**Smart City  
Smart Street Lighting using NodeMCU and ThingSpeak IoT**

FY B. Tech COMP Semester II 2023-24

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**Introduction -**

In today's fast-paced world, cities are evolving rapidly, presenting both opportunities and challenges. One of the most urgent challenges we face is the need for energy efficiency. That's where our project comes in.

We're on a mission to create smarter, more sustainable urban environments that prioritize energy efficiency. By optimizing energy distribution and usage, we can reduce environmental impact and build resilience for the future.

At the heart of our initiative is the concept of the smart city: Energy-Efficient lighting solution — a vision that harnesses technology and data to improve urban life. Through innovative approaches like integrating renewable energy sources and implementing IoT-enabled infrastructure, we're transforming energy management on a large scale.

Our multidisciplinary team is working tirelessly to develop cutting-edge solutions tailored to the specific energy needs of cities. From smart grid systems to energy-efficient building designs, we're paving the way for a more sustainable future.

But we know that real change requires more than just technology—it requires collaboration and community involvement. That's why we're partnering with governments, businesses, and local communities to drive meaningful change together.

Join us on this journey to create a future where cities are not only smart but also sustainable. Together, let's illuminate tomorrow with energy-efficient solutions that benefit us all.

**Literature Review -**Rapid urbanization is fueling the demand for energy, with lighting infrastructure emerging as a significant contributor. However, traditional lighting systems not only consume substantial power but also contribute to light pollution, impacting human health and ecosystems. In response, smart city initiatives are pioneering intelligent and sustainable lighting solutions to address these challenges effectively.

**Energy Efficiency Through LEDs**:  
Light-Emitting Diodes (LEDs) are hailed as the cornerstone of energy-efficient lighting for smart cities. Their high luminous efficacy enables them to convert a larger portion of electrical energy into light, leading to substantial energy savings. Additionally, LEDs boast a long lifespan, reducing maintenance costs and waste generation. Moreover, their dimmability allows for dynamic adjustments based on real-time needs.

**Smart Lighting Systems for Optimization**:  
Smart lighting systems integrate LEDs with sensors, communication networks, and control software to achieve further energy efficiency and improve urban livability. These systems offer functionalities such as occupancy sensing, daylight harvesting, and adaptive lighting control. By automatically adjusting lighting based on factors like occupancy, daylight levels, and environmental conditions, smart lighting systems optimize energy consumption while enhancing user experience.

**Benefits Beyond Energy Savings**:  
Beyond energy efficiency, smart lighting systems offer a plethora of benefits for smart cities. They enhance safety by improving visibility in specific areas, thereby deterring crime and enhancing pedestrian and driver safety. Furthermore, precise light direction and dimming capabilities minimize light pollution, safeguarding ecosystems and promoting stargazing opportunities. Additionally, sensor data from lighting systems can be leveraged for various purposes, including traffic monitoring and air quality analysis, further optimizing city management.

**Challenges and Considerations**:  
Despite the advantages, implementing smart lighting systems entails addressing several challenges. Initial investment costs for infrastructure upgrades can be significant, although LEDs offer long-term savings. Moreover, cybersecurity concerns regarding secure communication networks are crucial to prevent hacking and ensure system reliability. Furthermore, standardization and interoperability are essential to ensure compatibility between different lighting system components from various vendors.

The literature review confirms that energy-efficient lighting systems with LED technology and smart control features are pivotal in addressing urban challenges related to energy consumption, light pollution, safety, and sustainability in smart cities. Continuous research and development efforts are imperative to further optimize these systems, reduce costs, and ensure their seamless integration into smart city infrastructure.

**Problem Statement -  
Current Situation:**High Energy Consumption: Conventional lighting in cities contributes significantly to the overall energy demand, placing a strain on resources and leading to increased greenhouse gas emissions.  
Inefficient Infrastructure: Existing lighting infrastructure may lack smart controls or be outdated, leading to unnecessary energy use.  
Limited Data and Analytics: Cities often lack real-time data on energy usage patterns for lighting, hindering informed decision-making about optimization.

**Challenges:**  
Balancing Efficiency and Cost: While energy-efficient lighting solutions (like LEDs) exist, their upfront cost can be higher compared to traditional bulbs, creating a barrier for some city governments.  
Integration with Smart City Systems: New lighting solutions need to seamlessly integrate with existing and future smart city infrastructure for centralized management and data collection.

**Desired Outcomes:**  
Reduced Energy Consumption: Implement a comprehensive lighting strategy that significantly reduces energy use in public spaces across the city.  
Improved Sustainability: Promote a more sustainable future for the city by lowering greenhouse gas emissions associated with lighting.  
Enhanced Public Safety and Quality of Life: Well-designed and efficient lighting can improve visibility at night.  
Data-Driven Decision Making: Collect and analyse real-time data on lighting usage to optimize maintenance and reduce energy waste.

This project aims to develop and implement a comprehensive strategy for creating energy-efficient lighting solutions. By addressing the challenges and achieving the desired outcomes, the project will contribute to a more sustainable, cost-effective urban environment.

**Objectives –**

1. Develop an energy-efficient lighting system for a smart city initiative.
2. Optimize energy consumption and minimize light pollution in urban areas.
3. Implement intelligent control mechanisms for lighting systems across streets, public spaces, parks, and residential areas.
4. Utilize sensors, IoT technology, and data analytics to dynamically adjust lighting levels based on real-time factors.
5. Consider factors such as pedestrian activity, traffic flow, weather conditions, time of day in the control algorithms.
6. Aim to create a sustainable, cost-effective, environmentally friendly lighting solution.
7. Enhance safety, aesthetics, and the well-being of citizens while reducing energy consumption and carbon footprint.

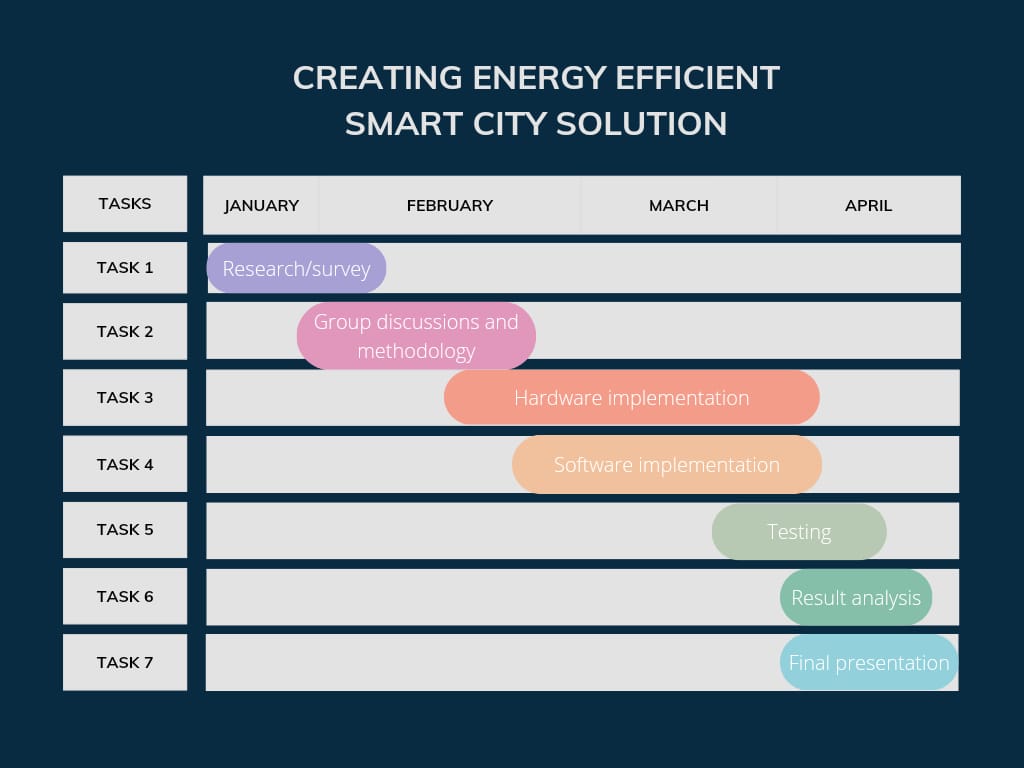
**Functions –**

1. Develop energy-efficient lighting system.
2. Optimize energy usage, reduce light pollution, wastage of light.
3. Implement intelligent lighting control.
4. Utilize sensors, IoT, and data analytics.
5. Enhance safety, aesthetics, and sustainability.

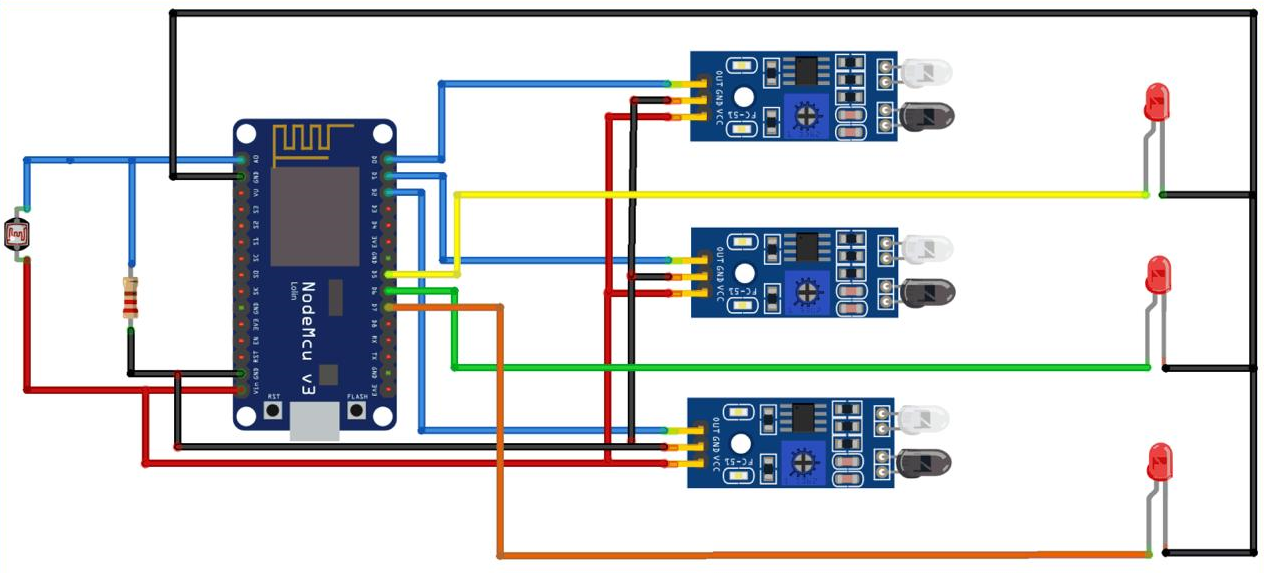
**Constrains –**

1. Budget Constraint: Develop the lighting system within a predetermined budget to ensure financial feasibility.
2. Regulatory Compliance: Ensure compliance with local regulations and standards related to energy efficiency, light pollution, and environmental impact.
3. Infrastructure Compatibility: Design the system to be compatible with existing urban infrastructure and lighting fixtures.
4. Data Privacy and Security: Implement measures to protect the privacy and security of data collected by sensors and IoT devices.
5. Maintenance and Upkeep: Develop a plan for regular maintenance and upkeep of the lighting system to ensure continued functionality and performance.
6. Limited processing power and memory capacity of ESP8266 NodeMCU. Dependency on stable Wi-Fi connectivity for communication with ThingSpeak platform.
7. Need for proper calibration and testing to ensure accurate sensor readings and reliable operation.

**Final Problem Statement –**Developing an energy-efficient lighting system for smart cities to address urban challenges by minimizing energy consumption and light pollution while enhancing safety and sustainability. Leveraging sensors, IoT, and data analytics, we'll dynamically adjust lighting levels based on real-time factors, ensuring regulatory compliance and infrastructure compatibility. Prioritizing data privacy and security, our solution aims to sustain functionality through regular maintenance, creating a cost-effective, environmentally friendly lighting solution that enhances citizen well-being.

**Time line chart –  
**

**Sketches, Block diagram of project –**

**Circuit diagram –**

**List of software/ hardware –**  
1.    LED Lights:

* High-efficiency LED lights for energy-efficient illumination.

2.    Sensors:

* Light Dependent Resistor (LDR) for ambient light detection.

3.    NodeMCU:

* ESP8266-based development board that integrates Wi-Fi connectivity, making it ideal for IoT projects.

4.    Battery:

* Rechargeable battery for uninterrupted power supply.

5. BreadBoard:

* A breadboard is a versatile prototyping tool used to quickly and easily build electronic circuits without soldering.

6. Jumper cables:

* Connecting wires essential conduits for electrical connectivity, enabling the transfer of power, signals, or data between components in a circuit.

7. Resistors:

* Resistors are used for voltage division, current limiting, temperature sensing, voltage regulation, signal conditioning, and impedance matching in electrical and electronic circuits.

8. IDE:

* Arduino IDE for NodeMCU or VSCode.

9. Sensor Libraries:

* Integration of LDR and IR sensor libraries.

10. ThingsSpeak:

* ThingSpeak is an IoT platform to collect, analyze, and visualize sensor data in real-time, facilitating remote monitoring, data logging, and IoT application development.

**Cost of material –**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sr No. | Equipment | Quantity | Price(₹) | Total(₹) |
| 1 | 9V Battery | 1 | 25 | 25 |
| 2 | Bread Board | 1 | 65 | 65 |
| 3 | Resistor | 5 | 1 | 5 |
| 4 | LED | 3 | 2 | 6 |
| 5 | NodeMCU | 1 | 325 | 325 |
| 6 | IR Sensor | 3 | 45 | 135 |
| 7 | LDR | 3 | 50 | 150 |
| 8 | Jumper Cables | 20 | 2 | 40 |
| 9 | Micro USB cable | 1 | 85 | 85 |
|  | **Total** |  |  | **831** |

**Function and working of circuit –**The primary function of this circuit is to detect light levels using the LDRs and transmit this information wirelessly using the ESP8266 module. It can be used for various applications such as ambient light sensing, smart lighting systems, or security systems.

*Components Needed*:  
ESP8266 Module: It is a Wi-Fi module that allows microcontrollers to connect to Wi-Fi networks and communicate with other devices over the internet.

Light-Dependent Resistors (LDRs): These are variable resistors whose resistance changes based on the intensity of light falling on them. They act as sensors to detect light levels.

Resistors: Used to create voltage dividers with the LDRs to measure their resistance.

Power Supply: Typically, a 3.3V power supply is used for the ESP8266 module.

*Working*:

LDR Setup: Each LDR is connected in series with a resistor to form a voltage divider circuit. As the light intensity changes, the resistance of the LDR changes, causing a variation in the voltage across it.  
Analog Readings: The ESP8266 module reads the analog voltage values from each voltage divider circuit. These readings correspond to the light levels detected by the LDRs.  
Data Transmission: Using the Wi-Fi capabilities of the ESP8266 module, the analog readings are converted into digital data and transmitted wirelessly to a receiver or a server. This allows for real-time monitoring of light levels.  
Data Processing: The received data can be processed as needed, such as adjusting lighting levels in response to changing ambient light conditions or triggering alerts in a security system.

In summary, this circuit with three LDRs and an ESP8266 module enables the detection of light levels and wireless transmission of this data, providing a versatile platform for various applications requiring light sensing and remote monitoring capabilities.

**Program Code –**#include <ESP8266WiFi.h>  
#include <WiFiClient.h>  
#include <ThingSpeak.h>

const char\* ssid = "Aayush's iPhone 1";  
const char\* password = "aayushiphone";  
WiFiClient client;

unsigned long myChannelNumber = 2501530;  
const char \*myWriteAPIKey = "NLT386PK44L6OZ3D";  
const char \*myReadAPIKey = "HG3B6HV2WRZBH5NG";

int led\_1;  
int led\_2;  
int led\_3;  
int ir1 = D0;  
int led1 = D5;  
int ir2 = D1;  
int led2 = D6;  
int ir3 = D2;  
int led3 = D7;  
int ldr = A0;  
int val =0;

void setup() {

Serial.begin(9600);

delay(10);

pinMode(ir1,INPUT);

pinMode(led1,OUTPUT);

pinMode(ir2,INPUT);

pinMode(led2,OUTPUT);

pinMode(ir3,INPUT);

pinMode(led3,OUTPUT);

WiFi.begin(ssid, password);

ThingSpeak.begin(client);

}

void loop() {

int s1 = digitalRead(ir1);

int s2 = digitalRead(ir2);

int s3 = digitalRead(ir3);

s3 = not(s3);

val = analogRead(ldr);

//int val = 400;

Serial.print(s1);

Serial.print(":");

Serial.print(s2);

Serial.print(":");

Serial.print(s3);

Serial.print(" ");

Serial.println(val);

if(val<800)

{

if(s1==0)

{

digitalWrite(led1,HIGH);

}

else

{

digitalWrite(led1,LOW);

}

if(s2==0)

{

digitalWrite(led2,HIGH);

}

else

{

digitalWrite(led2,LOW);

}

if(s3==0)

{

digitalWrite(led3,LOW);

}

else

{

digitalWrite(led3,HIGH);

}

}

else

{

digitalWrite(led1,LOW);

digitalWrite(led2,LOW);

digitalWrite(led3,LOW);

}

ThingSpeak.writeField(myChannelNumber, 1,val,myWriteAPIKey);

ThingSpeak.writeField(myChannelNumber, 2,s1, myWriteAPIKey);

ThingSpeak.writeField(myChannelNumber, 3,s2, myWriteAPIKey);

ThingSpeak.writeField(myChannelNumber, 4,s3, myWriteAPIKey);

ThingSpeak.writeField(myChannelNumber, 5,led1, myWriteAPIKey);

ThingSpeak.writeField(myChannelNumber, 6,led2, myWriteAPIKey);

ThingSpeak.writeField(myChannelNumber, 7,led3, myWriteAPIKey);

led\_1 = ThingSpeak.readIntField(myChannelNumber, 5, myReadAPIKey);

led\_2 = ThingSpeak.readIntField(myChannelNumber, 6, myReadAPIKey);

led\_3 = ThingSpeak.readIntField(myChannelNumber, 7, myReadAPIKey);

if(led\_1==1)

{

digitalWrite(led1,HIGH);

}

else

{

digitalWrite(led1,LOW);

}

if(led\_2==1)

{

digitalWrite(led2,HIGH);

}

else

{

digitalWrite(led2,LOW);

}

if(led\_3==1)

{

digitalWrite(led3,HIGH);

}

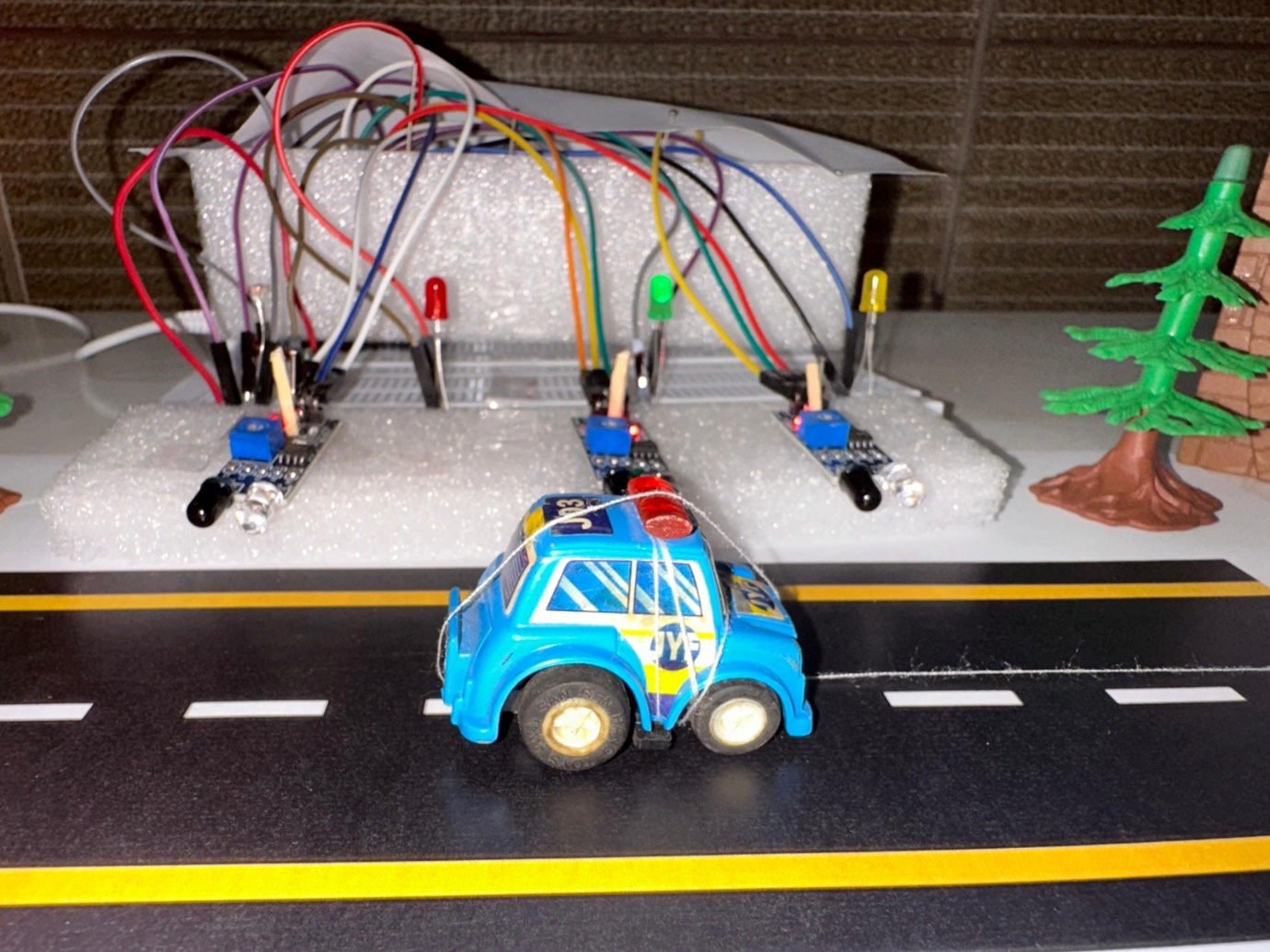
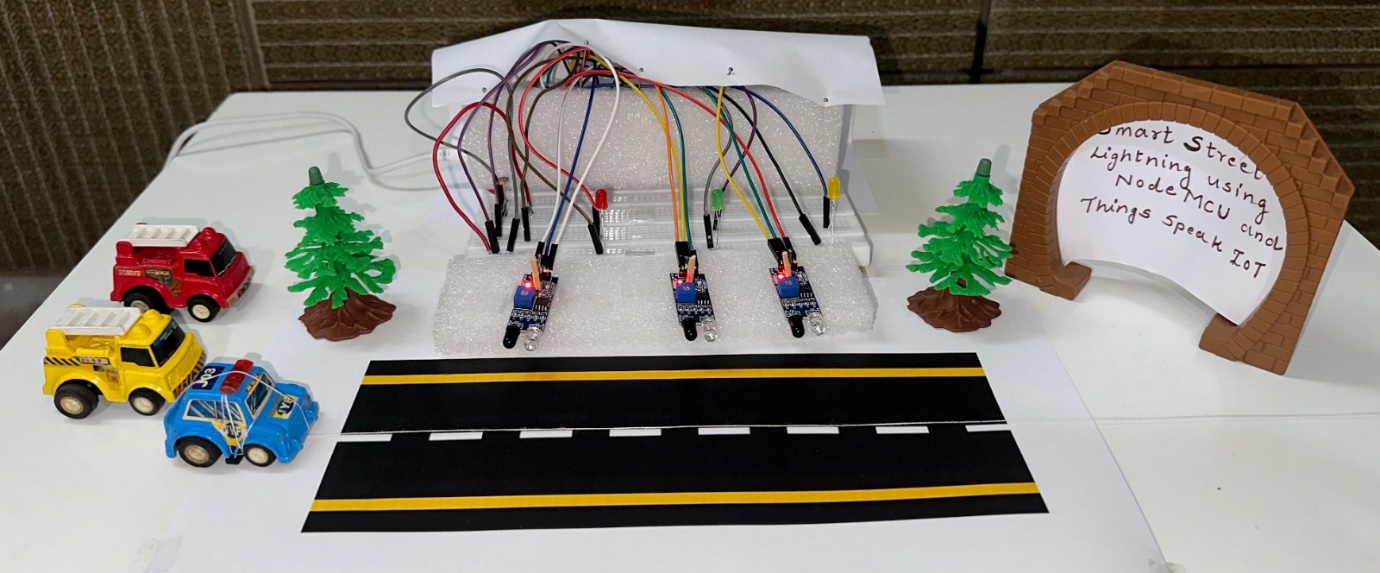
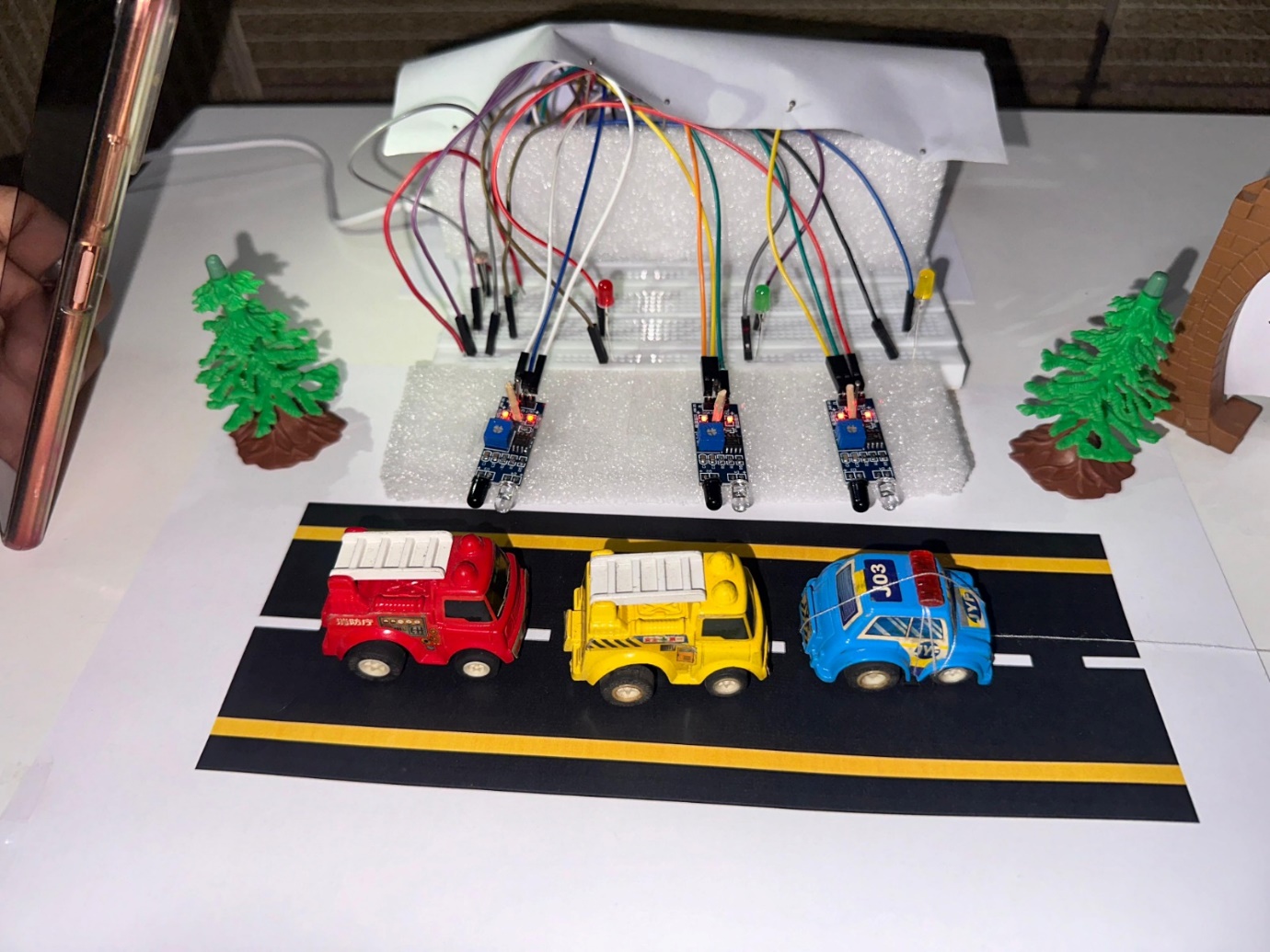
else

{

digitalWrite(led3,LOW);

  }

}

**Results –**   

**Video Of the project** -  
<https://drive.google.com/file/d/12F3k3nwJ3NYHeWNvVl8-aZU3Kro0kXkf/view?usp=drive_link>

**Observations–**1. Enhanced Energy Efficiency: The implementation of LED lighting solutions has led to substantial reductions in energy consumption, resulting in cost savings and environmental benefits.  
2. Mitigation of Light Pollution: By minimizing light spillage, glare, and skyglow, the project has contributed to reducing light pollution, thereby preserving the natural environment and promoting stargazing opportunities.  
3. Improved Safety and Security: The deployment of smart lighting systems has enhanced visibility in specific areas, deterring crime and improving pedestrian and driver safety, thus fostering a safer urban environment.  
4. Promotion of Sustainability: The project's emphasis on energy-efficient lighting solutions aligns with broader sustainability goals, contributing to resource conservation, environmental protection, and the overall resilience of smart cities.  
In summary, observations from the project underscore the pivotal role of energy-efficient lighting solutions in addressing urban challenges while advancing the goals of sustainability and safety. The project has demonstrated improved energy efficiency, reduced light pollution, enhanced safety, and sustainability through the implementation of LED technology, smart controls, and adaptive lighting systems.

**Limitations of project –**1. Limited Scalability: NodeMCU boards may have limited processing power and memory, limiting the scale of the street lighting network they can support.  
2. Reliability Concerns: Connectivity issues or hardware failures with NodeMCU boards or sensors may affect the reliability of the street lighting system.  
3. Data Privacy and Security: Using ThingSpeak IoT may raise concerns about data privacy and security, especially when transmitting sensitive information over the internet.  
4. Dependency on Internet Connectivity: Smart street lighting systems relying on ThingSpeak IoT may be affected by disruptions in internet connectivity, impacting their real-time monitoring and control capabilities.

**Conclusions or learnings and Future work –**1. Energy Efficiency: The project demonstrates the potential of IoT-enabled smart street lighting systems to improve energy efficiency by dynamically adjusting lighting levels based on real-time data. The implementation of LED technology and smart controls can lead to significant energy savings and environmental benefits.  
2. Cost Savings: By optimizing energy consumption and reducing maintenance costs through remote monitoring and control, smart street lighting solutions offer long-term cost savings for municipalities and utility providers.  
3. Enhanced Safety and Security: The integration of motion sensors and adaptive lighting algorithms enhances safety and security in urban environments by improving visibility and deterring criminal activities, contributing to the overall well-being of residents.  
4. Data Insights: The project generates valuable data insights on street lighting usage patterns, energy consumption trends, and environmental conditions. Analyzing this data can inform future decision-making processes, infrastructure planning, and policy development.  
5. Scalability and Adaptability: The project highlights the scalability and adaptability of IoT-based street lighting solutions, allowing for easy expansion and integration with other smart city initiatives, such as traffic management, environmental monitoring, and public safety.  
6. User Engagement and Feedback: Engaging with stakeholders and gathering feedback from end-users is crucial for the successful implementation and acceptance of smart street lighting systems.  
Continuous communication and collaboration with communities can help address concerns and improve user experience.  
7. Future Work includes:  
Further optimization of lighting algorithms to improve energy efficiency and lighting quality.  
Integration of additional sensors for collecting environmental data, such as air quality or temperature.  
Development of predictive maintenance algorithms to identify and address potential issues before they occur.  
Exploration of advanced functionalities, such as adaptive lighting based on traffic flow or pedestrian activity.  
Evaluation of alternative IoT platforms or communication protocols to enhance scalability, reliability, and security.  
Collaboration with other smart city initiatives to create synergies and maximize the benefits of interconnected urban infrastructure.

**References –**

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