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## Mathematics and Decision Science

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- Relation between New Transform
- Time's Acceleration and Velocity
- Iteration Method to Adequate Solutions

Discovering Thoughts, Inventing Future

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# Combing" The Hair of a Hairy Ball?. Geometry with the Hairy Ball Theorem: A Practical Proposal for Bringing the Sphere into the Mathematics Classroom

By Patricia Val Fernández & Colexio M. Peleteiro

*Abstract-* This research article addresses the application of the Hairy Ball Theorem in the teaching of geometry, proposing a practical activity to bring the concept of the sphere closer to the students. The Hairy Ball Theorem states that it is always possible to comb the hair of a hairy ball without leaving any unruly strands. This interesting topological property has implications in geometry and can be used as a teaching resource to promote understanding of the characteristics and properties of the sphere.

The main focus of this article is to present a practical approach that allows students to explore and experiment with the sphere.

*Keywords:* *mathematics, high school, adolescents, innovation, mathematics, mathematics, education.*

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# Combing" The Hair of a Hairy Ball?. Geometry with the Hairy Ball Theorem: A Practical Proposal for Bringing the Sphere into the Mathematics Classroom

## ø "Peinar" El Pelo De Una Bola Peluda?

## Geometría Con El Teorema De La Bola Peluda: Propuesta Práctica Para Acercar La Esfera En Las Clases De Matemáticas.

Patricia Val Fernández [α] & Colexio M. Peleteiro [σ]

*Resumen-* El presente artículo de investigación aborda la aplicación del Teorema de la Bola Peluda en la enseñanza de la geometría, proponiendo una actividad práctica para acercar el concepto de esfera a los estudiantes. El Teorema de la Bola Peluda establece que siempre es posible peinar el pelo de una bola peluda sin dejar ningún mechón alborotado. Esta interesante propiedad topológica tiene implicaciones en la geometría y puede ser utilizada como un recurso didáctico para promover la comprensión de las características y propiedades de la esfera.

El enfoque principal de este artículo es presentar una propuesta práctica que permita a los estudiantes explorar y experimentar con la esfera.

Además de fomentar la manipulación y la experimentación práctica, esta actividad busca desarrollar habilidades de razonamiento espacial, visualización y comprensión de conceptos geométricos. Los estudiantes pueden observar cómo las propiedades de la esfera, como la simetría y la curvatura constante, influyen en la forma en que se puede peinar el pelo de la bola peluda.

Se espera que esta propuesta práctica pueda ayudar a los educadores a acercar la geometría de la esfera de una manera más tangible y atractiva para los estudiantes. Además, esta actividad puede fomentar el interés y la participación activa de los estudiantes en las clases de matemáticas.

*Palabras clave: matemáticas, secundaria, adolescentes, innovación, matemáticas, educación.*

*Abstract-* This research article addresses the application of the Hairy Ball Theorem in the teaching of geometry, proposing a practical activity to bring the concept of the sphere closer to the students. The Hairy Ball Theorem states that it is always possible to comb the hair of a hairy ball without leaving any unruly strands. This interesting topological property has implications in geometry and can be used as a teaching resource to promote understanding of the characteristics and properties of the sphere.

The main focus of this article is to present a practical approach that allows students to explore and experiment with the sphere.

In addition to encouraging hands-on manipulation and experimentation, this activity seeks to develop spatial reasoning skills, visualization, and understanding of geometric concepts. Students can observe how properties of the sphere, such as symmetry and constant curvature, influence the way the hair on the furry ball can be combed.

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It is hoped that this hands-on approach can help educators approach the geometry of the sphere in a more tangible and engaging way for students. In addition, this activity can encourage students' interest and active participation in mathematics classes.

*Keywords:* *mathematics, high school, adolescents, innovation, mathematics, mathematics, education.*

## I. Introducción

El "Teorema de la bola peluda" es una frase coloquial que se refiere a un teorema matemático más formalmente conocido como el "Teorema de la bola peluda de Brouwer". Fue propuesto por el matemático holandés Luitzen Brouwer en 1912 (Mantilla Prada, 2020).

Se le llama así porque el teorema establece que, si una esfera está cubierta completamente por pelos, no es posible peinar los pelos de manera que todos queden acostados en la misma dirección. Es decir, siempre habrá algún punto en la superficie de la esfera donde el pelo sobresale en una dirección distinta a la de sus vecinos.

La analogía con una bola peluda se debe a que se imagina una bola como una esfera cubierta por pelo, y se intenta peinar todo el pelo de manera uniforme, lo cual es imposible según el teorema. Por lo tanto, la imagen de una bola peluda se utiliza como una forma de ilustrar la idea del teorema de manera gráfica y memorable (Mantilla Prada, 2020).

Este teorema establece que, en cualquier punto de una esfera, existe al menos un punto de la esfera que permanece fijo después de una rotación completa de 360 grados alrededor de ese punto. En otras palabras, no es posible peinar una bola peluda sin dejar un punto sin peinar.Tiene aplicaciones en muchas áreas de la matemática y la física, incluyendo la topología, la geometría y la teoría de juegos. También se ha utilizado en la construcción de algoritmos para resolver problemas en ciencias de la computación y en la mecánica cuántica(DiAmOnD, 2009).

Aunque su nombre puede parecer un tanto humorístico, el Teorema de la bola peluda es un resultado importante en matemáticas que ha sido objeto de estudio durante más de un siglo y que continúa siendo objeto de investigación (Luisyep, 2019) y aplicación en la actualidad.

La introducción del teorema de la bola peluda en las clases de geometría en secundaria puede ayudar a los estudiantes a desarrollar habilidades de pensamiento crítico, resolución de problemas y razonamiento matemático avanzado, lo que puede ser útil en su futuro académico y profesional.Además, la enseñanza de este, puede hacerse a través de ejemplos visuales, como la ilustración de una bola de billar que muestra cómo siempre hay dos puntos en la bola que se encuentran en los polos opuestos. También se pueden utilizar ejemplos de la vida real, como la explicación de cómo los sistemas GPS utilizan el teorema de la bola peluda para determinar la ubicación exacta de un objeto en la superficie terrestre.

La introducción del Teorema de la Bola Peluda en las clases de geometría en secundaria puede tener varios beneficios, entre ellos (fusioneducativa, s.f.):

1. Fomenta la curiosidad y el interés por las matemáticas: Al presentar un teorema con un nombre llamativo y una idea sorprendente, los estudiantes pueden sentirse más atraídos y motivados para aprender más sobre la geometría y sus aplicaciones.

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2. Desarrolla habilidades de razonamiento y resolución de problemas: El Teorema de la Bola Peluda es un teorema complejo que requiere de una comprensión profunda de la geometría y el cálculo para entenderlo y demostrarlo. Al trabajar en problemas relacionados con este teorema, los estudiantes pueden desarrollar habilidades importantes de razonamiento y resolución de problemas.
3. Introduce a los estudiantes a la geometría diferencial: El Teorema de la Bola Peluda es un resultado importante en la geometría diferencial, una rama de las matemáticas que estudia las propiedades geométricas de las superficies y los espacios curvos. La introducción de este teorema en las clases de geometría en secundaria puede despertar el interés de los estudiantes por la geometría diferencial y prepararlos para estudios más avanzados en esta área(Mantilla Prada, 2020).
4. Conecta las matemáticas con la física: El Teorema de la Bola Peluda tiene importantes aplicaciones en la física, especialmente en la teoría de campos vectoriales. La introducción de este teorema en las clases de geometría en secundaria puede ayudar a los estudiantes a comprender mejor las conexiones entre las matemáticas y la física y cómo se aplican en el mundo real.

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## II. Método

Presentar el Teorema de la Bola Peluda de una manera atractiva y relacionándolo con la vida cotidiana puede hacer que los estudiantes se interesen más en las matemáticas y comprendan la importancia de los conceptos que están aprendiendo. lo más importante es presentar el teorema de una manera clara y accesible, y fomentar la curiosidad y el entusiasmo por la geometría en tus estudiantes.

ø Cómo podemos presentar este teorema de una manera atractiva y relacionada con la vida cotidiana?

Imagínate que eres un escalador de montañas y te encuentras en la cima de una montaña esférica, como si fuera una pelota gigante. Si quisieras caminar por la superficie de la montaña en línea recta, en algún momento tendrías que caminar cuesta abajo para llegar a una zona plana, pero no podrías evitar resbalar y rodar. Sin embargo, según el teorema de la Bola Peluda, siempre habrá un punto en la superficie de la montaña donde podrás caminar horizontalmente sin resbalar, porque la tangente a la superficie será paralela al plano ecuatorial.

Este teorema también es relevante en la navegación. Imagina que estás navegando en un barco a través del océano, y tu barco se encuentra en una posición en la que su altura desde la superficie del océano es igual en todas las direcciones. Según el teorema de la Bola Peluda, siempre habrá un punto en la superficie del océano donde tu barco estará en una posición horizontal, porque la tangente a la superficie del océano será paralela al plano ecuatorial.

Una forma interesante de visualizar el teorema es a través de la analogía de una bola de pelo, en la que se imagina que la superficie de la bola es peluda, con cada pelo apuntando en una dirección diferente. Al tocar la bola con la mano, siempre encontrarás un punto en el que los pelos estén paralelos a tu mano, lo que te permite acariciar la bola sin que los pelos se muevan en otra dirección.

Otra forma podría ser hacer una analogía con un balón de fútbol. Si tomamos un balón de fútbol y lo inflamos, podemos ver que hay ciertas áreas en la superficie que están más tensas que otras, lo que hace que la pelota tenga una forma curvada. Sin embargo, incluso en el balón de fútbol más perfecto, siempre habrá un punto donde la superficie no está curvada. Este punto es importante, ya que nos muestra que incluso en objetos cotidianos, hay ciertas áreas que no están curvadas y que tienen un impacto en la forma en que interactúan con otros objetos.

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También le podemos pedir que imaginen que tienes una bola peluda en tus manos. Si intentas peinar toda la bola de forma suave y uniforme, es probable que encuentres un punto en el que algunos de los pelos se levanten en direcciones opuestas. En otras palabras, habrá un punto en el que no podrás peinar la bola sin encontrar algún tipo de "nudo" en el pelo.

Este mismo principio se aplica en la geometría. Si tienes una superficie esférica, siempre habrá al menos un punto en el que la curvatura es máxima. Y si tratas de "peinar" esa superficie, como si estuvieras tratando de colocar una manta sobre una pelota, siempre habrá un punto en el que no podrás hacerlo sin que se produzca algún tipo de deformación.

Este teorema es un ejemplo interesante de un resultado geométrico que se puede enseñar en una clase de secundaria (fusioneducativa, s.f.). Aquí hay algunas ideas para introducir el teorema en tus clases:

1. Contextualiza el teorema: Comienza por explicar a tus estudiantes lo que es una esfera y cuáles son sus propiedades. Luego, presenta el teorema como un resultado sorprendente que se aplica a todas las esferas.
2. Usa visualizaciones: Las visualizaciones son una herramienta poderosa para enseñar geometría. Puedes usar una presentación de diapositivas, un video o un applet interactivo para mostrar a tus estudiantes cómo funciona el teorema. Por ejemplo, puedes mostrar cómo los vectores normales en la superficie de una esfera se mueven de manera continua y cómo se intersectan en al menos un punto.
3. Resuelve ejemplos: Presenta algunos ejemplos de aplicación del teorema en situaciones cotidianas, como la geometría de los planetas, los satélites y otros objetos esféricos. De esta forma, los estudiantes pueden ver la importancia del teorema y cómo se puede aplicar en el mundo real.
4. Fomenta el pensamiento crítico: Anima a tus estudiantes a pensar en cómo podrían demostrar el teorema por sí mismos. Pídeles que trabajen en grupos y presenten sus ideas a la clase. Esto les ayudará a desarrollar habilidades de pensamiento crítico y les enseñará a trabajar en equipo.
5. Relaciónalo con otros temas: Finalmente, asegúrate de conectar el teorema con otros temas de geometría que se estén estudiando en la clase. Por ejemplo, puedes relacionarlo con el teorema de Pitágoras o el teorema de la altura, y mostrar cómo todos estos conceptos están relacionados entre sí. Esto ayudará a tus estudiantes a ver la geometría como una disciplina coherente y significativa.
6. Presenta el teorema de forma visual: muestra a los estudiantes una bola peluda y haz que piensen en la posibilidad de que el pelo no apunte en todas las direcciones.

Luego, demuestra mediante una simulación gráfica que siempre hay al menos un punto donde el pelo apunta en todas las direcciones.

7. Utiliza ejemplos concretos: muestra a los estudiantes cómo se puede aplicar el teorema en la vida real, como en la física y la ingeniería. Por ejemplo, cómo los ingenieros diseñan los airbags para que siempre se inflen de manera uniforme en caso de accidente.
8. Relaciona el teorema con otros conceptos matemáticos: haz que los estudiantes piensen en la relación entre el teorema y otros conceptos matemáticos que ya hayan aprendido, como la geometría o el cálculo.
9. Haz que los estudiantes apliquen el teorema: proporciona problemas prácticos para que los estudiantes apliquen el teorema en situaciones de la vida real y piensen en cómo se podría utilizar en diferentes situaciones.
10. Usa recursos interactivos: utiliza herramientas digitales o juegos interactivos para que los estudiantes exploren el teorema por sí mismos y puedan ver cómo se aplica en diferentes situaciones.

Pero øcómo podemos aplicar esto a nuestra vida cotidiana? La respuesta es simple: todo lo que nos rodea tiene forma y curvatura. Desde los objetos más simples hasta los más complejos, todo puede ser analizado y comprendido a través de la geometría.

Por ejemplo, si tienes una pelota de fútbol, la curvatura de la superficie afectará la forma en que la pelota rebota y se mueve por el aire. Si tienes una silla ergonómica, la curvatura de su superficie afectará la comodidad y la postura que adoptes al sentarte.

En conclusión, el Teorema de la Bola Peluda es una herramienta esencial para entender y analizar la geometría en nuestra vida cotidiana, desde la escalada en montaña hasta la navegación en alta mar. Presentar este teorema de una manera clara y accesible puede ayudar a los estudiantes a comprender la importancia de los conceptos matemáticos y fomentar su curiosidad y entusiasmo por la geometría.ΓAsí que no subestimes su importancia y sigue explorando el mundo de las matemáticas con entusiasmo y curiosidad!

## III. Resultados

Presentar el Teorema de la Bola Peluda de una manera atractiva y relacionándolo con la vida cotidiana puede tener varios resultados positivos entre los escolares de secundaria. A continuación, se describen algunos posibles efectos:

1. Aumento del interés por las matemáticas: Al presentar el teorema de una manera atractiva, utilizando ejemplos de la vida cotidiana, se puede despertar el interés de los estudiantes por las matemáticas. Al comprender cómo las matemáticas se aplican en situaciones reales, los estudiantes pueden darse cuenta de la relevancia de esta materia en su vida cotidiana.
2. Mayor comprensión del teorema: Al relacionar el teorema con ejemplos concretos, los estudiantes pueden comprender mejor la idea detrás del teorema y su importancia en el mundo real. También pueden visualizar mejor cómo funciona el teorema y cómo se aplica a diferentes situaciones.

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3. Desarrollo de habilidades de resolución de problemas: Al trabajar con ejemplos de la vida real, los estudiantes pueden desarrollar habilidades para resolver problemas y aplicar conceptos matemáticos en situaciones cotidianas. Esto puede ser útil para su futura vida laboral y personal.
4. Aumento de la confianza en sí mismos: Al entender mejor los conceptos matemáticos y su relevancia en la vida cotidiana, los estudiantes pueden sentirse más seguros y competentes en esta materia. Esto puede aumentar su confianza en sí mismos y su capacidad para aprender y aplicar nuevos conceptos matemáticos.
5. Aumento del interés en las matemáticas: Los estudiantes pueden sentir que las matemáticas son aburridas o difíciles, pero al presentarles el teorema de la Bola Peluda de una manera atractiva y relacionándolo con la vida cotidiana, pueden despertar su curiosidad y motivación para explorar más esta área.
6. Comprender la importancia de la visualización: El Teorema de la Bola Peluda puede ser difícil de visualizar, pero al presentarlo de manera gráfica, es posible que los estudiantes comprendan mejor su significado y cómo se aplica en la vida real.
7. Desarrollo de habilidades de resolución de problemas: Al trabajar con el Teorema de la Bola Peluda, los estudiantes pueden desarrollar habilidades de resolución de problemas y pensamiento crítico que pueden aplicar en otras áreas de su vida.
8. Integración de las matemáticas con otras disciplinas: El Teorema de la Bola Peluda se aplica en varios campos, como la física y la informática. Al presentarlo de manera atractiva y relacionándolo con la vida cotidiana, los estudiantes pueden comprender cómo las matemáticas se relacionan con otras disciplinas y cómo pueden ser útiles en la vida real.

## IV. Discusión

El Teorema de la Bola Peluda, es un concepto matemático avanzado que puede ser difícil de comprender para los estudiantes de secundaria. Sin embargo, hay maneras de presentar y trabajar este teorema de una manera atractiva y relacionarlo con la vida cotidiana para hacerlo más accesible y fácil de entender.

Trabajar este teorema en las clases de matemáticas en secundaria puede ser una buena manera de introducir a los estudiantes en el cálculo diferencial y mostrarles la importancia de la continuidad de las funciones.

Una posible forma de enseñar este teorema es a través de ejemplos prácticos que muestren su aplicación. Por ejemplo, se puede plantear un problema de optimización donde se busque el valor máximo o mínimo de una función en un intervalo cerrado. Luego, se puede explicar cómo el Teorema de la Bola Peluda puede ayudar a encontrar el punto donde se alcanza ese valor.

También es importante que los estudiantes entiendan la demostración del teorema y cómo se llega a su conclusión. Una forma de hacerlo es a través de demostraciones visuales, como gráficos o diagramas, que les permitan entender cómo funciona el teorema en la práctica.

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Además, se puede plantear a los estudiantes problemas para que ellos mismos apliquen el teorema y resuelvan situaciones prácticas. Esto les permitirá desarrollar su capacidad de análisis y razonamiento, y aplicar los conceptos que han aprendido.

Una forma de presentarlo es a través de imágenes y gráficos. Se puede utilizar una imagen de una bola peluda o una pelota de tenis con un patrón de puntos para ilustrar cómo el teorema describe la cantidad de puntos críticos en la superficie de una esfera. Además, se pueden utilizar gráficos tridimensionales para mostrar cómo los puntos críticos en la superficie de una esfera se relacionan con los campos vectoriales y las líneas de flujo.

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Otra forma de relacionar el teorema con la vida cotidiana es a través de ejemplos concretos. Por ejemplo, se puede explicar cómo el teorema se aplica a la circulación del aire en la atmósfera o al flujo de la sangre en el cuerpo humano. Los estudiantes también pueden explorar cómo el teorema se relaciona con patrones en la naturaleza, como la distribución de hojas en una planta o la ubicación de las células en un tejido.

Además, se puede hacer uso de actividades prácticas para ayudar a los estudiantes a comprender el teorema. Por ejemplo, se puede pedir a los estudiantes que dibujen una pelota de tenis con puntos para representar los puntos críticos en la superficie. También se puede pedir a los estudiantes que construyan modelos de campos vectoriales y líneas de flujo para visualizar cómo se relacionan con los puntos críticos en la superficie de una esfera.

En resumen, para presentar y trabajar el Teorema de la Bola Peluda de una manera atractiva y relacionándolo con la vida cotidiana entre los escolares de secundaria, es recomendable utilizar imágenes y gráficos, ejemplos concretos y actividades prácticas que permitan a los estudiantes visualizar y experimentar con el teorema.

## V. Conclusiones

Incluir este teorema en las clases de matemáticas en secundaria puede tener varios beneficios. En primer lugar, puede ayudar a los estudiantes a comprender la importancia de las demostraciones matemáticas y cómo se aplican en la resolución de problemas. También puede introducir a los estudiantes en conceptos avanzados de geometría y cálculo vectorial, lo que puede ser de gran ayuda para aquellos que deseen estudiar carreras relacionadas con la ciencia, la ingeniería o las matemáticas.

Además, trabajar con el Teorema de la Bola Peluda puede fomentar el pensamiento crítico y la creatividad en los estudiantes, ya que es un problema que no se resuelve fácilmente y requiere de un enfoque innovador para encontrar soluciones.

En resumen, trabajar el Teorema de la Bola Peluda en las clases de matemáticas en secundaria puede ser beneficioso para los estudiantes en términos de su comprensión de la importancia de las demostraciones matemáticas, así como para su introducción a conceptos avanzados de geometría y cálculo vectorial. Además, puede fomentar el pensamiento crítico y la creatividad en los estudiantes, lo que puede ser de gran ayuda en su futuro académico y profesional.

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# A New Integral Transform Called "Saxena & Gupta Transform" and Relation between New Transform and other Integral Transforms

By Hemlata Saxena & Sakshi Gupta

*Career Point University*

*Abstract-* We investigate a new integral transform called Saxena and Gupta transform, in this paper. Some important properties of this transform are also investigated. Also discussed relation between Saxena & Gupta transform and other integral transform like Laplace transform, Elzaki transform, Sumudu transform, Mahgoub transform. Integral transform of some elementary functions are given in table form in different section.

*Keywords:* *New integral transform, Laplace transform, Elzaki transform, Sumudu transform, Mahgoub transform, Aboodh transform.*

*GJSFR-F Classification:* *LCC: QA1-939*


*Strictly as per the compliance and regulations of:*

# A New Integral Transform Called "Saxena & Gupta Transform" and Relation between New Transform and other Integral Transforms

Hemlata Saxena [α] & Sakshi Gupta [σ]

*Abstract-* We investigate a new integral transform called Saxena and Gupta transform, in this paper. Some important properties of this transform are also investigated. Also discussed relation between Saxena & Gupta transform and other integral transform like Laplace transform, Elzaki transform, Sumudu transform, Mahgoub transform. Integral transform of some elementary functions are given in table form in different section.

*Keywords: New integral transform, Laplace transform, Elzaki transform, Sumudu transform, Mahgoub transform, Aboodh transform.*

## I. Introduction

Recently, Integral transformations have played an important role in many fields of science and engineering [1,10,14,15,], especially mathematical physics [5], engineering mathematics [16,19], Cryptography [11], image processing [18], mathematical electrodynamics [5] and, a few others, because they have been successfully used in solving many problems in those fields. Integral transforms are one of the most effective tools for solving problems in physics and engineering to obtain a solution for a given differential equation or integral equations by means of inverse transformation. The importance of an integral transforms is that they provide powerful operational methods for solving initial value problems and initial- boundary value problems for linear differential and integral equations.

In view of many interesting properties which make visualization easier, we introduced a new integral transform, termed as "Saxena and Gupta" Transformation. Many of these transforms have been introduced which were extensively used and applied on theory and applications, such as Laplace [6,12,13,17], Fourier [15], Sumudu [4,12], Elzaki [3,8,9], Aboodh [2,19]. Among these, the most widely used is the Laplace transform. Here, a new integral transform is proposed to avoid the complexity of previous transforms.

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*Definition of New Transform*

This transform of a function $f(t)$ defined for all real numbers $t \geq 0$ is the function

$$f(\upsilon) = Z[f(t)] = \frac{1}{\upsilon}\int_0^\infty f(\upsilon t)e^{-t}\,dt \qquad \ldots (1.1)$$

The above integral convergent.

*Definition of other transform*

*a) Aboodh transform:* The Aboodh transform[2,19] A of a function $f(t)$ for $t$ is greater than or equal to zero given by

$$A[f(t)] = \frac{1}{\upsilon}\int_0^\infty f(t)e^{-\upsilon t}\,dt \qquad (0 \leq k_1 \leq t \leq k_2) \qquad \ldots (1.2)$$

*b) Laplace transform:* The Laplace transform [6],[12],[13],[17] of a function $f(t)$ for $t$ is greater than zero given by

$$L[f(t)] = \int_0^\infty f(t)e^{-\upsilon t}\,dt \qquad \ldots (1.3)$$

*c) Sumudu transform:* The Sumudu transform S [4],[12] of a function $f(t)$for $t$ is greater than or equal to zero given by

$$S[f(t)] = \int_0^\infty f(\upsilon t)e^{-t}\,dt \qquad \ldots (1.4)$$

*d) Elzaki transform:* The Elzaki transform $E$ [3],[8],[9] of a function $f(t)$for $t$ is greater than or equal to zero given by

$$E[f(t)] = \upsilon\int_0^\infty f(t)e^{-t/\upsilon}\,dt \qquad \ldots (1.5)$$

*e) Mahgoub transform:* The Mahgoub (Laplace-Carson)M [1] transform of the function $f(t), t \geq 0$ is given by

$$M[f(t)] = \upsilon\int_0^\infty f(t)e^{-\upsilon t}\,dt \qquad \ldots (1.6)$$



Ref

9. Elzaki, Tarig. M.,(2011)."The New Integral Transform 'ELzaki Transform", Global Journal of Pure and Applied Mathematics, Vol. 7, No. 1, pp 57-64.

## II. Properties of Saxena and Gupta Transform

i) *Linearty property*

Let $Z\{f(t)\}$ denote the New transform of the real function $f$. Let $f, g$ be a function such that $Z\{f\}$and $Z\{g\}$ exist.

$$Z\{af(t) + bg(t)\} = aZ\{f(t)\} + bZ\{g(t)$$

Proof: Let $a, b \in c$ or $R$ be constant

$$Z\{af(t) + bg(t)\} = \frac{1}{u}\int_0^\infty e^{-ut}\ \{af(\upsilon t) + bg(\upsilon t)\}dt$$

$$Z\{af(t) + bg(t)\} = \frac{a}{u}\int_0^\infty e^{-ut}\, f(\upsilon t)dt + \frac{b}{u}\int_0^\infty e^{-ut}\, g(\upsilon t)dt$$

$$= aZ\{f(t)\} + bZ\{g(t) \qquad \ldots(2.1)$$

ii) *Shifting property*

If the function $\bar{f}(u) = Z\{f\}$ is the transform of the function $f(t)$ then

$$Z\{e^{at}f\} = \frac{1}{(1-a\upsilon)}\bar{f}\left(\frac{\upsilon}{1-a\upsilon}\right) \qquad \ldots (2.2)$$

Proof: $Z\{e^{at}f\} = \frac{1}{\upsilon}\int_0^\infty e^{-t}\, e^{a\upsilon t} f(\upsilon t)dt$

$$= \frac{1}{\upsilon}e^{-(1-a\upsilon)t} f(\upsilon t)dt \qquad \ldots (2.3)$$

Let $(1 - a\upsilon)t = x, t = \frac{x}{1-a\upsilon}, dt = \frac{dx}{1-a\upsilon}$ and put these values in eq.(2.3)

$$Z\{e^{at}f\} = \frac{1}{u}\int_0^\infty e^{-x} f\left(\frac{\upsilon x}{1-a\upsilon}\right)\frac{dx}{1-a\upsilon}$$

$$Z\{e^{at}f\} = \frac{1}{\upsilon(1-a\upsilon)}\int_0^{\infty} e^{-x} f\left(\frac{\upsilon x}{1-a\upsilon}\right) dx$$

$$Z\{e^{at}f\} = \frac{1}{(1-a\upsilon)}\bar{f}\left(\frac{\upsilon}{1-a\upsilon}\right)$$

iii) *The convolution of two function*

*Definition:* Assume that $f$ and $g$ are peicewise continuous function, or one of them is dirac's generalized function [7]. The convolution of $f$ and $g$ is a function denoted $f * g$ by and given by the following expression

$$(f * g)(t) = \int_0^t f(\tau)g(t-\tau)d\tau \qquad \ldots (2.4)$$

For every piecewise continuous function $f, g \text{ and } h$ the following properties hold.

1. Commutativity $f * g = g * f$
2. Associativity $f * (g * h) = (f * g) * h$
3. Distributivity $f * (g + h) = f * g + f * h$
4. Neutral element $f * 0 = 0$
5. Identity element $f * 1 = f$

*Theorem 1:* If the function $f$ and $g$ have well defined transform $Z\{f\}$ and $Z\{g\}$ then

$$Z\{f * g\} = \upsilon^2 Z\{f\}Z\{g\} \qquad \ldots (2.5)$$

*Proof:* $$Z\{f * g\} = \frac{1}{\upsilon}\int_0^{\infty} e^{-t}(f * g)(\upsilon t)dt$$

$$= \frac{1}{\upsilon}\int_0^{\infty} e^{-t}\left[\int_0^{\infty} f(\tau)g(\upsilon t - \tau)d\tau\right]dt \qquad \ldots (2.6)$$



Ref

7. Dirac, paul (1930), "The principal of Quantum Mechanics" (1st ed.), Oxford university press.

Let $\lambda = \upsilon t$, $d\lambda = \upsilon dt$ put these values in eq.(2.6) then

$$Z\{f * g\} = \frac{1}{\upsilon}\int_0^\infty e^{-\lambda/\upsilon}\left[\int_0^\lambda f(\tau)g(\lambda-\tau)d\tau\right]d\lambda/\upsilon$$

$$= \frac{1}{\upsilon^2}\int_0^\infty \int_0^\lambda e^{-\frac{\lambda}{\upsilon}} f(\tau)g(\lambda-\tau)d\tau d\lambda \qquad \ldots (2.7)$$

Put $\gamma = \lambda - \tau$, $d\gamma = d\lambda$ in eq. (2.7) since the variable $\tau$ is constant hence when we integrate with respect to $\tau$, we get

$$Z\{f * g\} = \frac{1}{\upsilon^2}\int_0^\infty \int_0^\infty e^{-\frac{\gamma+\tau}{\upsilon}} f(\tau)g(\gamma)d\tau d\gamma$$

$$= \frac{1}{\upsilon^2}\int_0^\infty e^{-\frac{\gamma}{\upsilon}} g(\gamma)d\gamma . \int_0^\infty e^{-\frac{\tau}{\upsilon}} f(\tau)d\tau \qquad \ldots (2.8)$$

$$let\ x = \frac{\gamma}{\upsilon}\ and\ y = \frac{\tau}{\upsilon}\ then\ we\ have\ dx = \frac{d\gamma}{\upsilon}\ and\ dy = \frac{d\tau}{\upsilon}$$

$$= \frac{1}{\upsilon^2}\left[\int_0^\infty e^{-x}\,\upsilon\, g(\upsilon x)dx\right]\left[\int_0^\infty e^{-y}\upsilon\, f(\upsilon y)dy\right]$$

$$Z\{f * g\} = \int_0^\infty e^{-x}\, g(\upsilon x)dx . \int_0^\infty e^{-y}\, f(\upsilon y)dy$$

$$Z\{f * g\} = \upsilon^2 Z\{f\}.Z\{g\}$$

iv) *The New Transform of Derivative and Integral*

*Derivative property:*

If the function $Z\{F\}$and $Z\{F'\}$ are well defined then

First derivative

$$Z\{f'(t)\} = \frac{1}{\upsilon}\int_0^\infty e^{-t} f'(\upsilon t)dt$$

$$= \frac{1}{\upsilon}\left[\frac{-f(0)}{\upsilon} + z\{f(t)\}\right]$$

$$Z\{F'(t)\} = \frac{F(\upsilon)}{\upsilon} - \frac{f(0)}{\upsilon^2} \quad \ldots (2.9)$$

Second derivative $Z\{F''(t)\} = \frac{1}{\upsilon}Z\{f'(t)\} - \frac{f'(0)}{\upsilon^2}$

$$= \frac{1}{\upsilon}\left[\frac{F(\upsilon)}{\upsilon} - \frac{f(0)}{\upsilon^2}\right] - \frac{f'(0)}{\upsilon^2}$$

$$Z\{F''(t)\} = \frac{F(\upsilon)}{\upsilon^2} - \frac{f(0)}{\upsilon^3} - \frac{f'(0)}{\upsilon^2} \quad \ldots (2.10)$$

Nth derivative

$$Z\{f^n(t)\} = \frac{F(\upsilon)}{\upsilon^n} - \frac{f(0)}{\upsilon^{n+1}} - \frac{f'(0)}{\upsilon^n} - \frac{f''(0)}{\upsilon^{n-1}}$$

$$Z\{F^n(t)\} = \frac{F(\upsilon)}{\upsilon^n} - \sum_{k=0}^{n-1}\frac{f^k(0)}{\upsilon^{n+1-k}} \quad \ldots (2.11)$$

v) *The New transform of Integral*

Theorem 2: If the following $Z[f(t)]$ is well defined then

$$Z\left[\int_0^t f(\tau)d\tau\right] = \upsilon^2 Z\{f\}$$

Proof: Suppose that g(t-τ)=1 then

$$Z\left[\int_0^t f(\tau)d\tau\right] = Z\left[\int_0^t g(t-\tau)f(\tau)d\tau\right] = Z[g * f]$$

$$= \upsilon^2 Z[f]Z[g]$$

$$= \upsilon^2 Z[f]$$

vi) *The inverse of New transform*

*Definition:* Let the function $\bar{f}(\upsilon)=\bar{Z}\{F\}$ is the transform of the function $f(t)$, then $f(t)$ is called the inverse transform $\bar{f}(\upsilon)$ and we will write it as

$$F(t) = Z^{-1}\{\bar{f}(\upsilon)\}$$

*Note:* The inverse transform has the linear combination property

vii) *Solution of some elementary function*

1. when $f(t) = 1$ then

$$\frac{1}{\upsilon}\int_0^\infty e^{-t} f(\upsilon t)dt = \frac{1}{v}\int_0^\infty e^{-t}.1dt = 1/\upsilon[-e^{-t}]_0^\infty = 1/\upsilon$$

2. when $f(t) = t$ then

$$\frac{1}{\upsilon}\int_0^\infty e^{-t} f(\upsilon t)dt = \frac{1}{\upsilon}\int_0^\infty e^{-t}.\upsilon t\, dt =$$

$$= 1/\upsilon[(-t-1)e^{-t}]_0^\infty = \frac{1}{\upsilon}$$

3. when $f(t) = t^2$ then

$$\frac{1}{\upsilon}\int_0^\infty e^{-t} f(\upsilon t)dt = \frac{1}{\upsilon}\int_0^\infty e^{-t}.\upsilon^2\, t^2 dt = \frac{1}{\upsilon}[(-t^2-2t-2)e^{-t}]_0^\infty = \frac{2}{\upsilon}$$

4. when $f(t) = t^n$ then

$$\frac{1}{\upsilon}\int_0^\infty e^{-t} f(vt)dt = \frac{1}{\upsilon}\int_0^\infty e^{-t}.\upsilon^n t^n dt = v^{n-1}\Gamma(n+1)$$

5. when $f(t) = e^{at}$ then

$$\frac{1}{\upsilon}\int_0^\infty e^{-t} f(\upsilon t)dt = \frac{1}{\upsilon}\int_0^\infty e^{-t}.e^{\upsilon at}dt$$

$$= \frac{1}{\upsilon}\left[\frac{e^{(av-1)t}}{a\upsilon - 1}\right]_0^{\infty} = \frac{1}{v\,(1-av)}$$

6. when $f(t) = sinat$ then

$$\frac{1}{v}\int_0^{\infty} e^{-t} f(\upsilon t)dt = \frac{1}{\upsilon}\int_0^{\infty} e^{-t}\,.sina\upsilon t\;dt$$

$$= 1/\upsilon\left[-\frac{e^{-t}.(\sin(a\upsilon t) + a\upsilon cos(avt))}{a^2\upsilon^2 + 1}\right]_0^{\infty}$$

$$= \frac{a}{a^2\upsilon^2 + 1}$$

7. when $f(t) = cosat$ then

$$\frac{1}{v}\int_0^{\infty} e^{-t} f(\upsilon t)dt = \frac{1}{\upsilon}\int_0^{\infty} e^{-t}\,.cosa\upsilon t\;dt$$

$$= \frac{1}{\upsilon}\left[\frac{e^{-t}(a\upsilon sin(a\upsilon t) - \cos(a\upsilon t))}{a^2\upsilon^2 + 1}\right]_0^{\infty}$$

$$= \frac{1}{\upsilon(a^2\upsilon^2 + 1)}$$

8. when$f(t) = sinhat$ then

$$\frac{1}{v}\int_0^{\infty} e^{-t} f(\upsilon t)dt = \frac{1}{\upsilon}\int_0^{\infty} e^{-t}\,.sinhavt\;dt$$

$$= \frac{1}{\upsilon}\int_0^{\infty}\left(\frac{e^{a\upsilon t} - e^{-avt}}{2}\right)e^{-t}dt$$

$$= \frac{1}{2v}\left[\int_0^{\infty} e^{t(a\upsilon-1)}dt - \int_0^{\infty} e^{-t(a\upsilon+1)}dt\right]$$

$$= \frac{1}{2v}\left[\frac{e^t}{a\upsilon - 1} + \frac{e^t}{av + 1}\right]_0^{\infty} = \frac{a}{1 - a^2\upsilon^2}$$

9. when $f(t) = coshat$ then

Notes

$$\frac{1}{\upsilon}\int_0^{\infty} e^{-t} f(\upsilon t)dt = \frac{1}{\upsilon}\int_0^{\infty} e^{-t}.coshav t\, dt$$

$$= \frac{1}{\upsilon}\int_0^{\infty}\left(\frac{e^{a\upsilon t} + e^{-avt}}{2}\right)e^{-t}dt$$

$$= \frac{1}{2\upsilon}\left[\int_0^{\infty} e^{t(a\upsilon - 1)}dt + \int_0^{\infty} e^{-t(a\upsilon + 1)}dt\right]$$

$$= \frac{1}{2\upsilon}\left[\frac{e^t}{a\upsilon - 1} - \frac{e^t}{a\upsilon + 1}\right]_0^{\infty}$$

$$= \frac{1}{\upsilon(1 - a^2\upsilon^2)}$$

viii) *New transform of some elementary function*

*Table 1*

| S.NO. | Function $f(t)$ | New transform $Z[f(t)]$ |
|---|---|---|
| 1 | 1 | $\frac{1}{v}$ |
| 2 | $t$ | 1 |
| 3 | $t^2$ | 2v |
| 4 | $t^n$ | $u^{n-1}\Gamma(n+1)$ |
| 5 | $e^{at}$ | $\frac{1}{v\,(1-av)}$ |
| 6 | $sinat$ | $\frac{a}{1+a^2v^2}$ |
| 7 | $cosat$ | $\frac{1}{v\,(1+a^2v^2)}$ |
| 8 | $sinhat$ | $\frac{a}{1-a^2v^2}$ |
| 9 | $coshat$ | $\frac{1}{v\,(1-a^2v^2)}$ |

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ix) *Compare between New transform and other transform*

*Table 2: Sumudu transform and New transform*

| S.NO. | Function $f(t)$ | Sumudu transform $S[f(t)]$ | New transform $Z[f(t)]$ |
|---|---|---|---|
| **1** | 1 | 1 | $\frac{1}{v}$ |
| 2 | $t$ | υ | 1 |
| 3 | $t^2$ | 2!/ $\upsilon^2$ | 2υ |
| 4 | $t^n$ | n!/$\upsilon^n$ | $\frac{v^{n-1}}{\Gamma(n+1)}$ |
| 5 | $e^{at}$ | $\frac{1}{(1-av)}$ | $\frac{1}{v(1-av)}$ |
| 6 | $sinat$ | $\frac{av}{1+a^2v^2}$ | $\frac{a}{1+a^2v^2}$ |
| 7 | $cosat$ | $\frac{1}{(1+a^2v^2)}$ | $\frac{1}{v(1+a^2v^2)}$ |
| 8 | $sinhat$ | $\frac{av}{1-a^2v^2}$ | $\frac{a}{1-a^2v^2}$ |
| 9 | $coshat$ | $\frac{1}{(1-a^2v^2)}$ | $\frac{1}{v(1-a^2v^2)}$ |

*Table 3: Aboodh transform and New transform*

| S.NO. | Function $f(t)$ | Aboodh transform $A[f(t)]$ | New transform $Z[f(t)]$ |
|---|---|---|---|
| **1** | 1 | $\frac{1}{v^2}$ | $\frac{1}{v}$ |
| 2 | $t$ | $\frac{1}{v^3}$ | 1 |
| 3 | $t^2$ | $\frac{2!}{v^4}$ | 2υ |
| 4 | $t^n$ | $\frac{n!}{v^{n+2}}$ | $\frac{v^{n-1}}{\Gamma(n+1)}$ |
| 5 | $e^{at}$ | $\frac{1}{\upsilon(\upsilon-a)}$ | $\frac{1}{v(1-av)}$ |
| 6 | $sinat$ | $\frac{a}{\upsilon(a^2+v^2)}$ | $\frac{a}{1+a^2v^2}$ |
| 7 | $cosat$ | $\frac{1}{(a^2+v^2)}$ | $\frac{1}{v(1+a^2v^2)}$ |

| | | | |
|---|---|---|---|
| 8 | $sinhat$ | $\frac{a}{\upsilon(v^2 - a^2)}$ | $\frac{a}{1 - a^2v^2}$ |
| 9 | $coshat$ | $\frac{1}{(v^2 - a^2)}$ | $\frac{1}{\upsilon(1 - a^2v^2)}$ |

*Table 4: Laplace transform and New transform*

| S.NO. | Function $f(t)$ | Laplace transform $L[f(t)]$ | New transform $Z[f(t)]$ |
|---|---|---|---|
| 1 | 1 | $\frac{1}{\upsilon}$ | $\frac{1}{v}$ |
| 2 | $t$ | $\frac{1}{\upsilon^2}$ | 1 |
| 3 | $t^2$ | $\frac{2!}{\upsilon^3}$ | $2\upsilon$ |
| 4 | $t^n$ | $\frac{n!}{s^{n+1}}$ | $\frac{v^{n-1}}{\Gamma(n+1)}$ |
| 5 | $e^{at}$ | $\frac{1}{s - a}$ | $\frac{1}{\upsilon(1 - av)}$ |
| 6 | $sinat$ | $\frac{a}{a^2 + s^2}$ | $\frac{a}{1 + a^2v^2}$ |
| 7 | $cosat$ | $\frac{s}{a^2 + s^2}$ | $\frac{1}{\upsilon(1 + a^2v^2)}$ |
| 8 | $sinhat$ | $\frac{a}{s^2 - a^2}$ | $\frac{a}{1 - a^2v^2}$ |
| 9 | $coshat$ | $\frac{s}{s^2 - a^2}$ | $\frac{1}{\upsilon(1 - a^2v^2)}$ |

*Table 5: Mahgoub and New transform*

| S.NO. | Function $f(t)$ | Mahgoub transform $M[f(t)]$ | New transform $Z[f(t)]$ |
|---|---|---|---|
| 1 | 1 | 1 | $\frac{1}{v}$ |
| 2 | $t$ | $\frac{1}{v}$ | 1 |
| 3 | $t^2$ | $\frac{2!}{v^2}$ | $2\upsilon$ |





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| | | | |
|---|---|---|---|
| 4 | $t^n$ | $\frac{n!}{v^n}$ | $\frac{v^{n-1}}{\Gamma(n+1)}$ |
| 5 | $e^{at}$ | $\frac{\upsilon}{(\upsilon - a)}$ | $\frac{1}{v(1-av)}$ |
| 6 | $sinat$ | $\frac{a\upsilon}{a^2+v^2}$ | $\frac{a}{1+a^2v^2}$ |
| 7 | $cosat$ | $\frac{v^2}{(a^2+v^2)}$ | $\frac{1}{v(1+a^2v^2)}$ |
| 8 | $sinhat$ | $\frac{a\upsilon}{v^2-a^2}$ | $\frac{a}{1-a^2v^2}$ |
| 9 | $coshat$ | $\frac{v^2}{(v^2-a^2)}$ | $\frac{1}{v(1-a^2v^2)}$ |

*Table 6: Elzaki and New transform*

| S.NO. | Function $f(t)$ | Elzaki transform $E[f(t)]$ | New transform $Z[f(t)]$ |
|---|---|---|---|
| **1** | 1 | $v^2$ | $\frac{1}{v}$ |
| 2 | $t$ | $v^3$ | 1 |
| 3 | $t^2$ | $2!\ v^4$ | $2\upsilon$ |
| 4 | $t^n$ | $n!\ v^{n+2}$ | $\frac{v^{n-1}}{\Gamma(n+1)}$ |
| 5 | $e^{at}$ | $\frac{v^2}{(1-a\upsilon)}$ | $\frac{1}{v(1-av)}$ |
| 6 | $sinat$ | $\frac{av^3}{1+a^2v^2}$ | $\frac{a}{1+a^2v^2}$ |
| 7 | $cosat$ | $\frac{v^2}{(1+a^2v^2)}$ | $\frac{1}{v(1+a^2v^2)}$ |
| 8 | $sinhat$ | $\frac{av^3}{1-a^2v^2}$ | $\frac{a}{1-a^2v^2}$ |
| 9 | $coshat$ | $\frac{v^2}{1-a^2v^2}$ | $\frac{1}{v(1-a^2v^2)}$ |

*Conclusion:* In this paper, we introduce a new integral transform. After that we compare some integral transforms with this new integral transform. It has shows that the new integral transform cover those exiting transforms such as Laplace, Elzaki and Sumudu transform for different values. Also gave properties of new transform and derivatives. Researcher can use this new integral transform for solving ODE, integral equations and fractional differential and integral equations.

Notes

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# Proton Polarization, Quark-Gluon Plasma and an Atom Model

By Stanislav Konstantinov

*Abstract-* The article deals with experiments performed at the National Laboratory named after. Jefferson, associated with elastic and inelastic collisions of the proton nucleus by an electron beam with an energy of 4.56 GeV. It has been experimentally proved that the local maximum found near 33 GeV during the polarization of protons by an electron flow is associated with the electric polarizability **αE** and the local maximum found at the Large Hadron Collider, but already at an energy of 28 GeV, during p-p collisions, is associated with the polarization of quark-gluon plasma. Thus, the electric polarizability **αE**, which is a fundamental property of the proton structure, like size or charge, does not consider the influence of the nuclear polarization of the quark-gluon plasma. This introduces its adjustments to the definition of the polarization radius.

*Keywords: physical vacuum, quark-gluon plasma, electron, proton, photon, polarization, resonance.*

*GJSFR-F Classification: MSC: 81V80, 81V45, 81V10*


*Strictly as per the compliance and regulations of:*

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*Keywords:* *physical vacuum, quark-gluon plasma, electron, proton, photon, polarization, resonance.*

## I. Introduction

Today on the pages of scientific journals began to appear messages related to the polarization of the physical vacuum and such composite systems as protons in the Large Hadron Collider [1]. Proton polarizabilities are fundamental structural constants. The CMS collaboration in the experiment at the Large Hadron Collider in 2019 demonstrated a decrease in the t-quark mass with increasing energy for the first time [2]. They studied the distribution of reaction products in pp collisions with energy from 1 [TeV] to 13 [TeV]. The decrease in the mass of elementary particles up to an energy of 13 [TeV], as well decrease in the magnitude of the interaction constants at a confidence level of 95%, depending on the energy at which measurements are made. This effect, explained by vacuum polarization, was indeed observed in experiments in particular, the decline in the mass of b- and c- quarks was measured, as well as the decrease in the strong interaction constant [2]. The latest experimental data obtained in Jefferson's laboratory say that one of the mysteries in physics is the polarizability of protons $\alpha_E$ [3]. According to calculations, $\alpha_E$ should decrease monotonically with increasing squared momentum transfer, but a local max was found near 33 GeV, which the authors of the communication associated with the polarization of the proton nucleus. In this case, the characteristic polarizability radius of the proton $r_E$ significantly exceeded the charge radius. The problem became even more acute (up to 7σ) if all the data obtained on the scattering of electrons by protons were considered. We are talking not only about elastically reflected protons, but also about inelastic

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collisions of electrons with a hydrogen nucleus. Modern quantum theory predicts a monotonic decrease in the polarizability of a proton with an increase in the square of the momentum. The University of Maryland theoretical physicist Xiangdong Ji describes the polarization process as follows: "Each model predicts a monotonic decrease. Monotonic decay is a general feature of the theory, which must be true." [4]. But the deceptive logic of modern theory contradicts the experimental data. In my article, I offer an answer to this and other questions related to the polarizability of the proton.

## II. Polarization of Physical Vacuum and Quark-Gluon Plasma

In quantum electrodynamics (QED), the instability of the physical vacuum under the action of high-energy cosmic radiation photons, relativistic protons, peak electric and magnetic fields, or high-intensity laser radiation is accompanied by vacuum polarization and is characterized by the formation of electron-positron pairs, which makes the vacuum unstable [5]. It has been experimentally established that in the presence of a magnetic field H ≈ $10^{-6}$ T or a peak of the electric field strength E ≈$10^{-6}$ V·cm$^{-1}$ in the quantum vacuum, relatively stable particles are formed from virtual particles (lifetime 16 × $10^{-}$ffl s.) [5]. During the polarization of the quantum vacuum and its transformation into the matter, the change in the vacuum energy w can be represented as a sum:

$$w = w^{p} + w^{e} \tag{1}$$

where $w^{p}$ is the vacuum polarization, $w^{p}$ ¡¡ Effl / 8π;
$w^{e}$ is the change in the energy of the substance at the production of particles

$$w^{e} = eET\varkappa, \quad \varkappa = \frac{e^2E^2T}{4\pi^3}\exp(-\pi\frac{m^2}{\hbar E}) \tag{2}$$

The creation of particles is the main reason for the change in the energy of the vacuum. For an electromagnetic field, the polarization energy density of a physical vacuum can also be represented as the sum of two terms (1). Where is the first term $w^{p}$ $(w_0)$ quadratic in the electric and magnetic fields [6]:

$$w_0 = \frac{\left(\mathbf{E}^2 + \mathbf{H}^2\right)}{8\pi} \tag{3}$$

determines the energy of a non-interacting electromagnetic field before critical values of electric strengths Schwinger's field **E**s = 1.32 × $10^{-6}$[V × cm$^{-1}$] and magnetic field strength **H** = $10^{-6}$ [Gs]. The second term, $w^{e}$ $(w_1)$ describes the interaction of photons due to the production of electron-positron pairs [6]:

$$w_I = 2D\left[3\mathbf{E}^2\mathbf{E}^2 - \mathbf{H}^2\mathbf{H}^2 - \left(\mathbf{E}^2\mathbf{H}^2 + \mathbf{H}^2\mathbf{E}^2\right)\right] + 7D\left[\left(\mathbf{EH}\right)^2 + \left(\mathbf{HE}\right)^2\right] \tag{4}$$

The constant D can be calculated by the methods of quantum electrodynamics and in Gaussian units





Notes

5. Adornov T.K., et al., Peculiarities of the production of particle pairs in a peak electric field // Russian Physics Journal, Vol. 60, N3, (2017)

$$D \equiv \eta \frac{\hbar_1}{m^4 c^5} \quad (5),$$

Where η is the dimensionless coefficient $\eta \equiv \frac{\alpha ffl}{45\times(4\pi)ffl} \approx 7.5 \times 10^{-9}$ (6)

α is the fine structure constant,
m is the mass of the electron,
c is speed of light.

It is convenient D to write the coefficient through the Compton wavelength of the electron $\lambda\!\!\!^{-} = \hbar/mc$ in the form [6]:

$$D = \eta \frac{\lambda\!\!\!^{-3}}{mc^2} \quad (7)$$

In quantum chromodynamics (QCD), the polarization of a quark-gluon plasma that fills the nucleus of a proton proceeds similarly to the polarization of the physical vacuum. Instead of the formation of electron-positron pairs with the participation of virtual exchange photons, in a quark-gluon plasma with a strong nuclear interaction, polarization is accompanied by the construction of three unstable $\pi^-$ mesons ($\pi^0$, $\pi^+$, $\pi^-$) with the participation of virtual exchange pions, which eventually decay into leptons [1]. At the same time, the energy spectrum of the birth of new particles and antiparticles difference, which indicates a change in the structure of the physical vacuum when it is included in the nuclei of atoms. Inside the proton nucleus, the quantum vacuum turns into a quark-gluon plasma, similar to the matter inside the most massive stable neutron stars. In 2018 Prof. Volker Burkert conducted a series of experiments at the CEBAF accelerator. After the collision of fast electrons with a mass of liquid hydrogen (the source of protons), the researchers registered the particles resulting from their interaction - an electron, a proton, and two photons. This made it possible for the first time to measure the pressure at the center of the proton by bombarding the proton with electrons whose energy reached 100 MeV or more, which allowed the electron to penetrate into the structure of the proton (Figure 1) [7].

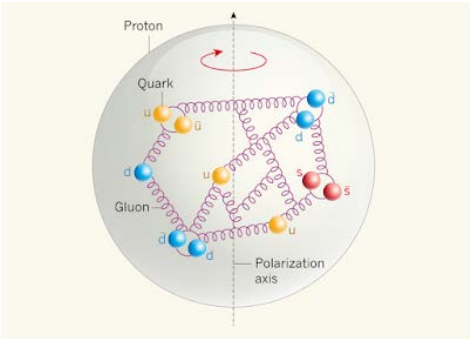


*Figure 1:* The structure of the proton, quarks and gluons

Volker Burkert and his colleagues at Jefferson's laboratory found that the pressure in a proton can exceed $10\imath^5$ Pascal [7]. Particle physics studies at the VEP-1 collider at the Novosibirsk Budker Institute of Nuclear Physics, Siberian Branch of the Russian Academy of Sciences has confirmed the validity of quantum electrodynamics up to an energy of 2 × 160 MeV. That is, it was confirmed that the electron is a point formation on scales up to $4\times10^{-14}$ cm and, unlike the proton, has no internal structure [8]. This is at least 100.000 times less than the radius of a hydrogen atom one

Ref

7. Burkert V.D., Elouadrhiri L. and Girod F.X., The pressure inside the proton // Nature, 557:396–399, (2018)

femtometer. At such a small value, electrons penetrate into the proton. The researchers then observed the scattering of the resulting photons, comparing their characteristics with information about the proton and the accelerated electron. This scattering gave scientists an energy and momentum diagram that allowed them to describe the extreme pressure at the center of a proton, which prevents the proton from collapsing by holding the quarks together. According to modern ideas, a proton consists of three quarks - two u-quarks (up quarks from the word up) and one d-quark (down quark from the word down). Gluons bind uud quarks into a single particle. The maximum repulsion between quarks is observed at a distance of $6\times10^{--}$ım, while the pressure reaches $10ı^{5}$ Pascals. This indicator is considered one of the critical characteristics of the proton: a colossal force is directed from the center outward, counteracting the force of the outer regions of the particle produced to the center [7].

Since the middle of the last century, the study of the interaction of high-energy particles has made it possible to detect resonances that manifest themselves in the form of peaks on the general monotonic behavior of the cross-sections of their interactions. Resonances were interpreted as a consequence of the presence of quantum levels in the systems themselves and identified in the SM as newly born unstable particles. Today, all resonances are classified and described within the framework of the Standard Model up to the Higgs boson. However, the production of unstable particles in the LHC at a proton energy of about 10-30 GeV is indeed observed and this effect can be explained by the polarization of atomic nuclei, accompanied by the formation of three unstable π-mesons ($\pi^0$, $\pi^+$ , $\pi^-$)with the participation of virtual exchange pions. [8]. Nuclear physicists led by Professor Mohammed Abdallah (American University, Cairo) has found a new way to use the Relativistic Heavy Ion Collider (RHIC) to see the shape and detail inside atomic nuclei [9]. This time, the instrument of physicists was but the Relativistic Heavy Ion Collider (RHIC), which is based on the principle of quantum entanglement. Recall that quantum entanglement is a bond between two (or more) particles whose properties remain the same no matter how far these particles are from each other. RHIC (The Relativistic Heavy Ion Collider) is a relativistic heavy ion collider located at the Brookhaven National Laboratory in the United States. Thanks to the new method, physicists have been able to gain insight into the internal structure of atoms, as well as witness a new type of quantum entanglement. Studying of this effect is considered one of the most promising in modern physics. Due to a series of quantum fluctuations during the polarization of the quark gluon plasma inside the nucleus, photons moving at a superrelativistic speed, interacted with gluons, forming an intermediate particle $\pi^0$, the rapid decay of which began two "pions" - $\pi^+$ and $\pi^-$. The information obtained allows displaying the location of gluons in the core of an atom with detailed accuracy (Figure 2)

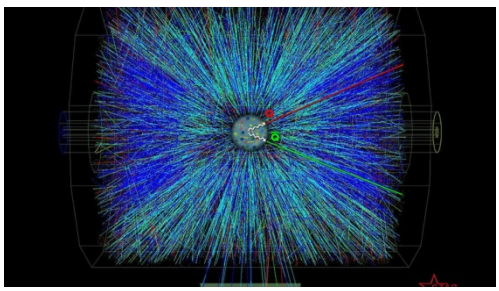

*Figure 2:* Image of the structure of the atomic nucleus and quantum entanglement

A linearly polarized photon can be quantized from the Lorentz-enhanced electromagnetic field of a core moving at super relativistic speed. When two relativistic heavy core pass each other at a distance of several nuclear radii, a photon from one nucleus can interact through a virtual quark-antiquark pair with gluons from the other nucleus, forming a short-lived vector meson (for example, $\pi^0$ ). In the experiment, polarization was used in diffraction photo production to observe a unique pattern of spin interference, with the angular distribution of the decay of $\pi^0$ into two "pions" – $\pi^+$ и $\pi^-$. The nuclear radii of the strong interaction were extracted from these diffraction interactions and found to be 6.53 ffi 0.06 fm (197Au) and 7.29 ffi 0.08 fm (238U), larger than the radii of nuclear charges.

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## III. Proton Polarizability

In the Jefferson Lab in 2022, a large group of physicists from Armenia, India, Canada and the States led by Nikolaos Sparveris from Temple University [3]. They measured the virtual Compton scattering cross section by bombarding protons with electrons during their elastic collision. At the same time, in the same Jefferson laboratory in 2018, Volker Burkert conducted experiments by bombarding protons with electrons during their inelastic collision, which the authors forgot about and, as a result, in the kinematic scattering model they created, the contribution of inelastic collisions of electrons with the nucleus was not fully taken into account hydrogen. The researchers measured the virtual Compton scattering cross section by bombarding protons with electrons during their elastic collision. As a result, the team confirmed the existence of the anomaly. The polarizability of atoms and molecules can be measured relatively easily by physicists. The same parameter for protons is much more difficult to measure due to different physical scales. Some conclusions about the electrical $\alpha_E$ and magnetic $\beta_M$ polarizability can be drawn by irradiating protons with electromagnetic radiation. One can offer a simplistic description of the polarizabilities through the resulting effect of an electromagnetic perturbation applied to the nucleon constituents. An electric field moves positive and negative charges inside the proton in opposite directions. The induced electric dipole moment is proportional to the electric field, and the proportionality coefficient is the electric polarizability which quantifies the stiffness of the proton. On the other hand, a magnetic field has a different effect on the quarks and on the pion cloud within the nucleon, giving rise to two different contributions in the magnetic polarizability, a paramagnetic and a diamagnetic contribution, respectively [3]. According to Ruonan Li, a graduate student at Temple University, measurements of the proton electric polarizability reveal how susceptible the proton is to deformation or stretching in an electric field. Like size or charge, the electric polarizability $\alpha_E$ is a fundamental property of proton structure. One can offer a simplistic description of the polarizabilities through the effect of an electromagnetic perturbation applied to the nucleon constituents. An electric field moves positive and negative charges inside the proton in opposite directions. The induced electric dipole moment is proportional to the electric field, and the proportionality coefficient is the electric polarizability which quantifies the stiffness of the proton. Therefore, polarizabilities fully manifest themselves when measuring virtual Compton scattering, in which an incident photon is produced in the act of interaction of an electron with a proton as a carrier particle (Figure 3). To study such scattering, physicists directed a beam of electrons with an energy of 4.56 gigaelectronvolts at a target of liquid hydrogen 10 centimeters thick. Spectrometers in the experimental chamber recorded the energies and momenta of the

scattered electrons and recoil protons. Coincidences from them could reconstruct the entire scattering kinematics.

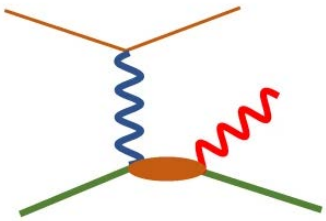

*Figure 3:* One of the Feynman diagrams includes virtual Compton scattering. The orange line is an electron, the green one is a proton, the blue one is a virtual photon. The red one is a real one. R. Li et al. / Nature, 2022

A feature of the experiment was that its authors carried out measurements near the nucleon resonance, where polarizabilities are more pronounced. In addition, physicists concentrated on azimuthally symmetric photon scattering, comparisons of which made it possible to some systematic factors. Plotting the dependence of the polarizabilities on the transmitted 4-pulses, the authors confirmed that for its electrical part there is a peak at 0.33 square giga electron volts, which, however, is approximately two times smaller than that observed earlier.

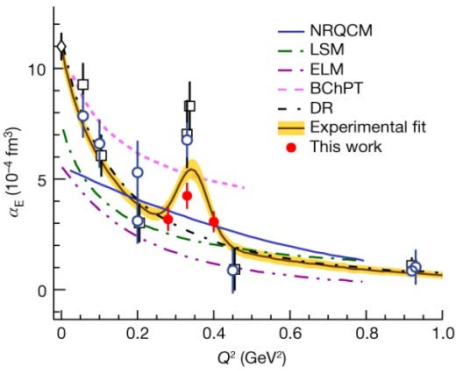


*Figure 4:* Dependence of the electric polarizability on the square of the transmitted 4-momentum. The red dots indicate the experimental results obtained by fitting the model (black line with a yellow stripe). Circles and squares indicate the results of previous experiments. R. Li et al. // Nature, 2022

Based on the model, the authors estimated the mean square radius of an electrically polarized proton, which turned out to be 1.36 ffi 0.29 square femtometers. This is almost twice as large as the average squared radius of an unpolarized proton, which is about 0.7 square femtometers. The found position of the local maximum αE coincides with the previously discovered one. The experiment was carried out on high resolution spectrometers (Mainz Microtron MAMI). In experiments on the scattering of electrons by protons, the polarizability makes a different contribution to its outcome, depending on the square of the 4-momentum transferred from the particle to the system. By measuring this dependence, Roche and colleagues found an anomalous peak at 0.33 square gigaelectronvolts back in 2000, which contradicts theoretical considerations predicting a monotonic decay to this region [10]. When this peak was recorded in previous measurements in 2000, many considered it to be an accident, but a



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new, more accurate measurement confirmed the presence of an anomaly. The experimentalists intend to perform more measurements to confirm that the peak does indeed exist and map out its shape. "Further into the future, one would ideally like to measure this through an independent reaction channel, which could potentially become available at Jefferson Lab if a positron beam were to become available" [3]. Nuclear physicist, Ronald Gilman of Rutgers University in New Jersey says: "I'd love to see another new result of the same quality before I'm completely convinced." However, there is no unity in the ranks of scientists on this issue. The theoretical physicist at the University of Maryland, Xiangdong Ji is more skeptical and believes that monotonic decay is a general feature of the theory [4]. But the deceptive logic of modern theory contradicts the experimental data. So back in 2018, during pp-collisions at the Large Hadron Collider, Roger Barlow discovered the formation of muon pairs in a narrow energy peak of colliding protons, strictly defined at the level of 28 GeV [11]. In light of a new approach to the polarization of the proton nucleus in p-p collisions, which have a larger square of momentum transfer than electrons in the experiments of Nikolaos Sparveris in the Jefferson Lab in 2022, it can be expected that Barlow discovered a local maximum at which in a quark-gluon plasma at In the strong nuclear interaction, polarization is accompanied by the formation of three unstable π-mesons ($\pi^0$, $\pi^+$, $\pi^-$) with the participation of virtual exchange pions and the subsequent production of short-lived protons and antiprotons [1]. In most cases, pairs of muons come from other sources associated with different events, and not from the decay of a single particle. If you try to calculate the original mass in such cases, it will spread over a wide range of powers rather than creating a narrow peak. In a new experiment, the CMS detector detected a large number of muon pairs and, by analyzing their energies and directions, found that these pairs were produced by the polarization of a single parent proton. You can look at Figure 5 and judge for yourself.

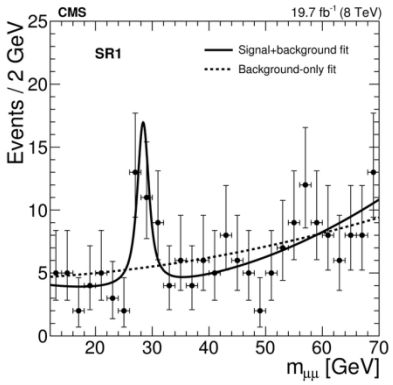


*Figure 5:* Energy peak of 28 GeV during proton polarization during p-p collisions

This is a real peak, not just a statistical fluctuation due to a random spread of background points (dashed curve in Figure 5) [11]. The CMS collaborations have rigorous internal validation procedures and you can be sure that the authors calculated the amounts correctly when they report a standard deviation value of 4.2. This means that there is only a 0.0013% chance of getting this prominent randomly generated noise peak in the data and not the real particle. It must be something so strange that no one has ever proposed it. Fortunately, another large LHC experiment, ATLAS, has similar data from its experiments, which the team is still analyzing and reported in due time. Let us consider why the average square of the radius of a polarized proton in p-p

collisions, commensurate with the proton radius [11], may differ from its value obtained with electric polarizability (1.36 ffi 0.29 square femtometers). To answer this question, let us recall the significant difference in the values of the root-mean-square proton charge radius, which were measured in ordinary (0.8 fm) hydrogen by the method of high-energy electron scattering on protons and muonic hydrogen (0.833 fm) [12]. A new method for determining the charge radius of a proton includes an experiment on the spectroscopy of muonic hydrogen, which is a bound system of a proton and a negatively charged muon. Like the electron, the muon is a lepton, which makes it possible to use the canonical methods of quantum electrodynamics (QED) of coupled systems. However, the muon is 207 times heavier than the electron; hence the Bohr radius of the muon turns out to be equal to $\alpha_0/207$, where the $\alpha_0$-Bohr radius of the electron. Accordingly, the contribution of the corrections associated with overlapping of the wave function with the nucleus increases by many orders of magnitude. This made it possible to measure the Lembol shift at a wavelength of 6 `m and to refine the proton charge radius by an order of magnitude [12]. Similarly, the average square of the radius of a polarized proton in p-p collisions differ significantly from its value obtained for the electric polarizability of the proton by relativistic electrons.

## IV. Conclusion

The article experimentally proves that the local maximum found near 33 GeV during the polarization of protons by an electron beam also exists in the Large Hadron Collider, but already at an energy of 28 GeV during p-p collisions. Thus, the conclusion of the authors of the article [3] that with an increase in the square of the momentum transfer, there is a local maximum near 33 GeV, associated with the electric polarizability $\alpha_E$ of the proton, was confirmed with the formation of muon pairs in a narrow energy peak of colliding protons, strictly defined at the level of 28 GeV at nuclear polarization of protons in the LHC [12]. Thus, the logic of modern quantum theory about the monotonic decrease in the dependence on the electric polarizability of protons with the increasing square of the transferred 4-momentum turned out to be erroneous. In the theoretical model Sylvester Kornowski's "Origin of the measured proton-electromagnetic structural anomaly" Poznań University (UAM) Poland, the academic results are in entire agreement with the experimental data of the Jefferson laboratory presented by R. Li, et al. (2022) [13]. In near-Earth outer space, the mechanism of formation of secondary electron-positron pairs is the collision of relativistic protons and cosmic radiation with protons and nuclei of the interstellar medium. In these collisions, as a result of the polarization of protons, produce pions and kaons, which eventually decay into leptons. Using AMS-02, the spectra of secondary electrons and positrons were measured in the energy range 0.5-700 GeV for electrons and 0.5-500 GeV for positrons and it was possible to fix the presence of a peak in the total spectrum of electrons and positrons at the energy of external relativistic protons Wp ≈ 20-30 GeV [14]. During the experiments Professor of the Massachusetts Institute of Technology Yuri Galaktionov notes that neither the electron nor the positron spectra can be described by a power law with a single exponent in the entire studied energy range [14]. This discovery confirms the erroneousness of the power dependence of the proton polarization on the energy of external particles. New experimental data obtained both in the Large Hadron Collider and in near-Earth space with the help of Alpha-magnetic spectrometer AMS-02 suggest the presence of a novel, not yet understood

dynamical mechanism in the proton and present significant challenges to the nuclear theory.

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# Use of Social Networks to Approach Topology in the Area of Mathematics in Secondary School. Practical Proposal to Work on the Development of Abstract Skills through the Möbius Strip and the Klein Bottle

By Patricia Val Fernández & Colexio M. Peleteiro

*Abstract-* Both the Möbius strip and the Klein bottle can be used to develop abstract skills in secondary mathematics classrooms. They are simple examples of topological objects through which students can develop abstract visual and spatial skills while relating it to other areas of mathematics, such as geometry and abstract algebra. Students can explore these connections and see how topological concepts apply to other fields of mathematics.

In addition, stimulation of creativity and curiosity is provoked. By exploring the properties of the Möbius ribbon and Klein bottle, students can discover new properties and patterns that can lead to greater understanding and interest in topology.

In summary, the Möbius strip and Klein bottle are useful topological objects that can be used to develop abstract skills in secondary mathematics classrooms. By working with these objects, students can develop a deeper understanding of topological concepts and improve their visual and spatial skills. In addition, working with topological objects can stimulate students' creativity and curiosity.

*Keywords:* *mathematics, teenagers, topology, education, education, innovation.*

*GJSFR-F Classification:* *MSC: 54*

# Use of Social Networks to Approach Topology in the Area of Mathematics in Secondary School. Practical Proposal to Work on the Development of Abstract Skills through the Möbius Strip and the Klein Bottle

## Uso De Las Redes Sociales Para Acercar La Topología En El Área De Matemáticas En Secundaria. Propuesta Práctica Para Trabajar El Desarrollo De Habilidades Abstractasmediante Lacinta De Möbius Y La Botella De Klein

Patricia Val Fernández[α] & Colexio M. Peleteiro [σ]

*Resumen-* Tanto la cinta de Möbius como la botella de Klein pueden ser utilizados para desarrollar habilidades abstractas en las aulas de matemáticas en secundaria. Son ejemplos simples de objetos topológicos mediante los cuales los estudiantes pueden desarrollar habilidades visuales y espaciales abstractas, mientras que lo relacionan con otras áreas de las matemáticas, como la geometría y el álgebra abstracta. Los estudiantes pueden explorar estas conexiones y ver cómo los conceptos topológicos se aplican en otros campos de la matemática.

Además, se provoca una estimulación de la creatividad y la curiosidad. Al explorar las propiedades de la cinta de Möbius y la botella de Klein, los estudiantes pueden descubrir nuevas propiedades y patrones que pueden llevar a una mayor comprensión y un mayor interés en la topología.

En resumen, la cinta de Möbius y la botella de Klein son objetos topológicos útiles que pueden ser utilizados para desarrollar habilidades abstractas en las aulas de matemáticas en secundaria. Al trabajar con estos objetos, los estudiantes pueden desarrollar una comprensión más profunda de los conceptos topológicos y mejorar sus habilidades visuales y espaciales. Además, trabajar con objetos topológicos puede estimular la creatividad y la curiosidad de los estudiantes.

*Palabras clave: matemáticas, adolescentes, topología, educación, innovación.*

*Abstract-* Both the Möbius strip and the Klein bottle can be used to develop abstract skills in secondary mathematics classrooms. They are simple examples of topological objects through which students can develop abstract visual and spatial skills while relating it to other areas of mathematics, such as geometry and abstract algebra. Students can explore these connections and see how topological concepts apply to other fields of mathematics.

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*Keywords: mathematics, teenagers, topology, education, education, innovation.*

*Author: e-mail: patryval5@hotmail.com*

## I. Introducción

La a topología es una rama de las matemáticas que se desarrolló a partir del siglo XIX, aunque se pueden encontrar escritos que se remontan a Leibniz en su obra Analysis Situs, la cual buscaba ofrecer un estudio más cualitativo del espacio.

Es probablemente la más joven de las ramas clásicas de las matemáticas en contraste con el álgebra, la geometría y la teoría de los números. Tal vez la primera obra que merece ser considerada como el inicio de la topología se debe a Euler . En 1736 publicó un documento sobre la solución al problema de los puentes de Königsberg, donde consiguió por primera vez el término "gráfico" para referirse a lo que hoy conocemos como grafo.

La topología se enfoca en el estudio de las propiedades de los objetos geométricos que permanecen invariantes bajo deformaciones continuas. Se ocupa de la definición y estudio de conceptos como espacio topológico, continuidad, convergencia, compacidad, conectividad, entre otros. Además, es una herramienta importante en diversas áreas de las matemáticas, la física y la ingeniería, como el análisis funcional, la geometría diferencial, la topología algebraica, la teoría de nudos, la teoría de categorías y la teoría de sistemas dinámicos. También se utiliza en la modelización y análisis de redes complejas, como las redes sociales, las redes neuronales y las redes de comunicaciones.

Los beneficios del estudio de la topología son muy diversos, desde el desarrollo del pensamiento abstracto al verse implicada la comprensión y manipulación de conceptos abstractos, hasta la comprensión de las propiedades geométricas, la resolución de problemas que contribuirán al desarrollo de habilidades enfocadas a la resolución de problemas o la preparación para el estudio de matemáticas más avanzadas.

En la vida real, la topología también tiene su aplicación práctica en áreas como la geometría computacional, la robótica, la teoría de grafos, la topología algebraica y otras áreas de investigación científica y tecnológica.

A la vista de estos beneficios, se quiere contribuir a la implementación de la topología matemática en las clases de secundaria, teniendo en cuenta los beneficios que esta puede originar en los adolescentes:

- El desarrollo del pensamiento lógico y abstracto: La topología matemática involucra la comprensión de conceptos abstractos y la capacidad de razonar de forma lógica, lo que puede ayudar a los estudiantes a desarrollar estas habilidades.
- El desarrollo de la visualización espacial: La topología matemática implica trabajar con objetos geométricos y sus propiedades, lo que puede ayudar a los estudiantes a mejorar a desarrollar habilidades de visualización espacial ya comprender mejor las relaciones entre formas y espacios.
- El desarrollo de habilidades de resolución de problemas: La topología matemática se centra en la resolución de problemas, lo que puede ayudar a los estudiantes a desarrollar habilidades de resolución de problemas ya aprender a aplicar los conceptos matemáticos a situaciones prácticas.

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- La preparación para carreras en matemáticas y ciencias: La topología matemática es un campo de estudio fundamental en la matemática y la física, y puede ser un buen punto de partida para estudiantes interesados en estas áreas de estudio.
- La estimulación del interés en las matemáticas: La topología matemática puede ser una forma interesante y desafiante de abordar las matemáticas, lo que puede ayudar a los estudiantes a encontrar una mayor motivación para aprender y explorar el campo.

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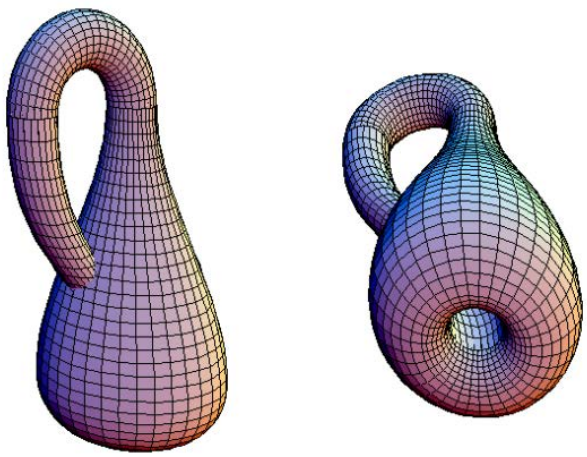
La topología puede ser una herramienta útil para enseñar geometría y noción de espacio en la educación secundaria, contribuyendo a los estudiantes a comprender la geometría y la noción del espacio mediante ejemplos concretos y actividades prácticas, concretamente, se recurrirá a la botella de Klein y la cinta de Möbius, dos superficies no orientables topológicas que gracias a las redes sociales están teniendo una gran visibilidad entre los adolescentes.

La botella de Klein es un objeto matemático que pertenece al campo de la topología. Se trata de una superficie cerrada no orientable, es decir, una superficie que no tiene dos caras claramente diferenciadas y que no se puede transformar en una superficie plana sin romperse o cortarse.



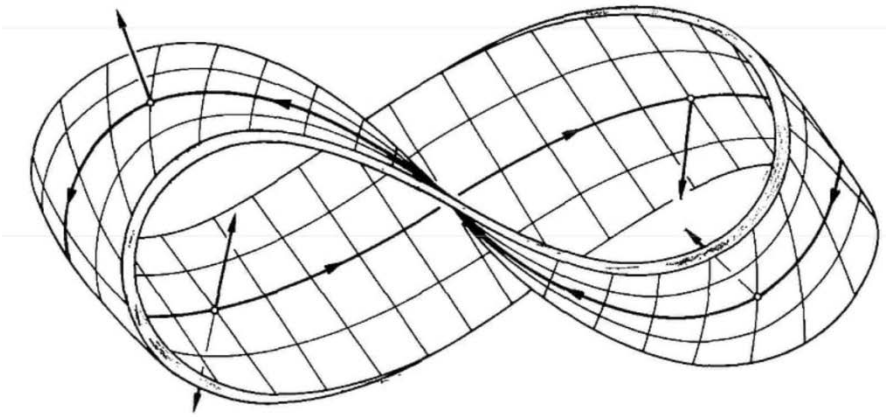
*Fuente: Alvi, 2015.*

*Ilustración 1:* Botella de Klein

La botella de Klein se puede visualizar como un objeto tridimensional que tiene una sola cara y que se curva de tal manera que sus dos lados terminan uniéndose. Esto puede parecer imposible en el espacio tridimensional euclidiano ordinario, pero en la topología se permite trabajar con objetos que no son estrictamente "geometría plana". Se trata de un ejemplo de una superficie no orientable, lo que significa que no hay manera de asignar una orientación consistente a la superficie. Esto se puede visualizar como un objeto tridimensional que no tiene una parte superior o inferior definida, como una cinta de Möbius.

La botella de Klein se utiliza a menudo como ejemplo en la enseñanza de la topología y ha encontrado aplicaciones en áreas como la física teórica, la geometría algebraica y la teoría de nudos.

Por otro lado, la cinta de Möbius, es un objeto matemático que pertenece al campo de la topología. Se trata de una banda de papel o cinta que se retuerce a la mitad y se une para formar una sola tira con una sola cara y un solo borde. La cinta de Möbius es otro ejemplo de una superficie no orientable.



*Fuente: pxfuel, s.f.*

*Ilustración 2:* Cinta de Möbius

La cinta de Möbius es una figura interesante porque tiene varias propiedades sorprendentes. Por ejemplo, si se toma un lápiz y se dibuja una línea a lo largo del centro de la cinta de Möbius, se llegará a todo el camino de la cinta de Möbius sin levantar el lápiz y sin cruzar la línea inicial. Además, si se corta la cinta de Möbius por la mitad a lo largo de su centro, se obtiene una cinta más grande con dos giros en ella en lugar de uno.

La cinta de Möbius se utiliza a menudo como ejemplo en la enseñanza de la topología debido a sus propiedades únicas y sorprendentes.

## II. Metodología

Las redes sociales son plataformas en línea que permiten a los usuarios conectarse y comunicarse entre sí a través de Internet. A través de estas plataformas, los usuarios pueden compartir información, fotos, videos y otros contenidos con sus amigos, familiares y seguidores. Hay muchas redes sociales populares, como Facebook, Twitter, Instagram, LinkedIn, Snapchat, TikTok y muchas otras. Cada plataforma tiene sus propias características únicas y audiencias, pero todas se basan en la idea de permitir a los usuarios interactuar y compartir contenido en línea. Además de ser una forma de comunicación y entretenimiento, las redes sociales también se utilizan a menudo como herramientas de marketing y publicidad. Las empresas y las organizaciones pueden utilizar las redes sociales para llegar a nuevos clientes y promocionar sus productos y servicios, también pueden tener un impacto en la sociedad y en la política.

Las redes sociales pueden tener varios usos en el contexto educativo y pueden ser una herramienta valiosa para los profesores y los estudiantes. Algunas formas en que las redes sociales pueden ser utilizadas en las clases son:

- Comunicación y colaboración: Las redes sociales pueden ser utilizadas para facilitar la comunicación y la colaboración entre profesores y estudiantes. Los profesores

pueden usar las redes sociales para publicar anuncios, asignaciones y recursos, y los estudiantes pueden usar las para hacer preguntas, colaborar en proyectos y comunicarse con sus compañeros.

- Discusión en línea: Las redes sociales pueden ser utilizadas para fomentar la discusión en línea y el intercambio de ideas. Los profesores pueden crear grupos de discusión en las redes sociales y animar a los estudiantes a participar en debates y discusiones.
- Compartir recursos: Las redes sociales pueden ser utilizadas para compartir recursos educativos, como videos, artículos, presentaciones y otros materiales de enseñanza. Los profesores pueden compartir estos recursos en sus perfiles de redes sociales o en grupos dedicados.
- Promoción del aprendizaje autónomo: Las redes sociales pueden ser utilizadas para promover el aprendizaje autónomo. Los estudiantes pueden utilizar las redes sociales para buscar información, hacer preguntas y conectarse con otros estudiantes que están interesados en el mismo tema.
- Aprendizaje basado en juegos: Las redes sociales también pueden ser utilizadas para crear juegos educativos y actividades interactivas que fomenten el aprendizaje. Por ejemplo, los profesores pueden utilizar plataformas de redes sociales para crear juegos de preguntas y respuestas o actividades de búsqueda del tesoro.

S in embargo, es importante tener en cuenta que el uso de las redes sociales en las clases también puede presentar desafíos y riesgos. Los profesores deben ser conscientes de los problemas de privacidad y seguridad y asegurarse de que los estudiantes entiendan las mejores prácticas para mantener seguros.

Concretamente en las clases de matemáticas, los beneficios que pueden acercar el uso de las redes sociales son:

Las redes sociales pueden ser una herramienta útil para enseñar matemáticas. Algunas formas en que las redes sociales pueden ser utilizadas en las clases de matemáticas son:

- Compartir recursos: Los profesores pueden utilizar las redes sociales para compartir recursos educativos con sus estudiantes, como videos, ejercicios y materiales de lectura. Esto puede ayudar a los estudiantes a encontrar información adicional ya profundizar su comprensión de los conceptos matemáticos.
- Discusión en línea: Los profesores pueden crear grupos de discusión en las redes sociales para fomentar la discusión en línea sobre los conceptos matemáticos y para que los estudiantes puedan hacer preguntas y compartir ideas.
- Colaboración en proyectos: Los estudiantes pueden utilizar las redes sociales para colaborar en proyectos y trabajos en equipo relacionado con las matemáticas. Esto puede ayudar a fomentar la colaboración y el trabajo en equipo, así como a desarrollar habilidades de comunicación.
- Uso de juegos y aplicaciones: Los profesores pueden utilizar juegos y aplicaciones educativas relacionadas con las matemáticas en las redes sociales para ayudar a los estudiantes a practicar y aplicar los conceptos matemáticos en un entorno lúdico.

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- Presentación de trabajos y proyectos: Los estudiantes pueden utilizar las redes sociales para presentar sus trabajos y proyectos relacionados con las matemáticas, lo que puede ayudar a fomentar su creatividad y su capacidad para comunicar sus ideas de manera efectiva.

En general, las redes sociales pueden ser una herramienta útil para enseñar matemáticas de manera más interactiva y atractiva para los estudiantes, siempre y cuando se utilicen de manera responsable y se aborden los posibles desafíos y riesgos, como la privacidad y la seguridad en línea.

Concretamente dos de las redes sociales que más pueden favorecer el aprendizaje del desarrollo de habilidades abstractas son TikTok e Instagram, redes sociales que se centran en la creación y el intercambio de contenido visual, y pueden ser utilizados de varias maneras para enseñar matemáticas de manera más creativa e interactiva. Algunas formas en que se pueden utilizar estas redes sociales en las clases de matemáticas son:

- Videos cortos educativos: TikTok e Instagram son ideales para crear videos cortos educativos que expliquen conceptos matemáticos complejos de una manera fácil de entender. Los profesores pueden utilizar estas plataformas para crear y compartir videos que expliquen desde operaciones básicas hasta temas más avanzados como álgebra y cálculo.
- Retos y desafíos matemáticos: Los profesores pueden crear desafíos matemáticos en TikTok e Instagram para que los estudiantes los resuelvan y compartan sus respuestas en las redes sociales. Esto puede ser una forma divertida de fomentar la participación de los estudiantes y mejorar su comprensión de los conceptos matemáticos.
- Gráficos y visualizaciones: TikTok e Instagram pueden ser utilizados para crear y compartir gráficos y visualizaciones que muestren cómo se aplican los conceptos matemáticos en la vida real.
- Proyectos y presentaciones: Los estudiantes pueden crear proyectos y presentaciones relacionados con las matemáticas en TikTok e Instagram, utilizando las herramientas de edición de video para presentar sus ideas de manera creativa y atractiva.
- Recursos educativos: Los profesores pueden compartir recursos educativos relacionados con las matemáticas en TikTok e Instagram, como videos, infografías y presentaciones, para que los estudiantes puedan acceder a ellos fácilmente y en cualquier momento.
- Colaboración y comunicación: TikTok e Instagram también pueden ser utilizados para fomentar la colaboración y la comunicación entre los estudiantes y el profesor. Los estudiantes pueden compartir sus ideas y soluciones a problemas matemáticos en línea, y el profesor puede utilizar estas plataformas para proporcionar retroalimentación y guía.

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## III. Resultados

Las redes sociales pueden ser una herramienta valiosa para acercar la topología en las aulas de secundaria. A continuación, se presentan algunas ideas para utilizar las redes sociales con este fin:

- Crear una página de Facebook o un perfil de Twitter para la clase de topología: Una página de Facebook o un perfil de Twitter pueden ser un lugar donde los estudiantes pueden acceder a información relevante sobre la topología, como videos educativos, artículos, noticias y enlaces a recursos en línea. También pueden publicarse preguntas y desafíos para que los estudiantes trabajen en conjunto.
- Publicar actividades y ejercicios en línea: Los profesores pueden utilizar las redes sociales para publicar actividades y ejercicios en línea que permiten a los estudiantes aplicar los conceptos aprendidos en clase. Por ejemplo, pueden publicar un problema de topología en Twitter y pedir a los estudiantes que lo resuelvan en un cierto plazo de tiempo.
- Fomentar la colaboración entre estudiantes: Las redes sociales pueden ser una herramienta útil para fomentar la colaboración entre estudiantes. Los profesores pueden crear grupos de Facebook o chats de Whats App en los que los estudiantes pueden discutir temas de topología y ayudarse en sus tareas.
- Compartir experiencias y trabajos pueden realizar en clase: Los estudiantes utilizar las redes sociales para compartir sus experiencias y trabajos realizados en clase. Pueden publicar fotos de los trabajos realizados, videos de presentaciones y comentarios sobre lo que aprendieron en clase.
- Promover la discusión pueden y el debate: Las redes sociales ser un lugar donde los estudiantes pueden discutir y debatir sobre temas de topología. Los profesores pueden publicar preguntas y pedir a los estudiantes que compartan sus opiniones y argumentos.

En resumen, las redes sociales pueden ser una herramienta muy útil para acercar la topología en las aulas de secundaria. Los profesores pueden utilizarlas para fomentar la colaboración entre estudiantes, compartir información relevante, publicar actividades y ejercicios, promover la discusión y el debate, y compartir experiencias y trabajos realizados en clase.

El uso de las redes sociales para acercar la topología en las aulas de secundaria puede ofrecer varios beneficios, entre los cuales se incluyen:

- Fomentar la participación activa de los estudiantes: Las redes sociales pueden ser un espacio en el que los estudiantes se sientan más cómodos para expresar sus opiniones y plantear preguntas, lo que puede aumentar su participación activa en el aprendizaje de la topología.
- Facilitar el acceso a recursos educativos: Las redes sociales pueden ser una herramienta muy útil para acceder a recursos educativos, como videos, artículos y actividades en línea, que pueden ayudar a los estudiantes a comprender mejor los conceptos de topología.

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- Promover la colaboración entre estudiantes: Las redes sociales pueden ser un espacio en el que los estudiantes pueden trabajar juntos en la resolución de problemas, lo que puede fomentar el trabajo en equipo y el aprendizaje colaborativo.
- Proporcionar un espacio para la discusión y el debate: Las redes sociales pueden ser un lugar donde los estudiantes pueden discutir y debatir sobre temas de topología, lo que puede mejorar su comprensión y su capacidad de análisis crítico.
- Facilitar la comunicación entre estudiantes y profesores: Las redes sociales pueden ser un canal de comunicación efectivo entre los estudiantes y los profesores, lo que puede mejorar la retroalimentación y la comunicación en general.

Notes

En general, el uso de las redes sociales puede ser una herramienta muy útil para acercar la topología en las aulas de secundaria, ya que puede fomentar la participación activa de los estudiantes, facilitar el acceso a recursos educativos, promover la colaboración entre estudiantes, proporcionar un espacio para la discusion y el debate, y facilitar la comunicacion entre estudiantes y profesores.

La cinta de Möbius es una superficie con una sola cara y un solo borde que puede ser utilizada para enseñar y desarrollar habilidades abstractas en los estudiantes. A continuación, se presenta una propuesta práctica para trabajar el desarrollo de habilidades abstractas a través de la cinta de Möbius:

- Objetivo: Desarrollar habilidades abstractas a través de la manipulación y el análisis de la cinta de Möbius.

## IV. Materiales

- Cinta de papel (preferiblemente de colores).
- Tijeras.
- Pegamento.
- Papel y lápiz para tomar notas y dibujos.

## V. Procedimiento

- Introducir el concepto de la cinta de Möbius y mostrar ejemplos en la vida cotidiana (por ejemplo, en la fabricación de bandas transportadoras).
- Proporcionar a cada estudiante una cinta de papel y pedirles que la corten por la mitad, obteniendo dos tiras de igual longitud.
- Pedir a los estudiantes que den una media vuelta a una de las tiras de papel y que la peguen a la otra extremidad, formando así una cinta de Möbius.
- Después de haber formado la cinta de Möbius, pedir a los estudiantes que dibujen una línea recta sobre ella y observen el resultado.
- Pedir a los estudiantes que corten la cinta de Möbius siguiendo la línea recta que han dibujado y que observen el resultado.
- Discutir en grupo los resultados y las características de la cinta de Möbius, como su propiedad de tener una sola cara y un solo borde.
- Pedir a los estudiantes que realicen diversas operaciones con la cinta de Möbius, como hacer cortes adicionales, pegar las extremidades juntas, y hacer torsiones, y que observen el resultado.

- Discutir en grupo las propiedades y características de la cinta de Möbius que se han descubierto a través de las operaciones realizadas, como la propiedad de tener una sola cara y un solo borde, y la imposibilidad de cortarla en dos mitades separadas.
- Resultados esperados: Los estudiantes podrán ser capaces de entender y analizar las propiedades y características de la cinta de Möbius, así como desarrollar habilidades abstractas a través de la manipulación y el análisis de esta superficie. Además, los estudiantes pueden ser capaces de identificar la presencia de la cinta de Möbius en situaciones cotidianas y aplicar su comprensión a situaciones similares en el futuro.

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La botella de Klein es una superficie no orientable que puede ser utilizada para desarrollar habilidades abstractas en los estudiantes. A continuación, se presenta una propuesta práctica para trabajar con la botella de Klein y fomentar el desarrollo de habilidades abstractas:

- Introducción a la botella de Klein: El profesor puede presentar la botella de Klein a los estudiantes y explicar sus propiedades únicas, como su no orientabilidad. También puede demostrar cómo se construye una botella de Klein a partir de un cilindro y cómo se puede cortar y pegar para obtener diferentes formas.
- Observación y exploración: Los estudiantes pueden observar y explorar la botella de Klein para comprender mejor sus propiedades. Pueden tratar de dibujarla o modelarla en arcilla o plastilina para tener una mejor comprensión de su estructura.
- Experimentación con formas y cortes: Los estudiantes pueden experimentar con diferentes formas y cortes en la botella de Klein para ver cómo cambia su estructura. Por ejemplo, pueden cortar la botella de Klein a lo largo de una línea central y pegar los bordes para obtener una esfera doble. También se pueden hacer cortes a lo largo de diferentes planos para obtener diferentes formas.
- Conexiones con otras áreas: El profesor puede destacar la conexión de la botella de Klein con otras áreas de las matemáticas y la física, como la teoría de nudos y la relatividad general.
- Presentación y discusión: Los estudiantes pueden presentar sus experimentos con la botella de Klein y discutir sus hallazgos y observaciones. También pueden discutir cómo la botella de Klein se relaciona con otros temas de matemáticas y ciencias.

En general, la botella de Klein es una herramienta útil para fomentar el desarrollo de habilidades abstractas en los estudiantes, ya que les permite explorar una superficie no orientable y experimentar con diferentes formas y cortes. Además, la botella de Klein puede ser utilizada para conectar las matemáticas y la física, y para fomentar la discusión y el pensamiento crítico.

El trabajo con la botella de Klein para desarrollar habilidades abstractas puede ofrecer varios beneficios a los estudiantes, entre los cuales se incluyen:

- Fomentar la capacidad de visualización: La botella de Klein es una superficie no orientable que puede ser difícil de visualizar. El trabajo con la botella de Klein puede ayudar a los estudiantes a desarrollar su capacidad de visualización ya entender mejor las propiedades de los objetos en tres dimensiones.
- Estimular la creatividad: La botella de Klein es una herramienta que puede ser utilizada de muchas maneras diferentes para explorar diferentes formas y cortes. Los

estudiantes pueden experimentar y ser creativos en su enfoque, lo que puede estimular su creatividad y pensamiento crítico.

- Desarrollar habilidades de pensamiento abstracto: El trabajo con la botella de Klein puede ayudar a los estudiantes a desarrollar habilidades de pensamiento abstracto, como la capacidad de pensar en objetos abstractos y comprender sus propiedades.
- Fomentar la conexión con otras áreas de las matemáticas y la física: La botella de Klein es una herramienta que está relacionada con otras áreas de las matemáticas y la física, como la teoría de nudos y la relatividad general. El trabajo con la botella de Klein puede ayudar a los estudiantes a ver estas conexiones ya entender mejor cómo se relacionan diferentes áreas de las ciencias.
- Desarrollar habilidades de presentación y discusión: El trabajo con la botella de Klein puede ser presentado y discutido en clase, lo que puede ayudar a los estudiantes a desarrollar habilidades de presentación y discusión. Esto puede mejorar su capacidad para comunicar ideas matemáticas de manera clara y efectiva.

En general, el trabajo con la botella de Klein puede ser una herramienta útil para fomentar el desarrollo de habilidades abstractas en los estudiantes, ya que puede ayudar a mejorar la capacidad de visualización, estimular la creatividad, desarrollar habilidades de pensamiento abstracto, fomentar la conexión con otras áreas de las ciencias, y mejorar las habilidades de presentación y discusión.

## VI. Conclusiones

En conclusión, el uso de las redes sociales para acercar la topología en las aulas de secundaria puede ofrecer múltiples beneficios. Estas pueden ser utilizadas para fomentar la participación activa de los estudiantes, facilitar el acceso a recursos educativos, promover la colaboración entre estudiantes, proporcionar un espacio para la discusión y el debate, y facilitar la comunicación entre estudiantes y profesores.

Además, el uso de las redes sociales en el aula puede ser especialmente beneficioso para los estudiantes que prefieren aprender de manera más interactiva y colaborativa. Las redes sociales pueden proporcionar un espacio seguro y acogedor para que los estudiantes interactúen entre sí y con los profesores, lo que puede mejorar su motivación y compromiso con el aprendizaje.

Sin embargo, es importante tener en cuenta que el uso de las redes sociales en el aula también puede presentar algunos desafíos, como el control de los contenidos inapropiados, la privacidad y seguridad de los estudiantes, y la necesidad de establecer límites claros y normas para el uso responsable de estas herramientas.

El uso de las redes sociales para acercar la topología en las aulas de secundaria puede ser una herramienta valiosa para fomentar el aprendizaje activo y colaborativo, así como para mejorar la comunicación y la interacción entre estudiantes y profesores. Sin embargo, es importante utilizar estas herramientas de manera responsable y tener en cuenta las posibles limitaciones y desafíos asociados con su uso.

En conclusión, propone una propuesta práctica para trabajar el desarrollo de habilidades abstractas a través de la cinta de Möbius y la botella de Klein puede ser una herramienta valiosa para fomentar el aprendizaje activo y el desarrollo de habilidades abstractas en los estudiantes.

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Estas herramientas pueden ayudar a los estudiantes a desarrollar habilidades de visualización, creatividad y pensamiento abstracto, así como a conectar diferentes áreas de las matemáticas y la física. Además, el trabajo con la cinta de Möbius y la botella de Klein puede estimular la curiosidad y el interés de los estudiantes en estas áreas, y mejorar su capacidad para comunicar ideas matemáticas de manera clara y efectiva.

Es importante destacar que estas herramientas pueden presentar algunos desafíos, como la necesidad de proporcionar una orientación clara a los estudiantes, la importancia de trabajar con precaución para evitar dañar las superficies y la necesidad de adaptar la propuesta a las habilidades y necesidades de cada grupo de estudiantes.

En resumen, proponer una propuesta práctica para trabajar el desarrollo de habilidades abstractas a través de la cinta de Möbius y la botella de Klein puede ser una herramienta valiosa para fomentar el aprendizaje activo y el desarrollo de habilidades abstractas en los estudiantes, siempre y cuando se aborden los desafíos asociados y se adapten a las necesidades de cada grupo de estudiantes.

Notes

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# By an Extended Iteration Method to Adequate Solutions of Jerk Oscillator Containing Displacement Times Velocity Time's Acceleration and Velocity

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*Abstract-* Mathematics has applications in every aspect of real life. So many such type of real-life problems are modeled by differential equations. Therefore, differential equations are used as tools to solve many complex situations. With the help of differential equations, we can find the formula to solve many significant issues in many areas of the Anatomy and Physiology of the human body like physical, mental physical, and medical principles. Differential equations can be linear, nonlinear, autonomous, or non-autonomous. Practically, most of the differential equations involving physical phenomena are nonlinear. Hence nonlinear differential equations play a vital role in case of science and engineering. Nonlinear systems are differently classified, and the 'nonlinear jerk oscillator' is one of the most essential parts of a nonlinear system. Different types of nonlinear jerk oscillators will be analyzed using Extended Iteration Method, and the outcome may leave an impact to be better than the current results.

*Keywords: jerk equation; truncated fourier series; newton's method; angular frequency; extended iteration technique.*

*GJSFR-F Classification: LCC: QA371.5*


*Strictly as per the compliance and regulations of:*

# By an Extended Iteration Method to Adequate Solutions of Jerk Oscillator Containing Displacement Times Velocity Time's Acceleration and Velocity

Md. Ishaque Ali [α] & B. M. Ikramul Haque [σ]

*Abstract-* Mathematics has applications in every aspect of real life. So many such type of real-life problems are modeled by differential equations. Therefore, differential equations are used as tools to solve many complex situations. With the help of differential equations, we can find the formula to solve many significant issues in many areas of the Anatomy and Physiology of the human body like physical, mental physical, and medical principles. Differential equations can be linear, nonlinear, autonomous, or non-autonomous. Practically, most of the differential equations involving physical phenomena are nonlinear. Hence nonlinear differential equations play a vital role in case of science and engineering. Nonlinear systems are differently classified, and the 'nonlinear jerk oscillator' is one of the most essential parts of a nonlinear system. Different types of nonlinear jerk oscillators will be analyzed using Extended Iteration Method, and the outcome may leave an impact to be better than the current results. The principal advantage of this method is that it paves a suitable and smooth way and is more accurate, practical, easy, and straightforward.

*Keywords: jerk equation; truncated fourier series; newton's method; angular frequency; extended iteration technique.*

## I. Introduction

The use of quadratic nonlinear terms, cubic nonlinear terms, and asymmetric behavior illustrate the researchers' concentration to a great extent. Similarly, in the case of studying elastic force, structural dynamics and elliptic curve cryptography oscillators are found in use. The demands of such oscillators with strong nonlinearities are very prevalent among researchers because of their importance. Because ofsolid nonlinearities, it isn't easy to get solutions to such oscillators. In these circumstances, researchers have developed different procedures to solve and describe the physical properties of different types of nonlinear equations. Such as the Perturbation Method (PM) (Nayfeh, 1973); Homotopy Perturbation Method (HPM) (Bélendez et al., 2007; Anjumet al., 2021);Differential Transform Method (DTM) (Alquran & Al-Khaled, 2012);Harmonic Balance Method (HBM) (Mickens, 1984; Hu & Tang, 2006; Hosen et al., 2016); Enhanced Cubication Method (ECM) (Elias-Zuniga et al., 2012); Energy Balance Method (EBM) (Ozis &Yildirim, 2007); Variational Iteration Method (VIM)

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(Alquran & Doğan 2010); Direct Iteration Method (DIM) (Mickens, 1987; Hu & Tang, 2007; Mickens, 2010); Extended Iteration Method (EIM) (Mickens, 2010; Haque, B.I, 2014;Haque &Flora, 2020; Haque, B.I & Iqbal, 2021) etc.
The general form of the jerk equation is

$$\dddot{x} = J(x, \dot{x}, \ddot{x}) \tag{1}$$

where $J(x, \dot{x}, \ddot{x})$ denotes the jerk functions.

In this article, to determine the approximate solution of the nonlinear jerk equation, we have used Mickens' extended iteration method where the jerk function is the velocity times the acceleration-squared.

## II. The Methodology

The vital base of the extended iteration method is to reconvey the prestige's solution to obtain the present stage's solution and its sequence of extensions. The most essential apprehension is

(i) How to reprocess the preliminary shape of the given nonlinear oscillator so that it will help us to handle step-by-step iterations with simplification of a term including the large number of harmonics.
(ii) How to reprocess the obtained solutions for the case of harmonic terms so that there is no algebraic complexity. The outline of the presented procedure is as follows:

*Step 1:* considering the general form of the oscillator in the following way:

$$\ddot{x} + f(x) = 0 \tag{2}$$

*Step 2:* setting initial conditions as

$$x(0) = A\,, \tag{3}$$

$$\dot{x}(0) = 0$$

*Step 3:* making standard form by adding$\Omega^2 x$on both sides, we have

$$\ddot{x} + \Omega^2 x + \Omega^2 x - f(x) \equiv G(x) \tag{4}$$

*Step 4:* formulizing the suitable iteration scheme as

$$\ddot{x}_{k+1} + \Omega_k^2 x_{k+1} = G(x_k) + G_x(x_0, \Omega_k)(x_k - x_0); \quad k = 1, 2, 3, \ldots\ldots \tag{5}$$

*Step 5:* setting initial guess as

$$x_0(t) = A\, cos\, (\Omega_0 t) \tag{6}$$

*Step 6:* setting iterated initial conditions as

$$x_{k+1}(0) = A, \tag{7}$$

$$\dot{x}_{k+1}(0) = 0$$

*Step 7:* executing the successive iteration from

$$k = 1, 2, 3, \ldots$$

## III. Solution Procedure

Notes

The nonlinear jerk oscillator, which we consider

$$.\dddot{x} + \dot{x} = x\,\dot{x}\ddot{x} \tag{8}$$

Let $\dot{x} = y$ where $y(t)$be the space variable. Then equation (8) becomes

$$\ddot{y} + y = y\,\dot{y}y' \tag{9}$$

Let $\dot{y} = z$ and $y' = w$Then equation (9) becomes

$$.\,\dddot{y} + \mathrm{y} = y\,z\,w \quad . \tag{10}$$

For getting standard form, adding $\Omega^2 y$on both sides of equation (10), we have

$$\dddot{y} + \Omega^2 y = \Omega^2 y - y + y\,\mathrm{z}\,\mathrm{w} = \mathrm{G}(y, z, w) \tag{11}$$

where $G(y, \mathrm{z},\ \mathrm{w}) = \Omega^2 y - y + y\,z\,w$

Then $G_y = \frac{\partial G}{\partial y} = \Omega^2 - 1 + z\,w, G_{\mathrm{z}} = \frac{\partial G}{\partial \mathrm{z}} = y\,w$ and $G_{\mathrm{w}} = \frac{\partial G}{\partial \mathrm{w}} = y\,z$

Thus, the extended iteration scheme of equation (11) is

$$\ddot{y}_{k+1} + \Omega_k^2 y_{k+1} = (\Omega_k^2 y_0 - y_0 + y_0 z_0 w_0) + (\Omega_k^2 - 1 + z_0 w_0)(y_k - y_0) +$$

$$y_0 w_0 (z_k - z_0) + y_0 z_0 (w_k - w_0); k = 1,2,3,\ldots. \tag{12}$$

wherethe initial guess is

$$y_0 = y_0(t) = A\cos\theta\,;\ \theta = \Omega t \quad . \tag{13}$$

$$z_0 = -A\,\Omega_0 \sin\theta \tag{14}$$

$$w_0 = \frac{1}{\Omega_0} A\ \sin\theta \tag{15}$$

First Iteration Step: Putting $k = 0$ in equation (12) and using initial guess (13), (14) and (15), we get

$$\ddot{y}_1 + \Omega_0^2 y_1 = (\Omega_0^2\, y_0 -\ y_0 + y_0 z_0 w_0) \tag{16}$$

Now, expanding the right-hand side of equation (16), then it reduces to

$$\ddot{y}_1 + \Omega_0^2 y_1 = \mathrm{a11}\cos\theta + \mathrm{a13}\cos 3\theta \tag{17}$$

where,

$$\text{a11} = \frac{1}{4}(-4A - A^3 + 4A\Omega_0^2) \tag{18}$$

$$\text{a13} = \frac{A^3}{4} \tag{19}$$

Now, solving equation (17), we have,

$$y_1 = \left(A + \text{a13}\frac{1}{8\Omega_0^2}\right)\cos\theta - \text{a13}\frac{1}{8\Omega_0^2}\cos 3\theta \tag{20}$$

$$z_1 = -\Omega_1\left(\left(A + \text{a13}\frac{1}{8\Omega_0^2}\right)\sin\theta - \text{a13}\frac{3}{8\Omega_0^2}\sin 3\theta\right) \tag{21}$$

$$w_1 = \frac{1}{\Omega_1}\left(\left(A + \text{a13}\frac{1}{8\Omega_0^2}\right)\sin\theta - \text{a13}\frac{1}{24\Omega_0^2}\sin 3\theta\right) \tag{22}$$

To avoid secular term from equation (17), we obtain

$$\Omega_0 = \frac{2}{\sqrt{4-A^2}} \tag{23}$$

Equation (20) is known as the first iterated approximate analytic solution, and equation (23) is known as the first approximate frequency of the oscillator (8).

Second Iteration Step: Putting $k = 1$ in equation (12), we get,

$$\ddot{y}_2 + \Omega_1^2 y_2 = (\Omega_1^2 y_0 - y_0 + y_0 z_0 w_0) + (\Omega_1^2 - 1 + z_0 w_0)(y_1 - y_0) + y_0 w_0 (z_1 - z_0) + y_0 z_0 (w_1 - w_0) \tag{24}$$

Now, substituting the value of $y_0$, $z_0$, $w_0$, $y_1$, $z_1$, and $w_1$ from equations (13), (14), (15), (20), (21), and (22) into (24) and expanding the right-hand side of equation (24), then it reduces to

$$\ddot{y}_2 + \Omega_1^2 y_2 = \text{a21}\cos\theta + \text{a23}\cos 3\theta + \text{a25}\cos 5\theta \tag{25}$$

where

$$\text{a21} = -\frac{4A}{4+A^2} - \frac{A^3}{8(4+A^2)} + \frac{3A^5}{16(4+A^2)} - \frac{2A^3}{(4+A^2)^{3/2}\Omega_1} - \frac{25A^5}{24(4+A^2)^{3/2}\Omega_1} - \frac{13A^7}{96(4+A^2)^{3/2}\Omega_1} - \frac{2A^3\Omega_1}{(4+A^2)^{3/2}} - \frac{3A^5\Omega_1}{8(4+A^2)^{3/2}} + \frac{4A\Omega_1^2}{4+A^2} + \frac{9A^3\Omega_1^2}{8(4+A^2)} \tag{26}$$

$$\text{a23} = -\frac{7A^3}{8(4+A^2)} - \frac{5A^5}{32(4+A^2)} + \frac{2A^3}{(4+A^2)^{3/2}\Omega_1} + \frac{17A^5}{16(4+A^2)^{3/2}\Omega_1} + \frac{9A^7}{64(4+A^2)^{3/2}\Omega_1} + \frac{2A^3\Omega_1}{(4+A^2)^{3/2}} + \frac{9A^5\Omega_1}{16(4+A^2)^{3/2}} - \frac{A^3\Omega_1^2}{8(4+A^2)} \tag{27}$$

$$\text{a25} = -\frac{A^5}{32(4+A^2)} - \frac{A^5}{48(4+A^2)^{3/2}\Omega_1} - \frac{A^7}{192(4+A^2)^{3/2}\Omega_1} - \frac{3A^5\Omega_1}{16(4+A^2)^{3/2}} \tag{28}$$

Now, solving equation (25), we have,

$$y_2 = \left(A + a23\frac{1}{8\Omega_1^2} + a25\frac{1}{24\Omega_1^2}\right)\cos\theta + a23\frac{1}{-8\Omega_1^2}\cos 3\theta + a25\frac{1}{-24\Omega_1^2}\cos 5\theta \tag{29}$$

$$z_2 = -\Omega_2\left(\left(A + a23\frac{1}{8\Omega_1^2} + a25\frac{1}{24\Omega_1^2}\right)\sin\theta + a23\frac{3}{-8\Omega_1^2}\sin 3\theta + a25\frac{5}{-24\Omega_1^2}\sin 5\theta\right) \tag{30}$$

$$w_2 = \frac{1}{\Omega_2}\left(\left(A + \mathrm{a23}\frac{1}{8\Omega_1^2} + \mathrm{a25}\frac{1}{24\Omega_1^2}\right)\sin\theta - \mathrm{a23}\frac{1}{24\Omega_1^2}\sin 3\theta - \mathrm{a25}\frac{1}{120\Omega_1^2}\sin 5\theta\right) \tag{31}$$

To avoid secular term from equation (29), we obtain

$$\Omega_1 = \frac{16A^2+3A^4}{3(32\sqrt{4+A^2}+9A^2\sqrt{4+A^2})} - (-24576 - 13824A^2 - 1496A^4 + 366A^6 + 63A^8)/$$
$$(3(32\sqrt{4+A^2} + 9A^2\sqrt{4+A^2})(9437184A^2 + 11206656A^4 + 5405696A^6 + 1321920A^8 +$$
$$163836A^{10} + 8235A^{12}(9437184A^2 + 11206656A^4 + 5405696A^6 + 1321920A^8 +$$
$$163836A^{10} + 8235A^{12} + 3\sqrt{(-13194139533312 - 22265110462464A^2 -$$
$$5037996638208A^4 + 19032610701312A^6 + 25146509230080A^8 +$$
$$16524372606976A^{10} + 6955567370240A^{12} + 2014431843328A^{14} +$$
$$409363828992A^{16} + 57734182080A^{18} + 5408255088A^{20} + 303693624A^{22} +$$
$$7757289A^{24}))^{1/3}) + \frac{1}{6(32\sqrt{4+A^2}+9A^2\sqrt{4+A^2})}(9437184A^2 + 11206656A^4 + 5405696A^6 +$$
$$1321920A^8 + 163836A^{10} + 8235A^{12} + 3\sqrt{(-13194139533312 - 22265110462464A^2 -$$
$$5037996638208A^4 + 19032610701312A^6 + 25146509230080A^8 +$$
$$16524372606976A^{10} + 6955567370240A^{12} + 2014431843328A^{14} +$$
$$409363828992A^{16} + 57734182080A^{18} + 5408255088A^{20} + 303693624A^{22} +$$
$$7757289A^{24}))^{1/3} \tag{32}$$

Equation (29) is known as the second iterated approximate analytic solution, and equation (32) is known as the second approximate frequency of the oscillator (8).

Third Iteration Step: Putting $k = 2$ in equation (12), we get,

$$\ddot{y}_3 + \Omega_2^2 y_3 = (\Omega_2^2 y_0 - y_0 + y_0 z_0 w_0) + (\Omega_2^2 - 1 + z_0 w_0)(y_2 - y_0) + y_0 w_0 (z_2 - z_0) + y_0 z_0 (w_2 - w_0) \tag{33}$$

Now, substituting the value of $y_0$, $z_0$, $w_0$, $y_2$, $z_2$, and $w_2$ from equations (13), (14), (15), (29), (30), and (31) into (33) and expanding the right-hand side of equation (33), then it reduces to

$$\ddot{y}_3 + \Omega_2^2 y_3 = \mathrm{a31}\cos\theta + \mathrm{a33}\cos 3\theta + \mathrm{a35}\cos 5\theta + \mathrm{a37}\cos 7\theta \tag{34}$$

where,

$$a31 = (47202034180423 68A^5)/((4 + A^2)^2 (-49152 - 27648A^2 - 2992A^4 + 732A^6 + 126A^8 - 32A^2(9437184A^2 + 11206656A^4 + 5405696A^6 + 1321920A^8 + 163836A^{10} + 8235A^{12} + 3\sqrt{(-13194139533312 - 22265110462464A^2 - 503799663820 8A^4 + 190326107013 12A^6 + 251465092300 80A^8 + 16524372606976A^{10} + 6955567370240A^{12} + 2014431843328A^{14} + 409363828992A^{16} + 57734182080A^{18} + 5408255088A^{20} + 303693624A^{22} + 7757289A^{24})}^{1/3} - 6A^4(9437184A^2 + 11206656A^4 + 5405696A^6 + 1321920A^8 + 163836A^{10} + 8235A^{12} \ldots . - (9437184A^2 + 11206656A^4 + 5405696A^6 + 1321920A^8 + 163836A^{10} + 8235A^{12} + 3\sqrt{(-13194139533312 - 22265110462464A^2 - 503799663820 8A^4 + 190326107013 12A^6 + 251465092300 80A^8 + 16524372606976A^{10} + 6955567370240A^{12} + 2014431843328A^{14} + 409363828992A^{16} + 57734182080A^{18} + 5408255088A^{20} + 303693624A^{22} + 7757289A^{24})}^{2/3})^3) \quad (35)$$

$$a33 = -(44530220924928 0A^5)/((4 + A^2)^2(-49152 - 27648A^2 - 2992A^4 + 732A^6 + 126A^8 - 32A^2(9437184A^2 + 11206656A^4 + 5405696A^6 + 1321920A^8 + 163836A^{10} + 8235A^{12} + 3\sqrt{(-13194139533312 - 22265110462464A^2 - 503799663820 8A^4 + 190326107013 12A^6 + 251465092300 80A^8 + 16524372606976A^{10} + 6955567370240A^{12} + 2014431843328A^{14} + 409363828992A^{16} + 57734182080A^{18} + 5408255088A^{20} + \cdots + 3\sqrt{(-13194139533312 - 22265110462464A^2 - 503799663820 8A^4 + 190326107013 12A^6 + 251465092300 80A^8 + 16524372606976A^{10} + 6955567370240A^{12} + 2014431843328A^{14} + 409363828992A^{16} + 57734182080A^{18} + 5408255088A^{20} + 303693624A^{22} + 7757289A^{24})}^{2/3})^3) \quad (36)$$

$$a35 = (11781954286387 2A^7)/((4 + A^2)^2(-49152 - 27648A^2 - 2992A^4 + 732A^6 + 126A^8 - 32A^2(9437184A^2 + 11206656A^4 + 5405696A^6 + 1321920A^8 + 163836A^{10} + 8235A^{12} + \cdots + 190326107013 12A^6 + 251465092300 80A^8 + 16524372606976A^{10} + 6955567370240A^{12} + 2014431843328A^{14} + 409363828992A^{16} + 57734182080A^{18} + 5408255088A^{20} + 303693624A^{22} + 7757289A^{24})}^{2/3})^3 \quad (37)$$

$$a37 = -(16234976378 88A^9)/((4 + A^2)^2 (-49152 - 27648A^2 - 2992A^4 + 732A^6 + 126A^8 - 32A^2(9437184A^2 + 11206656A^4 + 5405696A^6 + 1321920A^8 + 163836A^{10} + 8235A^{12} + \cdots + 16524372606976A^{10} + 6955567370240A^{12} + 2014431843328A^{14} + 409363828992A^{16} + 57734182080A^{18} + 5408255088A^{20} + 303693624A^{22} + 7757289A^{24})}^{2/3})^3 \quad (38)$$

After solving equation (34), we have,

$$y_3 = \left(A + a33\frac{1}{8\Omega_2^2} + a35\frac{1}{24\Omega_2^2} + a37\frac{1}{48\Omega_2^2}\right)\cos\theta + a33\frac{1}{-8\Omega_2^2}\cos 3\theta + a35\frac{1}{-24\Omega_2^2}\cos 5\theta + a37\frac{1}{-48\Omega_2^2}\cos 7\theta \quad (39)$$

$$z_3 = -\Omega_3\left(\left(A + a33\frac{1}{8\Omega_2^2} + a35\frac{1}{24\Omega_2^2} + a37\frac{1}{48\Omega_2^2}\right)\sin\theta + a33\frac{3}{-8\Omega_2^2}\sin 3\theta + a35\frac{5}{-24\Omega_2^2}\sin 5\theta + a37\frac{7}{-48\Omega_2^2}\sin 7\theta\right) \quad (40)$$

$$w_3 = \frac{1}{\Omega_3}\left(\left(A + \mathrm{a33}\frac{1}{8\Omega_2^2} + \mathrm{a35}\frac{1}{24\Omega_2^2} + \mathrm{a37}\frac{1}{48\Omega_2^2}\right)\sin\theta - \mathrm{a33}\frac{1}{24\Omega_2^2}\sin 3\theta - \mathrm{a35}\frac{1}{120\Omega_2^2}\sin 5\theta - \mathrm{a37}\frac{1}{336\Omega_2^2}\sin 7\theta\right) \quad (41)$$

To avoid secular term from equation (39), we obtain

$$\Omega_2 = (180495828815708 16A^6 + 44465899494703104A^8 + 500006864101048 32A^{10} + 33868321094893568A^{12} + 15353161074081792A^{14} + 4891022626127872A^{16} + 1117554239127552A^{18} + 183226816945152A^{20} + 21138775350336A^{22} + 1635969435120A^{24} + 76541101308A^{26} + 1642907205A^{28} + 5737807872A^4\sqrt{((128 + 68A^2 + 9A^4)^2(-805306368 - 503316480A^2 + 567803904A^4 + 831356928A^6 + 452990208A^8 + 135794368A^{10} + 23789664A^{12} + 2302128A^{14} + 95769A^{16}))} + 7321681920A^6\sqrt{((128 + 68A^2 + 9A^4)^2(-805306368 - 503316480A^2 + 567803904A^4 + 831356928A^6 + 452990208A^8 + 135794368A^{10} + 23789664A^{12} + 2302128A^{14} + 95769A^{16}))} + 3913629696A^8\sqrt{((128 + 68A^2 + 9A^4)^2(-805306368 - 503316480A^2 + 567803904A^4 + 831356928A^6 + 452990208A^8 + 135794368A^{10} + 23789664A^{12} + 2302128A^{14} + 95769A^{16}))} + 1121367552A^{10}\sqrt{((128 + 68A^2 + 9A^4)^2(-805306368 - 503316480A^2 + 567803904A^4 + 831356928A^6 + 452990208A^8 + 135794368A^{10} + 23789664A^{12} + 2302128A^{14} + 95769A^{16}))} + \cdots + 675A^6\sqrt{4 + A^2}\sqrt{((128 + 68A^2 + 9A^4)^2(-805306368 - 503316480A^2 + 567803904A^4 + 831356928A^6 + 452990208A^8 + 135794368A^{10} + 23789664A^{12} + 2302128A^{14} + 95769A^{16}))}(9437184A^2 + 11206656A^4 + 5405696A^6 + 1321920A^8 + 163836A^{10} + 8235A^{12} + 3\sqrt{((128 + 68A^2 + 9A^4)^2(-805306368 - 503316480A^2 + 567803904A^4 + 831356928A^6 + 452990208A^8 + 135794368A^{10} + 23789664A^{12} + 2302128A^{14} + 95769A^{16}))}^{2/3})) \quad (42)$$

Equation (39) is known as the third iterated approximate analytic solution, and equation (42) is known as the third approximate frequency of the oscillator (8).

## IV. Results and Discussions

To verify the exactness, we considered the percentage error (%) according to the definition:

$$\text{Error} = \left|\frac{T_e - T_k}{T_e}\right| \times 100\%$$

Where the various approximate periods obtained by $T_0; k = 0, 1, 2, \ldots\ldots$ are illustrated by the modified method and $T_e$ denotes the exact period of the oscillator.

Haque's extended iterative method (Haque, 2014); has been presented based on Mickens extended iteration method (Mickens, 1987); to obtain the approximate analytic solution of the jerk oscillator containing "velocity times acceleration-squared, "The frequency, in addition to amplitude, has been earned by a modified approach and compared with those made by another existing process. We have calculated the first, second, and third approximate frequencies and corresponding periods of the oscillator denoted by $\Omega_0, \Omega_1, \Omega_2$ and $T_0, T_1, T_2$, respectively. It is noteworthy that the analytical solutions of algebraic equations produced by the executed method are straightforward to calculate. So, the iteration steps can be preceded to a finite necessary level. In this modification, we have found the solution up to the third iteration step.

All the obtained results are presented in Table 1. Table 2 it has been shown the comparison of results. A graph is provided in figure 1 and figure 2, where the comparative diagram of the modified development and the exact result is presented. We have compared the solution with the numerical solution obtained by Ranjikutta's $4^{th}$ order method graphically; our solution shows good agreement with the numerical solution. A graph is provided in figure 1 and figure 2, where the comparative diagram of the modified result and the exact result is presented. We have compared the solution with the numerical solution obtained by Ranjikutta's $4^{th}$ order method graphically; our solution shows good agreement with the numerical solution.

*Table 1:* Analyzing the differences between the approximate and exact periods $T_e$ of $\dddot{x} + \dot{x} = x\ddot{x}\dddot{x}$:

| A | $T_{exact}$ | Modified $T_0$ Er(%) | Modified $T_1$ Er(%) | Modified $T_2$ Er(%) |
|---|---|---|---|---|
| 0.1 | 6.275347 | 6.275346<br>1.56 $e^{-5}$ | 6.275347<br>1.54 $e^{-5}$ | 6.275347<br>2.60 $e^{-6}$ |
| 0.2 | 6.252016 | 6.252003<br>2.07 $e^{-4}$ | 6.252016<br>3.10 $e^{-6}$ | 6.252016<br>9.53 $e^{-8}$ |
| 0.5 | 6.096061 | 6.095585<br>1.17 $e^{-1}$ | 6.096021<br>6.54 $e^{-4}$ | 6.096062<br>1.18 $e^{-5}$ |
| 1 | 5.626007 | 5.619852<br>1.09 $e^{-1}$ | 5.624396<br>2.86 $e^{-2}$ | 5.625880<br>2.26 $e^{-3}$ |
| 2 | 4.491214 | 4.442883<br>1.08 | 4.463964<br>6.07 $e^{-1}$ | 4.614498<br>2.74 |

Initial, second, and third modified approximate periods are denoted respectively by $T_0$, $T_1$ and $T_2$ and percentage error indicates by Er(%).

*Table 2:* Approximate periods obtained by our method compared with exact periods $T_e$ and other existing periods of $\dddot{x} + \dot{x} = x\dot{x}\ddot{x}$:

| A | $T_{exact}$ | Modified $T_{2(\text{Second})}$ Er(%) | Gottlieb $T_G$ Er(%) (2004) [6] | Ma et al. $T_M$ Er(%) (2008) [15] | Ramos $T_R$ (2010) [21] Er(%) | Karahan $K_R$ (2017) [14] Er(%) | Gamal $T_I$ (2021) [13] Er(%) |
|---|---|---|---|---|---|---|---|
| 0.1 | 6.275347 | 6.275347 $2.60\ e^{-6}$ | 6.275346 $1.3\ e^{-5}$ | 6.275347 $2.5\ e^{-6}$ | 6.275329 $7.2\ e^{-5}$ | 6.275347 $3.19\ e^{-6}$ | 6.275334 $2.11\ e^{-4}$ |
| 0.2 | 6.252016 | 6.252016 $9.53\ e^{-8}$ | 6.252003 $2.11\ e^{-4}$ | 6.252016 $1.6\ e^{-7}$ | 6.251740 $1.1\ e^{-3}$ | 6.252016 $3.20\ e^{-6}$ | 6.252016 $1.59\ e^{-7}$ |
| 0.5 | 6.096061 | 6.096062 $1.18\ e^{-5}$ | 6.095585 $7.08\ e^{-3}$ | 6.096059 $3.21\ e^{-5}$ | 6.085649 $4.6\ e^{-2}$ | 6.275334 2.94 | 6.275334 $3.28\ e^{-5}$ |
| 1 | 5.626007 | 5.625880 $2.26\ e^{-3}$ | 5.619852 $1.09\ e^{-1}$ | 5.625795 $3.8\ e^{-3}$ | 5.477174 $9.0\ e^{-1}$ | 5.624549 $2.60\ e^{-2}$ | 6.275334 $2.31\ e^{-4}$ |
| 2 | 4.491214 | 4.614498 2.74 | 4.442883 1.08 | 4.482081 2.03 | 4.466205 $5.6\ e^{-1}$ | 4.466455 $5.51\ e^{-1}$ | 4.47661 $3.25\ e^{-1}$ |

Approximate period obtained by Gottlieb, Ma et al. Ramos, Karahan, and Ismail, respectively denoted by $T_G$, $T_M$, $T_R, K_R, T_I$ and the modified second approximate periodreceived by us is represented by $T_2$. Percentage error is indicated by Er(%).

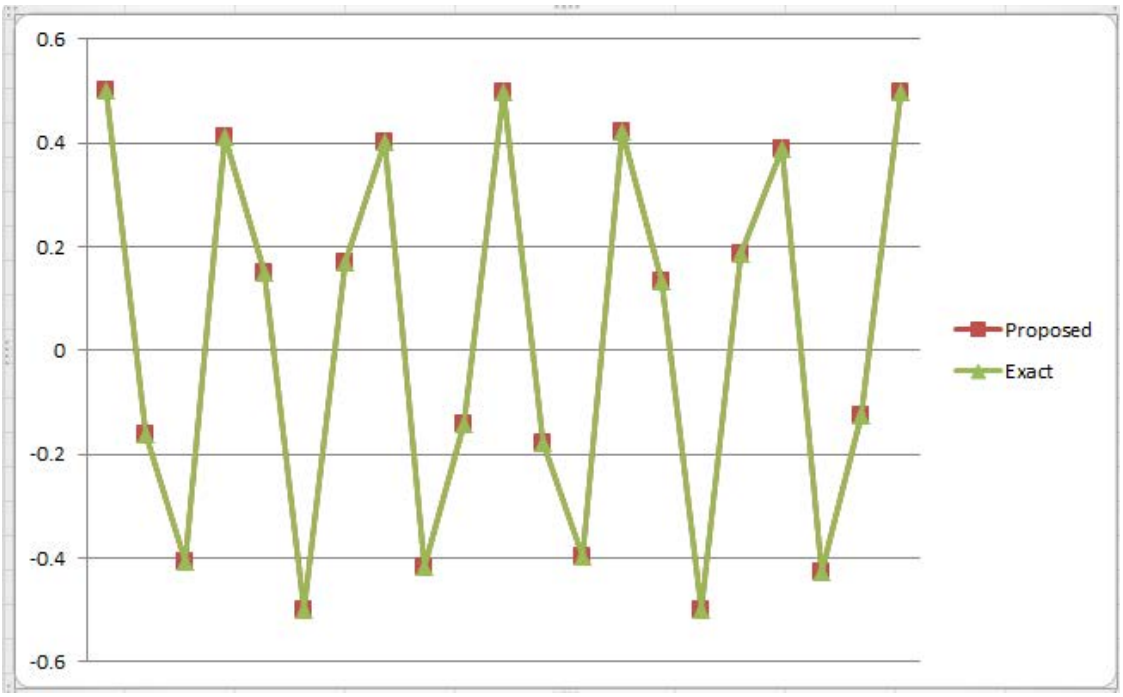


*Figure 1:* Approximate solutions of $\dddot{x} + \dot{x} = x\,\dot{x}\ddot{x}$ for $A = 0.5$ Compare with the corresponding numerical solution.

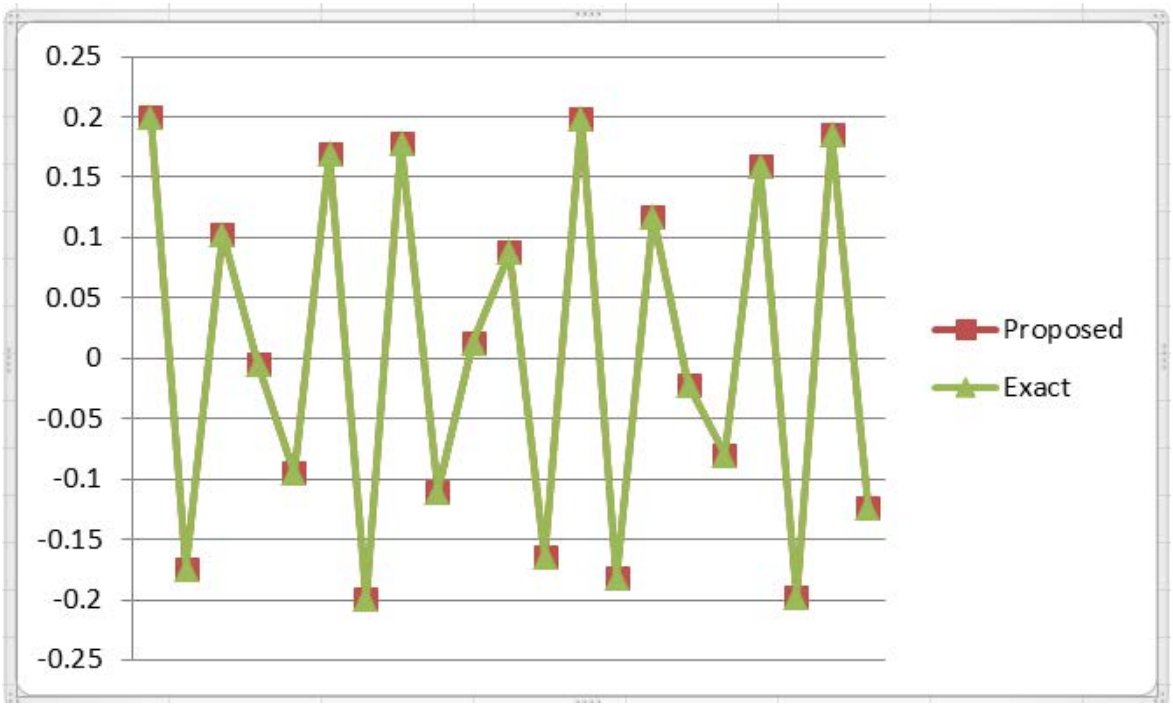


*Figure 2:* Approximate solutions of $\dddot{x} + \dot{x} = x\,\dot{x}\ddot{x}$ for $A = 0.1$Compare with the corresponding numerical solution.

## V. Convergence and Consistency Analysis

*Test of convergence:* The iteration method will be convergent if the set of solutions $x_k$ (or frequencies $\Omega_k$or amplitudes $T_k$) in ascending order satisfy the following property. $x_E = \mathrm{Lim}(x_k)$ or, $\Omega_E = \mathrm{Lim}(\Omega_k)$ or, $T_E = \mathrm{Lim}(T_k)$, k $\to\infty$ Here $x_E$ is considered as the exact solution, $\Omega_k$ denotes the frequencies and $T_k$ denotes the corresponding periods of the nonlinear oscillator.

In the obtained solutions, it has been indicated that there is less error to iterative steps in ascending order and finally it has been shown that $|T_2 - T_E| < \varepsilon$, where ε is a small positive number. Hence the presented extended iteration method is convergent.

*Test of consistency:* The iterative method will be consistent if the set of solutions $x_k$(or frequencies $\Omega_k$or amplitudes $T_k$) in ascending order satisfy the following property

$$\mathrm{Lim}|x_k - x_E| = 0\text{or, } \mathrm{Lim}|\Omega_k - \Omega_E| = 0\text{or, } \mathrm{Lim}|T_k - T_E| = 0,\ k \to \infty$$

In the obtained solutions, it has been indicated that there is less error to iterative steps in ascending order, and finally, it has been shown that,

$$\mathrm{Lim}|T_k - T_E| = 0,\ k \to \infty \text{ as} |T_2 - T_E| = 0.$$

Hence the presented extended iteration method is consistent.

## VI. Conclusion

In this research, it has been seen that the most significant part of solutions has been enhanced drastically. The modified solutions show that this modification is more





Notes

precise than other existing solution methods and resolution is valid for the large amplitude of oscillation for the jerk system. We have seen that it is not always true that the extended iteration method yields better results than the direct iteration method. It can be accomplished that the adopted modification is steadfast, effectual, and conformable also, it, also present sufficient well-suited solutions to the nonlinear jerk equations arising in mathematical physics, applied mathematics, and different field of engineering, specially in Mechanical, Electrical, and Space engineering.

Notes

*Availability of Data*

This study was not supported by any data.

*Conflict of Interest*

The authors affirm that they are impartial.

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Notes

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A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

## Format Structure

***It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.***

All manuscripts submitted to Global Journals should include:

**Title**

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

**Author details**

The full postal address of any related author(s) must be specified.

**Abstract**

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

**Keywords**

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

**Numerical Methods**

Numerical methods used should be transparent and, where appropriate, supported by references.

**Abbreviations**

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

**Formulas and equations**

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

**Tables, Figures, and Figure Legends**

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

**Figures**

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

## Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

## Tips for Writing a Good Quality Science Frontier Research Paper

Techniques for writing a good quality Science Frontier Research paper:

***1. Choosing the topic:*** In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

***2. Think like evaluators:*** If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

***3. Ask your guides:*** If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

***4. Use of computer is recommended:*** As you are doing research in the field of science frontier then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

***5. Use the internet for help:*** An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

***6. Bookmarks are useful:*** When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

***7. Revise what you wrote:*** When you write anything, always read it, summarize it, and then finalize it.

***8. Make every effort:*** Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

***9. Produce good diagrams of your own:*** Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

***10. Use proper verb tense:*** Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

***11. Pick a good study spot:*** Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

***12. Know what you know:*** Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

***13. Use good grammar:*** Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

***14. Arrangement of information:*** Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

***15. Never start at the last minute:*** Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

***16. Multitasking in research is not good:*** Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

***17. Never copy others' work:*** Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

***18. Go to seminars:*** Attend seminars if the topic is relevant to your research area. Utilize all your resources.

***19. Refresh your mind after intervals:*** Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

***20. Think technically:*** Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

***21. Adding unnecessary information:*** Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

***22. Report concluded results:*** Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

***23. Upon conclusion:*** Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

## Informal Guidelines of Research Paper Writing

***Key points to remember:***

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

**Final points:**

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

*The introduction:* This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

**The discussion section:**

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

**General style:**

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

**To make a paper clear:** Adhere to recommended page limits.

*Mistakes to avoid:*

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

**Title page:**

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

**Abstract:** This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

*Reason for writing the article—theory, overall issue, purpose.*

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

**Approach:**

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

**Introduction:**

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

*The following approach can create a valuable beginning:*

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

**Approach:**

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

**Procedures (methods and materials):**

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

**Materials:**

*Materials may be reported in part of a section or else they may be recognized along with your measures.*

**Methods:**

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

**Approach:**

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

**What to keep away from:**

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

**Results:**

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

**Content:**

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

**What to stay away from:**

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

**Approach:**

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

**Figures and tables:**

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

**Discussion:**

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

**Approach:**

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

## The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

*Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection*.

*Segment draft and final research paper:* You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

*Written material:* You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

## Criterion for Grading a Research Paper (Compilation) by Global Journals

**Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.**

| Topics | Grades | | |
|---|---|---|---|
| | **A-B** | **C-D** | **E-F** |
| ***Abstract*** | Clear and concise with appropriate content, Correct format. 200 words or below | Unclear summary and no specific data, Incorrect form<br><br>Above 200 words | No specific data with ambiguous information<br><br>Above 250 words |
| ***Introduction*** | Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited | Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter | Out of place depth and content, hazy format |
| ***Methods and Procedures*** | Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads | Difficult to comprehend with embarrassed text, too much explanation but completed | Incorrect and unorganized structure with hazy meaning |
| ***Result*** | Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake | Complete and embarrassed text, difficult to comprehend | Irregular format with wrong facts and figures |
| ***Discussion*** | Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited | Wordy, unclear conclusion, spurious | Conclusion is not cited, unorganized, difficult to comprehend |
| ***References*** | Complete and correct format, well organized | Beside the point, Incomplete | Wrong format and structuring |

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