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Senior Design Project Report

Design of an Energy-Efficient Bicycle

In partial fulfillment of the requirements for the
Degree of Bachelor of Science in Mechanical Engineering

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Abstract

A gear mechanism has been designed in this project. The mechanism is attached to an ordinary bicycle. The prime objective is to reduce the pedaling force in tough inclement. A small motor, generator, battery, and solar panel are also used to acquire the objective.

Generally, during downhill cycling, the speed of bicycles increase and the riders apply brakes to decelerate their bicycles. This application of brake converts excessively available mechanical energy into friction; which is a waste of energy. In addition, brake and friction mechanisms cause excessive wear of brake shoes resulting in frequent shoes (brake pads) replacement. Rather than applying brakes and through a clutch mechanism, cycle wheel is engaged with a dynamo/generator that will convert excessively available kinetic energy into electrical energy from the wheel rotation. This electrical energy can be stored and onwards can be utilized either for lighting or can be used during uphill cycling when the installed motor produces torque to, where more human effort is required to get the required speed in uphill cycling.

Additionally, by utilizing a solar panel to recharge the battery connected to the motor. We achieved an environmentally friendly system that will influence big companies to use and improve this idea. The aim of this project is to have an energy-efficient bicycle that can reduce the required pedaling force in different elevations, and increase brake's life.

Acknowledgment

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List of Acronyms (Symbols) Used in the Report

Symbol	Definition
R_c	Radius of Crank
R_p	Distance from Pedal To Center of Crank
R_g	Radius of Rear Multi-Gears
R_t	Radius of Tire
W	Mass of The Rider
T	Tension
τ	Torque
τ_c	Torque on Crank
τ_T	Torque on Rear Wheel
f	Friction Force
I	Moment of Inertia

Table of Contents

Abstract	2
Acknowledgment	3
List of Acronyms (Symbols) Used in the Report.....	4
Table of Contents	5
List of Figures	7
List of Tables	9
Chapter 1: Introduction	10
1.1 Project Definition:	10
1.2 Project Objectives:.....	10
1.3 Project Specifications:	11
1.4 Applications:.....	12
Chapter 2: Literature Review	13
2.1 Project Background and History of Bicycles:	13
2.2 Previous Work:	15
2.3 Comparative Study:	20
2.4 Parts:	20
2.4.1 Gear Mechanism of Bicycles:.....	21
2.4.2 Clutch:	22
2.4.3 DC Motor:.....	24
2.4.4 Generator:	25
Chapter 3: System Design.....	26
3.1 Design Constraints:.....	26
3.2 Design Methodology:	26
3.3 Product Subsystems and Components:	27
3.4 Implementation:.....	28
3.4.1 Sprocket Ratio:	31
3.4.2 Torque Calculations:.....	31
Chapter 4: System Testing and Analysis	36
4.1 Motor:	36
4.1.1 Bicycle Motor Simulation:	38
4.2 Power Generation:	44

4.3 Overall Results, Analysis and Discussion:	45
Chapter 5: Project Management.....	48
5.1 Project Plan:.....	48
5.1.1 Gantt Chart:	50
5.2 Contribution of Team Members:	51
5.3 Project Execution Monitoring:	52
5.4 Challenges and Decision Making:	53
5.4.1 Problems with Team Members:.....	53
5.4.2 Challenges of Project Parts:.....	54
5.4.3 Problems with Equipment:	54
5.5 Project Bill of Materials and Budget:	54
Chapter 6: Project Analysis	56
6.1 Life-long Learning:.....	56
6.1.1 Project Analysis:.....	56
6.1.2 Equipment's Specifications:.....	56
6.1.3 Installation:	57
6.1.4 Problem Solving:	57
6.1.5 Teamwork:.....	57
6.1.6 Engineering Sense:	57
6.2 Impact of Engineering Solutions:	58
6.3 Contemporary Issues Addressed:	58
Chapter 7: Conclusion and Future Recommendations.....	60
7.1 Conclusions:	60
7.2 Future Recommendations:.....	60
References:.....	61
Appendix A.....	64
Appendix B	73
Appendix C	84

List of Figures

Figure 2.1: Caprotti bicycle sketch.....	14
Figure 2.2: Karl Drais design.....	14
Figure 2.3: McCall design.....	15
Figure 2.4: Eugène Meyer high front wheel bicycle.....	15
Figure 2.5: A free body diagram for the bicycle.....	16
Figure 2.6: A free body diagram for the bicycle with a motor.....	17
Figure 2.7: A motor connected to the chain wheel.....	18
Figure 2.8: An electric assisted bicycle.....	18
Figure 2.9: The motor connected the hub by a chain.....	19
Figure 2.10: The final fabrication of the motor in the bicycle.....	19
Figure 2.11: Chainless bicycle.....	20
Figure 2.12: Gear mechanism of bicycles.....	21
Figure 2.13: Clutch description.....	23
Figure 2.14: Clutch pushing lever mechanism in motorcycle	24
Figure 2.15: DC motor connected to a gear.....	25
Figure 3.1: The components of the project.....	27
Figure 3.2: Side view of prototype showing the motor.....	29
Figure 3.3: Components of the prototype.....	29
Figure 3.4: The designed gear mechanism attached to the motor.....	30
Figure 3.5: Torque developed on crank.....	32
Figure 3.6: Torque developed on rear wheel.....	32
Figure 3.7: Motor.....	34
Figure 3.8: The Motor fabricated with a gear.....	34
Figure 3.9: Electrical connection drawing.....	35
Figure 4.1: A Multimeter.....	36
Figure 4.2: Testing setup.....	37
Figure 4.3: Parallel connection diagram.....	37
Figure 4.4: Graphical power, efficiency, torque, and load data.....	39

Figure 4.5: Graphical power, efficiency, torque, and load data.....	40
Figure 4.6: Bicycle simulation at speed of 20.1 km/h.....	41
Figure 4.7: Speed vs. distance traveled graph.....	41
Figure 4.8: Bicycle simulation at speed of 5 km/h and 5% inclined surface.....	42
Figure 4.9: Speed vs. distance traveled at 5% inclined surface.....	42
Figure 4.10: Bicycle simulation at speed of 10 km/h and 10% inclined surface.....	43
Figure 4.11: Speed vs. distance traveled at 10% inclined surface.....	43
Figure 4.12: Solar panel.....	44
Figure 4.13: Workshop.....	45
Figure 4.14: Generator.....	45
Figure 4.15: First test.....	46
Figure 4.16: Batteries connected in parallel.....	46
Figure 4.17: Thick Wires.....	47
Figure 4.18: Final installed system.....	47

List of Tables

Table 1.1: The specifications for the bicycle used in the project.....	11
Table 2.1: The effect of the required power when varying the inclement of a surface.....	18
Table 2.2: Parts description for gear mechanism.....	22
Table 2.3: Types of clutches according to the method of transmitting torque.....	23
Table 3.1: Installation parts.....	28
Table 3.2: Gear mechanism dimensions.....	30
Table 3.3: Design parameters.....	31
Table 3.4: Motor specifications.....	33
Table 4.1: One battery direct connection values.....	36
Table 4.2: Two batteries connection in parallel outputs.....	38
Table 5.1: List of items.....	48
Table 5.2: Tasks for team members.....	49
Table 5.3: Bill of Material and Budget.....	55

Chapter 1: Introduction

1.1 Project Definition:

In this project a design and installation of a new gear mechanism attached to a motor on a bicycle that contributes in decreasing the required torque efforts from the rider on inclined surfaces to accelerate a bicycle. This project mechanism will be applied in two main scenarios while going up on a hill and by going down. When going uphill, the driver of the bicycle will have to increase the effort, with that more pedaling will be required to overcome all forces acting against the bicycle.

The first part of the project is by utilizing a motor that will be connected to the rear gear hub by a chain initiated by a switch fixed right next to the rider's left hand. This switch will start/stop the motor to contribute in reducing the pedaling force.

The second part of the project is by a generator connected to clutch to be engaged in the hub to charge the battery and decelerate the bicycle at the same time. Mainly it is a mechatronic project; it will have a motor, gears, battery, clutch, and a generator.

The project is applicable and useful for sports activities, daily bicycle uses of transportation, and those who cycle/pedal on hills which vary in ground elevation. It is also important from the safety part, decreasing the speed while going down, and increasing the speed while going up.

1.2 Project Objectives:

- The design of an energy-efficient bicycle.
- Reducing the required pedaling effort by utilizing a motor.

- Converting mechanical energy from wheel rotation to electrical energy.
- Increasing the validity period of brakes.

1.3 Project Specifications:

The project is applicable for any bicycle available in the market. The bicycle that has been selected for this project has the specifications as listed in Table 1.1.

Table 1.1: The specifications for the bicycle used in the project [1]

Item	Specification
Best Use	Mountain Biking
Frame	6061 Aluminum
Fork	SR Suntour XCT, 75mm travel
Crankset	SR Suntour XR-170 24/34/42T
Bottom Bracket	Sealed cartridge
Shifters	Shimano EZ-Fire 8-speed
Front Derailleur	Shimano FD-C050
Rear Derailleur	Shimano Acera
Rear Cogs	Shimano HG30 cassette, 11-32T, x8
Brakes	Tektro alloy linear pull
Brake Levers	Shimano EZ-Fire
Rims	Alex alloy
Front Hub	Alloy

Rear Hub	Alloy
Tires	Kenda Klaw XT 26x2.1"
Handlebar	Steel riser
Stem	Alloy 1-1/8" threadless
Seat Post	Alloy micro-adjust,
Saddle	K2 Sport MTB
Pedals	Resin MTB
Headset	1-1/8" threadless
Chain	KMC Z7

1.4 Applications:

The application of this new mechanism is not complicated in terms of the design and motor installation. It is applicable for lots of utilizations such as:

- Sport activities using bicycles where people use to cycle/pedal for long distances.
- Daily life bicycle uses as a main tool of transportation for some people.
- Contribution to motivate old age people to use bicycles to exercise their legs.

Chapter 2: Literature Review

2.1 Project Background and History of Bicycles:

Gupta (2009) [2] states “A bicycle is the most efficient vehicle ever designed.” (p.3.). A bicycle is a widely-known tool of transportation in many countries. Bicycles have been invented back in the 1500s. There are many claims describe the invention of bicycles and their designs. In 1493, Gian Giacomo Caprotti alleged that he sketched a design of a bicycle as in Figure 2.1. In 1817, Karl Drais designed a new generation of bicycles as shown in Figure 2.2. Karl’s design has been developed and readjusted by other designers. The big evolution was in the 1860s which let bicycles have become more common around the world. In 1869 Thomas McCall has built a bicycle that inspired French designers as shown in Figure 2.3. In the 1870s, Eugène Meyer was a French mechanic who invented a new generation of the bicycles in Figure 2.4. He designed the high front wheel bicycles in order to increase the speed of bicycles. In the 1880s and 1890s, the safety bicycles have become the aim of John Kemp Starley who invented the first safety bicycle in order to decrease the danger of bicycle accidents. In the 20th century, more developments have been applied to bicycles in chain and gear mechanisms. In 1939 to 1945 military bicycles were used effectively during World War II for military purposes. In the 21st-century, technological advancement in bicycle manufacturing has become more effective in designing in terms of aerodynamics, materials, and computer aided design.[2]

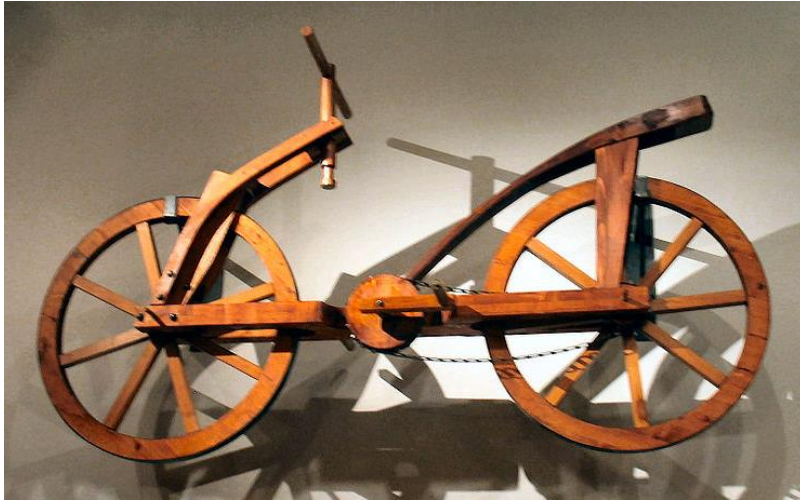


Figure 2.1: Caprotti bicycle sketch [3]



Figure 2.2: Karl Drais design [4]



Figure 2.3: McCall design [5]

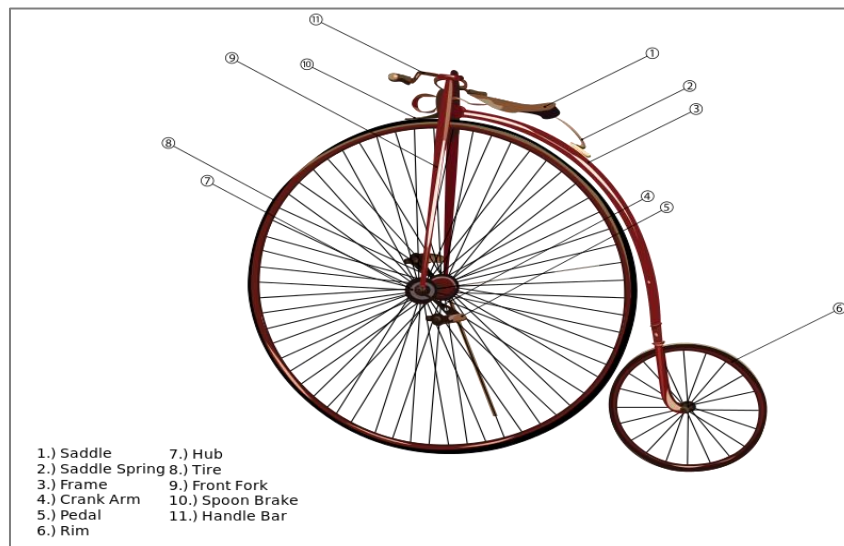


Figure 2.4: Eugène Meyer high front wheel bicycle [6]

2.2 Previous Work:

Hung, Jaewon, & Lim (2017) [7] hypothesis that “In order to develop a high performance electric bicycle, a simulation study of its dynamic characteristics and required power is conducted based on the effects of various input parameters such as rider mass, bicycle mass,

wind speed, crank length, wheel diameter, and grade.” (p.1.). They believe in order to select the proper motor the required power for the system has to be calculated first. The required power can be calculated using MATLAB or other mathematical software. According to their study, there will be two situations for the free body diagram force analysis as shown in Figure 2.5 and Figure 2.6. The total power needed to push the bicycle will be a summation of the slope from the inclined surface, air resistance, and friction from the surface. They concluded after their calculations for a rider with a mass of 57 kg the suitable motor will be with a rated power of 250 Watt.

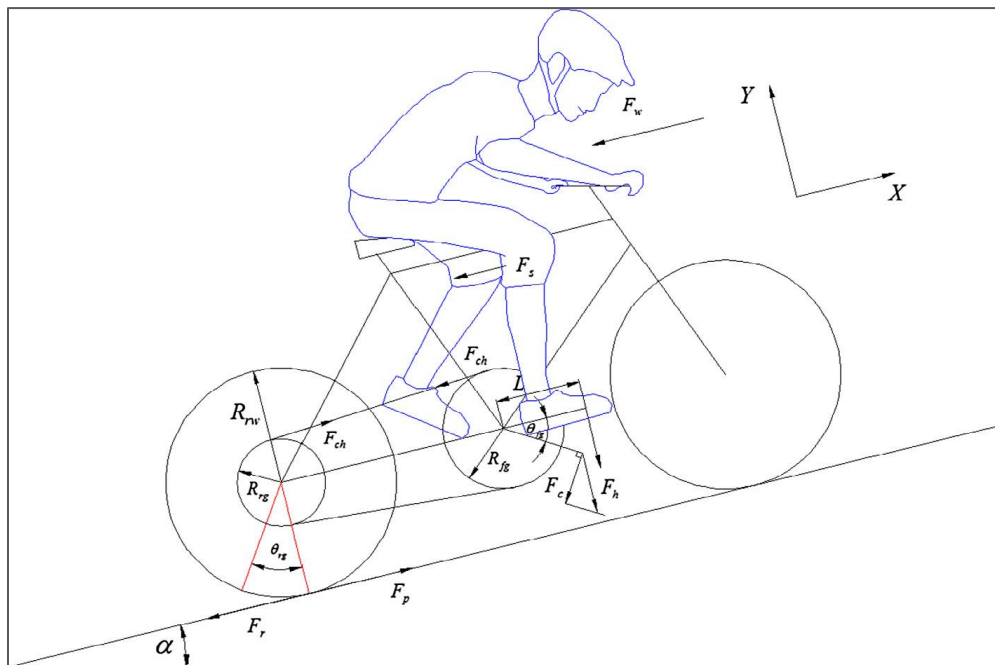


Figure 2.5: A free body diagram for the bicycle [7]

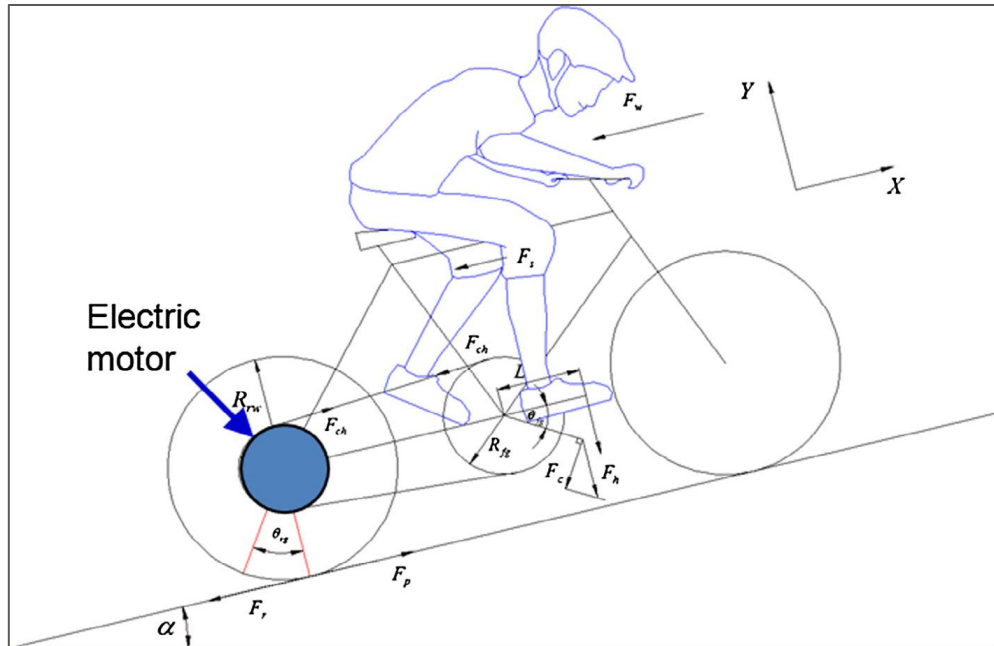


Figure 2.6: A free body diagram for the bicycle with a motor [7]

Alkhalifa, Al-Ghumgham, Alsalah, & Alsubaie (2015) [8] propose a solar assisted bicycle. They fabricated motor attached to rear hub gear as illustrated in Figure 2.7. Their objective was to assess power consumption required when a motor is attached to a bicycle. Furthermore, they used a solar panel to recharge the batteries and according to calculation the rated a 100 Watt output from the solar panel. They installed a motor with a rated power of 500 Watt, battery voltage of 48 V to run the motor. Their design is based on a rider with a mass of 105 kg. They concluded From Table 2.1 as the surface getting more inclined the power needed to overcome uphill cycling/pedaling increases.



Figure 2.7: A motor connected to the chain wheel [8]

Table 2.1: The effect of the required power when varying the inclement of a surface [8]

Inclination (%)	Speed (Km/h)	Range (Km)	Weight (Kg)	Power to overcome air resistance (W)	Power to overcome rolling resistance (W)	Power consumption (Wh/Km)
0	30	87	105	146	111	10.7
15	16	14	105	22	792	59.75
25	9.9	9	105	5	791	97.09

Scholten (2017) [9] proposed the electrically powered bicycle motor to be used as shown in Figure 2.8. A motor with rated power of 250 W was used to achieve the target of an electric assisted bicycle. The motor is fixed on the frame of the bicycle and connected the hub gear by a chain as shown in Figure 2.9.



Figure 2.8: An electric assisted bicycle [9]



Figure 2.9: The motor connected the hub by a chain [9]

Racer (2009) [10] has done a somehow similar project that has been in the making for about 3 years. He converted regular bicycle to a motor bicycle by installing a small engine on the bicycle. He started with just the frame of the bicycle. Then, he welded the motor and fixed it on the frame of the bicycle. The motor then is connected to rear hub gear by a chain to drive the wheel. The distance between the wheels is about a 55 inches. He concluded that it was not a practical application for a Board Track. The final achievement is shown in Figure 2.10.



Figure 2.10: The final fabrication of the motor in the bicycle [10]

2.3 Comparative Study:

Hanlon (2006) [11] hypothesis that most children would have many incidents when using bicycles involving lost skin, derailed chain, a destroyed cloth, and lost a bicycle. Furthermore, bicycles are the world's favorite vehicle of transport "More than 100 million bicycles are sold each year – double the number of cars" (p.1). He believes that bicycles are highly-efficient but potentially dangerous chain drive. Therefore, he prefers the idea of a chainless bicycle. US-based Dynacraft has designed a bike has an internal drive shaft mechanism as illustrated in Figure 2.11 which requires less maintenance compared with chain bicycles. It is more expensive than regular chain bicycles how it is less efficient around 10% less [12].



Figure 2.11: Chainless bicycle [11]

2.4 Parts:

This section is a general description of the functions of the main parts that are involved in a bicycle movement.

2.4.1 Gear Mechanism of Bicycles:

Bicycle gearing system is the most fundamental mechanism which converts a rider's force on pedals into a driving force to accelerate bicycles. Bicycles differ in gear combination number and gear ratios. Most bicycles now have multiple shifting gears between high and low in order to increase the efficiency or to have a smoother pedaling effort. Figure 2.12 shows the gear mechanism of bicycles that is responsible for how bicycles move. Table 2.2 summarizes the function of each part involved in converting the force from a rider to a wheel motion.

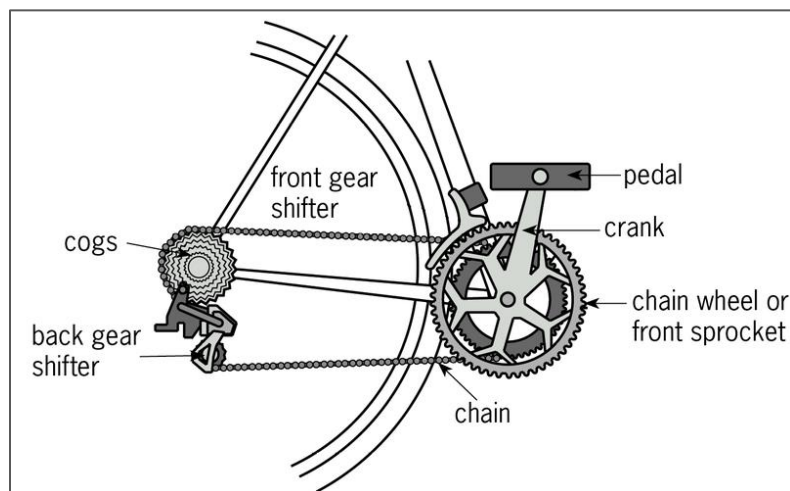


Figure 2.12: Gear Mechanism of bicycles [13]

- **Gear Ratio:**

Gear ratio calculation is very significant to be determined. There are some parameters for gear ratio calculation such as the number of teeth per gear, the diameter of the gear, the radius of the tires, the length of the pedal crank.

Table 2.2: Parts description for gear mechanism [14]

Part	Function
Pedal	Enables bicycle riders to push by their foot to drive the bicycle. (A flat part, connected to the crank)
Pedal Crank	Takes the force from the pedal and produces a rotational motion to rotate the chain wheel.
Chain Wheel (sprocket)	Transmits the pedaling torque to the chain. (It is a gear that connects the pedal crank and the chain)
Chain	Used for power transmission from the pedal crank to cogs in order to rotate the wheels.
Cogs	Attached to the hub in order to move the bicycle forward. (Rear gears combination)
Gear Shifter	Shifting the gear between high and low to adjust the desired gear ratio.
Wheel	The tool for the rotation.

2.4.2 Clutch:

It is a mechanical tool which connects and disconnects gears together in a mesh to transmit power as shown in Figure 2.13. Table 2.3 summarizes the types of clutch that one has to be selected for the application project to attach the hub gear to the generator.

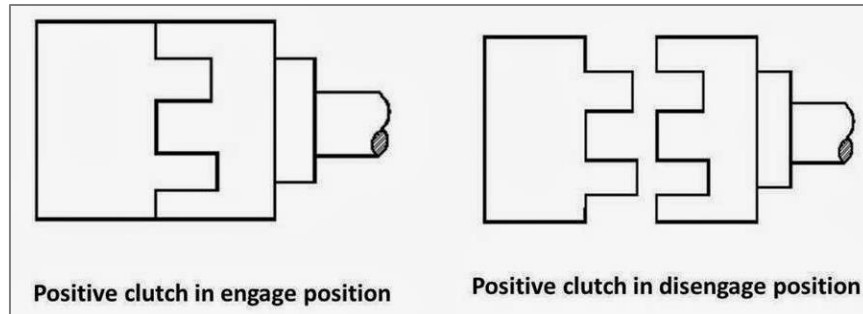


Figure 2.13: Clutch description [15]

Table 2.3: Types of Clutches According to the method of transmitting torque [15]

Clutch Type	Description
Positive clutch	Both driving and driven shaft revolve together.
Friction clutch	The friction force is used to engage and disengage the clutch.
Hydraulic clutch	A hydraulic fluid is used to transmit the torque.

- **The Clutch System in Motorcycles:**

The clutch used in motorcycles is operated by a simple mechanism when the rider's hand pushes the handle on the left steering as illustrated in Figure 2.14. This mechanism can be employed in the project design and installation [16]. The application of this principle will be used to engage and disengage the clutch in the bicycle between the motor and the generator. When there is no pressure acting on the handle it implies that the clutch plates are engaged (driving position). On

the other hand, when pulling the handle it disengages the clutch plates, it can be operated through cable or hydraulic actuation, allowing the rider to shift gears [17].

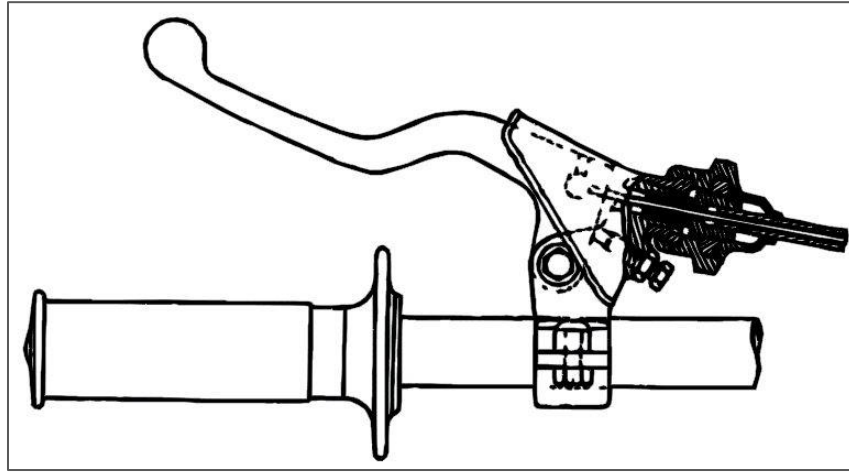


Figure 2.14: Clutch pushing lever mechanism in motorcycles [18]

2.4.3 DC Motor:

It is an electric motor that converts the electrical energy into mechanical energy. DC motors are electric motors that are powered by the direct current which called DC, such as from a battery or DC power supply. The installed in the bicycle DC motor helps the rider during downhill and uphill cycling as the example in Figure 2.15. During the uphill cycling, where a high effort from the rider is required to get the desired speed. Also, during downhill cycling, speed increases and riders apply brakes decelerate the speed of bicycles. However, by installing DC-motor mechanism that is connected to the chain drive, the speed will be reduced [19].

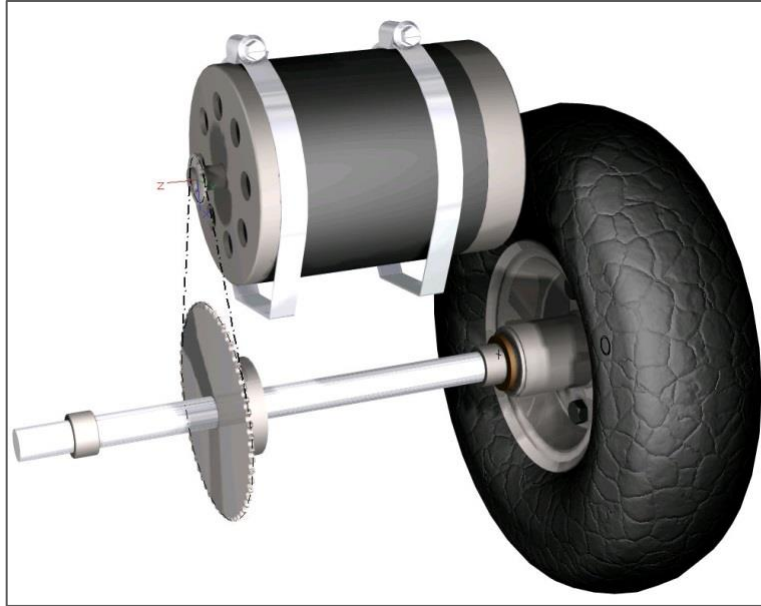


Figure 2.15: DC Motor connected to a gear [20]

- **Performance Specifications:**

Speed, torque, and operating voltage are the most important performance parameters for DC motors. Supplier datasheets list these specifications as numerical values.

2.4.4 Generator:

An electrical generator is a machine that converts mechanical energy to electrical energy. The mechanical energy can be supplied from wheel rotation then the generator converts it and recharges the battery.

Chapter 3: System Design

3.1 Design Constraints:

One of the most common difficulties students face in Saudi Arabia is the lack of the required parts for the projects in local markets. One of the constraints for this project is the motor weight and power output. A light weight motor has to be selected in order to avoid additional weight to bicycle. Furthermore, design and dimension accuracy constraints the project because the chain might impact the rider's legs. Additional to that it is not easy to weld the motor on the aluminum frame for the bicycle. The power of the motor has to overcome steeply inclined surfaces.

3.2 Design Methodology:

The design methodology for accomplishing the objectives of the project has to go through some significant stages. The result will be based on what has been used correctly in the design methodology to get the final prototype of the project. To get the final prototype we have to follow the following stages:

- A good relevant research and background of the project have to be completed at the first stage of the project.
- Design the preliminary drawings for the system through SOLIDWORKS.
- Selecting for a motor that is suitable for the prototype based on light weight and power of 280 W.
- Selecting for a generator that is able to charge the battery.
- Selecting for a solar panel with an enough rated power to contribute in battery charging.
- Fabrication and assembly of the prototype.

- Testing of the prototype to ensure that it is applicable.
- Generate future recommendations for bicycle manufacturers.

3.3 Product Subsystems and Components:

Generally, the major components of the prototype that have been designed are shown in Figure 3.1. Each item is summarized in Table 3.1 to explain the function involved from the components.

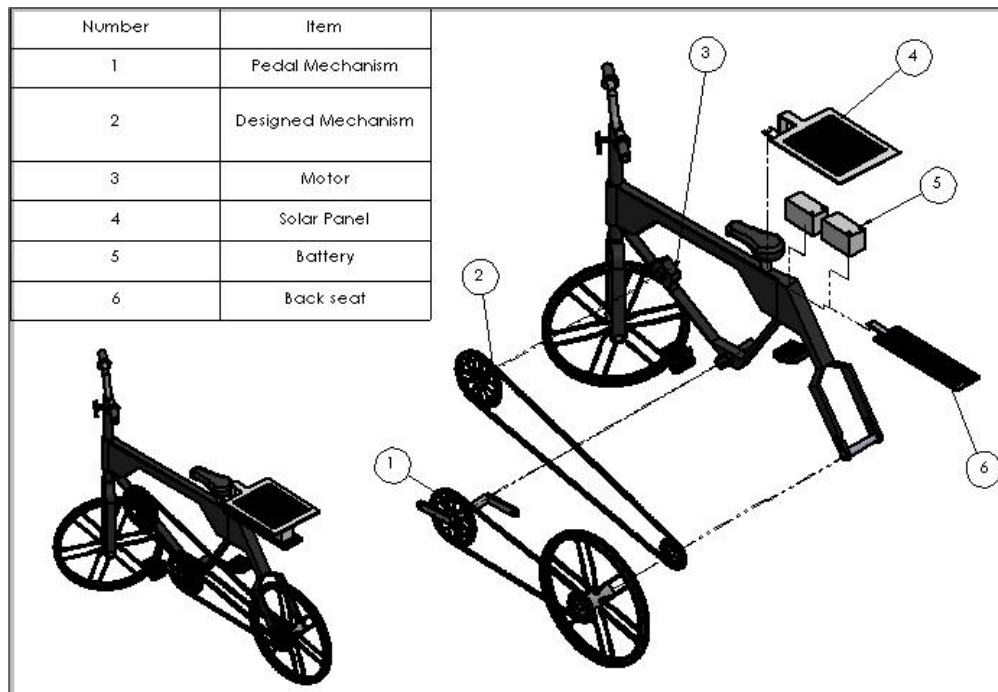


Figure 3.1: The components of the project

Figure 3.1 shows the first approach, in this approach the motor is attached to the rear hub by a chain. We believe this approach is more efficient, safer, and can be applicable easily. The whole system will be connected to main hub gear in the wheel to engage the motor when it is needed. The system is connected to the battery to supply power to the motor.

Table 3.1: Installation parts

Part	Comment
Switch	To run the motor (start/stop)
Electrical Wires	For connections
Battery	For electrical power supply
Solar panel	To recharge the battery
Motor	To produce torque for wheel rotation
Generator	To convert wheel rotation to electrical power to charge the battery

3.4 Implementation:

When the research has been completed, we started to implement the prototype by drawing the motor and the gear mechanism on SOLIDWORKS. Figure 3.2 and Figure 3.3 show the motor located at the upper gear and connected with a chain to rear hub of the bicycle. Table 3.2 illustrates all the dimensions between the rear hub gears and the motor.

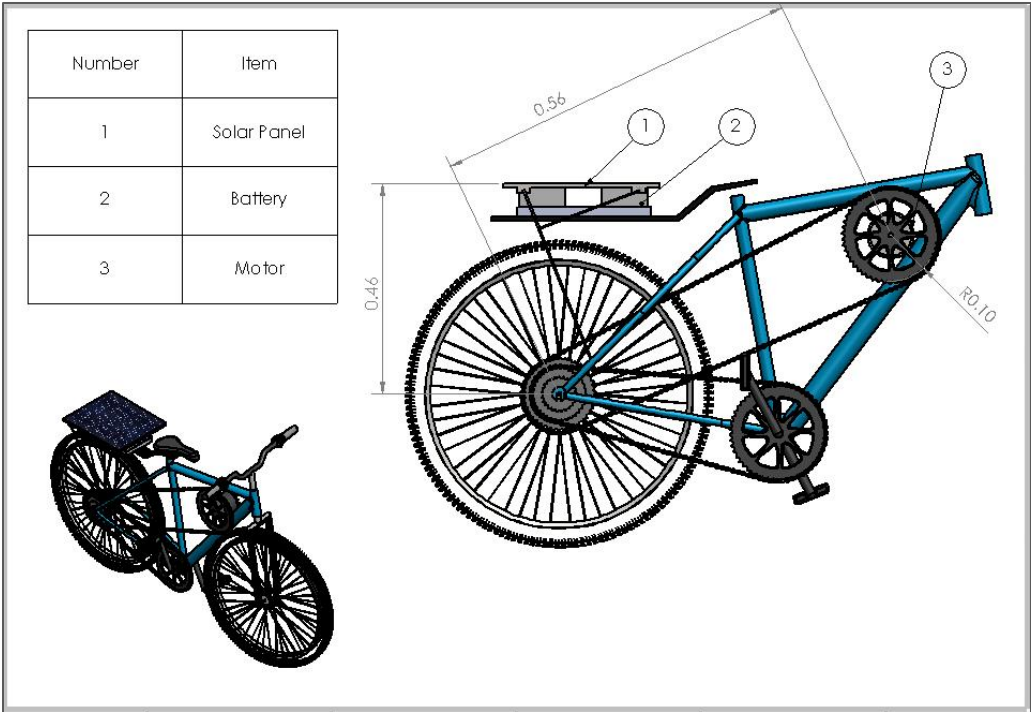


Figure 3.2: Side view of prototype showing the motor

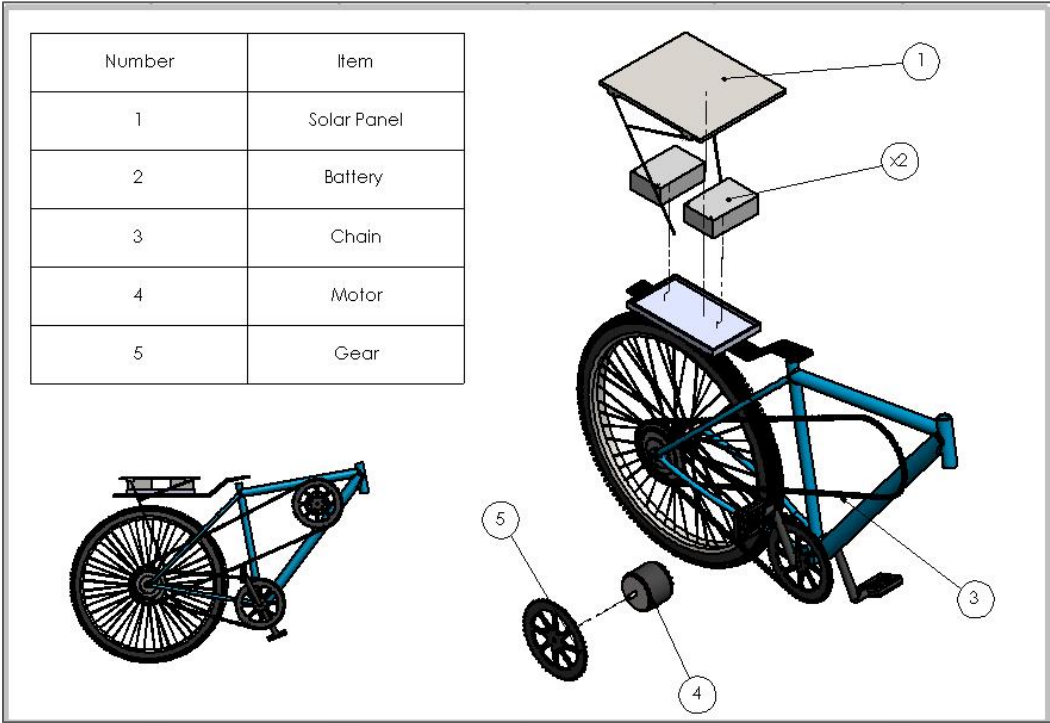


Figure 3.3: Components of the prototype

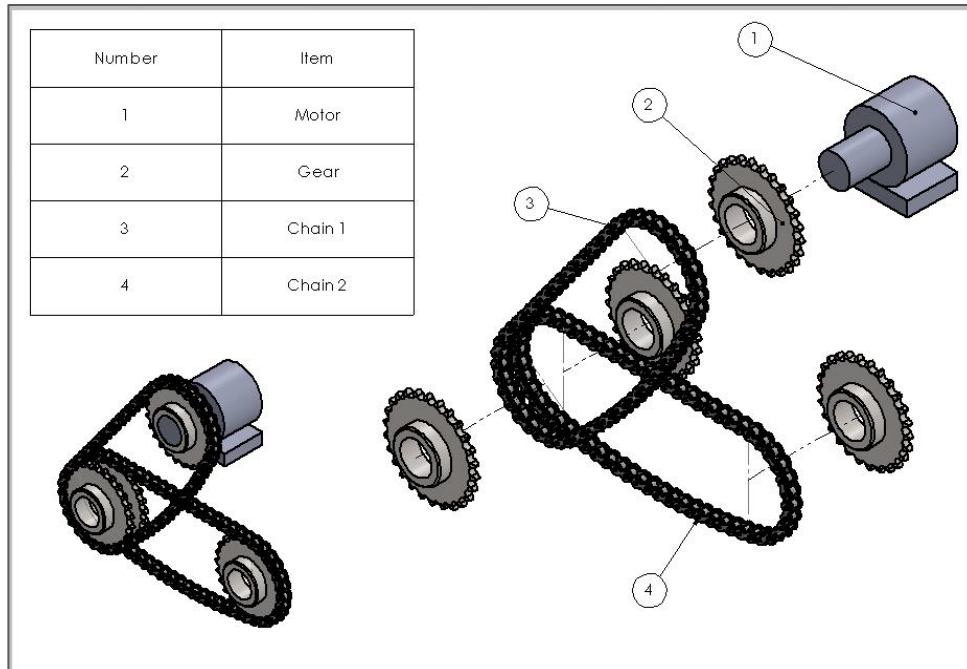


Figure 3.4: The designed gear mechanism attached to the motor

Table 3.2: Gear mechanism dimensions

Term	Dimension
Motor to rear gear	680 mm
Pedal to rear gear	465 mm
Teeth number of motor gear	44 teeth
D1	180 mm
D2	180 mm
d1	80 mm
d2	60 mm
Teeth number of rear gear1	20 teeth
Teeth number of rear gear2	16 teeth

3.4.1 Sprocket Ratio:

Sprocket ratio or gear ratio is the ratio is a mathematical representation of the mechanical advantage of a gear train system. It shows the change in speed between the sprocket of the motor and the rear hub of the bicycle [2].

$$\text{Sprocket ratio} = \frac{\text{number of teeth on driver}}{\text{number of teeth on driven}}$$

$$\text{Sprocket ratio} = \frac{44}{16} = 2.75$$

3.4.2 Torque Calculations:

Equation 3.1 is used to calculate the minimum torque required to accelerate the bicycle by normal pedaling without a motor, there are some parameters have to be known and they are listed in Table 3.3.

Table 3.3: Design parameters

Symbol	Definition	Dimension
R_c	Radius of Crank	80.0 mm
R_p	Distance from Pedal To Center of Crank	100.0 mm
R_g	Radius of Rear Multi-Gears	20.0 – 50.0 mm
R_t	Radius of Tire	300.0 mm
W	Mass of The Rider	Assuming Average Mass of 75 kg
T	Tension	-
τ	Torque	-

τ_c	Torque on Crank	-
τ_T	Torque on Rear Wheel	-
f	Friction Force	-
I	Moment of Inertia	-

Based on the bicycle's dimensions that have been determined, the torque equations:

- Torque on crank

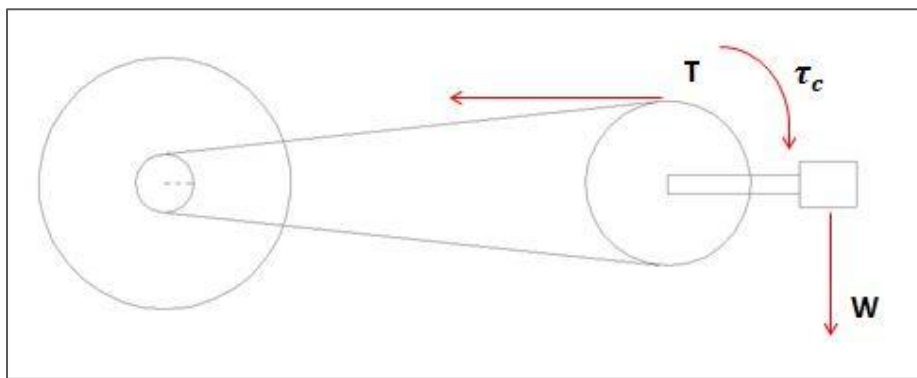


Figure 3.5: Torque developed on crank

$$\tau_c = R_c T - R_p W \tag{Eq 3.1}$$

$$0 = R_c T - R_p W \quad (\text{Assuming constant speed})$$

$$T = \frac{R_p W}{R_c} = \frac{100.0 \text{ mm} \times 75 \text{ kg} \times 9.81 \text{ m/s}^2}{80.0 \text{ mm}} = 919.70 \text{ N}$$

- Torque on rear wheel

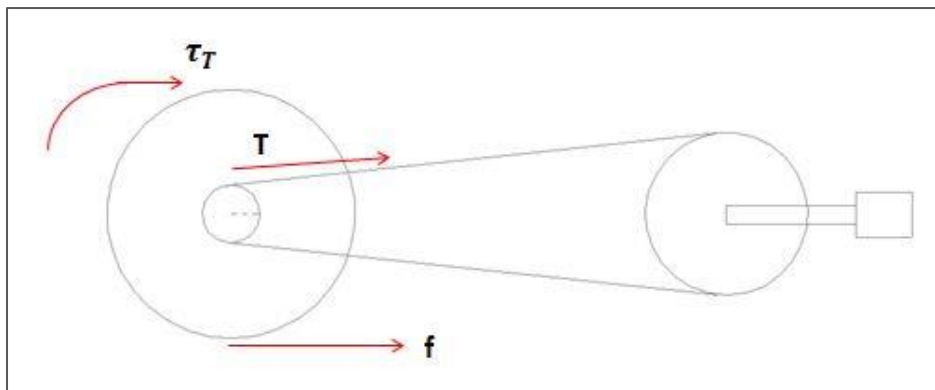


Figure 3.6: Torque developed on rear wheel

$$\tau_T = R_g T \quad (\text{Eq 3.2})$$

$$\begin{aligned} \tau_T &= 20.0 \text{ mm} \cdot 919.70 \text{ N} \\ \tau_T &= 0.02 \text{ m} \cdot 919.70 \text{ N} = 18.40 \text{ N m} \end{aligned}$$

$$\tau_T (\text{Total}) = \tau_{friction} - \tau_T$$

$$\tau_T (\text{Total}) = R_t f - R_g T$$

$$0 = R_t f - R_g T$$

$$f = \frac{R_g}{R_t} T$$

$$f = \frac{R_g}{R_t} \left(\frac{R_p}{R_c} W \right) = \frac{20.0 \text{ mm} \times 100.0 \text{ mm}}{300.0 \text{ mm} \times 80.0 \text{ mm}} \times 75 \text{ kg} \times 9.81 \text{ m/s}^2 = 6.25 \text{ N}$$

3.4.2 Motor Details:

The selected motor for the prototype has fixed specifications which are listed in Table 3.4. The original motor used in the project is shown in Figure 3.7. The motor was not suitable to be attached to the chain. Therefore, we had to fabricate and weld a gear on the motor to for reaching the objective of the project. Figure 3.8 shows the new shape of the motor after the fabrication with gear to be connected to the rear hub.

Table 3.4: Motor specifications

Term	Value
Voltage	24 V
Power	280 W
Current	15.4 A
Weight	2.04 kg
RPM	2750 rpm



Figure 3.7: Motor



Figure 3.8: The Motor fabricated with a gear

Figure 3.9 shows the electrical connection diagram between the batteries and the motor then the switch. It has to be in parallel to ensure that the voltage is distributed the same through the circuit.

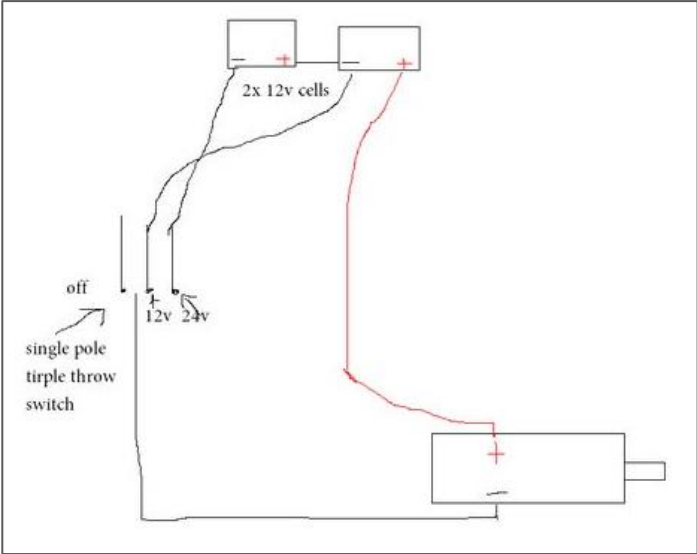


Figure 3.9: Electrical connection drawing [21]

Chapter 4: System Testing and Analysis

4.1 Motor:

The main component in the prototype is the motor performance output produced to accelerate the bicycle. Where the torque produced will contribute to reducing pedaling efforts. The objective of this test is to ensure that the motor is performing as design calculations.

A Multimeter has been used to test the output voltage and current through the system. The testing setup is shown in Figure 4.1 and 4.2. The values of the test are shown in Table 4.1.

Table 4.1: One battery direct connection values

Term	Value
Voltage	12 V
Current	12 A



Figure 4.1: A Multimeter to measure the voltage



Figure 4.2: Testing setup

As the results above show that the values have not met the requirements of the motor. Therefore, we have to connect two batteries in the system instead of one. The connections were set in series and due to the excessive load the switch was burned as a result, we have redesigned the connections to be in the parallel set as illustrated in Figure 4.3. As shown in Table 4.2 the values of the voltage and current when connected in parallel.

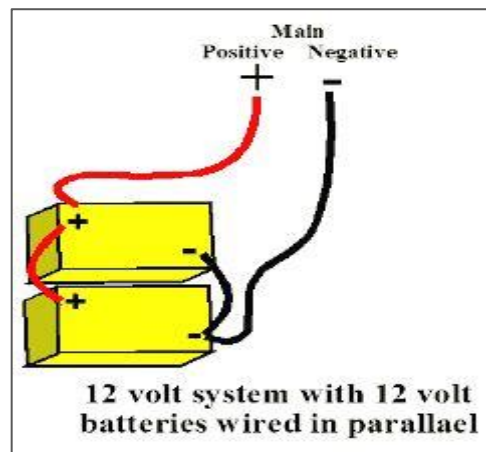


Figure 4.3: Parallel connection diagram [23]

Table 4.2: Two batteries connection in parallel outputs

Term	Value
Voltage	12 V
Current	24 A

4.1.1 Bicycle Motor Simulation:

A bicycle simulator was used to analyze the power and torque of the motor under various loads and different increments. The red line shows the power output of the hub motor. The power output is zero at 0 rpm, rises up to a maximum, and then falls back down to zero once the wheel is spinning at its normal unloaded speed.

The green curve is the efficiency curve for the electrical drive system. It is a ratio of the mechanical power coming out of the hub motor to the electrical power going into the controller.

The blue curve can be configured to display either the torque output of the hub in Newton-meters or the thrust of the wheel in pounds. Thrust naturally increases as you select smaller wheel sizes, while the torque of the motor is independent of wheel diameter. The pounds thrust needed to overcome gravity when climbing a hill is simply $\text{weight} * \% \text{grade}$.

The black curve shows the load line of the vehicle, or the % grade hill that the system will climb at steady state. The load line is the default choice, and it directly shows the amount of power necessary to move the bicycle.

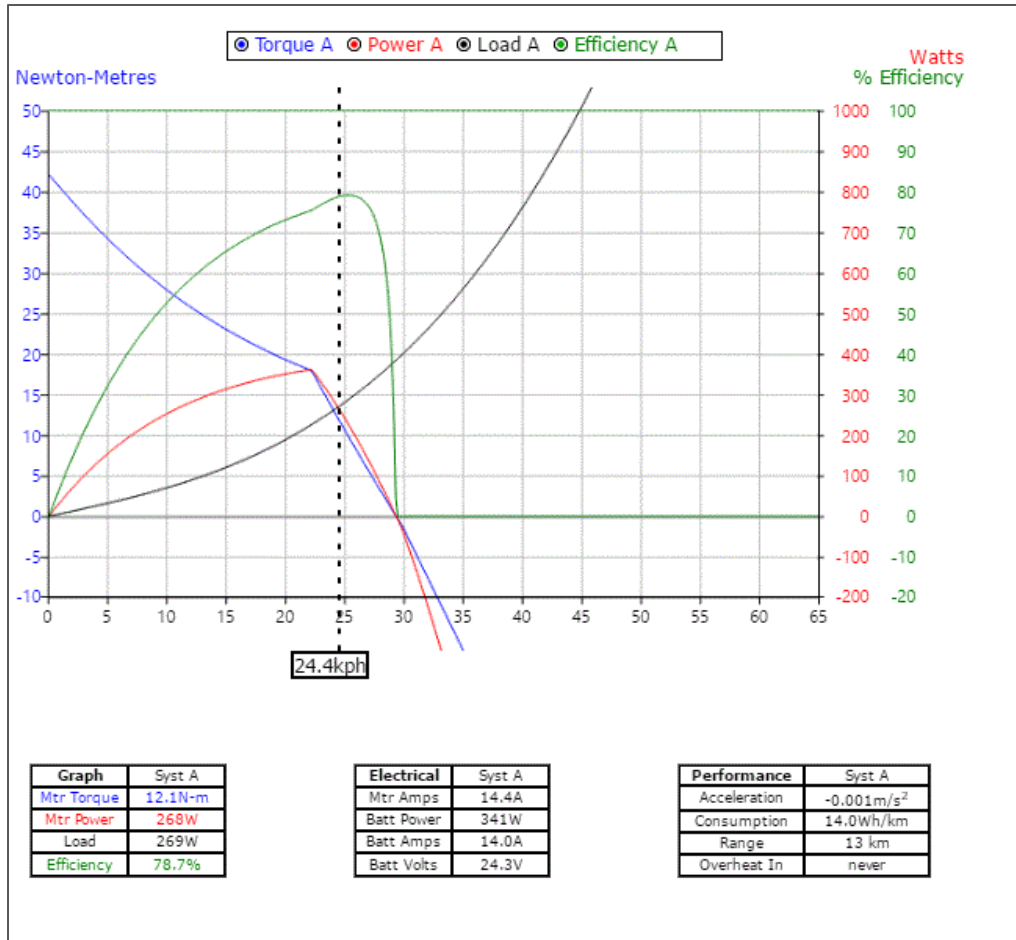


Figure 4.4: Graphical power, efficiency, torque, and load data

Figure 4.4 shows the torque needed to accelerate the bike. Also, it shows the maximum power needed at grade 1.5%. The maximum power needed in this situation is 268W.

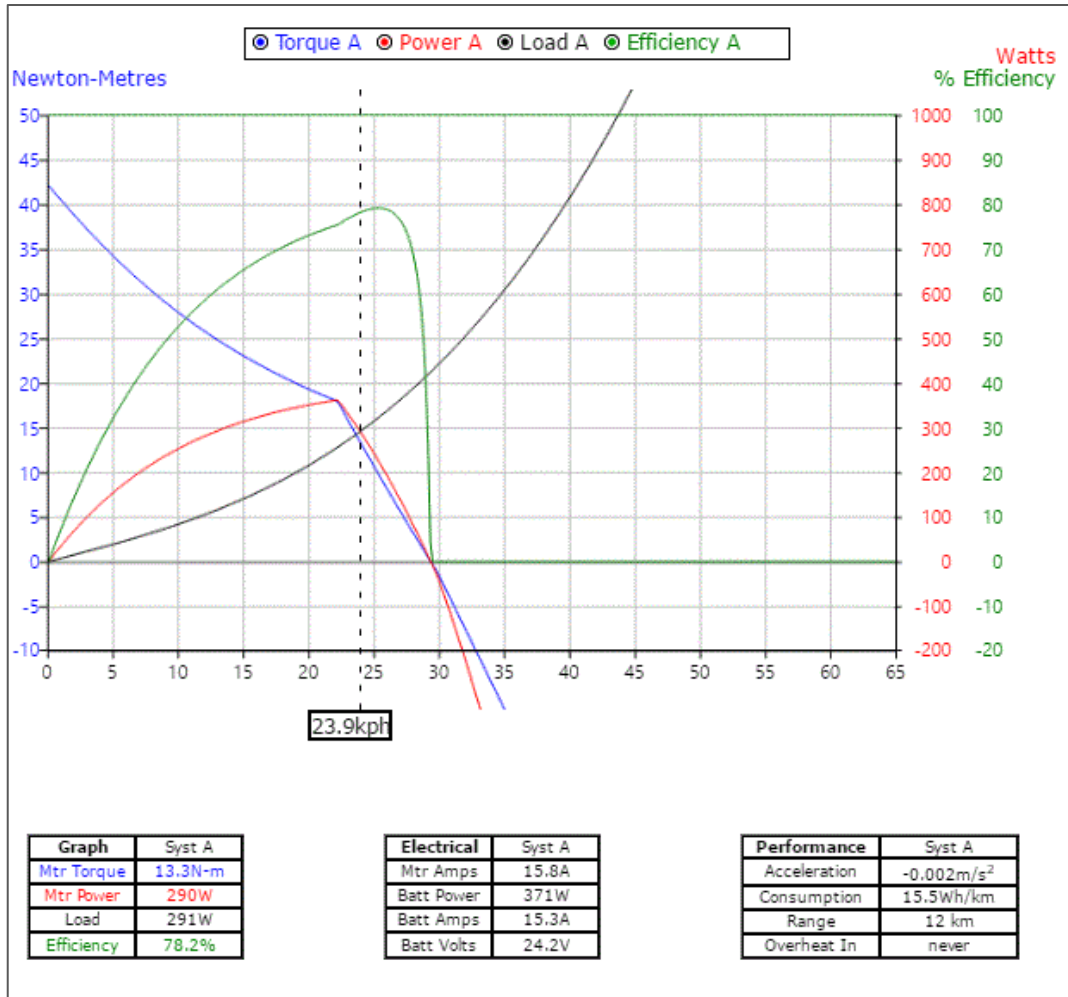


Figure 4.5: Graphical power, efficiency, torque, and load data

Figure 4.5 shows how the torque and the maximum power effected when the grade % is changed. When the grade is 2% the torque went up to 13.3 N.m and the maximum power went up to 290 W.

The bicycle parameters have been set in a bicycle simulator to test and analyze the power and torque inputs. The below Figures 4.6-4.11 simulate and analyze the inputs of the bicycle at different speeds and at straight line surface.



Figure 4.6: Bicycle simulation at speed of 20.1 km/h

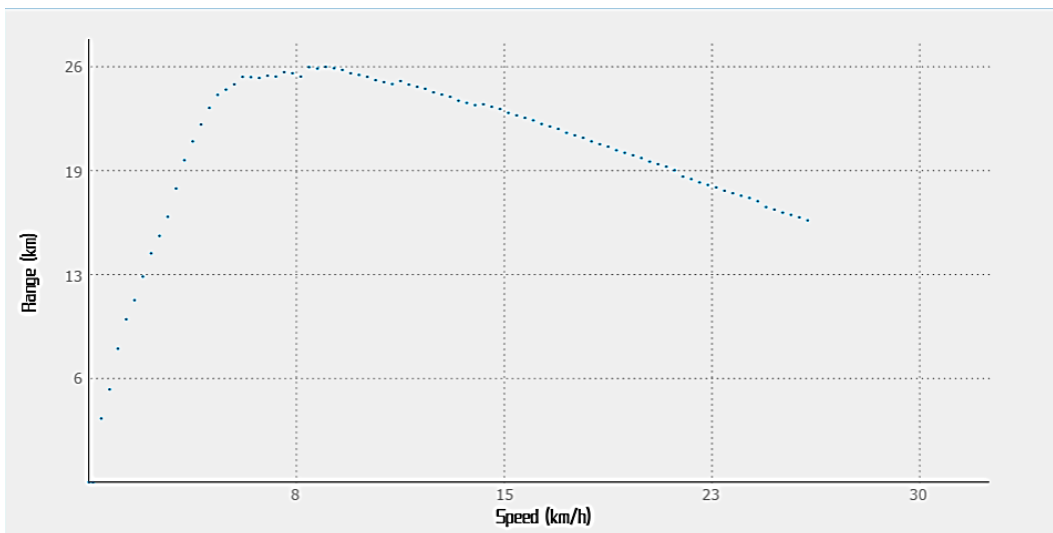


Figure 4.7: Speed vs. distance traveled graph



Figure 4.8: Bicycle simulation at speed of 5 km/h and 5% inclined surface

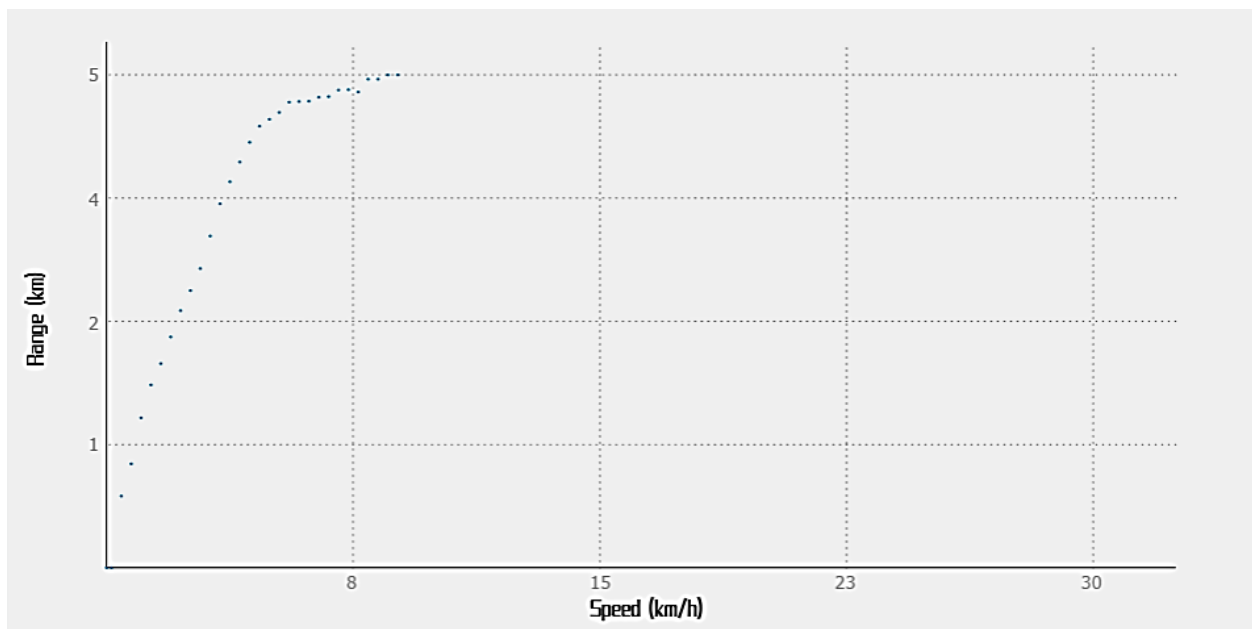


Figure 4.9: Speed vs. distance traveled at 5% inclined surface



Figure 4.10: Bicycle simulation at speed of 10 km/h and 10% inclined surface

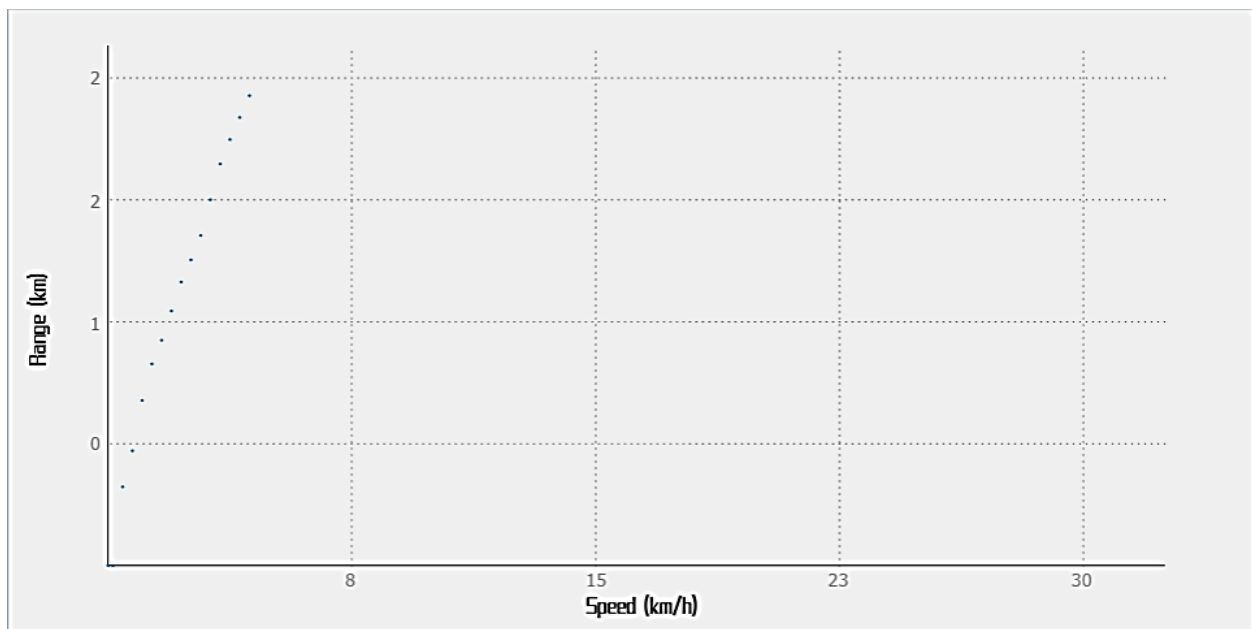


Figure 4.11: Speed vs. distance traveled at 10% inclined surface

4.2 Power Generation:

Power generation is the second part of the project where the solar panel will start to charge the batteries from sun heat, figure 4.12. The solar panel has been tested to recharge the batteries in the system and it has been measured 10 W of power as input to the batteries.



Figure 4.12: Solar Panel

The second source of power is a generator. After searching for the local market figure 4.13, a workshop has a generator of the car (Toyota Corrola, 2012) as shown in figure 4.14. The plan was to fabricate this generator to fit in our mechanism by welding a gear on the pulley and attach it to the rear gear. The generator did not achieve the design specification needed, it is heavy and the capacity of the rear basket was not enough.



Figure 4.13: Workshop



Figure 4.14: Generator

4.3 Overall Results, Analysis and Discussion:

We have conducted two tests described as follows:

- First Test:

As the motor has been installed on the bicycle's frame, a 12 V battery was connected to the motor to start the test figure 4.15. As a result of the lack of voltage, the bicycle did not move at all and the battery got empty within 30 seconds. Therefore, group members were evaluating the problem that prevented the bicycle from moving. We had to seek assistance from electrical and

mechanical instructors to assist in finding the issue, the final decision was to connect two batteries in parallel to get 12V and 24aH figure 4.16.



Figure 4.15: First test



Figure 4.16: Batteries connected in parallel

- Second Test:

The test has been conducted again with holding the bicycle at a certain level from the ground and giving the rear wheel a little push. The result was a good start and it worked. One more thing, we have noticed that the wires connected to the motor plus motor itself got heated during the process. The wires we had are thin wires and the switch was burned, therefore, we have replaced it with thick wires figure 4.17.



Figure 4.17: Thick Wires

- Third Test:

After doing two tests, fixing the problems mention before, in addition to installing the solar panel, the system seemed to be working fine. Weight was added to the bicycle, however, the system worked properly figure 4.18. At the end, a third test was initiated, the results were as expected, the motor worked properly, the wires did the job perfectly, and the switch worked fine.



Figure 4.18: Final Installed System

Chapter 5: Project Management

5.1 Project Plan:

Table 5.1 shows the items that were needed to be purchased from the market to be assembled in our prototype. After research and looking through the Saudi market, we have found all of the items except for the motor. We had to buy it from abroad. We have searched online for the motor with an exact performance that fulfills our need for the project. Regarding the rest of the items, we have purchased from the local market.

Table 5.1: List of items

Item	Quantity
Motor	1
Battery	2
Chain	1
Gear	1
Switch	1
Wires	2 colors
Solar panel	1
Generator	1

Table 5.2 shows the tasks for each member. For the bicycle, we have decided that Ahmed Mohammed and Faisal Aldosari should get a proper bicycle that meets our specifications in the project. For the motor, after doing a search on the internet and looking through previous works,

we have found a proper motor on the website Amazon, which was purchased by the member Abdulaziz Alghamdi. For the electric parts of the project, Ahmed Mohammed, Faisal Aldosari, and Abdulaziz Alghamdi went to an electric shop in Alkhobar called “Waves”, they had the electrical components that we were looking for. Going through our project we had to buy Gears and Chains to assemble them in the system, Ahmed Mohammed and Abdulaziz Alshamrani went to Dammam looking for these parts, eventually, they found the needed parts. Last but not least a generator was needed, as same as the way of purchasing the motor we did it for the generator.

Table 5.2: Tasks for team members

Item	Team Member
Bicycle	Ahmed Mohammed, Faisal Aldosari
Motor	Ahmed Mohammed, Faisal Aldosari, Abdulaziz Alghamdi
Battery, solar panel, wires, and switch	Ahmed Mohammed, Faisal Aldossari, Abdulaziz Alghamdi
Gear, chains	Ahmed Mohammed, Abdulaziz Alshamrani
Generator	Ahmed Mohammed, Abdulaziz Alghamdi

5.1.1 Gantt Chart:

Task Name	Duration	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Initiation	12d																
1.1. Kick-off meeting	1d		█														
1.2. Gantt chart	4d		█	█	█	█											
1.3. Project definition	2d			█	█												
1.4. Project objectives	4d			█	█	█	█										
1.5. Project specification	1d				█												
1.6. Application	2d				█	█											
2. Planning	10d																
2.1. Literature review	10d																
2.1.1. Project background and history of bicycles	2d			█	█												
2.1.2. Previous work	2d			█	█												
2.1.3. Comparative study	1d				█												
2.1.4. Parts	3d				█	█	█										
2.1.4.1. Gear mechanism	3d				█	█	█										
2.1.4.2. Clutch	1d					█											
2.1.4.3. DC motor	1d						█										
2.1.4.4 Generator	1d							█									
3. Execution	10d																
3.1 System design	10d																
3.1.1 design constraints	3d							█	█	█							
3.1.2 design methodology	6d							█	█	█	█	█					
3.1.3 product subsystems and components	2d									█	█						
3.2 system implementation	7d																
3.2.1 torque calculations	4d										█	█	█	█			
3.2.2 drawings	4d										█	█	█	█			
4. Controlling	7d																
4.1 system testing and analysis	3d																
4.1.1 motor	1d																
4.1.2 power generation	2d																
4.1.3 overall results, analysis and discussion	2d																
5. Monitoring	28d																
5.1 project management	16d																
5.1.1 project plan	2d																
5.1.2 contribution of team members	2d																
5.1.3 project execution monitoring *	2d																
5.1.4 challenges and decision making	11d																
5.1.4.1 problems with team members	2d																
5.1.4.2 challenges of project parts	4d																
5.1.4.3 problems with equipment	3d																
5.1.5 project bill of material and budget	4d																
5.2 project analysis	13d																
5.2.1 life-long learning	4d																
5.2.2 impact of engineering solutions	4d																
5.2.3 contemporary issues addressed	5d																
5. Close-out	9d																
6.1 conclusion	2d																
6.2 recommendations	2d																
6.3 Final report and presentation	5d																

- On 1st of March, Ahmed Mohammed and Faisal Aldosari purchased the bicycle. Abdulaziz Alghamdi ordered the motor from Amazon online shopping, and it took two weeks to arrive.
- On 6th of March, Ahmed Mohammed and Abdulaziz Al-shamrani went to bicycle stores in Dammam to look for chains and gears.
- On the 10th of March, Faisal Aldosari went to Aramex and received the Motor.
- On the 11th of March, Ahmed Mohammed and Abdulaziz Alghamdi purchased the batteries, solar panel, and wires.
- On the 12th of March, the whole group went to a workshop to weld the gear with the motor.
- On the 15th of March, Mohanad Alyami took the bicycle to a workshop to assemble the chain with the gear
- On the 25th of March, we installed the parts on the bicycle.
- On the 1st of April, we installed the stand for the batteries.
- On the 8th of April, we started testing until the end of the month.
- On the 1st of May, we have faced an issue with the switch.
- On the 4th of May, we installed a new switch. We are still in the testing period.

5.2 Contribution of Team Members:

- Ahmed Mohammed:
 - a. Team Leader
 - b. Designer “Solid-Works drawings”
 - c. Parts decider

- d. Tasks distributor
- Faisal Aldosari:
 - a. Calculation analysis
 - b. Engineering concepts and analysis
 - c. Report organizer
 - d. Workshop connections
- Abdulaziz Alghamdi:
 - a. Online shopping
 - b. Group enthusiasm
 - c. New ideas
- Abdulaziz Alshamrani:
 - a. Market expert
 - b. Parts installation
- Muhanad Alyami:
 - a. Prototype transportation
 - b. Market expert

5.3 Project Execution Monitoring:

The executing, monitoring and controlling phases of the project management lifecycle consist of completing and managing the work required to meet the project objectives. This phase also ensures that the project performance is monitored and adjustments to the project schedule are made as needed. Since the first lecture, we attended we have created a WhatsApp group to make sure every member of the group is updated with the progress. Also, we have used Google drive

to share the documents we needed and to upload the research so we all worked on the same word file and that was very helpful and effective.

We have started our meetings on the 18 February and we agreed to have at least two meetings per week. Every member was a cooperative and willing to do his best. We arranged the meetings days through the WhatsApp group considering all the group member's exams or any other university work. That was a good experience for the group members and helped us to go over many barriers and obstacles.

On the other hand, we have had several meetings with our advisor and co-advisor. To reviewing our research with them and get their comments and feedback. Also, we went to the advisor to help us with some calculation and design specifications. Those meetings had a great impact on our project and played the main role in our performance and progress. Furthermore, we had two meetings with some of the electrical engineering faculties to discuss some calculation with them.

5.4 Challenges and Decision Making:

Through the senior year semester, we have faced a couple of challenges such as:

- Problems with team members.
- Challenges of project parts allocation.
- Problems with equipment.

5.4.1 Problems with Team Members:

First, we had a time conflict with group meetings because of the classes' schedules. Also, it was the first time of working on a project with the team members. Furthermore, when the ending

period of the semester has been shifted earlier, it was a challenge to finish the project which caused us to double the effort.

5.4.2 Challenges of Project Parts:

First, we have faced problems with the motor; we could not find the required motor specifications in the local market. We have decided to order the missing part from the abroad website markets. Secondly, the chain was not fitted on the chain wheel gear. Therefore, we have tried two different sizes of the chain to get the proper one. Thirdly, the connected motor gear was small difficult as a result, we have fabricated bigger gear that connects the rear gear to the motor.

5.4.3 Problems with Equipment:

We had a problem with the motor switch because it was burned while we were testing the project due the overload. Also, we have tried to find a proper battery because it became empty while we were testing the motor.

5.5 Project Bill of Materials and Budget:

At the beginning of the project, we have estimated the amount of our budget to be around 2000 SR. As we kept purchasing the equipment that is required to build the prototype, we have noticed that the required equipment is not that expensive. When we have reached the final shape of our project, we have calculated each part so the total was 1847 which is less than our approximate budget. Table 5.3 shows all the needed components to complete building the prototype and their costs.

Table 5.3: Bill of Material and Budget

Part Name	Description	Quantity	Unit Price	Total Amount
Bicycle	-	1	799 SR	799 SR
Battery	12 V, 12 Amp	2	170 SR	340 SR
Battery Charger	10 Amp	1	110 SR	110 SR
Solar Panel	10 Watt	1	175 SR	175 SR
Switch	-	1	5 SR	5 SR
Motor	12 V, 280 Watt	1	170 SR	170 SR
luggage carrier	-	1	62 SR	62 SR
Chain	-	2	27.5 SR	55 SR
Generator	6 Watt	1	131 SR	131 SR
Total				1847 SR

Chapter 6: Project Analysis

6.1 Life-long Learning:

The senior project is assigned for students to gain experience, problem-solving, and learning. To have a project to do within the four-month period is not as easy as it seems, it includes a lot of challenges, time management, and writing reports. With these factors, gaining knowledge is a must. The following points will specify in detail the knowledge we have gained during this project:

6.1.1 Project Analysis:

Starting a project, as engineers we must have design calculations before even purchasing parts. While going through the phases of the project, we have learned from our mistakes which enable us to resolve some trouble with getting a better-quality part. The analysis took place on the tasks given and the target that we must achieve. At the end, we have had better outcomes because we started with analyzing the project.

6.1.2 Equipment's Specifications:

Choosing the proper equipment and parts for our project was a challenge for us. We had to be specific to each part. We had to choose proper parts relating to our initial design. Finding this equipment was not easy since some of the parts were purchased locally, the rest was purchased from abroad through online shopping websites. The knowledge in this factor was to learn about a new local market, and searching online for specific equipment.

6.1.3 Installation:

At the beginning, we have struggled in motor installation; the problem was with the frame. The frame material was made from aluminum. The initial idea was to weld the motor to the frame. When we tried to weld the motor, we have noticed that there was no sign for welding. The reason we have discovered was that the aluminum is not easy in to be welded, more advanced welding technology is needed to do this job.

6.1.4 Problem Solving:

Going through the phases of the project, we have faced a lot of problems that was solved eventually. The first problem was related to the battery. When we started the motor the battery got drained out in almost thirty seconds. The second problem we faced was regarding locating the motor in a proper distance that will suit our final mechanism. The knowledge we have gained through all problems is finding solutions.

6.1.5 Teamwork:

One of the major factors of being successful at any workplace is teamwork. We have scheduled meetings for brainstorming, discussion, and sharing ideas. We have learned patience while working together, we stood up for each other, and we went through a lot together. The knowledge gained by this important factor is patience and team management.

6.1.6 Engineering Sense:

Relating what we have studied in the university to our project was a major use in our decisions. We have applied many formulas learned in different courses. Some problems we faced could not be solved by formulas; the solution was to think in engineering sense regarding our eminent experience and creativity throughout the courses' projects we have done. The knowledge in this factor was to mix critical thinking and creativity to engineering.

6.2 Impact of Engineering Solutions:

The impact of our project on the society is to reduce pedaling effort on bicycles for riders. Cycling in various roads and landscapes conditions easily is our target. Moreover, the impact on the environment is by ignoring the use of Internal Combustion Engines (ICE). Our project is not consisting of any Internal Combustion engines (ICE), it is only depending on a mechanism that we get its power from an electric source. For example, batteries usually charged by chargers. On the other hand, we use a small generator to charge the battery that acts as the power supplier. This kind of mechanism is not affecting the environment. Furthermore, our project is a simple example of an efficient economic bicycle. The installed parts are not that expensive, its range around 70 – 150 SR each. The total amount and its efficiency are better to use rather than other bikes which cost and consume more budget.

6.3 Contemporary Issues Addressed:

Renewable energy sources in Saudi Arabia are still under development in some new applications. The main use of solar panel is to generate electrical energy from sun heat and radiations, in addition to that, it is a source of clean energy that does not affect the atmosphere comparing to gasoline engines. Automobiles in Saudi Arabia are the most major mean of transportation, which pollutes the environment. We have focused on renewable energy (solar panel) and its design

calculations, which is friendly to the environment. In Saudi Arabia the weather conditions are hot in summer and cold in winter, bicycles will be useful in both conditions. First, the hot climate will be a great opportunity for reducing the weight of people. Secondly, the cold weather is a great time for cycling and getting warmed up. Linking our new mechanism to both scenarios (hot and cold weathers) will contribute in both of the conditions mentioned earlier about the difference in inclement.

Chapter 7: Conclusion and Future Recommendations

7.1 Conclusions:

After we have completed our research project we have conducted a lot of results regarding our project. First, we have learned a lot about the local market, compared parts, dimensions, decision making, and finally installation and fabrication. Second, our project works effectively, we had a minor problem with the motor it kept getting heated when working. The problem was due to the extra load on the motor because we were starting the motor while the bicycle is not moving. One of the major challenges that we faced was the battery until finally, we solved that problem as mentioned before.

7.2 Future Recommendations:

- We recommend and motivate people to start utilizing electric bicycles since they are effective in reducing the pedaling efforts.
- Installing a motor that produces more power than 280 W to overcome steeply inclined surfaces.
- Installing a wind turbine on the front side of the bicycle to generate power in order to charge the connected batteries.
- Connecting a controller in the system to control the performance of the motor when needed.
- Installing a larger solar panel to absorb a large amount of sunlight in order to accelerate the charging time.

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Appendix A

	SDP – WEEKLY MEETING REPORT
	Department of Mechanical Engineering Prince Mohammad bin Fahd University

SEMESTER:	Spring	ACADEMIC YEAR:	2017
PROJECT TITLE	Design of an Energy-Efficient Bicycle		
SUPERVISORS	Dr. Muhammad Asad		

Month 1: February

ID Number	Member Name
Ahmed Mohammed	201200501
Faisal Aldosari	201200888
Abdullaziz Alshamrani	201203368
Abdulaziz Alghamdi	201102875
Muhanad Alyami	201200665

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
	Project definition	All Team Members	100%	
	Project objectives	All Team Members	100%	
	Project specifications	All Team Members	100%	
	Gantt Chart	Ahmed	100%	

List the tasks planned for the month of February and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
	Research	All Member

- To be Filled by Project Supervisor and team leader:
- Please have your supervisor fill according to the criteria shown below

Outcome f:
An understanding of professional and ethical responsibility.

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d:
An ability to function on multidisciplinary teams.

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
d1. Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Understands and applies proper and accurate team work plans and allocate resources and tasks
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects
d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	Ahmed Mohammed	4	4	4	4
2	Faisal Aldosari	4	4	4	4
3	Abdullaziz Alshamrani	4	4	4	4
4	Abdulaziz Alghamdi	4	4	4	4
5	Muhanad Alyami	4	4	4	4

Handwritten signature/initials

Comments on individual members

Name	Comments



SDP – WEEKLY MEETING REPORT

**Department of Mechanical Engineering
Prince Mohammad bin Fahd University**

SEMESTER:	Spring	ACADEMIC YEAR:	2017
PROJECT TITLE	Design of an Energy-Efficient Bicycle		
SUPERVISORS	Dr. Muhammad Asad		

Month 2: March

ID Number	Member Name
Ahmed Mohammed	201200501
Faisal Aldosari	201200888
Abdullaziz Alshamrani	201203368
Abdulaziz Alghamdi	201102875
Muhanad Alyami	201200665

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Bicycle purchasing	Ahmed & Faisal	100%	
2	Motor purchasing	Ahmed & Ab. Alghamdi	100%	
3	Chain purchasing	Ahmed & Ab. Alshamrani	100%	
4	Batteries and electrical wires	Ahmed & Ab. Alghamdi	100%	

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	Motor receiving	Faisal
2	Chain assembly	Muhanad
3	Parts installation	All team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	Ahmed Mohammed	4	4	4	4
2	Faisal Aldosari	4	4	4	4
3	Abdullaziz Alshamrani	4	4	4	4
4	Abdulaziz Alghamdi	4	4	4	4
5	Muhanad Alyami	4	4	4	4

Comments on individual members

Name	Comments

W. Alshamrani



SDP – WEEKLY MEETING REPORT

**Department of Mechanical Engineering
Prince Mohammad bin Fahd University**

SEMESTER:	Spring	ACADEMIC YEAR:	2017
PROJECT TITLE	Design of an Energy-Efficient Bicycle		
SUPERVISORS	Dr. Muhammad Asad		

Month 3: April

ID Number	Member Name
Ahmed Mohammed	201200501
Faisal Aldosari	201200888
Abdullaziz Alshamrani	201203368
Abdulaziz Alghamdi	201102875
Muhanad Alyami	201200665

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Parts installation & fabrication	All team members	100%	
2	Testing & analysis	All team members	100%	

List the tasks planned for the month of April and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	Report re-editing	All team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	Ahmed Mohammed	4	4	4	4
2	Faisal Aldosari	4	4	4	4
3	Abdullaziz Alshamrani	4	4	4	4
4	Abdulaziz Alghamdi	4	4	4	4
5	Muhanad Alyami	4	4	4	4

ASm

Comments on individual members

Name	Comments



SDP – WEEKLY MEETING REPORT

Department of Mechanical Engineering
Prince Mohammad bin Fahd University

SEMESTER:	Spring	ACADEMIC YEAR:	2017
PROJECT TITLE	Design of an Energy-Efficient Bicycle		
SUPERVISORS	Dr. Muhammad Asad		

Month 4: May

ID Number	Member Name
Ahmed Mohammed	201200501
Faisal Aldosari	201200888
Abdullaziz Alshamrani	201203368
Abdulaziz Alghamdi	201102875
Muhanad Alyami	201200665

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Project analysis	All Team Members	100%	
2	Project management	All Team Members	100%	
3	Conclusion	All Team Members	100%	
4	Recommendations	All Team Members	100%	

List the tasks planned for the month of May and the team member/s assigned to conduct these tasks

#	Task description	Team member/s Assigned
	Final editing	All Team Members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	Ahmed Mohammed	4	4	4	4
2	Faisal Aldosari	4	4	4	4
3	Abdullaziz Alshamrani	4	4	4	4
4	Abdulaziz Alghamdi	4	4	4	4
5	Muhanad Alyami	4	4	4	4

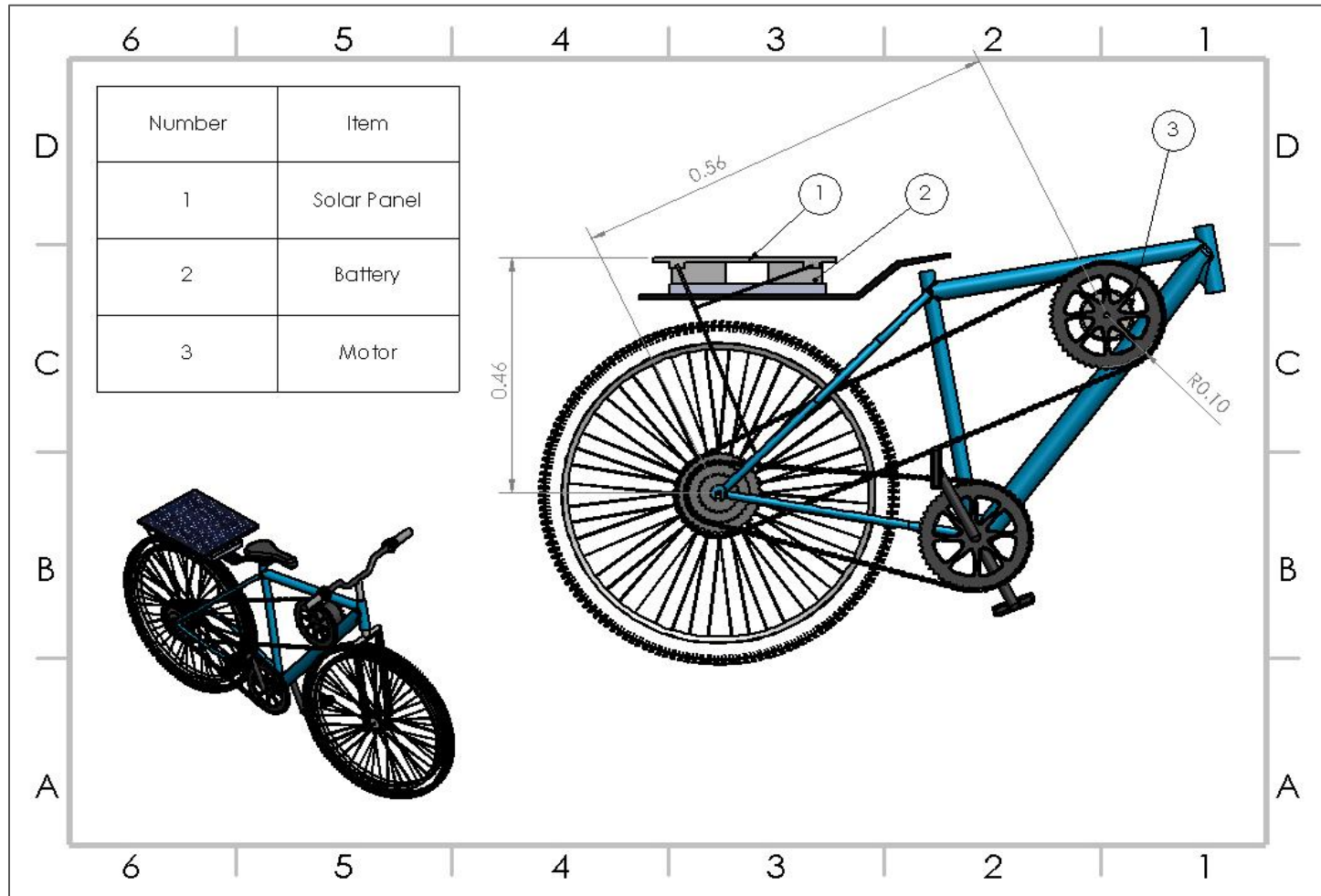
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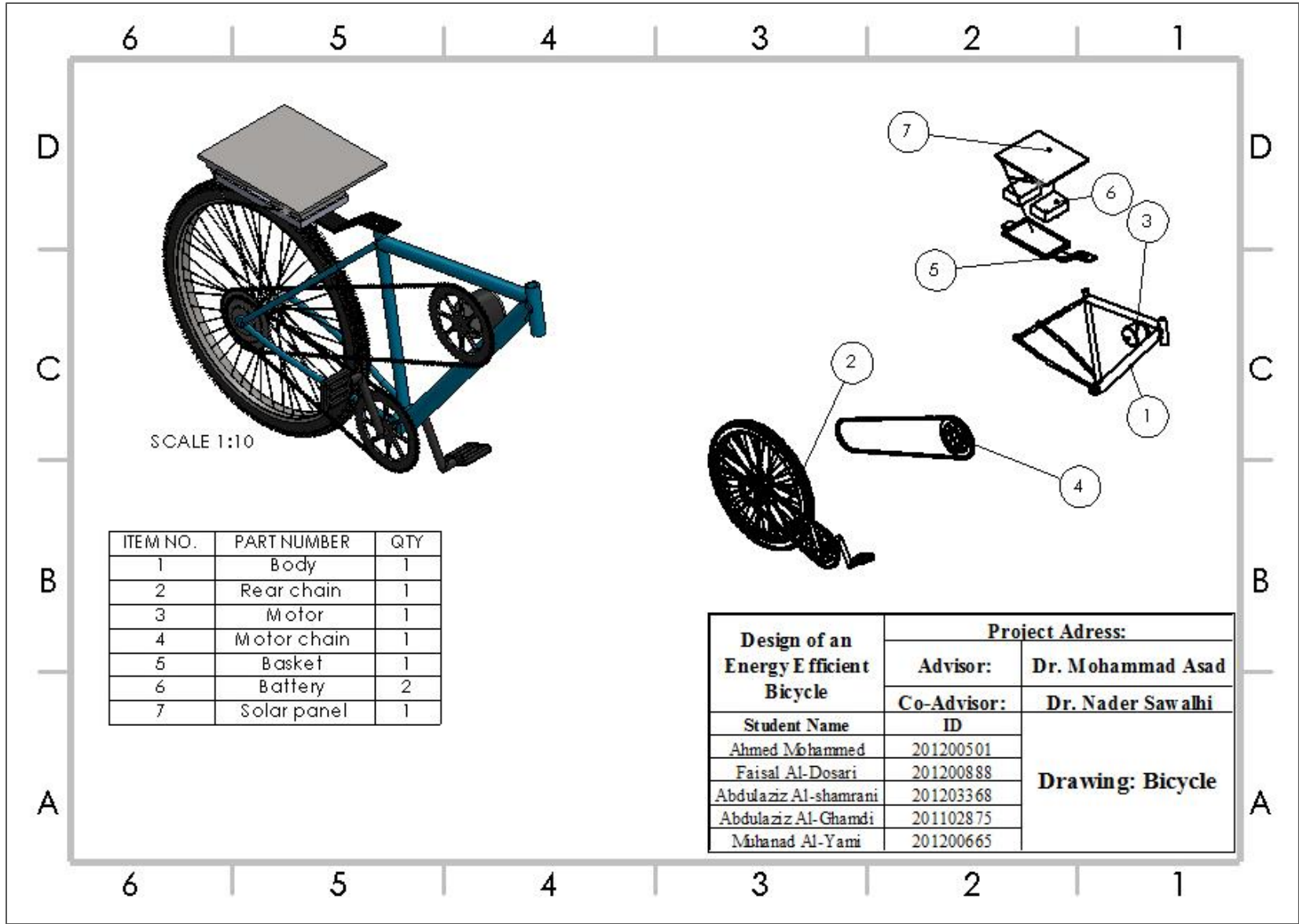
Comments on individual members

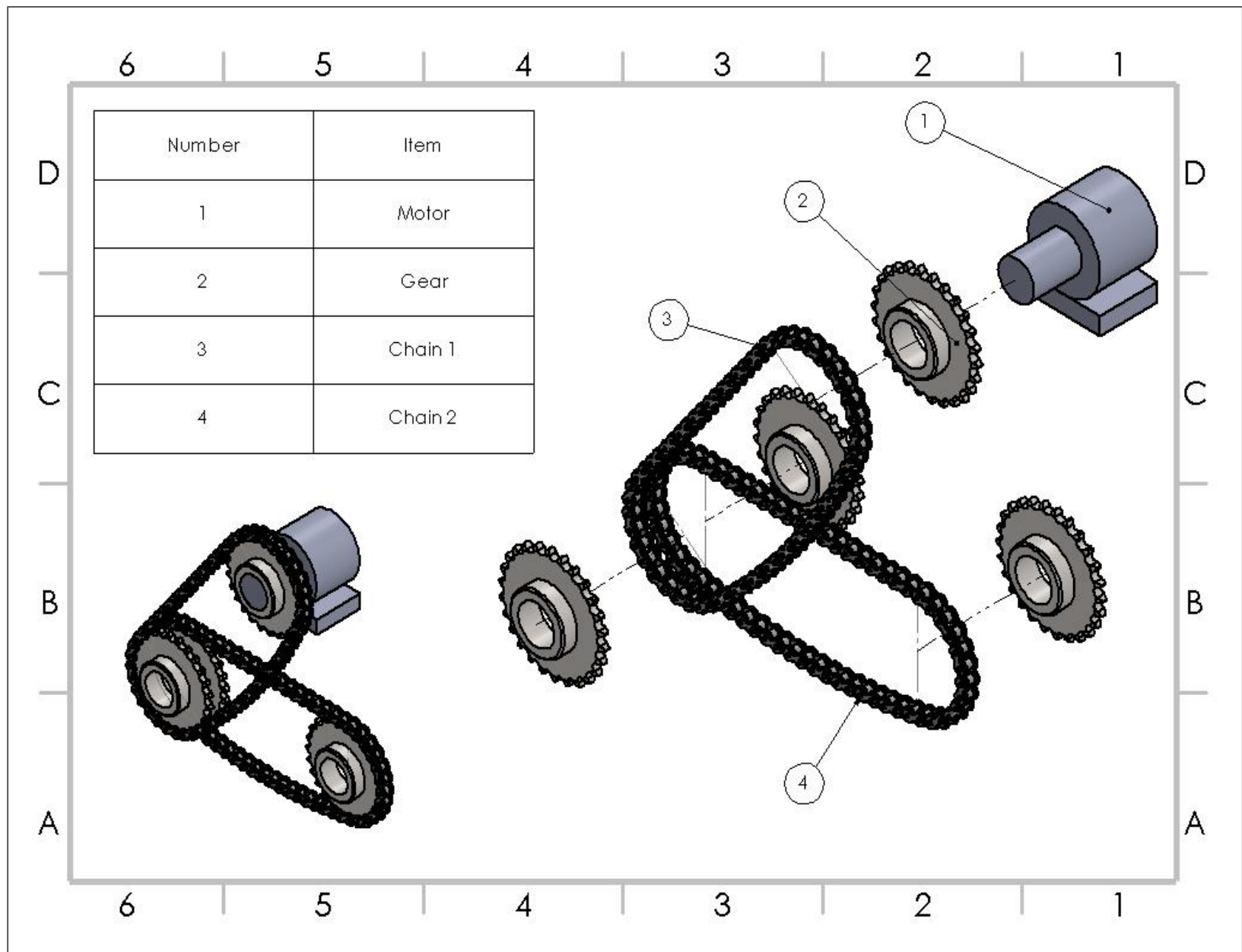
Name	Comments

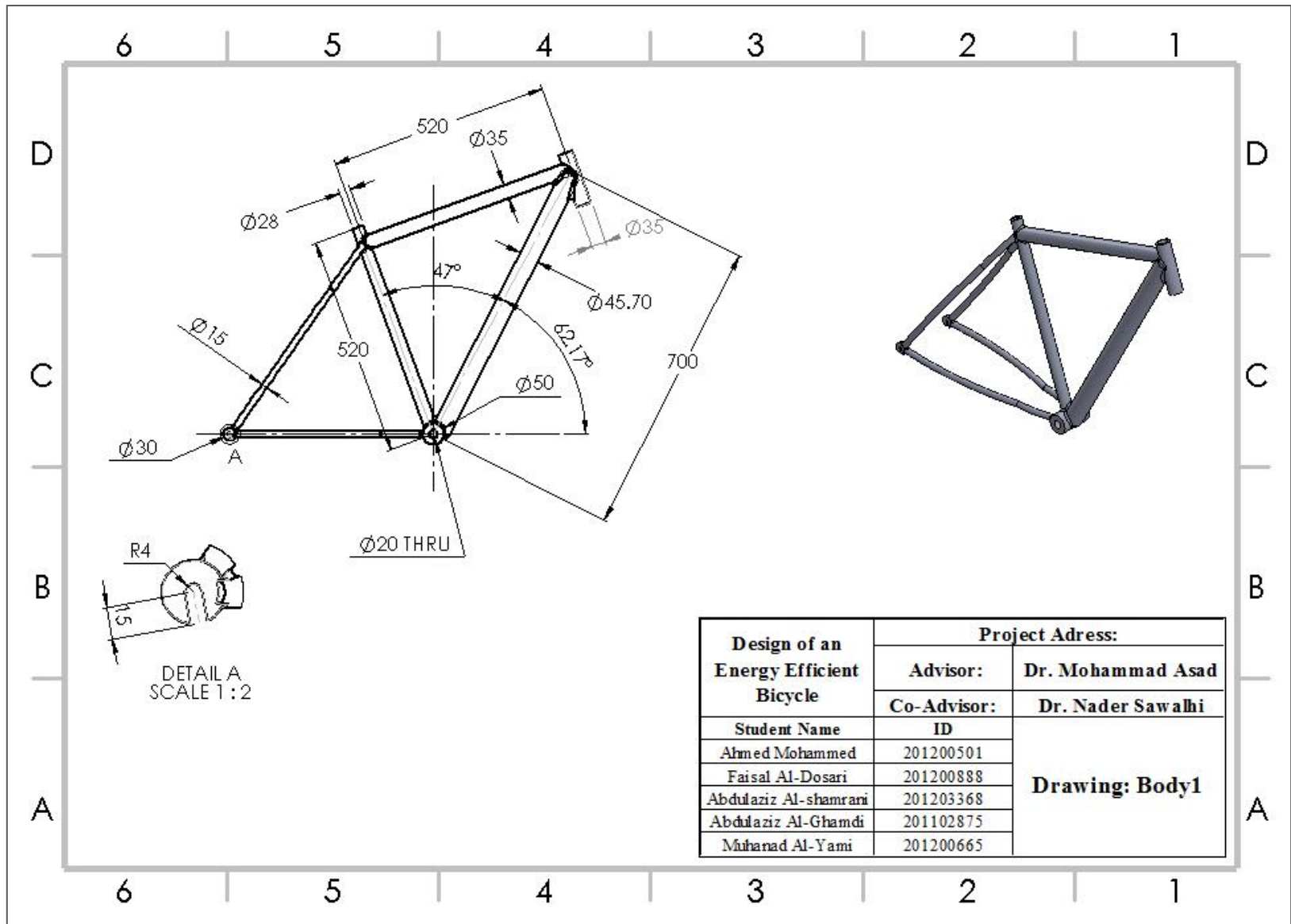
Appendix B

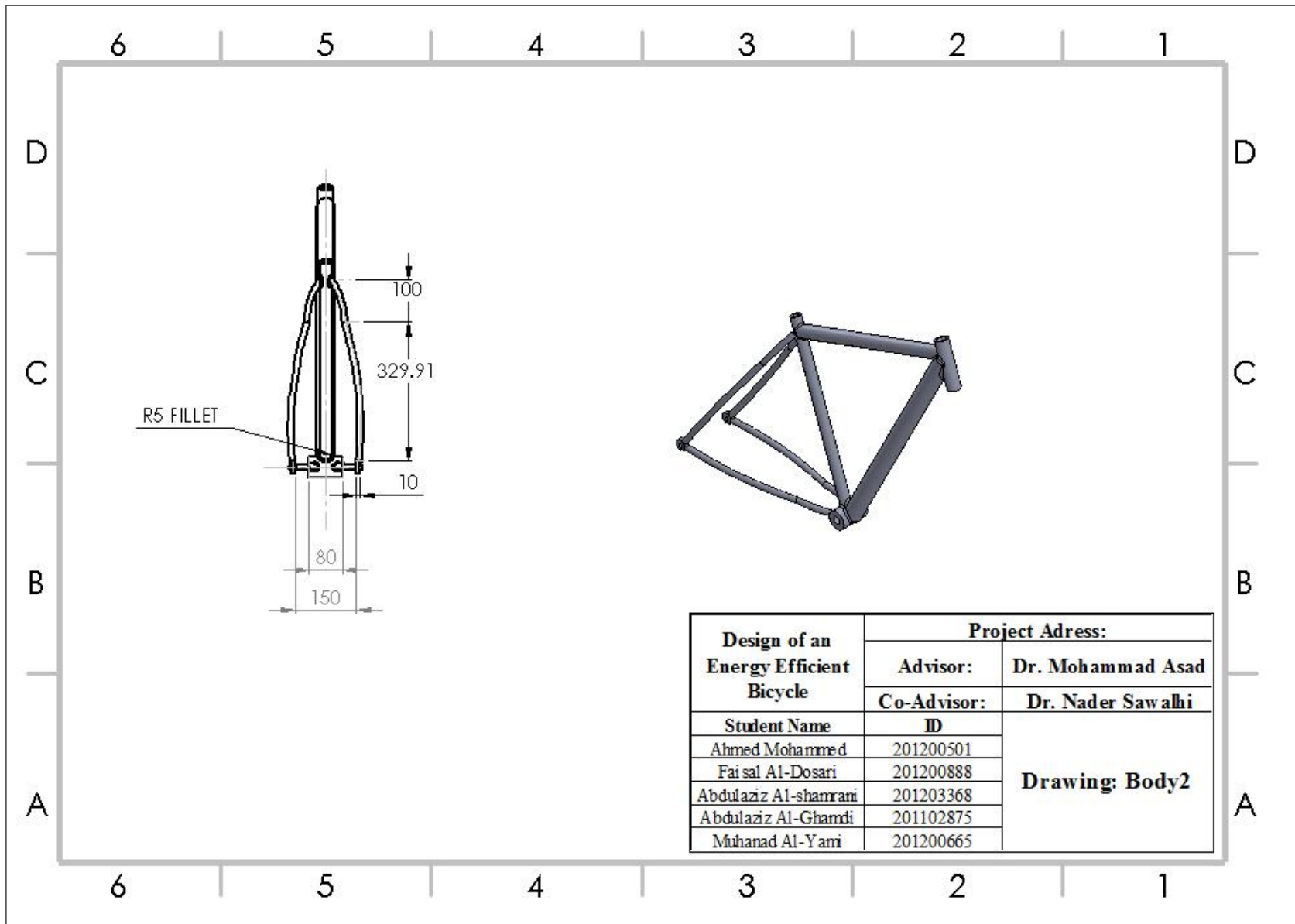
Solidworks Drawings:

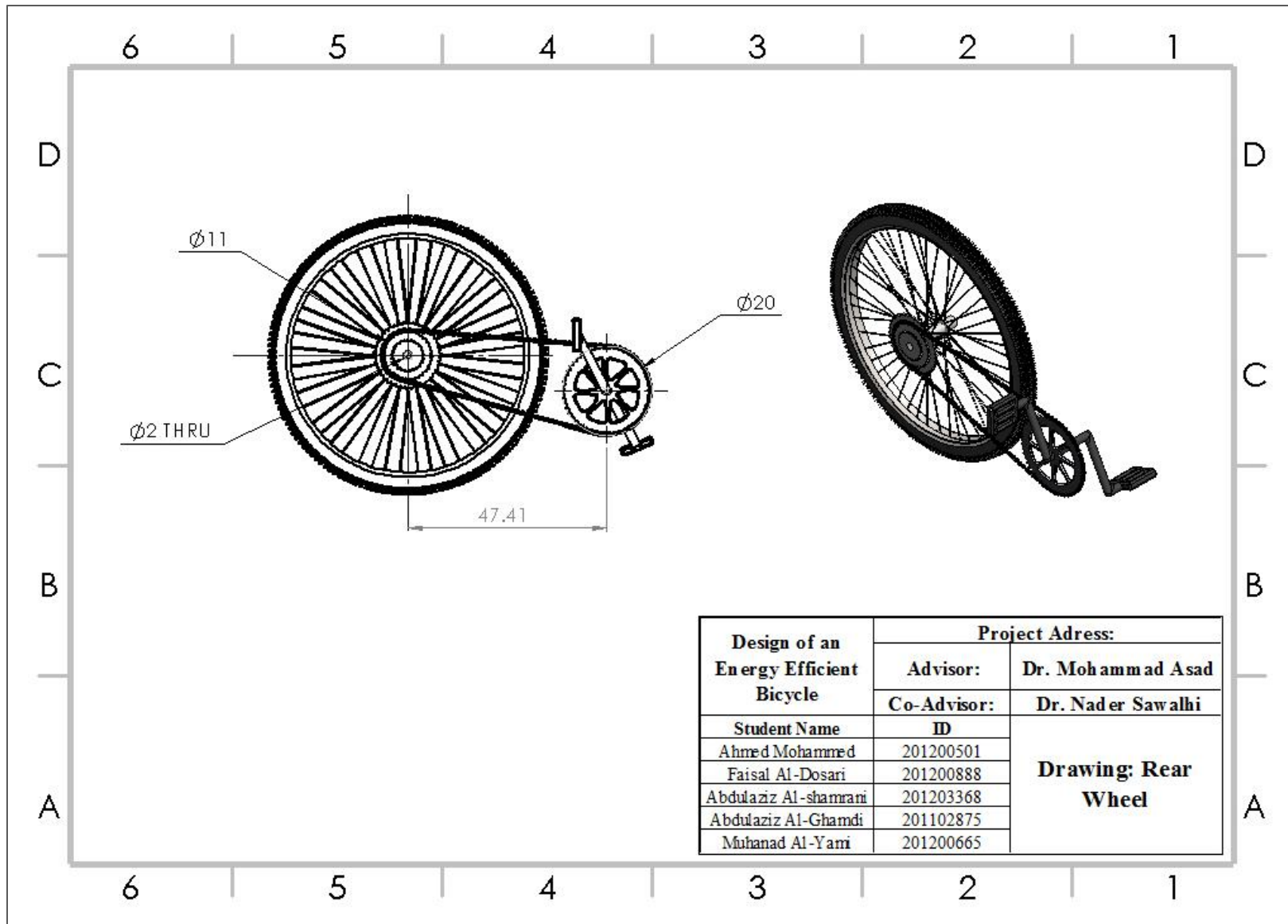


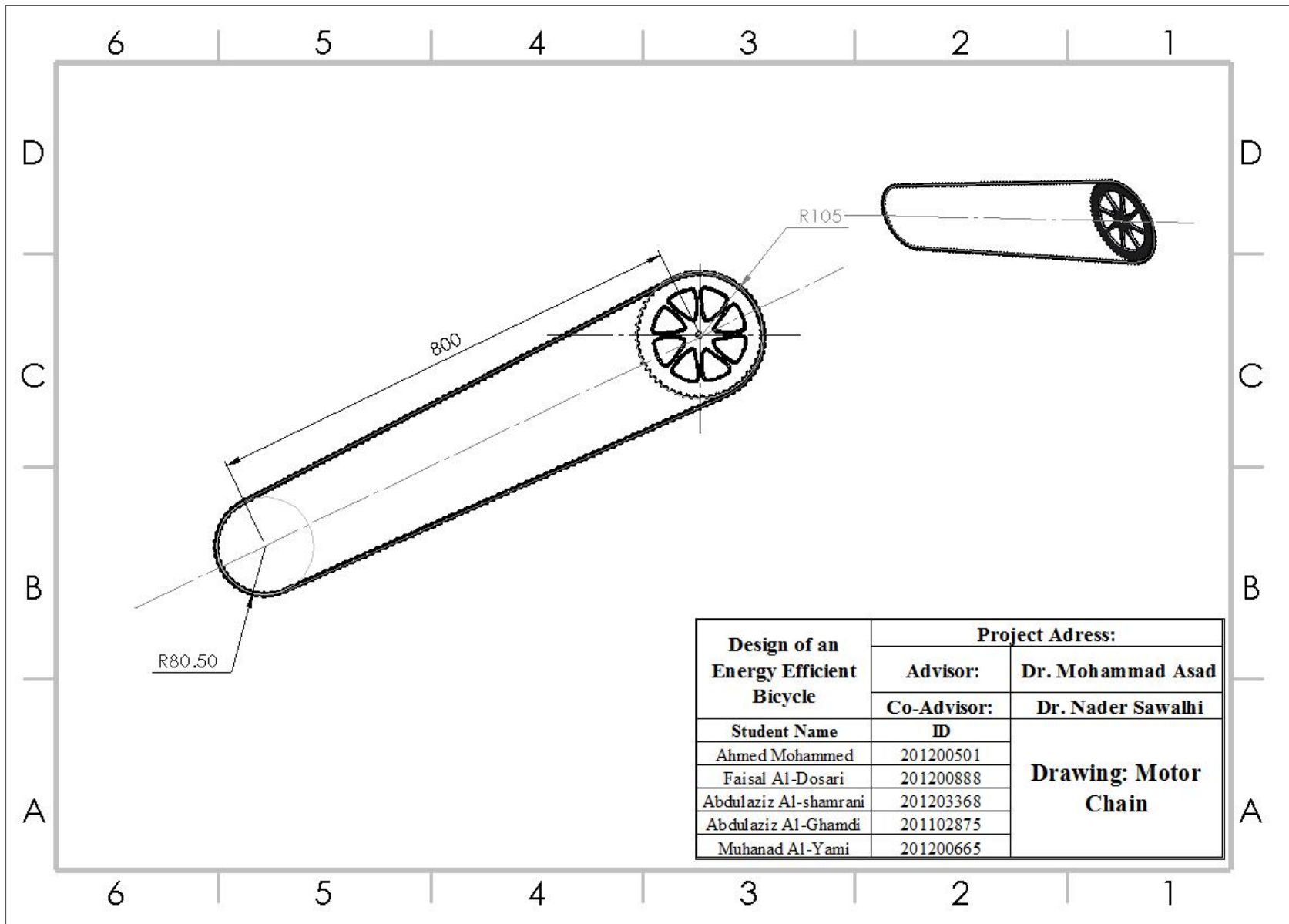


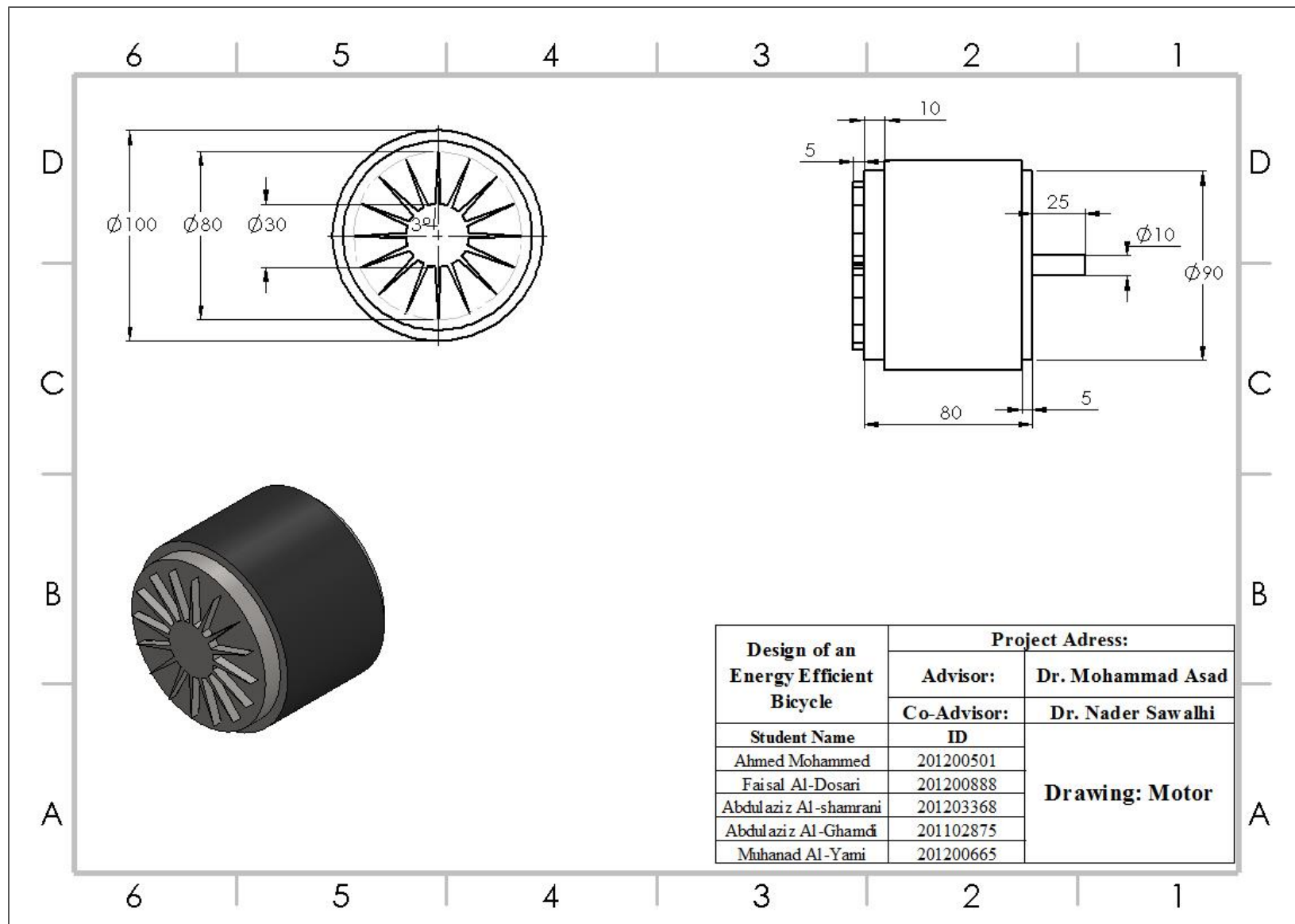


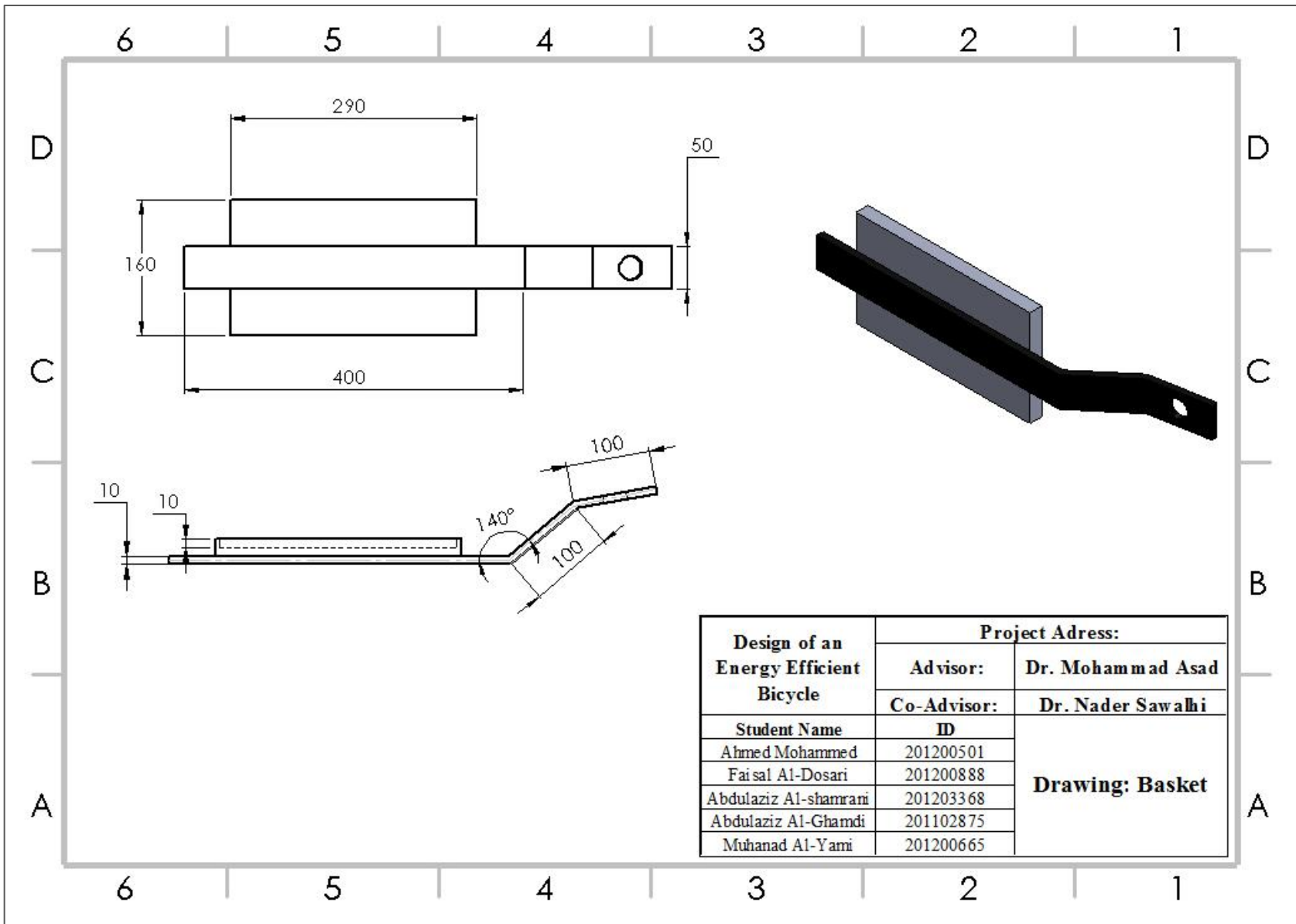


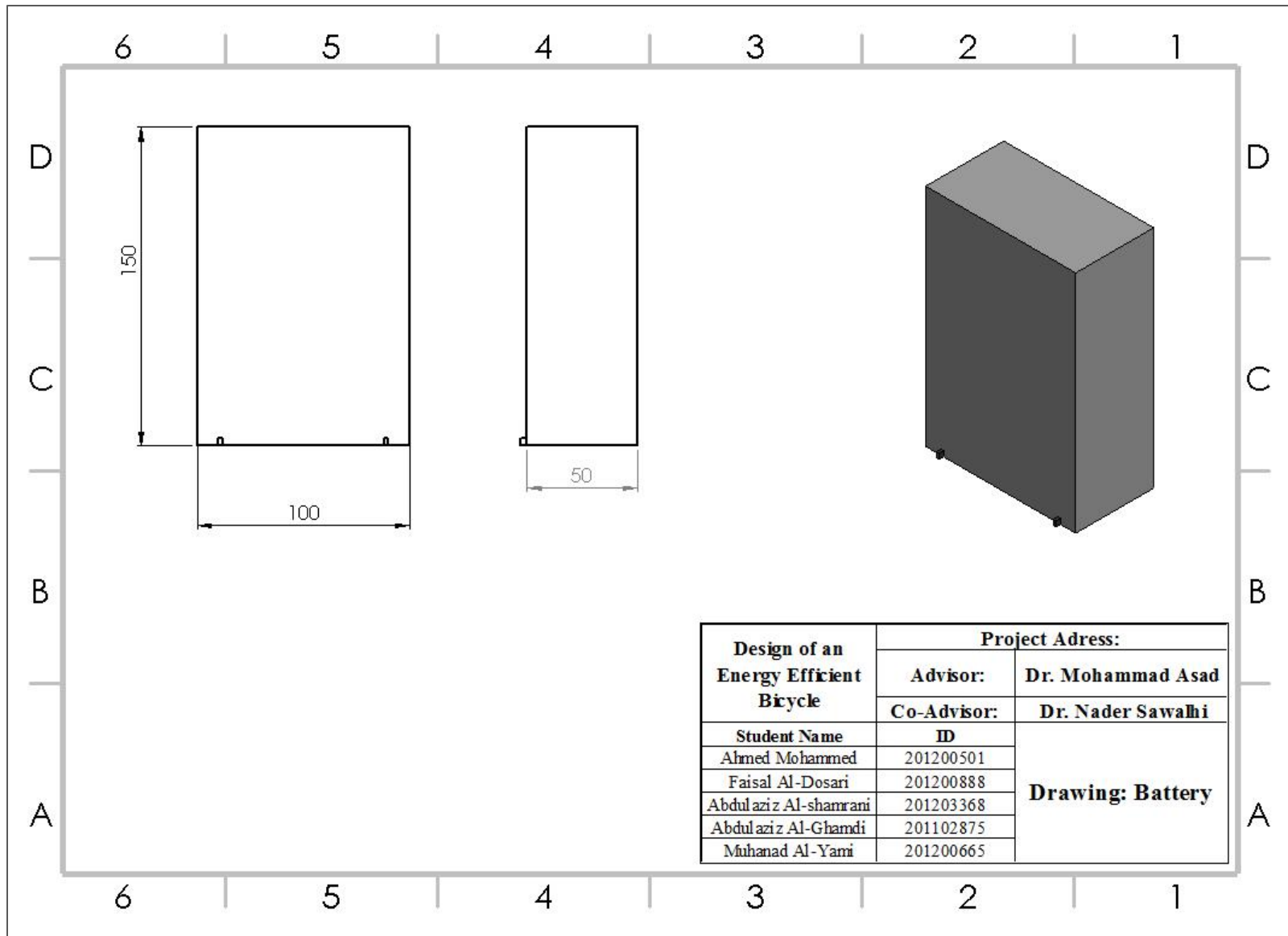


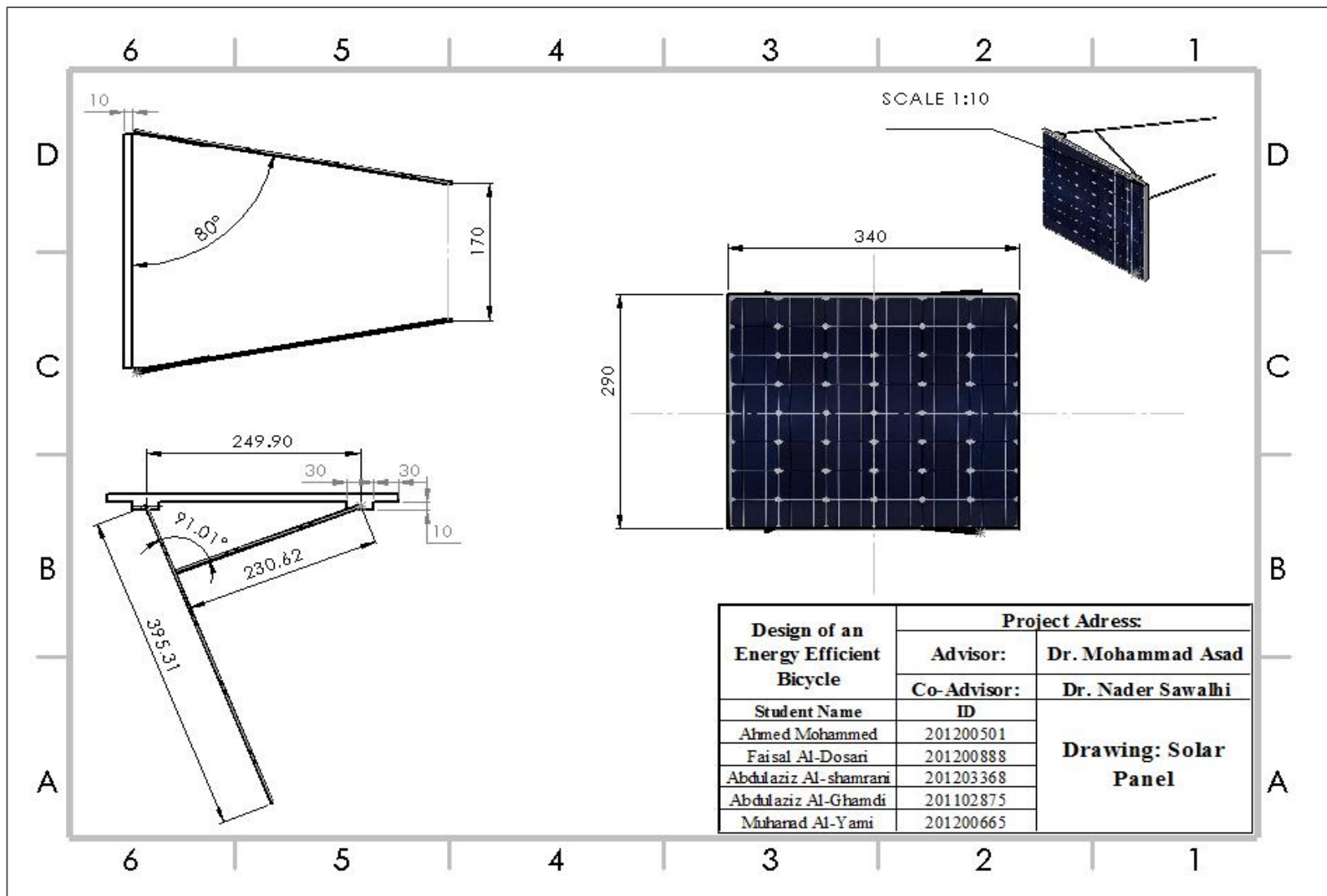












Design of an Energy Efficient Bicycle	Project Adress:	
	Advisor:	Dr. Mohammad Asad
Co-Advisor:	Dr. Nader Sawalhi	
Student Name	ID	Drawing: Solar Panel
Ahmed Mohammed	201200501	
Faisal Al-Dosari	201200888	
Abdulaziz Al-shamrani	201203368	
Abdulaziz Al-Ghamdi	201102875	
Muharad Al-Yami	201200665	

Appendix C

DRIVING PARAMETERS

Total weight (kg)
 Rolling resistance
 Aerodynamics coefficient
 Face surface (m²)

BIKE SPECIFICATIONS

Voltage (V): 12	Max current (A): 24
Battery capacity(Ah): 15	Max power (W): 288
Battery energy (Wh): 180	Max efficiency (%): 82
Torque (Nm): 35	Rim size ("): 12
Max speed (km/h): 30	30

RIM SIMULATION Rim size:

DIAGNOSTICS DRIVE

Power to overcome air resistance: 0	Wat (W)
Power to overcome rolling resistance: 0	Wat (W)
Power consumption: 0	Wh/km
Drive time: 1:13	Efficiency: 11 %

Made in Poland

DRIVING PARAMETERS

Total weight (kg)
 Rolling resistance
 Aerodynamics coefficient
 Face surface (m²)

BIKE SPECIFICATIONS

Voltage (V): 12	Max current (A): 24
Battery capacity(Ah): 15	Max power (W): 288
Battery energy (Wh): 180	Max efficiency (%): 82
Torque (Nm): 35	Rim size ("): 12
Max speed (km/h): 30	30

RIM SIMULATION Rim size:

DIAGNOSTICS DRIVE

Power to overcome air resistance: 1	Wat (W)
Power to overcome rolling resistance: 26	Wat (W)
Power consumption: 7.25	Wh/km
Drive time: 26:40	Efficiency: 73 %

Made in Poland



ELECTRIC BIKE SIMULATOR
www.electricbikesimulator.com

DRIVING PARAMETERS

- Total weight (kg): 144
- Rolling resistance: 0.013
- Aerodynamics coefficient: 0.9
- Face surface (m²): 0.46

BIKE SPECIFICATIONS

- Voltage (V): 12
- Battery capacity (Ah): 15
- Battery energy (Wh): 180
- Torque (Nm): 35
- Max current (A): 24
- Max power (W): 288
- Max efficiency (%): 82
- Rim size ("): 12
- Max speed (km/h): 30

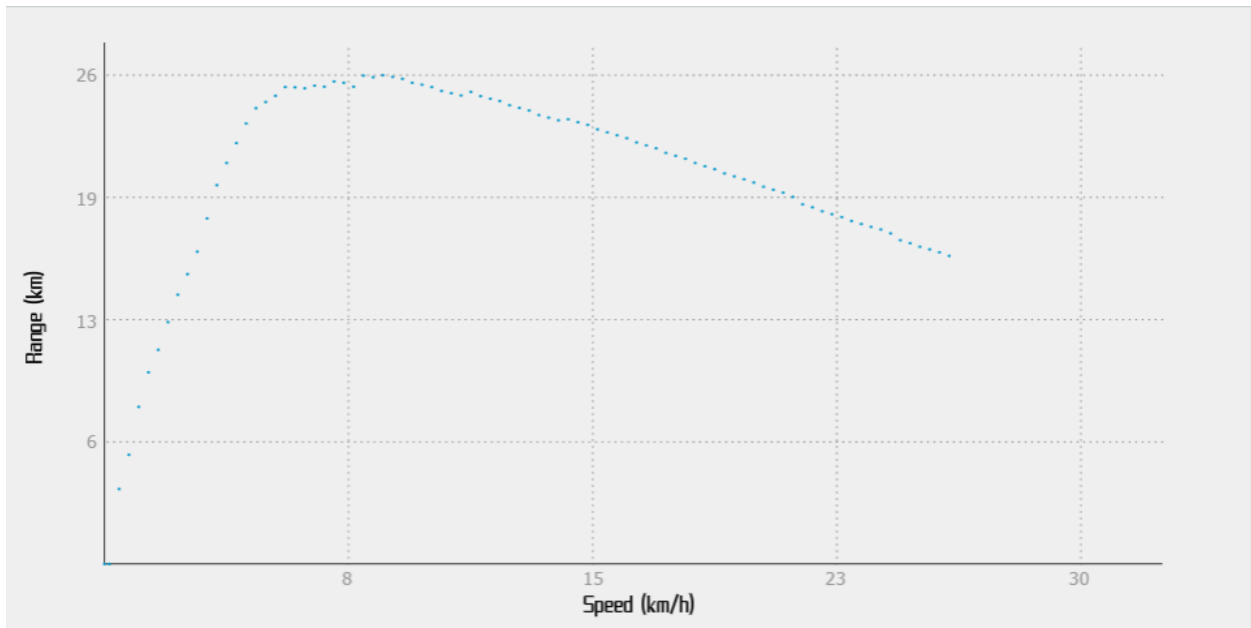
RIM SIMULATION Rim size: 12

DIAGNOSTICS DRIVE

- Power to overcome air resistance: 44 Wat (W)
- Power to overcome rolling resistance: 102 Wat (W)
- Power consumption: 8.86 Wh/km
- Drive time: 5:55
- Efficiency: 82 %

THROTTLE 67% BRAKE

Made in Poland



ELECTRIC BIKE SIMULATOR
www.electricbikesimulator.com

DRIVING PARAMETERS

Total weight (kg): 144

Rolling resistance: 0.013

Aerodynamics coefficient: 0.9

Face surface (m²): 0.46

BIKE SPECIFICATIONS

Voltage (V): 12 Max current (A): 24

Battery capacity(Ah): 15 Max power (W): 288

Battery energy (Wh): 180 Max efficiency (%): 82

Torque (Nm): 35 Rim size ("): 12

Max speed (km/h): 30

RIM SIMULATION Rim size: 12

CHANGE SETTINGS RESET RANGE

DIAGNOSTICS DRIVE

Power to overcome air resistance: 1 Wat (W)

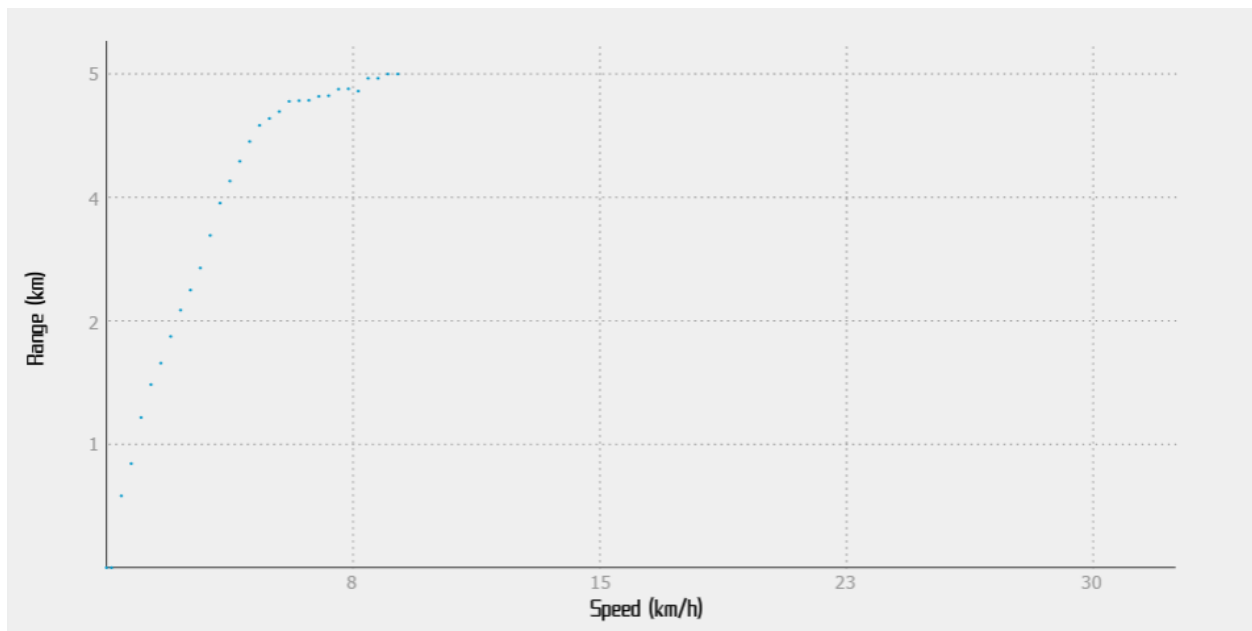
Power to overcome rolling resistance: 125 Wat (W)

Power consumption: 33.92 Wh/km

Drive time: 31:03 Efficiency: 73 %

THROTTLE 17% BRAKE

Made in Poland



ELECTRIC BIKE SIMULATOR
www.electricbikesimulator.com

DRIVING PARAMETERS

- Total weight (kg): 144
- Rolling resistance: 0.013
- Aerodynamics coefficient: 0.9
- Face surface (m²): 0.46

BIKE SPECIFICATIONS

- Voltage (V): 12
- Max current (A): 24
- Battery capacity (Ah): 15
- Max power (W): 288
- Battery energy (Wh): 180
- Max efficiency (%): 82
- Torque (Nm): 35
- Rim size ("): 12
- Max speed (km/h): 30

RIM SIMULATION Rim size: 12

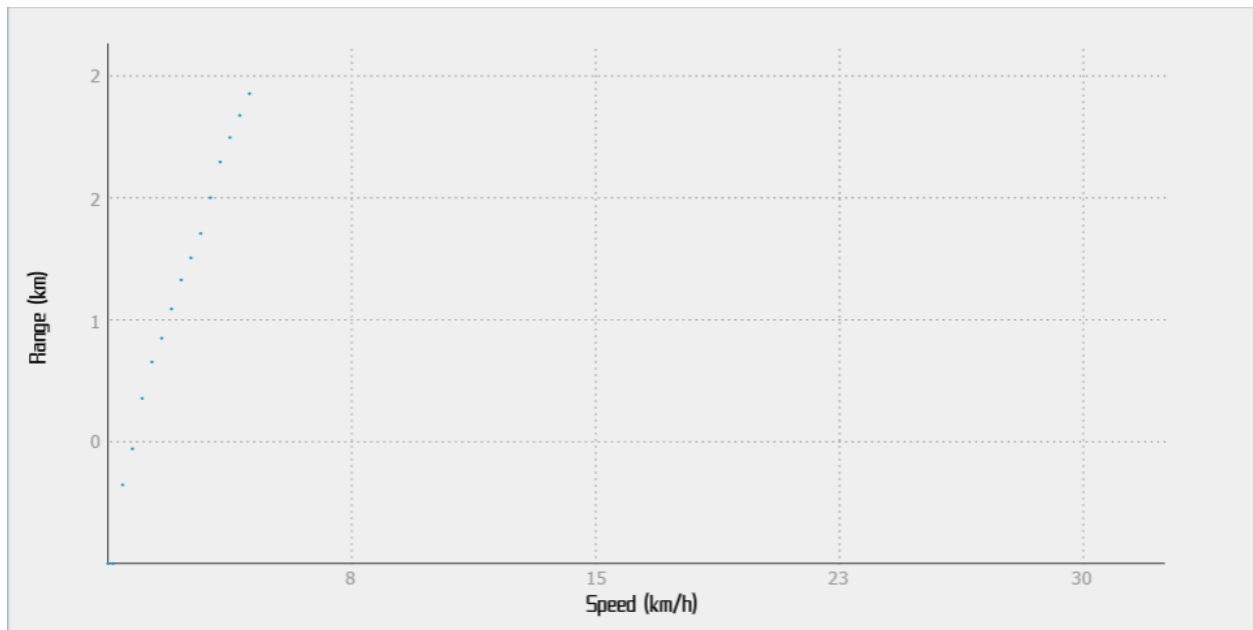
DIAGNOSTICS DRIVE

- Power to overcome air resistance: 1 Wat (W)
- Power to overcome rolling resistance: 203 Wat (W)
- Power consumption: 62.81 Wh/km
- Drive time: 10:00
- Efficiency: 71 %

Current Simulation Data:

- RANGE km: 2
- ENERGY Wh: 156
- POWER W: 288
- CURRENT A: 24
- SPEED km/h: 4.6
- DISTANCE km: 194
- THROTTLE: 33%
- BRAKE: [Button]

Made in Poland



ELECTRIC BIKE SIMULATOR
www.electricbikesimulator.com

RANGE km: 0

ENERGY Wh: 114

POWER W: 288

CURRENT A: 24

SPEED km/h: 1.7

DISTANCE km: 291

THROTTLE 67%

BRAKE

DRIVING PARAMETERS

Total weight (kg): 144

Rolling resistance: 0.013

Aerodynamics coefficient: 0.9

Face surface (m²): 0.46

BIKE SPECIFICATIONS

Voltage (V): 12 Max current (A): 24

Battery capacity(Ah): 15 Max power (W): 288

Battery energy (Wh): 180 Max efficiency (%): 82

Torque (Nm): 35 Rim size ("): 12

Max speed (km/h): 30

RIM SIMULATION Rim size: 12

CHANGE SETTINGS RESET RANGE

DIAGNOSTICS DRIVE

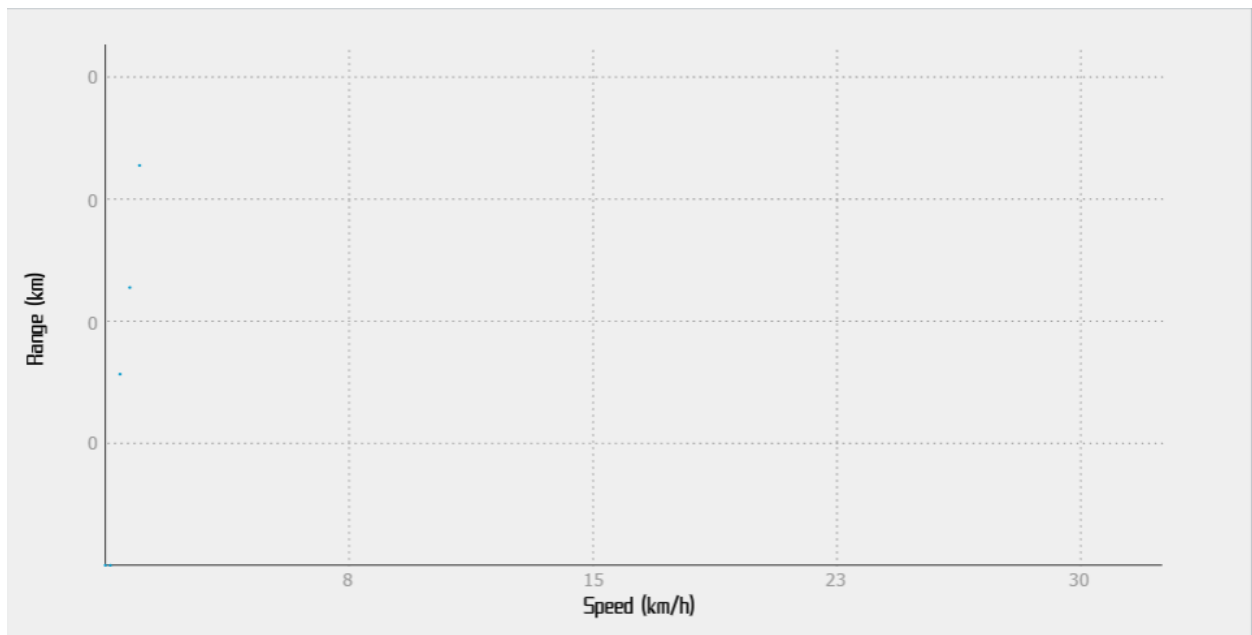
Power to overcome air resistance: 0 Wat (W)

Power to overcome rolling resistance: 106 Wat (W)

Power consumption: 172.38 Wh/km

Drive time: 19:50 Efficiency: 37 %

Made in Poland



ELECTRIC BIKE SIMULATOR
www.electricbikesimulator.com

DRIVING PARAMETERS

- Total weight (kg): 144
- Rolling resistance: 0.013
- Aerodynamics coefficient: 0.9
- Face surface (m²): 0.46

BIKE SPECIFICATIONS

- Voltage (V): 12
- Max current (A): 24
- Battery capacity(Ah): 15
- Max power (W): 288
- Battery energy (Wh): 180
- Max efficiency (%): 82
- Torque (Nm): 35
- Rim size ("): 12
- Max speed (km/h): 30

RIM SIMULATION Rim size: 12

CHANGE SETTINGS RESET RANGE

DIAGNOSTICS DRIVE

- Power to overcome air resistance: 67 Wat (W)
- Power to overcome rolling resistance: 118 Wat (W)
- Power consumption: 12.47 Wh/km
- Drive time: 36:39
- Efficiency: 81 %

THROTTLE 100% BRAKE

Made in Poland

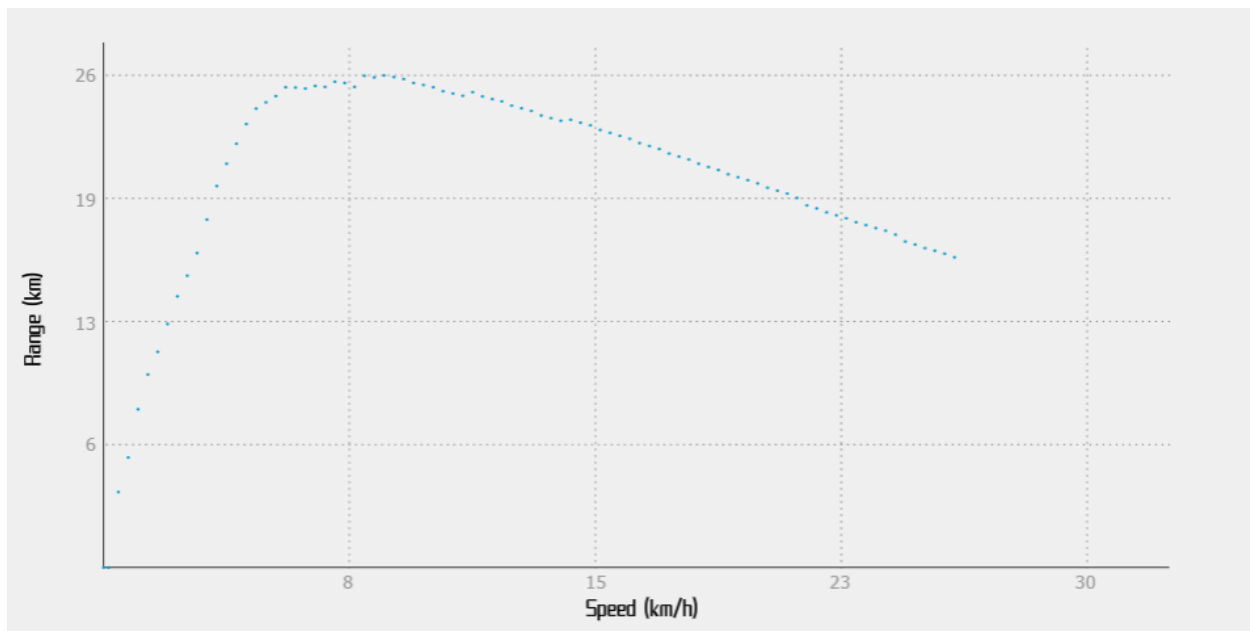
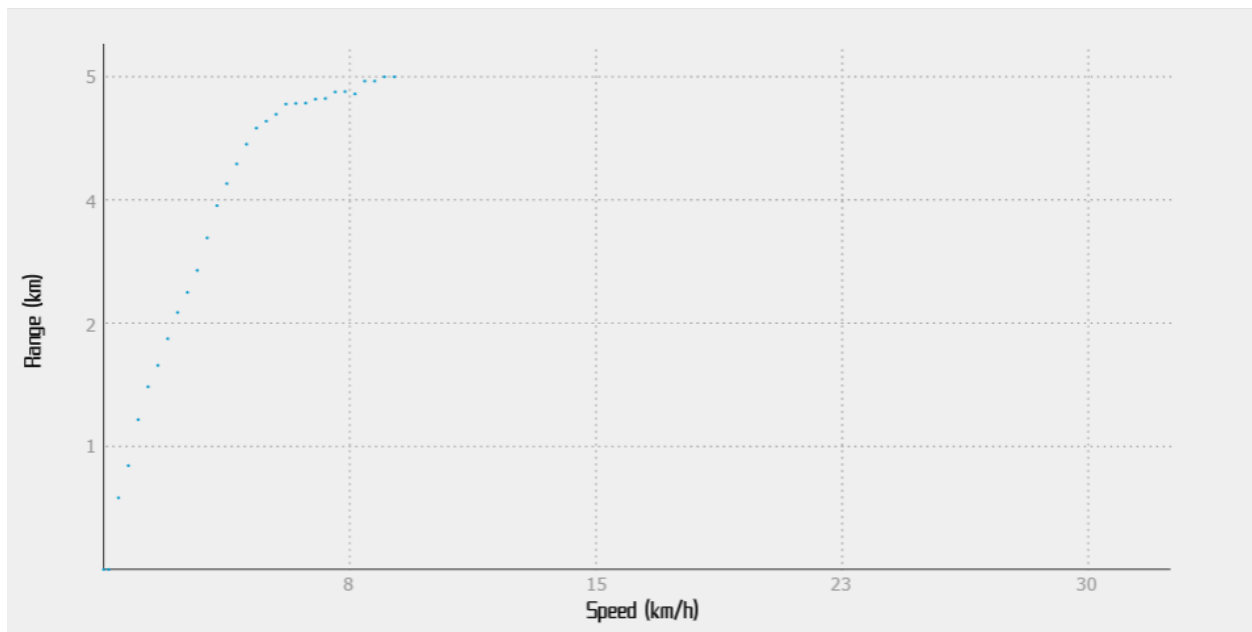




Figure 4.15: Bicycle simulation at maximum power of the motor and 5% inclined



ELECTRIC BIKE SIMULATOR
www.electricbikesimulator.com

DRIVING PARAMETERS

- Total weight (kg): 144
- Rolling resistance: 0.013
- Aerodynamics coefficient: 0.9
- Face surface (m²): 0.46

BIKE SPECIFICATIONS

- Voltage (V): 12
- Max current (A): 24
- Battery capacity(Ah): 15
- Max power (W): 288
- Battery energy (Wh): 180
- Max efficiency (%): 82
- Torque (Nm): 35
- Rim size ("): 12
- Max speed (km/h): 30

RIM SIMULATION Rim size: 12

CHANGE SETTINGS RESET RANGE

DIAGNOSTICS DRIVE

- Power to overcome air resistance: 1 Wat (W)
- Power to overcome rolling resistance: 206 Wat (W)
- Power consumption: 61.61 Wh/km
- Drive time: 40:49
- Efficiency: 72 %

THROTTLE 100% BRAKE

Made in Poland

