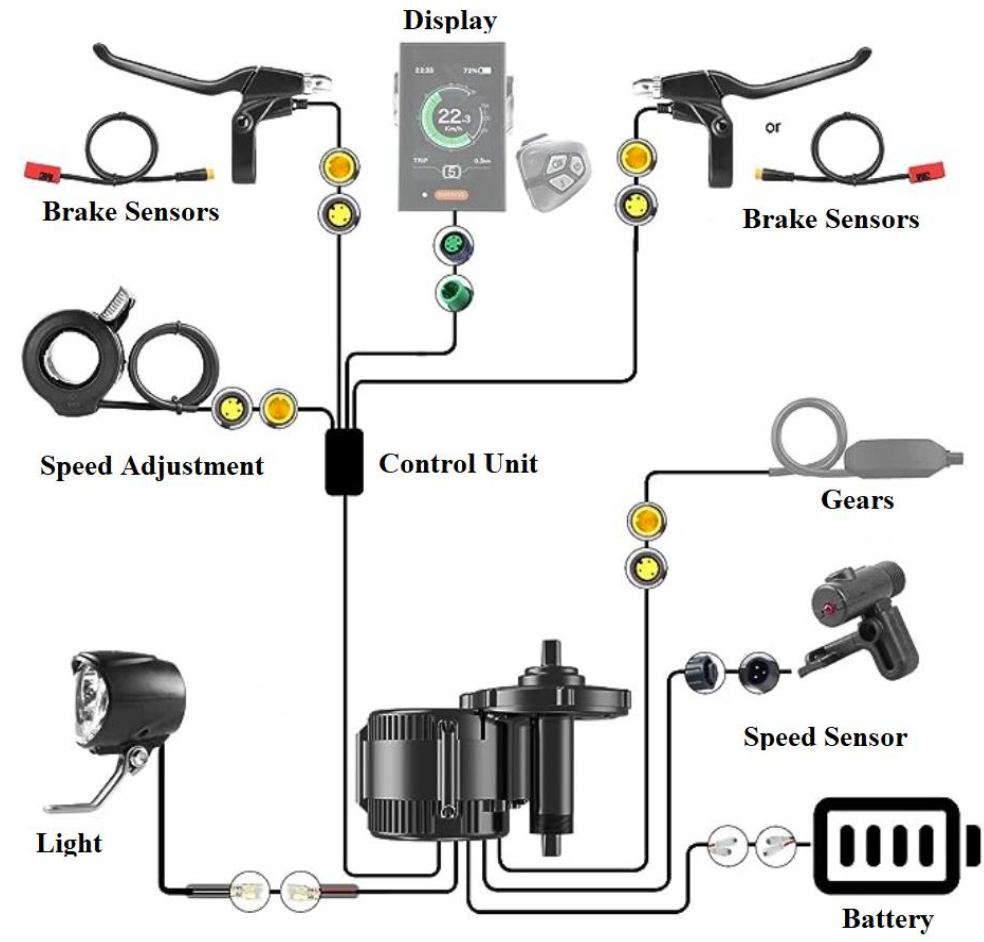

Figure 6.3.1: Medium Hub Motor e-bike conversion kit

Figure 6.3.2: Medium Hub Motor electric bicycle (e-Bike)

e) Requirements: A normal bike will be converted into an electric bike using the mid-hub Motorized e-bike conversion kit. Do the necessary research on the internet about this subject and review all the information. Provide this material and equipment, make a sample application and test the work by making the connections. Photograph each process step and record it by taking a video. Evaluate the study and interpret the differences of the study from the normal electric bike. Deliver the obtained information and visual materials on DVD.

f) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Research was conducted and a report was generated.	20p
2	The materials and equipment to be used have been determined and supplied.	20p
3	Materials and equipment are mounted on the bicycle.	20p
4	All stages were photographed and videotaped and recorded.	20p
5	The obtained study was analysed and evaluated.	20p
	Out of 100 points in total ... scored.	100 p

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6.4. Conversion kit-3: Rear-mounted friction drive e-bike conversion kit

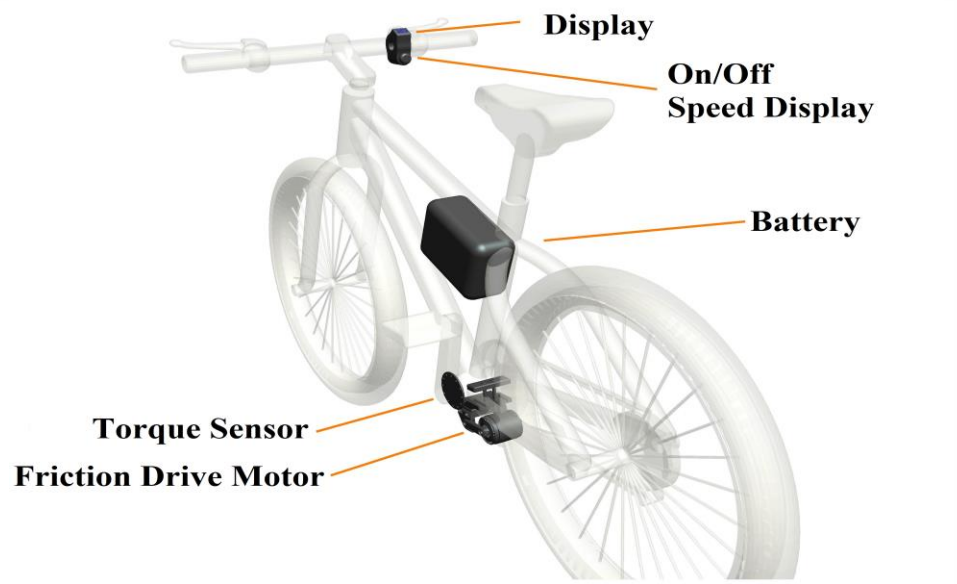

Figure 6.4.1: Rear Wheel Friction Motor e-bike conversion kit

Figure 6.4.2: Assembly of e-bikes with Rear Wheel Friction Motor

e) Requirements: A normal bike will be converted into an electric bike with the Rear Wheel Friction Kit. Do the necessary research on the internet about this subject and review all the information. Provide this material and equipment, make a sample application and test the work by making the connections. Photograph each process step and record it by taking a video. Evaluate the study and interpret the differences of the study from the normal electric bike. Deliver the obtained information and visual materials on DVD.

f) Scoring: Evaluate the study in accordance with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Research was conducted and a report was generated.	20p
2	The materials and equipment to be used have been determined and supplied.	20p
3	Materials and equipment are mounted on the bicycle.	20p
4	All stages were photographed and videotaped and recorded.	20p
5	The obtained study was analysed and evaluated.	20p
Out of 100 points in total ... scored.		100 p

Questions: Please answer the questions given below.

1. Describe the operation of each system.
2. Explain the operating logic of the engine speed control.
3. Describe the task of the Torque control in the circuit.
4. Explain the operation of the brake system.
5. Describe the technical characteristics of the battery.

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You can switch to the other application.

MODULE 7. LEGAL REGULATIONS ON ELECTRIC BICYCLES

MODULE 7. OBJECTIVES

To have information about legal regulations related to electric bicycles.

MODULE 7. TOPICS

7.1. Points to consider when using an electric bike.
7.2. Electric bike license
7.3. The ethics of using an electric bike
7.4. Electric bicycle frame and design
7.5. Environmental sustainability and the role of electric bikes in urban transport

MODULE 7. APPLICATIONS

Application 7.1. Obtaining a License on Electric Bicycle
Application 7.2. Design and Operation of Electric Bicycle
Application 7.3. Effects of Electric Bicycle on Urban Use

Application 7.1.	Obtaining a License on Electric Bicycle

a) Purpose of Implementation: To investigate the license procurement process of the electric bicycle, to discuss the results and to plan a sample license acquisition.

b) Duration of Application: 2 weeks

c) Process Steps: Perform the following steps in order.

1- Licensing practices and procedures of electric bicycles,

d) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Guidelines for obtaining a license for electric bicycles have been investigated.	20 p
2	He learned the procedure applied when obtaining a license.	20 p
3	Filling out the necessary documents for obtaining an electric bicycle conformity certificate and filling sample documents have been made.	20 p
4	Sample license purchase has been made. Research has been done and a report has been prepared.	20 p
5	The process of performing the work is listed with descriptions.	20 p
	Out of a total of 100 points ... scored.	100 p

e) Questions: Answer the following questions.

1. Explain the license procurement stages of electric bicycles.
2. What are the documents to be filled in the license purchase?
3. Which institution should I apply for a license?

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You can switch to the other application.

Application 7.2.	Design and Operation of Electric Bicycle

a) Purpose of Application: To design the electric bicycle and to examine the experience of use on the bicycle.

b) Duration of Application: 2 hours

c) List of Materials and Equipment Used: Provide the materials and equipment in the table below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	Electric Bicycle	1 piece
2	Paper	1 piece
3	Ruler	1 piece
4	Compass	1 piece
5	Miter	1 piece

d) Process Steps: Perform the following process steps in order.

1- Body Design
2- Steering Wheel Design
3- Wheel Design
4- Front Hub Design
5- Rear Hub and Gear Design
6- Seat Design
7- Pedal Design
8- Pedal Gear Design
9- Chain Design
10- Hand Brake System Design

e) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Dimensional conformity, parallelism and aesthetics	20 p
2	Ability to use drawing sets	20 p
3	Efficient use of time	20 p
4	Cleanliness and order	20 p
5	Aesthetics of the design	20 p
	Out of a total of 100 points ... scored.	100 p

f) Questions: Answer the following questions.

1. What are the painting tools used in electric bicycle design?
2. What are the parts that make up an electric bike?
3. What are the points to be considered in design?
4. What should be considered when using drawing paper?
5. What are the painting tools to use in chain design?
6. What are the computer programs used in design?

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You can switch to the other application.

Application 7.3.	Effects of Electric Bicycle on Urban Use

a) Purpose of the Application: To investigate and report the effects of the use of electric bicycles in the city.

b) Duration of Application: 1 week

c) Requirements: Investigation of laws and regulations related to the use of electric bicycles

d) Process Steps: Perform the following process steps in order.

1. Rules for using electric bicycles in traffic
2. Legal regulations for electric bicycles
3. Regulations on highways for electric bicycles
4. Types of electric bicycles

e) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Learning the rules of using an electric bicycle in traffic	20 p
2	Researching legal regulations for electric bicycles	20 p
3	Investigating regulations on roads for electric bicycles	20 p
4	Knowing the types of electric bicycles	20 p
5	Knowing the laws related to electric bicycles in road traffic legislation	20 p
	Out of a total of 100 points ... scored.	100 p

f) Questions: Answer the following questions.

1. What rules must be followed when using electric bicycles in city traffic?
2. According to the power and speed of electric vehicles per hour, it has imposed obligations such as helmet, license plate, registration, driver's license. Accordingly, what is the required driver's license class for electric bicycles?
3. What is the name given to the distance between two vehicles moving one after the other in the same lane on the highway?
4. What should be the power of the electric bicycle, which can be used without a license and license plate?

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Signature:		**Signature:**	

You can switch to the other application.

MODULE 8. PERIODIC MAINTENANCE AND SERVICING OF ELECTRIC BICYCLES

MODULE 8. OBJECTIVES

To know the repair, maintenance and service of electric bicycles.

MODULE 8. TOPICS

8.1. Daily, weekly and monthly maintenance
8.2. Electric motor malfunctions
8.3. Mechanical system failures
8.4. Charging system malfunctions
8.5. Warning and display system malfunctions
8.6. General Maintenance

MODULE 8. APPLICATIONS

Application 8.1. Electric Motor Malfunctions and Elimination
Application 8.2. Mechanical System Failures and Elimination
Application 8.3. Charging System Malfunctions and Troubleshooting
Application 8.4. Warning and Display System Malfunctions and Elimination
Application 8.5. Maintenance Operations on Electric Bicycles

Application 8.1.	Electric Motor Malfunctions and Elimination

a) Purpose of Application: To identify and eliminate electric motor malfunctions.

b) Duration of Application: 60 minutes.

c) List of Materials and Equipment Used: Provide the materials and equipment in the table below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	Direct current motor	1 piece
2	Multimeter	2 pcs.
3	DC power supply	1 piece
4	Hand tools (yanke, screwdriver, pliers, etc.)	Enough
5	Control cables (1.5 or 2.5 mm2 NYA)	Enough
6	Protection elements (fuse 6 A, package switch 0-1)	2 pcs.
7	Series lamp (connected)	1 piece
8	Growler device	1 piece

d) Requirements: Fault detection related to the electric (DC) motor and application work will be carried out to eliminate these malfunctions. Accordingly, follow the steps given below in order.

e) Process Steps: Perform the following steps in order.

1. Make the necessary connections between the DC motor and the power supply using the control cables. Include protection elements in this connection.

2. Turn on the package switch and fuse.

3. Connect the ammeter and voltmeter (i.e. 2 x multimeters) to the circuit accordingly and set it to the appropriate level.

4. Under the control of the teacher, energize the circuit and turn off the protection elements.

5. Observe the operation of the engine and the readings on the measuring instruments. If the motor is running, check the current and voltage values. If the measured values at this moment are observed normally, then there is no malfunction of the engine. At this moment, you can dismantle the circuit by de-energizing.

6. If the engine is not running, check whether a value is read on the measuring instruments. If an incorrect value is read here or no value is read, it can be said that there is a malfunction in the engine. Open the inside of the motor by cutting off the energy.

7. The controls of the windings are carried out with a serial lamp. Accordingly, the insulation of the interconnections at the poles is removed and the pole coils are checked separately using a series lamp. If the lamp does not light up in which coil, there is a break in that coil. When these checks are completed, the coil groups that the lamp does not light up are determined and dismantled, rewound

with new coil wires and placed in the relevant area. At the end of this, controls are provided with the lamp again.

8. It is checked whether there is a short circuit between the coil wires. To find the short circuit, the insulation of the interconnection in the coils is opened and a voltage of half the operating voltage of the motor is applied. The voltage measured at the end of the coil, which is shorted, is smaller than the value measured compared to the normal coil, and the normally heated windings either heat up little or not at all if there is a short circuit. In this case, the windings are removed and replaced with new wrapping. At the end of this, the same checks are made again.

9. It is checked whether there is a leak between the coil and the body. The connections of the poles are opened and the serial lamp is used to search for leaks in each coil separately to the body. If there are leaky windings, they are replaced with new ones and the same operations are done again.

10. It is checked whether there is a break in the inductive windings. An inductor is placed on the Growler device and necessary disconnection tests are performed. If there is a short circuit in the induction, the slices to which it is connected darken and the motor works by arcing. At the end of this determination, the relevant winding is changed and re-controls are provided.

11. It is checked whether there is a short circuit between the collector slices. For this, neighbouring slices are examined with a serial lamp. The lamp will not light up between the slices with a short circuit. In this case, the charred micas between the slices are cleaned with a pocketknife, knife or hacksaw tip.

12. It is checked whether the motor windings are connected correctly. If the input-output connections are connected incorrectly or the coils are grouped incorrectly in the field, the motor does not start or starts incorrectly. Necessary calculations are made and according to these calculations, the windings and their connections are checked. As a result of the control, the faulty places are corrected and it is checked whether the engine is working or not.

13. The bearings of the engine are checked. Bearings get stuck in the area when the bearings overheat, become oil-free, the balls scatter, or the covers are not closed correctly. The necessary maintenance of each of them is carried out and it is checked whether the engine is turning or not.

14. The brushes are checked for malfunctions. Brush failure occurs when the coals break or the brush-spring pressure decreases. Shrank and broken brushes are identified and replaced with new ones. In addition, spring pressures are controlled and adjusted. If the adjustment is not resolved, it is replaced with new ones. The alternating brushes are accustomed to the brush slots, and the places where the brushes contact the collector are accustomed to the collector round. Here, if the brushes are not in place or have shifted, an arc occurs in the collector. In this case, while the motor is running, the assembly process is carried out by bringing it to the place that creates the least arc with brush holders.

15. It is checked whether the cooling fan rotates.

16. As a result of all these controls, if the problems are not resolved, the rotor is replaced first, as there is a comprehensive malfunction. If this replacement still does not solve the problem, the engine must be subjected to a comprehensive replacement.

f) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	The pole windings were checked and maintenance repairs were carried out.	20 p
2	Inductive windings were checked and maintenance repairs were carried out.	20 p
3	It was checked for a short circuit and corrected.	20 p
4	Collector faults were identified and maintenance repairs were carried out.	20 p
5	Brush failures were identified and maintenance repairs were carried out.	20 p
	Out of a total of 100 points ... scored.	100 p

g) Questions: Answer the following questions.

1. What is the function of the brush and collector in induction?

2. How does the motor work if a change occurs in the pole winding poles?

3. How to do a series lamp test on the engine? Which method can be used instead?

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You can switch to the other application.

Application 8.2.	Mechanical System Failures and Elimination

a) Purpose of Application: To identify and eliminate mechanical system malfunctions.

b) Duration of Application: 60 minutes.

c) List of Materials and Equipment Used: Provide the materials and equipment in the table below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	Electric Bicycle	1 piece
2	Air pressure for tyres	1 piece
3	Bicycle mechanical parts (as seen in the catalogue)	Enough
4	Hand tools (screwdriver, crow nose, etc.)	Enough

d) Requirements: It will be checked whether the electric bicycle has a mechanical problem. Accordingly, follow the steps given below in order.

e) Process Steps: Perform the following steps in order.

1. The front and rear wheels of the electric bike are checked. If the pressure value on the wheels is not between 35-40 psi, air is pressed into it to reach this pressure range. In addition, it is checked whether there are problems around the wheel and whether there are foreign objects.

2. The rims, spokes and disc brake rotors on the wheels are checked. If there are fractures or cracks in the rim and spokes, they are replaced with new rims. It is examined whether the brake rotor is also working. If it does not tighten appropriately, this brake is replaced.

3. The strength of the main and side bodies of the electric bicycle is checked. When it is seen that there is a broken dislocation, these bodies are replaced with new ones.

4. The seat of the electric bicycle is checked. It is examined whether this seat fits well in the body, whether it is adjusted and whether it is firmly at the appropriate angle. If there are necessary defects, the seat (saddle) is replaced with a tube.

5. It is checked whether the pedal of the electric bicycle rotates. Depending on the gear lever, the rotation of the pedal varies. If the pedal does not rotate at the appropriate intensity depending on the gear lever, there is a problem with the chain and transmitter section. The chains are checked and replaced if there is a faulty section. Otherwise, it is examined whether there is a problem in the relay section. If both are in order, the rear suspension is checked. Finally, the rotation of the pedal is checked.

6. The neck section in the front section is checked. It is examined whether this part keeps the bike in balance and the necessary tests are performed.

f) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Bicycle wheels were checked and maintenance repairs were carried out.	20 p
2	Bicycle rims, spokes and brake rotors were checked.	20 p
3	The body and side frames were checked and the problems were fixed.	20 p
4	The seat seat and pipe were checked and the problems were fixed.	20 p
5	The pedal section has been checked and the problems have been fixed.	20 p
	Out of a total of 100 points ... scored.	100 p

g) Questions: Answer the following questions.

1. What is the role of relays?
2. What is the purpose of a brake rotor?
3. What is the effect of gear on the wheel and pedal?

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You can switch to the other application.

Application 8.3.	Charging System Malfunctions and Troubleshooting

a) Purpose of Application: To identify and eliminate charging system malfunctions.

b) Duration of Application: 60 minutes.

c) List of Materials and Equipment Used: Provide the materials and equipment in the table below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	Electric Bicycle	1 piece
2	Battery (lithium-ion) charger	1 piece
3	Pedal sensor	1 piece
4	Console (display)	1 piece
5	Electric motor (DC motor)	1 piece
6	Multimeter	1 piece
7	Hand tools	Enough

d) Requirements: It will be checked whether there is a problem with the charging system of the electric bicycle. Accordingly, follow the steps given below in order.

e) Process Steps: Perform the following steps in order.

1. Charge the electric bike before using it. Check if it is charged while charging.

2. Do the general test of the electric bike. Check that the DC motor is running and the battery is discharged by turning the pedal. Check this situation on the screen. If there is a problem with the operation of the system, follow the other steps.

3. First, check whether the DC motor is working by rotating the pedal. If the engine does not start, check the mechanism and the motor supply and replace the problematic parts.

4. Secondly, check whether the battery is discharged with the rotation of the DC motor. Check this both with a multimeter and with a display console. If the battery does not discharge at the time the engine starts and cannot be charged normally, replace the battery with a new one.

5. Thirdly, check if the pedal sensor is active. If the sensor cannot be activated sufficiently or malfunctions, replace the sensor with a new one. In addition, check the cable connections of the sensor and determine with a multimeter whether the signals from the sensor go to the relevant unit.

6. Fourth, check whether the screen monitor is working and whether the necessary adjustments have been made to it as soon as it is running. An automatic program is installed within these consoles. If the necessary adjustments cannot be made with the buttons or the measured values cannot be displayed correctly on the

screen, it is time to change the panel. The connecting cables should also be checked before replacing.

7. Finally, the control card on the bike should be checked. If the motor does not start when the pedal turns, or if the battery does not charge when the motor starts, there is a problem with the operation of this card. The card is checked and if there is no improvement as a result of the control, it is replaced with a new one. With the addition of a new card, the entire system is examined and controls are provided.

f) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	DC motor control has been provided and the relevant parts have been corrected.	20 p
2	The battery has been checked and its problems have been solved.	20 p
3	The pedal sensor has been checked and its problems have been solved.	20 p
4	The monitor screen has been controlled and its problems have been solved.	20 p
5	The control board has been checked and its problems have been resolved.	20 p
	Out of a total of 100 points ... scored.	100 p

h) Questions: Answer the following questions.

1. What is the function of the control card?
2. What is the pedal sensor used for?
3. In what situations does the battery charge and discharge?
4. What operations can be performed on the monitor?

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You can switch to the other application.

Application 8.4.	Warning and Display System Malfunctions and Elimination

a) Purpose of Application: To identify warning and display system malfunctions and to eliminate these malfunctions.

Figure 8.1: Display and warning systems on an electric bicycle

b) Duration of Application: 60 minutes.

c) List of Materials and Equipment Used: Provide the materials and equipment in the table below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	Electric Bicycle	1 piece
2	Warning system elements	Enough
3	Display system elements	Enough
4	Multimeter	1 piece
5	Hand tools	Enough

d) Requirements: It will be checked whether there are problems with the warning and display systems of the electric bicycle (Figure 8.1-Figure 8.2). Accordingly, follow the steps given below in order.

Figure 8.2: Display and warning parts of the electric bicycle

e) Process Steps: Perform the following steps in order.

1. Place the key on the on-off contact of the electric bicycle and activate its operation by turning it. Check that this status appears on the screen (Figure 8.3).

Figure 8.3: On-off contact of the electric bicycle

2. Press the right and left sides of the signal button alternately. Check whether both the display and the corresponding signal lamps are lit (Fig. 8.4). If the lamps do not light up, test the lamps first. If the lamps still do not light up, inspect the connection cables.

Figure 8.4: Operation of the left signal on the monitor screen and other indicators

3. Press the headlight on-off button and observe whether it is active on the display (Fig. 8.5).

Headlight

Figure 8.5: Activating the headlight lamp on the monitor screen

4. Press the high and low beam adjustment button alternately. Check whether both the display and the corresponding headlamps are lit. If the headlight lamps do not light up, test the lamps first. If the lamps still do not light up, inspect the connection cables.

5. Press the throttle. Observe that the speed limit changes on the monitor according to the compression intensity. Otherwise, inspect the connection cables.

6. Press the horn button. Check if there is any sound output at the time it is pressed. Otherwise, check the connection cables first. If there is still no problem, replace the audio device.

7. Check the charge status of the battery on the monitor by checking that the battery is connected (Figure 8.6). If this indicator appears passive, the battery message cannot be made to the monitor. In such a case, check whether the connection cables and battery are working.

Charge Status Indicator

Figure 8.6: Battery charge status indicator on monitor (fully charged)

8. Check if the gear status appears on the monitor. Pull the position of the gear to the position you have determined and observe whether it changes on the screen. If there is no gear change, first examine the connection cables. If the change is still not visible, change the gear to a new one (Figure 8.7).

Gear Status Monitor

Figure 8.7: Indication of gear status on the monitor (in 1st gear)

9. Press the brake lever. As soon as you press it, observe whether the brake signal lights up on the screen. If there is a possible malfunction in the brake, check that a signal is lit as in Figure 8.8 by creating a brake failure.

Figure 8.8: Brake failure indicator on monitor

10. Examine the other settings of the monitor. Check if other settings appear. Identify possible malfunctions and take precautions according to these malfunctions.

f) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Signal lamps were checked and notifications were received from the screen.	20 p
2	The front and rear lights were checked and notifications were received from the screen.	20 p
3	Speed was adjusted with the throttle lever and observed from the area on the screen.	20 p
4	The brake lever was pressed and notifications were received from the screen.	20 p
5	Gear changes were observed on the screen.	20 p
	Out of a total of 100 points ... scored.	100 p

g) Questions: Answer the following questions.

1. Under what conditions does brake failure occur?

2. If an indicator part of the screen is inactive, does that part indicate that it is defective?

3. Normally, the battery is not discharged, but the charge status is shown on the screen as maximum. What could be the possible problem?

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You can switch to the other application.

Application 8.5.	Maintenance Operations on Electric Bicycles

a) Purpose of Application: To carry out daily, weekly, monthly and general maintenance operations on electric bicycles and to ensure their control.

b) Duration of Application: 60 minutes.

c) List of Materials and Equipment Used: Provide the materials and equipment in the table below in the light of what is requested.

No.	Properties of Materials and Equipment	Units
1	Electric Bicycle	1 piece
2	Hand tools	Enough
3	Maintenance and repair materials	Enough

d) Requirements: Maintenance and repair operations will be carried out on the electric bicycle. Accordingly, follow the steps given below in order.

e) Process Steps: Perform the following steps in order.

1. Do the following before maintenance and repair on the electric bicycle.

- *Check the strength of the tires.*
- *Check the tyre pressures.*
- *Check the condition of the movement organs.*
- *Check the rearview mirrors (must be at the appropriate angle).*
- *Check if the horn makes any noise.*
- *Check if the front and rear lights are lit.*
- *Check if the signal lamps are lit.*
- *Check the rotating parts.*
- *Check that all nuts and bolts on the housing are securely tightened.*
- *Check that the seat is at the proper angle and secure.*
- *Check whether the bike is balanced by holding it firmly on the handlebars with both hands.*
- *Slowly press the throttle lever with your right hand. Check if the speed of the bike has increased (in this case, make sure that the side leg is closed).*
- *Slowly press the brake lever with your left hand. Check that the wheel of the bicycle stops suddenly (do not forget to adjust the brake intensity).*
- *Check that the battery is fully charged and ready to be used on the bike.*
- *Check if the electric motor is running.*

2. Maintain the batteries. During maintenance, do not disassemble the battery, do not connect the anode and cathode leads, avoid contact with water, stay away from a high temperature environment, do not create physical impacts and move away from the battery in case of possible physical changes.

3. Maintain the battery charger. Use the original charger during maintenance, turn off the engine while the battery is charging and do not shake the vehicle in any way.

4. Clean the vehicle. Use a wet cloth during cleaning, do not lubricate the tires with the brake system, use oil for cleaning metal parts, do not use high-pressure water and rinse with fabrics after cleaning.

5. Maintain the engine and the drive brain. During maintenance, stay away from water ingress and do not cause shaking.

6. Make sure that the electric bike is regularly maintained. Table 8.1 shows regular maintenance operations.

Table 8.1: Regular Maintenance Operations on Electric Bicycles

<table>
<tr><th>Electric Bicycle Parts</th><th>Daily Maintenance</th><th>2 Months Maintenance</th><th>4 Months Maintenance</th></tr>
<tr><td>Tire Pressure</td><td rowspan="5">Check.</td><td>-</td><td>-</td></tr>
<tr><td>Horn</td><td>-</td><td>-</td></tr>
<tr><td>Light Bulbs (Headlight, Signal)</td><td>-</td><td>-</td></tr>
<tr><td>Charger and Voltage</td><td>-</td><td>-</td></tr>
<tr><td>Brake</td><td>Check.
Set.</td><td>Check.
Set.</td></tr>
<tr><td>Tire Rims</td><td>-</td><td rowspan="2">Check.</td><td rowspan="2">Check.</td></tr>
<tr><td>Front Fork</td><td>-</td></tr>
<tr><td>Throttle, Rotating Parts</td><td>-</td><td>Check.
Oil.</td><td>Check.
Oil.</td></tr>
<tr><td>Brake Pads & Discs</td><td>-</td><td>-</td><td>Set.</td></tr>
</table>

7. The maintenance of the electric bicycle in terms of distance should be done monthly or when a distance of 500 km is reached. In the first maintenance, there will be a general check, and after this maintenance, the second maintenance operation will be carried out as soon as it reaches 2000 km. In other words, maintenance will be carried out in the form of 2000.x (km). The interval between both treatments should be no more than 4 months.

8. As soon as the electric bike is transported, the ignition and fuse must be off. In addition, the battery should be disconnected, the front and rear brakes should be tightened, and protective equipment should be placed around the bike.

9. Maintain the mechanical parts of the electric bicycle. In particular, the chains on the pedal should be cleaned and lubricated at regular intervals.

10. Some problems may occur in the operation of the electric bicycle. Table 8.2 presents such problems and the methods of solving these problems.

Table 8.2: Problems That May Occur in the Electric Bicycle and Their Solutions

Problems	Problem Causes	Solutions to the Problem
The power light is on, but the vehicle does not move.	The throttle lever does not work, the parking brake is stationary or the brake breakers are faulty.	• The throttle lever will change. • The parking brake will be turned off. • It will be taken to the service.
The ignition is on; but the tool does not start.	The socket of the fuse or fuse is burnt or the battery connections are faulty.	• The fuse and socket will change. • The battery connections will be made correctly.
The range seems short.	Low pressure in the tires, low battery charge, frequent stops and starts, overloading, climbing hills or being exposed to the wind.	• The tires will be inflated. • The battery will be recharged or replaced. • It will be used on designated roads.
The vehicle is not charging.	The main fuse is off, the charger is broken, or the charging socket is disconnected.	• The main fuse will open. • The charging socket will be replaced. • It will be taken to the service.
The electric vehicle is losing speed.	The battery is low or has a bad charge.	• The battery will be recharged. • The battery will be replaced.

11. Perform general checks and maintenance of the electric bike.

f) Scoring: Evaluate the study in line with the criteria given below and perform the scoring process.

No.	Scoring Criteria	Score
1	Maintenance of the battery was carried out.	20 p
2	Vehicle cleaning was carried out under appropriate conditions.	20 p
3	The engine and the driver's brain were maintained.	20 p
4	Maintenance of mechanical parts was carried out.	20 p
5	General maintenance of the electric bicycle was done.	20 p
	Out of a total of 100 points ... scored.	100 p

g) Questions: Answer the following questions.

1. Why should maintenance be done frequently on an electric bike?
2. What type of oils should be used in the maintenance of mechanical parts?
3. What possible problems can be seen in an electric bicycle and what could be their solutions?
4. What can be experienced and what kind of problems can be experienced when it is understood that the bicycle is powered in the transportation of the electric bicycle?

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You can switch to the other application.

DEFINITIONS

1. **Hill Climbing Power:** The maximum slope that a vehicle can climb at any constant speed (without acceleration); It is defined as the climbing ability of the vehicle. The maximum slope it can climb determines its maximum climbing ability. This capability is especially important for heavy vehicles and off-road vehicles.

2. **Power to Overcome Wind Resistance (Aerodynamic resistance power):** The aerodynamic resistance force is met by the traction force provided by the engine. Therefore, the resistive force is directly effective on the power of the engine and thus on the fuel consumption. Fuel consumption at any speed is directly proportional to the power required.

3. **Strength to Overcome Rolling Resistance:** Rolling resistance (RR) has a significant impact on the energy a vehicle needs to move. Therefore, about 20% for combustion engine vehicles is directly linked to fuel consumption, or for electric vehicles, it is the battery range. Tire design can help reduce rolling resistance (RR).

4. **Power Required for Acceleration:** If the vehicle is required to reach high speeds immediately, the high It must have torque power. If the vehicle is not desired to accelerate suddenly on a long road, but if it is desired to maintain its speed, high horsepower should be given importance.

5. **Motor-Road Power Scaling:** Dynamometers are devices used to measure the output force of an engine or machine. Dynamometers, also known as force meters, are generally; It is used to measure the horsepower of an energy engine or automobile engine.

6. **Framework and Design Determination Processes:** The most important issue that determines the characteristics of a vehicle is its design. This design starts with the chassis and ends with the accessories. In this process, all kinds of features require a large number of trials and engineering studies. This process continues until it becomes acceptable. Therefore, it is not possible to give a certain time. The goal should be to achieve acceptability as soon as possible.

7. **Using Measurements and Formulas:** The branch of science that studies the force effects of air is called Aerodynamics. The aerodynamic structure of the vehicle is considered as an important parameter in vehicle design. Therefore, the smoother and more uninterrupted the friction of the air on the vehicle, the more successful results are obtained.

For this purpose, for example,

a) Designing door windows and headlights on a surface with the vehicle bodywork,
b) Aerodynamic features of the side mirrors,
c) Designing the front and rear windows in a more horizontal way,
d) Expansion of tire cavities,

e) Covering the fenders,
f) Placing skirts between the front and rear wheels,
g) Camouflaging and flattening the recesses and protrusions under the vehicle.
h) Improvements are used, such as the installation of air cutters under the front panel.
Aerodynamic resistance acting on the vehicle.

Rax= 0.5 .p . It is calculated by the equation Cd .A. $(V\pm V0)^2$.

Here; p = Density of air

Cd = coefficient of aerodynamic resistance

A = area of the front projection of the vehicle, m2

V = speed of the vehicle m/s V0 = wind speed in the direction of motion, m/s

8. **Aerodynamic Drag Force:** It is called the fluid drag force acting on any solid body in motion in the direction of a fluid.

9. **Underbody airflow,** Aerodynamic lift is crucial for high-performance and fast cars. The air from below wants to lift the body of the car upwards, so the handling is significantly reduced. It is possible to reduce this force with the help of spoilers placed under the front bumper and above the rear of the vehicles. For this reason, high-performance vehicles have a much more sophisticated infrastructure.

10. **Horsepower** generally car and electric motors. The unit of power used for the determination of their power. The abbreviation for the unit is hp. 1 horsepower is 0.745 kW

11. **To9rk and Current,** Torque is the torque of rotation of the motor. The motor with high torque is more powerful than the low one. The torque depends on the electrical and mechanical characteristics of the motor and the radius of the motor shaft. The torque of a motor can be changed by gearboxes (reducer) connected to the motor. When a DC motor is operated at the specified voltage value, the current to be drawn by the DC motor depends on the load. As the load increases, the current drawn by the DC motor also increases.

12. **Charge Control,** it is an electronic device that is usually located in the charging units in order to prevent the battery or battery group from being damaged by overcharging or high voltage

13. **Trunk Panel:** Today, electric bicycles are manufactured for different uses. The most important part affected by these different structures is the body. The stems are diverse according to the following characteristics.

a- Two-wheeled fixed-body e-bikes,

b- E-bikes with two-wheeled folding bodies,

c- E-bikes with aluminium bodies,

d- bikes with three-wheel bodies,

e- There are varieties such as e-bikes with mountain bike bodies.

14. **a- Suspension:** The e-bike suspension improves control and comfort when riding on flat road and rough terrain, resulting in a smoother, more relaxed ride and improved handling. As a variety, it can be spring or shock absorber.

Front forks are the most common type of suspension on e-bikes. It is usually springy.

Rear shock absorbers provide a smoother ride. It can be with shock absorbers and springs.

Full suspension e-bikes offer both systems together but can be more expensive.

When choosing an e-bike suspension, it's important to consider the budget, riding style, and what kind of terrain it will be used on.

b-Brake System:

Bicycles usually use 2 types of braking systems.

i- V-BRAKE (SHOE BRAKE): Among the brake types in bicycles, the oldest and simplest type of brake is shoe brakes, also known as v-brake. Braking in shoe brakes, which has a very simple and easy mechanism, takes place by compressing the shoes parallel to the rim. It is very easy to install, maintain and adjust, and all you need for healthy brake adjustment is a Phillips screwdriver and a number 5 Allen.

ii- DISC BRAKE: While the mechanical disc brake provides braking with wire pulling the braking of the hydraulic disc brake is carried out by oil pumping. Disc brakes are much better than v-brakes in terms of braking quality. Especially in wet weather and on sandy, dirt surfaces, the braking quality of the disc brake is much better.

c- Lighting: Lighting on bicycles is done with headlights attached to the front and horse. The headlight system can be made of different materials. It can also be battery-powered or pedal-powered.

Today, LED headlights are often used. In this way, both savings and high quality are achieved.

d- Indicator: It is the part that shows all the controls and warnings required for the user in electric bicycles. It is usually manufactured as an LCD screen and is mounted in the middle of the handlebar in a position that can be easily seen.

e-Switch: It works as a main current control switch on electric bicycles. The switch is turned on and the bike is ready to start.

f- Maintenance Rules: Maintenance is very important in electric bicycles. The most important maintenance is a regular check of the battery check and charge level.

Then comes the preventive maintenance of the engine and the driver, respectively. Tire pressure, brake and transmitter elements should be checked regularly. Headlights, horn and throttle control elements should also be maintained at intervals.

g- General Inspection: General inspection and maintenance of electric bicycles should be done periodically. For this purpose, it is necessary to fulfil the instructions by paying attention to the inspection rules and times in the catalogue and user manuals.

h- Battery and Charger Assembly: The battery, which is necessary for the operation of the motor and peripheral elements in electric bicycles, is inserted and removed by moving up and down on the sled. Therefore, when fixing the battery shoe, a few inches should be left so that the battery can be driven on the cradle.

Since Li-ion batteries are used in E-Bikes, they can be charged without waiting for the battery to be completely discharged. The adapter is designed to charge Li-ion batteries. When the charging time is complete, the current will be cut off automatically. In cases where the e-Bike has not been used for a long time, the battery must be charged at least once every two months.

15. **Acceleration Resistance (Inertial Resistance**), inertia is defined as the desire to maintain the state in which objects are. Leaning forward in the car during braking or leaning backwards during acceleration is due to inertia. During the movement of vehicles from a stationary state, a resistance force occurs due to inertia. It is called **acceleration resistance** or **Inertial resistance** to this resistance.