Hall Current Effects on MHD Convective Flow Past A Porous Plate with Thermal Radiation, Chemical Reaction and Heat Generation /Absorption

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Abstract

In this paper an attempt is made to study the chemical reaction and combined buoyancy effects of thermal and mass diffusion on MHD convective flow along an infinite vertical porous plate in the presence of Hall current with variable suction and heat generation. A uniform magnetic field is applied in a direction normal to the porous plate. The equations governing the fluid flow are solved using the perturbation technique and the expressions for the velocity, the temperature and the concentration distributions have been obtained. Dimensionless velocity, temperature and concentration profiles are displayed graphically for different values of the parameters entering into the problem have been investigated. It has been observed that an increase in the Prandtl number leads to a decrease in the primary and secondary velocities, and also a decrease in the temperature. The primary and secondary velocities decrease with increase in the Chemical reaction parameter or Magnetic field parameter.

Keywords: MHD, Hall effect, Porous medium, Radiation, Chemical reaction, Heat generation/absorption.

Nomenclature

u, v - Velocity components

x, y - Cartesian coordinates

t - Time

g - Acceleration due to gravity

ρ - Density

w - Velocity ratio parameter

ω - Frequency parameter

U_0-Mean velocity

Γ - Dimensionless temperature

λ - Dimensionless concentration

β - Coefficient of volume expansion due to temperature

β * - Coefficient of volume expansion due to concentration

Cp - Specific heat at constant pressure

v - Kinematic viscosity

k - Thermal conductivity

M - Magnetic field parameter

Pr - Prandtl number

G - Thermal Grashof number

Gc - Mass Grashof number

m - Hall parameter

Sc - Schmidt number

χ- Heat source parameter

ξ - Chemical reaction rate constant

ε - Small reference parameter <<1

D - Chemical molecular diffusivity

D1 - Chemical reaction coefficient

Q - Rate of heat absorption per unit volume per degree Kelvin

τ - Skin friction coefficient

Nu - Nusselt number

Sh - Sherwood number

1. Introduction

The Hall effect is observed in charge carriers flowing in a conductor: on the application of a magnetic field, the charge carriers experience a transverse force perpendicular to both the current direction and the applied magnetic field. The charge carriers are pushed towards the edge of the conductor resulting in a voltage build-up, which can be measured with carefully positioned contacts. This effect is used in a Hall effect sensor for sensitive measurements of the magnetic field. In condensed matter physics, the Hall Effect is used as a probe for the measurement of a range of materials including semiconductors, magnetic materials and superconductors. The crystal we've been studying, BSCCO, is a member of the cuprate family of superconductors. These materials are characterized by high superconducting transition temperatures and copper oxide layers, which are responsible for the superconducting phase. When a magnetic field is applied to BSCCO, vortices enter and form a known structure. Beyond a certain applied field, the structure 'melts', producing a peak in the magnetic field inside the superconductor. Measurements of the Hall voltage as a function of applied magnetic field are able to reveal the location of this melting line. So far, we've been introduced to the struggles of experimental physics as we've experienced several difficulties with the resolution of our probe! But we've finally managed to track the melting line over a range of temperatures. The next step is to observe melting as a function of applied magnetic field angle. These measurements are important in BSCCO because of its high anisotropy, therefore the measurements will help us understand how the vortices act along the different directions of the crystal.

Measurements using the Hall effect have been advanced in recent years thanks to a new technique known as Scanning Hall probe microscopy (SHPM) developed by Simon and his group in Bath. The technique makes use of small GaAs/AlGaAs Hall probes with extremely high sensitivity in combination with a scanning tunneling microscope. Scanning Hall microscopes can therefore spatially map the magnetic state of a material making them a useful tool in many areas of condensed matter physics. Hall effects on unsteady MHD oscillatory free convective flow of second grade fluid through porous medium between two vertical plates was studied by Veera Krishna et al. [1]. Veera Krishna [2] to studied hall effects on unsteady MHD flow of second grade fluid through porous medium with ramped wall temperature and ramped surface concentration. The influence of hall effect on the flow in the presence of various physical parameters has been investigated by Veera Krishna and Chamkha [3], Satyanarayana, Venkateswarlu and Venkatraman [4], Masthanra and Balamurugan et al. [5].

The MHD heat and mass transfer processes over a moving surface are of interest in engineering and geophysical applications such as geothermal reservoirs, thermal insulation, enhanced oil recovery, packed-bed catalytic reactors, cooling of nuclear reactors. Many chemical engineering processes like metallurgical and polymer extrusion processes involve cooling of a molten liquid being stretched into a cooling system; the fluid mechanical properties of the penultimate product depend mainly on the cooling liquid used and the rate of stretching. Some polymer fluids like polyethylene oxide and polyisobutylene solution in cetane, having better electromagnetic properties, are normally used as cooling liquid as their flow can be regulated by external magnetic fields in order to improve the quality of the final product. Veera Sankar et al. [6] considered unsteady MHD convective flow of Rivlin-Ericksen fluid over an infinite vertical porous plate with absorption effect and variable suction. Rama Krishna Reddy et al. [7] studied the MHD free convective flow past a porous plate. Heat transfer on MHD convective flow of heat generating/absorbing second grade fluid through porous medium in a rotating parallel plate was studied by Suresh babe et al. [8]. Shyam lal Yadav et al. [9] have discussed the magneto hydro dynamic flow in horizontal concentric cylinders.

Matters with masses form naturally into porous structures. They occur almost over the entire world at different scales under considerations. Materials with porous structures are called porous media. A porous medium (or a porous material) is a solid matrix which is characterized by the presence of void spaces within its own volume. The medium can thus be modelled as a solid matrix permeated by a network of channel, or pores, where a fluid (liquid or gas) can move. Usually both the solid matrix and the fluid are assumed to be continuous. One very good example of a porous medium can be a sponge. Many natural substances such as rocks, soils, biological tissues (e.g. bones), and manmade materials such as cements, foams and ceramics can be considered as porous media. A porous medium is defined by its porosity, permeability as well as by the properties of its constituents (solid matrix and uid). In clear fluids, the momentum balance equation commonly used is the well-known Naiver-Stokes equation. On modelling flows in porous media, the Naiver-Stokes equation does not provide a satisfactory description of the system. In fact, different approaches to the formulation of the momentum balance equation for fluid owing in saturated porous media have been proposed. Unsteady flows in porous media have recently received great attention. One example is the oscillating flow in the regenerators used in Sterling engines and catalytic converters. Others are the transient processes in the start-up and shut down of a capillary heat pipe in mechanical engineering, and the well-bore pumping in hydraulic and petroleum engineering. Because of the lack of adequate equations to describe the unsteady flows in porous media.

Sharma [10] considered unsteady natural convection flow past a vertical surface in a rotating porous medium with variable permeability. Effects of chemical reaction on free convection flow through a porous medium bounded by a vertical surface, was studied by Mahapatra et al. [11]. Raju et al. [12] considered the unsteady MHD free convection oscillating couette flow through a porous medium with periodic wall temperature in presence of chemical reaction and thermal radiation. Researchers [13 -15] shown interest in this area.

Simultaneously, radiation of thermal can be described as electromagnetic waves in all matter emitted by the charged particles thermal motion, and it has a temperature more than absolute zero. Since radiation is one of the three fundamental methods of heat transfer, thus a continuous progress on the interpretation of flow with radiative heat transfer processing in engineering and industry sectors is highly considered. The reason behind this consideration is because any flow processing that requires high temperature are highly considered the thermal radiation effects at most of the time, because the radiation can significantly affect the participating heat transmit rate of fluids, in addition with the distribution of temperature in the boundary layer flow when temperatures are high. Hence, compared to other well-known methods, the thermal radiation concept is still in a high level of interest as it may achieve a significant control on cooling rate and also providing better results in such a way as to monitor the solidification at a slower rate.

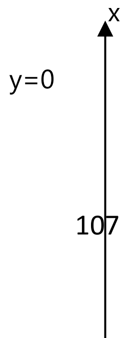
Ananda Reddy et al. [16] studied the effect of radiation and dufour effects on laminar flow of a rotating fluid past a porous plate in conducting field. Effects of Radiation and Chemical Reaction on MHD Flow Past an Oscillating Inclined Porous Plate with Variable Temperature and Mass Diffusion was studied by Hari Krishna et al. [17]. Khem Chand et al. [18] considered the effects of rotation, radiation and hall current on mhd flow of a viscoelastic fluid past an infinite vertical porous plate through porous medium with heat absorption, chemical reaction and variable suction. Rama Krishna Reddy [19] studied thermal diffusion effect on MHD free convective heat absorbing fluid with variable temperature and concentration.

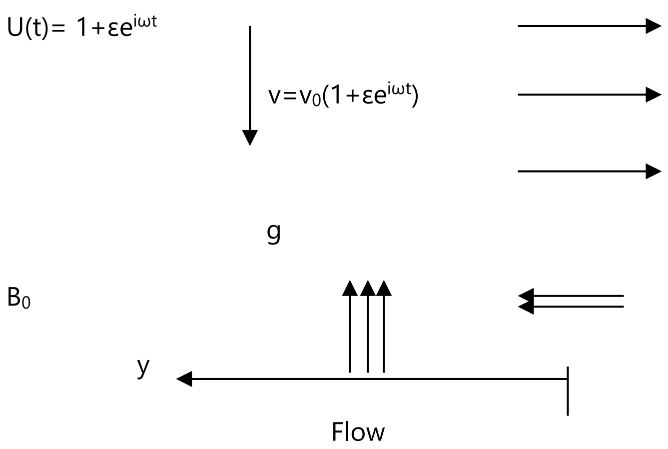
In many chemical engineering and hydrometallurgical practices, it is required to investigate the influence of chemical reaction on heat and mass transfer flow because of the growing need for chemical reactions. This study is further plays outstanding role industries such as chemical industry, power and cooling industry for the applications of evaporation, flow in a desert cooler, energy transfer in a cooling tower, drying etc. Mahapatra et al. [20] studied the effects of chemical reaction on free convection flow through a porous medium bounded by a vertical surface. Heat source and chemical effects on MHD convection flow embedded in a porous medium with Soret, viscous and Joules dissipation was studied by Mohammed Ibrahim et al. [21]. Effects of chemical reaction on free convection flow through a porous medium bounded by a vertical surface was discussed by Mahapatra et al. [22]. Sudhakar Reddy [23] studied chemical reaction and radiation effects on MHD free convection flow through a porous medium bounded by a vertical surface with constant heat and mass flux. The effect of chemical reaction on MHD free convection flow of dissipative fluid past an exponentially accelerated vertical plate was studied by Kishore et al. [24].

The Study of heat generation or absorption effects in moving fluids is important in view of several physical problems such as fluids under-going exothermic or endothermic chemical reactions. The volumetric heat generation has been assumed to be constant or a function of space variable. For example, a hypothetical core-disruptive accident in a Liquid Metal Fast Breeder Reactor (LMFBR) could result in the setting of fragmented fuel debris on horizontal surfaces below the core. The porous debris could be saturated sodium coolant and heat generation will result from the radioactive decay of the fuel particulate. Chemical reaction and radiation absorption effects on MHD convective heat and mass transfer flow of a visco-elastic fluid past an oscillating porous plate with heat generation / absorption was studied by Ramaiah et al. [25]. Recently researchers [26-41] showed interest in this area.

2. Formulation of the Problem

The transient MHD free connection flow of an electrically conducting fluid over a porous vertical infinite plate with variable suction and heat generation has been considered. The x axis is assumed to be along the plate and the *y* axis is normal to the plate. Under the Boussinesq's approximation and the boundary layer theory, the governing equations for the problem under consideration are as follows:





Physical model of the problem

Continuity equation:

$$\frac{\partial v^*}{\partial y^*}=0 \tag{1}$$

Momentum equation:

$$\frac{\partial u^*}{\partial t^*}+V^*\frac{\partial u^*}{\partial y^*}=\frac{\partial U^*}{\partial t^*}+\vartheta\frac{\partial^2 u^*}{\partial y^{*2}}+g\beta\ (T^*-T_\infty^*)+gB^*(C^*-C_\infty^*) -\frac{\sigma B_0^2}{\rho(1+m^2)}(u^*-U^*+mw^*)-\frac{\vartheta}{K}(u^*-U^*) \tag{2}$$

$$\frac{\partial w^*}{\partial t^*}+V^*\frac{\partial w^*}{\partial y^*}=\vartheta\frac{\partial^2 w^*}{\partial y^{*2}}+\frac{\sigma B_0^2}{\rho(1+m^2)}[m(u^*-U^*)-w^*]-\frac{\vartheta}{K}w^* \tag{3}$$

Energy equation:

$$\frac{\partial T^*}{\partial t^*}+V^*\frac{\partial T^*}{\partial y^*}=\frac{K}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}}-\frac{1}{\rho C_p}\frac{\partial q_r^*}{\partial y^*}-\frac{Q}{\rho C_p}(T^*-T_\infty) \tag{4}$$

Concentration equation:

$$\frac{\partial C^*}{\partial t^*}+V^*\frac{\partial C^*}{\partial y^*}=D\frac{\partial^2 C^*}{\partial y^{*2}}-K_r(C^*-C_\infty) \tag{5}$$

The relevant boundary conditions are given as follows

$$u^* = 0, \quad w^* = 0, \quad T^* = T_\infty + (T_w^* - T_\infty^*), \quad C^* = C_\infty + (C_w^* - C_\infty^*) \quad \text{at} \quad y^* = 0 \tag{6}$$

$$u^* \to U^*(t^*),\ w^* \to 0, \quad T^* \to T_\infty^*, \qquad C^* \to C_\infty^* \quad \text{as } y^* \to \infty$$

The plate is subjected to a variable suction velocity with time so that we can replace

$v^* = -v_0(1+\varepsilon e^{i\omega t})(\varepsilon << 1)$, where v_0 is the steady suction velocity.

On introducing the following non-dimensional quantities,

$$u = \frac{u^*}{U_0^*}, \quad w = \frac{w^*}{U_0^*} \quad y = \frac{v_0^{\ *} y^*}{\vartheta}, \quad t = \frac{t^* v_0^{*2}}{4\vartheta} \quad \Gamma = \frac{T^* - T_\infty}{T_w^* - T_\infty^*}, \qquad \lambda = \frac{C^* - C_\infty}{C_w^* - C_\infty^*},$$

$$\Pr = \frac{\mu C_p}{K}, \ Sc = \frac{\vartheta}{D}, \ M^2 = \frac{\sigma B_0^2 \vartheta}{\rho v_0^{*2}}, G = \frac{\vartheta g \beta \ (T_W^* - T_\infty^*)}{U_0^* v_0^{*2}}, \quad Gc = \frac{\vartheta g \beta^* (C_w^* - C_\infty^*)}{U_0^* v_0^{*2}} \tag{7}$$

$$K_1 = \frac{K v_0^{*2}}{\vartheta^2}, U = \frac{U^*}{U_0^*}, \ \xi = \frac{\vartheta K_r}{v_0^{*2}}, \eta = \frac{4 I_1 \vartheta^2}{K v_0^{*2}}, \ \chi = \frac{Q\ v^2}{K v_0^{*2}}$$

We obtain the following equations in dimensionless form.

$$\frac{1}{4}\frac{\partial F}{\partial t} - (1+\varepsilon e^{i\omega t})\frac{\partial F}{\partial y} - \frac{\partial^2 F}{\partial y^2} + \frac{M^2}{1+m^2}(F - U\ \ )(1 - im) = \frac{1}{4}\frac{\partial u}{\partial t} + G\Gamma + Gc\lambda - \frac{(F-U)}{K_1} \tag{8}$$

$$\frac{\Pr}{4}\frac{\partial \Gamma}{\partial t} - \Pr(1+\varepsilon e^{i\omega t})\frac{\partial \Gamma}{\partial y} = \frac{\partial^2 \Gamma}{\partial y^2} - \eta_1 \Gamma \tag{9}$$

$$\frac{Sc}{4}\frac{\partial \lambda}{\partial t} - Sc(1+\varepsilon e^{i\omega t})\frac{\partial \lambda}{\partial y} = \frac{\partial^2 \lambda}{\partial y^2} - Sc\xi\lambda \tag{10}$$

Where F=u+iw

The corresponding boundary conditions are

F=0, Γ=1, λ=1, at y=0 (11)

F→v(t), Γ→0, λ→0, as y→∞

3. Method of Solution

To solve the nonlinear equations (8) to (10) with the boundary conditions (11), we assume that

$$F=(1-F_0)+\varepsilon(1-F_1)e^{i\omega t},\ U=1+\varepsilon e^{i\omega t},\Gamma=\Gamma_0+\varepsilon\Gamma_1 e^{i\omega t},\lambda=\lambda_0+\varepsilon\lambda_1 e^{i\omega t} \tag{12}$$

We now substitute equation (12) into equations (8) to (10) and equating the like terms,

neglecting higher order terms in ε, we obtain

Zero order terms :

$$F_0''+F_0'-(\alpha_1+\frac{1}{K_1})\mathrm{F}_0=\mathrm{G}\,\Gamma_0+\mathrm{Gc}\,\lambda_0 \tag{13}$$

$$\Gamma_0''+\mathrm{Pr}\,\Gamma_0'-\ \eta_0\Gamma_0=0 \tag{14}$$

$$\lambda_0''+Sc\lambda_0'-\ Sc\xi\lambda_0=0 \tag{15}$$

First order terms:

$$F_1''+F_1'-(\alpha_1+\frac{i\omega}{4}+\frac{1}{K_1})\mathrm{F}_1=-\frac{\partial F_0}{\partial y}+\mathrm{G}\,\Gamma_1+\mathrm{Gc}\,\lambda_1 \tag{16}$$

$$\Gamma_1''+\mathrm{Pr}\,\Gamma_1'-(\eta_1-\frac{i\omega\mathrm{Pr}}{4})\Gamma_1=-\mathrm{Pr}\frac{\partial\Gamma_0}{\partial y} \tag{17}$$

$$\lambda_1''+Sc\lambda_1'-\mathrm{Sc}(\xi+\frac{i\omega}{4})\lambda_1=-Sc\frac{\partial\lambda_0}{\partial y} \tag{18}$$

The boundary conditions are

$F_0=1$, $F_1=1$ $\Gamma_0=1$, $\Gamma_1=0$, $\lambda_0=1$, $\lambda_1=1$, at $y=0$ (19)

$F_0\to0$, $F_1\to0$ $\Gamma_0\to0$, $\Gamma_1\to0$, $\lambda_0\to0$, $\lambda_1\to0$, as $y\to\infty$

In Equations (13) to (18), the primes denote the derivatives with respect to *y*. Solving equations (13) to (18) subject to the boundary conditions (19), we get

$$\Gamma_0=e^{-\eta_2 y} \tag{20}$$

$$\Gamma_1 = \frac{\Pr\eta_2}{a_1}(e^{-\eta_2 y} - e^{-\eta_3 y}) \tag{21}$$

$$\lambda_0 = e^{-\eta_4 y} \tag{22}$$

$$\lambda_1 = \frac{Sc\eta_4}{a_2}(e^{-\eta_4 y} - e^{-\eta_5 y}) \tag{23}$$

$$F_0 = A_1 e^{-\eta_2 y} + A_2 e^{-\eta_4 y} + A_3 e^{-\eta_6 y} \tag{24}$$

$$F_1 = A_4 e^{-\eta_4 y} - A_5 e^{-\eta_3 y} + A_6 e^{-\eta_4 y} - A_7 e^{-\eta_5 y} + A_8 e^{-\eta_6 y} + A_9 e^{-\eta_7 y} \tag{25}$$

Substituting equations (20) – (25) in equation (12) we obtain the Velocity, Temperature and Concentration field

$$\begin{aligned} F &= [1-(A_1 e^{-\eta_2 y} + A_2 e^{-\eta_4 y} + A_3 e^{-\eta_6 y})] \\ &+ \varepsilon[1-(A_4 e^{-\eta_4 y} - A_5 e^{-\eta_3 y} + A_6 e^{-\eta_4 y} - A_7 e^{-\eta_5 y} + A_8 e^{-\eta_6 y} + A_9 e^{-\eta_7 y})]e^{i\omega t} \end{aligned} \tag{26}$$

$$\Gamma = e^{-\eta_2 y} + \varepsilon \frac{\Pr\eta_2}{a_1}(e^{-\eta_2 y} - e^{-\eta_3 y})e^{i\omega t} \tag{27}$$

$$\lambda = e^{-\eta_4 y} + \varepsilon \frac{Sc\eta_4}{a_2}(e^{-\eta_4 y} - e^{-\eta_5 y})e^{i\omega t} \tag{28}$$

Skin Friction: he **s**kin-friction coefficient (τ) at the plate is:

$$\tau = \left(\frac{\partial F}{\partial y}\right)_{y=0}$$

$$\begin{aligned} \tau &= (A_1\eta_2 + A_2\eta_4 + A_3\eta_6) \\ &+ \varepsilon(A_4\eta_2 - A_5\eta_3 + A_6\eta_4 - A_7\eta_5 + A_8\eta_6 + A_9\eta_7)e^{i\omega t} \end{aligned} \tag{29}$$

Nusselt Number:

The rate of heat transfer in terms of the Nusselt number is given by

$$Nu = -\left(\frac{\partial \Gamma}{\partial y}\right)_{y=0}$$

$$Nu = -\eta_2 + \varepsilon \frac{\Pr\eta_2}{a_1}(\eta_3 - \eta_2)e^{i\omega t} \tag{30}$$

Sherwood Number:

The rate of mass transfer on the wall in terms of Sherwood number is given by

$$Sh = -\left(\frac{\partial \lambda}{\partial y}\right)_{y=0}$$

$$Sh = -\eta_4 + \varepsilon \frac{Sc\eta_4}{a_2}(\eta_5 - \eta_4)e^{i\omega t} \quad (31)$$

4. Results and Discussion

In order to get a physical insight into the problem numerical calculations are carried out for the

transient primary velocity u, the secondary velocity *w*, the temperature *Γ* and concentration λ,

in terms of the parameters *M, K*$_1$, *Sc, Pr ,m, G, Gc, η and χ* respectively. Throughout the computations we employ the Prandtl number *Pr* = 0.71, Grashoff number *G* = 5.0, Modified Grashoff number *Gc*= 2.0, Schmidt number *Sc* = 0.22, Magnetic field parameter *M* = √10 , Radition parameter η=0.5, Heat absorption parameter χ=1, Chemical reaction parameter ξ=0.1, Hall parameter m=1 Permeability Parameter $K_{1=}$ 0.5, ω = 5.0, ε = 0.01, and ω*t* =π/2.

4.1. Velocity Profiles

Figures 1 to 14 display the effects of a Magnetic field parameter (*M*), Permeability parameter (K_1), Grash of number(G), Modified Grash of number (Gc), Prandtl number (*Pr*), Heat absorption parameter (*χ*), Hall parameter (*m*) on primary and secondary velocity distributions respectively. From Figures 1 and 2, it is observed that an increase of Magnetic field parameter leads to decrease in primary and secondary velocity fields. It is because that the application of transverse magnetic field will result a resistive type force (Lorentz force) similar to drag force which tends to resist the fluid flow and thus reducing its velocity. In Figures 3 and 4, we represent the velocity profiles for different values of Permeability parameter (K_1). The flow field suffers an increase in the primary velocity and secondary velocity at all points in the presence of Permeability parameter(K_1). In Figures 5 and 6, velocity profiles are displayed with the variation in Grash of number(G). From this figure it is noticed the velocity gets increase by the increase of Grash of number(G). In Figures 7 and 8, we represent the velocity profiles for different values of Modified Grash of number (Gc). From this figure it is noticed that, velocity increases with increases in Modified Grash of number (Gc). The behavior of the primary velocity and secondary velocity for different values Prandtl number is shown in Figures 9 and 10. The numerical results show that the effect of increasing values of Prandtl number results in decreasing both primary and secondary velocity fields. Figures 11 and 12 discuss the effect of Heat absorption parameter on the velocity of the flow field. It is found that an increase in Heat absorption parameter leads to a reduction in the primary and secondary velocity fields. It is seen from Figures 13 and 14 that hall parameter(m) accelerates the both primary and secondary velocity field.

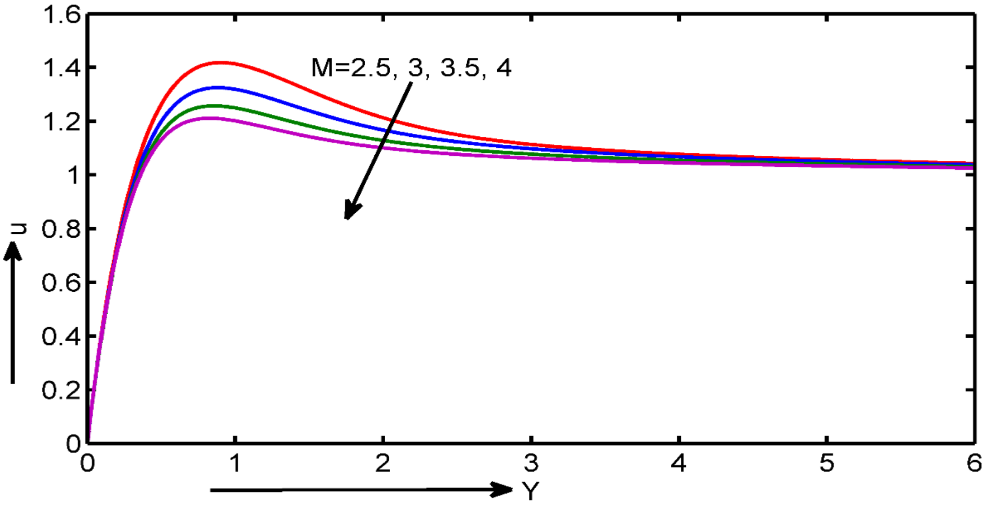


Figure 1: Effect of Magnetic Parameter on Primary Velocity

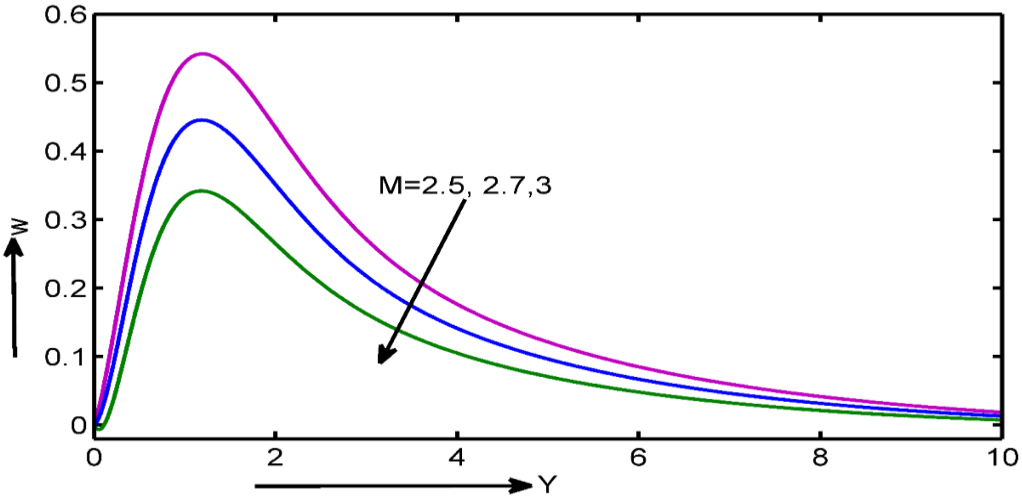


Figure 2: Effect of Magnetic Parameter on Secondary Velocity

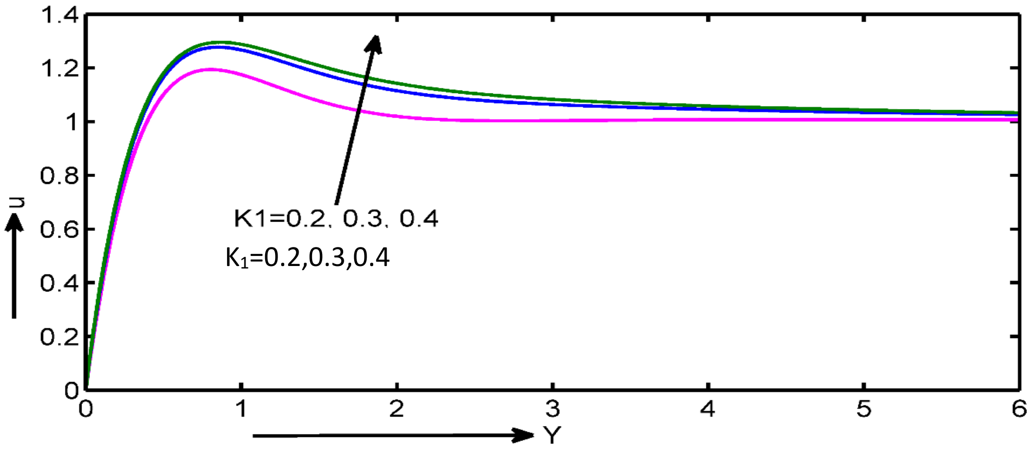


Figure 3: Effect of Permeability Parameter on Primary Velocity

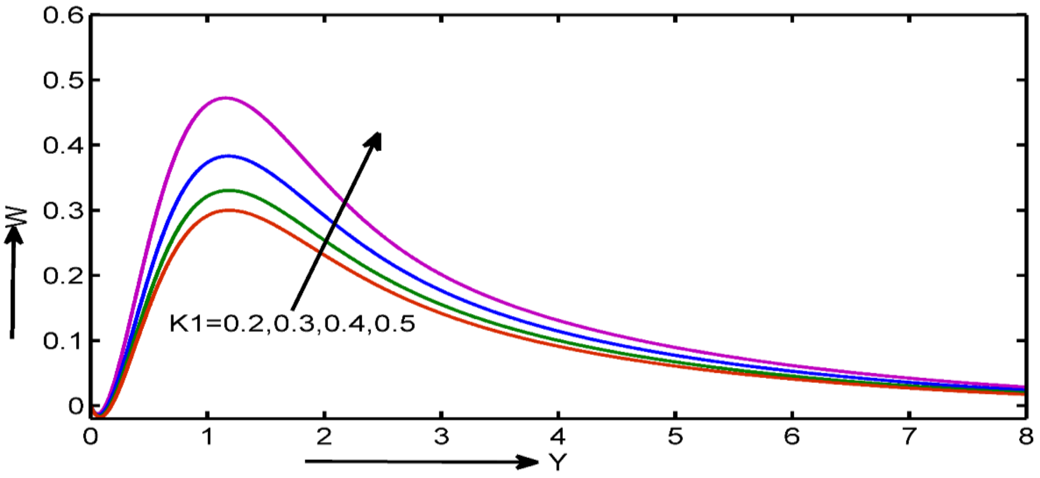


Figure 4: Effect of Permeability Parameter on Secondary Velocity

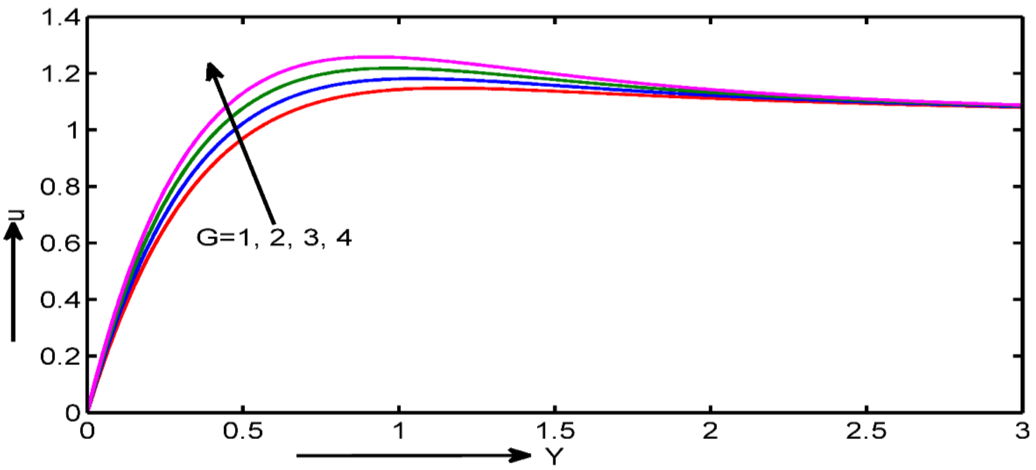


Figure 5: Effect of Grashoff Number on Primary Velocity

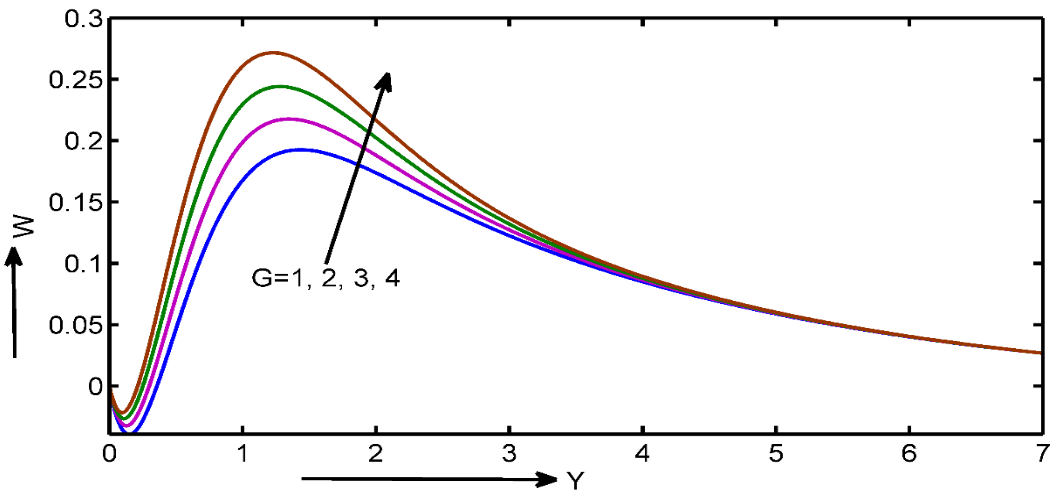


Figure 6: Effect of Grashoff Number on Secondary Velocity

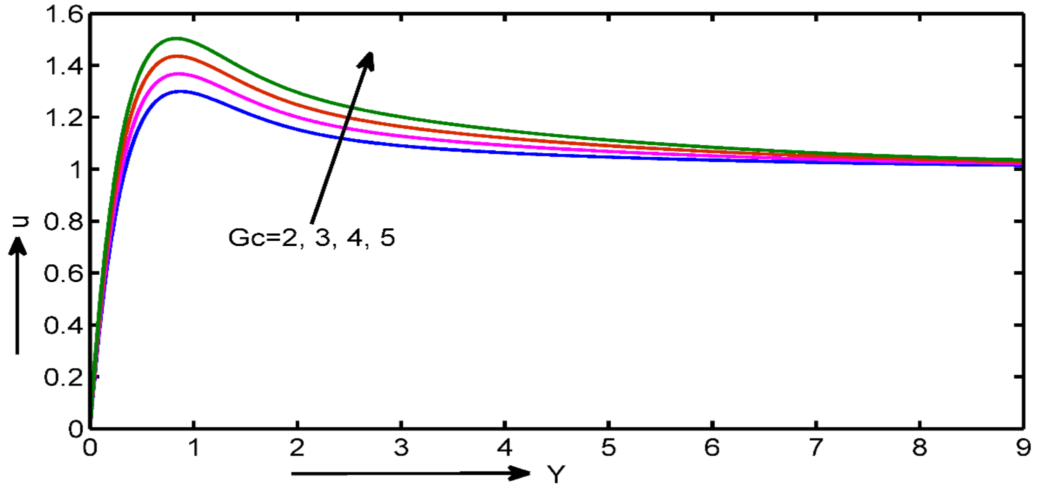


Figure 7: Effect of Modified Grashoff Number on Primary Velocity

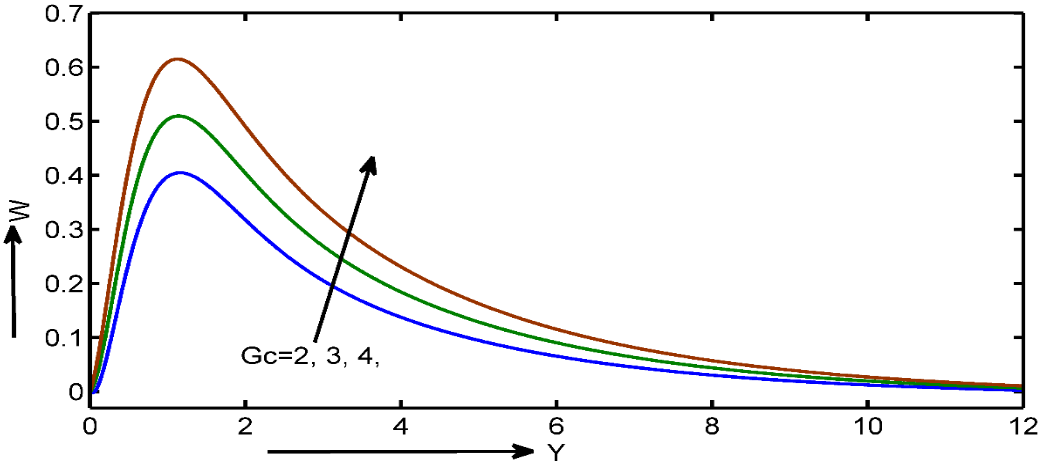


Figure 8: Effect of Modified Grashoff Number on Secondary Velocity

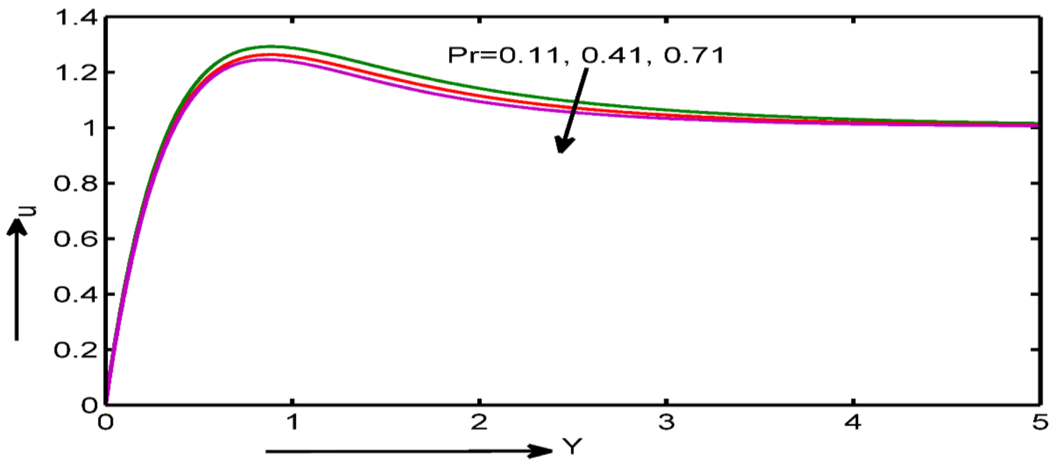


Figure 9: Effect of Prandtl Number on Primary Velocity

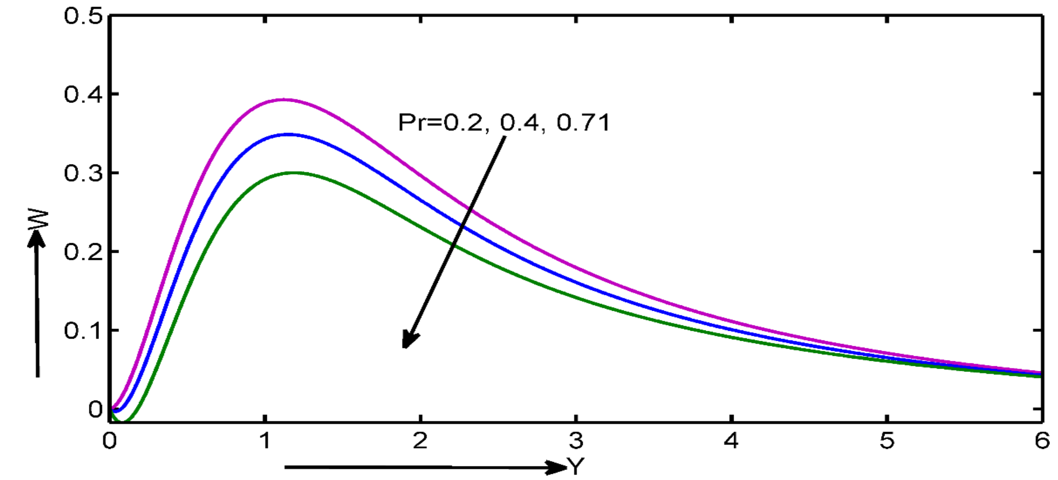


Figure 10: Effect of Prandtl Number on Secondary Velocity

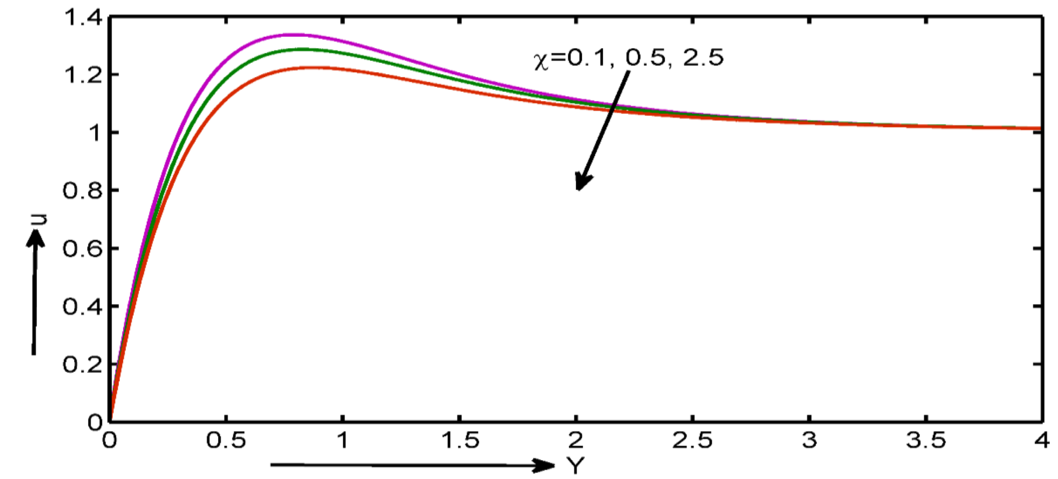


Figure 11: Effect of Heat absorption Parameter on Primary Velocity

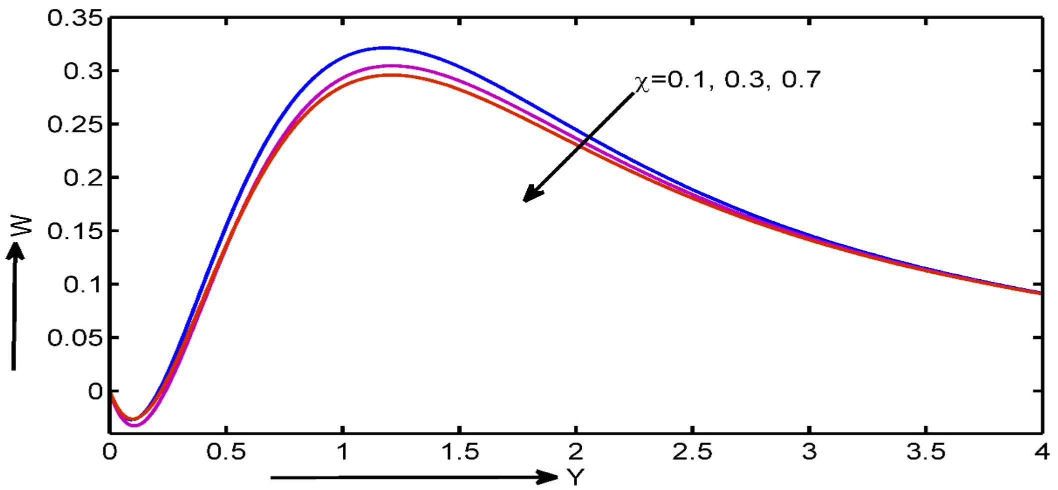


Figure 12: Effect of Heat absorption Parameter on Secondary Velocity

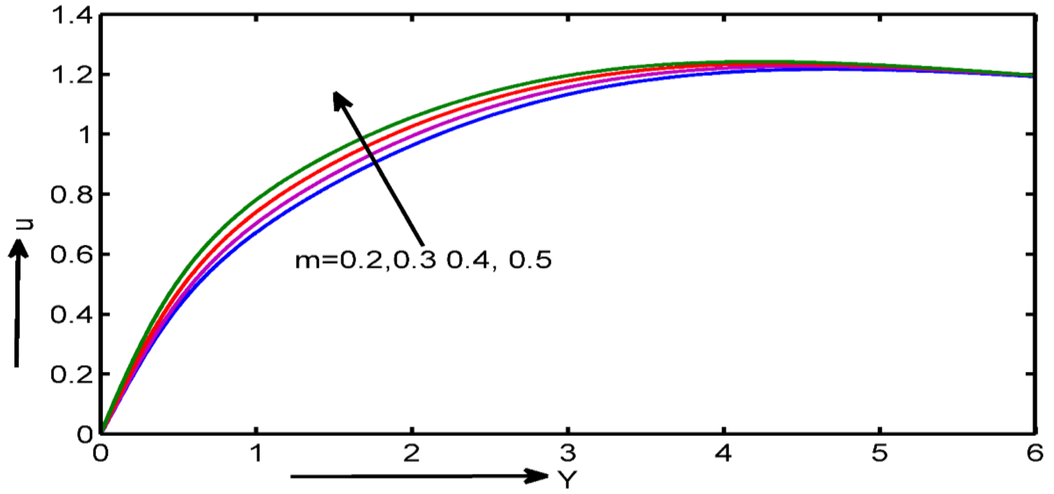


Figure 13: Effect of Hall Parameter on Primary Velocity

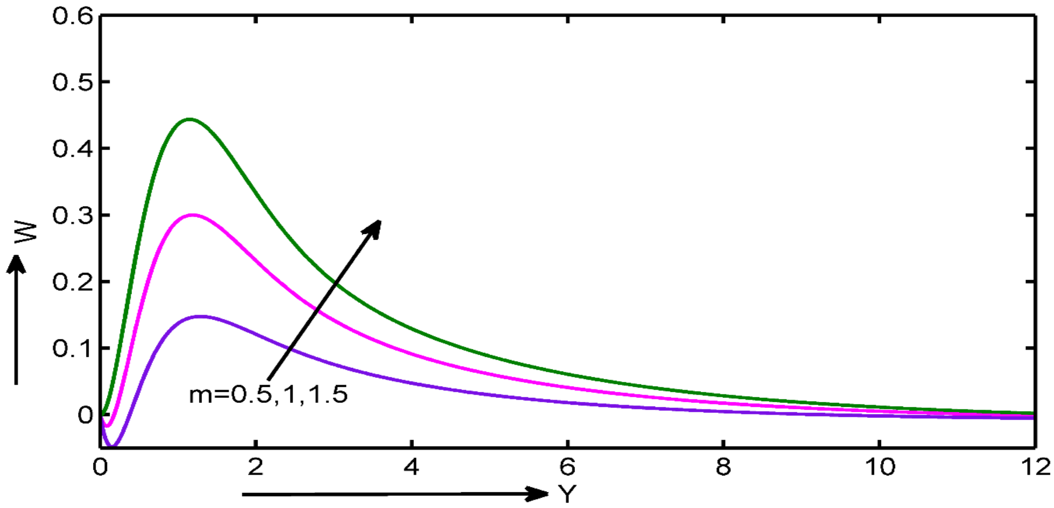


Figure 14: Effect of Hall Parameter on Secondary Velocity

4.2 Temperature Profiles

Figures 15 to 17 show the effects of material parameters such as *Pr, η* and χ *on* temperature distribution. The effect of Prandtl number is very important in temperature profiles. There is a decrease in temperatures due to increasing values of the Prandtl number (Pr) as shown in Figure 15. From Figure16, it is clear that temperature decreases with the increase in radiation parameter (η). In Figure17, the effect of Heat absorption parameter (χ) is shown on temperature profile. From this figure it is observed that temperature decreases with an increase in χ.

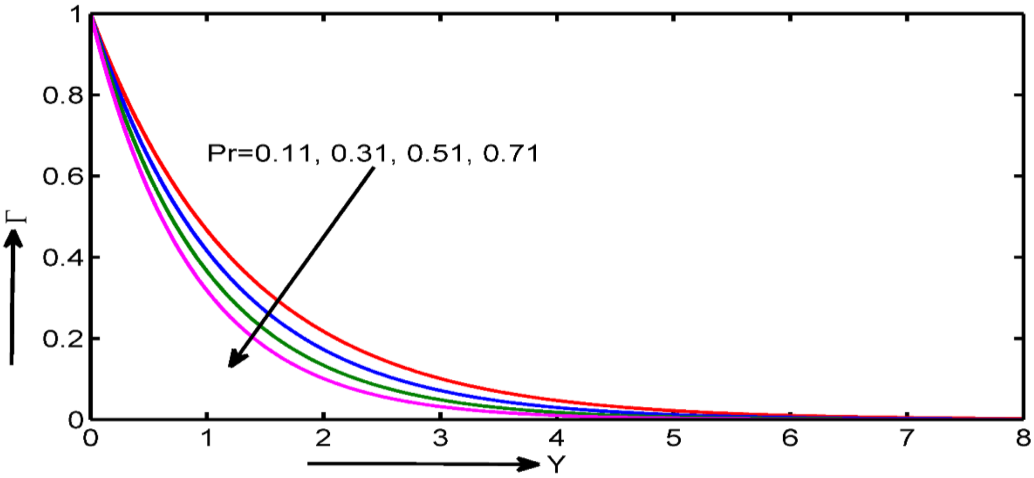


Figure 15: Effect of Prandtl Number on Temperature

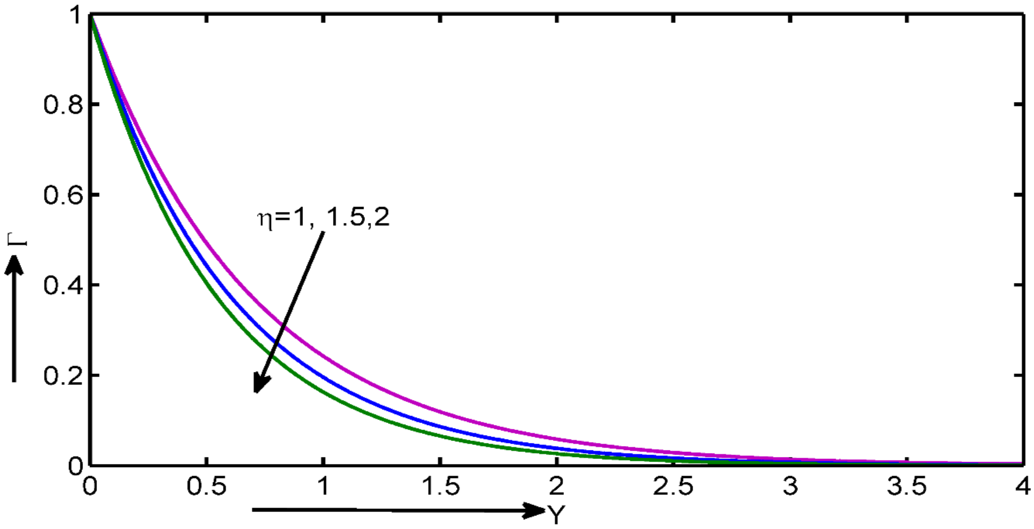


Figure 16: Effect of Radiation Parameter on Temperature

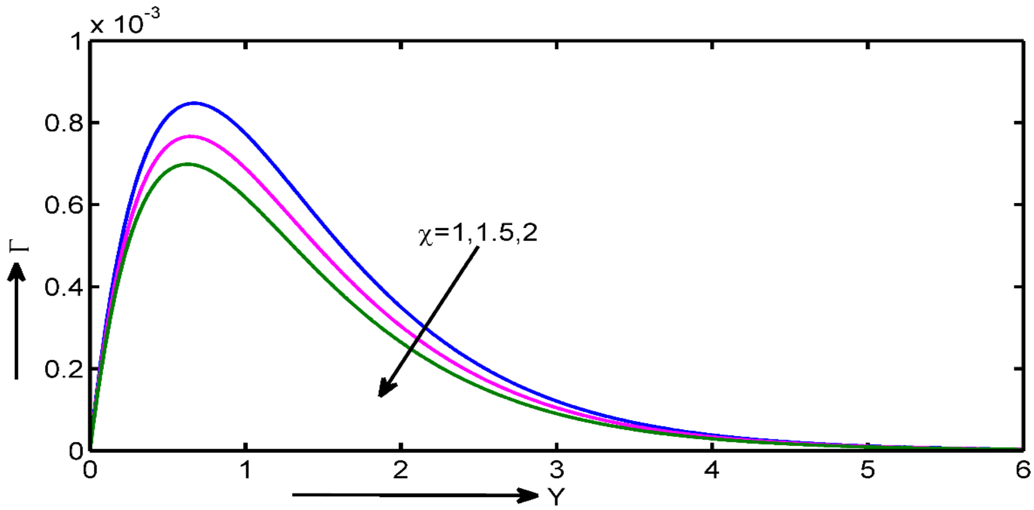


Figure 17: Effect of Heat absorption Parameter on Temperature

4.3. Concentration Profiles

Figures 18 and 19 show the profile of concentration. Figure 18 shows the effect of Schmidt number on the concentration. It is found that the concentration decreases with increase in *Sc*. From figure 19, it is found that the concentration decreases as the Chemical reaction parameter(ξ) increase.

Table – 1, shows numerical values of skin-friction for various of Prandtl number (Pr), Heat absorption parameter (χ), Chemical reaction parameter (ξ), Schmidt number (Sc) and Magnetic parameter (M). From table 1, we observe that the skin-friction decreases with an increase Prandtl number (Pr), Heat absorption parameter (χ), Chemical reaction parameter (ξ), Schmidt number (Sc) and Magnetic parameter(M). Table – 2 demonstrates the numerical values of Nusselt number (Nu) for different values of Prandtl number (Pr), Heat absorption parameter (χ) and Radiation parameter(η). From table 2, we noticed that the Nusselt number increases with an increase in Prandtl number (Pr), Heat absorption parameter (χ) and Radiation parameter(η). Table – 3 shows numerical values of Sherwood number (Sh) for the distinction values of Schmidt number (Sc) and Chemical reaction parameter (ξ). It can be noticed from Table - 3 that the Sherwood number enhances with rising values of Schmidt number and the Chemical reaction parameter.

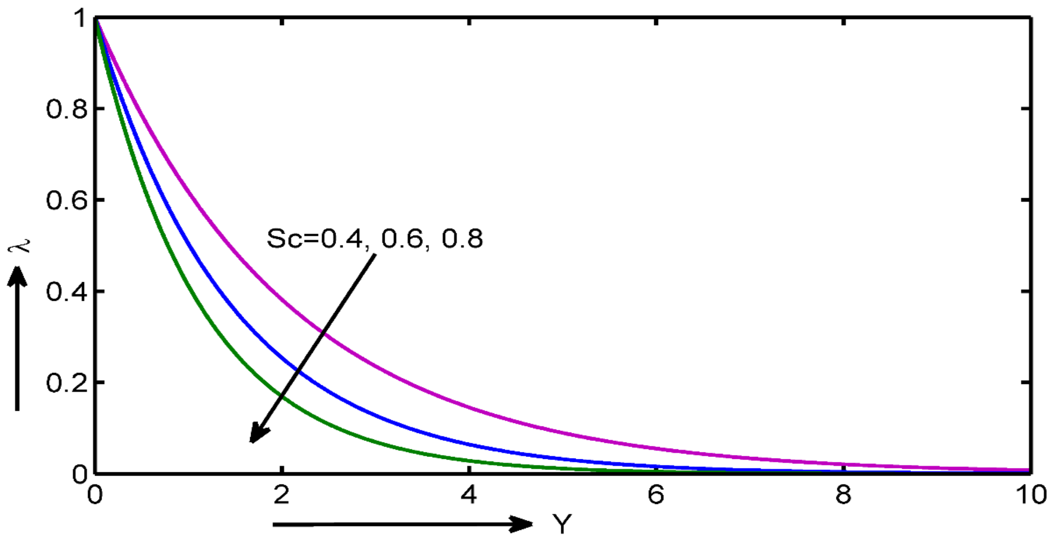


Figure 18: Effect of Schmidt Number on Concentration

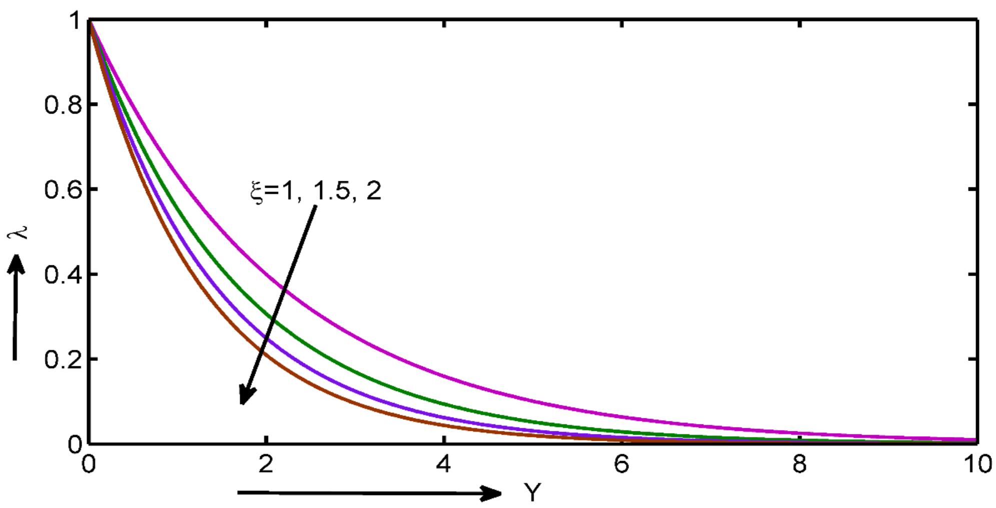


Figure 19: Effect of Chemical reaction Parameter on Concentration

Table-1: Variations in Skin Friction

Pr	χ	ξ	Sc	M	τ
0.3	1	0.1	0.22	√10	4.8208
0.5	1	0.1	0.22	√10	4.7738
0.71	1	0.1	0.22	√10	4.7687
0.71	0.2	0.1	0.22	√10	5.3222
0.71	0.3	0.1	0.22	√10	5.2151
0.71	0.4	0.1	0.22	√10	5.1147
0.71	0.5	0.1	0.22	√10	5.0256
0.71	1	0.2	0.22	√10	4.7432
0.71	1	0.3	0.22	√10	4.7227
0.71	1	0.4	0.22	√10	4.7052
0.71	1	0.5	0.22	√10	4.6898
0.71	1	0.1	0.3	√10	4.7333
0.71	1	0.1	0.6	√10	4.6334
0.71	1	0.1	0.7	√10	4.6118
0.71	1	0.1	0.22	2	4.7385
0.71	1	0.1	0.22	3	4.6092

Table-2: Variations in Nusselt Number

Pr	χ	ɳ	Nu
0.1	1	0.5	0.7597
0.5	1	0.5	1.0014
0.71	1	0.5	1.1479
7	1	0.5	7.0735
0.71	-5	0.5	1.1471
0.71	-4	0.5	1.1500
0.71	-3	0.5	1.1503
0.71	1	0.6	1.2087
0.71	1	0.7	1.2655
0.71	1	0.8	1.3189

Table-3: Variations in Sherwood Number

ξ	Sc	Sh
0.1	0.22	0.2944
0.5	0.22	0.4594
1	0.22	0.5918
1.5	0.22	0.6950
0.1	0.3	0.3788
0.1	0.4	0.4824
0.1	0.5	0.5848
0.1	0.6	0.6866

Appendix

$$\eta_1 = \eta + \chi \qquad \delta_1 = \eta_1 - \frac{i\omega \Pr}{4} \qquad \eta_2 = \frac{\Pr + \sqrt{\Pr^2 + 4\eta}}{2}$$

$$\eta_3 = \frac{\Pr + \sqrt{\Pr^2 + 4\delta_1}}{2} \qquad \eta_4 = \frac{Sc + \sqrt{Sc^2 + 4Sc\xi}}{2} \qquad \eta_5 = \frac{Sc + \sqrt{Sc^2 + 4Sc(\xi + \frac{i\omega}{4})}}{2} \qquad \alpha_1 = \frac{M^2}{1+m^2}(1-im)$$

$$\alpha_2 = \alpha_1 + \frac{1}{k_1} \qquad \alpha_3 = \alpha_1 + \frac{i\omega}{4} + \frac{1}{k_1} \qquad \eta_6 = \frac{1+\sqrt{1+4\alpha_2}}{2}$$

$$\eta_7 = \frac{1+\sqrt{1+4\alpha_3}}{2} \qquad a_1 = \eta_1^2 - \Pr \eta_1 - \delta_1 \quad a_2 = \eta_4^2 - Sc\eta_4 - Sc(\xi + \frac{i\omega}{4})$$

$$a_3 = \eta_2^2 - \eta_2 - \alpha_2 \qquad a_4 = \eta_4^2 - \eta_4 - \alpha_2 \qquad a_5 = \eta_2^2 - \eta_2 - \alpha_3$$

$$a_6 = \eta_4^2 - \eta_4 - \alpha_3 \qquad a_7 = \eta_6^2 - \eta_6 - \alpha_3 \qquad a_8 = \eta_3^2 - \eta_3 - \alpha_3$$

$$a_9 = \eta_5^2 - \eta_5 - \alpha_3 \qquad A_1 = \frac{G}{a_3}$$

$$A_2 = \frac{Gc}{a_4} \qquad A_3 = 1 - (A_1 + A_2) \qquad A_4 = \frac{G\eta_2}{a_5}(\frac{1}{a_1} + \frac{\Pr}{a_3})$$

$$A_5 = \frac{G\Pr\eta_2}{a_1 a_8} \qquad A_6 = \frac{Gc\eta_4}{a_6}(\frac{Sc}{a_2} + \frac{1}{a_4}) \qquad A_7 = \frac{GcSc\eta_4}{a_2 a_9} \quad A_8 = \frac{A_3\eta_6}{a_7}$$

$$A_9 = 1 - A_4 + A_5 - A_6 + A_7 - A_8$$

5. Conclusions

In this problem, we have studied Hall current effects on MHD convective flow past a porous plate with thermal radiation, chemical reaction and heat generation /absorption. In the analysis of the flow the following conclusions are made:

1. The primary and secondary velocities increase with an increase in Permeability parameter, Grashof number, modified Grashof number and Hall parameter.

2. The primary and secondary velocities decrease with an increase in Magnetic parameter, Prandtl number and Heat absorption parameter.
3. Temperature decreases with an increase in Prandtl number, Radiation parameter and Heat absorption parameter.
4. Concentration decreases with an increase in Schmidt number and chemical reaction parameter.
5. As significant decreases in seen in skin friction for increase Prandtl number, Heat absorption parameter, Chemical reaction parameter, Schmidt number and Magnetic parameter.
6. The rate of heat transfer increases with an increase Prandtl number, Heat absorption parameter, and Radiation parameter.
7. The rate of mass transfer increases with an increase Schmidt number and Chemical reaction parameter.

Conflict of Interest

Authors state no conflict of interest with any one

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