Online ISSN: 2249-4596
Print ISSN: 0975-5861
DOI: 10.17406/GJRE

Global Journal

of Researches in Engineering: I

Numerical Methods

STEM in Engineering Courses

Science, Technology and Society

Highlights

Effects of Physical Parameters

Low-Frequency Ultrasound Excitation

Discovering Thoughts, Inventing Future

VOLUME 24 ISSUE 1 VERSION 1.0

Global Journal of Researches in Engineering: I
Numerical Methods

Global Journal of Researches in Engineering: I
Numerical Methods

Volume 24 Issue 1 (Ver. 1.0)

Open Association of Research Society

Incorporation No.: 0423089
License No.: 42125/022010/1186
Registration No.: 430374
Import-Export Code: 1109007027
Employer Identification Number (EIN):
USA Tax ID: 98-0673427

Global Journals Inc.

*(A Delaware USA Incorporation with "Good Standing"; **Reg. Number: 0423089**)*

Sponsors: *Open Association of Research Society*
Open Scientific Standards

Publisher's Headquarters office

Global Journals® Headquarters
945th Concord Streets,
Framingham Massachusetts Pin: 01701,
United States of America
USA Toll Free: +001-888-839-7392
USA Toll Free Fax: +001-888-839-7392

Offset Typesetting

Global Journals Incorporated
2nd, Lansdowne, Lansdowne Rd., Croydon-Surrey,
Pin: CR9 2ER, United Kingdom

Packaging & Continental Dispatching

Global Journals Pvt Ltd
E-3130 Sudama Nagar, Near Gopur Square,
Indore, M.P., Pin:452009, India

Find a correspondence nodal officer near you

To find nodal officer of your country, please email us at *local@globaljournals.org*

eContacts

Press Inquiries: *press@globaljournals.org*
Investor Inquiries: *investors@globaljournals.org*
Technical Support: *technology@globaljournals.org*
Media & Releases: *media@globaljournals.org*

Pricing (Excluding Air Parcel Charges):

Yearly Subscription (Personal & Institutional)
250 USD (B/W) & 350 USD (Color)

Dr. Omid Gohardani

Ph.D. Senior Aerospace/Mechanical/ Aeronautical, Engineering professional M.Sc. Mechanical Engineering, M.Sc. Aeronautical Engineering B.Sc. Vehicle Engineering Orange County, California, US

Dr. Paolo Veronesi

Ph.D., Materials Engineering, Institute of Electronics, Italy President of the master Degree in Materials Engineering Dept. of Engineering, Italy

Contents of the Issue

Global Journal of Researches in Engineering: I
Numerical Methods
Volume 24 Issue 1 Version 1.0 Year 2024
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Science, Technology and Society: Challenges and Possibilities for STEM in Engineering Courses

By Felicien Gonçalves Vásquez, Nataliana de Souza Paiva & Ana Cláudia Ribeiro de Souza
Universidade do Estado do Amazonas

Abstract- Ingês: The study of Science, Technology and Society (STS) is quite embracing and relevant to today's society. In this article, we intend to approach the issue and reflect on the interaction that exists between the three areas and education, as well as the relationship with Science, Technology, Engineering and Mathematics (STEM). For that, a qualitative research was carried out from a narrative review about the subject in books, articles and works presented in event annals highlighting STS in the context of education, the challenges faced in relation to the STEM approach and the possibilities of integration between science, technology and society in engineering courses. The results indicate that there are challenges such as lack of adequate training for teachers, lack of didactic resources and resistance to change on the part of some educators and managers, as well as that the STS approach in education and STEM in the training of engineers makes it possible to develop professional skills and competencies focused on sustainability, innovation and a fairer and more humane society.

Keywords: STS, STEM, Engineering Education.

GJRE-I Classification: LCC: T65

Science, Technology and Society: Challenges and Possibilities for STEM in Engineering Courses

Ciência, Tecnologia e Sociedade: Desafios e possibilidades para o STEM nos cursos de Engenharia do Amazonas

Felicien Gonçalves Vásquez [α], Nataliana de Souza Paiva [σ] & Ana Cláudia Ribeiro de Souza [ρ]

Resumo- O estudo do tema Ciência, Tecnologia e Sociedade (CTS) é bastante abrangente e relevante para a sociedade atual. Neste artigo, pretende-se abordar a temática e refletir a respeito da interação que existe entre as três áreas e a educação, como também, a relação com a Ciência, Tecnologia, Engenharia e Matemática (STEM). Para tanto, foi realizada uma pesquisa qualitativa a partir de uma revisão narrativa sobre o tema em livros, artigos e trabalhos apresentados em anais de eventos destacando a CTS no contexto da educação, os desafios enfrentados em relação à abordagem STEM e as possibilidades de integração entre ciência, tecnologia e sociedade nos cursos de Engenharia. Os resultados apontam a falta de formação adequada dos professores, falta de recursos didáticos e resistência à mudança por parte de alguns educadores e gestores, como também que a abordagem CTS na educação e no STEM na formação de engenheiros possibilita desenvolver habilidades e competências profissionais voltadas à sustentabilidade, inovação e uma sociedade mais justa e humanitária.

Palavras-chave: CTS, STEM, Ensino de Engenharia.

*Abstract- **Ingês:*** The study of Science, Technology and Society (STS) is quite embracing and relevant to today's society. In this article, we intend to approach the issue and reflect on the interaction that exists between the three areas and education, as well as the relationship with Science, Technology, Engineering and Mathematics (STEM). For that, a qualitative research was carried out from a narrative review about the subject in books, articles and works presented in event annals highlighting STS in the context of education, the challenges faced in relation to the STEM approach and the possibilities of integration between science, technology and society in engineering courses. The results indicate that there are challenges such as lack of adequate training for teachers, lack of didactic resources and resistance to change on the part of some educators and managers, as well as that the STS approach in education and STEM in the training of engineers makes it possible to develop professional skills and competencies focused on sustainability, innovation and a fairer and more humane society.

Keywords: STS, STEM, Engineering Education.

I. Introdução

A busca humana pelo entendimento das leis da natureza remonta à antiguidade, quando os gregos e egípcios realizavam estudos e observações para entender os fenômenos naturais – conhecimentos esses que foram se acumulando e dando origem ao que entendemos hoje como ciência. Ao longo dos séculos, a ciência vem evoluindo e se desenvolvendo em diferentes culturas e sociedades, sendo influenciada por diversas correntes filosóficas e contextos sociais complexos.

O estudo do tema Ciência, Tecnologia e Sociedade (CTS) é bastante abrangente, indo além do que se discute neste artigo. Temos como objetivo revisitar uma reflexão a respeito não só da interação que existe entre essas três áreas e a educação, mas também a relação com Ciência, Tecnologia, Engenharia e Matemática (STEM).

A discussão a respeito do papel do STEM, em particular nos cursos de Engenharia, se dá pela possibilidade que essa abordagem traz para o desenvolvimento não só de habilidades profissionais dos estudantes, como também pela busca em formar indivíduos cada vez mais comprometidos com o meio ambiente e com uma sociedade mais justa e humana.

No contexto amazônico, especificamente no Amazonas, torna-se estruturante pensar nas questões sociais, ambientais, éticas, políticas e suas conexões com os povos do campo, das águas e das florestas que aqui habitam e se relacionam com: o Polo Industrial de Manaus (PIM) nos segmentos eletroeletrônico, duas rodas, naval, mecânico, metalúrgico e termoplástico, entre outros (Brasil, 2017); a extração de minerais que vem fazendo parte da economia do estado (Hauradou e Amaral, 2019); e a bioeconomia gerada do

Author α: Doutorando do programa stricto sensu em Ensino Tecnológico, pelo Instituto Federal de Educação, Ciência e Tecnologia do Amazonas, docente da Universidade do Estado do Amazonas, Brasil. e-mail: fgvasquez@uea.edu.br
ORCID: https://orcid.org/0009-0000-7667-5731
Author σ: Doutoranda do programa stricto sensu em Ensino Tecnológico, pelo Instituto Federal de Educação, Ciência e Tecnologia do Amazonas, docente da Universidade do Estado do Amazonas, Brasil. e-mail: npaiva@uea.edu.br
ORCID: https://orcid.org/0000-0002-9124-7580
Author ρ: Doutora em História, docente titular do Instituto Federal de Educação, Ciência e Tecnologia do Amazonas, Manaus, Amazonas, Brasil. e-mail: ana.souza@ifam.edu.br
ORCID: https://orcid.org/0000-0002-0066-7038

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

desdobramento das ciências básicas, aplicadas e áreas tecnológicas (informática, robótica e controle de processos) (Willerding, et al, 2020).

Diante dos impactos que as questões econômicas podem causar na sociedade e no meio ambiente, a engenheira dialoga com estes cenários locais e globais, tonando-se campo fértil para integração de CTS e STEM, numa perspectiva de ensino crítico e reflexivo sobre ciência e tecnologia, possibilitando uma capacidade de resposta rápida as inovações e soluções tecnológicas.

Apesar de importante, a abordagem STEM nas instituições de ensino superior enfrenta desafios aos quais podemos elencar como sendo a sua implementação, a mudança na cultura educacional, falta de formação pedagógica dos professores, ausência de recursos didáticos adequados e a necessidade de uma abordagem interdisciplinar e aplicada. Dessa forma, para torná-la possível é necessário que as instituições de ensino superior estejam preparadas para enfrentá-los, investindo em recursos e formação adequada de seu corpo docente.

Neste estudo discutimos quais os desafios e as possibilidades para o STEM nos cursos de engenharia, com foco na temática CTS? Para isso, realizamos uma revisão narrativa sobre o tema em livros, artigos e trabalhos apresentados em anais de evento, a fim de discutir alguns apontamentos sobre a abordagem Ciência, Tecnologia e Sociedade (CTS) na educação e o STEM na formação de engenheiros relacionado com CTS, de maneira que possam contribuir para a formação de profissionais críticos e reflexivos.

II. Abordagem Ciência, Tecnologia e Sociedade (cts) na Educação

Quando questionados quanto ao conceito de tecnologia, logo nos vem à mente, aparelhos eletrônicos, de informática e comunicação, pois estamos acostumados a nos referir à tecnologia como equipamentos e aparelhos. Estes são considerados exemplos de tecnologia, assim como um simples lápis ou um caderno também o são, pois, a tecnologia não é representada apenas pelo produto final, mas pelo conjunto de saberes necessários desde a sua concepção, execução e à utilização do produto ou serviços (Veraszto *et al*, 2008; Oliveira, 2008).

A tecnologia, então, surge da capacidade do homem em expandir seus conhecimentos, facilitar seu trabalho, tornar a vida mais agradável a partir das dificuldades encontradas e com criação de instrumentos (artefatos, sistemas, processos e ambientes), capazes de suprir suas necessidades históricas pessoais e coletivas, garantindo sua sobrevivência em qualquer ambiente com diferentes formas, usos e aplicações (Kenski, 2007; Veraszto e*t al*, 2008; Araújo e Sá, 2021).

Na antiguidade, a tecnologia estava voltada para o comércio, transporte de água, para uma economia predominantemente doméstica, mais tarde virou força propulsora da expansão social para o crescimento das cidades pelo desenvolvimento da tecnologia do transporte e hoje como em outros momentos da história da humanidade o monopólio das armas e do poderio militar, do emprego de imagens, assim como também as tecnologias digitais (Elias, 1994).

A temática que envolve a tecnologia, continua alvo de preocupação e exige reflexões, por ser um dos principais problemas teóricos e práticos da atualidade, abordados nos mais diversos campos de estudo,

> Da Engenharia à Sociologia da Ciência, da História à Biotecnologia, da Antropologia aos Estudos Sociais da Ciência, da Física/Química/Matemática à Pedagogia/ Psicologia/Economia, passando pelas Ciências da Computação, ecoam questões que envolvem a condição tecnológica. Não só! O tema não se restringe ao universo acadêmico e um observador mais estimulado não terá dificuldade de encontrar nas transmissões televisivas, nos jornais, nos mercados, nas praças, nos diálogos do cotidiano, elementos teóricos problematizadores da referida temática (Silva, 2007, p.116).

Nessa perspectiva, na busca incessante pelo bem-estar humano, surge o conflito entre a manutenção dessa situação e o risco à sobrevivência devido à exploração excessiva, destruição dos recursos naturais e até mesmo da degradação humana, pois se tornou acessório da tecnologia, sendo substituído até mesmo das relações afetivas e morais constituindo-se como fenômeno de alienação (Oliveira, 2008).

A abordagem CTS tem como um de seus objetivos a compreensão da ciência e da tecnologia como atividades humanas, socialmente situadas e culturalmente mediadas – que superará a visão ingênua e idealizada da ciência e da tecnologia como atividades neutras, objetivas e desinteressadas, propondo uma reflexão crítica sobre as implicações sociais, políticas, econômicas e ambientais em nossa sociedade (Bazzo, 2018).

Apesar de haver muitas iniciativas e produções bibliográficas em CTS, ainda há desafios a serem enfrentados - como a falta de formação adequada dos professores para trabalhar com CTS e a dificuldade em integrar essa abordagem ao currículo escolar. Além disso, Bazzo (2018) aponta haver uma tendência em reduzir a abordagem CTS a um conjunto de técnicas ou atividades pontuais, sem considerar sua dimensão crítica e reflexiva.

> A visão desta dificuldade de CTS chegar até a escola sempre me acometeu desde que comecei a trabalhar com a relação ciência, tecnologia e sociedade. [...] Essa dificuldade se acentuou nesses últimos anos porque pela 'febre' das publicações em revistas 'indexadas' muitos autores se despreocuparam em chegar até os

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

professores que estavam na lida diária da construção de conhecimento (Bazzo, 2018, p.262).

Mesmo promissora, ainda há muito o que ser feito para consolidar a abordagem CTS na educação brasileira. O autor destaca haver muitas iniciativas e produções bibliográficas na área, bem como a criação de grupos de pesquisa e redes colaborativas. Isso porque, o ensino de ciências no Brasil ainda é marcado por uma visão tecnicista e descontextualizada da ciência, que não considera as dimensões sociais, culturais e políticas envolvidas na produção do conhecimento científico (Bazzo, 2018).

É necessário avançar na consolidação da abordagem CTS na educação brasileira, buscando superar os desafios mencionados. Ele também ressalta a importância de se manter uma perspectiva crítica e reflexiva sobre a ciência e a tecnologia, buscando desmistificar esses temas e promover um desenvolvimento tecnológico mais humano (Bazzo, 2018).

Nesse processo civilizatório é importante entender as concepções dos processos sociais, a economia, a política, a tecnologia, a cultura ao que tange a mudança de conduta e sentimentos humanos em outras direções. Muito embora essa mudança não tenha sido "racionalmente" planejada, não quer dizer que tão pouco foi aleatória, foi pela ação integrada do homem (ações coletivas são mais fortes para o processo civilizador).

De acordo com N. Elias (1994, p. 199) "a transformação da existência social na totalidade é a condição básica para civilizar-se a conduta", mas apesar disso costuma-se mensurar o grau de civilização pela estrutura social a qual pertencem, geralmente julgando-se civilizados aqueles inseridos numa cultura digital.

A aplicação da ciência e tecnologia trouxeram implicações na organização do trabalho e das empresas e, consequentemente, nas profissões e na maneira como ocorre o processo de formação destes no contexto educacional. Desta forma, os avanços tecnológicos, em especial na informação e comunicação, impactam na formação de professores, nos processos de ensino e aprendizagem, nos currículos e nas políticas educacionais de CTS, ou seja, na forma de conceber a educação (Peña; Alves; Peppe, 2003).

Na busca por uma sociedade mais justa e igualitária, a educação tecnológica é uma possibilidade de emancipação do cidadão, quando visa formar cidadãos críticos e reflexivos para o mundo, por conhecimentos técnicos das ferramentas necessárias para o trabalho, para contribuir na construção de uma sociedade mais humana (Durães, 2009).

Desta forma, Gonçalves e Azevedo (2021), ressalta que a "Educação Tecnológica busca não somente formar um nível ou grau, mas sim uma formação que consiga proporcionar aos indivíduos um olhar crítico e reflexivo para as questões do mundo". Ou seja, deve-se incentivá-los a pensar de forma crítica e analítica sobre o papel da tecnologia em nossa sociedade e refletir sobre as implicações éticas, sociais, ambientais e econômicas do uso da tecnologia, tais como o impacto da tecnologia na privacidade, segurança, saúde, emprego, relações sociais, entre outras.

Para Harari (2018), compreender o impacto da tecnologia na sociedade, reforça a ideia de que a educação tecnológica deve incluir uma formação mais ampla, que vá além das habilidades técnicas e profissionais, buscando desenvolver um pensamento crítico e reflexivo das implicações que a tecnologia pode trazer para a sociedade.

O autor argumenta que a tecnologia está mudando rapidamente a sociedade, criando oportunidades e desafios, dessa forma, o ensino tecnológico pode ajudar a preparar os estudantes para lidar com essas mudanças, capacitando-os a adaptar-se a novas tecnologias e contextos (Harari, 2018).

Não podemos deixar de descrever a relação entre a Educação Tecnológica com o STEM, o qual é uma abordagem interdisciplinar para o ensino que integra essas quatro áreas de conhecimento, e é amplamente reconhecido como uma forma de preparar os estudantes para as demandas do mercado de trabalho atual, valorizando habilidades em tecnologia e ciência. Além disso, "permitem desenvolver a observação, o questionamento e a resolução de problemas no processo de ensino e aprendizagem" (Bacich; Moran, 2018).

Bazzo, Pereira e Bazzo (2014) apontam três alternativas para a inserção do enfoque CTS no currículo de Engenharia, a) inserção de temas sobre CTS nos conteúdos; b) inserção de disciplinas específicas de CTS, c) organização de um currículo no qual todas as disciplinas tenham enfoque CTS (descritas pelos autores como a abordagem ideal) e na formação didático-pedagógica que apontam para um olhar reflexivo na abordagem STEM.

III. STEM na Formação de Engenheiros e a Relação Com CTS

Os estudos sobre STEM emergem nos Estados Unidos a partir da corrida espacial de 1950 e 1960 engenheiros, cientistas e matemáticos ajudaram a enviar os primeiros objetos ao espaço, em 1970 e 1980 o EUA tornou-se líder global de educação científica e os computadores passaram cada vez mais parte da vida das pessoas. Nos anos de 1990, ciências, matemática, engenharia e tecnologia, SMET, foi utilizado pela National Science Foundation (NSF), orientaram políticas de currículo integrado, avaliações externas e em larga escala, levando para as escolas a alfabetização

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

científica, fortalecendo sobretudo a economia competitiva usando como fundamento a tecnologia e engenharia (Pugliese, 2020; Hardoim e Santos, 2021).

Nos anos 2000, a palavra do acrônico STEM aparece na literatura perdurando até os dias atuais, contudo só em 2008 passou a chamar-se STEAM, que para alguns aparece como estímulo à criativade e estética e para outros como forma de evitar a preeminência da Ciência e da Tecnologia em relação aos demais (Pugliese, 2021). Em 2010 o termo STEM tornou-se popular, mas referia-se as quatro áreas do conhecento de forma distinta, de lá para cá em 2024 podemos perceber que no contexto educacional brasileiro há movimentos de integrar essas áreas numa abordagem de aprendizagem integrada e interdisiclinar (Gamboa et al., 2020; Hardoim e Santos, 2021).

Internacionalmente existem muitas críticas à educação STEM, por estar relacionada a movimentos de políticas educacionais globalizantes para atender sobretudo ao mercado de trabalho competitivo e impulsionar ao crescimento econômico, com algumas ações voltadas as mudanças nos currículos, entregas de pacotes metodológicos de ensino, materiais (kits de maker) e espaços, principalmente no ensino médio (Pugliese, 2020b).

Embora seja importante preparar estudantes para as demandas do mundo do trabalho atual e futuro, é importante que carreiras relacionadas à ciência, tecnologia, engenharia e matemática suscitam uma educação ampla, humanizada e equilibrada para a vida profissional.

Para Bacich e Holanda (2020) as palavras do acrônico STEM, nome utilizado neste estudo, ganham sentido quando relacionados a aprendizagem ativa e integrativa. Para a Ciência estão os conhecimentos científicos e a experimentação que levam à reflexão e modelagem de diferentes fenômenos; a Tecnologia para obtenção de informação, análise, uso de programação para soluções de problemas; a Engenharia para estudantes realizam o planejamento, o design e a construção de objetos para solucionar algo para compreensão de um fenômemo ou conceito científico; a Arte, como forma transversal da arte-educação na proposta de inovação, criatividade, pensamento crítico, comunicação, integração; e a Matemática empregada para medir, calcular, projetar soluções, ajudar nas análises dos dados obtidos e desta forma integrar a educação científica e tecnológica. (Bacich; Holanda, 2020)

Na abordagem STEM são considerados relevantes os conhecimentos das áreas STEM pelo menos ao nível de compreensão conceitual, poisajuda o professor a apreender e desenvolver o conhecimento pedagógico no ensino STEM. Esse diálogo entre conheicmento e ensino possibilita estudantes a desenvolvem sua capacidade de realizar investigações, resolver problemas da vida cotidiana, trabalharem colaborativamente e desenvolverem sua capacidade de criação, que são balizares na formação do engenheiro e do papel da CTS (Kutlu, Bakirci e Kara, 2022; Tekin e Şan, 2023).

Em consonância com Bazzo e Costa (2019) é questão de engenharia pensar o uso dos recursos naturais, as questões climáticas, os impactos na distribuição de renda na sociedade, refletindo o papel CTS na formação de engenheiros e na formação dos professores de engenharia para uma toma de consciência crítica, criativa, resolutiva, ética e humanista.

Desta forma, esta abordagem é vista cada vez mais como caminho possível aos cursos de Engenharia, à medida que as questões ambientais e sociais das quais estamos vivendo e que colocam em risco a segurança global. Logo a demanda por habilidades STEM articuladas à CTS está se tornando exasperada devido ao cenário econômico, social, ambiental e político enfrentados por muitos países.

No Brasil, a Resolução Nº 2, de 24 de abril de 2019, estabelece as novas Diretrizes Curriculares Nacionais (DCN) para a formação em engenharia. Essas diretrizes propõem uma nova proposta de formação do egresso, baseado em competências e habilidades, em contraposição ao modelo tradicional focado apenas no conteúdo, trazendo os fundamentos científicos e tecnológicos, projeto e análise de sistemas, produtos e processos, comunicação, trabalho em equipe e liderança, autoaprendizagem e educação continuada (DCN Nº 2, 2019).

Além disso, as DCN enfatizam a importância da integração do estudante às demandas sociais por meio da curricularização da extensão. Conforme Vásquez, Paiva e Souza (2022), isso é relevante porque a engenharia é uma das profissões responsáveis pelas transformações no planeta e precisa considerar a responsabilidade social e a qualidade de vida humana, considerando os possíveis impactos ambientais e sociais.

> Em 2015 a Organização das Nações Unidas - ONU adotou a Agenda 30 com os 17 objetivos para o desenvolvimento sustentável para assegurar um futuro melhor, onde engenheiros são chamados a desempenhar papel essencial para que essas metas sejam atingidas não só através da criação de tecnologias ambientalmente amigáveis, mas também com aplicações de soluções ambientalmente sustentáveis, diretamente relacionada à redução da pobreza, ao desenvolvimento de infraestrutura, de promoção da saúde e da educação (Vásquez; Paiva; Souza, 2022, p. 2).

Nesse contexto, é urgente olhar para a formação dos estudantes de engenharia, que devem ser capazes de pesquisar, adaptar e utilizar tecnologias inovadoras e empreendedoras, assim como reconhecer as exigências do mercado e resolver problemas de engenharia com perspectivas multidisciplinares,

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

transdisciplinares e com foco na redução da pobreza e dos impactos ambientais. Habilidades essas que inclusive já são mencionadas no Art 3º da DCNs do CNE/CES nº 02/2019.

Os estudantes de curso de engenharia na abordagem STEM com enfoque CTS problematizam, constroem perguntas, identificam conhecimentos científicos necessários para a solução, são estimulados à autodisciplina, tem oportunidade de errar, autoconfiança e ao professor o papel mediador que permita ao estudante construir seus próprios projetos (Pugliese, 2020; Gamboa *et al.*, 2020).

Kelley e Knowles (2016) pontuam o problema de desinteresse que os estudantes geralmente apresentam em relação às ciências e matemática quando aprendem de maneira isolada e desarticulada, acabando por perder as conexões entre os conceitos e o mundo real, que acaba contribuindo para que muitas instituições de ensino procurem formas de manter o interesse e a motivação dos alunos em relação à abordagem STEM.

Assim como a CTS, a abordagem STEM surgi como alternativa de pensar em uma educação mais contextualizada e interdisciplinar, que considere as implicações sociais, políticas e ambientais da ciência e da tecnologia. Ambas as abordagens pretendem formar cidadãos críticos e conscientes, capazes de compreender e intervir nos processos de produção, difusão do conhecimento científico e tecnológico.

Reforçando esse ideia, para Pugliese (2020) é fundamental refletir que quem trabalha com a abordagem STEM, a reconheça como um processo dialógico, não se tem uma receita pronta, mas aponta uma uma possiblidade de encontrar os seus próprios caminhos para promover as experiências.

Enquanto o STEM se concentra principalmente nas áreas do conhecimento de ciências, tecnologia, engenharia e matemática, a abordagem CTS amplia essa perspectiva para incluir outras áreas do conhecimento, como as ciências humanas e sociais. Faz-se necessário uma interdisciplinaridade efetiva entre os campos do saber para formar seres humanos mais críticos e preocupados com o coletivo (Bordin; Bazzo, 2017).

A educação STEM pode desenvolver nos estudantes a compreensão da base social e institucional da credibilidade científico-tecnológica, como estimular e habilitar os estudantes a aprender ciências a partir de seus próprios interesses. Os principais percalços enfrentados no STEM se voltam para um ensino centrado no docente, na aprendizagem mecânica de conteúdos, na falta de integração entre componentes curriculares (Moreira, 2018).

O STEM ancorado numa abordagem CTS otimiza e enfatiza a reflexão crítica sobre as implicações sociais da ciência e da tecnologia em nossa sociedade como na Figura 1.

Fonte: Produção dos próprios autores. 2024.

Figura 1: Relação STEM e CTS

É preciso que as escolas de engenharia pensem em soluções sustentáveis, criativas e inovadoras, ao pressupor a integração de conhecimentos que possibilite ao estudante se preparar para desafios como cidadão crítico, colaborativo, produtivo para a vida e o mercado de trabalho, integrando diferentes áreas do conhecimento e resolutivo diante dos problemas diários, ultrapassando os modelos tradicionais de ensino e suas relações didático-pedagógicas.

Podemos dizer que do ponto de vista da educação, na relação engenharia e vida, serão necessárias outras concepções epistemológicas de ciência e tecnologia, romper com a perspectiva de

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

ensino instrumental, investimento na formação continuada em questões didático-pedagógicas e mobilizar os saberes docentes dos engenheiros a partir de formações de professores priorizadas por suas instituições (Bordin; Bazzo, 2017).

No STEM, o foco significativo de trabalho está na ressignificação da prática pedagógica do corpo docente, apoiando-se na mudança da apresentação baseada em palestras para a prática baseada em evidências, pela investigação (Stainset *al*., 2018).

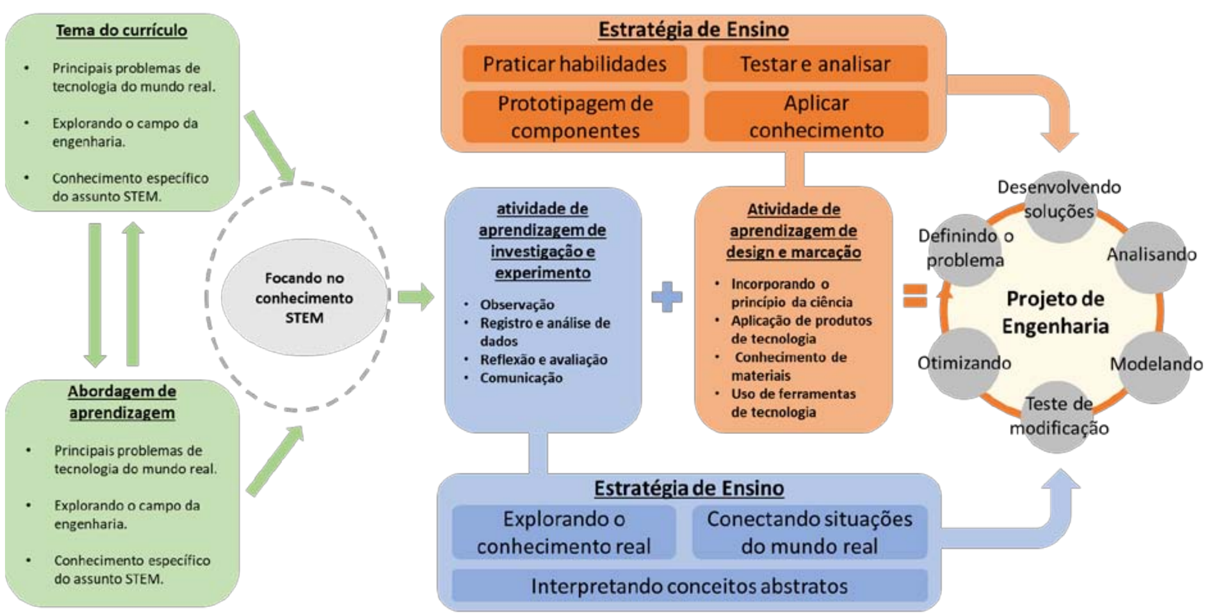
É importante ressaltar que estar que professores engenheiros que participam de processos formativos didático-pedagógicos, tem possibilidade de trabalhar melhor as atividades de aprendizagem, escolher seu material significativo, definir a melhor metodologia de ensino para sua realidade, redimensionar o papel da avaliação da aprendizagem, entre outros elementos conseguem articular sua atividade de ensino ao STEM articulado a CTS na engenharia (Rüütmann, 2023).

Moreira (2018, p.224) apresenta algumas estratégias de ensino para disciplinas de STEM, com a utilização de atividades práticas e experimentais, o uso de tecnologias educacionais, a integração de componentes curriculares STEM, a promoção da criatividade e do pensamento crítico, com participação em atividades contextualizadas com a vida cotidiana dos estudantes. Além disso, é importante que os professores tenham um profundo conhecimento do seu componente de ensino articulado com práticas pedagógicas inovadoras.

Corroborando neste sentido de práticas pedagógicas ressaltamos Tardif (2014), ao dizer que a pedagogia na sala de aula é feita de negociações, pois "ensinar é fazer escolhas constantemente, em plena interação com os alunos", (Tardif, 2014, p. 132). Logo no ensino de engenharia que abordagem STEM de enfoque CTS propiciam situações e respostas únicas para cada local e realidade trabalhada.

O ensino STEM na abordagem CTS, emergem condições basilares focada em pensamento crítico, questionamentos, problemas da vida real, contextualizado, de natureza multidisciplinar, interdisciplinar, envolvido com a inovação, resolução de problemas, trabalho colaborativo, desenvolvimento da capacidade de observação e comunicação. (Thibaut *et al.*, 2018).

Outro ponto relevante nesta discussão está voltado para o currículo, no STEM está geralmente centrado em projetos de engenharia, que pode ajudar a desenvolver o conhecimento dos estudantes por meio da aplicação prática do conteúdo (Fan; Yu e Lin, 2021). Os autores exploram as etapas importantes na aplicação do conhecimento de conteúdo ao processo da elaboração de um projeto de engenharia, propondo uma estrutura para implementar um currículo STEM focado tanto na engenharia, quanto no projeto, conforme figura 2.



Fonte: adaptado de Fan; Yu; Lin (2021, p. 1528).

Figura 2: Estrutura para implementar um currículo STEM focado em engenharia

No caso de um currículo STEM, geralmente as seguintes características são consideradas: um histórico do mundo real; conteúdo de integração e aplicação de ciência, tecnologia, engenharia e matemática; atividades baseadas em investigação, problema ou projeto; um ambiente que inspira os alunos a se tornarem aprendizes ativos; e cultivo de habilidades de pensamento de alto nível em estudantes (Bayer Corporation, 2010; Hudson, English e Dawes, 2014; Roehrig, Moore, Wang e Park, 2012 apud Fan *et al*, 2021, p.1525).

Fan *et al* (2021) também define as principais etapas utilizadas na aplicação do conhecimento STEM no processo de construção de um projeto de engenharia, tais como: identificar um problema ou necessidade; definir os requisitos do projeto; gerar soluções conceituais; avaliar e selecionar uma solução; desenvolver um modelo ou protótipo da solução selecionada assim como testar e avaliar a solução. Essas etapas são descritas como fundamentais para a implementação de um currículo STEM centrado em um projeto de engenharia.

IV. Considerações Finais

Hoje, quer na Amazônia como em todo o mundo, as questões ambientais, sociais e econômicas nos levam a refletir a formação técnica e humanista do papel do engenheiro na sociedade e o uso da tecnologia. Contribuindo com essa discussão, o STEM se apresenta como possiblidade, quando crítico e reflexivo, de pensar um ensino pautado em situações reais que levam o futuro profissional engenheiro a refletir as possíveis consequências de suas tomadas de decisões frente a sociedade, a natureza e ecossistema.

Diante deste cenário, este estudo apresenta os desafios enfrentados pelos cursos de Engenharia em relação ao STEM, apontando a falta de formação adequada dos professores para trabalhar com CTS e a dificuldade em integrar essa abordagem ao currículo. Além disso, foi apontada uma tendência em reduzir a abordagem CTS a um conjunto de técnicas ou atividades pontuais, sem considerar sua dimensão crítica e reflexiva.

Neste contexto, é de fundamental importância relacionar a educação STEM à CTS, pois esta interconexão pode ajudar os estudantes a entenderem como essas áreas estão interconectadas e como elas se aplicam no mundo real, o que é um dos objetivos da CTS.

É fundamental refletir que quem trabalha com a abordagem STEM no ensino de engenharia com enfoque CTS, reconheça o processo dialógico, sem receita pronta ou uma metodologia a ser seguida, mas aponta possiblidades de encontrar seus próprios caminhos para promover suas experiências.

Dessa forma, entendemos com este estudo que a abordagem integrada pode ajudar a desenvolver, quer em docentes e discentes, habilidades importantes, como resolução de problemas com um pensamento crítico e colaborativo, contribuindo para a formação de indivíduos comprometidos com o meio ambiente e com uma sociedade mais justa e humana. E o âmbito das Engenharias é sensível a está construção. Portanto, destacamos ser de fundamental importância que os cursos de Engenharia incluam essa abordagem em seus currículos e que os professores sejam capacitados para trabalhar com ela.

References Références Referencias

1. ARAUJO, M. T. M. de; SÁ, R. A. de. *Saber tecnológico:* a construção dos saberes docentes à luz da epistemologia da complexidade. Curitiba: Appris, 2021.
2. AZEVEDO, R. O. M. *et al*. O enfoque CTS na formação de professores de Ciências e a abordagem de questões sociocientíficas. *Encontro Nacional de Pesquisa em Educação em Ciências,* v. 9, p. 1-8, 2013.
3. BACICH, L.; MORAN, J. *Metodologias ativas para uma educação inovadora:* uma abordagem teórico-prática. Porto Alegre: Penso, 2018.
4. BAZZO, W. A. *Quase três décadas de CTS no Brasil!:* sobre avanços, desconfortos e provocações. Revista Brasileira de Ensino de Ciência e Tecnologia, v. 11, n. 2, p. 260-278, mai./ago., 2018.
5. BAZZO, W; PEREIRA, L. T. V; BAZZO, J. L. S. *Conversando sobre educação tecnológica.* Florianópolis: Ed. da UFSC, 2014.
6. BAZZO, W. A.; COSTA, L. A. C. da. A Revolução 4.0 e seus Impactos na Formação do Professor em Engenharia. *Revista de Ensino de Engenharia*, v. 38, n. 3, p. 28-39, 2019. DOI: 10.37702/REE2236-0158.v38n3p28-39.2019.
7. BORDIN, L.; BAZZO, W. A. Sobre as muitas variáveis – e incógnitas – que se articulam em torno da complexa e não linear relação entre Engenharia e Vida. *R. Tecnol. Soc.,* Curitiba, v. 13, n. 28, p. 224-239, mai./ago. 2017.
8. BRASIL. Superintendência da Zona Franca de Manaus. *Polo Industrial de Manaus.* 2017. Disponível em: https://www.gov.br/suframa/pt-br/assuntos/polo-industrial-de-manaus. Acesso em: 1 jul. 2024.
9. BRASIL. Conselho Nacional de Educação. *Resolução CNE/CES n.2/2019.* Disponível em: <http://portal.mec.gov.br/index.php?option=com_docman&view=download&alias=112681-rces002-19&category_slug=abril-2019-pdf&Itemid=30192>. Acesso em: 04 mai. 2023.
10. DURÃES, M. N. Educação Técnica e Educação Tecnológica Múltiplos Significados no Contexto da Educação Profissional. *Educação & Realidade,* Rio Grande do Sul, v. 34, n. 3, p. 159-175, 2009.
11. ELIAS, N. *O processo civilizador.* 2 vol, Rio de Janeiro, Jorge Zahar Editor, 1994.
12. FAN, S. C.; YU, K. C.; LIN, K.Y. *A Framework for Implementing an Engineering-Focused STEM Curriculum.* Int J of Sci and Math Educ 19, 1523–1541 (2021). Disponível em: https://doi.org/10.1007/s10763-020-10129-y. Acesso em: 13 mai. 2023.

13. GAMBOA, M. V. L.; GONZÁLEZ, C. ML. C.; SOTO, J. F. S. Educación STEM/STEAM: modelos de implementación, estrategias didácticas y ambientes de aprendizaje que potencianlas habilidades para elsiglo XXI. *Latin America Journal of Science Education,* v. 7, p. 1 15, 2020. Disponível em: http://www.lajse.org/may20/2020_12002.pdf. Acesso em 01 jul. de 2024.
14. GONÇALVES, K. M; AZEVEDO, R. O. M. *Discussões em torno do ensino tecnológico.* VII SETA – Simpósio em Ensino Tecnológico no Amazonas, 2021.
15. HARARI, Y. N. *21 Lições Para o Século 21.* São Paulo: Companhia das Letras, 2018.
16. HARDOIM, E. *Breve História da abordagem Stem, Steam.* [Programa de Pós-Graduação em Ensino de Ciências Naturais– IFMT]. Formação de Metodologia Ativas e abordagem STEAM. 08 de mai. 2021. Disponível em https://www.youtube.com/watch?v=Kg6FICFDXgQ. Acesso em 01 jul. 2024.
17. HAURADOU, G. R.; AMARAL, M. V. B. MINERAÇÃO NA AMAZÔNIA BRASILEIRA: aspectos da presença e avanço do capital na região. Revista de Políticas Públicas, v. 23, n. 1, p. 402–420, 25 Jul 2019 Disponível em: https://periodicoseletronicos.ufma.br/index.php/rppublica/article/view/11929. Acesso em: 9 jul 2024.
18. KELLEY, T.R., KNOWLES, J.G. *A conceptual framework for integrated STEM education.* IJ STEM Ed 3, 11 (2016). Disponível em: https://doi.org/10.1186/s40594-016-0046-z. Acesso em: 13 mai. 2023.
19. KENSKI, V. M.; MOREIRA, J. A. *Educação e tecnologias:* o novo ritmo da informação. Campinas, SP: Papirus, 2007.
20. KUTLU, E.; BAKIRCI, H.; KARA, Y. STEM Education Effect on Inquiry Perception and Engineering Knowledge. *Participatory Educational Research* (PER), v. 9, n. 3, p. 249-263, 1 maio 2022. Disponível em https://acikerisim.bartin.edu.tr/bitstream/handle/11772/11104/10.17275-per.22.64.9.3-1757419.pdf?sequence=1&isAllowed=y Acesso em 30 jun. de 2024.
21. MOREIRA, M. A. O ensino de STEM (Ciência, Tecnologia, Engenharia e Matemática) no século XXI. *Revista Brasileira de Ensino de Ciências e Tecnologia,* Ponta Grossa, v. 11, n. 2, p. 224-233, mai./ago. 2018.
22. PEÑA, M. D. J.; ALVES, M. R.; PEPPE, M. A. Educação, tecnologia e humanização. *Cad. de Pós-Graduação em Educ., Arte e Hist. da Cult.* São Paulo, v.3, n.1, p. 9-19, 2003.
23. PUGLIESE, G. O. *STEM education no contexto das reformas educacionais:* os efeitos das políticas de educação globalizantes no currículo e na profissionalização docente. 2021. Tese (Doutorado em Educação Científica Matemática e Tecnológica) - Faculdade de Educação, Universidade de São Paulo, São Paulo, 2021. doi:10.11606/T.48.2022.tde-17032022-110235. Acesso em: 01 jul. 2024.
24. PUGLIESE, G. O. Um panorama do STEAM education como tendência global. In: BACICH, L.; HOLANDA, L. (org.). *STEAM em sala de aula:* a aprendizagem baseada em projetos integrando conhecimentos na educação básica. Porto Alegre: Penso, 2020.
25. PUGLIESE, G. O. STEM education – um panorama e sua relação com a educação brasileira. *Currículo sem Fronteiras,* v. 20, n. 1, p. 209–232, 1 abr. 2020b. https://doi.org/10.35786/1645-1384.v20.n1.12. Acesso em 01 jul. de 2024.
26. RÜÜTMANN, T. Engineering Pedagogy and Engineering Educators' Competency Model for Effective Teaching and Learning STEAM. *Problems of Education in the 21st Century*, v. 81, n. 4, 2023. DOI 10.33225/pec/23.81.531.
27. STAINS M.; H. *et al*. *Anatomy of STEM teaching in North American universities.* Science. Epub 2018 Mar 29.
28. TARDIF, M. *Saberes docentes e formação profissional.* 17. ed. Petrópolis, RJ: Vozes, 2014.
29. TEKIN, Ö. G.; ŞAN, İ. Teachers' basic knowledge level of STEM education. *African Educational Research Journal,* v. 11, n. 4, p. 580-587, out. 2023. DOI: 10.30918/AERJ.114.23.092. Disponível em https://files.eric.ed.gov/fulltext/EJ1412612.pdf Acesso em 01 jul. de 2024.
30. THIBAUT, L., CEUPPENS, S., LOOF, H. D., MEESTER, J. D., GOOWAERTS, L., Struyf, A. Depaepe, F. (2018). Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education. European Journal of STEM Education, 3(1), 02, 2-12. http://doi.org/10.20897/ejsteme/85525
31. VÁSQUEZ, F. G.; PAIVA, N. S.; SOUZA, K. C. S. *Academia STEM/UEA:* Uma análise preliminar sobre o sucesso acadêmico dos estudantes dos cursos de engenharia da Universidade do Estado do Amazonas - UEA. In: 50º Congresso Brasileiro De Educação Em Engenharia, 6., 2022, Evento Online. Anais - Artigo. Disponível em: http://www.abenge.org.br/sis_artigo_doi.php?e=COBENGE&a=22&c=4041. Acesso em: 12 mai. 2023.
32. WILLERDING, A. L. *et al*. Estratégias para o desenvolvimento da bioeconomia no estado do Amazonas. *Estudos Avançados,* v. 34, n. 98, p. 145–166, jan. 2020.

Global Journal of Researches in Engineering: I
Numerical Methods
Volume 24 Issue 1 Version 1.0 Year 2024
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Application of Differentialintegral Functions

By Alexey S. Dorokhov, Solomashkin Alexey Alekseevich, Vyacheslav A. Denisov & Kataev Yuri Vladimirovich

Summary- The article is devoted to the development and implementation of new mathematical functions, differentialintegral functions that provide differentiation and integration operations not only according to existing algorithms described in textbooks on higher mathematics, but also by substituting a certain parameter k into formulas developed in advance, forming the necessary derivatives and integrals from these formulas.

The Purpose of the Research: The expansion of the concept of number, in particular, in classical mechanics, physics, optics and other sciences, including biological and economic, which makes it possible to expand some understanding of the essence of space, time and their derivatives.

Materials and Methods: The idea of fractional space, time and its application is given. The usual elementary functions and the Laplace transform were chosen as the object of research. New functions, differentialintegral functions, have been developed for them. A graphical representation of these functions is given, based on the example of the calculation of the sine wave. Examples of calculating these functions for elementary functions are given.

Keywords: differentialintegral functions, derivative, fractional derivative, integral, fractional integral.

GJRE-I Classification: ACM: (G.1), (G.2), (G.4), (F.1)

APPLICATIONOFDIFFERENTIALINTEGRALFUNCTIONS

Strictly as per the compliance and regulations of:

Application of Differentialintegral Functions

Alexey S. Dorokhov [α], Solomashkin Alexey Alekseevich [σ], Vyacheslav A. Denisov [ρ] & Kataev Yuri Vladimirovich [ω]

Summary- The article is devoted to the development and implementation of new mathematical functions, differentialintegral functions that provide differentiation and integration operations not only according to existing algorithms described in textbooks on higher mathematics, but also by substituting a certain parameter k into formulas developed in advance, forming the necessary derivatives and integrals from these formulas.

The Purpose of the Research: The expansion of the concept of number, in particular, in classical mechanics, physics, optics and other sciences, including biological and economic, which makes it possible to expand some understanding of the essence of space, time and their derivatives.

Materials and Methods: The idea of fractional space, time and its application is given. The usual elementary functions and the Laplace transform were chosen as the object of research. New functions, differentialintegral functions, have been developed for them. A graphical representation of these functions is given, based on the example of the calculation of the sine wave. Examples of calculating these functions for elementary functions are given. Of particular interest is the differentialintegral function, in which the parameter k is a complex number s, s = a + i · b, although in general, the parameter k can be any function of a real or complex argument, as well as the differentialintegral function itself.

Research Results: As a result of the research, it is shown how the Laplace transform and Borel's theorem are used to calculate differentialintegral functions. It is shown how to use these functions to carry out differentiation and integration. It is presented how fractional derivatives and fractional integrals should be obtained. Dependencies for their calculation are obtained. Examples of their application for such functions as cos(x), exp(x) and loudness curves in music, Fletcher-Manson or Robinson-Dadson curves are shown.

Conclusions: Studies show the possibility of a wide application of differentialintegration functions in modern scientific research. These functions can be used both in office and in specialized programs where calculations of fractional derivatives and fractional integrals are needed.

Keywords: *differentialintegral functions, derivative, fractional derivative, integral, fractional integral.*

I. Introduction

In modern sciences, such as mathematics, physics, astronomy, economics and other sciences, there is little use of differential functions in calculations, because with the help of fractional derivatives and integrals, very few physical, natural, social and other processes are described that use not only the first and second derivatives, single and double integrals, but fractional derivatives and fractional integrals. So in classical mechanics, the first derivative is used as velocity, the second as acceleration, and the third as a jerk. A one-time integral is used to calculate the area under the curve, the mass of an inhomogeneous body, a two–time integral is used to calculate the volume of a cylindrical beam, a three-time integral is used to calculate the volume of the body.

They can be found in the equations of mathematical physics, where, in particular, generalized functions and convolutional operations on them are used, and in spectral analysis, and in operational calculus based on integral Fourier and Laplace transformations, and in many other methods where differentiation and integration of functions are used.

The basis of all these concepts is the derivative and integral[1]. Two mathematical operations that are "opposite" to each other, like addition and subtraction, multiplication and division. Two "reciprocal" functions like *sin(x)* and *arcsin(x)*, x^2 and $\sqrt{x}$, e^x and *ln(x).* Two mathematical operations that logically complement each other, the derivative of the integral does not change the integrable function, as does the integral of the derivative, leaves it unchanged.

Let us recall the symbols on graphs and in computer programs. Like any mathematical operation, they have their symbols (designations) on a piece of paper, like ordinary symbols on a computer screen. So, differentiation is denoted as *y'* or *d/dx*, and integration is $\int y(x)dx$. In this case, a one – time integral is denoted as $\int y(x)dx$, and a two - time integral is $\iint y(x)z(t)dxdt$. With the derivative, the situation is more complicated, it has two designations:

Author α: Chief Researcher, Doctor of Technical Sciences, Professor. e-mail: dorokhov.vim@yandex.ru
Author σ: Leading Specialist. e-mail: littor2013@gmail.com
Author ρ: Chief Researcher, Doctor of Technical Sciences. e-mail: va.denisov@mail.ru
Author ω: Leading Researcher, Candidate of Technical Sciences. e-mail: ykataev@rgau-msha.ru

[1] And also, definitions of derivatives/integrals based on such concepts as the Riemann-Liouville, Grunwald-Letnikov and Weyl differentialintegrals.

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

y' and *d/dx*. Figure 1 shows (as one of the options) the currently existing designations of differentials and integrals, widely used in the literature.

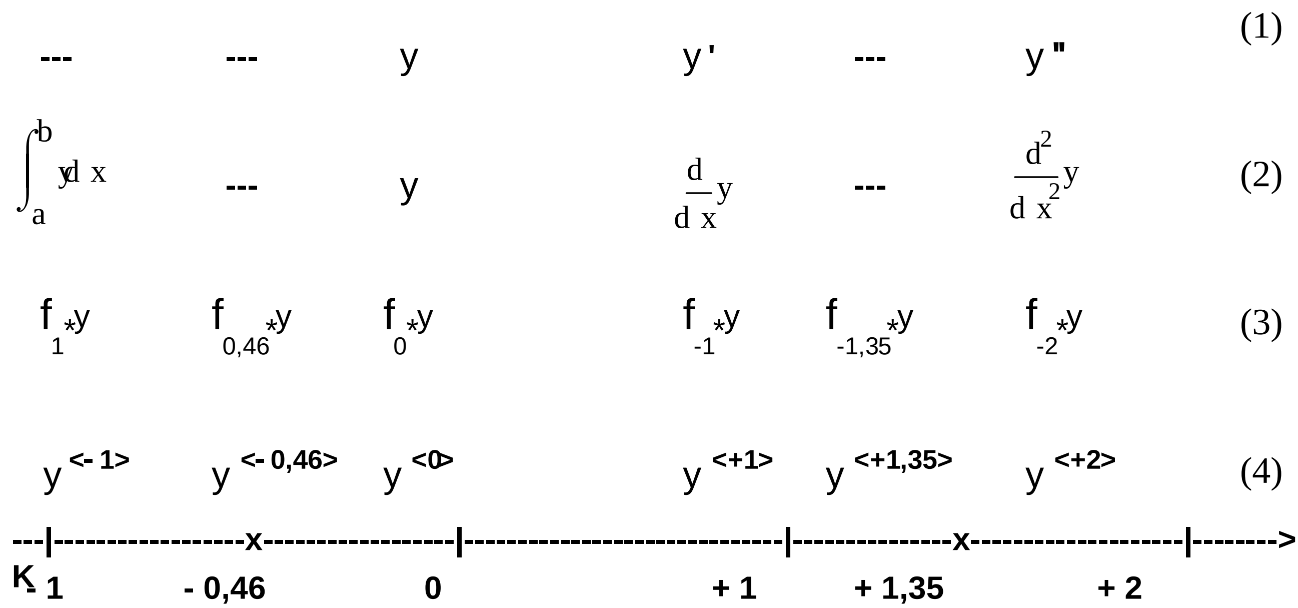


Figure 1: Notation of integrals and derivatives

As can be seen from Figure 1, all the variety of these notations has one property common to all: they try to reflect in various ways, either with the help of numbers or graphically, the order of derivatives or the multiplicity of the integral.

In order to unify the record of derivatives and integrals, consider them relative to a certain numerical axis "*K*" (Figure 2), where the value of the parameter *k* corresponds to the multiplicity of the integral or the order of the derivative. So, in this scenario of notation, $k = -1$ corresponds to the designation of a single integral $\int y(x)dx$ from the 2nd line and the designation of the same integral $f_1 * y$ from the 3rd row, and for $k = 1$- we have the designation of the first derivative y' from the 1st row and the designation of the same first derivative *d /dx* from the 2nd row.

The third line contains the notation of differentials and integrals based on convolutional operations of generalized functions: $y^{(k)} = f_{-k} * y$, where $k > 0$, a value unequal to an integer is called a fractional derivative of order *k*. An expression of the form: $y_{(k)} = f_k * y$ is called a primitive of order *k*, i.e. an integral of multiplicity *k* [1].

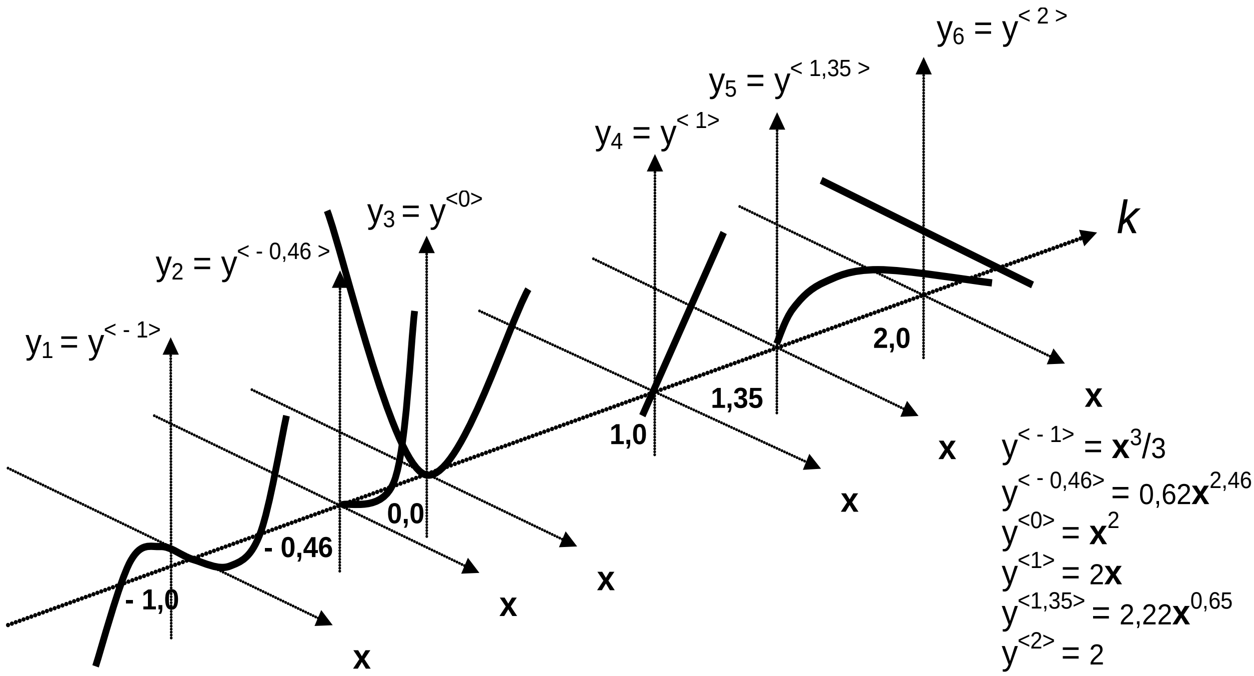


Figure 2: Notation of derivatives and integrals for a parabola$y(x) = x^2$

At the same time, all derivatives, including fractional ones, having a negative index, are located on the numerical axis on the right, and all integrals with a positive index - on the contrary, on the left. It was possible to arrange the designations differently, change the plus to minus, but the essence would not change at the same time. There are many types of symbols, binding to the numeric axis requires clarification.

To bring these notations in line with the numerical axis "*K*", the 4th line contains universal notations for derivatives of any order and integrals of any multiplicity, using angle brackets.

The angle brackets denote the order of the derivative or the multiplicity of the integral, for example, $y^{<0>} = y(x)$ is the function under study, and $y^{<-1>} = \int y(x)dx$ is its integral, multiplicity 1. So $y^{<2>} = d^2/dx^2 = y''$ is the second derivative, and $y^{<-0,46>}$ is the integral, multiplicity *0,46*. For example, a certain derivative of the order of 1,35 is denoted as $y^{<1,35>}$. In other words, if there is a positive number in the angle brackets, it means it is some kind of derivative, and if it is negative, it means it is an integral. And it is easy to read, and it is located correctly on the numeric axis: negative values of the *k* index are on the left, and positive values are on the right. This form of writing integrals and derivatives is very convenient, for example, for their designation on graphs or diagrams.

Figure 2 shows an example of the notation of derivatives and integrals for the parabola $y(x) = x^2$.

In addition to notation on graphs, this method can be used for programmers writing programs in various programming languages, for example,

```
...
int main () {
float y, u, z;
int n3;
...
z= y (4) <1.5>;
u=n3 <-0,25>;
…
```

where $y^{<1,5>}$ is the derivative of the function *y(4)* of order *1,5* and $n3^{<-0.25>}$ is the integral of multiplicity *0,25* of the function *n3*.

In Figure 2, the integral of multiplicity *–0,46* and the derivative of the order of *1,35* are shown for $x > 0$.

It should be borne in mind that when calculating a derivative of a "high" order, say, *123* orders – $y^{<123>}$, previously it was necessary to perform *122* differentiation operations beforehand. This is due to the fact that the definition of the derivative/integral implies an increase in the order of the derivative/integral by only 1. It is impossible, using the existing definition of the derivative, to immediately calculate a high-order derivative from it. Only with the

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

help of sequential multiple calculations can the order of the derivative be increased to the desired value. The same applies to integration.

II. Materials and Methods

This method of calculating derivatives reduces the efficiency of using the differentiation operation, for example, in series expansions, because it requires calculating derivatives of a "high" order, and this is time-consuming and involves calculation errors. Therefore, in such calculations, only the first few terms of the decomposition are taken, and the rest are discarded, which increases the calculation error.

As for calculating integrals, especially multiplicities greater than *2*, this is an even more difficult task. Thus, the lack of a simple, reliable and accurate method of differentiation and/or integration significantly hinders computational progress in mathematics.

The same problem is observed in physics. Many laws of mathematical physics, most often appearing in simple, accessible calculations, are based on the use, mainly, of the 1st, maximum 2nd derivative (for example, current $i = dq / dt$, force $F = m \cdot d^2x / dt^2$) and a single integral, for example, voltage across the capacitor $u(t) = 1 / C \cdot \int i(t)dt$.

It is very rare in everyday physics or mathematics to find a 3rd derivative or a 3-fold integral. This does not happen often. One of the ways to use a 3-fold integral is the Ostrogradsky-Gauss integral to calculate the volume of a body if the surface bounding this body is known.

And if you look more broadly, then neither in physics nor in mathematics have the everyday laws of the universe using fractional derivatives and integrals been discovered so far, because their calculation is fraught with great difficulties [1]. At the same time, it is possible that all the diversity of the world exists exactly there, in a fractional dimension, which can be described and studied, precisely with the help of fractional (analog), and not integer (discrete) integrals and differentials.

Take, for example, the mechanism of describing multidimensional structures, for example, multidimensional space. Our 3-dimensional space and one-dimensional time are described by discrete (integer) coordinate values, in this case one and three. At the same time, the question of the existence of a space having, not 3, but, say, 2,345 coordinates is of great scientific and practical interest. In other words, the structure of a special "fractional" space, no longer two-dimensional, is a plane (because to describe the plane, you need 2 coordinates, and we have more – 2,345), but also not a three-dimensional volume (where 3 coordinates are needed), i.e. something average between the plane and the volume. It is very difficult to imagine such a structure. In nature, such a space does not seem to exist.

It is even more difficult to determine the velocity or acceleration in such a space, i.e. to describe the kinematics of the motion of bodies. If it is possible to define the force in such a space (or to use the already existing classical method of specifying forces), then we can count on success in creating the dynamics of such structures, i.e., in other words, to create the mechanics of multidimensional space. At the same time, our classical 3-dimensional mechanics will turn out to be a special case of a more general mechanics – the mechanics of multidimensional spaces. This can be said about other physical laws of the universe.

And whether our idea of the world will change with the emergence of a new, more general, idea of space. So far we don't know much about this, because our concepts are tied to a three-dimensional dimensional space, and all the diversity of the world "lies" in a multidimensional "fractional" world that has not been studied at all.

A number of legitimate questions arise:

- What kind of space is "located", say, between a plane (2-dimensional space) and a volume (3-dimensional), i.e. a substance with the dimension of space *R*, where $2<R<3$?
- What kind of physical quantity, which is between speed and acceleration between $y^{<1>}$ and $y^{<2>}$ from the move, i.e. a physical quantity, defined, for example, the fractional derivative of $y^{<1,23>}$, the order of *1,23* (not 1 or 2)?
- Whether Newton's laws are applicable to the so-called fractional space?
- How will the definition of force in fractional space change (if it changes)?
- Will it be possible to apply the classical laws of mechanics to fractional space, or will it be necessary to create a new, more general, mechanics of the macro and microcosm?
- Will the interaction between space and time change if we "replace" the classical concept of space with a fractional one?
- Will there be changes in Einstein's theory of relativity and will the concepts of "gravitational, electromagnetic and other interactions" and much, much more remain the same?

Answers to these and other questions can be obtained if you have a convenient apparatus for calculating derivatives/integrals of any order/multiplicity, including fractional ones. In other words, it is necessary to create such a calculation algorithm, simple and convenient, especially for novice researchers, where instead of calculating integrals/differentials, it would be possible to use the usual substitution of numbers, in which the desired order or multiplicity could be set without performing calculations, but simply substitute the desired parameter into the desired formula and get a ready derivative/integral without their calculations, i.e. immediately. Such a tool, which could be called, for example, functions - *SL(x, k)*, would greatly simplify the process of calculating derivatives and integrals and significantly expand the boundaries of our knowledge.

First, we introduce the concepts of a differential integral function based on the definition of a differential integral. The differential integral function *SL (x, k)* is an ordinary function of several arguments, where, separated by commas, its arguments (in this case one – *x*) and the parameter *k*, the order of future derivatives and/or the multiplicity of integrals are indicated[2].

For example, for a parabola $y(x) = x^2$, such a differentialintegral function *SL(x, k)* will have the form[3].

$$SL(x,k) := 2 \cdot \frac{x^{2-k}}{\Gamma(3-k)} \tag{1}$$

where, *x* is the argument of the function,
k is a parameter that specifies the order of the derivative or the multiplicity of the integral.

This is the differential integral function of a parabola, the usual function of 2 arguments, argument *x* and parameter *k*. It represents a whole set of integrals and derivatives of any order and multiplicity[4] (the main, mother function). How to use it? You need to set the parameter *k* and get the desired derivative or integral.

For example, for a parabola, we substitute $k = 0$ into it. Then, for $k = 0 y(x, k) = x^2$, $(\Gamma(3 - k) = 2)$[5] the function (parabola) does not change. When $k = 1 y(x, k) = 2x$ and the parabola is transformed into its 1st derivative - $y^{<1>}$. When $k = -1$ $y(x, k) = x^3/3$ and the function becomes its one-time integral $-y^{<-1>}$, and for $k = -2$ $y(x, k) = x^4/12$ - double - $y^{<-2>}$. No calculations, just substitution.

Fractional derivatives and integrals are of particular interest, because there is no simple and reliable way to calculate them, except for the method indicated above [2]. In this case, the method of obtaining is the same. To calculate them, it is enough to substitute the necessary value of the derivative instead of the parameter k, for example, k = 0.123 and the parabola becomes its derivative of the order 0.123 – $y^{<0.123>}$:

$$SL(x,k) := 2 \cdot \frac{x^{2-0,123}}{\Gamma(3-0,123)}\ float, 3\ \rightarrow 1,12 \tag{2}$$

If it is necessary to obtain an integral of multiplicity *3,45* - $y^{<-3,45>}$, it is enough to substitute $k = -3,45$ into the differential function (1) and the parabola becomes its integral of multiplicity *3,45* - $y^{<-3,45>}$:

$$SL(x,k) := 2 \cdot \frac{x^{2+3,45}}{\Gamma(3+3,45)}\ float, 3\ \rightarrow 7,6060^{-3} x^{5,4} \tag{3}$$

This method of calculating fractional derivatives is no different from the method of obtaining integer (discrete) derivatives – the same substitution. There is no difference between an integer or fractional derivative/integral. Simple substitution to get a given result.

Consider another example: $y(x)=\sin(x)$. For a sine wave, the differentialintegral function *SL(x,k)* will have the following form:

$$SL(x,k) := \sin\left(x + k \cdot \frac{\pi}{2}\right) \tag{4}$$

This is a sine wave whose phase shift depends on the order of its derivative/multiplicity of its integral. At $k = 0$, the sine wave does not change, at $k = 1$, and becomes *cos(x)*, i.e. its the first derivative is $y^{<1>}$, and at $k = -1$ it becomes *-cos(x)*, i.e. its integral is $y^{<-1>}$. At $-1<k<1$, the function occupies an intermediate position between *-cos(x)* and *cos(x),* including *sin(x)* at $k = 0$.

The differential integral function for the sine wave (4) is a graphical representation of the differential integral function, namely, the parameter *k* represents a part of the right angle for unit orts. At $k = 1$, the function *SL(x,1)* becomes the 1st derivative, such a unit ort is perpendicular to the abscissa axis, and at $k = var$ it is a fractional derivative of *k* order and the angle *k* (in values from 0 to 1 or in % of 90 degrees) it is only a part of the right angle.

For the exponent $y(x) = e^x$, the differential integral function *SL(x, k)* does not depend on *k* and all its derivatives and integrals are equal to each other and equal to the exponent itself.

---

[2] Here *SL(x, k)* is another form of writing a power differential function, different from writing the form$y^{<k>}$.
[3] Here and further calculations are performed in the MathCad program, so it uses a dot in its formulas instead of a comma.
[4] As the latter, there may be the differentialintegral functions themselves. In this case, the parameter k can also be a complex value.
[5] G(x) - gamma function.

These examples can be summarized in Table 1, where its derivatives and integrals are given for some elementary functions.

Table 1: Examples of calculation of derivatives and integrals

$y^{<-1>}$	$y^{<-0.5>}$	$y^{<0>}$	$y^{<0.5>}$	$y^{<1.5>}$	*SL (x, k)*
$\frac{\Gamma(n+1)\,x^{n+1}}{\Gamma(n+2)}$	$\frac{\Gamma(n+1)\,x^{n+0,5}}{\Gamma(n+1,5)}$	x^n	$\frac{\Gamma(n+1)\,x^{n-0,5}}{\Gamma(n+0,5)}$	$\frac{\Gamma(n+1)\,x^{n-1,5}}{\Gamma(n-0,5)}$	$\frac{\Gamma(n+1)\,x^{n-k}}{\Gamma(n+1-k)}$
$x^3/3$	$0{,}601x^{2.5}$	x^2	$1{,}504x^{1.5}$	$2{,}256x^{0.5}$	$\frac{2\,x^{2-k}}{\Gamma(3-k)}$
e^x	e^x	e^x	e^x	e^x	e^x
$\sin(x-\pi/2)$	$\sin(x-0{,}5\cdot\pi/2)$	$\sin(x)$	$\sin(x+0{,}5\cdot\pi/2)$	$\sin(x+1{,}5\cdot\pi/2)$	$\sin(x+k\cdot\pi/2)$

Differential functions can be a function of 2 or more arguments, for example, *SL (x, y, k),* where *(x)* and *(y)* are two arguments of the same function: $SL(x, y, k_x, k_y) = 2 \cdot k_y + (x - y) \cdot k_x$, and k_x and k_y- are still a parameter. In addition, any continuous elementary function can be used as a parameter, including the same differential integral function, for example:

$$(x, y, k1, k2) := x^{\sin\left(y\cdot k1+\frac{\pi}{2}k2\right)} \tag{5}$$

Of particular interest is the differential integral function, in which the parameter *k* is a complex number *s*, $s = a + i \cdot b$, although in general, the parameter *k* can be any function of a real or complex argument.

III. Research Results

To obtain the differential integral function, we recall the Laplace integral transformation and Borel's theorem.

The integral Laplace transform has the form

$$L[f(t)] = F(s) = \int_0^\infty f(t)e^{-st}\,dt \equiv [f(t)\cdot e^{-st}\,dt]^{<-1>}{}_{0<t<\infty} \tag{6}$$

where $s = a + i * b$ is a complex quantity. Here *f (t)* is the original function, and *F(s)* is its Laplace image. This is a direct conversion of the original into an image. The inverse Laplace transform

$$f(t) := \frac{1}{2\pi i}\cdot\int_{\sigma-i\cdot\infty}^{\sigma+i\cdot\infty} e^{st}F(s)ds \ \equiv [e^{st}\cdot F(s)\cdot ds]^{<-1>}{}_{\sigma-i\infty<\sigma+i\infty} \tag{7}$$

it is necessary to find the original of the function by its image.

Let's consider one of the main properties of this transformation – the differentiation of the original function.

Let $L[f(t)] = F(s)$. Let's find $L[f(t)^{<1>}]$, where $f(t)^{<1>}$- is the 1st derivative, and $L[f(t)^{<1>}]$- is its image.

$$L[f(t)^{<1>}] = [f(t)^{<1>}\cdot e^{-st}dt]^{<-1>}{}_{0<t<\infty} = e^{-st}\cdot f(t)_{0<t<\infty} + s\cdot[f(t)\cdot e^{st}dt]^{<-1>}{}_{0<t<\infty} \tag{8}$$

If for $t\to\infty$ the function *f (t)* increases no faster than $M * e^{at}$, then
$e^{-st} * f(t) \to 0$ for $t\to\infty$ and is equal to *f (0)*, and

$$L[f(t)^{<1>}] = s * F(s) - f(0) \tag{9}$$

For $f(0) = 0$

$$L[f(t)^{<1>}] = s * F(s) \tag{10}$$

and the differentiation of the original function corresponds to the multiplication of the image of the function by *s.* Let's consider another important property – the integration of the original.

If $g(t) = [f(\tau)d\tau]^{<-1>}{}_{0<\tau<t}$, then under zero initial conditions $g(t)^{<1>} = f(t)$ and

$$L[g(t)^{<1>}] = L[f(t)] = s * L[g(t)] = s * L[[f(\tau)\,d\tau]^{<-1>}{}_{0<\tau<t}] \tag{11}$$

Since $L[f(t)] = F(s)$, then

$$L[[f(\tau)^*\,d\tau]^{<-1>}{}_{0<\tau<t}] = F(s)/s \tag{12}$$

that is, the integration of the function corresponds to the division of the image *F (s)* by *s*.

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

Taking into account expressions (14) and (16), we can conclude that the operations of differentiation/integration of the original can be replaced by algebraic actions (multiplication/division by s) on their images [3]. Thanks to this replacement, this method has found the widest application in integral and differential calculus [4].

However, the case is of particular interest when the function is represented as

$$L\ [f\ (t)] = F(s)/(s^{-k}) \tag{13}$$

that is, the image is divided by *(s-k).* In this case, depending on *k*, we get fractional derivatives/integrals. For *k> 0*, fractional derivatives of the order *k* are formed, and for *k <0*, fractional integrals of the same multiplicity are formed.

$$L[f(t)] = \frac{\text{F}(s)}{s^{-k}} = 1/(\Gamma(-k)) \tag{14}$$

$$SL\ (x,\ k) = L\ [f\ (t)] \tag{15}$$

These expressions (18) and (19) define fractional derivatives/integrals of order *k*, and are the differential functions of the desired function *f(t).* Examples of these functions are shown in Table 1.

Let's consider some examples of the use of differential integral functions in solving approximation problems. Suppose must be approximated by a power series ***ряд***_*cos(x)* in a neighborhood of the point *x0,* the function *cos(x),* and choose the polynomial coefficients $a_0...a_5$ so as to minimize the mean square error of approximation of this polynomial are:

$$\_cos(x) = a_0 + a_1{\cdot}x + a_2{\cdot}x^2 + a_3{\cdot}x^3 + a_4{\cdot}x^4 + a_5{\cdot}x^5 \tag{16}$$

and at the selected point is known for its derivatives and differentials, as an integer and the fraction.

To do this, we fulfill the approximation conditions according to which the value of the polynomial _*cos(x)* and its fractional derivatives (for simplicity of calculation, only six (5) derivatives are used[6]. To increase the accuracy, you can use more, for example, several dozen derivatives, the computer allows it. Instead of derivatives, its integrals can also be used in the same way) in the vicinity of a given point x0, from the domain of the polynomial definition, should equal the corresponding values of the desired function *cos(x)* and its fractional derivatives (and integrals). 2 points are selected as points – *x = 3* and *x = 15*.

The fractional derivatives/integrals for the elements of the polynomial are defined as

$$SL(x, n, k) := \frac{\Gamma(n+1)\cdot x^{n-k}}{\Gamma(n+1-k)} \tag{17}$$

where *x* -is the matrix of diagnostic information;
n - is the exponent of the polynomial;
k- is a parameter that sets the multiplicity of the integral or the order of derivatives.

Further, solving a linear algebraic equation of the form:

$$a = A1^{-1}\cdot B1 \tag{18}$$

we obtain the solution of this equation in the form of the desired coefficients $a_0...a_5$ (Application A Figure A.1).

The solution was made in the MathCad program, the calculation listing is given for the point *x = 3* and additionally for *x = 15.*

Another example. In addition to the approximation at a point, using the differential integral functions, it is possible to approximate on a given segment. Examples of this approximation are given below.

Let it be necessary to approximate, for simplicity, the known functions cos (x) and the exponent *exp(x)*, as well as *cos(x)* on the plot *4 <x <6*, as well as volume curves, according to the type of Fleicher-Manson or Robinson-Dadson curves. For ease of calculation, we approximate 6 points for 2 *cos (x)* functions, 4 (four) points for the exponent *exp(x)* and 23 for volume curves.

For a sine wave, the desired points will be of two types. In the first case, these are the points -5, -4, -2, 1, 3, 5. In the second case, this is -5, -3, -1, 1, 3, 5.

We will approximate the sinusoid with a polynomial (17).

Exponent – exponent.

[6] To approximate in this case, it is to decompose into a power series using differential integral functions in the vicinity of the point x_0, bearing in mind that these points are the values of the function *f (x) = cos (x).*

For the first case, for points -5, -4, -2, 1, 3, 5 the initial data obtained by formula (17) will have the following form.

$$A2 := \begin{pmatrix} 1 & -5 & 25 & -125 & 625 & -3125 \\ 1 & -4 & 16 & -64 & 256 & -1024 \\ 1 & -2 & 4 & -8 & 16 & -32 \\ 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 3 & 9 & 27 & 81 & 243 \\ 1 & 5 & 25 & 125 & 625 & 3125 \end{pmatrix} \quad B2 := \begin{pmatrix} \cos(-5) \\ \cos(-4) \\ \cos(-2) \\ \cos(1) \\ \cos(3) \\ \cos(5) \end{pmatrix} \quad b2 := A2^{-1} \cdot B2 \quad b2 = \begin{pmatrix} 0.615 \\ 0.207 \\ -0.257 \\ -0.036 \\ 9.731 \times 10^{-3} \\ 1.117 \times 10^{-3} \end{pmatrix}$$

As a result of calculating the series *rjad_cos (x),* we get the values of *cos (x).*

$$rjad\_1\_\cos(x) := b2_0 + b2_1 + b2_2 \cdot x^2 + b2_3 \cdot x^3 + b2_4 \cdot x^4 + b2_5 \cdot x^5 \qquad (19)$$

The graphs of these two functions *cos (x)* and *rjad_1_cos(x)* and some values of these graphs are shown in Figure 3.

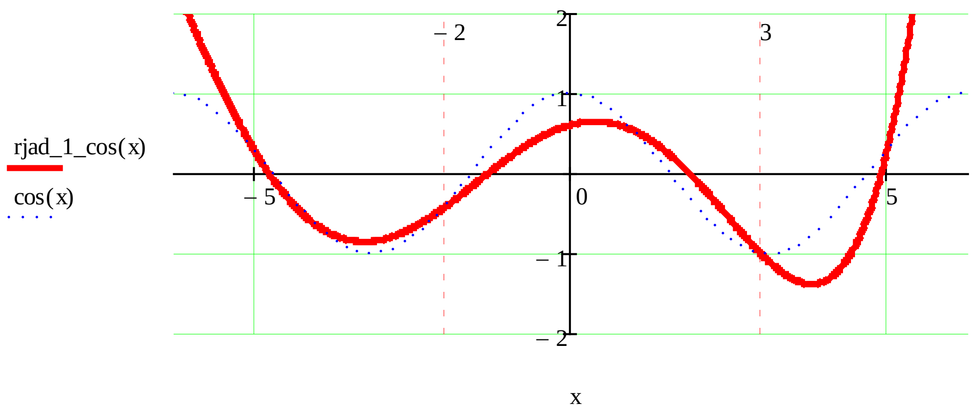


Figure 3: Values of the functions-*rjad_1_cos (x)* and *cos (x)*

$rjad\_1\_\cos(-5) = 0.284$
$\cos(-5) = 0.284$

$rjad\_1\_\cos(-4) = -0.654$
$\cos(-4) = -0.284$

$rjad\_1\_\cos(-2) = -0.416$
$\cos(-2) = -0.416$

$rjad\_1\_\cos(-1) = 0.54$
$\cos(-1) = 0.54$

$rjad\_1\_\cos(3) = -0.99$
$\cos(3) = -0.99$

$rjad\_1\_\cos(5) = 0.284$
$\cos(5) = 0.284$

For another cosine, for the values -5, -3, -1, 1, 3, 5 the initial data obtained by the formula (17) will have the following form:

$$A3 := \begin{pmatrix} SL(\_x_0,\_n_0,0) & SL(\_x_0,\_n_1,0) & SL(\_x_0,\_n_2,0) & SL(\_x_0,\_n_3,0) & SL(\_x_0,\_n_4,0) & SL(\_x_0,\_n_5,0) \\ SL(\_x_1,\_n_0,0) & SL(\_x_1,\_n_1,0) & SL(\_x_1,\_n_2,0) & SL(\_x_1,\_n_3,0) & SL(\_x_1,\_n_4,0) & SL(\_x_1,\_n_5,0) \\ SL(\_x_2,\_n_0,0) & SL(\_x_2,\_n_1,0) & SL(\_x_2,\_n_2,0) & SL(\_x_2,\_n_3,0) & SL(\_x_2,\_n_4,0) & SL(\_x_2,\_n_5,0) \\ SL(\_x_3,\_n_0,0) & SL(\_x_3,\_n_1,0) & SL(\_x_3,\_n_2,0) & SL(\_x_3,\_n_3,0) & SL(\_x_3,\_n_4,0) & SL(\_x_3,\_n_5,0) \\ SL(\_x_4,\_n_0,0) & SL(\_x_4,\_n_1,0) & SL(\_x_4,\_n_2,0) & SL(\_x_4,\_n_3,0) & SL(\_x_4,\_n_4,0) & SL(\_x_4,\_n_5,0) \\ SL(\_x_5,\_n_0,0) & SL(\_x_5,\_n_1,0) & SL(\_x_5,\_n_2,0) & SL(\_x_5,\_n_3,0) & SL(\_x_5,\_n_4,0) & SL(\_x_5,\_n_5,0) \end{pmatrix}$$

$$B3 := \begin{pmatrix} \cos(-5) \\ \cos(-3) \\ \cos(-1) \\ \cos(1) \\ \cos(3) \\ \cos(5) \end{pmatrix} \quad \_x := \begin{pmatrix} -5 \\ -3 \\ -1 \\ 1 \\ 3 \\ 5 \end{pmatrix} \quad d := A3^{-1} \cdot B3$$

$$rjad\_2\_\cos(x) := d_0 + d_1 x + d_2 x^2 + d_3 x^3 + d_4 x^4 + d_5 x^5 \tag{20}$$

The graphs of these two functions *cos (x)* and *rjad_2_cos(x)* and some values of these graphs are shown in Figure 4.

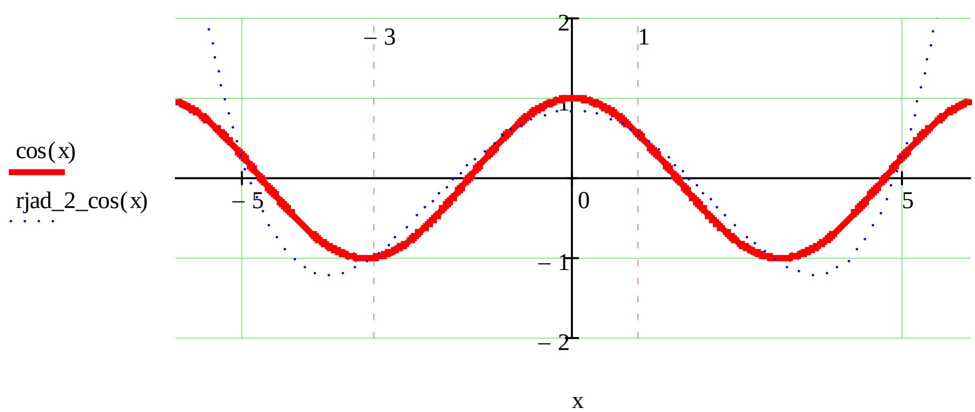


Figure 4: Values of the functions - *rjad_2_cos (x)* and *cos (x)*

$rjad\_2\_\cos(-5) = 0.284$
$\cos(-5) = 0.284$

$rjad\_2\_\cos(1) = 0.54$
$\cos(1) = 0.54$

$rjad\_2\_\cos(-3) = -0.99$
$\cos(-3) = -0.99$

$rjad\_2\_\cos(-3) = -0.99$
$\cos(3) = -0.99$

$rjad\_2\_\cos(-1) = 0.54$
$\cos(-1) = 0.54$

$rjad\_2\_\cos(5) = 0.284$
$\cos(5) = 0.284$

If we look at the same graphs in other coordinates, we can say that at these points the graphs coincide with their values, and at other points they do not, and they differ significantly.

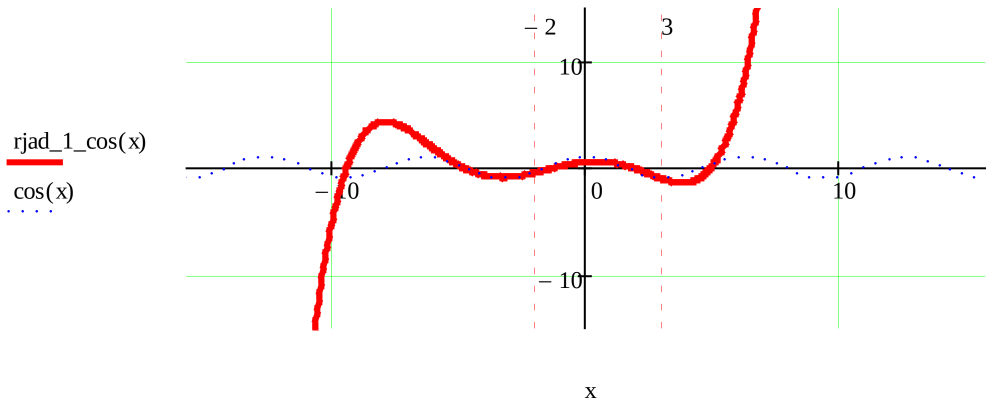


Figure 5: Values of the functions-*rjad_1_cos (x)* and *cos (x)*

The values of these two functions-*rjad_1_cos(x)* and *cos (x)* in other coordinate systems coincide only in this section in $\pm 2\pi$, and for other values of the argument they differ greatly.

Figure 6 shows the values of these two functions *rjad_2_cos(x)* and *cos (x).*

In the given figure shows that the values of these two functions *rjad_2_cos(x)* and *cos (x)* in different coordinate systems coincide only in this region of ± 6, and for other values of the argument vary greatly.

This suggests that approximation by differential integral functions is possible both at a point and at a certain area. The approximation error is minimal and can be reduced by increasing the number of terms of the polynomial.

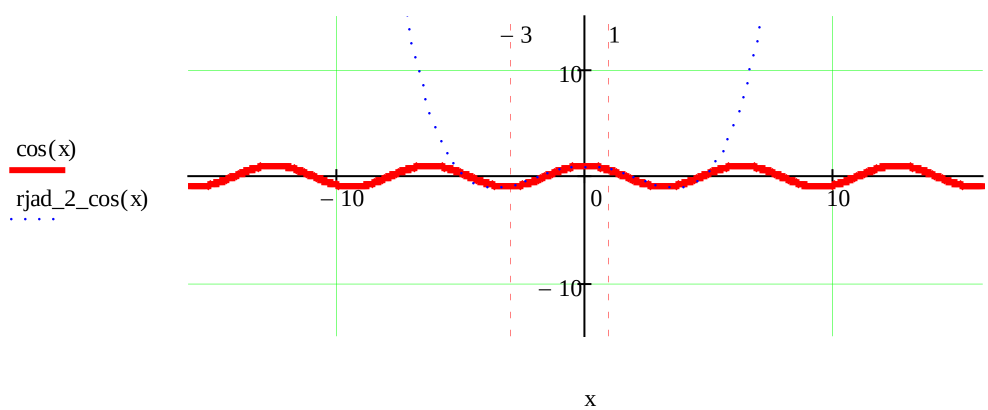


Figure 6: Values of the functions-rjad_2_cos (x) and cos (x)

The exponent can be approximated by the exponent itself. An example is shown below in Figure 7.

$$\begin{matrix} n & 0 & 1 & 2 & 3 \end{matrix}$$

$$A1 := \begin{pmatrix} 1^0 & 1^1 & 1^2 & 1^3 \\ 2^0 & 2^1 & 2^2 & 2^3 \\ 7^0 & 7^1 & 7^2 & 7^3 \\ 10^0 & 10^1 & 10^2 & 10^3 \end{pmatrix} \qquad B1 := \begin{pmatrix} e^1 \\ e^2 \\ e^7 \\ e^{10} \end{pmatrix} \qquad a := A1^{-1} \cdot B1 \qquad a = \begin{pmatrix} -1.19 \times 10^3 \\ 1.966 \times 10^3 \\ -863.71 \\ 89.924 \end{pmatrix}$$

$$k := (1 \ \ 2 \ \ 7 \ \ 10)^T$$

$$e^k = \begin{pmatrix} 2.718 \\ 7.389 \\ 1.097 \times 10^3 \\ 2.203 \times 10^4 \end{pmatrix}$$

$$rjad\_\exp(x) := a_0 + a_1 x + a_2 x^2 + a_3 x^3 \tag{21}$$

$$rjad\_exp\,(1) = 2.718 \qquad e^1 = 2.718$$

$$rjad\_exp\,(2) = 7.389 \qquad e^2 = 7.389$$

$$rjad\_exp\,(7) = 1.097 \times 10^3 \qquad e^7 = 1.097 \times 10^3$$

$$rjad\_exp\,(10) = 2.203 \times 10^4 \qquad e^{10} = 2.203 \times 10^4$$

Figure 7 shows the values of these two functions - *rjad_exp(x)* and *exp (x).*

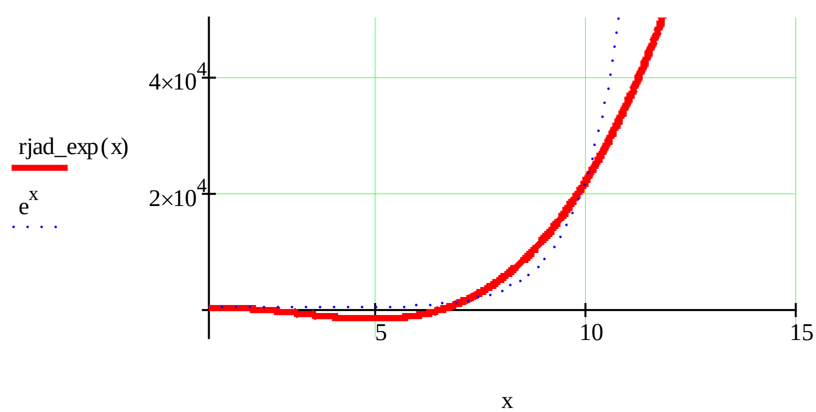


Figure 7: Values of the functions - *rjad_exp (x)* and *exp (x)*

The graph of the cos(x) function on the section from $x = 4$ to $x = 6$ and the initial data are shown below in Figure 8.

$$k\_1 := 1 + 1\cdot 10^{-6} \qquad SL(x,k,n) := \frac{x^{n-k}\cdot\Gamma(n+1)}{\Gamma(n-k+1)}$$

The set point - μ

$$\mu := 5$$

$$A1 := \begin{pmatrix} 1 & \mu & \mu^2 & \mu^3 & \mu^4 & \mu^5 \\ \frac{\mu^{-0.25}\cdot\Gamma(1)}{\Gamma(1-0.25)} & \frac{\mu^{1-0.25}}{\Gamma(2-0.25)} & \frac{2\cdot\mu^{2-0.25}}{\Gamma(3-0.25)} & \frac{6\cdot\mu^{3-0.25}}{\Gamma(4-0.25)} & \frac{24\cdot\mu^{4-0.25}}{\Gamma(5-0.25)} & \frac{120\cdot\mu^{5-0.25}}{\Gamma(6-0.25)} \\ \frac{\mu^{-0.5}\cdot\Gamma(1)}{\Gamma(1-0.5)} & \frac{\mu^{1-0.5}}{\Gamma(2-0.5)} & \frac{2\cdot\mu^{2-0.5}}{\Gamma(3-0.5)} & \frac{6\cdot\mu^{3-0.5}}{\Gamma(4-0.5)} & \frac{24\cdot\mu^{4-0.5}}{\Gamma(5-0.5)} & \frac{120\cdot\mu^{5-0.5}}{\Gamma(6-0.5)} \\ \frac{\mu^{-0.75}\cdot\Gamma(1)}{\Gamma(1-0.75)} & \frac{\mu^{1-0.75}}{\Gamma(2-0.75)} & \frac{2\cdot\mu^{2-0.75}}{\Gamma(3-0.75)} & \frac{6\cdot\mu^{3-0.75}}{\Gamma(4-0.75)} & \frac{24\cdot\mu^{4-0.75}}{\Gamma(5-0.75)} & \frac{120\cdot\mu^{5-0.75}}{\Gamma(6-0.75)} \\ \frac{\mu^{-k\_1}\cdot\Gamma(1)}{\Gamma(1-k\_1)} & \frac{\mu^{1-1}}{\Gamma(2-1)} & \frac{2\cdot\mu^{2-1}}{\Gamma(3-1)} & \frac{6\cdot\mu^{3-1}}{\Gamma(4-1)} & \frac{24\cdot\mu^{4-1}}{\Gamma(5-1)} & \frac{120\cdot\mu^{5-1}}{\Gamma(6-1)} \\ \frac{\mu^{-1.25}\cdot\Gamma(1)}{\Gamma(1-1.25)} & \frac{\mu^{1-1.25}}{\Gamma(2-1.25)} & \frac{2\cdot\mu^{2-1.25}}{\Gamma(3-1.25)} & \frac{6\cdot\mu^{3-1.25}}{\Gamma(4-1.25)} & \frac{24\cdot\mu^{4-1.25}}{\Gamma(5-1.25)} & \frac{120\cdot\mu^{5-1.25}}{\Gamma(6-1.25)} \end{pmatrix}$$

$$B1 := \begin{pmatrix} \cos\left(\mu + 0.00\cdot\frac{\pi}{2}\right) \\ \cos\left(\mu + 0.25\cdot\frac{\pi}{2}\right) \\ \cos\left(\mu + 0.50\cdot\frac{\pi}{2}\right) \\ \cos\left(\mu + 0.75\cdot\frac{\pi}{2}\right) \\ \cos\left(\mu + 1.00\cdot\frac{\pi}{2}\right) \\ \cos\left(\mu + 1.25\cdot\frac{\pi}{2}\right) \end{pmatrix} \qquad a := A1^{-1}\cdot B1$$

$$\_cos(x) := a_0 + a_1\cdot x + a_2\cdot x^2 + a_3\cdot x^3 + a_4\cdot x^4 + a_5\cdot x^5 \qquad (22)$$

$\_cos\ (5) = 2{,}836622\cdot 10^{-1}$

$\cos\ (5) = 2{,}836622\cdot 10^{-1}$

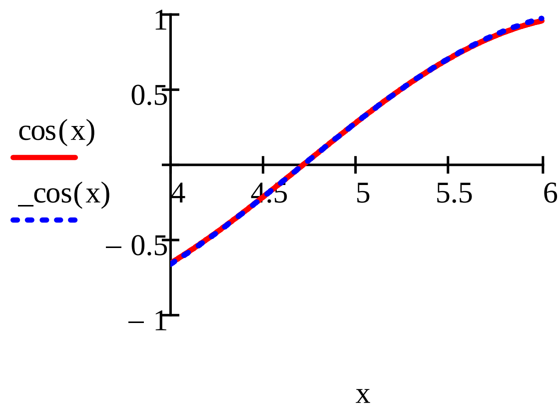


Figure 8: Values of the functions – *cos(x)* and *_cos (x)*

Additionally, the application of differential integration functions in music, curves of equal loudness, for example, Fletcher-Manson curves or Robinson-Dudson curves, Figure 9, is presented.

KRG=

	0	1	2	3	4	5	6	7	8	9	10	11
0	20	40	63	100	160	200	250	315	400	500	630	800
1	2.996	3.689	4.143	4.605	5.075	5.298	5.521	5.753	5.991	6.215	6.446	6.685
2	119	105.3	98.4	92.5	87.8	85.9	84.3	82.9	81.7	80.9	80.2	79.7

	12	13	14	15	16	17	18	19	20	21	22	23
0	$1\cdot10^3$	$1.25\cdot10^3$	$1.6\cdot10^3$	$2\cdot10^3$	$2.5\cdot10^3$	$3.15\cdot10^3$	$4\cdot10^3$	$5\cdot10^3$	$6.3\cdot10^3$	$8\cdot10^3$	$1\cdot10^4$	1.25·10
1	6.908	7.131	7.378	7.601	7.824	8.055	8.294	8.517	8.748	8.987	9.21	9.43
2	80	82.5	83.7	80.6	77.9	77.1	78.3	81.6	86.8	91.4	91.7	85.

$$SL(x,n,k) := \frac{x^{n-k}\cdot\Gamma(n+1)}{\Gamma(n-k+1)}$$

$i := 0..\,23$

$j := 0..\,23$

$k := 0$

0, 2, 7, 11, 12, 14, 16, 17, 19, 21, 22, 23

$$n := \begin{pmatrix} 0 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \end{pmatrix} \quad x := \begin{pmatrix} 2.996 \\ 4.143 \\ 5.753 \\ 6.685 \\ 6.908 \\ 7.378 \\ 7.824 \\ 8.055 \\ 8.517 \\ 8.987 \\ 9.21 \\ 9.433 \end{pmatrix} \quad y := \begin{pmatrix} 119 \\ 98.4 \\ 82.9 \\ 79.7 \\ 80 \\ 83.7 \\ 77.9 \\ 77.1 \\ 81.6 \\ 91.4 \\ 91.7 \\ 85.4 \end{pmatrix}$$

$\_A :=$ for $j \in 0..\,11$
  for $i \in 0..\,11$
    $\_SL(i,j) \leftarrow SL(x_i, n_j, 0)$

$a := \_\_A^{-1} \cdot B$

Year 2024 21 Global Journal of Research in Engineering (I) XXIV Issue I Version I

$$A := \begin{pmatrix}
SL(x_0,n_0,k) & SL(x_0,n_1,k) & SL(x_0,n_2,k) & SL(x_0,n_3,k) & SL(x_0,n_4,k) & SL(x_0,n_5,k) & SL(x_0,n_6,k) & SL(x_0,n_7,k) & SL(x_0,n_8,k) & SL(x_0,n_9,k) & SL(x_0,n_{10},k) & SL(x_0,n_{11},k) \\
SL(x_1,n_0,k) & SL(x_1,n_1,k) & SL(x_1,n_2,k) & SL(x_1,n_3,k) & SL(x_1,n_4,k) & SL(x_1,n_5,k) & SL(x_1,n_6,k) & SL(x_1,n_7,k) & SL(x_1,n_8,k) & SL(x_1,n_9,k) & SL(x_1,n_{10},k) & SL(x_1,n_{11},k) \\
SL(x_2,n_0,k) & SL(x_2,n_1,k) & SL(x_2,n_2,k) & SL(x_2,n_3,k) & SL(x_2,n_4,k) & SL(x_2,n_5,k) & SL(x_2,n_6,k) & SL(x_2,n_7,k) & SL(x_2,n_8,k) & SL(x_2,n_9,k) & SL(x_2,n_{10},k) & SL(x_2,n_{11},k) \\
SL(x_3,n_0,k) & SL(x_3,n_1,k) & SL(x_3,n_2,k) & SL(x_3,n_3,k) & SL(x_3,n_4,k) & SL(x_3,n_5,k) & SL(x_3,n_6,k) & SL(x_3,n_7,k) & SL(x_3,n_8,k) & SL(x_3,n_9,k) & SL(x_3,n_{10},k) & SL(x_3,n_{11},k) \\
SL(x_4,n_0,k) & SL(x_4,n_1,k) & SL(x_4,n_2,k) & SL(x_4,n_3,k) & SL(x_4,n_4,k) & SL(x_4,n_5,k) & SL(x_4,n_6,k) & SL(x_4,n_7,k) & SL(x_4,n_8,k) & SL(x_4,n_9,k) & SL(x_4,n_{10},k) & SL(x_4,n_{11},k) \\
SL(x_5,n_0,k) & SL(x_5,n_1,k) & SL(x_5,n_2,k) & SL(x_5,n_3,k) & SL(x_5,n_4,k) & SL(x_5,n_5,k) & SL(x_5,n_6,k) & SL(x_5,n_7,k) & SL(x_5,n_8,k) & SL(x_5,n_9,k) & SL(x_5,n_{10},k) & SL(x_5,n_{11},k) \\
SL(x_6,n_0,k) & SL(x_6,n_1,k) & SL(x_6,n_2,k) & SL(x_6,n_3,k) & SL(x_6,n_4,k) & SL(x_6,n_5,k) & SL(x_6,n_6,k) & SL(x_6,n_7,k) & SL(x_6,n_8,k) & SL(x_6,n_9,k) & SL(x_6,n_{10},k) & SL(x_6,n_{11},k) \\
SL(x_7,n_0,k) & SL(x_7,n_1,k) & SL(x_7,n_2,k) & SL(x_7,n_3,k) & SL(x_7,n_4,k) & SL(x_7,n_5,k) & SL(x_7,n_6,k) & SL(x_7,n_7,k) & SL(x_7,n_8,k) & SL(x_7,n_9,k) & SL(x_7,n_{10},k) & SL(x_7,n_{11},k) \\
SL(x_8,n_0,k) & SL(x_8,n_1,k) & SL(x_8,n_2,k) & SL(x_8,n_3,k) & SL(x_8,n_4,k) & SL(x_8,n_5,k) & SL(x_8,n_6,k) & SL(x_8,n_7,k) & SL(x_8,n_8,k) & SL(x_8,n_9,k) & SL(x_8,n_{10},k) & SL(x_8,n_{11},k) \\
SL(x_9,n_0,k) & SL(x_9,n_1,k) & SL(x_9,n_2,k) & SL(x_9,n_3,k) & SL(x_9,n_4,k) & SL(x_9,n_5,k) & SL(x_9,n_6,k) & SL(x_9,n_7,k) & SL(x_9,n_8,k) & SL(x_9,n_9,k) & SL(x_9,n_{10},k) & SL(x_9,n_{11},k) \\
SL(x_{10},n_0,k) & SL(x_{10},n_1,k) & SL(x_{10},n_2,k) & SL(x_{10},n_3,k) & SL(x_{10},n_4,k) & SL(x_{10},n_5,k) & SL(x_{10},n_6,k) & SL(x_{10},n_7,k) & SL(x_{10},n_8,k) & SL(x_{10},n_9,k) & SL(x_{10},n_{10},k) & SL(x_{10},n_{11},k) \\
SL(x_{11},n_0,k) & SL(x_{11},n_1,k) & SL(x_{11},n_2,k) & SL(x_{11},n_3,k) & SL(x_{11},n_4,k) & SL(x_{11},n_5,k) & SL(x_{11},n_6,k) & SL(x_{11},n_7,k) & SL(x_{11},n_8,k) & SL(x_{11},n_9,k) & SL(x_{11},n_{10},k) & SL(x_{11},n_{11},k)
\end{pmatrix}$$

$$B := \begin{pmatrix} 119 \\ 98.4 \\ 82.9 \\ 79.7 \\ 80 \\ 83.7 \\ 77.9 \\ 77.1 \\ 81.6 \\ 91.4 \\ 91.7 \\ 85.4 \end{pmatrix}$$

$$rjad(x) := a_0 + a_1 \cdot x + a_2 \cdot x^2 + a_3 \cdot x^3 + a_4 \cdot x^4 + a_5 \cdot x^5 + a_6 \cdot x^6 + a_7 \cdot x^7 + a_8 \cdot x^8 + a_9 \cdot x^9 + a_{10} \cdot x^{10} + a_{11} \cdot x^{11} \quad (23)$$

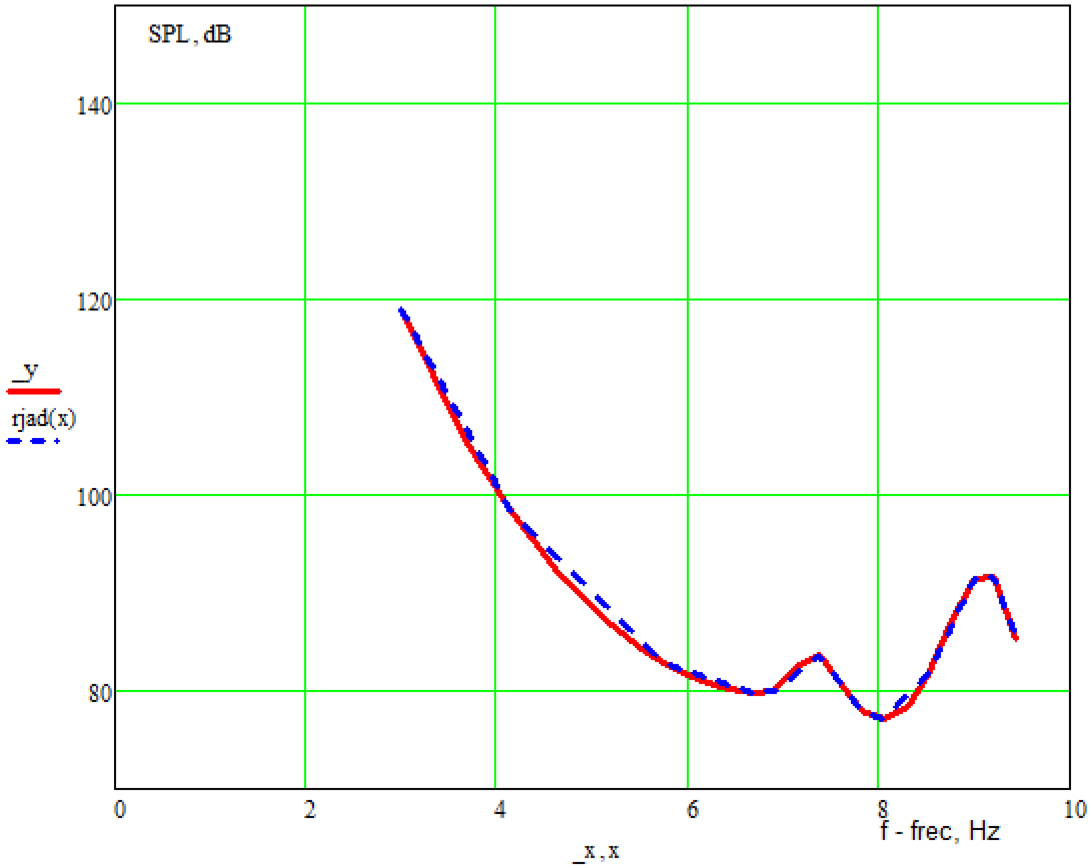


Figure 9: Curves of equal loudness *_y, dB* and a curve approximating them *rjad(x)*, Hertz

From the materials presented in the figures, it can be seen that for a given number of points, the approximation is satisfactory.

IV. Conclusions

Differential integral functions, this is the Riemann-Liouville differential integral, written in a convenient form, as a function of two variables[7]: the usual argument x and the parameter k, which sets the multiplicity of the integral or the order of the derivative. These functions allow you to calculate the desired integral or derivative by substituting the parameter k into the established formula. The formula does not change, only one parameter changes. Classical tables of integrals and differentials are not required. Only tables of pre-prepared formulas of differential functions are used, which can be represented in simple calculations in the form of icons, and in the form of SL (x, k) functions in computer programs written in programming languages such as VBasic, C++, Excel, MathCad, Python, etc.

These differential integral functions are of great practical importance, for example, they allow us to approximate a certain given function in the vicinity of the desired point (by the type of decomposition into a Taylor, Maclaurin, Fourier series or Z transformation) or on a segment. At the same time, the conditions of equality of not only the function itself, but also the selected derivatives and differentials, integer and fractional, are observed at the desired approximation points themselves.

Examples of approximation of some elementary functions are shown, for example, using a standard polynomial. It is also possible to approximate trigonometric, power functions and their combinations.

To simplify working with differential integral functions, they can be represented in two forms: for a graphic image-as a function with angle brackets, and for writing in the program text-as a function *SL (x, k)* of two or more arguments (Application B).

[7] There may be other parameters, for example, integration limits, constants, etc.

References Références Referencias

1. Collection of problems on equations of mathematical physics, edited by V.S. Vladimirova, Nauka Publishing House, Main Editorial Office of Physical and Mathematical literature, 1974, 271s.
2. Tikhonov A.N., Samarsky A.A. Equations of mathematical physics: Textbook. Manual. - 6th ed., ispr. and add. - M.: Publishing House of Moscow State University, 1999.
3. Vladimirov V.S., Vasharin A.A., Karimova H.H. Mikhailov V.P., etc. Collection of problems on equations of mathematical physics. / Edited by V.S. Vladimirova– - 3rd ed. corrected. - M.: FIZMATLIT. 2001– - 288 p.
4. Vladimirov V.S. Equations of mathematical physics. - ed. 4-E. - M.: Science. The main editorial office of the physical and mathematical literature. 1981– - 512 p.
5. Vladimirov V.S., Zharinov V.V. Equations of mathematical physics: Textbook for universities. - 2nd ed., stereotype. - M.: FIZMATLIT, 2004. - 400 p.
6. Mikusinsky Yan, Operational calculus, M.: Foreign Literature, 1956 -367s.
7. V.S. Martynenko Operational calculus. Vishcha Shkola. - 1990. 660 p.
8. Sidorov Yu.V., Fedoryuk M.V., Shabunin M.I. Lectures on the theory of functions of a complex variable: Textbook for universities– - 3rd ed., ispr. - M.: Nauka. Gl. ed. phys.-mat. lit., 1989– - 480 p.
9. Gustav Dech Guide to practical application of the Laplace transform and Z-transform (Series "Physical and mathematical library of an engineer"). - M.: - 1971. - 288 p.
10. Ditkin V.A., Prudnikov A.P. Operational calculus in two variables and its applications, State Publishing House of Physical and Mathematical Literature, Moscow, 1959.
11. Lykov A.V. Thermal conductivity of non-stationary processes, M.: Gosenergoizdat, 1948 - 232s.
12. Voronenko B.A., Krysin A.G., Pelenko V.V., Tsuranov O.A. Analytical description of the process of non-stationary thermal conductivity. - Study. - method. - St. Petersburg: ITMO Research Institute, IHiBT, 2014. - 48 p.
13. Kontorovich M.I. Operational calculus and processes in electrical circuits. Textbook for universities. Ed. 4th, revised, and supplemented. M., "Sov. Radio", 1975, 320 pages.
14. Shostak R.Ya. Operational calculus. A short course. 2nd ed. supplement. 1972. 289 p.
15. Zolotarev I.D. Application of the method simplifying the inverse Laplace transform in the study of the dynamics of oscillatory systems. Study guide. Omsk. GU, 2004. 136 p.

Application A

$$k\_1 := 1 + 1\cdot 10^{-6} \qquad SL(x,k,n) := \frac{x^{n-k}\cdot\Gamma(n+1)}{\Gamma(n-k+1)}$$

The set point - μ

$$\mu := 3$$

k = 0 ->

k = 0,25 ->

k = 0,50 ->

k = 0,75 ->

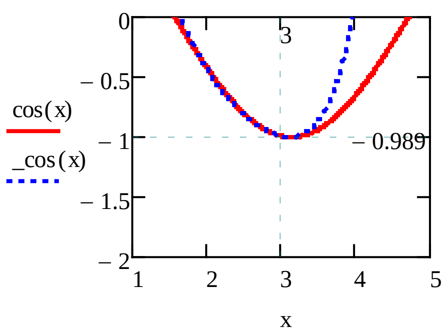
k = 1,00 ->

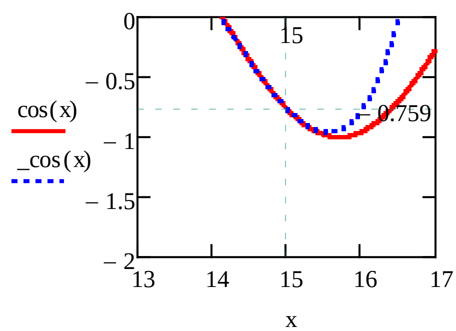
k = 1,25 ->

$$A1 := \begin{pmatrix} 1 & \mu & \mu^2 & \mu^3 & \mu^4 & \mu^5 \\ \frac{\mu^{-0.25}\cdot\Gamma(1)}{\Gamma(1-0.25)} & \frac{\mu^{1-0.25}}{\Gamma(2-0.25)} & \frac{2\cdot\mu^{2-0.25}}{\Gamma(3-0.25)} & \frac{6\cdot\mu^{3-0.25}}{\Gamma(4-0.25)} & \frac{24\cdot\mu^{4-0.25}}{\Gamma(5-0.25)} & \frac{120\cdot\mu^{5-0.25}}{\Gamma(6-0.25)} \\ \frac{\mu^{-0.5}\cdot\Gamma(1)}{\Gamma(1-0.5)} & \frac{\mu^{1-0.5}}{\Gamma(2-0.5)} & \frac{2\cdot\mu^{2-0.5}}{\Gamma(3-0.5)} & \frac{6\cdot\mu^{3-0.5}}{\Gamma(4-0.5)} & \frac{24\cdot\mu^{4-0.5}}{\Gamma(5-0.5)} & \frac{120\cdot\mu^{5-0.5}}{\Gamma(6-0.5)} \\ \frac{\mu^{-0.75}\cdot\Gamma(1)}{\Gamma(1-0.75)} & \frac{\mu^{1-0.75}}{\Gamma(2-0.75)} & \frac{2\cdot\mu^{2-0.75}}{\Gamma(3-0.75)} & \frac{6\cdot\mu^{3-0.75}}{\Gamma(4-0.75)} & \frac{24\cdot\mu^{4-0.75}}{\Gamma(5-0.75)} & \frac{120\cdot\mu^{5-0.75}}{\Gamma(6-0.75)} \\ \frac{\mu^{-k\_1}\cdot\Gamma(1)}{\Gamma(1-k\_1)} & \frac{\mu^{1-1}}{\Gamma(2-1)} & \frac{2\cdot\mu^{2-1}}{\Gamma(3-1)} & \frac{6\cdot\mu^{3-1}}{\Gamma(4-1)} & \frac{24\cdot\mu^{4-1}}{\Gamma(5-1)} & \frac{120\cdot\mu^{5-1}}{\Gamma(6-1)} \\ \frac{\mu^{-1.25}\cdot\Gamma(1)}{\Gamma(1-1.25)} & \frac{\mu^{1-1.25}}{\Gamma(2-1.25)} & \frac{2\cdot\mu^{2-1.25}}{\Gamma(3-1.25)} & \frac{6\cdot\mu^{3-1.25}}{\Gamma(4-1.25)} & \frac{24\cdot\mu^{4-1.25}}{\Gamma(5-1.25)} & \frac{120\cdot\mu^{5-1.25}}{\Gamma(6-1.25)} \end{pmatrix}$$

$$B1 := \begin{pmatrix} \cos\left(\mu + 0.00\cdot\frac{\pi}{2}\right) \\ \cos\left(\mu + 0.25\cdot\frac{\pi}{2}\right) \\ \cos\left(\mu + 0.50\cdot\frac{\pi}{2}\right) \\ \cos\left(\mu + 0.75\cdot\frac{\pi}{2}\right) \\ \cos\left(\mu + 1.00\cdot\frac{\pi}{2}\right) \\ \cos\left(\mu + 1.25\cdot\frac{\pi}{2}\right) \end{pmatrix}$$

$$a := A1^{-1}\cdot B1 \qquad \_cos(x) := a_0 + a_1\cdot x + a_2\cdot x^2 + a_3\cdot x^3 + a_4\cdot x^4 + a_5\cdot x^5$$





$$\_cos(3) = -9{,}899925 \times 10^{-1} \qquad \_cos(15) = -7.596879\times 10^{-1}$$

$$cos(3) = -9{,}899925 \times 10^{-1} \qquad cos(15) = -7.596879\times 10^{-1}$$

Figure A.1: Decomposition of the function *cos (x)* into a series *_cos*(*x*) in the vicinity of two different points $\mu = 3$ and $\mu = 15$

The system consists of the polynomial *cos (x)* and its six fractional derivatives *ki*, with a maximum multiplicity of 1.25. The order of the derivatives of *k* changes after 0.25.

Application B

Differential integral functions of SL().

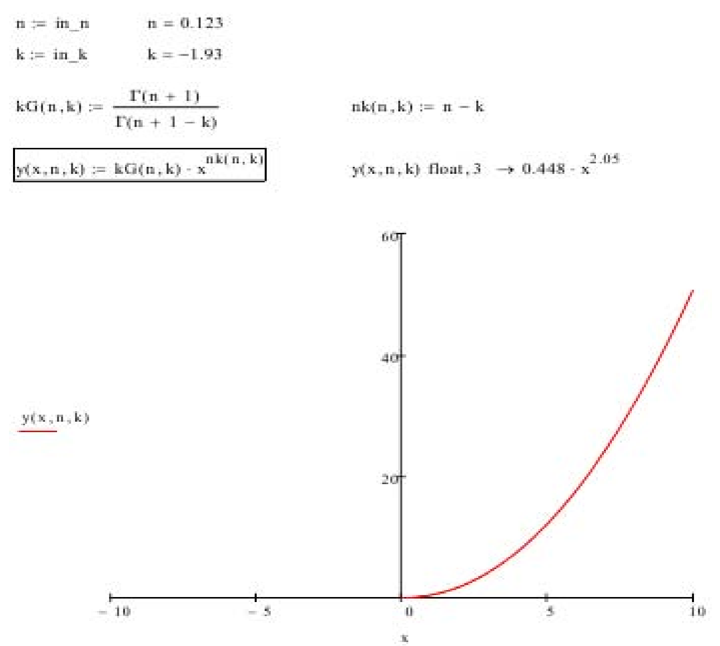
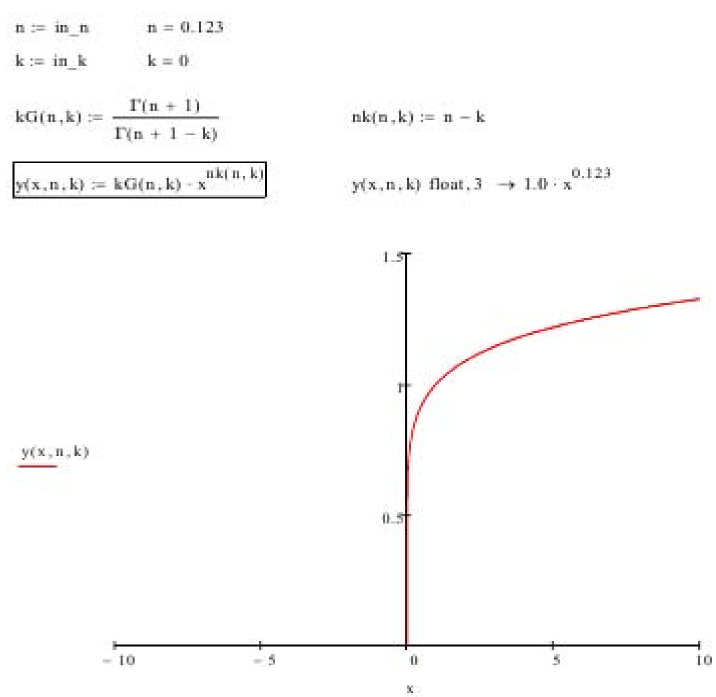
The text of the VBasic program for calculating the differentialfunctions of SL() is given below.

The text of the program in VBasic for calculating the differential functions of SL ().

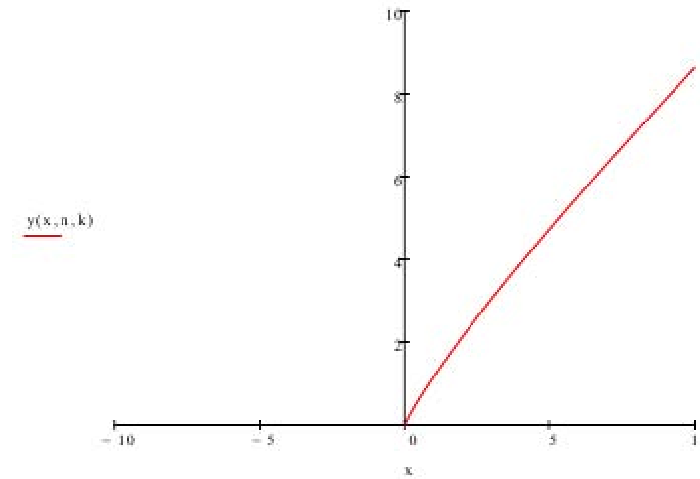
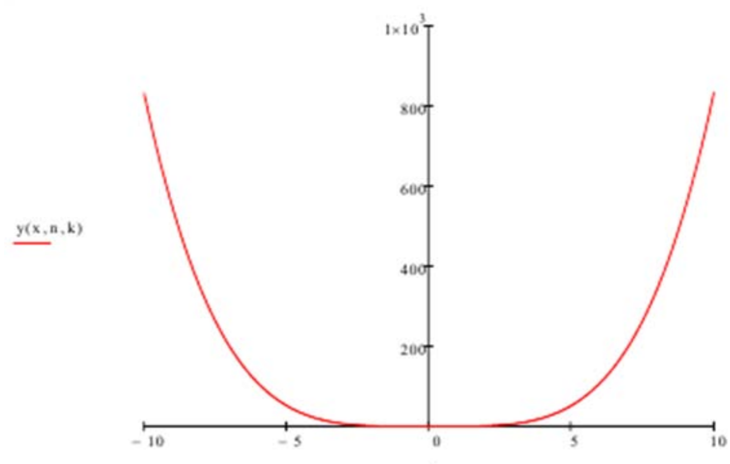
```
Option Explicit

Dim n, k As Double
Dim in_n, in_k As Double
Dim Message1, Title1, Default, MyValue
Dim Message2, Title2
Dim MathcadObj
Dim MCWSheet

Private Sub Form_Load ()
Form1.Enabled = True
Form1.Cls
Form1.Visible = False
Form1.Appearance = 0
Form1.WindowState = 2
Call nk
End Sub

Private Sub nk ()
Message1 = "Enter the degree <n> for the power function y = x^n"
Title1= "Default n =2"
Default= "2"
MyValue = InputBox (Message1, Title1, Default)
n = CDbl (MyValue)
'--------------------------------------------------
Message2 = ""Enter K. If K < 0, then it is an integral of multiplicity K, and if K > 0, then it is a derivative of order K"
k = InputBox (Message2, Title1, Default)
Call Gam
End Sub

Private Sub Gam()
'Setting a custom function
Set MathcadObj = OLE1.object
Set MCWSheet = MathcadObj.Worksheet
in_n = n
in_k = k
Call MathcadObj.setcomplex("in_n", n, 0)
Call MathcadObj.setcomplex("in_k", k, 0)
'Recalculating results in MathCad and getting a custom SLFunctions function
Call MathcadObj.Recalculate
'End of the program
Dim Msg, Style, Title, Response
Msg = "Continue? Yes"
Style = vbYesNo + vbCritical + vbDefaultButton2
Title = "The program has finished working. Viewing the result"
Response = MsgBox (Msg, Style, Title)
If Response = 6 Then Form1.Enabled = False
Set MathcadObj = Nothing
Set MCWSheet = Nothing
End
End Sub
```

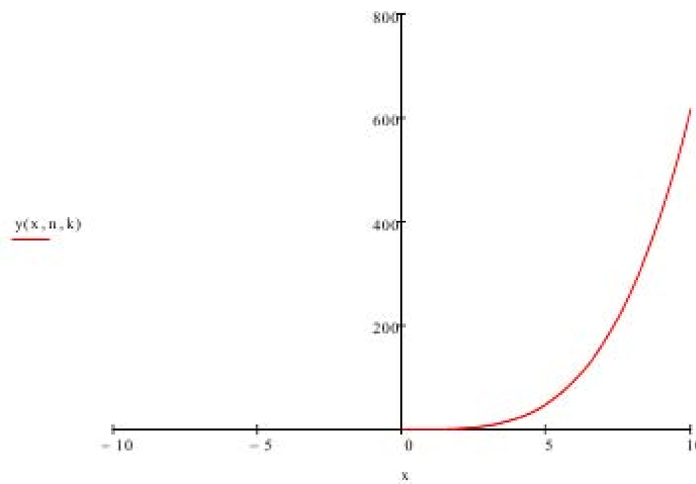
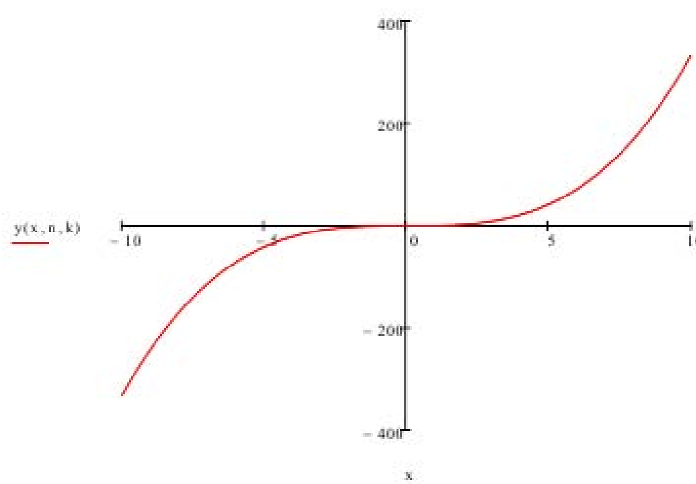
Below, as an example, is a table (Table 1) with the results of calculating the differential functions on VBasic, where n is the exponent of the power function, and k is the parameter of the differential function. For k < 0 it is a fractional integral, k = 0 is the parent function, and for k > 0 it is a fractional derivative.

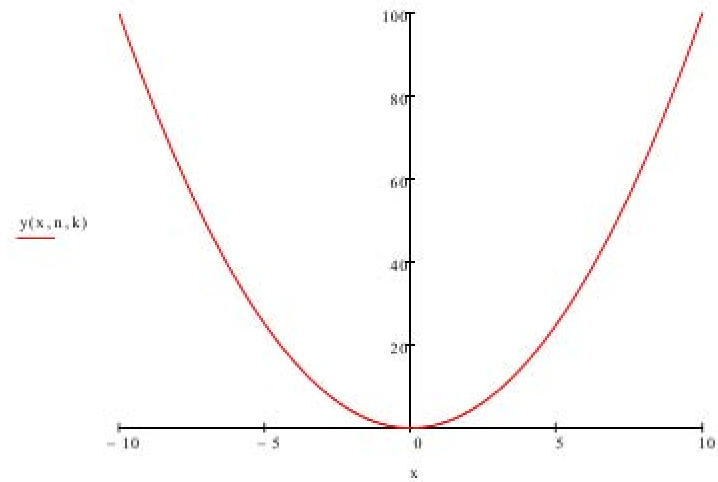
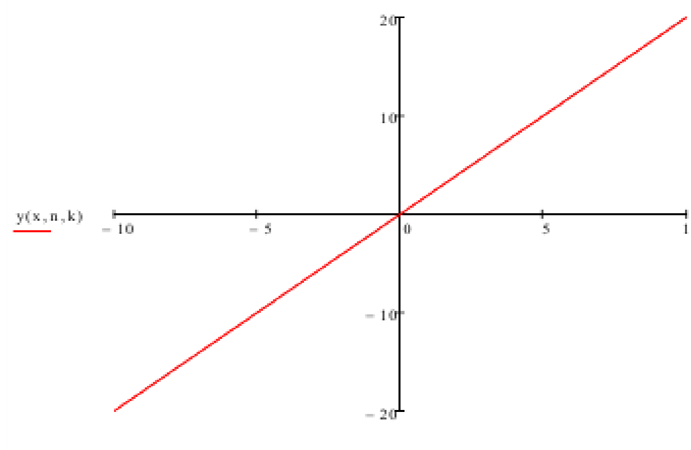
Table B.1: Values of functions $x^{0,123}$, x^2, $x^{12,3}$ and *sin(x)*

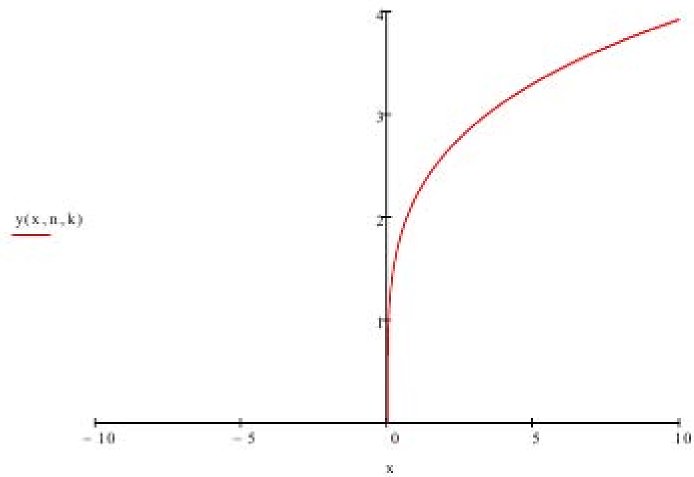
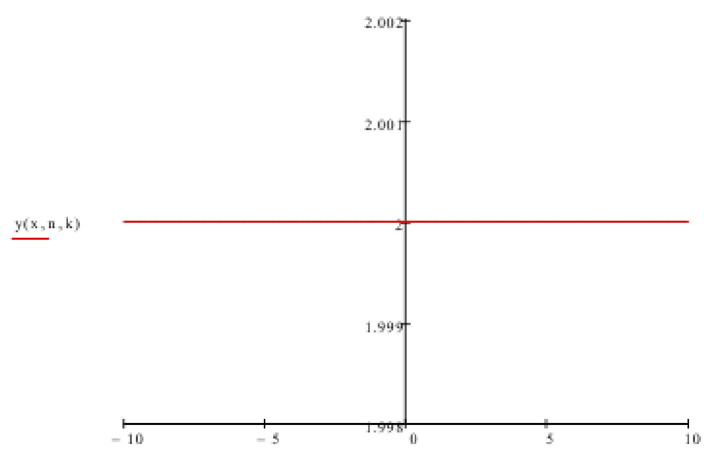
PDF File	n	k	Figure
(0,123) <-1,93> Fractionalintegral 1.1 SLFunction n=0,123 k=-1,93.pdf	0,123	-1,93	
0,123 <0> Maternalfunction No. 1 SLFunction n=0,123 k=0.pdf	0,123	0	

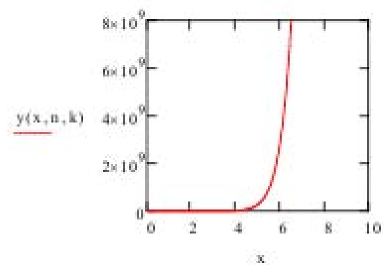
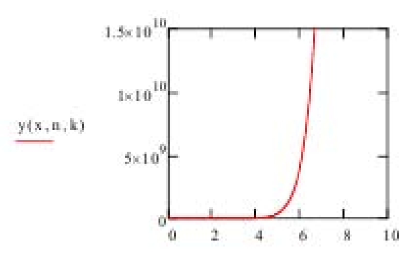
Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

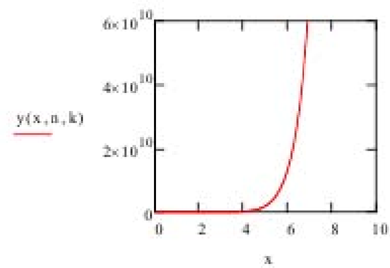
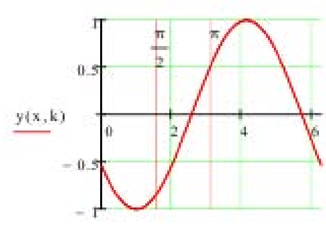
$(0{,}123)^{<0{,}37>}$ Fractionalderivative 1.1 SLFunction n=1,234 k=0,37.pdf	0,123	0,37	n := in_n n = 1.234 k := in_k k = 0.37 $kG(n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)}$ nk(n,k) := n − k $y(x,n,k) := kG(n,k)\cdot x^{nk(n,k)}$ y(x,n,k) float,3 → $1.18\cdot x^{0.864}$ 
$2^{<-2>}$ The two-foldintegral 2.1 SLFunction n=2 k=-2.pdf	2	-2	n := in_n n = 2 k := in_k k = −2 $kG(n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)}$ nk(n,k) := n − k $y(x,n,k) := kG(n,k)\cdot x^{nk(n,k)}$ y(x,n,k) float,3 → $0.0833\cdot x^{4}$ 

$2^{<-1,64>}$ Fractionalintegral 2.2 SLFunction n=2 k=-1,64.pdf	2	-1,64	n := in_n n = 2 k := in_k k = −1.64 $kG(n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)}$ $nk(n,k) := n - k$ $y(x,n,k) := kG(n,k)\cdot x^{nk(n,k)}$ y(x,n,k) float,3 → $0.141\cdot x^{3.64}$ 
$2^{<-1>}$ Singleintegral 2.3 SLFunction n=2 k=-1.pdf	2	-1	n := in_n n = 2 k := in_k k = −1 $kG(n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)}$ $nk(n,k) := n - k$ $y(x,n,k) := kG(n,k)\cdot x^{nk(n,k)}$ y(x,n,k) float,3 → $0.333\cdot x^{3}$ 

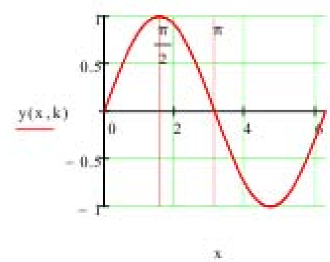
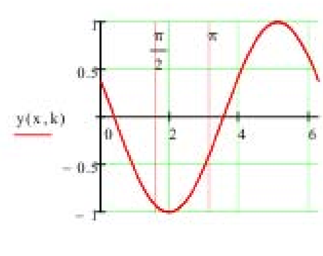
$2^{<0>}$ Maternal functionNo.2 SLFunction n=2 k=0.pdf	2	0	$n := in\_n$ $\quad n = 2$ $k := in\_k$ $\quad k = 0$ $kG(n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)}$ $\quad nk(n,k) := n - k$ $y(x,n,k) := kG(n,k) \cdot x^{nk(n,k)}$ $\quad y(x,n,k)\ \mathrm{float},3 \rightarrow x^2$ 
$2^{<1>}$ The firstderivative 2.1 SLFunction n=2 k=1.pdf	2	1	$n := in\_n$ $\quad n = 2$ $k := in\_k$ $\quad k = 1$ $kG(n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)}$ $\quad nk(n,k) := n - k$ $y(x,n,k) := kG(n,k) \cdot x^{nk(n,k)}$ $\quad y(x,n,k)\ \mathrm{float},3 \rightarrow 2.0 \cdot x$ 

2 <1,75> Fractionalderivative 2.2 SLFunction n=2 k=1,75.pdf	2	1,75	$n := in\_n$ $n = 2$ $k := in\_k$ $k = 1.75$ $kG(n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)}$ $nk(n,k) := n - k$ $y(x,n,k) := kG(n,k) \cdot x^{nk(n,k)}$ $y(x,n,k) \text{ float}, 3 \rightarrow 2.21 \cdot x^{0.25}$ 
2 <2> The secondderivative 2.3 SLFunction n=2 k=2.pdf	2	2	$n := in\_n$ $n = 2$ $k := in\_k$ $k = 2$ $kG(n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)}$ $nk(n,k) := n - k$ $y(x,n,k) := kG(n,k) \cdot x^{nk(n,k)}$ $y(x,n,k) \text{ float}, 3 \rightarrow 2.0$ 

$(12,34)^{<-0,45>}$ Fractionalintegral 3.1 SL Fun 12,34 -0,45.xmcd	12,34	-0,45	Введите показатель степенной функции < n > n := 12,34 Введите порядок производной или интеграла < k > Для производной k > 0 для интеграла k < 0 k := -0,45 Дифферинтегральная Функция Y равна $y(x,n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)} \cdot x^{n-k}$ $y(x,n,k)$ float, 3 $\rightarrow 0.315 \cdot x^{12.8}$ Вид этой функции представлен на графике 
$12,34^{<0>}$ Maternal functionNo.3 SL Fun 12,34 0.xmcd	12,34	0	Введите показатель степенной функции < n > n := 12,34 Введите порядок производной или интеграла < k > Для производной k > 0 для интеграла k < 0 k := 0 Дифферинтегральная Функция Y равна $y(x,n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)} \cdot x^{n-k}$ $y(x,n,k)$ float, 3 $\rightarrow 1.0 \cdot x^{12.3}$ Вид этой функции представлен на графике 

$(12,34)^{<1,75>}$ Fractionalderivative 3.1 SL Fun 12,34 1,75.xmcd	12,34	1,75	Введите показатель степенной функции < n > n := 12,34 Введите порядок производной или интеграла < k > Для производной k > 0 для интеграла k < 0 k := 1,75 Дифферинтегральная Функция Y равна $y(x,n,k) := \frac{\Gamma(n+1)}{\Gamma(n+1-k)} \cdot x^{n-k}$ $y(x,n,k)$ float, 3 $\rightarrow 76.9 \cdot x^{10.6}$ Вид этой функции представлен на графике 
$\sin(x)^{<-1,64>}$ Fractionalintegral 4.1 sin x -1,64.pdf		-1,64	Введите порядок производной или интеграла < k > Для производной k > 0 для интеграла k < 0 k := -1,64 Дифферинтегральная Функция Y равна $y(x,k) := \sin\left(x + k \cdot \frac{\pi}{2}\right)$ $y(x,k)$ float, 3 $\rightarrow \sin(x - 2.58)$ Вид этой функции представлен на графике 

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

sin(x) <0> Maternal function No.4 sin x 0.pdf		0	Введите порядок производной или интеграла < k > Для производной k > 0 для интеграла k < 0 k := 0 Дифферинтегральная Функция Y равна $y(x,k) := \sin\left(x + k\cdot\frac{\pi}{2}\right)$ $y(x,k)$ float, 3 $\rightarrow \sin(x)$ Вид этой функции представлен на графике 
sin(x) <1,75> Fractionalderivative 4.1 sin x 1,75.pdf		1,75	Введите порядок производной или интеграла < k > Для производной k > 0 для интеграла k < 0 k := 1,75 Дифферинтегральная Функция Y равна $y(x,k) := \sin\left(x + k\cdot\frac{\pi}{2}\right)$ $y(x,k)$ float, 3 $\rightarrow \sin(x + 2.75)$ Вид этой функции представлен на графике 

Global Journal of Researches in Engineering: I
Numerical Methods
Volume 24 Issue 1 Version 1.0 Year 2024
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Investigating the Effects of Physical Parameters on First and Second Reflected Waves in Air-Saturated Porous Media under Low-Frequency Ultrasound Excitation

By Mustapha Sadouki & Abd El Madjid Mahiou
Khemis-Miliana University

Abstract- This simulation study investigates the impact of a 20% variation in physical parameters, including porosity, tortuosity, viscous and thermal characteristic lengths, and two newly introduced viscous and thermal shape factor parameters, on reflected waves at the first and second interfaces in air-saturated porous media under low-frequency ultrasound excitation. The acoustic behavior of air-saturated porous media is modeled using the equivalent fluid theory and the Johnson-Allard model, refined by Sadouki [Phys. Fluids 33, (2021)]. Our results demonstrate that a 20% variation in certain physical parameters significantly affects the reflected waves at the first and second interfaces in the low-frequency domain of ultrasound. This study enhances our understanding of the underlying mechanisms governing acoustic wave propagation in air-saturated porous media, which is valuable for optimizing ultrasound-based techniques in a range of applications, such as nondestructive testing, medical imaging, and noise pollution control in buildings, aircraft, automobile industry, and civil engineering sectors.

Keywords: air-saturated porous media, ultrasound, physical parameters, reflected waves, simulation study, equivalent fluid theory, Johnson-Allard model.

GJRE-I Classification: LCC: TA705

INVESTIGATINGTHEEFFECTSOFPHYSICALPARAMETERSONFIRSTANDSECONDREFLECTEDWAVESINAIRSATURATEDPOROUSMEDIAUNDERLOWFREQUENCYULTRASOUNDEXCITATION

Strictly as per the compliance and regulations of:

Investigating the Effects of Physical Parameters on First and Second Reflected Waves in Air-Saturated Porous Media under Low-Frequency Ultrasound Excitation

Mustapha Sadouki [α] & Abd El Madjid Mahiou [σ]

Abstract- This simulation study investigates the impact of a 20% variation in physical parameters, including porosity, tortuosity, viscous and thermal characteristic lengths, and two newly introduced viscous and thermal shape factor parameters, on reflected waves at the first and second interfaces in air-saturated porous media under low-frequency ultrasound excitation. The acoustic behavior of air-saturated porous media is modeled using the equivalent fluid theory and the Johnson-Allard model, refined by Sadouki [Phys. Fluids 33, (2021)]. Our results demonstrate that a 20% variation in certain physical parameters significantly affects the reflected waves at the first and second interfaces in the low-frequency domain of ultrasound. This study enhances our understanding of the underlying mechanisms governing acoustic wave propagation in air-saturated porous media, which is valuable for optimizing ultrasound-based techniques in a range of applications, such as nondestructive testing, medical imaging, and noise pollution control in buildings, aircraft, automobile industry, and civil engineering sectors.

Keywords: air-saturated porous media, ultrasound, physical parameters, reflected waves, simulation study, equivalent fluid theory, Johnson-Allard model.

I. Introduction

Porous materials have a rich history that dates back to ancient times, and they continue to be of great importance in modern chemistry and materials science [1]. These materials exhibit unique properties that make them valuable across a wide range of applications, including biomedical, building and construction, aerospace, and environmental domains. Their diverse classifications, such as fibrous, granular agglomerates, polymeric, and construction materials, contribute to their widespread use in our daily lives.

In recent years, there has been a growing interest in the use of porous materials due to their versatility and unique properties. For example, in the biomedical field [2], porous materials have shown tremendous potential for drug delivery and tissue engineering. The porous structure of these materials allows for controlled drug release and promotes cell growth, making them ideal candidates for advanced medical applications. In the building and construction industry [3], porous materials are commonly used for insulation and soundproofing. Their ability to absorb sound waves through viscous friction and thermal exchanges makes them an excellent choice for reducing noise pollution. Similarly, in the aerospace industry[4], porous materials are used for thermal insulation and noise reduction.

The physical and mechanical parameters used to characterize the properties of porous materials include geometric tortuosity, viscous and thermal characteristic lengths [5-8], Young's modulus of elasticity, and Poisson's ratio. In the field of acoustics, porous materials are widely used to reduce noise pollution by absorbing a part of the sound waves through viscous friction and thermal exchanges [4]. Previous studies have been conducted to investigate the influence of physical parameters describing porous media on the transmitted signal in the low-frequency ultrasound regime [9-11]. However, there is a need for a more comprehensive numerical simulation study to determine the effect of physical parameters on the low-frequency ultrasonic signal reflected by the first and second interfaces of the medium.

In this study, we address this gap by investigating the impact of a 20% variation in physical parameters, including porosity, tortuosity, viscous and thermal characteristic lengths, and two newly introduced viscous and thermal shape factor parameters, on the reflected waves at the first and second interfaces in air-saturated porous media in the low-frequency domain of ultrasound. The acoustic behavior of air-saturated porous media is modeled using the equivalent fluid theory and the Johnson-Allard model refined by Sadouki [12]. This study enhances our understanding of the underlying mechanisms governing acoustic wave propagation in porous media, providing valuable insights for optimizing ultrasound-based techniques in a range of applications, such as nondestructive testing, medical imaging, and noise pollution control in

Author α: Acoustics and Civil Engineering Laboratory. Khemis-Miliana University. Ain Defla, Algeria. e-mail: mustapha.sadouki@univ-dbkm.dz
Author σ: Acoustics and Civil Engineering Laboratory. Khemis-Miliana University. Ain Defla, Algeria. Theoretical Physics and Radiation Matter Interaction Laboratory, Soumaa, Blida, Algeria.

buildings, aircraft, automobile industries, and civil engineering.

II. Model

Acoustic propagation in porous materials is a complex phenomenon that involves the interaction of sound waves with fluid and solid components of the porous medium. When considering air-saturated porous materials with immobile solid skeletons, wave propagation is confined to the fluid, and this behavior is typically modeled using the equivalent fluid model [5,6], which is a particular case of Biot theory [13-15]. The two frequency response factors, the dynamic tortuosity of the medium $\alpha(\omega)$ and the dynamic compressibility of air in the porous material $\beta(\omega)$, are used to account for structure-fluid interactions. The dynamic tortuosity is provided by Johnson et al [5,6], while the dynamic compressibility is given by Allard [7]. In the frequency domain, these factors are multiplied by the density and compressibility of the fluid.

At extremely low and high frequencies, the equations governing the acoustic behavior of the fluid simplify and the parameters involved are different. In the high-frequency range [7], this simplification occurs when the viscous and thermal skin thicknesses $\delta(\omega) = \sqrt{\frac{2\eta}{\rho_0\omega}}$ and $\delta'(\omega) = \sqrt{\frac{2\eta}{P_r\rho_0\omega}}$ are smaller than the pore radius r. (Here, the density of the saturating fluid is represented by ρ_0, the viscosity by η, the pulse frequency by ω, and the Prandtl number by Pr). In the low-frequency range of the ultrasonic domain, the dynamic tortuosity and compressibility are given by [12]:

$$\alpha(\omega) = \alpha_\infty\left(1 + \frac{\delta(\omega)}{\Lambda}\left(\frac{2}{j}\right)^{\frac{1}{2}} + \xi\left(\frac{\delta(\omega)}{\Lambda}\right)^2\left(\frac{2}{j}\right) + \cdots\right) \quad (1)$$

$$\beta(\omega) = 1 + (\gamma - 1)\left(\frac{\delta'(\omega)}{\Lambda'}\left(\frac{2}{j}\right)^{1/2} + (\xi' - 1)\left(\frac{\delta'(\omega)}{\Lambda'}\right)^2\left(\frac{2}{j}\right) + \cdots\right) \quad (2)$$

where, $j = \sqrt{-1}$ and γ is the adiabatic constant.

The relevant physical parameters of the models are the high-frequency limit of the tortuosity α_∞, the viscous and thermal characteristic lengths Λ and Λ', respectively, and the dimensionless parameter ξ introduced by Sadouki [12], which is a shape factor related to the correction of the viscous skin depth of the air layer near the tube surface where the velocity distribution is significantly perturbed by the viscous forces generated by the stationary frame in the low-frequency ultrasonic regime. ξ' is the associated thermal counterpart.

Consider a homogeneous porous material that occupies the region $0 \leq x \leq L$. A sound pulse normally strikes the medium, generating an acoustic pressure field p(x,t) and an acoustic velocity field v(x,ω) within the material (Fig. 1). These fields satisfy the Euler equation and the constitutive equation along the x-axis:

$$\rho_0\alpha(\omega)j\omega\, v(x,\omega) = \frac{\partial p(x,\omega)}{\partial x}, \qquad \frac{\beta(\omega)}{K_a}j\omega\, p(x,\omega) = \frac{\partial v(x,\omega)}{\partial x}, \quad (3)$$

Here, K_a is the compressibility modulus of the fluid.

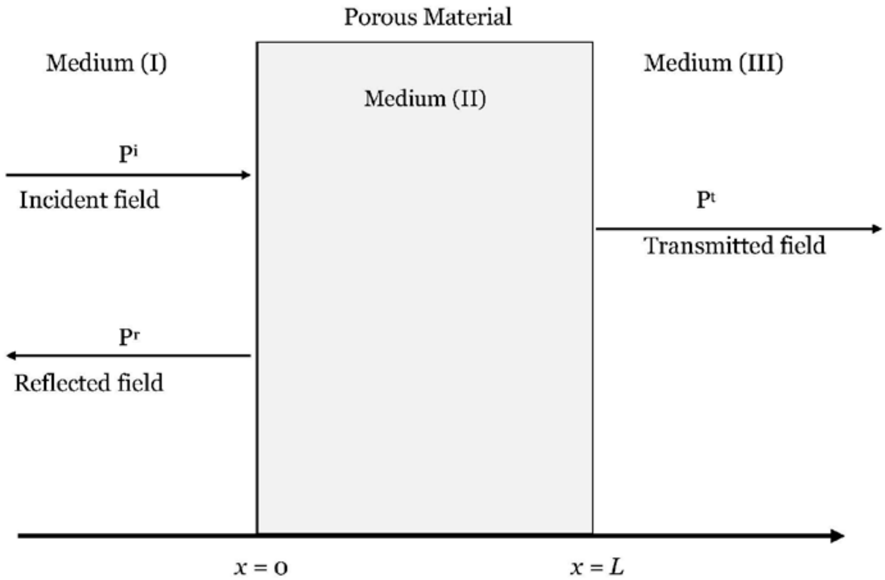


Figure 1: Problem geometry

The continuity of the pressure and velocity fields at the medium boundary gives the reflection coefficient of the porous material [17]:

$$R = \frac{(1-\tilde{Z}^2)\sinh(j\tilde{k}L)}{2\tilde{Z}\cosh(j\tilde{k}L)+(1+\tilde{Z}^2)\sinh(j\tilde{k}L)} \qquad (4)$$

Where $\tilde{Z} = \frac{1}{\phi}\sqrt{\frac{\alpha(\omega)}{\beta(\omega)}}$ is the normalized characteristic impedance of the material, ϕ is the porosity, and $\tilde{k} = \omega\sqrt{\frac{\rho_0\alpha(\omega)\beta(\omega)}{K_a}}$ is the wave number of the acoustic wave in the porous medium. The incident and reflected fields p^i and p^r_{sim} are related in the frequency domain by the reflection coefficient R:

$$p^r_{sim}(x,\omega) = R\, p^i(x,\omega) \qquad (5)$$

In the time domain, the reflected signal $p^r_{sim}(x,t)$ is obtained by taking the inverse Fourier transform of Eq. (5):

$$P^t(x,t) = \mathcal{F}^{-1}\left(R\, P^i(x,\omega)\right) \qquad (6)$$

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

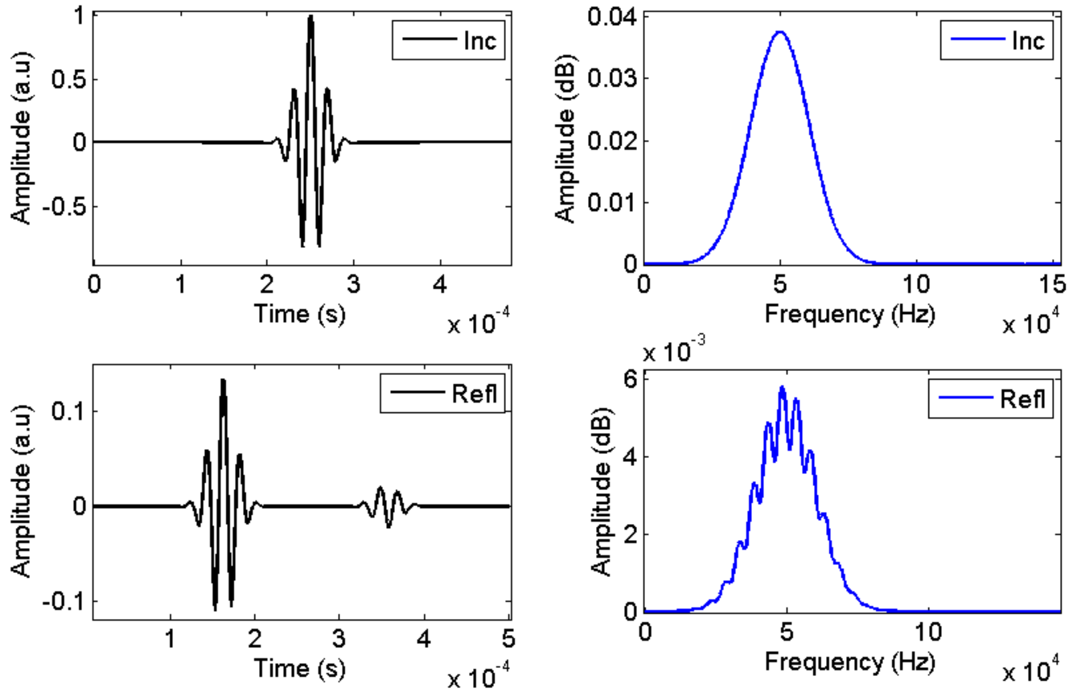


Figure 2: The incident and reflected signals of a monolayer porous medium constructed in frequency via expression (5) and in time via Eq. (6)

The simulated incident and reflected signals of a single-layer porous medium are shown in Fig. 2, and were obtained by expression (5) in the frequency domain and equation (6) in the time domain. The characteristic parameters of the porous medium are as follows: L = 3.0 cm, $\phi = 0.85$, $\alpha_\infty = 1.2$, $\Lambda = 300$ μm, $\Lambda'/\Lambda = 3$, $\xi = 10$, and $\xi/\xi' = 2$. These signals were generated using the Gauss function in Matlab with center frequencies of 50 kHz and 120 kHz. In the time domain, two successive reflections on the first and second interface can be clearly observed, as shown in black color below in Figure 2.

III. Simulation Study

To investigate the influence of physical parameters, such as porosity, tortuosity, viscous and thermal characteristic lengths, and newly introduced shape factors on the reflected waves, a parameter analysis was performed. Specifically, each parameter was varied while holding the others constant, and the impact on the first and second reflected waves in the time domain, as indicated by equation (6), was observed. By systematically varying each parameter and analyzing its effect on the reflected waves, we can better understand the individual contributions of these physical factors to the overall acoustic behavior of the porous material.

a) *Effect of Porosity* $\boldsymbol{\phi}$ *on the Reflected Signal*

Figure 3 shows the impact of varying the porosity (ϕ) on the amplitude of the first and second reflected waves through a rigid porous medium, while keeping the other parameters fixed at $\alpha_\infty = 1.2$, $\Lambda = 300$ μm, $\Lambda'/\Lambda = 3$, $\xi = 10$, and $\xi/\xi' = 2$. The porosity ϕ varies from +20% to -20% of its initial value ($\phi = 0.85$). Table 1 presents the variation ratio of the reflection coefficient compared to a ±20% variation of each parameter.

According to Table 1, a significant influence of porosity on the reflected signal is observed at frequencies of 50 kHz and 120 kHz. When the porosity increases by +20%, the modulus of the first and second reflected signals decrease by -66.84% and -65.06%, respectively. Conversely, when the porosity decreases by -20%, the amplitude of the 1st and 2nd reflected signals increases by +80.26% and +71.32% respectively. Moreover, the sensitivity of the porosity ϕ increases with frequency, as also shown in Table 1.

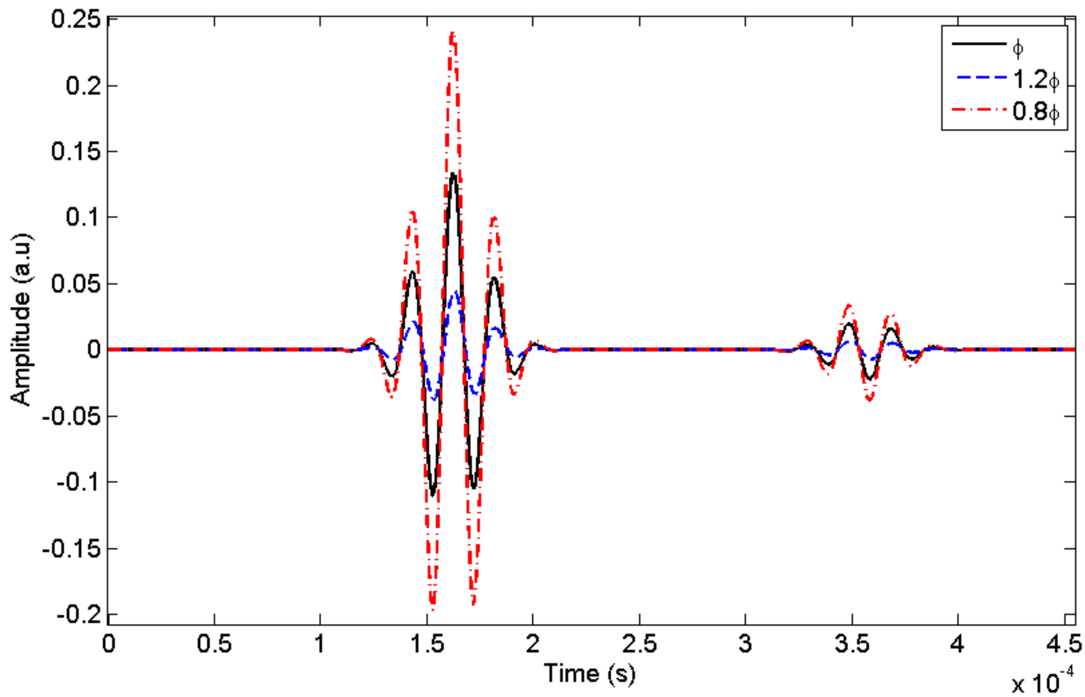


Figure 3: Sensitivity of porosity ϕ on the 1st and 2nd reflected signals at 50 kHz

b) Effect of Tortuosity α_∞ on the Reflected Signal

Figure 4 illustrates the sensitivity of tortuosity α_∞ on the 1st and 2nd reflected waves, for an excitation pulse of frequency 50 kHz. When the initial tortuosity value is increased by +20%, the amplitude of the 1st and 2nd reflected waves increases by +33.16% and 10.82%, respectively. Conversely, a decrease of -20% in tortuosity results in a decrease in the amplitude of the 1st and 2nd reflected waves by -40.98% and -27.47%, respectively. Notably, the impact of tortuosity is more pronounced on the 1st reflected signal than on the 2nd. Additionally, the sensitivity of tortuosity to the reflected signal increases with frequency, as detailed in Table 1.

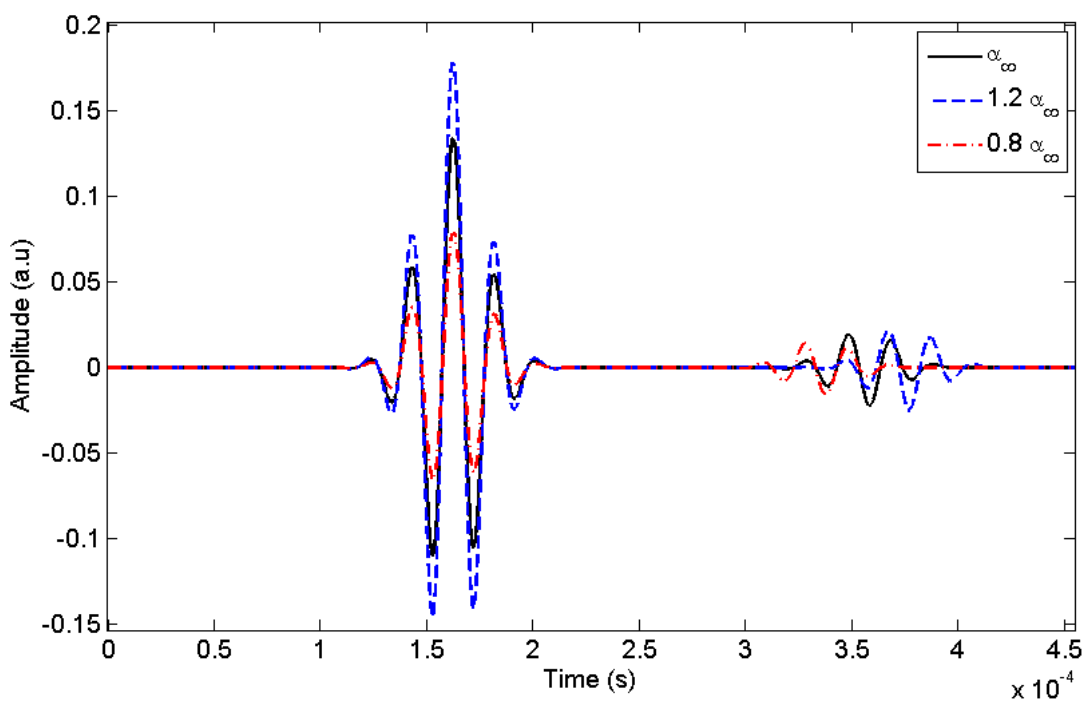


Figure 4: Sensitivity of Tortuosity α_∞ on the 1st and 2nd Reflected Waves

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

c) Effect of Viscous Characteristic Length Λ *on the Reflected Waves*

The impact of varying the viscous characteristic length on the 1st and 2nd reflected waves at high frequency is shown in Figure 5. With an excitation frequency of 50 kHz, a +20% change in Λ results in a -1.07% decrease in the amplitude of the first reflected wave and a 42.76% increase in the amplitude of the second reflected signal. Furthermore, as the frequency increases, the sensitivity of the viscous characteristic length decreases for the 1st reflected wave and increases for the 2nd reflected wave. Therefore, we can conclude that the viscous characteristic length has a relatively small influence on the 1st reflected wave at high frequency but a high sensitivity on the 2nd reflected wave.

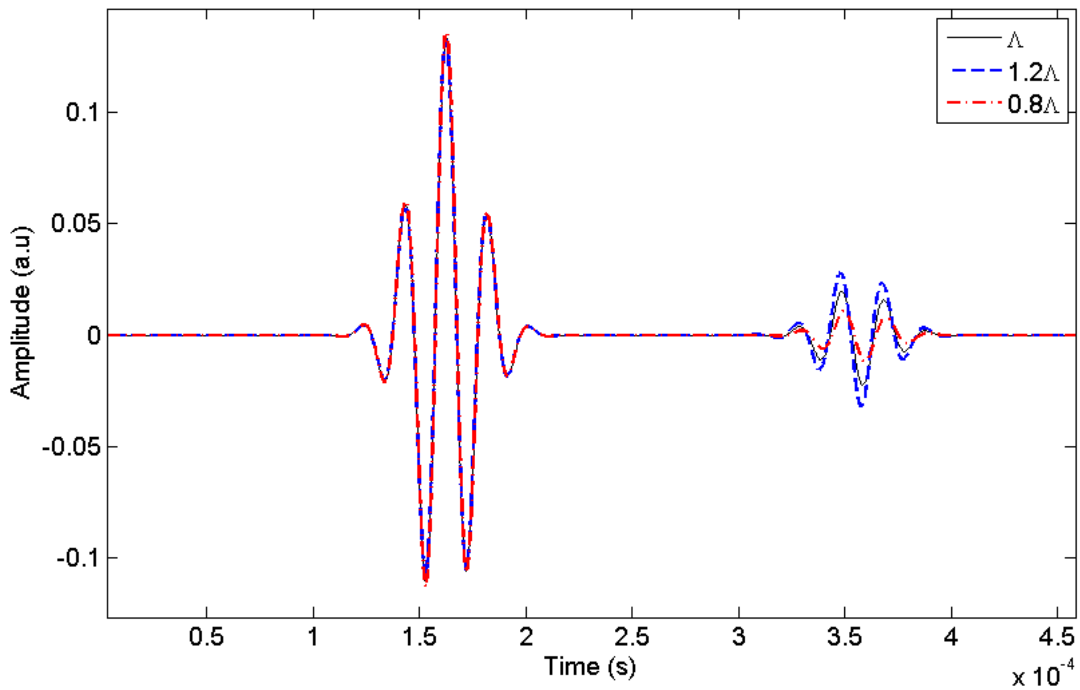


Figure 5: The sensitivity of the viscous characteristic length on the 1st and 2nd reflected waves at a frequency of 50 kHz

d) Effect of Thermal Characteristic Length Λ' *on the 1st and 2nd Reflected Waves*

The sensitivity of the thermal characteristic length Λ' on the two reflected waves at low ultrasonic frequency is shown in Figure 5 for a variation from +20% to -20% of its initial value. From Figure 6, we can see that for a frequency of 50 kHz, there is very little influence of the thermal characteristic length on the 1st reflected signal. An increase of +20% in Λ' results in a 0.17% increase in the modulus of the 1st reflected signal, while a variation of -20% results in a -0.26% decrease in the amplitude of the 1st reflected signal. However, the second reflected wave is more sensitive than the first. For a variation of +20% of Λ', the amplitude of the 2nd reflected wave increases by 3.29%. Moreover, according to Table 1, we observe that the sensitivity of the thermal characteristic length slightly decreases with frequency for the first reflection, while it increases for the second reflected wave.

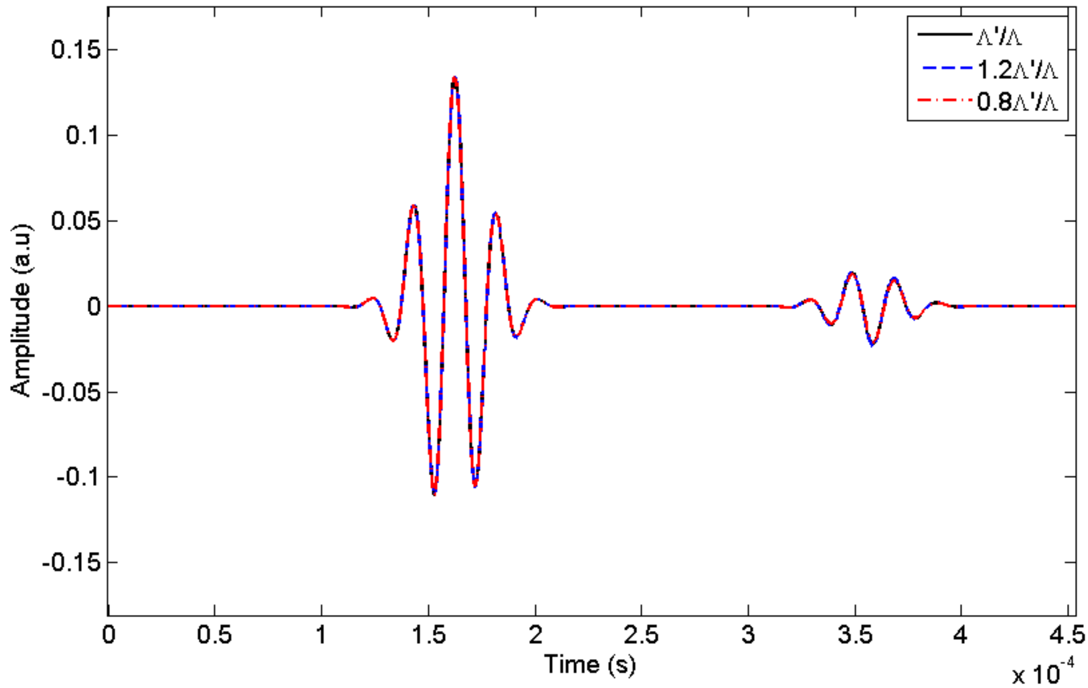


Figure 6: The sensitivity of the thermal characteristic length on the 1st and 2nd reflected waves for a frequency of 50 kHz

e) Effect of Viscous Shape Factor ξ *on the Reflected Signal*

The sensitivity of the shape factor ξ on the 1st and 2nd reflected waves in the Low-Frequency Ultrasound regime is presented in Figure 7. According to this figure, a -20% variation of ξ results in a regression of -0.26% and -4.89% in the amplitude of the 1st and 2nd reflected waves, respectively. For a variation of +20% of ξ, we observe a growth of +0.17% and 3.29% in the amplitude of the 1st and 2nd reflected waves. It can be concluded that the shape factor ξ has a weak influence on the first reflected wave but a strong sensitivity on the second wave in the low-frequency range of ultrasound. Moreover, the variation decreases for the first reflected wave and increases for the second wave as the frequency increases.

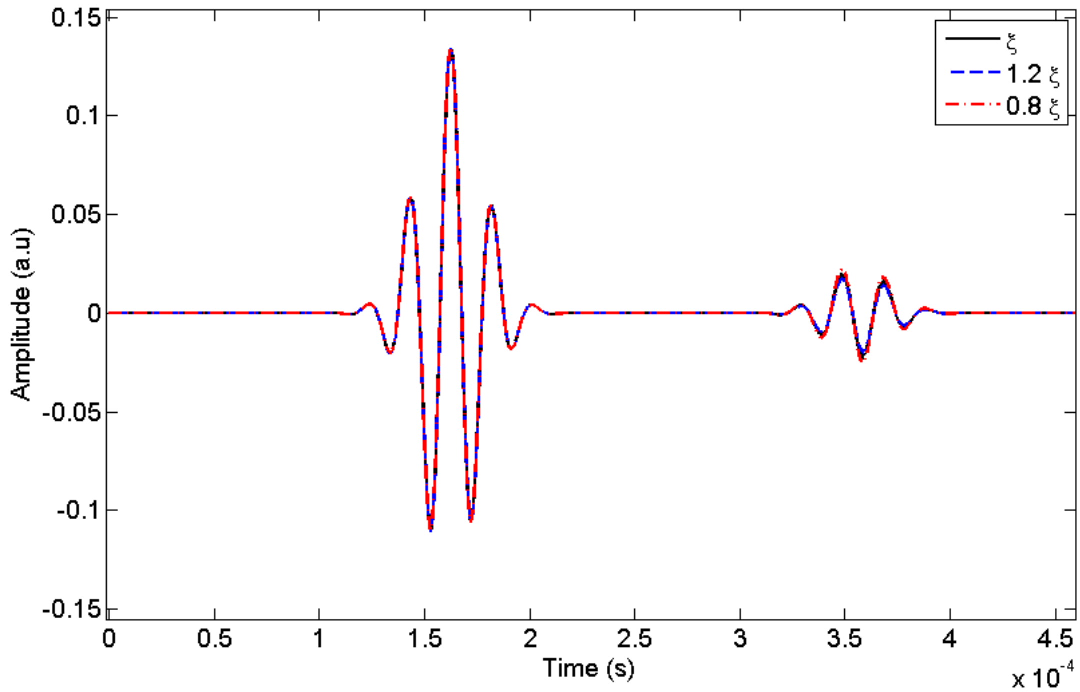


Figure 7: Sensitivity of the shape factor ξ on the 1st and 2nd reflected waves in the low-frequency ultrasound regime

f) Effect of Thermal Shape Factor ***ξ*** *on the Reflected Signal*

To investigate the impact of varying the thermal shape factor ξ' on the 1st and 2nd high-frequency reflected waves, Figure 8 is presented. At an excitation frequency of 50 kHz, a +20% variation in ξ/ξ' results in a +0.10% increase and a -1.91% attenuation in the amplitude of the 1st and 2nd reflected waves, respectively. This parameter exhibits a weak influence on the 1st reflected wave but a more significant effect on the 2nd reflected wave in the low-frequency ultrasound regime. Table 1 summarizes the effects of porosity, tortuosity, viscous and thermal characteristic lengths, as well as the two shape factors on the 1st and 2nd reflected waves in the low-frequency regime of ultrasound (50-120 kHz).

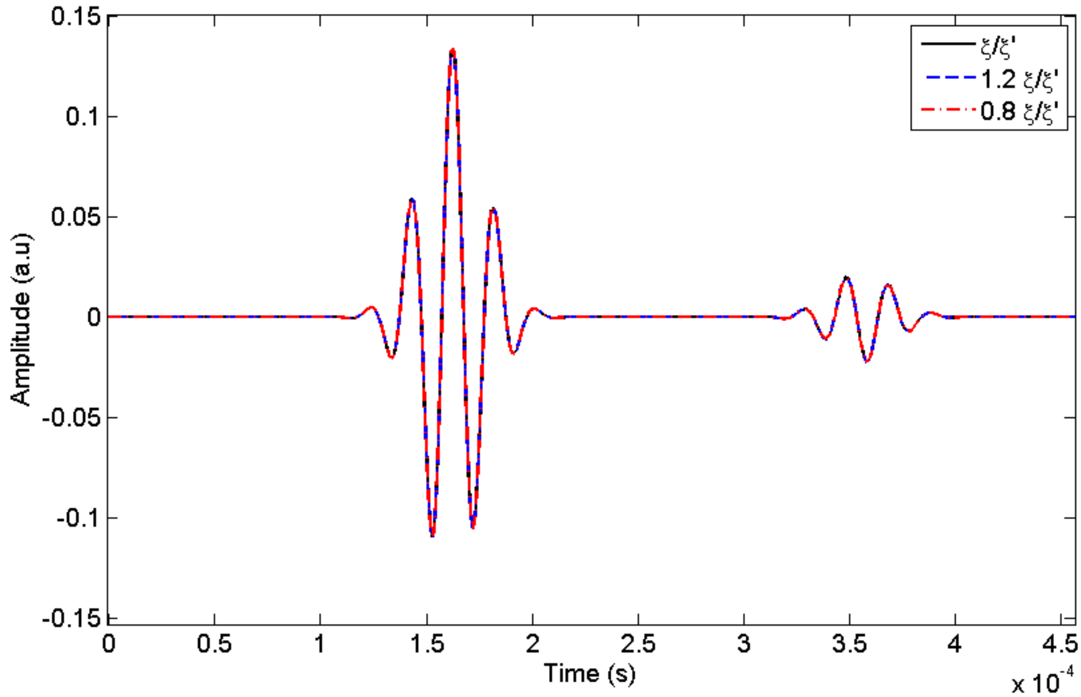


Figure 8: Sensitivity of thermal shape factor ξ' on the 1st and 2nd high-frequency reflected waves at an excitation frequency of 50 kHz

Based on the results presented in Table 1 and Figures 3-8, we can classify the sensitivity of each parameter on the reflected signal in the order of decreasing influence as presented in Table 2.

Table 1: Relative variation of the reflection coefficient $\frac{\Delta R}{R}$% corresponding to a variation of ± 20% of each physical parameter

		$\frac{\Delta R}{R}$ %			
		1st reflected wave		2nd reflected wave	
Parameters	Variations	50 kHz	120 kHz	50 kHz	120 kHz
Porosity φ	+20%	-66.84	-68.88	-65.06	-67.66
	-20%	80.26	82.30	71.32	74.12
Tortuosity α_∞	+20%	33.16	34.02	10.82	5.82
	-20%	-40.98	-42.10	-27.47	-24.77
Viscous characteristic length Λ (μm)	+20%	-1.07	-0.61	42.76	58.54
	-20%	1.77	0.93	-44.86	-52.95
Ratio thermal-viscous characteristic lengths (Λ'/Λ)	+20%	0.17	0.11	3.29	4.63
	-20%	-0.26	-0.16	-4.89	-6.57
Viscous shape factor ξ	+20%	0.10	0.19	-11.91	-12.16
	-20%	-0.97	-0.18	13.56	13.88
Ratio viscous-thermal shape factors ξ/ξ'	+20%	0.16	0.25	0.35	0.34
	-20%	-0.25	-0.38	-0.52	-0.51

Global Journal of Research in Engineering (I) XXIV Issue I Version I Year 2024

Table 2: Classification of the sensitivity of each parameter on the 1st and 2nd reflected signal

Parameters	ϕ	α_∞	Λ	ξ	Λ'	ξ'
Influence on the 1st reflected signal	+++	++	+	~	~~	~~~
Influence on the 2nd reflected signal	+++	+	++	+	~	~~

+: Considerable
~: Weak

IV. Conclusion

In conclusion, this study investigated the influence of physical parameters on the reflected wave at the 1st and 2nd interface of rigid porous media in the low-frequency ultrasound regime. The results show that porosity and tortuosity are the most influential parameters affecting the two reflected signals. This influence varies proportionally with the frequency and inversely with the porosity for both the 1st and 2nd reflected waves. For the 1st reflected wave, the influence varies proportionally with the tortuosity and frequency, while for the 2nd reflected wave; it varies proportionally with the tortuosity and inversely with the frequency. However, the impact of porosity and tortuosity on the 1st reflected wave is greater than on the 2nd reflected wave. Moreover, the viscous characteristic length has a small effect on the 1st reflected wave but a substantial influence on the 2nd reflected wave, exceeding the impact of tortuosity. On the other hand, the shape factor has a minor impact on the 1st reflected wave and a significant sensitivity on the 2nd reflection. Concerning the thermal parameters, the thermal characteristic length and the thermal shape factor have a negligible impact on the 1st reflected wave, while the sensitivity of the thermal characteristic length on the 2nd reflected wave is considerable.

The study's strength is that it analyzed the two reflected waves separately and independently, which allows us to treat each wave individually. These results could have important implications for the design and optimization of ultrasound-based techniques in various applications such as medical imaging, non-destructive testing, and materials characterization. However, further research may be necessary to investigate the effect of these parameters in other frequency ranges and porous medium structures.

Acknowledgment

This work was funded by The General Directorate of Scientific Research and Technological Development (DGRSDT) under grant number PRFU: B00L02UN440120200001, Algeria.

References Références Referencias

1. Day, G. S., Drake, H. F., Zhou, H. C., & Kitagawa, S. (2021). Evolution of porous materials from ancient remedies to modern frameworks. Communications Chemistry, 4(1), 114.
2. Khanafer, K., & Vafai, K. (2006). The role of porous media in biomedical engineering as related to magnetic resonance imaging and drug delivery. Heat and Mass Transfer, 42, 939-953.
3. Rashidi, S., Abolfazli Esfahani, J., & Karimi, N. (2018). Porous materials in building energy technologies—A review of the applications, modeling, and experiments. Renewable and Sustainable Energy Reviews, 91, 229-247.
4. Teruna, C., Rego, L., Avallone, F., Ragni, D., & Casalino, D. (2021). Applications of the Multilayer Porous Medium Modeling Approach for Noise Mitigation. Journal of Aerospace Engineering, 34(6), 04021022.
5. Johnson, D. L., Koplik, J., & Daschen, R. (1987). Theory of dynamic permeability and tortuosity in fluid-saturated porous media. Journal of Fluid Mechanics, 176, 379.
6. Melon, M., Lafarge, D., Castagnède, B., & Brown, N. (1995). Measurement of tortuosity of anisotropic acoustic materials. Journal of Applied Physics, 78, 4929.
7. Allard, J. F. (1993). Propagation of sound in porous media. Elsevier Applied Science Publishers LTD.
8. Lafarge, D., Lemarinier, P., Allard, J. F., & Tarnow, V. (1997). Dynamic compressibility of air in porous structures at audible frequencies. Journal of the Acoustical Society of America, 102(4), 1995-1997.
9. Mahiou, A., Sellami, I., & Sadouki, M. (2021). Sensitivity of transmitted low-frequency ultrasound physical parameters describing a rigid porous material. Proceedings of Meetings on Acoustics, 45, 045004.
10. Sadouki, M., Mahiou, A., & Souna, N. (2022). Effect of acoustic low-frequency ultrasound parameters on the reflected signal from a rigid porous medium. Proceedings of Meetings on Acoustics, 50(1), 045002.
11. Sadouki, M. (2018). Experimental measurement of tortuosity, viscous and thermal characteristic lengths of rigid porous material via ultrasonic

transmitted waves. Proceedings of Meetings on Acoustics, 35, 045005.

12. Sadouki, M. (2021). Experimental characterization of air-saturated porous material via low-frequency ultrasonic transmitted waves. Physics of Fluids, 33, 037102.
13. Biot, M. A. (1956). The theory of propagation of elastic waves in a fluid-saturated porous solid. Higher frequency range. Journal of the Acoustical Society of America, 28, 179.
14. Sadouki, M., & Hamadouche, F. Z. (2021). Impact of acoustic parameters on the reflected signal from a hypothetical human cancellous bone - Biot's theory application. Proceedings of Meetings on Acoustics, 45, 045003.
15. Sadouki, M., Fellah, M., Fellah, Z.E.A., & Ogam, E., Depollier, C. (2015). Ultrasonic propagation of reflected waves in cancellous bone: Application of Biot theory. ESUCB 2015, 6th European Symposium on Ultrasonic Characterization of Bone, 1-4, Corfu, Greece.
16. Zwikker, C., & Kosten, C. W. (1949). Sound absorbing materials. Elsevier, New York.
17. Sadouki, M. (2017). Experimental characterization of rigid porous material via the first ultrasonic reflected waves at oblique incidence. Journal of Applied Acoustics, 133, 64-72.

Global Journals Guidelines Handbook 2024

www.GlobalJournals.org

Memberships

Fellows/Associates of Engineering Research Council

FERC/AERC Memberships

Introduction

FERC/AERC is the most prestigious membership of Global Journals accredited by Open Association of Research Society, U.S.A (OARS). The credentials of Fellow and Associate designations signify that the researcher has gained the knowledge of the fundamental and high-level concepts, and is a subject matter expert, proficient in an expertise course covering the professional code of conduct, and follows recognized standards of practice. The credentials are designated only to the researchers, scientists, and professionals that have been selected by a rigorous process by our Editorial Board and Management Board.

Associates of FERC/AERC are scientists and researchers from around the world are working on projects/researches that have huge potentials. Members support Global Journals' mission to advance technology for humanity and the profession.

FERC

Fellow of Engineering Research Council

FELLOW OF ENGINEERING RESEARCH COUNCIL is the most prestigious membership of Global Journals. It is an award and membership granted to individuals that the Open Association of Research Society judges to have made a 'substantial contribution to the improvement of computer science, technology, and electronics engineering.

The primary objective is to recognize the leaders in research and scientific fields of the current era with a global perspective and to create a channel between them and other researchers for better exposure and knowledge sharing. Members are most eminent scientists, engineers, and technologists from all across the world. Fellows are elected for life through a peer review process on the basis of excellence in the respective domain. There is no limit on the number of new nominations made in any year. Each year, the Open Association of Research Society elect up to 12 new Fellow Members.

Benefits

To the Institution

Get letter of appreciation

Global Journals sends a letter of appreciation of author to the Dean or CEO of the University or Company of which author is a part, signed by editor in chief or chief author.

Exclusive Network

Get access to a closed network

A FERC member gets access to a closed network of Tier 1 researchers and scientists with direct communication channel through our website. Fellows can reach out to other members or researchers directly. They should also be open to reaching out by other.

Career | Credibility | Exclusive | Reputation

Certificate

Certificate, LoR and Laser-Momento

Fellows receive a printed copy of a certificate signed by our Chief Author that may be used for academic purposes and a personal recommendation letter to the dean of member's university.

Career | Credibility | Exclusive | Reputation

Designation

Get honored title of membership

Fellows can use the honored title of membership. The “FERC” is an honored title which is accorded to a person’s name viz. Dr. John E. Hall, Ph.D., FERC or William Walldroff, M.S., FERC.

Career | Credibility | Exclusive | Reputation

Recognition on the Platform

Better visibility and citation

All the Fellow members of FERC get a badge of "Leading Member of Global Journals" on the Research Community that distinguishes them from others. Additionally, the profile is also partially maintained by our team for better visibility and citation. All fellows get a dedicated page on the website with their biography.

Career | Credibility | Reputation

Future Work

Get discounts on the future publications

Fellows receive discounts on the future publications with Global Journals up to 60%. Through our recommendation programs, members also receive discounts on publications made with OARS affiliated organizations.

Career Financial

GJ Account

Unlimited forward of Emails

Fellows get secure and fast GJ work emails with unlimited storage of emails that they may use them as their primary email. For example, john [AT] globaljournals [DOT] org.

Career Credibility Reputation

Premium Tools

Access to all the Premium Tools

To take future researches to the zenith, fellows receive access to all the premium tools that Global Journals have to offer along with the partnership with some of the best marketing leading tools out there.

Financial

Conferences & Events

Organize Seminar/Conference

Fellows are authorized to organize symposium/seminar/conference on behalf of Global Journal Incorporation (USA). They can also participate in the same organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent. Additionally, they get free research conferences (and others) alerts.

Career Credibility Financial

Early Invitations

Early invitations to all the symposiums, seminars, conferences

All fellows receive the early invitations to all the symposiums, seminars, conferences and webinars hosted by Global Journals in their subject.

Exclusive

Publishing Articles & Books

Earn 60% of sales proceeds

Fellows can publish articles (limited) without any fees. Also, they can earn up to 70% of sales proceeds from the sale of reference/review books/literature/publishing of research paper. The FERC member can decide its price and we can help in making the right decision.

Exclusive Financial

Reviewers

Get a remuneration of 15% of author fees

Fellow members are eligible to join as a paid peer reviewer at Global Journals Incorporation (USA) and can get a remuneration of 15% of author fees, taken from the author of a respective paper.

Financial

Access to Editorial Board

Become a member of the Editorial Board

Fellows may join as a member of the Editorial Board of Global Journals Incorporation (USA) after successful completion of three years as Fellow and as Peer Reviewer. Additionally, Fellows get a chance to nominate other members for Editorial Board.

Career Credibility Exclusive Reputation

And Much More

Get access to scientific museums and observatories across the globe

All members get access to 5 selected scientific museums and observatories across the globe. All researches published with Global Journals will be kept under deep archival facilities across regions for future protections and disaster recovery. They get 10 GB free secure cloud access for storing research files.

ASSOCIATE OF ENGINEERING RESEARCH COUNCIL

ASSOCIATE OF ENGINEERING RESEARCH COUNCIL is the membership of Global Journals awarded to individuals that the Open Association of Research Society judges to have made a 'substantial contribution to the improvement of computer science, technology, and electronics engineering.

> The primary objective is to recognize the leaders in research and scientific fields of the current era with a global perspective and to create a channel between them and other researchers for better exposure and knowledge sharing. Members are most eminent scientists, engineers, and technologists from all across the world. Associate membership can later be promoted to Fellow Membership. Associates are elected for life through a peer review process on the basis of excellence in the respective domain. There is no limit on the number of new nominations made in any year. Each year, the Open Association of Research Society elect up to 12 new Associate Members.

To the Institution

Get letter of appreciation

Global Journals sends a letter of appreciation of author to the Dean or CEO of the University or Company of which author is a part, signed by editor in chief or chief author.

Exclusive Network

Get access to a closed network

A AERC member gets access to a closed network of Tier 1 researchers and scientists with direct communication channel through our website. Associates can reach out to other members or researchers directly. They should also be open to reaching out by other.

Career | Credibility | Exclusive | Reputation

Certificate

Certificate, LoR and Laser-Momento

Associates receive a printed copy of a certificate signed by our Chief Author that may be used for academic purposes and a personal recommendation letter to the dean of member's university.

Career | Credibility | Exclusive | Reputation

Designation

Get honored title of membership

Associates can use the honored title of membership. The “AERC” is an honored title which is accorded to a person’s name viz. Dr. John E. Hall, Ph.D., AERC or William Walldroff, M.S., AERC.

Career | Credibility | Exclusive | Reputation

Recognition on the Platform

Better visibility and citation

All the Associate members of AERC get a badge of "Leading Member of Global Journals" on the Research Community that distinguishes them from others. Additionally, the profile is also partially maintained by our team for better visibility and citation. All associates get a dedicated page on the website with their biography.

Career | Credibility | Reputation

Future Work

Get discounts on the future publications

Associates receive discounts on the future publications with Global Journals up to 60%. Through our recommendation programs, members also receive discounts on publications made with OARS affiliated organizations.

Career Financial

GJ Account

Unlimited forward of Emails

Associates get secure and fast GJ work emails with unlimited storage of emails that they may use them as their primary email. For example, john [AT] globaljournals [DOT] org..

Career Credibility Reputation

Premium Tools

Access to all the premium tools

To take future researches to the zenith, associates receive access to all the premium tools that Global Journals have to offer along with the partnership with some of the best marketing leading tools out there.

Financial

Conferences & Events

Organize seminar/conference

Associates are authorized to organize symposium/seminar/conference on behalf of Global Journal Incorporation (USA). They can also participate in the same organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent. Additionally, they get free research conferences (and others) alerts.

Career Credibility Financial

Early Invitations

Early invitations to all the symposiums, seminars, conferences

All associates receive the early invitations to all the symposiums, seminars, conferences and webinars hosted by Global Journals in their subject.

Exclusive

Publishing Articles & Books

Earn 30-40% of sales proceeds

Associates can publish articles (limited) without any fees. Also, they can earn up to 30-40% of sales proceeds from the sale of reference/review books/literature/publishing of research paper.

Exclusive Financial

Reviewers

Get a remuneration of 15% of author fees

Associate members are eligible to join as a paid peer reviewer at Global Journals Incorporation (USA) and can get a remuneration of 15% of author fees, taken from the author of a respective paper.

Financial

And Much More

Get access to scientific museums and observatories across the globe

All members get access to 2 selected scientific museums and observatories across the globe. All researches published with Global Journals will be kept under deep archival facilities across regions for future protections and disaster recovery. They get 5 GB free secure cloud access for storing research files.

Associate	Fellow	Research Group	Basic
$4800 **lifetime designation**	$6800 **lifetime designation**	$12500.00 **organizational**	APC **per article**
Certificate, LoR and Momento **2** discounted publishing/year **Gradation** of Research **10** research contacts/day **1 GB** Cloud Storage **GJ** Community Access	**Certificate,** LoR and Momento **Unlimited** discounted publishing/year **Gradation** of Research **Unlimited** research contacts/day **5 GB** Cloud Storage **Online Presense** Assistance **GJ** Community Access	**Certificates,** LoRs and Momentos **Unlimited** free publishing/year **Gradation** of Research **Unlimited** research contacts/day **Unlimited** Cloud Storage **Online Presense** Assistance **GJ** Community Access	**GJ** Community Access

Preferred Author Guidelines

We accept the manuscript submissions in any standard (generic) format.

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

Alternatively, you can download our basic template from https://globaljournals.org/Template.zip

Authors should submit their complete paper/article, including text illustrations, graphics, conclusions, artwork, and tables. Authors who are not able to submit manuscript using the form above can email the manuscript department at submit@globaljournals.org or get in touch with chiefeditor@globaljournals.org if they wish to send the abstract before submission.

Before and during Submission

Authors must ensure the information provided during the submission of a paper is authentic. Please go through the following checklist before submitting:

1. Authors must go through the complete author guideline and understand and *agree to Global Journals' ethics and code of conduct,* along with author responsibilities.
2. Authors must accept the privacy policy, terms, and conditions of Global Journals.
3. Ensure corresponding author's email address and postal address are accurate and reachable.
4. Manuscript to be submitted must include keywords, an abstract, a paper title, co-author(s') names and details (email address, name, phone number, and institution), figures and illustrations in vector format including appropriate captions, tables, including titles and footnotes, a conclusion, results, acknowledgments and references.
5. Authors should submit paper in a ZIP archive if any supplementary files are required along with the paper.
6. Proper permissions must be acquired for the use of any copyrighted material.
7. Manuscript submitted *must not have been submitted or published elsewhere* and all authors must be aware of the submission.

Declaration of Conflicts of Interest

It is required for authors to declare all financial, institutional, and personal relationships with other individuals and organizations that could influence (bias) their research.

Policy on Plagiarism

Plagiarism is not acceptable in Global Journals submissions at all.

Plagiarized content will not be considered for publication. We reserve the right to inform authors' institutions about plagiarism detected either before or after publication. If plagiarism is identified, we will follow COPE guidelines:

Authors are solely responsible for all the plagiarism that is found. The author must not fabricate, falsify or plagiarize existing research data. The following, if copied, will be considered plagiarism:

- Words (language)
- Ideas
- Findings
- Writings
- Diagrams
- Graphs
- Illustrations
- Lectures

- Printed material
- Graphic representations
- Computer programs
- Electronic material
- Any other original work

Authorship Policies

Global Journals follows the definition of authorship set up by the Open Association of Research Society, USA. According to its guidelines, authorship criteria must be based on:

1. Substantial contributions to the conception and acquisition of data, analysis, and interpretation of findings.
2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

Changes in Authorship

The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

Copyright

During submission of the manuscript, the author is confirming an exclusive license agreement with Global Journals which gives Global Journals the authority to reproduce, reuse, and republish authors' research. We also believe in flexible copyright terms where copyright may remain with authors/employers/institutions as well. Contact your editor after acceptance to choose your copyright policy. You may follow this form for copyright transfers.

Appealing Decisions

Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

Declaration of funding sources

Global Journals is in partnership with various universities, laboratories, and other institutions worldwide in the research domain. Authors are requested to disclose their source of funding during every stage of their research, such as making analysis, performing laboratory operations, computing data, and using institutional resources, from writing an article to its submission. This will also help authors to get reimbursements by requesting an open access publication letter from Global Journals and submitting to the respective funding source.

Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

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 Engineering Research Paper

Techniques for writing a good quality engineering 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 research engineering 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:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o 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:

- o Explain the value (significance) of the study.
- o 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.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o 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 Above 200 words	No specific data with ambiguous information 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

Index

save our planet

Global Journal of Researches in Engineering

Visit us on the Web at www.GlobalJournals.org | www.EngineeringResearch.org
or email us at helpdesk@globaljournals.org

ISSN 9755861