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Conceptualizing the fluid suction on an oscillatory MHD channel flow with heat transfer

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Abstract

One of the most significant areas of research that has been conducted all over the world over the past 10 years has been the investigation of materials on the micro and nanoscales. The advancements that have been made in this field have resulted in the creation of a great deal of engineering gadgets and systems that are on the microscale and nanoscale. Three years ago, Kuo *et al*. Microflows are the term used to describe the flow of fluid through microchannels, which are typically involved in these devices and systems. Examples of applications include mechanisms for the distribution of drugs. Su and Lin (2004), Nakane *et al*. (2005), and other researchers have developed biological sensing and energy conversion systems. Since the functional properties of the system are dependent on the flow behaviour of the fluid inside the system, the study of microflows is drawing an increasing amount of attention from the research community.

Keywords: Fluid, dynamics, heat transfer, viscous fluids

Introduction

One of the most significant areas of research that has been conducted all over the world over the past 10 years has been the investigation of materials on the micro and nanoscales. The advancements that have been made in this field have resulted in the creation of a great deal of engineering gadgets and systems that are on the microscale and nanoscale. Three years ago, Kuo *et al*. Microflows are the term used to describe the flow of fluid through microchannels, which are typically involved in these devices and systems. Examples of applications include mechanisms for the distribution of drugs. Su and Lin (2004) [11], Nakane *et al*. (2005) [12], and other researchers have developed biological sensing and energy conversion systems. Since the functional properties of the system are dependent on the flow behaviour of the fluid inside the system, the study of microflows is drawing an increasing amount of attention from the research community. This is being done to derive a better knowledge of the mechanism of microflows and to design better models. Both the incompressible continuity equation and the Navier–Stokes equations are the governing field equations for the flow of incompressible Newtonian fluids. A boundary condition must also be put on the field equations to complete the process. The no-slip condition is utilised. As a result of the fact that it is a hypothesis rather than a condition that is derived from a principle of physics, the validity of this hypothesis has been the subject of ongoing discussion in the scientific literature. According to Wu and Wiwatanapataphee (2008) [13].

Evidences of slip flow of a fluid on a solid surface have been recorded in a variety of different combinations. For instance, conducted research on the flow of polymer solutions in porous media. Their findings demonstrated that the apparent viscosity of the fluids near the wall is lower than that of the fluids in the bulk. As a result, the fluids can demonstrate the phenomenon of apparent slip on the wall. To investigate flow problems involving Newtonian and non-Newtonian fluids with Navier slip boundary condition, a number of different experiments have been carried out. Additionally, there have been several attempts made to develop alternate equations for the purpose of determining the slip length, as stated by Yang and Zhu (2006) [14]. Even while accurate and numerical solutions to a variety of flow issues involving Newtonian fluids have been developed and are available in the literature, there are only a relatively small number of exact solutions for the slip case that are available in the literature. A number of steady state and transient slip solutions for the flows that occur in a pipe, a channel, and an annulus have been developed with relative ease in recent times. Recently, Wu *et al*. conducted research on pressure gradient induced transient flows of incompressible Newtonian liquids in micro-annuals while a Navier slip boundary condition was applied. According to Wu and Wiwatanapataphee (2008) [13], in order to determine the exact solutions, they make use of the Fourier series in time and the Bessel functions in space. We provide a new finding for the transient flow of Newtonian fluids in rectangular microtubes with a slip boundary condition in this paper. The result is presented in the context of the paper.

The transportation of fluids and heat are fundamental parts of engineering and physics, and they play an important part in a variety of industrial processes as well as applications that are used in everyday life. Understanding the behaviour of fluids and the way heat is transferred between various systems requires a thorough understanding of fluid dynamics and heat transfer, both of which are crucial fields of study. During this in-depth investigation, we will investigate the fundamentals, theories, and applications of fluid and heat transfer. We will also investigate the interconnections between these two types of transfer and the significance they hold in a variety of industries.

Fluid mechanics is a subfield of physics that examines the behaviour of fluids, including gases and liquids, as well as the forces that are exerted on them. A fundamental aspect of the study of fluid dynamics is the comprehension of the motion and deformation of fluids under a variety of different situations. In the field of fluid mechanics, some of the most important ideas are viscosity, turbulence, and the equations that control fluid flow, such as the Navier-Stokes equations. There are several different businesses that rely heavily on fluids, including the aerospace industry, the automobile industry, and environmental engineering.

Transferring heat, on the other hand, refers to the process by which thermal energy is transferred from one system to another. The basic mechanisms of heat transport are conduction, convection, and radiation. Conduction is the most common technique. In contrast to convection, which refers to the movement of heat through a fluid (either a liquid or a gas), conduction is the process by which heat is transferred through a substance. In the process of radiating, electromagnetic waves that carry thermal energy are released into the atmosphere. When it comes to constructing effective heating and cooling systems, as well as optimising thermal processes in industries such as manufacturing and energy production, having a solid understanding of various modalities of heat transmission is necessary.

The principle of the conservation of mass and energy is one of the fundamental laws that control the transport of heat and molecules of fluid. The continuity equation is a symbolic representation of the principle of mass conservation, which states that the mass that enters a system must be equal to the mass that exits it. There is no such thing as the creation or destruction of energy, according to the first law of thermodynamics, which is sometimes referred to as the principle of energy conservation. Energy can only be moved or changed from one form to another. These concepts offer a strong basis for analysing and resolving issues that are associated with the transport of heat and fluids.

During their work in the field of fluid dynamics, researchers and engineers frequently face difficulties that are associated with turbulence. Turbulent flow is characterised by the chaotic and uneven motion of fluid particles, which results in increased mixing and heat transmission. Understanding and being able to forecast turbulence is absolutely necessary in order to build fluid systems that are both efficient and stable. It is usual practice to make use of the Reynolds number, which is a dimensionless parameter, in order to forecast the transition from laminar flow to turbulent flow.

Literature review

Ibrahim, Syed & Khan Marwat, Dil Nawaz (2023) [1] Free convection, wind, gravity, pressure gradients, side wall motion, and MHD are all examples of forces that can cause fluid to flow. Other examples include pressure gradients. In this study, the behaviour of viscus fluid flow with streamwise vortices in a sinusoidal wavy meandering channel of non-uniform radius is investigated in order to investigate the impact that meanders have on heat transmission. Through the utilisation of innovative transformations and the regular perturbation approach, the study reduces the equations that regulate the motion and energy of the fluid while it is flowing. According to the findings of the study, reducing the wavelength results in flow separation close to the channel surface. This was discovered by the plotting of graphs for various parameter values, such as Pr, Re, and Ec among others. The stream, on the other hand, travels forward with a rapid meander disruption, which causes the flow to become rectilinear and independent of centrifugal forces that are generated by the vertex. Within the scope of this study, a stream function is determined by utilising recognised and standard relations. The patterns of fluid flow and the behaviour of temperature distribution are displayed in a variety of graphs, which highlights the enormous impact that meanders have on fluid flow.

Adibi, Tohid & Adibi, Omid & Athari, Hassan (2023) [2] Heat exchangers are utilised extensively across a variety of industries and technological application areas. As a consequence of this, optimising heat exchangers has been a primary priority for researchers. The utilisation of a wavy wall in the presence of various types of heat transfer mechanisms has not been examined, even though several research have been carried out with the purpose of enhancing the rate of heat transmission. Therefore, the purpose of this study is to analyse the behaviour of fluid in a horizontal channel that has a cavity and a hot wall that is wavy using mixed heat transfer. The flow of fluid in the channel is supposed to be laminar, and the equations that regulate the flow, which include continuity, momentum, and energy, are all solved numerically. Through the utilisation of a first-order multi-dimensional characteristic based scheme in conjunction with a fifth-order Runge-Kutta approach, the numerical solution is stabilised. In this study, the effects of different Richardson numbers, Reynolds numbers, wave amplitude, wavelength, channel height, and cavity width on flow and heat transfer are investigated. When the Reynolds number, wave amplitude, and cavity width are all increased, the mean Nusselt number is found to grow. On the other hand, the mean Nusselt number drops when the Richardson number, wavelength, and channel height are increased. According to the calculations, the Nusselt number ranges from 0.7 to 27.09, with 0.7 being the minimum and 27.09 being the greatest. Although the Richardson number is 10,000 times greater, the Nusselt number has only increased by forty percent in the deeper parts of the cavity. The number, however, rises to 130% when one descends to lower depths. The channel height and cavity width are therefore two factors that have a considerable impact on the mean Nusselt number. When it comes to the mean Nusselt number, the influence of wave amplitude is twice as significant as that of wavelength.

Alqarni, Mohanad & Ali, Abid & Memon, Muhammad (2023) [3] In recent studies on natural and forced convection, the features of nanomaterials have received a substantial amount of interest. The forced convection features of ternary nanofluids within convergent and divergent channels are the primary focus of this research project. Titanium oxide (TiO 2), zinc oxide (ZnO), and silver are all suspended in water, which acts as the base fluid. The ternary nanofluid is composed of these three elements. The numerical simulations for stable and incompressible two-dimensional flow were carried out with the help of COMSOL Multiphysics 6.0, which is a dependable piece of software for finite element analysis. Within the scope of the investigation on forced convection, Reynolds numbers ranging from 100 to 800 were utilised. We also investigated the channel height divided by the height of the convergent or diverging section, which is known as the aspect ratio. The ratios that we investigated were -0.4, -0.2, 0, 0.2, and 0.4. Based on our observations, we discovered that the average outlet temperature only increased when the Reynolds number increased when the aspect ratio was equal to 0.4. Other aspect ratios, on the other hand, showed a decrease in average temperatures as the Reynolds number decreased. Furthermore, there was a considerable rise of one hundred percent in the average Nusselt number when the Reynolds number climbed from one hundred to eight hundred and the total volume percentage of the ternary nanofluids ranged from one hundred three to fifteen. For the sake of clarity, this article provides a concise presentation of crucial facts, including the numerical nature of the study, the fluid properties (constant-property fluid), and the methodology (COMSOL Multiphysics 6.0, finite element analysis). It is important to highlight the most important findings so that readers can quickly understand the most important results. In order to facilitate a full comprehension of the research, these particulars are also adequately described in the text. It is possible that the utilisation of this developing phenomena could have enormous potential in a variety of applications, ranging from the development of heat exchangers that are extremely efficient to the optimisation of thermal energy systems. In circumstances when efficient cost management in thermal production is an essential factor to take into consideration, this phenomena can be utilised to their full potential.

Abbas, Shajar & Ahmad, Mushtaq (2023) [4] The fundamental objective of the present investigation is to create and improve a flow model of Brinkman flow via a channel consisting of two vertical plates that are parallel to one another. By utilising the more sophisticated and generalised definition of the Prabhakar operator, the constitutive relations for mass and heat fluxes may be generalised. This is accomplished while maintaining the same level of precision. Due to the fact that the Prabhakar operator utilised the three parameters of the Mittag-Leffler mapping as a kernel of an operator, this derivative is considered to be a more general and sophisticated fractional derivative in comparison to the other fractional derivatives. It is possible to obtain the governing equations for this flow model by combining the generalised constitutive laws for heat and mass fluxes that were mentioned earlier. In addition, in order to acquire a more comprehensive and in-depth understanding of the behaviour of flow, the derived governing equations are converted into dimensionless form by incorporating appropriate relations for the variables that are involved. The precise answer for the temperature, concentration, and velocity of the flow is something that we are interested in obtaining. In order to accomplish this objective, the Laplace transform is utilised to prescribe partial differential governing equations for temperature, velocity, and concentration. It is possible to perform the inverse of the Laplace transform by utilising the technique developed by Stehfest and Tzou to change the equations that determine temperature, velocity, and concentration simultaneously. Graphical representations are used to display the outcomes of the inversion process that are produced by the algorithm developed by Stehfest and Tzou. Additionally, a graphical explanation of the parametric analysis of the research results is provided with the explanation. Additionally, the field variables, which include temperature, velocity, and concentration, are presented in certain graphs for the aim of achieving this goal. As a result of the parametric analysis, it has been determined that increasing the values of the fractional parameter results in an increase in velocity, while simultaneously observing a trend towards a decrease in concentration and temperature for a brief period of time.

Ene, Remus & Pop, Nicolina & Badarau, Rodica (2023) [5] At the same time as thermal effects are taken into consideration, the purpose of this study is to investigate dual analytic approximation solutions that are both effective and accurate. Using a modified version of the Optimal Homotopy Asymptotic Method (OHAM), an analytical investigation of the heat and mass transfer problem in a viscous fluid flow is carried out. It is possible to reduce the motion equations to a set of nonlinear ordinary differential equations by the utilisation of similarity transformations. The numerical results showed that there are dual analytic approximation solutions within the mass transfer problem. This was discovered from the findings of the numerical analysis. For the first approximate and the corresponding dual solution, respectively, the fluctuation of the physical parameters (the Prandtl number and the temperature distribution parameter) along the temperature profile is investigated analytically and graphically. This is done for both solutions. The proposed method has the advantage of just requiring one iteration to produce the dual analytical answers, which is the primary advantage of the method. The solutions that have been presented are efficient, accurate, and in good agreement with the numerical results that correspond to them. These results have importance for further engineering applications of heat and mass transport problems.

The boiling heat transfer that occurs in the flow of water through an asymmetrically heated horizontal rectangular mini-channel is the topic of discussion in this journal article. Through the use of glue, three transparent glass plates and a block of copper were assembled to form the mini-channel. For the purpose of determining the local values of the void fraction, the variable along the length of the mini-channel two-phase flow structures was recorded through the glass window. The copper block was equipped with four resistance heaters that were powered by direct current. These heaters were responsible for producing the heat that enabled the flow to begin boiling inside the channel. The following were measured over the course of the experiment: the volumetric flow rate of water, the inlet pressure along with the pressure drop, the temperature of the water at the inlet and outlet, the temperatures of the copper block at three different sites throughout its body, as well as the voltage and current that was given to the heaters. During the process of developing the mathematical model of heat transfer in certain components of the measurement module, it was believed that the fluid flow would be stationary and laminar, with low Reynolds numbers. The relevant energy equations were used to describe the temperature distributions in the copper block and the flowing water. The Laplace equation was used to describe the temperature distributions in the copper block, and the Fourier–Kirchhoff equation with parabolic fluid velocity was used to explain the temperature distributions in the flowing water.

Effect of fluid suction on an oscillatory MHD channel flow with heat transfer

Most people consider magnetohydrodynamics, often known as MHD, to be the science that studies the motion of electrically conducting fluids, such as plasmas and liquid metals, when they are subjected to electromagnetic fields. In these kinds of circumstances, the field is altered by the currents that are formed in the fluid as a result of induction, which ultimately leads to the coupling of the field equations with the dynamics equations. MHD is particularly concerned with conductive fluids, regardless of whether they are liquid or gaseous, and requires the acceptance of certain idealisations, which are simplified assumptions. The studies of MHD channel flows are of great interest to many professionals because of the significant role that they play in the field of industrial applications. Some examples of these applications include nuclear reactors, MHD generators, and MHD pumps. The works of Chang and Yen (1965) [15], Cowling (1957) [16], Hughes and Young (1960) [17], Sutton and Sherman (1965) [18], Sengupta (2015) [15], and Oahimire and Olajuwon (2014) [20], to name just a few, contain a multitude of significant works on a variety of subjects pertaining to MHD scenarios. Fluid suction is an essential component in the management of laminar flow and has numerous applications in a variety of fields, including rocket science, vehicle engineering, and aeronautical engineering, among others. Through their respective publications, a number of researchers, including Muhuri (1963) [21], Rathy (1963) [22], Verma and Bansal (1966) [23], Govindarajulu (1976) [24], as well as Dessie and Kishan (2014) [25], have brought attention to the significance of laminar flow regulation through the utilisation of fluid suction. In engineering applications such as turbines and in physiological investigations such as flow of bio-fluid (blood, blood plasma, etc.), time-dependent flows, also known as unstable or transient flows, are of enormous significance.

It is possible to experience channel flows in a variety of contexts, including the natural drainage of water through river systems, the flow of water in canals and sewers, the flow of water in pipes, and so on. The research of subsurface water resources, oil and natural gas reserves, the flow of fluid in geothermal zones, chemical purification procedures, cooling techniques in electronic devices, and other related topics are all areas that can benefit greatly from the modelling of channel flows through porous surfaces. It should come as no surprise that engineering geophysics, chemical engineering, electronics, and other fields also have a significant interest in channel flows. In this context, it is possible to refer to the works of Jain and Gupta (2006) [26] as well as Ahmed and Barua (2010) [27]. When the combined influence of magnetic field and viscous thermal energy dissipation is considered for the purpose of investigating high speed flows, the analysis of MHD channel flow problems becomes meaningful. Researchers such as Hitesh Kumar (2009) [28], Soundalgekar and Bhatt (1976) [29], Cookey Israel (2003) [30], Ahmed and Kalita (2010) [27], and Manjulatha *et al*. (2014) [31], to name a few, have attempted to investigate high speed flows in this manner. Our current research aims to enhance the work that Soundalgekar and Bhatt (1976) [29] have done by taking into consideration the impact that suction and injection have on the flow and transport characteristics. This is the primary purpose of our study. The problem of a transient channel flow with heat transfer has been attempted to be studied analytically in the work that is currently being presented. The channel in question is bordered by two infinite parallel porous walls. To this pressure-driven flow, we suppose that there is an oscillating pressure gradient. There is a magnetic field that is uniformly applied to the flow, and it is normal to the walls. The equations that regulate our flow and transport model are solved by applying the regular perturbation technique. This is done after the requisite idealisation of the momentum and energy equations has been completed. In this study, the flow and heat transfer are studied and visually presented, with particular attention paid to the effects of magnetic field, suction velocity, viscous dissipation, Reynolds number, and Prandtl number, among other factors.

MHD Casson fluid flow, heat and mass transfer in a vertical channel with stretching walls

The prediction of space weather, the dampening of turbulent oscillations in semiconductor melts during crystal development, and the measuring of flow rates of beverages in the food sector are all examples of conditions that can give rise to MHD difficulties. As a result of their uses in MHD generators, accelerators, and blood flow measurements, MHD channel flows have gained a large amount of theoretical and practical importance. There are several applications in the fields of engineering and industry for the investigations that are conducted for the purpose of studying MHD flow and heat transfer of non-Newtonian fluid flows that are generated by a stretching sheet. As an illustration, the sheet is occasionally stretched during the process of extruding moulton polymers via a slit die in order to make plastic sheets. In these kinds of procedures, the pace of cooling is the primary factor that determines the characteristics of the finished product. The rate of cooling can be controlled if such a sheet is drawn in an electrically conducting Casson fluid while being subjected to the effect of a magnetic field. This allows for the end product to be obtained with the quality that is desired. As a result of Crane's investigation into the steady two-dimensional incompressible boundary layer flow of a viscous fluid, which is generated by an elastic flat sheet that moves in its plane with velocity varying linearly with distance from a fixed point due to the application of a uniform stress, a closed form solution was obtained. MHD boundary layer flow of a viscous fluid across a stretching surface was analysed by Misra. The work was conducted in the presence of a uniform transverse magnetic field with Hall currents. When dealing with issues involving the convective heat transfer of atoms and molecules, the study of mass transfer is an important topic to investigate. There is a phenomena known as mass transfer that occurs during the evaporation of water and the separation of compounds during distillation processes. Mass transfer with chemical reaction, on the other hand, has uses in the chemical industry as well as the hydrometallurgical industry. Some chemical reactions are homogeneous, whereas others are heterogeneous. Both types of reactions are possible. The reaction that takes place at the interface as a single phase volume reaction is what determines the exact nature of the reaction. Within the context of chemical reactions, a number of researchers investigated the challenges that arise when mass transfer occurs.

Blood has been modelled as a Newtonian viscous incompressible fluid, and several mathematical models have been constructed to simulate the flow of blood via arteries. The non-Newtonian nature of blood can be attributed to the fact that it is composed of cells suspended in plasma, which is called an aqueous solution. Experiments carried out on blood found that at a hematocrit level of forty percent, blood has a limited yield stress of 0.04 dynes per square centimetre. It has been discovered that the influence of yield stress is severe when blood flows through arteries that are smaller in size. It was demonstrated that the Casson's equation provided the best fit for the experimental data on the flow properties of the substance when the shear rate was low (less than as well as when the hematocrit was lower than forty percent). Casson's fluid model was able to accurately represent the flow of blood over a wide range of shear rates, particularly at low shear rates (less than), according to the results of a number of experiments that were carried out on blood with varying hematocrits, anticoagulants, and temperatures. These studies demonstrated that the flow of blood could be described by the model. Elbashbeshy conducted research on the temperature and mass transfer that occurred along a vertical plate while a magnetic field was present. In the presence of a chemical reaction, Anjalidevi and Kandasamy investigated on the heat and mass transfer that occurs during sustained laminar flow along a semi-infinite horizontal plate. There are applications in blood flow that make it possible to comprehend the rate of dispersion of medications and nutrients. These applications are made possible by the chemical reaction that occurs during the transport of solutes. Since blood is an electrical conductor, it is quite probable that a magnetic field will alter the velocity of blood flow inside the circulatory system. Apparently, the heat reactivity of living tissues is influenced by the flow of blood through those tissues. Several factors, including the shape of the blood arteries and the variation in blood flow, are responsible for the transfer of heat between living tissues and the blood. In their study, Craciunescu and Clegg investigated the oscillatory flow of heat transfer in blood flow while taking into consideration the rigidity of blood vessels. When conducting their research on bio heat transmission, Weinbaun and Jiji took into consideration the various types of blood walls. In his research, Cavaliere investigated the use of heat to treat tumours in human beings located in the extremities using local perfusion with warm blood. They saw that the only factor responsible for the complete regression of melonomas and sarcomas was heat, which resulted in an increase in the percentage of patients who survived their cancer. In their explanation, Shitzer and Eberhart provided several theoretical factors that will make it easier to estimate the amount of heat that is transferred from an external and internal heat source to a tissue. The results of their experiments were also helpful in predicting the temperature distribution that would occur in normal tissues of a variety of mammals that were experiencing hyperthermia. As a result, the findings will be of use in the development of heating protocols for the treatment of hyperthermia.

Conclusions

The primary results of the current investigation are outlined below:

- The fluid movement speeds up as the thermal Grashoff number increases.
- Increased levels of porosity and magnetic parameters decrease flow distribution.
- Increasing the thermal radiation parameter, heat source/sink parameter, and Prandtl number leads to a reduction in the temperature distribution.
- Velocity profiles drop near the lower plate and increase close to the top plate with the magnetic parameter.
- The temperature profile increases with the radiation parameter and Dufour number, but drops with the Prandtl number and Soret number.
- Dufour number, Schmidt number, and chemical reaction parameter decrease the concentration profile. The Soret number influences the concentration profile. Higher magnetic parameter values lead to increased fluid velocity near the higher plate and decreased fluid velocity near the lower plate.
- Velocity, temperature, and concentration profiles decrease as the squeezing parameter increases.

References

1. Ibrahim S, Khan Marwat DN, Ullah N, Nisar K, Kamran. Flow and heat transfer in meandering channel;

c2023.
2. Adibi T, Adibi O, Athari H, Badruddin I, Syed J. Fluid flow and mixed heat transfer in a horizontal channel with an open cavity and wavy wall. Intelligent Automation & Soft Computing. 2023;37:147-163. Available from: https://doi.org/10.32604/iasc.2023.035392
3. Alqarni M, Ali A, Memon M, Emad E, Fenta A. Numerical investigation of heat transfer and fluid flow characteristics of ternary nanofluids through convergent and divergent channels. Nanoscale Advances; c2023, 5. Available from: https://doi.org/10.1039/D3NA00818E
4. Abbas S, Ahmad M, Nazar M, Amjad M, Ali H, Jan A. Heat and mass transfer through a vertical channel for the Brinkman fluid using Prabhakar fractional derivative. Applied Thermal Engineering. 2023;232:121065. Available from: https://doi.org/10.1016/j.applthermaleng.2023.121065
5. Ene R, Pop N, Badarau R. Heat and mass transfer analysis for the viscous fluid flow: dual approximate solutions. Mathematics. 2023;11:1648. Available from: https://doi.org/10.3390/math11071648
6. Choudhary S, Choudhary P, Pattanaik B. Tangent hyperbolic fluid flow under condition of divergent channel in the presence of porous medium with suction/blowing and heat source: emergence of the boundary layer. International Journal of Mathematics and Mathematical Sciences. 2023;2023:1-14. Available from: https://doi.org/10.1155/2023/6282130
7. Kocić M, Stamenkovic Z, Petrović J, Bogdanovic-Jovanovic J. Control of MHD flow and heat transfer of a micropolar fluid through porous media in a horizontal channel. Fluids. 2023;8:93. Available from: https://doi.org/10.3390/fluids8030093
8. Asghar Z, Khalid U, Nazeer M, Rasheed HS, Kausar A. Computational study of flow and heat transfer analysis of Ellis fluid model in complicated divergent channel. Modern Physics Letters B; c2023. Available from: https://doi.org/10.1142/S0217984924501197
9. As A, Wei W, Abbas T, Bhatti M. A computational investigation of diffusivities and heat transfer in the flow of viscoelastic fluid through Darcy-Brinkman-Forchheimer medium. Numerical Heat Transfer, Part B: Fundamentals; c2023. p. 1-18. Available from: https://doi.org/10.1080/10407790.2023.2296076
10. Algwauish G, Hammodat AAR, Dawood H. A numerical simulation of convection and conduction heat transfer for a fluid in a porous medium. European Journal of Pure and Applied Mathematics. 2023;16:833-846. Available from: https://doi.org/10.29020/nybg.ejpam.v16i2.4711
11. Lin CY. Rouge: A package for automatic evaluation of summaries. In Text summarization branches out; c2004. p. 74-81.
12. Nakane T, Jiang CH, Mochiku T, Fujii H, Kuroda T, Kumakura H. Effect of SiC nanoparticle addition on the critical current density of MgB2 tapes fabricated from MgH2, B and MgB2 powder mixtures. Superconductor Science and Technology. 2005;18(10):1337.
13. Wu YH, Wiwatanapataphee B, Hu M. Pressure-driven transient flows of Newtonian fluids through microtubes with slip boundary. Physica A: Statistical Mechanics and Its Applications. 2008 Oct 15;387(24):5979-90.
14. Yang A, Zhu Z, Kapranov P, McKeon F, Church GM, Gingeras TR, *et al*. Relationships between p63 binding, DNA sequence, transcription activity, and biological function in human cells. Molecular cell. 2006;24(4):593-602.
15. Adney JE, Yen T. Automorphisms of $ p $-group. Illinois Journal of Mathematics. 1965;9(1):137-143.
16. Cowling TG. The dynamo maintenance of steady magnetic fields. The Quarterly Journal of Mechanics and Applied Mathematics. 1957;10(1):129-136.
17. Young L. Steady-state kinetics of formation of anodic oxide films on tantalum in sulphuric acid. Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences. 1960;258(1295):496-515.
18. Sherman F, Taber H, Campbell W. Genetic determination of iso-cytochromes c in yeast. Journal of molecular biology. 1965;13(1):21-39.
19. Sengupta AS, Balaji MS, Krishnan BC. How customers cope with service failure? A study of brand reputation and customer satisfaction. Journal of business research. 2015;68(3):665-674.
20. Oahimire JI, Olajuwon BI. Effect of Hall current and thermal radiation on heat and mass transfer of a chemically reacting MHD flow of a micropolar fluid through a porous medium. Journal of King Saud University-Engineering Sciences. 2014;26(2):112-121.
21. Muhuri KP. Flow formation in Couette motion in magnetohydrodynamics with suction. Journal of the Physical Society of Japan. 1963;18(11):1671-1675.
22. Rathy RK. Flow between Two Co-axial Rotating Cones with Common Vertex under a Radial Force. ZAMM-Journal of Applied Mathematics and Mechanics/Zeitschrift für Angewandte Mathematik und Mechanik. 1963;43(6):281-283.
23. Verma PD, Bansal JL. Flow of a viscous incompressible fluid between two parallel plates, one in uniform motion and the other at rest with uniform suction at the stationary plate. In Proceedings of the Indian Academy of Sciences-Section A. 1966;64(6):385-396.
24. Govindarajulu Z. A central limit theorem for independent summands. Applicationes Mathematicae. 1976;1(15):39-53.
25. Dessie H, Kishan N. MHD effects on heat transfer over stretching sheet embedded in porous medium with variable viscosity, viscous dissipation and heat source/sink. Ain shams engineering journal. 2014;5(3):967-77.
26. Gupta AK, Smith KG, Shalley CE. The interplay between exploration and exploitation. Academy of management journal. 2006;49(4):693-706.
27. Ahmed N, Kalita H, Barua DP. Unsteady MHD free convective flow past a vertical porous plate immersed in a porous medium with Hall current, thermal diffusion and heat source. International Journal of Engineering, Science and Technology. 2010;2(6):59-74.
28. Kumar H. Radiative heat transfer with hydromagnetic flow and viscous dissipation over a stretching surface in the presence of variable heat flux. Thermal Science. 2009;13(2):163-169.

29. Bhatt GM. Variation of harvest index in several wheat crosses. Euphytica. 1976;25:41-50.
30. Israel-Cookey C, Ogulu A, Omubo-Pepple VB. Influence of viscous dissipation and radiation on unsteady MHD free-convection flow past an infinite heated vertical plate in a porous medium with time-dependent suction. International Journal of Heat and Mass Transfer. 2003;46(13):2305-2311.
31. Manjulatha M, Sreevathsa R, Kumar AM, Sudhakar C, Prasad TG, Tuteja N, *et al*. Overexpression of a pea DNA helicase (PDH45) in peanut (*Arachis hypogaea* L.) confers improvement of cellular level tolerance and productivity under drought stress. Molecular biotechnology. 2014;56:111-125.