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Effects of Heat Transfer on Flow of MHD Maxwell Nanofluid on Stretching and Shrinking Surfaces

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Abstract In this article , there is studied boundary layer flow, heat and the mass transfer characteristics of maxwell-Nano fluid over a stretching/ shirinking surface along with chemical reactions, transverse magnetic field and thermal radiation. Applying similarity transformation, the system of governing nonlinear PDEs are reduced into the form of ODEs. The achived equations are solved with the help of bvp4c in matlab computer software. The impacts of specified parameters include, suction parameter, Deborah number , magnetic parameter, thermophoresis parameter, chemical reaction parameter, schmidt nuumber, Brownian motion parameter, prandtl number and thermal slip parameterare are examined on velocity, temprature and nano particale concentration fields (profiles). Morover, Skin friction, Nusselt number and sherwood number are achived at diffrent values of Applied parameters which are demonstrated through graphs. Some of the key results show that an increase in suction increase skin friction, Nusselt number and sherwood number along the variation of the streching/ shirinking parameter λ. Where as an increase thermophoresis magnetic and Brownian motion parameters increase the temperature fields of Maxwell Nanofluid, while Deborah nubmer, prandtle number, suction parameter and thermal slip parameter decrease it. The Browninan motion parameter,Deborah number, prandtl number, schimt number suction parameter and thermal slip parameter decreases concentration rate of nanoparticles.

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1 Introduction

One of most significant theories in study of fluid mechanics is derivation of boundary layer equations for the flow and their corresponding solutions by applying the similarity transformation [31].The flow patterns of a variety of fluid types, which include both fluids Newtonian and non-Newtonian, have been magnificently mathematically modelled and solved by means of this boundary layer theory. The obtained results and the experimental results are very similar. However, the majority of important fluids for industry are non-Newtonian in nature. Nowadays, it is generally regarded that non-Newtonian fluids are more useful in real-life applications in industries than Newtonian fluids, because of their uses in certain separation processes, polymer engineering, paper, petroleum drilling and food manufacturing and many other industrial processes[5, 28].Therefore, it is very important to investigate flow behavior of non-Newtonian fluids. The flow on a flat plate near stagnation point was first illustrated by [12]. It is essential to keep in mind that stagnation flow exhibits itself at any point where a solid object is in the path of the flow and the local fluid velocity at that point (called stagnation point) is zero. He was incapable to generate a boundary layer near the sheet by replacing a stretched sheet with a solid body with equal stretching and straining velocities. MHD Casson nanofluid over a stretching/shrinking surface with effects of the radiation and thermal slip parameters was numerically investigated by [20],Whereas using different stretching and straining velocities on stagnation-point flow on stretched surface were re-analyzed by [23].Depending upon the ratio of stretching and straining constants, two different types of boundary layers nearby surface are observed. [19] investigated unsteady flow for drainage through a circular tank of an isothermal and in-compressible Newtonian magneto hydrodynamic (MHD) fluid. [24] studied electrically conducting, in-compressible and isothermal Newtonian fluid-flow in unsteady tank drainage. [32] investigated the problem of a study of thin film flow for lift while considering a steady, in-compressible, non-isothermal, Phan-Thien Tanner fluid on a vertical belt with slip condition. As opposed to the forward flow of a stretched surface,the flow caused by the king Surface has very distinct characteristics [8, 34] describes the flow of shrinking surfaces as basically one of the reversing flows. The physical characteristics of flow are fascinating because of the vorticity generated by shrinking.[25] demonstrated the need for a sufficient quantity of fluid mass suction over the permeable surface for the purpose of continuing the Newtonian fluid's boundary layer flow despite the permeable shrinking surface's tendencies to shrink. Actually,the vorticity that is developed by the shrinking of surface inside the boundary layer is reduced through fluid mass suction. In this regard [6] and [7] examine a variety of essential features of shrinking sheet flows containing Newtonian fluid. There are several non-Newtonian industrial fluids. The investigation of boundary layer flows of non-Newtonian fluids have received a greater amount of interest now a days because of their many real-world uses in industrial operations and manufacturing. The production of paper, polymeric solutions, optical fibers, and hot rolling are some of the uses. Hundreds of models have been presented over decades,Maxwell model is one of them, which is a particularly basic subcategory of a fluid of a rate-type and is capable to guess impact of time of relaxation [29]. On the other hand, magneto hydrodynamic (MHD) evaluates the study of how conducting fluids and electromagnetic fields interact with one another. It is frequently employed in engineering and science for awide range of applications, including the design and development of heat exchanger devices, plasma confinement, thermal insulation systems, MHD generators and accelerators, and many more.

Investigations of the MHD and Maxwell fluid flows are very important because of their applications. [29] investigated the MHD flow of a Maxwell fluid across a stretched surface along with existence of nanoparticles. While investigating the impacts of nanoparticles, they took into account the impacts of elasticity and MHD on the flow. The examination of MHD unsteady flow of Maxwell fluid on stretched surface with heat source effects was provided by [27]. Under influence of several conditions, MHD Maxwell fluid flow have been studied by [10, 11].They deliberated impacts on MHD flow Maxwell fluid with radiation in a channel with permeable medium [11], the effects on MHD Maxwell fluid flow with Joule heating and thermal radiation in existence of a thermophoresis [10]. [1] analyzed unsteady three dimensional bio-convective flow of Maxwell nanofluid over an exponentially stretching sheet with variable thermal conductivity and chemical reaction. [33] examined the unsteady flow of a thermomagnetic reactive Maxwell nanofluid flow over a stretching/shrinking sheet with Ohmic dissipation and Brownian motion.

In recent times,[4] have identified nanofluids for advancement in nanotechnology. These fluids are comprised of nanoparticles (less than 100 nm in size) suspended in common base fluids, which involve water, oil, and ethylene glycol, whereas the nano layer operates as a thermal connection between the base fluids and solid nanoparticles. Nanofluids exhibit Heat transfer and Brownian diffusion are primarily consequences of the nanoparticles contained. As a consequence of this, nanofluids are highly conductive fluids for heat transfer, which improve the efficiency of large- and small-scale heat exchangers used in chemical processing plants and automobiles,respectively. Nanofluids are being used for industrial cooling applications because of their enhanced thermal conductivity, according to [2], and this results in energy savings. In an effort to raise heat transmission, [26] mentioned the implementation of nanofluids and several mini-channel designs. Nanofluids are used in several kinds of heat transfer applications, namely soil remediation procedures, oil recovery, home refrigerator chillers, electronic cooling,heated pipes,lubrication, microelectronic fuel cells, detergency, and solar-powered water chillers. Nanofluids are referred to study regarding enhancing heat transmission when refrigerating central processing unit (CPU) system [9]. Nanofluids are utilized for fluid cooling of computer processors because of their enhanced thermal conductivities. [21] studied the heat transfer of Fe3O4-water base nanofluid past on an exponential porous shrinking/stretching surface. Tiwari-Das model has been used to modify the system of equations of considered problem. Mixed convection, slips and the radiative influences are incorporated in equations.

Additionally, nanofluids are employed in bio-medicine for magnetic cell separation, hyperthermia, and delivering drugs. A cancer therapy uses certain nanofluids for tumor imaging. Nanofluids enable doctors to provide large local dosages of medication or radiation to the patient because magnetic nanoparticles are more adherent to cancer cells without harming neighboring healthy tissues. One of the most significant recent developments in bio-medicine is nano cryosurgery, a more affordable treatment that successfully kills cancerous cells without causing any side effects and assures a safe and quick recovery. [22] and [3] conversed about how to treat cancer surgically while reducing the risks of surgery and destroying cancers in the chosen area. In addition to medical treatment of skin, breast, lung, liver, brain, prostate cancers, glaucoma, etc. Imaging technology represents one of the benefits of cryosurgery. Many technical and physical disciplines, involving packed-bed catalytic reactors, plasma physics, geothermal reservoirs, insulation of thermal energy, etc., are applications of MHD boundary layer flow of mass and heat transference. [13] studied the impacts of a radiation over a MHD flow. [30] examined MHD flow of viscous fluid in occurrence of radiation effects. The MHD transfer of mass and heat with nanofluid flow across a moving sheet was researched by [17].

Motivated from above discussed literature, It is realized that the non-Newtonian stagnation point flow on stretching/shrinking surface has gotten a limited attention. Hence, the goal of the existing investigation is to analyze behavior of the flow, mass and heat transference of the Maxwell nanofluid with magnetic fields, chemical reaction and radiation effects. The numerical findings of present problem is achieved with aid of bvp4c Matlab software. The impact of achieved parameters on velocity, temperature and nanoparticles concentration fields are demonstrated through tables and graphs. The flow, heat and the nanoparticles concentrations aspects are also demonstrated through graphs. It is hoped that this study will help the new researcher who want to study of the higher order fluids and Nanofluids having high order base fluids. It is hoped that this work will prove beneficial which want to work applications of nanofluid with higher order base fluids. This work can also be further extended by considering other base fluids related to nanofluids like as Kelvin–Voigt, Jeffreys, Oldroyd-B,and Burgers.

2 Mathematical Formulation

There has been Considered in-compressible steady, two dimensional, mass and heat transfer features of MHD stagnation-point flow of the Maxwell nanofluid across a linearly permeable stretching/shrinking surface along with thermal radiation influence is considered. A Cartesian coordinate system is taken such that y-axis is perpendicular to it and x-axis has been restrained along surface. The surface is stretched with plane $y = 0$ and the flow is expected to be restricted to $y > 0$. The surface is stretched with velocity $u_W(x) = ax$, the surface is considered stretched, where a is velocity constant. The surface of a plate is kept at uniform concentration and temperature, C_W and T_W respectively, while C_∞ is ambient concentration and T_∞ ambient temperature. A uniformly constant magnetic field is applied normal to the flow direction. Magnetic Reynolds number has been supposed to be the small as the persuaded magnetic field is negligible. The physical model with coordinate system of the present study as shown Figure 1.

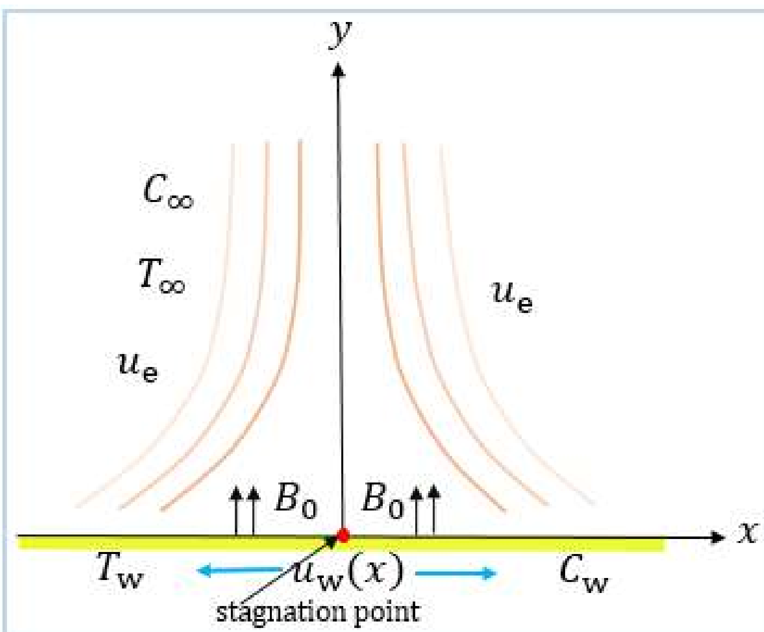

Figure 1. Co-ordinate System and Physical Flow Model

Following to above assumptions and [16], the governing equations for the present problem are defined as:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0, \tag{1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\vartheta\frac{\partial^2 u}{\partial y^2}-\frac{\sigma B^2 u}{\rho_f}\left(u+vk_1\frac{\partial u}{\partial y}\right)+k_1\left(u^2\frac{\partial^2 u}{\partial x^2}+2uv\frac{\partial^2 u}{\partial x\partial y}+v^2\frac{\partial^2 u}{\partial y^2}\right), \tag{2}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\left(\alpha+\frac{16\sigma^* T_\infty^3}{3K^*\rho c_p}\right)\left\{\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right\}+\tau_w\left[D_B\left\{\frac{\partial C}{\partial x}\frac{\partial T}{\partial x}+\frac{\partial C}{\partial y}\frac{\partial T}{\partial y}\right\}+\frac{D_T}{T_\infty}\left\{\left(\frac{\partial T}{\partial x}\right)^2+\left(\frac{\partial T}{\partial y}\right)^2\right\}\right] \tag{3}$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_B\left(\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial y^2}\right)+\frac{D_T}{T_\infty}\left(\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial y^2}\right)-\gamma\left(C-C_\infty\right), \tag{4}$$

subject to boundary conditions:

$$v=v_w(x);\quad u=u_w(x)=\lambda ax;\quad T=T_w(x)+N\frac{\partial T}{\partial y};\quad C=C_w(x)\quad at\quad y=0$$

$$u\to u_e;\quad T\to T_\infty;\quad C\to C_\infty\quad as\; y\to\infty, \tag{5}$$

where T_∞ represent ambient fluid temperature, T is temperature, T_w is surface temperature, volumetric fractions of nanoparticles is denoted by C, D_T and D_B are thermophoresis and Brownian diffusion's coefficients, respectively.

3 Similarity Transformation

Here system of the PDEs is transferred to system of the non-linear ODEs. The similarity variables that was utilized by [18] are utilized in present problem.

$$\begin{gathered}u=axf'(\eta),\ \eta=y\sqrt{\tfrac{a}{\vartheta}},\ v=-\sqrt{a\vartheta}f(\eta),\\ (T_w-T_\infty)\,\theta(\eta)=(T-T_\infty),(C_w-C_\infty)\varnothing(\eta)=(C-C_\infty)\end{gathered} \tag{6}$$

Where, dimensionless stream function is represented by $\psi=\sqrt{a\vartheta}xf(\eta)$ and according to given transformation u and v are velocity components:

$$\mathrm{v}=-\frac{\partial\psi}{\partial x}\quad and\quad \mathrm{u}=\frac{\partial\psi}{\partial y} \tag{7}$$

here,

$$v=-\sqrt{a\vartheta}f(\eta)\quad and\quad \mathrm{u}=\mathrm{ax}f'(\eta) \tag{8}$$

by using the equation (6) in the equations (2)-(5), we have:

$$f'''(\eta)-\beta\left(\left(f(\eta)\right)^2f'''(\eta)-2f(\eta)f'(\eta)f''(\eta)\right)+f(\eta)f''(\eta)-\left(f'(\eta)\right)^2+M\left(1-f'(\eta)+\beta f(\eta)f''(\eta)\right)+1=0, \tag{9}$$

$$\frac{1}{\Pr}\left(1+\frac{4Rd}{3}\right)\theta''(\eta)+Nb\phi'(\eta)\theta'(\eta)+f(\eta)\theta'(\eta)+Nt\left(\theta'(\eta)\right)^2=0 \tag{10}$$

$$\frac{1}{Sc}\phi''(\eta)-\chi\phi(\eta)+f(\eta)\phi'(\eta)+\ \frac{1}{Sc}\frac{Nt}{Nb}\theta''(\eta)=0 \tag{11}$$

Associated boundary conditions are

$$f^{'}(0)=\lambda,\ f(0)=s\ ,\ \theta(0)=1+\delta_T\theta(0),\ \phi(0)=1,\ \ f^{'}(\eta)\to 1,\ \theta(\eta)\to 0,\ \phi(\eta)\to 0 \quad as \quad \eta\to\infty \tag{12}$$

where, $Rd=\frac{4\sigma^*T_\infty^3}{k^*k}$ is radiation parameter, $Pr=\frac{\nu}{\alpha}$ Prandtl number,$Nb=\frac{D_B(C_w-C_\infty)}{\nu}$ Brownian motion parameter, $\beta=ak_1$ Deborah number, $Nt=\frac{D_T(T_w-T_\infty)}{\nu T_\infty}$ thermophoresis parameter, $\tau_W=\frac{(\rho C)_p}{(\rho C)_f}$, $\chi=\frac{k_c}{a}$ chemical reaction, and $Sc=\frac{\vartheta}{D_B}$ Schmitt number. Physical quantities related to engineering interests are Nusselt number, Sherwood number and skin-friction are computed by below equations.

$$C_f=\frac{\left[\vartheta\frac{\partial u}{\partial y}\right]_{y=0}}{\rho u_w^2},\ \ N_u=\frac{-x\left[\left(\frac{16\sigma^*T_\infty^3}{3k^*}+k\right)\frac{\partial T}{\partial y}\right]_{y=0}}{(T_w-T_\infty)},\ S_h=\frac{-x\left(\frac{\partial C}{\partial y}\right)_{y=0}}{(C_w-C_\infty)}. \tag{13}$$

Using equation (6) in equation (13),

$$C_f=(Re_x)^{-\frac{1}{2}}f^{''}(0),\ (Re_x)^{-\frac{1}{2}}N_u=-\left(1+\frac{4}{3}Rd\right)\theta^{'}(0),(Re_x)^{-\frac{1}{2}}S_h=-\varnothing^{'}(0), \tag{14}$$

here $Re_x=\frac{ax^2}{\vartheta_f}$ is the local Reynolds number.

4 Numerical Methodology

The equations (9)-(11) with boundary conditions (12) are solved applying bvp4c technique in Matlab software. That is one of the finite difference scheme with 4$^{\text{th}}$ order accuracy. The bvp4c functions solve first order differential equations. For that purpose, as mentioned in abstract, the equations (9) to (11) are converted into the order differential equations. The interval of convergence is taken between 0 to 3. Some of our acquired results are compared with results mentioned in previous research, in order to validate our computed results. The comparison demonstrates the excellent resemblance that has been presented in Table 1. The absolute convergence criteria were taken as [15].The algorithm is followed as:

$$\left[f=y(1),f'=y(2),f''=y(3),\theta=y(4),\theta'=y(5),\phi=y(6),\phi'=y(7)\right] \tag{15}$$

$$yy_1=\left[\frac{1}{1-\beta\left(y(1)\right)^2}\right]\left[\left(y(1)\right)^2-y(1)y(3)-2\beta y(1)y(2)y(3)-M\left\{1-y(2)+\beta y(1)y(2)\right\}-1\right] \tag{16}$$

$$yy_2=\left[\frac{3Pr}{3+4Rd}\right]\left[-y(1)y(5)-Nby(7)y(5)-Nt\left(y(5)\right)^2\right] \tag{17}$$

$$yy_3=Sc\left[y(1)y(7)-\chi y(6)\right]-\frac{Nt}{Nb}yy_2 \tag{18}$$

Subject to the boundary conditions

$$y_0(1)=S,\ y_0(2)=\lambda,y_0(5)=1+\delta_T y_0(5),\ y(6)=1y_\infty(2)=1,\ y_\infty(4)=0,y_\infty(6)=0 \tag{19}$$

λ	[14]	[16]	Present study
0.00	0.8113013	0.811302	0.8113013
−0.250	0.6685728	0.668573	0.668573
−0.500	0.5014476	0.501448	0.501448
−0.750	0.2931625	0.293163	0.293163

Table 1. Comparison $N_u(Re_x)^{-\frac{1}{2}}$ for several values of shrinking parameter λ as β = 0.3

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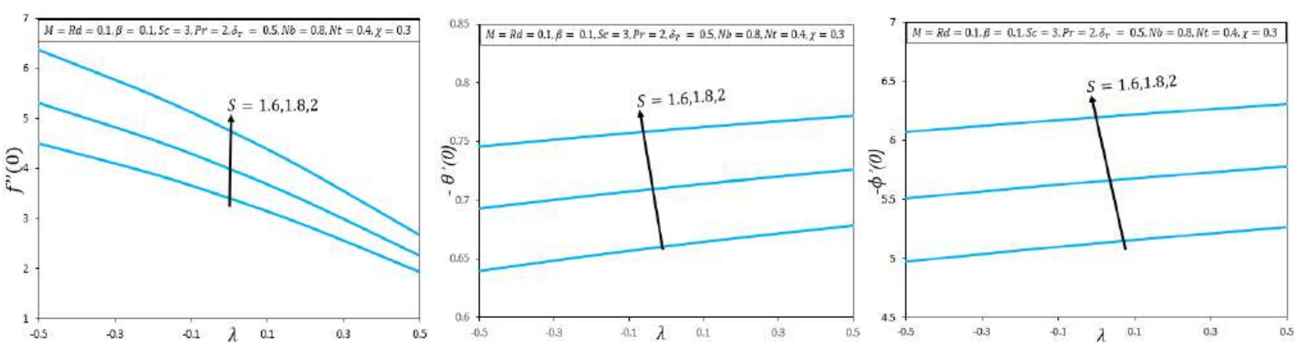
5 Results and Discussion

The heat, and the mass transference of laminar MHD stagnation-point flow of Maxwell nano fluid on a linear stretching/shrinking surface is considered. To study the physical importance of the problem, numerically achieved values associated to the velocity temperature and concentration fields (profiles) along with coefficient of skin friction, Nusselt number as well as Sherwood number are calculated for various values of specified parameters that includes, Deborah number (β), Brownian motion parameter (*Nb*), magnetic parameter (*M*), Schmitt number (*Sc*), chemical reaction parameter (χ), radiation parameter (*Rd*), thermophoresis parameter (*Nt*), the Prandtl number (*Pr*), suction parameter (*S*) and thermal slip parameter δ_T respectively.

Figure 2(a-c) depicts influence on a skin friction, Nusselt number and Sherwood number for increasing values of the suction parameter with variation of stretching and shrinking parameter λ. These figures show that an increase in rate of the suction increases co-efficient of a skin friction, Nusselt number, and the Sherwood number throughout the Maxwell nanofluid flow in both cases of the surfaces stretching as well as shrinking surface.



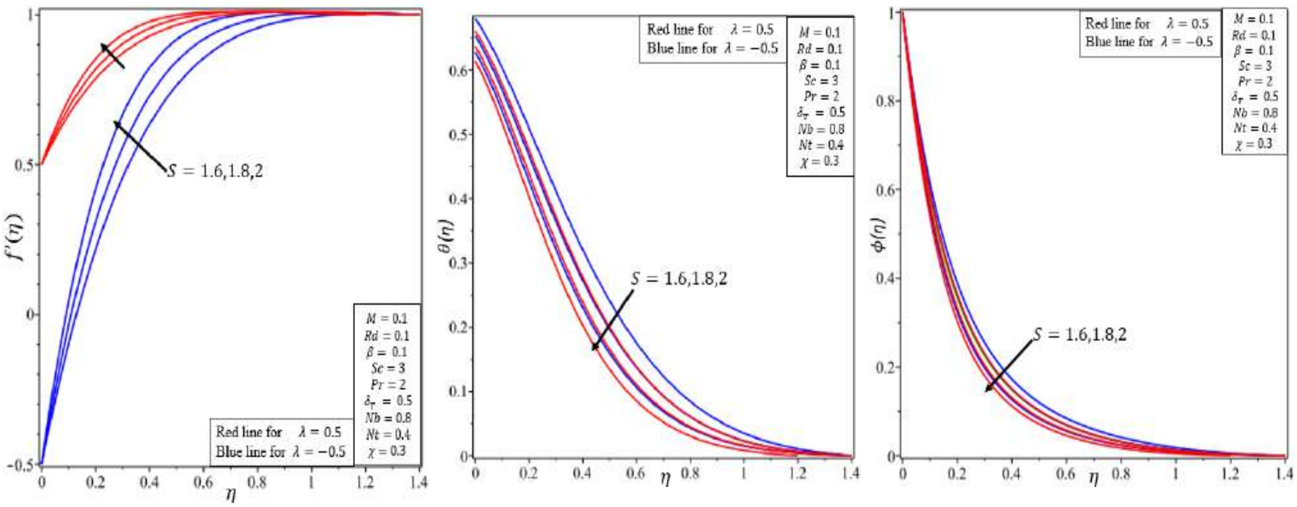
(a) Variation of the skin friction coefficient with λ at various values of *S*.

(b) Variation of Nusselt number with λ at various values of *S*.

(c) Variation of the Sherwood number with λ at various values of *S*.

Figure 2. Caption for Figure 2.

The change in velocity, temperature and concentration fields at different values of suction parameters is depicted in Figures 3(a-c),respectively.These figures show that velocity, temperature and nanoparticles concentrations fields are decreasing as suction is increased. This behaviour occurs in the presence of suction at the surface, which is the result to draw the quantity of fluid on the surface and therefore hydrodynamic boundary layer flow becomes thinner and both thermal, and concentration boundary layers are decreasing by increasing suction parameter.



(a) Velocity field for various values of *S*.

(b) The temperature field for various values of *S*.

(c) Concentration field for various values of *S*.

Figure 3. Combined figures

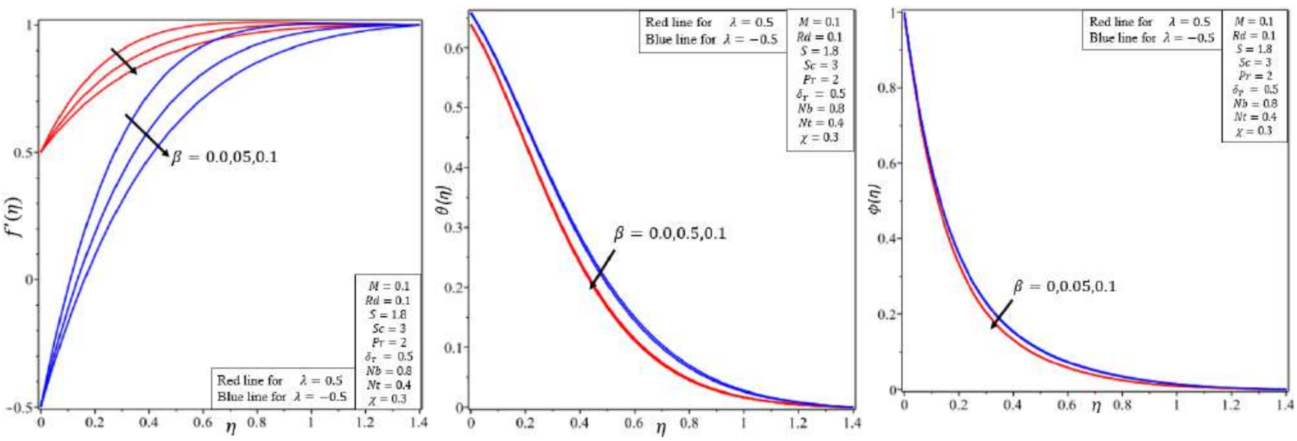
Figures 4(a-c) demonstrate the effect of the Deborah number on the velocity, temperature and concentration fields, respectively. The figures show that an increase in Deborah number increases velocity field of the Maxwell nanofluid, while temperature and nanoparticles concentration fields are decreased with increase in value of the Deborah number whether flow is in situation of stretching or shrinking.

Figure 5 and 6 show the influence of thermal slip parameter on the temperature and concentration fields of Maxwell nanofluid. These figures show that increasing value of the thermal slip parameter reversely decreases the temperature and concentration fields in flow of the Maxwell nanofluid in both considered situations of the surface.

Figures 7 and 8 illustrate the variation in temperature and nanoparticles concentration fields for increasing value of Prandtl number. These figures show that an increase in Pr acts inversely over the temperature and concentration fields for both cases of the surface. In fact growing value of Prandtl number reduces thermal diffusivity due to having inverse proportionality to it.

Figures 9-10 demonstrate influence on Brownian motion parameter on temperature and nanoparticles concentration fields. It is observed that an increase in *Nb* increases the temperature field along its thermal boundary layers thicknesses and converse to it concentration of nanoparticles decreases for both cases of the surface. It should be noted that an increase in Brownian motion, the size of particles reduce. Henceforth, heat and mass transfer increase and consequently temperature and its related thermal boundary layer thickness are raised. Brownian motion develops the micro-mixing of particles which develops thermal conductivity of the Maxwell nanofluid. As it is discussed that the size of particles and Brownian motion have inverse relation, therefore the large influence of Brownian motion reduces the concentration of particles (see, Figure 10).

Figure 11 exhibit impacts on temperature field due to increment in thermophoresis parameter (*Nt*) .



(a) Velocity field for various values of β.

(b) Temperature field for various values of β.

(c) Concentration field for various values of β.

Figure 4. Combined figures

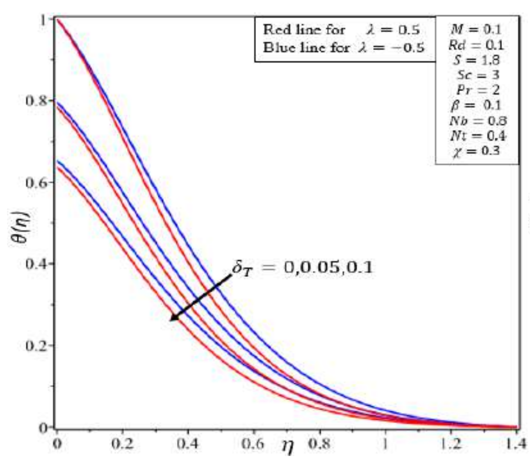


Figure 5. Temperature field for various values of δ_T.

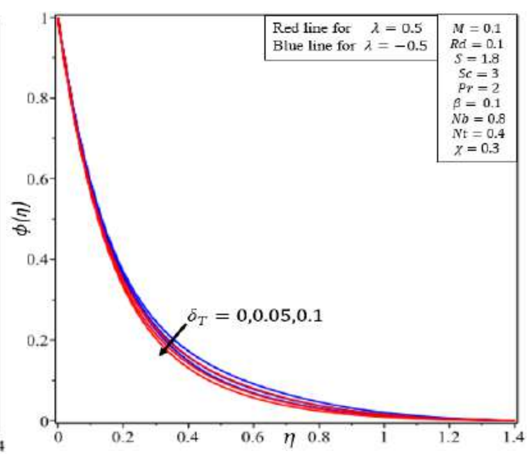


Figure 6. Concentration field for various values of δ_T.

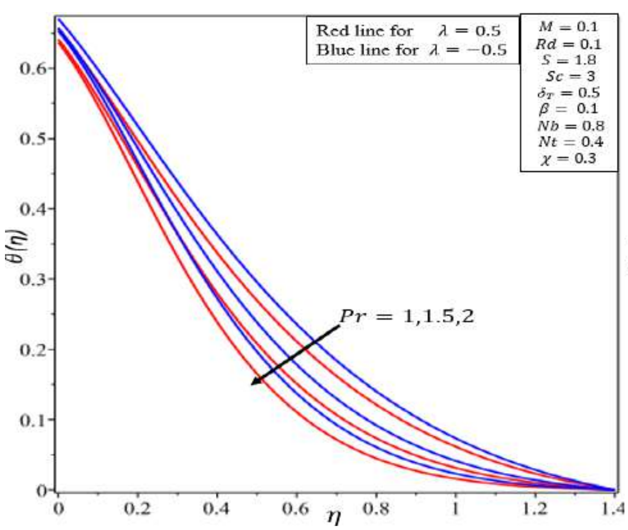


Figure 7. Temperature field for various values of *Pr*.

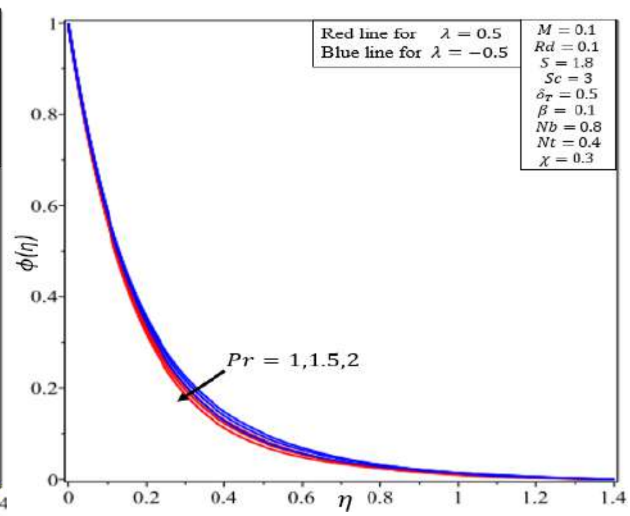


Figure 8. Concentration field for various values of *Pr*.

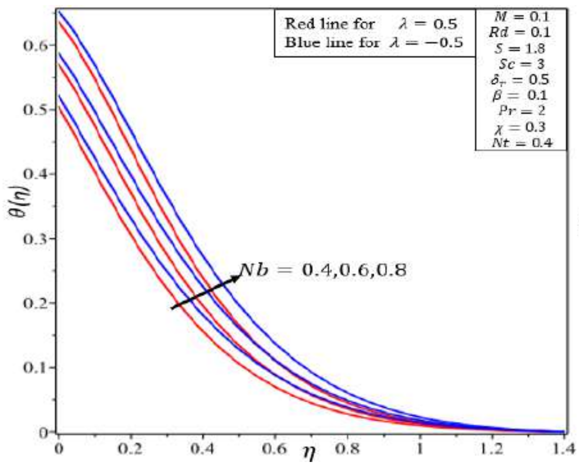


Figure 9. Temperature field for various values of *Nb*.

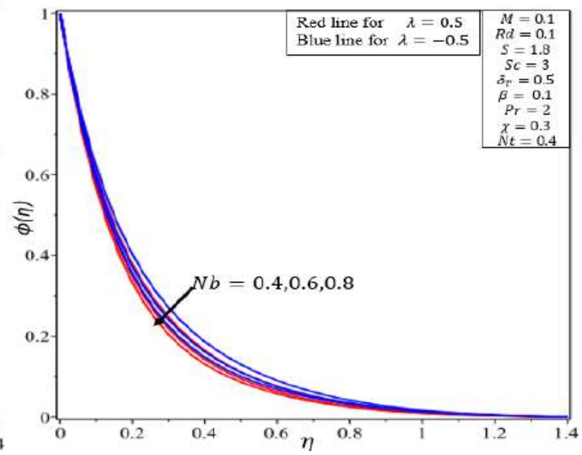


Figure 10. Concentration field for various values of *Nb*.

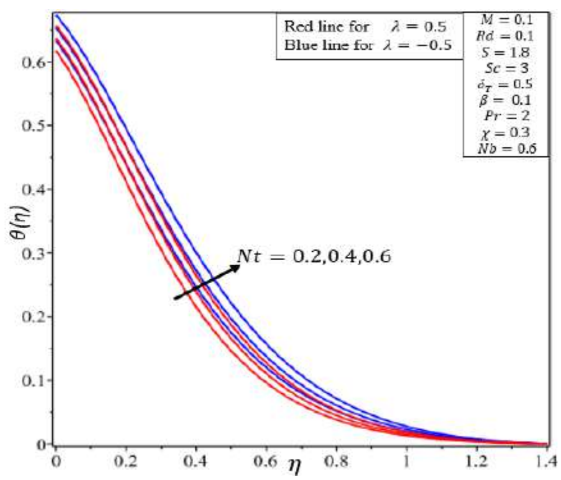


Figure 11. Temperature field for various values of *Nt*.

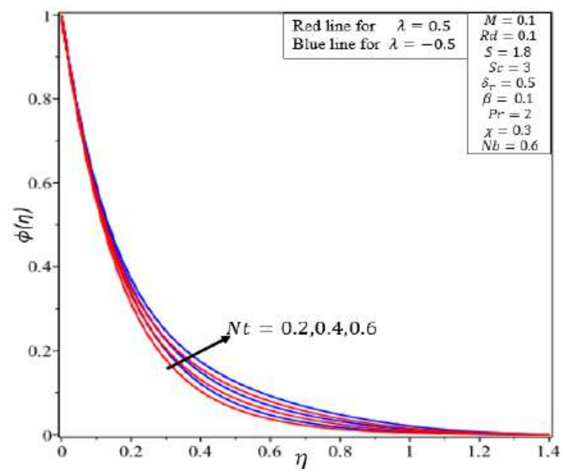


Figure 12. Concentration field for several values of *Nt*.

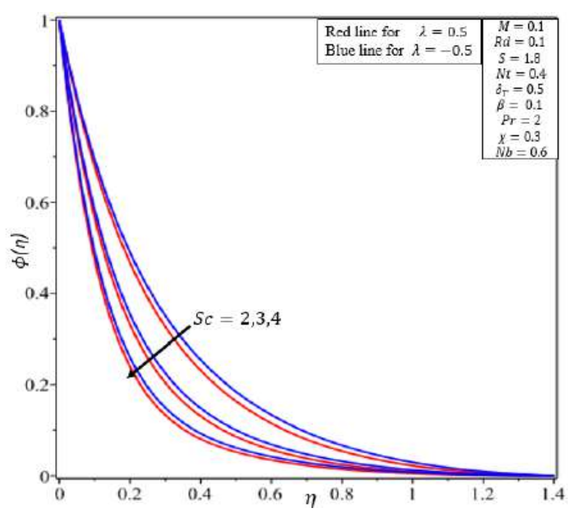


Figure 13. Concentration field for various values of *Sc*

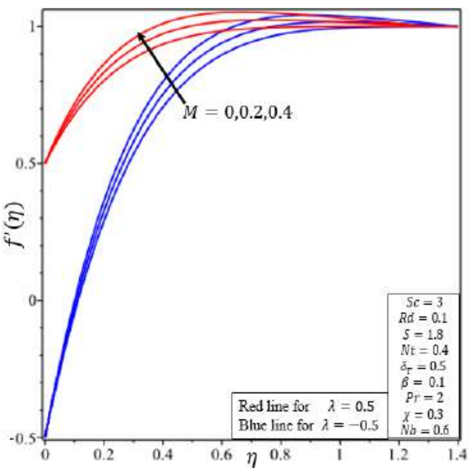


Figure 14. Velocity field for various values of M..

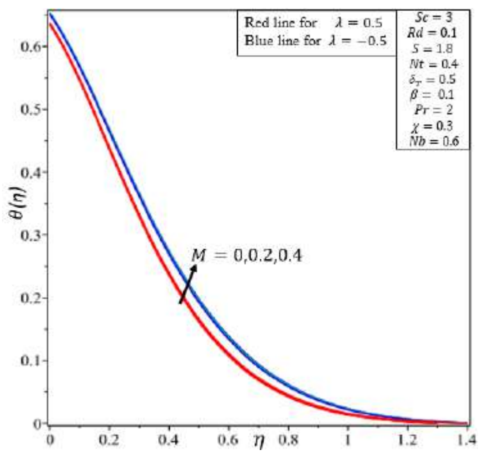


Figure 15. Temperature field for various values of *M.*

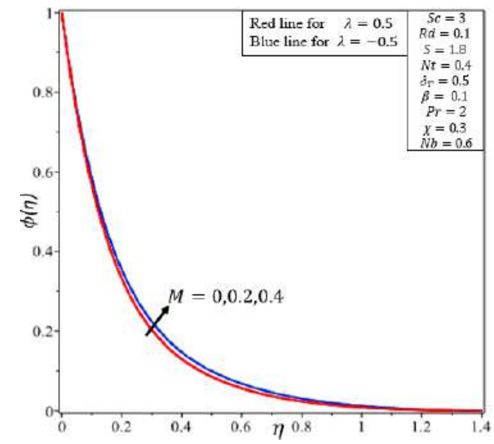


Figure 16. Concentration field for various values of *M.*

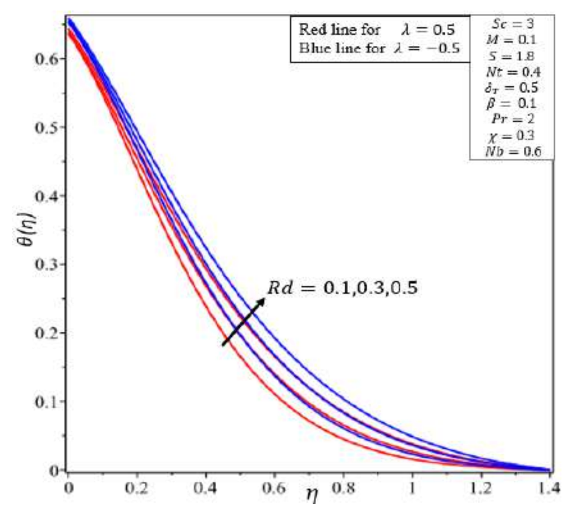


Figure 17. Temperature field for various values of *Rd*

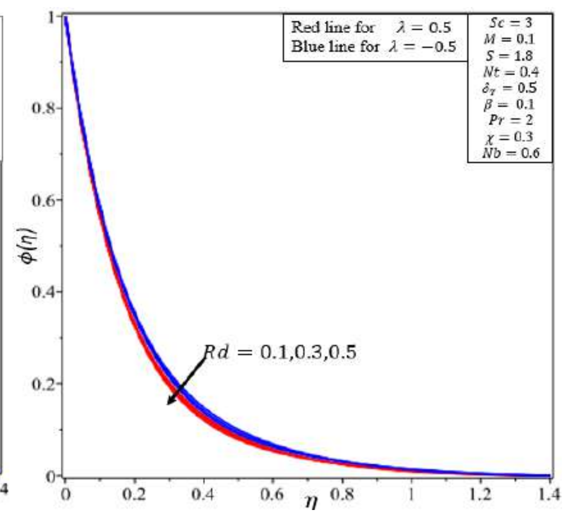


Figure 18. Concentration field for various values of *Rd*

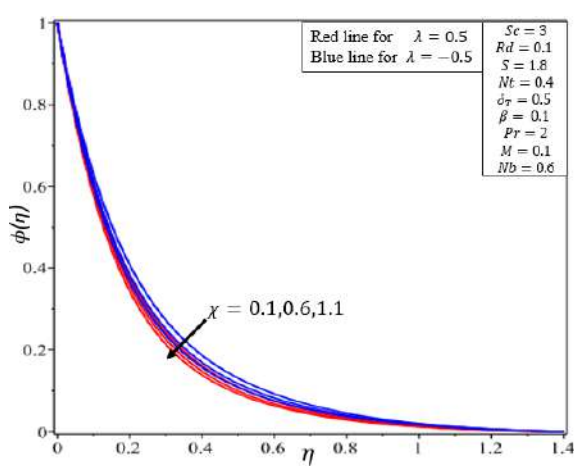


Figure 19. Concentration field for various values of χ

It has been examined that temperature field along with thickness of its thermal boundary layer increase due to any increment in thermophoresis parameter. The effect of thermophoresis enables nanoscale particles to be transported from the proportionally heated stretching surface to the cooler portion of the fluid, causing a temperature gradient. This happens when the thermophoresis parameter (*Nt*) rises, which consequently increases the temperature field. The fluid with suspended nanoparticles is invaded to a greater extent by an intense thermophoretic behavior, raising the thermal boundary layer thickness. Figure 12 demonstrates that nanoparticle concentration is directly proportional to thermophoresis parameter (*Nt*). It is due to the fact that when *Nt* rises diffusion penetrates the fluid deeply, causing the thickness of the thermal and concentration boundary layers to increase.

Figure 13 depicts the influence on nanoparticle concentration field for increasing value of Schmitt number. It is investigated boundary layer thickness and the nanoparticles concentration field are reduced when Schmitt number is increased. Because the nanoparticle concentration rate in the nanofluid rises with an increase in Schmitt number, concentration field is reduced.

Figure 14-16 display whenever the magnetic parameter (*M*) value is raised. The velocity filed decreases, while temperature and concentration fields increase for both situations of the solid surface. Physically, when the magnetic parameter (*M*) increases, the Lorentz forces with direction of the flow perpendicular to the x-axis are enhanced, causing higher resistance in the nanofluid flow. As the result, the velocity profile and boundary thickness decrease, while temperature and concentration fields with boundary layer thicknesses are enhanced.

Figure 17 and 18 demonstrate the influence of the thermal radiation *Rd* on temperature and nanoparticles concentration fields,respectively. Which shows that an increase in radiation (*Rd*) rises the temperature field and converse to it, decreases nanoparticles concentration field for both situations of the surface whether it is stretching or shrinking. Due to the fact that mean absorbing coefficient k* reduces with rising *Rd*, the inconsistency in flow of radiative heat is enhanced. Thus, rate of the radiating heat to the moving fluid increases, resulting an increment in fluid temperature.

Figure 19 show the influence of chemical reaction on nanoparticles concentration field. It is observed that nanoparticles concentration field and its boundary layer thickness are decreasing with increase in parameter of chemical reaction. Physical point of view chemical reaction for destructive case ($\chi > 0$) is very large. Because of this fact molecular motion is quite higher which enhances the transport phenomenon, thus suppressing the concentration field in the fluid flow.

6 Conclusion

The boundary layer MHD Maxwell nanofluid flow across a linear stretching/shrinking surface is studied. The numerical computations are carried out applying bvp4c technique in Matlab software. The main observations of this study are as follows:

1. An increase in suction increases skin friction, Nusselt number and Sherwood number along the variation of the stretching/shrinking parameter λ.
2. An increase in magnetic parameter and Deborah number increase the velocity of the Maxwell nanofluid, while suction decreases it.

3. An increase in thermophoresis, magnetic and Brownian motion parameters increase the temperature fields of Maxwell nanofluid, while Deborah number, Prandtl number, suction parameter and thermal slip parameter decrease it.
4. An increase in thermophoresis and magnetic increase the nanoparticles concentration fields of Maxwell nanofluid, while Brownian motion parameter, Deborah number, Prandtl number, Schmitt number, suction parameter and thermal slip parameter decrease it.

Credit Author Statement

Ibrahim Dayo: Conceptualization, Methodology, Software. **Syed Feroz Shah.**: Data curation, Writing- Original draft preparation. **Fozia Shaikh**: Visualization, Software, Validation, Investigation. **Sanjay Kumar***:* Writing- Reviewing and Editing Supervision

Compliance with Ethical Standards

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