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Rectilinear Motion Study Using Sensor-Based Experiments

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Abstract: *Rectilinear motion refers to the motion of a body along a straight line and is one of the fundamental concepts in engineering mechanics and physics. Sensor-based experiments provide accurate and real-time analysis of displacement, velocity, and acceleration during rectilinear motion. This paper presents the study of rectilinear motion using modern sensors such as ultrasonic sensors, infrared sensors, accelerometers, and motion detectors. Experimental observations are analyzed using mathematical equations and graphical representations. The study demonstrates how sensor technology improves measurement accuracy, reduces human error, and enhances understanding of motion characteristics in engineering applications.*

Keywords: Rectilinear Motion, Sensors, Motion Analysis, Velocity, Acceleration, Engineering Mechanics

I. INTRODUCTION

Rectilinear motion is defined as the motion of an object along a straight-line path. It is one of the simplest forms of motion studied in mechanics and forms the foundation for advanced topics such as dynamics, robotics, vehicle motion, and automation systems.

Traditional methods of studying motion involve manual measurements, which may introduce human error. Modern sensor-based experiments provide accurate, fast, and automated data collection for analyzing motion parameters.

The objectives of this study are:

- To analyze straight-line motion using sensors
- To measure displacement, velocity, and acceleration accurately
- To compare theoretical and experimental results
- To understand practical applications of sensor-based motion analysis

II. THEORY OF RECTILINEAR MOTION

In rectilinear motion, the object moves along a straight path. Motion may be:

- Uniform motion
- Non-uniform motion
- Accelerated motion
- Decelerated motion

The displacement equation is:

$$s = s_0 + vt + \frac{1}{2}at^2$$

Where:

- (s) = displacement
- (s_0) = initial displacement

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- (v) = initial velocity
- = acceleration
- (t) = time

III. VELOCITY ANALYSIS

Velocity is defined as the rate of change of displacement.

$$v = \frac{ds}{dt}$$

In sensor-based experiments:

- Velocity is measured automatically
- Motion graphs are generated in real time
- Continuous monitoring is possible

IV. ACCELERATION ANALYSIS

Acceleration is the rate of change of velocity.

$$a = \frac{dv}{dt}$$

Acceleration analysis helps determine:

- Speed variation
- Dynamic behavior
- Motion control performance

V. SENSOR-BASED EXPERIMENTAL SETUP

A. Components Used

The experimental setup consists of:

- Ultrasonic sensor
- Infrared sensor
- Accelerometer
- Arduino microcontroller
- Computer interface
- Moving cart

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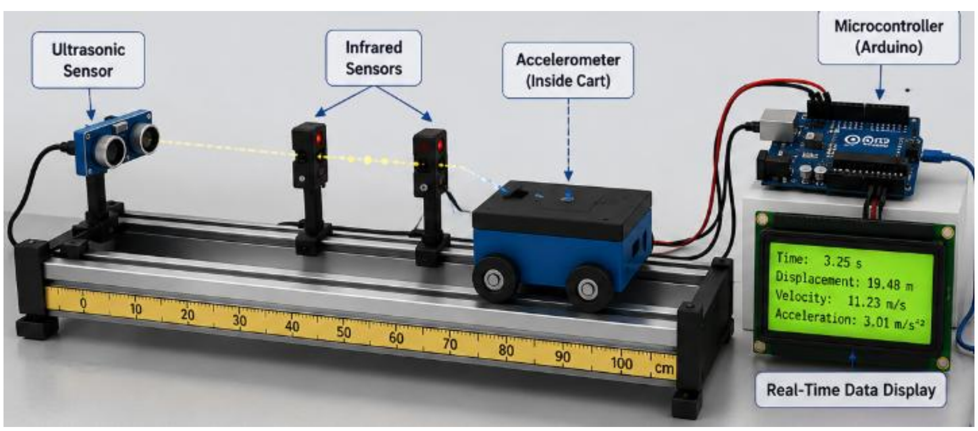

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B. Working Principle

The sensor continuously detects the position of the moving object and sends signals to the microcontroller. The data is processed to calculate:

- Displacement
- Velocity
- Acceleration
- Time intervals

VI. TYPES OF SENSORS USED

A. Ultrasonic Sensors

Ultrasonic sensors use sound waves to measure distance.

1) Advantages

- High accuracy
- Non-contact measurement
- Low cost

2) Applications

- Robotics
- Vehicle parking systems
- Motion tracking

B. Infrared Sensors

Infrared sensors detect object motion using reflected infrared radiation.

3) Advantages

- Fast response
- Compact size
- Easy implementation

C. Accelerometers

Accelerometers directly measure acceleration.

4) Applications

- Mobile devices
- Vehicle dynamics
- Structural vibration analysis

VII. EXPERIMENTAL PROCEDURE

1. Place the object on a straight track.
2. Connect sensors to the microcontroller.
3. Record motion data during movement.
4. Transfer readings to the computer.
5. Plot displacement-time and velocity-time graphs.
6. Compare theoretical and experimental results.

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VIII. NUMERICAL ANALYSIS OF RECTILINEAR MOTION

Problem Statement

A sensor-based experimental setup is used to study the rectilinear motion of a moving cart on a straight track. The cart starts with an initial velocity of (2 , m/s) and moves with a constant acceleration of (3 , m/s^2) for (5 , seconds).

Determine:

1. Final velocity of the cart
2. Total displacement covered
3. Distance traveled during the last second

Given Data

u=2m/s

a=3m/s^2

t=5s

A. Final Velocity Calculation

Using the equation:

$$v=u+at$$

Substituting values:

$$V = 2 + (3\times5) \quad v = 17 \text{ m/s}$$

Final Velocity

17 m/s

B. Displacement Calculation

Using the equation:

$$s = ut + \frac{1}{2}at^2$$

Substituting values:

$$s = (2 \times 5) + \frac{1}{2}(3)(5^2)$$

$$s = 10 + 37.5$$

$$s = 47.5\, m$$

Total Displacement

47.5 m

C. Distance Traveled During the Last Second

Distance traveled in the nth second:

$$s_n = u + \frac{a}{2}(2n - 1)$$

For the 5th second:

$$s_5 = 2 + \frac{3}{2}(9)$$

$$s_5 = 15.5\, m$$

Distance in 5th Second: 15.5 m

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IX. SENSOR OBSERVATION TABLE

Time (s)	Velocity (m/s)	Displacement (m)
0	2	0
1	5	3.5
2	8	10
3	11	19.5
4	14	32
5	17	47.5

X. RESULTS AND DISCUSSION

The experimental analysis shows:

- Accurate measurement of displacement and velocity
- Real-time graphical representation
- Reduced human error
- Better understanding of acceleration behavior

Sensor data helps identify:

- Sudden changes in speed
- Friction effects
- Motion irregularities

The velocity-time and displacement-time graphs clearly represent the characteristics of rectilinear motion.

XI. APPLICATIONS OF SENSOR-BASED MOTION ANALYSIS

Sensor-based rectilinear motion analysis is widely used in:

- Robotics
- Automated vehicles
- Conveyor systems
- Industrial automation
- Railway systems
- Motion control systems

XII. ADVANTAGES OF SENSOR-BASED EXPERIMENTS

- High accuracy
- Real-time monitoring
- Reduced manual effort
- Better visualization
- Fast data processing
- Improved reliability

XIII. LIMITATIONS

- Sensor calibration errors
- Environmental disturbances
- Signal noise
- Limited sensor range
- Power dependency
- Proper calibration and filtering techniques help reduce these limitations.

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XIV. CONCLUSION

Rectilinear motion analysis using sensor-based experiments provides an efficient and accurate method for studying motion characteristics. Sensors improve the precision of displacement, velocity, and acceleration measurements while reducing human error. Integration of sensors with microcontrollers and computer systems enhances engineering education and industrial applications. Sensor-based experiments are highly effective for understanding practical motion behavior.

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