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The Role of Mathematics in Motion: An Analysis of Speed and Distance

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Abstract: Mathematics permeates almost every aspect of our daily lives. It is fundamental to our understanding of the motion of humans and the earth around us. This paper aims to evaluate the motion from various points of view through basic mathematical concepts such as speed, time, and distance. It starts with introducing and comparing the average speed with instantaneous speed, gives some equations that relate distance to time, and supports that with analysis of practical examples of vehicles motion, pedestrians' motion, and freely falling objects motion to ensure the veracity of these equations. Moreover, it discusses the significance of viewing motion as a change with graphical representations in a way that enhances readers' understanding of mathematical relationships. It also aims to enhance our mathematical thinking in the study of motion and show how to utilize mathematics to promote our vigour in explaining the natural world and the human mutual action.

Keywords: Motion analysis, velocity calculations, distance equations, kinematics, mathematical modeling

1. Introduction

Motions has fascinated humankind throughout history, starting with Aristotle's informal study of motion, moving to Galileo's systematic experimental method, and ending with Newton's laws of motion [1]. Mathematics is the global language used for describing motion. It is the experimenter language that supports us to shape what we see. It supports us with a set of instruments to display, analyze, calculate, and measure the world around us. The mathematics of motion, or kinematics shapes the basis of many fields of science and higher studies, such as sport, transportation, engineering, and physics science [2].

Motion is an integral part of real life situations. Every day we experience a situation involving motion, whether going to work, driving a vehicle, watching an object falling, or anything else, indicting that we are dealing with motion. Such motions can be explained and calculated by the similar simple mathematical equations, all of which involve the concepts of speed, distance, and time. Understanding such relationships not only promotes our scientific knowledge but also improves our ability to solve problems in diverse contexts [3].

This paper aims to relate the world of motion to mathematics by investigating one of basic principles of motion, hoping that the fundamental mathematical equations could be utilized to outline an intricate phenomena, and tell a huge number of audience that mathematics is not just an academic pursuit but also a matter of comprehending our natural world around us.

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2. Materials and Methods

Definitions of key Concepts

Speed and Velocity Vector

Speed refers to how fast an object is moving to cover a distance in a certain time. The following equation is used to express the speed.

$$\text{Speed} = \text{Distance} / \text{Time} \text{ Or mathematically: } s = d / t$$

Where s stands for speed, d stands for distance, and t stands for time [4].

It is essential to differentiate between speed and velocity vector. Whereas velocity refers to a scalar quantity that shows just the magnitude of kinematics, velocity refers to a vector quantity that describes both magnitude and direction. To achieve the objectives of this study, the researcher focused mainly on velocity because it gives a practical foundation for understanding motion [5].

Average Speed Compared to Instantaneous Speed

Average speed is the total distance traveled divided by the total needed time for the travel. This gives a general measure of motion but does not reflect any alternation in speed during the travel. This average speed could be expressed by the following equation:

$$\text{Average Speed} = \text{Total Distance} / \text{Total Time}$$

On contrary, instantaneous speed refers to the speed of an object at a particular moment of a time. From mathematical point of view, it is the limited value of an average speed when the time interval draws near zero. It could be achieved by calculating the speed over very short time intervals [6].

Displacement Compared to Distance

Distance is the total length of the path traveled by an object from one point to another in any case of its direction. Because distance is a scalar quantity, it has a zero value that expresses the accruing measure of all motions. On contrast, displacement measures the distance in an alignment line between an object's initial and final spot, taking direction into consideration [7].

In real life situations, distance and displacement become equivalent, especially when analyzing motion along an alignment path, allowing us to use fundamental mathematical relations without having any intricacies of vector calculations.

The Mathematical Framework

Basic Formulas of Motion

The basic relations between velocity, distance, and time are shown in the following equivalent formulas:

$$\text{Distance} = \text{Speed} \times \text{Time} (d = st)$$

$$\text{Speed} = \text{Distance} / \text{Time} (s = d/t)$$

$$\text{Time} = \text{Distance} / \text{Speed} (t = d/s)$$

These formulas make the basics of motion mathematical analysis and could be used to solve a wide range of practical problems of real life situations [8].

Uniform Motion

Uniform motion refers to the movement of an object that travels equal distance in equal time intervals. For a moving object at a constant velocity, the analysis is simple, making the relationship between distance and time linear. In such situation, the distance increases proportionally with time. This can be shown graphically by a straight line on a distance time graph, where the slope of the line stands for the velocity [9].

Non-Uniform Motion

Non-uniform motion refers to the movement of an object that travels unequal distance in equal time intervals or unequal time intervals. When the speed of an objects changes because of acceleration or deceleration, the analysis becomes more complicated. For uniformly accelerated motion (with fixed acceleration), we add the following equations:

$$v = u + at \text{ (final velocity} = \text{initial velocity} + \text{acceleration} \times \text{time)}$$

$$s = ut + \frac{1}{2}at^2 \text{ (displacement} = \text{initial velocity} \times \text{time} + \frac{1}{2} \times \text{acceleration} \times \text{time}^2)$$

$$v^2 = u^2 + 2as \text{ (final velocity}^2 = \text{initial velocity}^2 + 2 \times \text{acceleration} \times \text{displacement)}$$

Where u refers to initial velocity, v represents the final velocity, a represents the acceleration, t represents the time, and s represents the displacement [10].

3. Results and Discussion

Practical Applications and Examples

Vehicle Motion Analysis

Suppose a vehicle travels between city (A) and (B), with a distance of 240 kilometers (km), in 3 hours (h). We can express this as follows:

$$\text{Average speed} = \text{distance} / \text{time} = 240 \text{ km} / 3 \text{ hours} = 80 \text{ km/h}$$

This analysis gives us worthy information for journey planning, estimating fuel consumption, and predicting arrival times. However, it is important to note that this speed represents an average speed; the actual speed likely varied during the trip depending on traffic conditions, types of streets, and stops [11].

Pedestrian Movement

Suppose that a person walks at a fixed pace of 5 km/h and wants to reach a destination of 2 km away. The time needed can be estimated as follows:

$$\text{Time} = \text{Distance} / \text{Speed} = 2 \text{ km} / 5 \text{ km/h} = 0.4 \text{ hours} = 24 \text{ minutes}$$

This type of calculation is basic for urbanization planning, urgent response to circumstances, and management of personal time [12].

Falling Objects

If an object falls down freely under the impact of gravity, its falling could be calculated through the movement equation with uniform acceleration where the acceleration becomes about 9.8 m/s^2 due the gravity near Earth's surface. For an object falling from rest from a height h , the time of falling could be estimated through the following equation:

$$h = \frac{1}{2}gt^2$$

The rearrangement of the formula makes: $t = \sqrt{(2h/g)}$

For example, the time it takes for an object to fall from a house of 45 meters is:

$$t = \sqrt{(2 \times 45 / 9.8)} = \sqrt{(9.18)} \approx 3.03 \text{ seconds}$$

This calculations have been applied in safety engineering, establishments, and physics science (13).

Sport Applications

In sport, speed calculations are basics to the analysis of athletes' performance. A runner who runs 100 meters in 10 seconds obtains an average speed of:

$$\text{Speed} = 100 \text{ meters} / 10 \text{ seconds} = 10 \text{ meters/second} = 36 \text{ km/h}$$

This type of calculations enable trainers to improve training programs and helps runners know their levels of performance compared to universal standards [14]

Graphical Representations of Motion

Distance Time Graphs

The use of distance time graphs provides an effective visual representation of motion. In the case of uniform motion, these graphs show straight lines, with a steeper slope confirming greater speeds whereas the slope of any point on the graph stands for the instantaneous speed of an object at that moment of time [15].

Key characteristics of distance time graphs are:

1. Horizontal lines are used to show stationary objects
2. Straight diagonal lines stand for constant speed
3. Curved lines clarify the object acceleration or deceleration
4. The line slope demonstrate speed magnitude

Speed Time Graphs

Speed time graphs provide further views of motion changes. At constant speed, these graphs show horizontal lines. The area below the speed time graph represents the distance traveled, providing another way to calculate the displacement [16].

Interpretation of Real Life Motion

Suppose you have a typical vehicle trip involving a city road drive, highways, and traffic stops. They will produce a distance time graph with different inclines, showing a gradual inclines during city road drive (low speeds), a steeper inclines during highways (high speeds), and horizontal sections during traffic stops (zero speed).

The analysis of this graph enables us enablesto determine the patterns of movement and could be utilized to optimize routes and develop transportation efficiency [17].

Advanced Applications

Relative Motion

When studying the motion of related objects, the mathematical analysis becomes more complex. For instance, when two cars are moving towards one another at 60 km/h and 80 km/h respectively, their relative approached speed is:

$$\text{Relative Speed} = 60 + 80 = 140 \text{ km/h}$$

This concept is essential for understanding the analysis of collision, traffic flow mechanism, and air navigation [18].

Compound Motion

Many actual forms of motion include multidimensional motion. Projectile motion is one of these forms where the horizontal and vertical elements of the motion are calculated individually and then combined to show the whole trajectory [19].

Optimization Challenges

Optimization challenges are the results of mathematical calculation of motion. For instance, defining the optimal speed for fuel consumption requires balancing time savings against energy costs. These challenges involve calculus based optimization techniques, though they could be approached via fundamental mathematical principles [20].

Educational Implications

Connecting Mathematics to Real Life

Motion study provides us with an effective chance to prove the practical principles of mathematics in real life situations. We could relate the mathematical equations to real life experiences, and obtain a deeper knowledge of abstract and concrete mathematical concepts [21].

Problem Solving Skills

The problems of motion lead to the development of critical and analytical thinking skills of students. It enables them to determine relevant information, implement suitable formulas, and explain results in meaningful situations. Such skills are transferred to some academic disciplines and professional fields [22].

Technology Integration

Advanced technology support us with a huge number of instruments for analyzing motion, starting from smartphone applications that monitor the walking speed to modern software of recorded videos analysis. The integration of such technologies with conventional mathematical approaches increase the outcomes of learning and prepares students for advanced analytical techniques [23].

Limitations and Considerations

Assumptions and Simplification

The fundamental formulas introduced in this paper depend on many simplified assumptions:

1. Motion occurs along straight lines.
2. Air resistance is negligible.
3. Gravity influences are constant.
4. Measurement errors are small.

Though these assumptions simplify a straightforward analysis, practical applications often need more sophisticated mathematical models that consider these factors (24).

Accuracy of Measurement

The accuracy of motion analysis depends heavily on the accuracy of time and distance measurements. Any errors in time or distance measurements could significantly affect the calculated velocities, especially when analyzing short duration events or distances (25).

Environmental Factors

Motion is really affected by many real life situation factors, including weather circumstances, surface features, and natural forces. Though basic equations provide beneficial estimates, a more detailed analysis often need some attention to other environmental variables [26].

Discussion

The analysis of motion is conducted by mathematics to highlight the beauty and power of simple equations or models in describing complicated relationships. We

encounter motion daily, from driving to work to more complex engineering applications, and we rely on fundamental relationships of speed, distance, and time to enable us to comprehend our natural world.

The global application of the mathematical principles of motion is truly remarkable. In motion analysis, the same formulas utilized to describe a child's walk to school are used to express and clarify planetary motion, transportation flow, and working with sophisticated equipment. This basic interconnectedness of phenomena explains the basic nature of mathematical laws and their capability to encompass and describe phenomena occurring in the real life situations [27].

Another advantage of this analysis is the accessibility of mathematical relations, making it a readily available and educationally useful field. The subject matter of motion analysis helps us to directly connect our everyday experiences, whether it be a walk or a car ride, to our understanding of speed or distance. It also helps us bridge the gap between reality and the theories we learn [28].

The visual representations of motion gives us a deeper understanding on how to see important visual patterns that add significant value to abstract mathematical principles. Such visual representations provide us with different cognitive tools for rapid explanation of mathematical relationships and models without relying solely on numerical values. They also promote our understanding of relationships and patterns that might not provide a complete picture based on numerical information [29].

The analysis of motion, with relation to technology, is constantly evolving and becoming more complex. However, the mathematics upon which we base our understanding of motion and technology remains constant. When we grasp the core of the fundamental concepts, we open the door to more advanced concepts in physics, engineering, and applied mathematics, concepts that go beyond simple analyses [30].

4. Conclusion

This paper began by introducing the basic mathematical concepts of motion analysis and showing the benefits of utilizing simple equations to comprehend and expect relatively sophisticated phenomena. It showed the initial velocity analysis and, in a more comprehensive context, scenarios, including acceleration and relative motion, demonstrated how the mathematical calculation of motion helps us determine and visualize motion in natural world.

Practical applications illustrating the fundamental factors demonstrate how deeply these four principles are embedded in real life situations. From planning trips to visualizing a player motion during a game or physical contexts. Furthermore, it provided some examples that contextualize speed, distance, and time within everyday circumstances, and offered valuable analytical equipment.

It also allow us to build understand motion more deeply, graphical representation allows us to construct visual representation that embody insights into predictive mathematical relations to enable learners measure concepts, transform ideas of "representation" into explainable models, and make strong decisions about natural physical phenomenon.

With the advancement and evolution of technology, the fundamental mathematical principles remain the same. They support learners with useful platforms to apply new methods in a more complex motions, imbuing them with similar significance. It is significant not only to appreciate its abstract value and inspiration, but also to appreciate it ability to express and predict natural world, and understand the acts of people and the objects around us. This study of the mathematics of motion serves as a practical example of how seemingly simple concepts are of paramount importance in numerous fields outside of mathematics, including economics, biology, human geography, and anthropology. By appreciating these fields, we not only appreciate the beauty of mathematics but also its usefulness in understanding both natural and human phenomena.

To sum up, the study of the mathematics of motion plays an important role in joining concepts with concrete reality, linking questions and hypotheses with answers and discussions, and formulating theories and studying practices.

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