REVISITING THE DEFINITION OF ELASTIC COLLISION: A PEDAGOGICAL ANALYSIS OF KINETIC ENERGY CONSERVATION

Sabir Haneef*

Department of Physics, Amar Singh College, Cluster University Srinagar, India

*Corresponding Author: sabirhaneef07@gmail.com

Abstract: The definition of an elastic collision is typically introduced early in undergraduate mechanics. Although the underlying physics is universally agreed upon, introductory mechanics textbooks employ different linguistic formulations to express the conservation of kinetic energy. Some texts use concise statements such as "the total kinetic energy is unchanged" or "kinetic energy is conserved," whereas others explicitly state that the kinetic energy before the collision is equal to that after the collision or clarify that kinetic energy need not remain constant during the collision. For novice learners, the distinction between these formulations may be pedagogically significant. During a finite-duration collision between deformable bodies, translational kinetic energy can be temporarily converted into elastic potential energy and subsequently restored. Thus, equality of the initial and final kinetic energies should not be interpreted as instantaneous constancy throughout the collision interval. This study examines the physical and pedagogical implications of these alternative formulations and argues that explicitly identifying the initial and final states can provide greater clarity for novice learners. The study further proposes such wording as a pedagogical baseline for introducing elastic collisions, while recognizing that similar clarifications are already present in some existing textbooks.

Keywords: elastic collision; kinetic energy conservation; introductory mechanics; physics education; textbook definitions; conceptual clarity.

(Received: 13 August 2026; accepted: 15 October 2026; published: 30 October 2026)

1 Introduction

Definitions are among the first tools that students encounter when studying physics. The wording of a definition can significantly influence the understanding of a concept. A concise definition may be adequate for experts, but the same wording may be less clear for learners who have not yet developed the surrounding model for the concept. Elastic collisions provide a useful example of this.

Elastic collisions are commonly introduced as collisions in which the kinetic energy is conserved, although introductory mechanics textbooks employ different formulations of this idea. Some texts use concise expressions such as "the total kinetic energy is unchanged" or "kinetic energy is conserved," whereas others explicitly identify the initial and final states being compared. For example, some formulations clarify that the kinetic energy need not remain constant during the collision and that the initial kinetic energy is equal to the final kinetic energy. Thus, the issue is not that existing textbook definitions are universally incorrect, but that the degree of explicitness varies among formulations.

For novice learners, this distinction may be pedagogically significant. A concise statement such as "kinetic energy is unchanged" may be interpreted literally as implying that kinetic energy remains constant throughout the entire collision interval. This interpretation is inconsistent with the temporary conversion of translational kinetic energy into elastic potential energy during deformation and its subsequent conversion back during restitution. The present study therefore examines the pedagogical implications of these alternative formulations

and considers whether an explicit initial-and-final-state formulation can provide a clearer baseline for introductory instruction.

This study has a limited scope. It does not propose a new definition of mechanics. Rather, it examines the wording of an established definition and proposes an explicit pedagogical baseline for introductory instruction. The argument is conceptual rather than empirical.

2 Energy Evolution During an Elastic Collision

An elastic collision is characterized by conservation of linear momentum and by equality of the total kinetic energy of the system between its initial and final states. This does not require the translational kinetic energy to remain constant at every instant during the finite collision interval.

Consider the following situation: two perfectly elastic balls of masses m_1 and m_2 move along the same straight line on a frictionless horizontal table. Before the collision, the ball of mass m_2, which is ahead of m_1, moves with a velocity u_2 smaller than the velocity u_1 of m_1.

Before contact, the system's energy is entirely translational kinetic energy. At the instant they come into contact, the rear ball has a larger velocity u_1 and the front ball has smaller velocity u_2. However, the surfaces in contact must move equal distances to acquire a common velocity while the bodies remain in contact. The balls must be deformed upon contact. As the bodies deform, a part of the translational kinetic energy is converted into elastic potential energy stored within the bodies. The deformation (i.e. elastic potential energy) is maximum and the kinetic energy is minimum when the two balls attain equal velocities.

The subsequent motion of the balls after this depends on the nature of the ball materials. As the balls were perfectly elastic, forces may have developed inside them, causing the balls to attempt to regain their original shape. In this case, the balls continue to exert forces on each other, while remaining in contact. The contact force acts in the direction of the motion of m_2, causing it to accelerate. According to Newton's third law, an equal and opposite force acts on m_1, causing it to decelerate. The velocity of the front ball (which was initially slower) gradually increased, and the velocity of the rear ball (which was initially faster) gradually decreased.

After separation, the balls regain their original shapes, and the elastic potential energy is completely converted back into translational kinetic energy. Consequently, although the total mechanical energy is conserved throughout the collision, the translational kinetic energy generally varies during the finite contact interval

3 Standard Physical Meaning

For two bodies forming an isolated system, the conservation of linear momentum is expressed as:

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2 \tag{1}$$

For an ideal elastic collision, the total translational kinetic energy of the isolated system is equal in the initial and final states. If t_i denotes the initial state and t_f the final state, this condition can be written as:

$$K(t_i) = K(t_f) \tag{2}$$

or, explicitly,

$$\frac{1}{2}m_1 u_1^2 + \frac{1}{2}m_2 u_2^2 = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2 \tag{3}$$

where u_1 and u_2 are the velocities before the collision and v_1 and v_2 are the velocities after separation.

Equivalently, for one-dimensional elastic collisions, the relative speed of approach equals the relative speed of separation:

$$u_1 - u_2 = -(v_1 - v_2) \quad (4)$$

with signs consistently chosen along the line of motion.

The condition $K(t_i) = K(t_f)$ should be distinguished from the stronger condition $K(t)$ = constant for all t during the collision. The latter would imply that the translational kinetic energy remains unchanged throughout the interaction, which is not generally the case for a finite-duration collision involving deformation.

These equations refer specifically to the initial and final states normally used in collision problems: the bodies are separated, interaction energy is negligible, and the mechanical energy is represented by the translational kinetic energies of the bodies. Thus, the conservation condition is an equality between two specified states, $K(t_i) = K(t_f)$, rather than a statement that $K(t)$ remains constant throughout the collision interval. During contact, translational kinetic energy may vary as energy is temporarily stored as elastic potential energy and subsequently returned.

4 Two Linguistic Formulations

A comparison of selected introductory mechanics texts reveals two broad styles of definition.

- **Formulation A:** "An elastic collision is a collision in which the total kinetic energy is unchanged."

- **Formulation B:** "An elastic collision is a collision in which the total kinetic energy after the collision equals the total kinetic energy before the collision."

From a mathematical perspective, when interpreted within the standard collision framework, these formulations express the same initial–final conservation condition, $K(t_i) = K(t_f)$. However, the phrase "kinetic energy is unchanged" can also be read linguistically as suggesting $K(t)$ = constant throughout the collision. The latter is a stronger statement and is not required for an elastic collision. The formulation explicitly referring to the initial and final states therefore makes the intended mathematical condition more transparent.

5 Comparison of Textbook Definitions

Introductory mechanics textbooks use several closely related formulations. Some definitions state that kinetic energy is conserved or unchanged in an elastic collision, whereas others explicitly state that the total kinetic energy after the collision is equal to the total kinetic energy before the collision.

Table 1: Pedagogical comparison of textbook definitions. The table classifies wording styles rather than asserting that any textbook is incorrect.

Source	Representative definition
An Introduction to Mechanics [1]	"A collision in which total kinetic energy is unchanged is called an elastic collision."
Mechanics and Properties of Matter [2]	"If the total kinetic energy of the colliding particles like bodies remain constant, the collision is said to be an elastic collision."
Sears and Zemansky's University Physics with Modern Physics [3]	"Elastic collision in an isolated system is one in which kinetic energy (as well as momentum) is conserved."
Concepts of Physics, Part 1 [4]	"Thus, although kinetic energy is not constant, the initial kinetic energy is equal to the final kinetic energy. Such a collision is called an elastic collision."

Introduction to Classical Mechanics: With Problems and Solutions [5]	"There are two types of collisions among particles, namely elastic ones (in which kinetic energy is conserved) and inelastic ones (in which kinetic energy is lost)."
Fundamentals of Physics [6]	"In an elastic collision, the kinetic energy of each colliding body may change, but the total kinetic energy of the system does not change."
Classical Dynamics of Particles and Systems [7]	"A collision is elastic if no change in the internal energy of the particle results; thus, the conservation of energy may be applied without regard to the internal energy."

The comparison also shows that the distinction between the kinetic energy during the collision and the equality of the initial and final kinetic energies is already made explicitly in some introductory texts. [4], for example, explicitly notes that kinetic energy is not constant while the initial kinetic energy is equal to the final kinetic energy. Similarly, [6] clarify that the kinetic energy of an individual colliding body may change even though the total kinetic energy of the system remains unchanged. These formulations provide useful clarification of the physical meaning of an elastic collision. The present discussion therefore does not suggest that existing textbook definitions are physically incorrect. Rather, it emphasizes the value of making the initial and final states explicit and considers such wording as a possible pedagogical baseline for introductory instruction.

6 Potential Ambiguity for Novice Learners

The phrase "kinetic energy is unchanged" may be interpreted in two distinct ways:

• The kinetic energy remains constant throughout the collision.

• The initial and final kinetic energies are equal.

Professional physicists generally infer the second interpretation automatically. However, students encountering the concept for the first time may not. Some introductory texts already make this distinction explicit, as illustrated in Table 1. However, such clarification is not uniform across the formulations considered here.

This distinction between physical correctness and communicative clarity provides the basis for considering the issue in the context of physics education research, where students' difficulties with conservation concepts have been documented.

Therefore, the issue concerns not the correctness of the physics but rather the clarity of the communication. In expert use, the concise definition is accurate. The issue is whether the definition provides sufficient information for students encountering the concept for the first time to understand it.

7 Connection with Physics Education Research

Physics education research has documented difficulties in student's understanding of conservation principles in mechanics, including the coordination of momentum, kinetic energy, and conservation laws in collision contexts. Grimellini-Tomasini and colleagues examined conceptual change in students learning conservation laws in mechanics [8]. Bryce and MacMillan reported that momentum and kinetic energy can be confused by students in school physics, highlighting difficulties in distinguishing related physical quantities and their respective conservation conditions [9]. More recent work has examined student and teacher mental models in Newton's cradle contexts [10], the redistribution of translational kinetic energy in bouncing phenomena [11], and student understanding of energy and momentum using the Energy and Momentum Conceptual Survey [12].

These studies provide a broader pedagogical context for the present discussion. Understanding an elastic collision requires students to distinguish between momentum and kinetic energy, identify which quantities are conserved, and recognize that conservation does not necessarily mean that a quantity remains numerically constant at every instant of a physical process. These distinctions can be particularly important in collision

problems, where translational kinetic energy may change during the interaction even though the initial and final kinetic energies of an ideal elastic collision are equal.

The existing studies cited here do not directly establish that the phrase "kinetic energy is unchanged" causes students to interpret kinetic energy as constant throughout the collision. Rather, they indicate that students can experience difficulties with conservation concepts and with distinguishing related physical quantities. This provides a pedagogical basis for examining whether greater explicitness in the wording of an elastic-collision definition can make the intended initial–final conservation condition clearer to novice learners.

8 Pedagogical Considerations

Physics education often balances brevity against precision. The concise definition, "An elastic collision is a collision in which total kinetic energy is unchanged," has the advantage of simplicity and is physically correct. However, it does not explicitly identify the states being compared and may therefore require additional explanation for novice learners.

A more explicit formulation, "An elastic collision is a collision in which the total kinetic energy after the collision equals the total kinetic energy before the collision," retains the same physical meaning while specifying the initial and final states. From a pedagogical perspective, explicitly identifying these states may provide greater clarity concerning the distinction between equality of initial and final kinetic energies and constancy of kinetic energy throughout the collision process.

This consideration is consistent with the broader concerns identified in physics education research regarding students' understanding of conservation principles, while recognizing that the specific effect of alternative definitions on student learning would require empirical investigation.

9 Proposed Pedagogical Baseline for Introductory Teaching

For introductory instruction, the following wording is proposed as an explicit pedagogical baseline:

> "An elastic collision is a collision in which, for an isolated system and under ideal non-dissipative conditions, the total kinetic energy of the system after separation is equal to the total kinetic energy of the system before contact."

A shorter classroom formulation is also possible:

> "In an elastic collision, the total kinetic energy of the system before the collision is equal to its total kinetic energy after the collision."

The longer formulation is more precise because it makes three assumptions explicit: the system is isolated during the short collision interval, dissipative losses are neglected, and the kinetic energy is compared between the initial and final states. The shorter formulation may be adequate when these assumptions are discussed.

This formulation is consistent with the explicit initial–final treatment already found in some introductory texts, while presenting the boundary states in a single definition intended for introductory classroom use.

10 Limitations and Future Work

This study was conceptual rather than experimental. No classroom studies, student interviews, or statistical analyses were conducted to determine whether alternative definitions produced measurable differences in students' understanding. Consequently, the arguments presented here should be regarded as pedagogical considerations rather than as empirical conclusions.

Future studies could experimentally examine this question by presenting alternative definitions to student groups and evaluating differences in conceptual understanding. One group could receive the conventional definition,

whereas the other could receive the explicit before-and-after formulation. Both groups could then answer diagnostic questions asking whether kinetic energy remained constant during contact, whether total mechanical energy was conserved, and which states were compared in the definition of an elastic collision. Such a study should report the sample size, item wording, scoring rubric, confidence intervals, and measures of statistical uncertainty.

11 Conclusion

The standard definitions of an elastic collision used in introductory mechanics remain physically correct and are consistent with the established mechanics framework. The comparison presented here also shows that some textbooks already explicitly distinguish the initial and final kinetic energies or clarify that kinetic energy need not remain constant throughout the collision. However, the degree of explicitness varies among formulations. Definitions that explicitly compare the kinetic energy of the system before and after the collision can make the boundary states being compared clearer to novice learners and can help distinguish initial-to-final equality from instantaneous constancy. The contribution of the present discussion is therefore not to replace an incorrect definition, but to emphasize explicit before-and-after wording as a possible pedagogical baseline for introductory instruction.

Conflict of Interest Statement

The author declares that there are no conflicts of interest regarding the publication of this manuscript.

Funding Statement

This research received no external funding.

Data Availability Statement

No datasets were generated or analyzed during the current study.

Ethics Statement

This study did not involve human participants, animals, or any research requiring ethical approval.

Acknowledgements

The author gratefully acknowledges Dr. Waseem Bashir (Head of the Department of Physics, Amar Singh College, Srinagar) for his invaluable guidance, continuous encouragement, and insightful discussions throughout the course of this work. The author is especially thankful to him for reviewing the manuscript and for the knowledge and understanding of Mechanics and Properties of Matter imparted during his teaching, which provided an important foundation for the present study.

The author also extends his heartfelt gratitude to Dr. D. C. Tayal (Former Head of the Department of Physics and Retired Principal, NREC College, Khurja) and Dr. Pranjal Trivedi (Research Associate at the University of Hamburg, Germany) for their careful review of the manuscript and for the constructive suggestions and valuable comments, which significantly improved the quality, clarity, and presentation of this paper.

AI Disclosure Statement: In preparing this work, the author used QuillBot for grammatical correction and language refinement. The author subsequently reviewed and revised the content as necessary and accepts full responsibility for the final published work.

References

[1] D. Kleppner and R. J. Kolenkow, An Introduction to Mechanics, (Cambridge University Press, Cambridge, 2014).

[2] D. C. Tayal and P. Tayal., Mechanics and Properties of Matter, (Dinesh Chandra Tayal and Sons, Greater Noida, 2023).

[3] H. D. Young and R. A. Freedman, Sears and Zemansky's University Physics with Modern Physics, (Addison-Wesley, San Francisco, CA, 2012).

[4] H. C. Verma, Concepts of Physics, Part 1, (Bharati Bhawan, New Delhi, 2015).

[5] D. Morin, Introduction to Classical Mechanics: With Problems and Solutions, (Cambridge University Press, Cambridge, 2008).

[6] D. Halliday, R. Resnick and J. Walker, Fundamentals of Physics, (John Wiley & Sons, Hoboken, NJ, 2014).

[7] S. T. Thornton and J. B. Marion, Classical Dynamics of Particles and Systems, (Brooks/Cole, Belmont, CA, 2004).

[8] N. Grimellini-Tomasini, B. Pecori-Balandi, J. L. A. Pacca and A. Villani, "Understanding Conservation Laws in Mechanics; Students' Conceptual Change in Learning About Collisions", Science Education 77, 169-189 (1993).

[9] T. G. K. Bryce and K. MacMillan, "Momentum and kinetic energy: Confusable concepts in secondary school physics", Journal of Research in Science Teaching 46, 739-761 (2009).

[10] C. Sarapak and K. Kearns, "Diagnosing Mental Models of Undergraduate Student and Physics Teachers: Study Case in the Momentum and Energy Conservation Principles Using Newton's Cradle", Jurnal Pendidikan IPA Indonesia 11, 684-691 (2022).

[11] C. D'Angelo, L. Viennot, M. Argentina, F. Celestini and C. Raufaste, "Redistribution of translational kinetic energy: the surprise of bounces", European Journal of Physics 43, 065005 (2022).

[12] M. J. Brundage, A. Maries and C. Singh, "Using the Energy and Momentum Conceptual Survey to investigate progression in student understanding from introductory to advanced levels", Physical Review Physics Education Research 19, 020132 (2023).