Generalization of Newton's 340-Year-Old Third Law: An Open Challenge for Experimental Verification Using Low-Cost Methods.

Ajay Sharma

Fundamental Physics Society. His Mercy Enclave, Post Box 107 GPO Shimla 171001 HP India Email: ajoy.plus@gmail.com Mobile 0091 94184-50899

Abstract

Newton has expressed the third law of action and reaction in terms of force, i.e. Reaction (F_{BA}) = − Action (F_{AB}). In the standard textbooks, the law is understood with the help of many qualitative examples and thus needs to be understood quantitatively. For simplicity, the experiments concerning falling and rebounding bodies are considered in a closed room.

In the past decade, some deviations from Newton's third law have been reported by scientists in state-of-the-art experiments in electromagnetism, statistical physics, astronautics, biological and chemical physics, etc.

These independent observations also compel us to look at the author's generalized form of the third law (within the domain of Newtonian mechanics).

The typical shapes of bodies may be semi-spherical, polygon, long-thin pipe, flat, or any typical shape, etc. If the mass and composition of the bodies are precisely the same, then anomalous results would be because of the shape of the body only. The effect of the shape may be confirmed in specific experiments.

Here, the reaction is also theorized to depend on the **shape, size, symmetry, composition of bodies, characteristics of the target, or other relevant factors.** Thus, the purported equation becomes Reaction (F_{BA}) = −Action (F_{AB}) [$K_{shape} \times K_{composition} \times K_{target} \times K_{other}$].

For simplicity, the discussion involves falling and rebounding bodies, the recoil of guns, etc.

The generalized form of Newton's third law needs to be validated through precise experiments, as completely described here.

1.0 Introduction and Background

Newton formulated the Third Law of Motion in Latin in the Principia (1686), later translated into English by Andrew Motte in 1729, whose brother published it for commercial gain primarily.

In the English edition, the law appeared in Volume I of the Principia, under the section titled **Axioms or Laws of Motion,** on pages 19–20.

"To every action there is an equal and opposite reaction, or the mutual actions of two bodies upon each other are always equal and directed to opposite parts."

Newton did not present mathematical equations for the law, as symbolic formulations were uncommon during his time. Newton interpreted physical phenomena using ratios and proportional relationships. The Third Law's definition remained unchanged across all three editions of the Principia (1686, 1713, and 1726), spanning a period of forty years.

Mutual interactions occur simultaneously between bodies; hence, action and reaction forces always arise in pairs. While explaining the law, Newton stated in the Principia Mathematica:

"Whatever draws or presses another is equally drawn or pressed by that other."

Newton provided three illustrative examples in the Principia to support the Third Law of Motion.

(i) Newton wrote: If a horse pulls a stone tied to a rope, the horse is equally pulled back toward the stone.

(ii) If you press a stone with your finger, the stone simultaneously exerts pressure on your finger.

In both cases, Newton considered the limited force exerted by the finger or horse on the stone, keeping the system in equilibrium. If sufficient force is applied to the stone by either the finger or the horse, the stone begins to move, a case Newton did not address.

Newton described action and reaction as manifestations of force, expressed through pushing or pulling interactions. Today, Newton's Third Law is represented mathematically as:

Reaction = - Action (1)

Force of Action of Body B on Body A (F_{BA}) =
- Force of Action of Body A on Body B (F_{AB}) (2)

(iii) Newton, in the third example of the third law of motion in Principia stated :

"If a body impinges upon another and by its force change the motion of the other, that body also (because of the quality of the mutual pressure) will undergo an equal change, in its own motion, towards the contrary part."

Again, equal and opposite interactions are trademarks of Newton's interpretation of the third law in all interpretations.

In this case, Newton considered the state of motion of bodies.

Consider that body A (projectile) of mass M_p applies force and changes the motion of body B (target) of mass M_t. Let the initial velocity of body A be u_1 and that of body B be u_2. After the collision, the velocity of body A becomes v_1, and that of body B, v_2.

[Change in motion of the body B (target) when the body A (projectile) impinges on it] or [Reaction] =

- [Change in motion of the body A (projectile)] or [Action] (3)

or $[M_tv_2 - M_tu_2] = - [M_pv_1 - M_pu_1] = - M_pv_1 + M_pu_1$

$M_pu_1 + M_tu_2$ (Initial momentum of the system)

$= M_pv_1 + M_tv_2$ (Final momentum of the system) (3)

which is the law of conservation of momentum.

The importance of Eq.(3) follows from the third law at the macroscopic level

Recoil Velocity of the gun

or $v_{gun} = - m_{bullet} . v_{bullet} / m_{gun}$ (4)

Eq.(4) is discussed and taught, in support of Newton's Third Law in science, n-number of times theoretically, but not confirmed experimentally, even once taking all possible factors into account.

Ideal Rocket Equation

Using Eq.(3) has also been used by Tsiolkovsky in the derivation of the Ideal Rocket Equation in 1897 and published in 1903 in the paper "Exploration of Outer Space by Means of Reaction Devices" as

$V = V_e \ln M_0 - V_e \ln M = V_e \ln M_0/M$ (5)

The equation may be experimentally judged for fireworks under ideal conditions. Historically, fireworks or rockets were discovered centuries earlier in 1100 AD by the Chinese.

1.1 Mathematical Foundations of Freely Falling and Rebounding Bodies.

Euler formulated the equation F=ma in 1776, nearly 90 years after Newton's Principia. This equation was subsequently interpreted in terms of gravitational weight, replacing 'a' with 'g'.

Newton presented the law of gravitation in *The System of the World,* considered the third volume of the Principia. The standard value of gravitational acceleration ($g = 9.80665\ m/s^2$) was first determined in 1888 by the Geographic Service of the French Army.

Hence, gravitational acceleration (g) was quantified 202 years after Newton proposed the law of gravitation in the Principia. Later, the 3rd General Conference on Weights and Measures (CGPM), in 1901, via Resolution 2, formally defined weight (from F=ma) as ,

Weight = mg (6)

In equations describing free-falling and floating bodies, force is the measurable quantity; thus, such equations became viable in 1901, i.e., 125 years ago, when weight was defined, and are now proposed for QUANTITATIVE experimental validation at the MACROSCOPIC scale. In the case of a freely falling body, the action is force or weight (mg).

Similarly, Eq. (4) is significantly older, yet it remains experimentally unverified. Additional efforts are needed to validate Eq. (5) for fireworks under rigorously controlled laboratory conditions. Scientific theory is validated through repeated precise experimentation, not by continuous theoretical examinations or teachings.

2.0 Research Gap or Significance of Discussion in 2025, i.e., 339 Years Later.

Newton proposed the Third Law of Motion during the era of natural philosophy, without using equations. Hence, the law remained qualitative for nearly two centuries due to the absence of mathematical formalism.

Newton's Principia concluded Natural Philosophy and marked the theoretical origin of classical Physics. Newton stated the Third Law with qualitative illustrations, and later scientists expanded its applications to various phenomena. **These include bouncing balls, swimming, rowing, jumping ashore, walking, balloon recoil, gun recoil, fireworks, and rocket propulsion.**

All such examples have traditionally been taught through theoretical explanations for centuries. generations. The objective of this discussion is to resolve these issues using quantitative experimental methods.

This investigation leads to a generalized expression of Newton's Third Law of Motion as:

$$\textbf{Reaction } (F_{BA}) = -\textbf{ Action } (F_{AB})[K_{shape} \times K_{composition} \times K_{target} \times K_{other}] \quad (7)$$

Original Law : **Reaction (F_{BA}) = - Action (F_{AB})**

$$K = [K_{shape} \times K_{composition} \times K_{target} \times K_{other}] \quad (8)$$

K is an additional significant factor introduced in the law.

3.0 Objectives

Experimental validation of Newton's Third Law requires confirming two essential conditions:

(a) Every action must produce an equal reaction

(b) The direction of the reaction must oppose that of the action.

Both criteria must be satisfied to ensure the law's precise applicability. The negative sign denotes that the reaction force acts in the opposite direction to the action. Therefore, our primary objective is to measure the magnitudes of action and reaction, and the direction of reaction.

Newton described action and reaction as forces, either pushing or pulling in nature. Hence, the force exerted by the second body on the first, along with both force directions, must be quantified.

(ii) Introductory textbooks present Newton's Third Law qualitatively through **familiar examples. These include bouncing balls, swimming, rowing, jumping ashore, walking, balloon recoil, gun recoil, fireworks, and rocket propulsion.**

Such examples have long been taught theoretically, but require quantitative experimental verification. At the macroscopic scale, confirming the law experimentally remains a significant challenge.

Physical Considerations of Freely Falling and Rebounding Bodies

For simplicity, we consider the case of freely falling and floating bodies. In these experiments, body and target characteristics like shape, size, symmetry, and composition must be evaluated.

Reliable results can be obtained if mass and composition are held constant while varying only the shape. If bodies with identical mass and composition but different shapes fall and rebound from the same target, then any observed discrepancies must arise solely due to the shape of the bodies.

(iv) Practical Observations

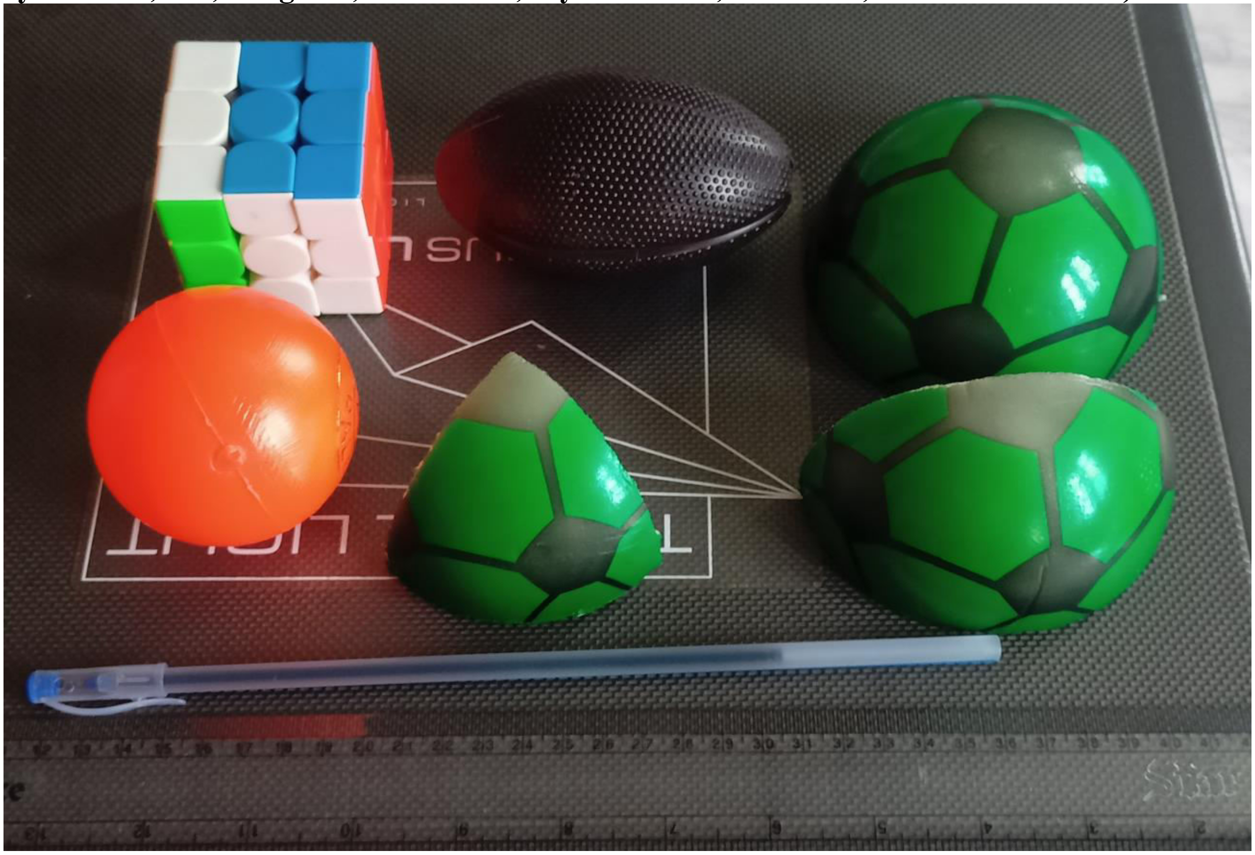
Consider a spherical body that freely falls from the initial point A_0, from a height $H_{original}$, above the floor or ground surface. It is attracted by Earth due to the gravitational force, which corresponds to its weight (mg); which is the action (force or weight) of a falling body.

If the mass of the body is 1 kg, then the action or force or weight exerted by the falling body equals 9.8 newtons (mg). This is reaction irrespective of shape and characteristics of body.

(a) When the body strikes the surface, interactions between the sphere and surface generate a reaction, causing rebound in the opposite direction [as per Newton's Third Law and Eq. (1)].

Under specific conditions, the sphere rebounds to its original point, retracing the same vertical path. Therefore, for a sphere, the reaction's magnitude equals the action, and its direction is precisely opposite, completely validating the law in this case. This example is commonly illustrated in both elementary and advanced physics textbooks regarding Newton's Third Law.

(b) Newton's Third Law applies universally to all bodies regardless of shape. The mass of a body remains constant across shapes; hence, bodies of 1 kg with identical composition but different geometries **(e.g., spherical, hemispherical, triangular, hexagonal, polygonal, conical, cylindrical, flat, irregular, needle-like, asymmetrical, sheet-like, or thin cardboard).**



The action or force, or weight, remains the same for all such falling bodies as mass is the same. Newton's law requires a reaction of the same magnitude and opposite direction. When a spherical body falls, it should ideally rebound to point A_0, retracing its descent path. The explanation is straightforward: action and reaction for a sphere and any shaped body (Action = Reaction = -9.8 newtons), so all should rebound identically under Newton's Law.

(c) Inconsistent Qualitative Observations at MACROSCOPIC LEVEL.

However, even qualitatively, bodies of identical mass and composition but different shapes rebound to varying heights (H_{rebound}) and angles (A_{rebound}). Newton's Third Law appears to be violated when differently shaped bodies (with the same mass and composition) rebound inconsistently. Therefore, such qualitative observations must be repeated for final validation of the law.

(v) Quantitative Measurement of Rebound Parameters

Thus, we must accurately measure the following physical parameters. First, the height from which the body is released from point A_0 (H_{original} or 1 m, for example). The body descends vertically, and the angle is taken as the reference angle ($\text{Angle}_{\text{fall}}$). The body should touch the surface after 0.45s ($S = gt^2/2$)

$$t_{\text{theory}} = \sqrt{\frac{2S}{g}} = 0.45\text{s} \qquad (9)$$

Second, the height to which the body rebounds (H_{rebound}) after interactions between body and surface (floor). The corresponding time may also be measured.
Third, the angle at which the body rebounds ($\text{Angle}_{\text{rebound}}$), measured relative to $\text{Angle}_{\text{fall}}$.

4.0 Methodology

In simple terms, the procedure involves measuring H_{rebound} and $Angle_{\text{rebound}}$, and comparing them with their original values.

1. Release the body from a predetermined height. Capture fall and rebound using a high-speed camera.
2. Quantify rebound height (H_{rebound}). using a calibrated distance sensor.
3. Assess rebound angle through video-based analysis or a precision inclinometer
4. Analyze data across varied shapes while maintaining constant mass and composition.

5.0 Expected Outcome

Basis of projections of experiments: At the qualitative level, a spherical body may rebound to its original point A_0, retracing its initial path of descent. Thus, Eq. (1) is precisely obeyed. In addition, we can also measure the experimental time $t_{\text{experimental}}$ when H_{rebound} is maximum. t_{theory} is 0.45s as given by Eq.(9).

Whereas bodies of different geometries, e.g. **spherical, hemispherical, triangular, hexagonal, polygonal, conical, cylindrical, flat, irregular, needle-like, asymmetrical, or sheet-like—rebound to varying (lower) heights and at distinct angles.** This behavior requires quantitative evaluation, as no comparable data have been reported in the literature.

(i) We aim to measure H_{rebound} and compare it with H_{original}. Likewise, $Angle_{\text{rebound}}$ needs to be measured and compared with the reference $Angle_{\text{fall}}$.

These qualitative trends will be experimentally validated.

(ii) Based on the observed qualitative behavior, it is inferred that H_{rebound} will generally be less than H_{original}—possibly ½ H_{original}, or another fraction thereof. If $Angle_{\text{fall}}$ is taken as a reference, then $Angle_{\text{(rebound)}}$ may be 30° or differ, depending on the body's shape, size, and symmetry. In this regard point of impact is significant. Hence, the law is not quantitatively obeyed.

These elusive experiments may have a far-reaching impact on the basic aspects of science.

6.0 Generalized Form of Newton's Third Law of Motion

In such experiments, parameters like **shape, size, symmetry, composition, and impact characteristics of the bodies** may have a significant influence. Hence, Newton's Third Law,

$$\text{Reaction } (F_{BA}) = -\text{Action } (F_{AB}) \qquad (1)$$

may be generalized as:

$$\text{Reaction } (F_{BA}) = -\text{ Action } (F_{AB})[K_{\text{shape}} \times K_{\text{composition}} \times K_{\text{target}} \times K_{\text{other}}] \qquad (7)$$

(i) If a spherical body rebounds to its original point A_0, then the values of all Ki's are unity.

(ii) Since the mass and composition of the bodies are identical, all fall identically on the same target. Hence, all factors other than the body's shape may be treated as unity ($K_{composition}$, K_{target}, and $K_{other} = 1$), so any variation arises solely due to K_{shape}.
If a body rebounds to ½ H_{original}, then $K_{shape} = ½$. Thus,

$$\text{Reaction } (F_{BA}) = -\text{Action } (F_{AB})\cdot K_{\text{shape}} = -\text{Action } (F_{AB})\cdot ½ \text{ at an angle of } 30° \qquad (10)$$

(iii) In the case of a flat body (same mass and composition) that does not rebound at all,

$$\text{Reaction } (F_{BA}) = 0 \qquad (11)$$

In such cases, $K_{other} = 0$. (12)

7.0 Equipment:

Practically, it requires extensive discussion on the topic. Here is the first glimpse, I have produced from internet research. I have not used these gazettes, but while purchasing the method of their application can be learnt from the supplier's technicians and literature.

(i) To measure the time of impact (when the body touches the floor)

1. Industrial USB cameras (₹30,000–₹50,000): With frame rates up to 500 fps, suitable for basic motion tracking.
Available: AlphaTech Systems:

2. Photogate Timer System. To measure the exact time interval between two positions (start of fall and impact at the bottom).
Rs. 15,000 – Rs 50,000
Available: Eduscope India:

(ii) To measure the angle at which the body rebounds.

1. Angular Calibration Grid Options

Printed Angular Calibration Grids (for camera alignment and angle measurement):
Price: ₹2,000–₹10,000 depending on size and precision
Available. Amazon India

2. Inclinometer / Digital Angle Finder
Model: Bosch GIM 60 L Digital Inclinometer.
cost Rs. 10,000 – 15,000
Available: Drihten Technology Pvt. Ltd. (Pune), Vasu International in New Delhi

(iii) To measure rebounding heights
1. The KICKPI K1 developer kit costs ₹14,058 in India,
Available. Amazon India
2. Laser Displacement Sensor, cost Rs 50,000-2,00,000
Available: Orbital Mekatronik Systems Pvt. Ltd. (Mumbai)
Also, there is a wide range of instruments for conducting experiments.

8.0 Budget Estimate and duration

The estimate includes detailed costs for manpower, equipment, materials, and contingencies. It is under preparation and is expected not to exceed Rs.10,00,000 even higher precision equipment are used. The total cost depends on the precision and quality of the instruments used.
The author is willing to work continuously without honorarium or salary, considering the successful completion of experiments within six months after the funding as he has spent more than 43 years on such topics. The experiments may be done within six months of the financial approval of the project.

9.0 Conclusions

The validity of the law's definition stated in the Principia (1686) is universally recognized. It continues to be discussed **qualitatively** in standard textbooks. **Quantitative** observations are essential and must be explored at the **macroscopic scale**. Such observations have never been documented in the 339-year history of Newton's Third Law of Motion. For simplicity, the experiments concerning falling and rebounding bodies are considered in a closed room. These experiments may cause a paradigm shift in classical mechanics about the action and reaction law.

Acknowledgments

The author expresses deep gratitude to Professor Gordon Ramsey, President of the AAPT; Dr. Stephan Crothers; Dr. V. P. S. Awana of NPL, New Delhi; and Dietician Anjana Sharma for their encouragement and insightful comments during various stages of this work. The author also gratefully acknowledges the financial support provided by the Fundamental Physics Society, Shimla.

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[22] Few more publications on the topic i.e. generalization of Newton's third law as

Reaction $(F_{BA}) = -$ Action $(F_{AB})[K_{shape} \times K_{composition} \times K_{target} \times K_{other}]$

in conferences and under consideration by Editors for journals.