MHD WILLIAMSON HYBRID NANOFLUID FLOW WITH CATTANEO-CHRISTOV FLUX MODEL

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Abstract

In this research, the numerical simulation of the Williamson hybrid nanofluid's MHD heat and mass transfer flow over a porous stretched sheet with Cattaneo-Christov heat and mass flux was found. The underlying physics of the situation are modelled by governing equations. After applying a suitable similarity transformation, these equations were converted into an ODE system and solved numerically using MATLAB and the BVP4C tool.The study's findings indicate that while raising the mass relaxation flux raises concentration distributions, increasing the heat relaxation flow raises temperature. To improve temperature and velocity distributions, an additional value of thermal radiation, heat generation, and Eckert number were observed. Due to the imposed electromagnetic force, a higher value of the magnetic field is observed. Also, the enhance in the thermal radiation parameter is observed to increase the velocity and temperature distributions. This research benefits from biomedical engineering, biological sciences, astrophysics, and geophysics.

Keywords: Williamson fluid, MHD, velocity, temperature, concentration.

1. Introduction

Numerous scholars have examined the connection between heat transmission and viscous dissipation and thermal radiation. Thermal radiation and viscous dissipation are used in underground storage systems and in the extraction of geothermal energy. Thermal radiation is highly important in satellites, nuclear power plants, gas turbines,and the alteration of high temperature energy processes. This fluid was subjected to Chemical reaction and ionizing radiationby Kataria et al (2016). Electricity was used to illuminate the Soret-Dufour mechanism, the MHD buoyancy force, and dissipative viscous significance in a conducting fluid. Analysis of radiation's impact on stagnation flow with second order slip and melting heat transfer was carried out by Hayat et al [2017]. Ahmed Alsaedi et al [2017] investigated the possibility of radiative flow because of a circulating disk with different thicknesses. An investigation of the effect of joule heating along with viscous dissipation and magnetic field on Power-law fluid was conducted by Motahar Reza et al [2022]. A colloidal nanoparticle suspension in a base fluid was first developed by Chaio [1995] as a mixture of chemical nanoparticles such as nitride-AiN, metals-Al, nonmetals-Graphite, oxide ceramics, and metal carbides-SiC. There are numerous uses for nanofluids in cancer therapy; industrial cooling; biomedical engineering; biological science; and the solar sector. Murthy et al [2016] studied boundary layer motion of Williamson nanofluid in the passable region using MHD boundary layer motion. Hashim et al [2020] was studied by the Williamson fluid flow time is dependent on a heated surface. Reddy et al [2018] address the impacts of radiation and warm dissemination on MHD heat move stream of a dusty viscoelastic liquid between two moving equal plates. Synthetic response impact on MHD stream of Casson liquid with permeable extending sheet concentrated by Makinde et al[2018].Krishna et al [2018] showed the mathematical arrangements of precarious MHD stream heat move over an extending surface with pull or infusion. Reddy et al [2018] thoroughly searched in the impacts of radiation and Soret on a shaky progression of a Casson liquid through permeable vertical channel with development and constriction. Warm radiation and compound response consequences for MHD stream along a moving vertical permeable plate was investigated by Sreedevi et al [2017].Many researchers [Sharada and Shankar 2015, Dulal Pal and Gopinath Mandal 2021, Sugunamma et al. 2022, Surya kanta Mondal and Dulal Pal 2022, Kankanala Sharada 2022, Sudarshan Reddy et al. 2022, Vishvambhar S. Patil et al. 2022, K Sharada and B Shankar 2017, Reddy et al. 2014, S Jagadha et al. 2021] have studied and analysed the solution of MHD flows on radiation and chemical reaction effects of the Newtonian and non-Newtonian fluid flows. Using non-isothermal and non-isosolutal limitations, Dawar et al [2021] studied convective flow over a cone and wedge of Williamson nanofluid. The influence of thermal radiation on nanofluid mixed convective flow on an inclined wavy surface was studied by Srinivasacharya et al [2018]. Chemically reacting nanofluid convective flow via mobile or stationary vertical plate was the subject of research by Gireesha et al [2016]. The effect of a constant heat source/sink on the convective nonlinear flow of nano Oldroyd-B fluid over a stretchy surface was examined by Ganesh kumar et al [2018]. Ahmad Farooq et al [2021] investigated the flow of a stretchy sheet of Maxwell viscoelastic MHD nanofluid. Nadeem et al [2021] studied the effects of natural convection motion and heat transfer in two upright plates on fuzzy nano-hybrid fluids. Idowu et al [2020a] studied the simultaneous motion of Casson-Walters-B fluid over a vertical porous plate by altering thermal conductivity and viscosity.

The MHD Falkner-skan-Sutter by nanofluid was studied using the nanofluid model and theCattaneo-Christov heat flux theory by Khan et al [2020]. Williamson hybrid engine oil nanofluids and Cattaneo-Christov heat flux. The MHD Casson-Ferro fluid's heat radiative transport was modelled numerically by Ali et al [2017]. Zhang Yan et al [2021] investigated the melting heat reaction in a von Karman circulating motion of hybrid nanofluids by employing a Cattaneo-Christov heat flux. The Cattaneo-Christov model and a chemical process on an exponentially stretchable surface were used by Hayat Tanzila at al [2018] to address the motionof 3D Eyring-Powell. The Cattaneo-Christov model was used to investigate the flow of Carreaufluid across a thin sheet of material. The Cattaneo-model Christov's was used in the work toconnect viscoelastic fluid flow with heat transport processes by Shihao Han et al [2014].

The magnetic and electric field-induced flow of highly conducting fluids is explained by MHD.Astrophysicists and geophysicists use a variety of techniques to study astrophysics, geophysics,MHD power generation, and heat exchanger design. A large number of researchers have investigated MHD flows on non-Newtonian fluids over stretched surfaces. Plasma research, flowmeters, aerodynamics, and solar energy devices are examples of MHD processes. As a result of the wide range of MHD applications, the studies listed below have documented the flow phenomena associated with MHD. Falodun et al [2016] evaluated the flow of a chemically reactive fluid past a half infiniteupright plate with heat radiation and Soret-Dufour significance was studied. Multiple slides on the relevance of MHD and the non-Newtonian flow of nanofluids across a stretchable cylinder were explored by Khan et al [2018]. Mishra Satya Ranjan et al[2018] investigated the dissipation relevance of Casson fluid's MH stagnation-point motion past a stretchy sheet. MHD mass transport via a slanting plate with thermophoresis, a non-constant heat source/sink, chemical reaction, and Soret-Dufour significance was studied by Mondal et al [2018]. Ramzan et al [2021] used heat transport analysis across a stretchy sheet with thermal and velocity slip limitations to investigate MHD hybrid nanofluids with heat transport.Omowaye et al [2018] elucidated the MHD flow of viscosity-elastic fluid past an accelerating penetrable surface. Reddy et al [2016] studied Soret-Dufour effects on MHD convective flow of Al2O3-water and TiO2-waternanofluids past a stretching sheet. Rashidi et al [2022] did an extensive survey of energy examination of shell andtube heat exchangers. Farooq Umar et al [2022] as of late analysed the calculation of nonlinear warm radiation in magnetized nanofluid stream with entropy age. Bhatti et al [2022] concentrated on normal convection non-Newtonian EMHD dissipative move through a microchannel containing a non-Darcy porous medium utilizing the homotopy bother technique.Therefore,mentioned above authors show that Cattaneo-Christov models are used to study magnetohydrodynamic with a distinct approach. To the absolute best of our insight, no concentrate in the writing has considered MHD intensity and mass exchange stream of Williamson Half and half nanofluids over a permeable extending sheet with Cattaneo-Christov hypotheses. Subsequently, this paper zeroed in on intensity and mass exchange on Williamson mixture nanofluid stream by means of an extending penetrable surface with attractive and electromagnetic powers. This paper investigated the exploration on crossover nanofluid stream by means of an extended sheet by inspecting Cattaneo-Christov models and the Soret-Dufour system, as well as MHD Williamson stream by taking both attractive field and electromagnetic power importance on stream course into account. Tables and charts are utilized to delineate the effect of stream boundaries on speed, temperature, and fixation in a way that is straightforward. For instance, MHD gas pedals, biomedical and cell research, heat exchangers, and subsurface stockpiling gadgets all advantage from the discoveries of this review.

2. Mathematical analysis

This work considers a2-D free convective flow of MHD Williamson hybrid nanofluids that is laminar and incompressible, passing through a stretched sheet that is saturated in the passable zone. In Figure 1 treats the x-axis along the stretching surface, while the y-axis is evaluated at the surface. In order to coordinate the electric current, a uniform Magnetization B_0 is forced while Magnetic force is applied to the stretched surface. According to the earliest research, the magnetism is unaffected by the produced magnetic field. The stretching surface is kept at a constant temperature (T_w) and concentration (C_w). Both the temperature $T_\infty$and concentration C_∞ are far away from the plate. A state of thermal equilibrium is maintained because no slip considerations exist. The water-based nanofluids are considered to have nonlinear viscous dissipative effects. Estimates of radiative heat flux are made using theRosseland approximation Soret-Dufour mechanisms are also significant because of the high concentrations of the compounds.

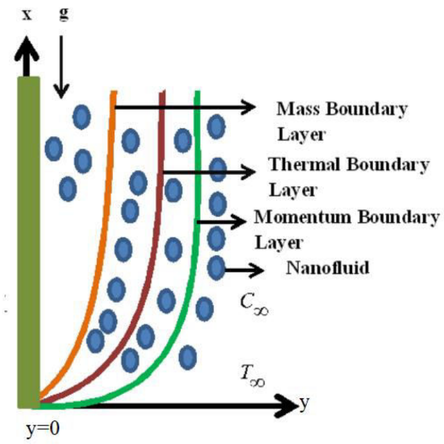


Figure-1: The physical model of the problem.

In view of the assumptions, the governing equations are designed as follows.

$$u_x + v_y = 0 \tag{1}$$

$$uu_x + vu_y = \frac{\mu_{nf}}{\rho_{nf}} u_{yy} + \sqrt{2}\nu\Gamma u_y u_{yy} - \frac{\sigma_{nf}}{\rho_{nf}} B_0^2 u - \frac{\sigma_{nf}}{\rho_{nf}} E_0 B_0 - \frac{\mu_{nf}}{\rho_{nf}} \frac{u}{K} \tag{2}$$

$$uT_x + vT_y = \left[\begin{array}{l} \alpha_{nf} T_{yy} - \dfrac{1}{(\rho Cp)_{nf}} q_{ry} + \dfrac{\mu_{nf}}{(\rho Cp)_{nf}} \left[u_y + \dfrac{\Gamma}{\sqrt{2}} u_y^2 \right] + \dfrac{1}{(\rho Cp)_{nf}} q''' + \dfrac{D_C}{(\rho Cp)_{nf}} C_{yy} \\ + \dfrac{\sigma B_0^2}{(\rho Cp)_{nf}} u^2 - \lambda_1 \left\{ uu_x T_x + vv_y T_y + uv_x T_y + v^2 T_{yy} + vu_y T_x + 2uvT_{xy} + u^2 T_{xx} \right\} \end{array} \right] \tag{3}$$

$$uC_x + vC_y = \left[D_M C_{yy} + D_T T_{yy} - Kr^*(C - C_\infty) - \lambda_2 \left\{ \begin{array}{l} uu_x C_x + vv_y C_y + uv_x C_y \\ + v^2 C_{yy} + vu_y C_x + 2uvC_{xy} + u^2 C_{xx} \end{array} \right\} \right] \tag{4}$$

The appropriate boundary conditions for the model under consideration are given by:

$$\begin{array}{ll} u = bx, v = 0, T = T_w, C = C_w & \text{at} \quad y = 0 \\ u \to 0,\ T \to T_\infty, C \to C_\infty & \text{as} \quad y \to \infty \end{array} \tag{5}$$

$u$and $v$are velocity features along $x$and $y$direction. $b$is stretching rate, $C$is concentration of the fluid, $T$is temperature of the fluid, Kr*is chemical rate of reaction, $\sigma$is electrical conductivity, $\rho_{nf}$is the density of nanofluid, $\alpha_{nf}$is the thermal diffusivity of nanofluid, $\mu_{nf}$is dynamic viscosity of nanofluid, $K$is permeability parameter, $D_M$is diffusivity of species, (ρCp) is heat capacitance of nanofluid, $D_T$indicates mass flux in temperature gradient, $D_C$indicates heat flux in concentration gradient.

The stretching sheet stretches on its plane with surface velocity $U(x) = bx$ where b is stretching rate considered to be positive constant.

In the view of the Rosseland approximation q_r is defined as

$$q_r = -\left(\frac{4\sigma^*}{3k_{nf}} \right) \left(\frac{\partial T^4}{\partial y} \right) \tag{6}$$

where σ^* stands for the Stefan-Boltzmann constant and k_{nf} is the coefficient of mean absorption. Under the above assumptions that the variation of temperature is low between the layers, the following relationship is used

$$T^4 \cong 4T_2^3 T - 3T_2^4 \tag{7}$$

The non-uniform heat Source or Sink

$$q''' = \frac{k_{nf}}{\nu_f} a\left[A\left(T_w - T_\infty\right) f' + \left(T - T_\infty\right) B\right] \tag{8}$$

The similarity transformations considered for the problem are:

$$\begin{aligned} &\eta = \sqrt{\left(b / \nu_f\right)}, \psi = \sqrt{\left(b\nu_f\right)} x f\left(\eta\right), u = bxf'\left(\eta\right), v = -\sqrt{b\nu} f\left(\eta\right) \\ &\zeta\left(\eta\right) = \frac{T - T_\infty}{T_w - T_\infty}, \varpi\left(\eta\right) = \frac{C - C_\infty}{C_w - C_\infty} \end{aligned} \tag{9}$$

Employing the Equations (7-10) on the governing Equations (1-4), subjected to the boundary conditions (5):

$$f''' + K_1 K_2 \left[ff'' - f'^2 - \frac{M}{K_2} f' + E_0 M \right] - A_1 f' + Wef''f''' = 0 \tag{11}$$

$$\left(1 + \frac{4}{3} R\right)\zeta'' + \Pr \frac{K_3}{K_5} \left[\begin{aligned} & f\zeta' - 2f'\zeta + \frac{Ec}{K_4} f''^2 + 0.5Wef''^3 \\ & + \frac{1}{K_3}\left(K_1 f' + L_1 \zeta + Du\varpi''\right) - \beta_1\left(ff'\zeta' + f^2 f''^2\right) \end{aligned} \right] \tag{12}$$

$$\varpi'' Sc\left(f\zeta' - Kr\varpi + Sr\zeta'' - \beta_2\left(ff'\varpi' + f^2\varpi^2\right)\right) = 0 \tag{13}$$

The associated boundary conditions are:

$$\begin{aligned} & f = 0, f' = 1, \zeta = 1, \varpi = 1 \text{ at } \eta = 0 \\ & f' \to 0, \zeta \to 0, \varpi \to 0 \quad \text{as } \eta \to \infty \end{aligned} \tag{14}$$

where

$$M = \frac{\sigma B_0^2}{\rho_f}, \Pr = \frac{\nu_f}{\alpha_f}, K = \frac{\nu_f}{K_p}, We = \Gamma x\sqrt{\frac{2b^3}{\nu_f}}, E_0 = \frac{E}{B_0 U_w}, \beta_1 = \frac{A}{b\left(\rho C_p\right)_f}, Kr = \frac{Kr^*}{b}$$

$$Sc = \frac{\nu_f}{D_M}, So = \frac{D_T\left(T_w - T_\infty\right)}{\nu_f\left(C_w - C_\infty\right)}, Du = \frac{D_C\left(C_w - C_\infty\right)}{\nu_f\left(\rho C_p\right)_f\left(T_w - T_\infty\right)}, \beta_2 = \frac{B}{b\left(\rho C_p\right)_f}, Ec = \frac{U_w^2}{\left(C_p\right)_f\left(T_w - T_\infty\right)}$$

The thermal properties of nanofluid are defined as follows:

$$\begin{aligned} & K_{nf} = k_f \frac{k_s + 2k_f - 2\phi\left(k_f - k_s\right)}{k_s + 2k_f + 2\phi\left(k_f - k_s\right)}, \left(\rho Cp\right)_{nf} = \left(1 - \phi\right)\left(\rho Cp\right)_s + \phi\left(\rho Cp\right)_s, \\ & \alpha_{nf} = \frac{K_{nf}}{\left(\rho Cp\right)_{nf}}, \mu_{nf} = \left(1 - \phi\right)^{-2.5} \mu_f, \rho_{nf} = \left(1 - \phi\right)\rho_f + \phi\rho_s, \nu_f = \frac{\mu_f}{\rho_f}. \end{aligned} \tag{15}$$

4. Result and discussion

The limit esteem issue conditions (11)- (13) were settled mathematically utilizing the capability BVP4C from MATLAB. This BVP4C capability is planned to utilize the 3-stage Lobatto IIIa equation under the limited contrast conspire with fourth request accuracy. Thetables and charts introduced in this part thus compares to these qualities aside from where it is otherwise expressed.

The influence of attractive term (M) on the profile of velocity is displayed in figure 2. The velocity circulation and the whole hydrodynamic limit layer are worked on because of an expansion in M. A forced attractive field produces Lorentz force and this power influences the electrically conductive liquids. For instance, Lorentz force significantly affects speed dissemination in figure 2, since electric component boundary is available in stream system.
The permeability parameter (K) affects the velocity appropriation, as displayed in Figure 3. The porousness boundary increments, bringing about a remarkable change in the velocity profile. The penetrability boundary in a limit layer stream permits liquids to venture out starting with one layer then onto the next genuinely. While expanding K builds the permeable system, it likewise permits more liquid particles to go through. Along these lines, the thickness of the hydrodynamic limit layer continues to rise.
Prandtl (Pr) effect on velocity and temperature appropriations should be visible in Figures 4(a) and 4(b). The velocity and temperature diagrams degenerate emphatically when the Pr is expanded. Since any liquid with a bigger Prandtl will have an extremely high thickness, this outcome is sensibly right. As per the result displayed in Figure 4, the plate has started to cool from the wall up. Due to the low plate surrounding consistency, this is valid. Pr checks the stream conduct of liquid warm and energy boundaries during heat move. Truly, the thickness of the hydrodynamic and warm limit layer upgrades because of expansion in Pr.
On the velocity and fixation charts, Soret (Sr) has an impact displayed in Figure 5. Solutal and hydrodynamic limit layers seem to accelerate because of an expansion in Sr. To settle two-fold diffusive stream, a more noteworthy Sr esteem has been found. For instance, on the off chance that the fixation inclination is more prominent than nothing, the thickness of the nanoparticles falls because of this slope, and they diffuse to a cooler medium. Nonetheless, when the liquid temperature climbs to Sr, the thickness of the liquid ascents and the nanoparticles spread to a hotter climate.
Williamson boundary (Weissenberg number) (We) effects on the profile of velocity is found in Figure 6. The hydrodynamic layer and speed profile are upgraded by expanding We. With regards to speed, the effect of We is most perceptible when you're near the wall and nearly non-existent when you're a long way from the plate. Along these lines, liquid stream is impacted by the wall's thickness.
Figures 7(a) and 7(b) portrays the impact of Dufour (Du) on the velocity and temperature designs in the district. For the dispersion warm nature of the cycle, the meaning of Du should be visible. The energy transition inside the layer is dispersed by the focus inclinations depicted by the Du.
This outcomes in a synchronous decrease of the Solutal and hydrodynamic limit layers. Eckert's (Ec) impact on velocity and temperature conveyances is found in Figures 8(a) and8(b). The Eckert number is a proportion of the enthalpy and dynamic energy in the stream. In a high incompressible stream, Ec fundamentally affects the temperature, which is the reason it is significant at high rates in compressible streams. The result, which indicates that the flow gains more energy and hence improves the thermal and hydrodynamic boundary layers.
To represent the effect of synthetic response term (Kr) on velocity and concentration circulations, Figures 9(a) and 9(b) was made. Destructive outcomes are gotten by decreasing the convergence of species and the energy limit layer at the pace of substance response. Species focus and rubbing coefficient are decreased by the destructive responsive cycle.

Figure 10(a) and 10(b) shows that the velocity and temperature profiles for different values of thermal radiation parameter. The electromagnetic radiation produced by the material medium in view of intensity energy is called warm radiation. The climb in temperature is a consequence of the energy delivered because of warm radiation. Nonetheless, convective stream is supported.

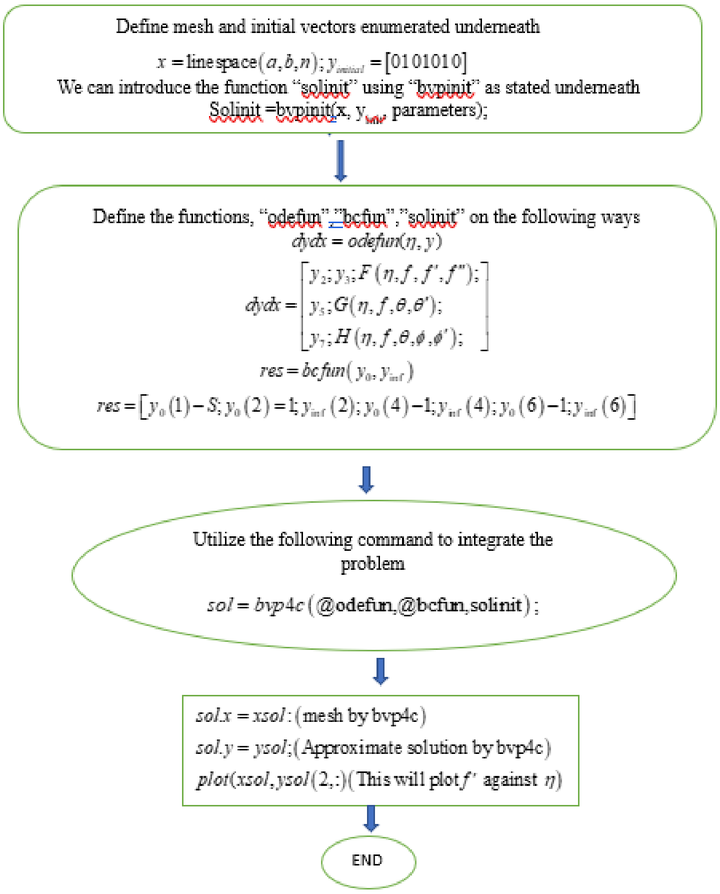
Table I shows the comparison of the present study and that of Sudarshana Reddy and Ali J Chamkha[2016] when $E = We = \beta 1 = \beta 2 = 0$. The present study was found to be in good agreement.

Table II shows that designing amounts is essentially influenced by the flow parameters. Expansion of ‘Pr’ will speed up the coefficient of skin contact and heat transport. No matter how quickly mass is transferred, Prandtl's significance remains constant. As the ‘M’ boundary expands, the coefficient of skin rubbing decreases. The rate of intensity and mass transfer remain constant at the point when ‘M’ expands.There is an expansion in the coefficient of skin grinding and the change of intensity transmission with an expansion in Du, R, Ec, and β_1. Table - II shows that rising the worth of Kr, Sc diminishes the Sherwood coefficient and skin erosion.

5. Conclusion

The following observations can be concluded from the above:

- If the fluid velocity is raised, then the two factors heat generation and thermal radiation enhances the warm fluid particles and fluid temperature.
- A component in the energy equation known as the viscous dissipation term is responsible for the reduction of heat energy into the flow of a fluid. So, heat energy increases the thickness of hydrodynamic and thermal layers.
- This study has shown that the local mass transfer and skin friction increases due to chemical reaction. As the thermal layer thickens, a higher heat relaxation flow and a higher mass relaxation flux were shown to improve fluid particle concentrations and the overall concentration layer.



Flow chart

Table I: Comparison of the present study with the details of Sudarshana Reddy and Ali J Chamkha[2016] when $We = \beta_1 = \beta_2 = 0$

M	ϕ	Ramana Reddy et al[14]				Present study			
		$-f''(0)$		$-\theta'(0)$		$-f''(0)$		$-\theta'(0)$	
		Al_2O_3	TiO_2	Al_2O_3	TiO_2	Al_2O_3	TiO_2	Al_2O_3	TiO_2
0.0	0.05	1.00657	1.01167	1.62258	1.63832	1.00659	1.01169	1.62253	1.63829
	0.10	1.01002	1.01032	1.49187	1.51984	1.01001	1.01031	1.49185	1.51983
	0.15	0.98954	0.99666	1.37561	1.41387	0.98953	0.99665	1.37559	1.41385
	0.20	0.95601	0.97294	1.27153	1.31856	0.95600	0.97294	1.27151	1.31855
0.5	0.05	1.20481	1.20961	1.57892	1.59484	1.20479	1.20960	1.57894	1.59486
	0.10	1.17592	1.18502	1.45312	1.48162	1.17590	1.18501	1.45312	1.48164
	0.15	1.13924	1.15183	1.34128	1.37981	1.13922	1.15181	1.34130	1.37981
	0.20	1.09601	1.10857	1.24152	1.28814	1.09589	1.10754	1.24153	1.28819

Table II: The significance of flow parameters on the skin friction, Nusselt and Sherwood numbers.

Pr	M	K	Sc	Sr	Du	Ec	Kr	R	β1	β2	We	Cf	Nu	Sh
0.71												0.0574	0.3380	0.6781
3.0												1.2168	0.3447	0.6781
7.0												1.4571	0.3697	0.6781
	0.0											0.7676	0.7000	0.0561
	0.5											0.4220	0.7000	0.0561
	1.0											0.1846	0.7000	0.0561
		0.3										0.8929	0.4111	0.5261
		0.6										0.1437	0.4111	0.5261
		1.0										1.1804	0.4111	0.5261
			0.61									1.2363	0.3377	0.5918
			1.0									0.3856	0.3377	0.6352
			3.0									0.1034	0.3377	0.6866
				1.0								0.5045	0.7141	0.1205
				2.0								1.5431	0.7141	0.4484
				3.0								2.3307	0.7141	0.5353
					1.0							0.1042	0.1066	0.3971
					2.0							1.1989	0.2226	0.3971
					3.0							2.2937	0.5518	0.3971
						0.2						0.5565	0.2584	0.6121
						0.4						1.7755	0.8541	0.6121
						0.6						2.9945	1.4498	0.6121
							0.1					0.4467	0.3141	0.7761
							0.3					0.7770	0.3141	0.8430
							0.5					1.2266	0.3141	1.0361
								0.0				0.0845	0.3427	0.8120
								0.5				0.9431	0.3597	0.8120
								1.0				1.8569	0.3777	0.8120
									2.0			0.4343	0.1581	0.1782
									4.0			1.0864	0.2812	0.1782
									6.0			2.4042	0.3318	0.1782
										2.0		0.7126	0.5858	0.0176
										4.0		0.8710	0.5858	0.3897
										6.0		1.2396	0.5858	0.4858
											0.0	1.3434	0.5240	0.6015
											0.5	2.7060	0.5240	0.6015
											1.0	3.0687	0.5240	0.6015

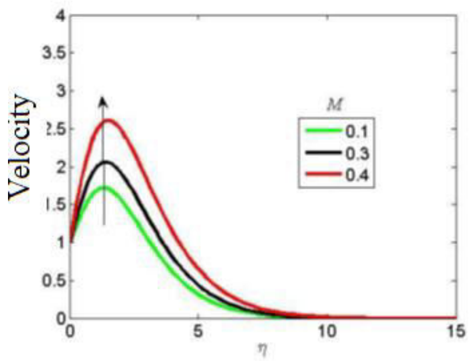


Figure 2: Impact of Magnetic parameter on velocity profiles.

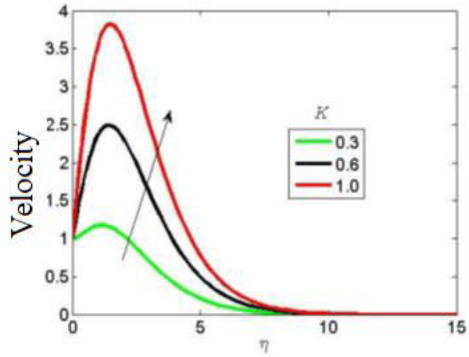


Figure 3: Impact of Permeability parameter on velocity profiles.

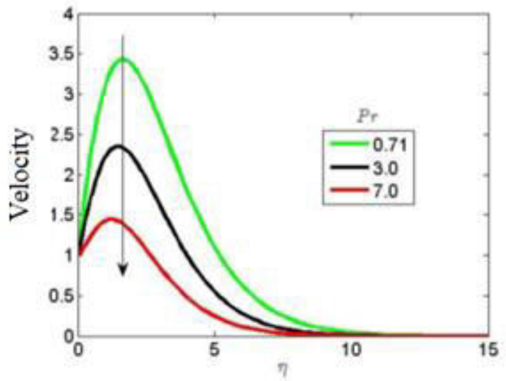


Figure 4(a): Impact of velocity profiles for various values of Prandtl number.

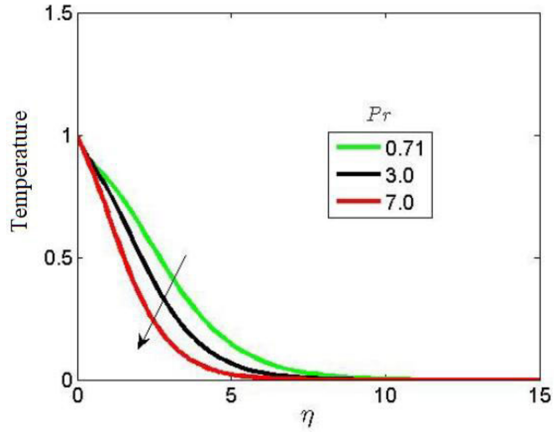


Figure 4(b): Impact of temperature profiles for various values of Prandtl number.

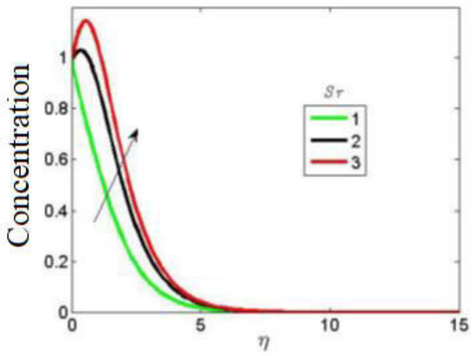


Figure 5: Impact of Soret number on Velocity profiles.

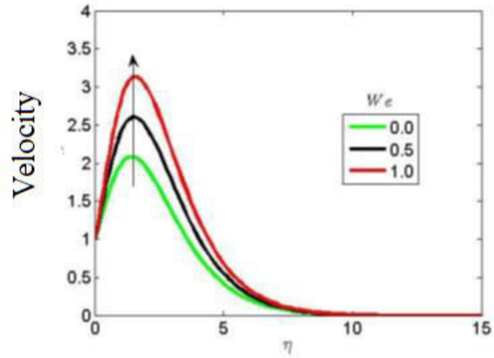


Figure 6: Impact of Weissenberg number on velocity profiles.

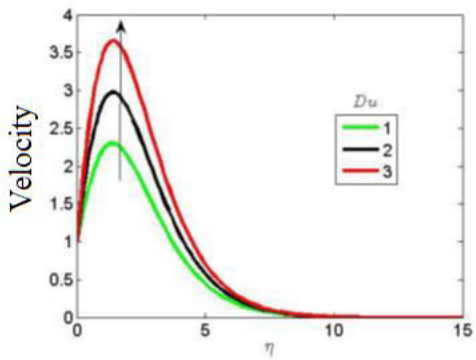


Figure 7(a): Impact of Dufour number on velocity profiles.

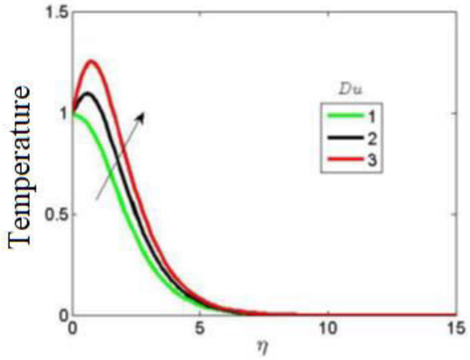


Figure 7(b): Impact of Dufour number on temperature profiles

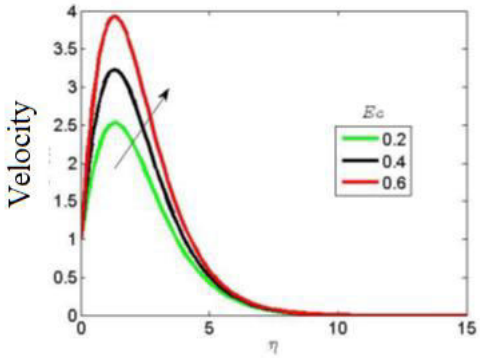


Figure 8(a): Impact of Eckert number on velocity profiles.

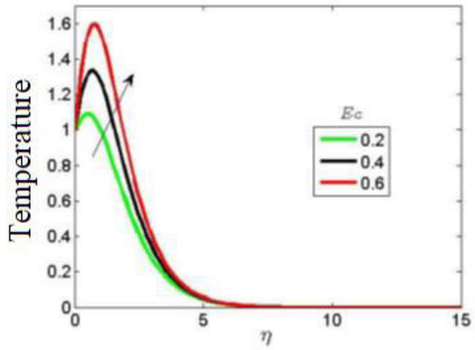


Figure 8(b): Impact of Eckert number on temperature profiles.

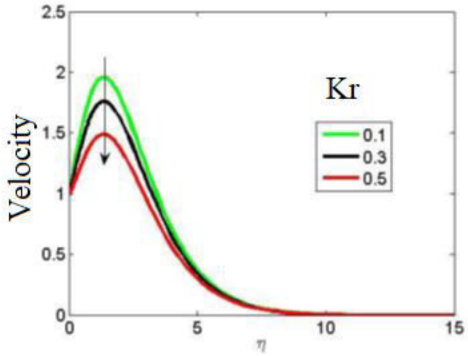


Figure 9(a): Impact of chemical reaction on velocity profiles.

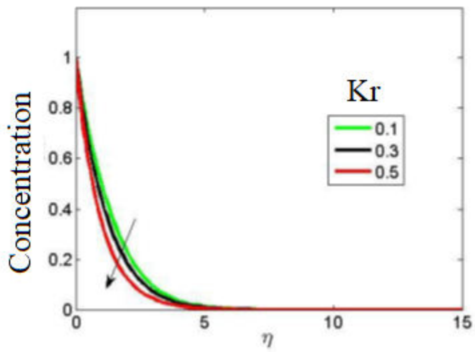


Figure 9(b): Impact of Chemical reaction on concentration profiles.

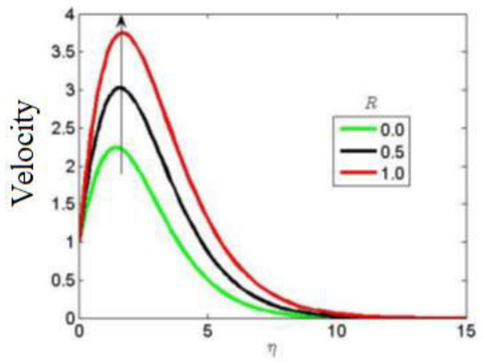
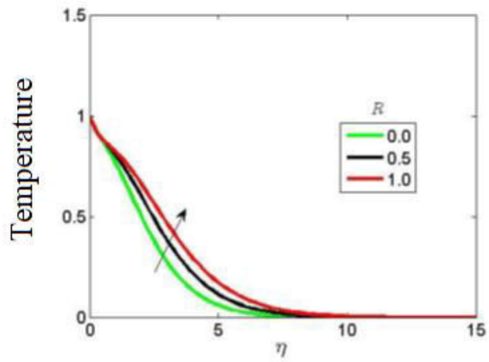
	

Figure 10(a): Impact of radiation parameter on velocity profiles.	Figure 10(b): Impact of radiation parameter on temperature profiles.

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