CHAPTER-6

UNSTEADY MHD FREE CONVECTION BOUNDARY LAYER FLOW OF RADIATION ABSORBING KVUSHINSKI FLUID THROUGH POROUS MEDIUM
6.1. INTRODUCTION

Convective flow with simulation heat and mass transfer under the influence of magnetic field and chemical reaction arise in many transfer process both natural and artificial in many branches of sciences and engineering applications. This phenomenon plays an important role in the chemical industry, power and cooling industry for drying, chemical vapor deposition on surfaces, cooling of nuclear reactors and petroleum industry. Natural convection flow occurs frequently in nature, as well as due to concentration differences or the combination of these two, for example in atmosphere flows, there exists differences in water concentration and hence the flow is influenced by such concentration difference. Abo and Gendy [1] studied a problem of convective heat transfer past a continuously moving plate embedded in a non-Darcian porous medium in the presence of a magnetic field. Abo and Gendy [2] also studied radiation effects on convective heat transfer in an electrically conducting fluid past a stretching surface with variable viscosity and uniform free-stream. Anjalidevi et al. [3] investigated the effects of chemical reaction, heat and mass transfer on laminar flow along a semi-infinite horizontal plate. Beg et al. [4] studied the magneto hydrodynamic convection flow from a sphere to a non-Darcian porous medium with heat generation or absorption. Chamkha [5] considered unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption. Cortell [6] investigated, the suction, viscous dissipation and thermal radiation effects on the flow and heat transfer of a power-law fluid past an infinite porous plate. Shateyi [23] considered the magneto hydrodynamic flow past a vertical plate with radiative heat transfer. Soudalgekar [24] analyzed the viscous dissipation effects on unsteady free convective flow past an infinite vertical porous plate with constant suction. Changes in fluid density gradients may be caused by non-reversible chemical reaction in the system as well as by the differences in molecular weight between values of the reactants and the products. In most cases of a chemical reaction, the reaction rate depends on the concentration of the species itself. A reaction is said to be first order, if rate of reactions is directly proportional to the concentration itself, for example, the formation smog is a first order homogeneous reaction. Consider the emission of nitrogen dioxide from the automobiles and other smoke –stacks, this Nitrogen dioxide reacts chemically in the atmosphere with unburned hydrocarbons (aided by sunlight) and produce peroxyacety nitrate. Anjalidevi and Kandasamy [3]
investigated the effects of chemical reaction, heat and mass transfer on laminar flow along a semi-infinite horizontal plate. Das et al. [7] studied the effects of mass transfer on flow past an impulsively started infinite vertical plate with constant heat flux and chemical reaction. Ibrahim et al. [8] considered the effects of chemical reaction and radiation absorption on unsteady MHD free convection flow past a semi-infinite vertical permeable moving plate with heat source and suction. Kesavaih et al. [28] considered the effects of the chemical reaction and radiation absorption on unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat source and suction. Sudheer babu et al. [29] studied the effects of the chemical reaction and radiation absorption on free convection flow through porous medium with variable suction in the presence of uniform magnetic field. Satyanarayana et al. [30] investigated the chemical reaction and radiation absorption effects on the flow and heat transfer of a nano fluid in a rotating system. Kandasamy et al. [9, 10] discussed the effects of chemical reaction, heat and mass transfer in boundary layer flow over a porous wedge with heat radiation in presence of suction or injection. Mahdy [11] considered the effect of chemical reaction and heat generation or absorption on double-diffusive convection from a vertical truncated cone in a porous media with variable viscosity. Muthucumarswamy and Ganesan [12] analyzed the diffusion and first order chemical reaction on impulsively started infinite vertical plate with variable temperature. Muthucumarswamy [13] studied the chemical reaction effects on vertical oscillating plate variable temperature. Patil and Kulkarni [14] considered the effects of chemical reaction on free convective flow of a polar fluid through a porous medium in the presence of internal heat generation. Raju et al. [15, 16] studied heat and mass transfer flow problems in the presence of chemical reaction and radiation. Heat absorption effect on MHD convective Rivlin-Ericksen fluid flow past a semi-infinite vertical porous plate was investigated by Ravi kumar et al. [17]. Reddy et al. [18, 19] studied radiation and chemical reaction effects on unsteady MHD free convection flow past a moving vertical plate.

In all the above studies the fluid considered is Newtonian. Most of the practical problems involve non-Newtonian fluids type. Saleh et al. [20] considered the heat and mass transfer in MHD visco-elastic fluid flow through a porous medium over a stretching with chemical reaction. Seddek et al. [21, 22] studied the effect of
chemical reaction and variable viscosity on hydromagnetic mixed convection heat and mass transfer for Hiemenz flow through porous media with radiation in different flow geometries. Umamaheswar et al. [25] studied an unsteady MHD free convective visco-elastic fluid flow bounded by an infinite inclined porous plate in the presence of heat source. In all the above studies the fluid considered was Newtonian and in few cases a non-Newtonian fluid. Motivated by the above studies, in this paper we have considered a well-known non Newtonian fluid namely Kuvshinski fluid in the presence of thermal radiation, radiation absorption and chemical reaction of first order. MHD free convection flow of a visco-elastic (Kuvshinski type) dusty gas through a semi-infinite plate moving with velocity decreasing exponentially with time and radiative heat transfer was investigated by Prakash et al. [26]. Effect of the chemical reaction and radiation absorption on the unsteady MHD free convection flow past a semi-infinite vertical permeable moving plate with heat source and suction was investigated by Ibrahim et al. [27]. Motivated by the above studies in this chapter we have studied an unsteady MHD two dimensional free convection flow of a viscous, incompressible, radiating, chemically reacting and radiation absorbing Kuvshinski fluid through a porous medium past a semi-infinite vertical plate. Kesavaiah et al. [28] effects of the chemical reaction and radiation absorption in an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat source and suction.

6.2 FORMULATION OF THE PROBLEM

We have considered an unsteady MHD two dimensional free convection flow of a viscous, incompressible, radiating, chemically reacting and radiation absorbing Kuvshinski fluid through a porous medium past a semi-infinite vertical plate. Let \( x^* \) axis is taken along the vertical plate in the upward direction in the direction of the flow and \( y^* \) axis is taken perpendicular to it. It is assumed that, initially, the plate and the fluid are at the same temperature \( T_o^* \) and concentration \( C_o^* \) in the entire region of the fluid. The effects of Soret and Dufour are neglected, as the level of foreign mass is assumed to be very low. The radiative heat flux in \( x^* \) direction is considered to be negligible in comparison to that of \( y^* \) axis. The fluid considered here is gray, emitting and absorbing radiation but non scattering medium. The presence of viscous dissipation cannot be neglected and also the presence of chemical reaction of first order and the influence of radiation absorption are considered. All the fluid properties
are considered to be constant except the influence of the density variation caused by the temperature changes, in the body force term. It is also assumed that the induced magnetic field is neglected in comparison with applied magnetic field, as the magnetic Reynolds number is very small. Now, under the above assumptions, the flow field is governed by the following set of equations.

Continuity equation

$$\frac{\partial \nu^*}{\partial y^*} = 0 \quad (6.1)$$

Momentum equation

$$\left(1 + x^* \frac{\partial}{\partial x^*}\right) \frac{\partial u^*}{\partial x^*} + v^* \frac{\partial u^*}{\partial y^*} = g \beta(T^* - T_{*u}) + g \beta^* (C^* - C_{*u})$$

$$+ g \frac{\partial^2 u^*}{\partial y^*} \left(\frac{\sigma T_{*u}^4}{\rho} + \frac{g}{K_{*}}\right) (1 + x^* \frac{\partial}{\partial x^*}) u^* \quad (6.2)$$

Energy equation

$$\left(1 + x^* \frac{\partial}{\partial x^*}\right) \frac{\partial T^*}{\partial x^*} + v^* \frac{\partial T^*}{\partial y^*} = \frac{K_{*}}{\rho C_{*u}} \frac{\partial^2 T^*}{\partial y^*} + \frac{g}{C_{*u}} \left(\frac{\partial \nu^*}{\partial y^*}\right)^2 - \frac{1}{\rho C_{*u}} \frac{\partial q_{*u}}{\partial y^*} + \frac{R_{*}}{\rho C_{*u}} (C^* - C_{*u}) \quad (6.3)$$

Diffusion equation

$$\left(1 + x^* \frac{\partial}{\partial x^*}\right) \frac{\partial C^*}{\partial x^*} + v^* \frac{\partial C^*}{\partial y^*} = D \frac{\partial^2 C^*}{\partial y^*} - K_{*} (C^* - C_{*u}) \quad (6.4)$$

The boundary conditions at the wall and in the free stream are

$$u^* = u_{*w} (1 + \epsilon e^{-\gamma' y^*}), \quad T^* = T_{*w}, \quad C^* = C_{*w} \quad \text{at} \quad y^* = 0 \quad (6.5)$$

$$u^* \to 0, \quad T^* \to T_{*w}, \quad C^* \to C_{*w} \quad \text{as} \quad y^* \to \infty \quad (6.6)$$

The equation (6.1) gives $v^* = -u_{*w}$

Where $u_{*w}$ is the constant suction velocity the radiative heat flux $q_{*w}$ using the Roseland diffusion model for radiation heat transfer is expressed as
Where $\alpha'$ and $K'$ are respectively the Stream-Boltzmann constant and the mean absorption coefficient. We assume that the temperature difference with in the flow are sufficiently small and $T^{*4}$ may be expressed as a linear function of the temperature. This is accomplished by expanding in Taylor series about $T_{w}^{*}$ and neglecting higher order terms, thus

$$T^{*4} \approx 4T_{w}^{*4} - 3T_{w}^{*4}$$  (6.8)

In view of equations (6.7) and (6.8) the equation (6.3) reduced to the following form

$$\left( 1 + \lambda' \frac{\partial}{\partial \tau'} \right) \frac{\partial T^{*}}{\partial \tau'} + v' \frac{\partial T^{*}}{\partial y'} = \frac{K}{\rho C_{p} \alpha'} \frac{\partial^{2} T^{*}}{\partial y'^{2}} + \frac{16 \sigma' T_{w}^{*4}}{3 \rho C_{p} K' \alpha'} \frac{\partial T^{*}}{\partial y'} + \frac{\theta}{C_{p}} \left( \frac{\partial u'}{\partial y'} \right)^{3} + \frac{R_{t}}{\rho C_{p}} \left( C^{*} - C_{w}^{*} \right)$$  (6.9)

Introducing the following dimensionless variables and parameters,

$$u = \frac{u^{*}}{V_{0}}, y = \frac{y^{*} V_{0}}{g}, \tau = \frac{\tau^{*} V_{0}^{2}}{g}, \theta = \frac{T^{*} - T_{w}^{*}}{T_{w}^{*} - T_{w}^{*}}, \phi = \frac{C^{*} - C_{w}^{*}}{C_{w}^{*} - C_{w}^{*}}$$

$$Gr = \frac{g \beta^{*} \theta \left( T_{w}^{*} - T_{w}^{*} \right)}{V_{0}^{2}}, \text{Gm} = \frac{g \beta' \theta \left( C^{*} - C_{w}^{*} \right)}{V_{0}^{2}}, \text{Pr} = \frac{\mu C_{p}}{k}, \text{Sc} = \frac{g}{D},$$

$$K = \frac{K' V_{0}^{2}}{g}, M = \sqrt{\frac{\alpha' \beta^{*} B_{0}}{\rho V_{0}}}, R = \frac{4 \sigma' T_{w}^{*4}}{K' K}, \lambda = \frac{V_{0}^{2} \lambda^{*}}{g}, E = \frac{V_{0}^{2}}{C_{p} \left( T_{w}^{*} - T_{w}^{*} \right)},$$

$$Ra = \frac{R_{t} \theta \left( C^{*} - C_{w}^{*} \right)}{k V_{0}^{2} \left( T_{w}^{*} - T_{w}^{*} \right)}, \text{Kr} = \frac{K' \theta}{V_{0}}$$  (6.10)

In to set of equations (6.2)-(6.5), we obtain

$$\alpha_{1} \frac{\partial u}{\partial \tau} + \lambda \frac{\partial^{2} u}{\partial \tau^{2}} = \frac{\partial^{2} u}{\partial y^{2}} + \frac{\partial u}{\partial y} - M_{1} u + Gr \theta + Gm \phi$$  (6.11)

$$Pr \frac{\partial \theta}{\partial \tau} + Pr \lambda \frac{\partial^{2} \theta}{\partial \tau^{2}} = N_{1} \frac{\partial^{2} \theta}{\partial y^{2}} + Pr \frac{\partial \theta}{\partial y} + Pr E \left( \frac{\partial u}{\partial y} \right)^{3} + R_{e} \phi$$  (6.12)
The corresponding boundary conditions in non-dimensional form are:

\[ u = 1 + ae^{-\mu}, \quad \theta = 1, \quad \phi = 1 \text{ at } y = 0 \]

\[ u \to 0, \quad \theta \to 0, \quad \phi \to 0 \text{ as } y \to \infty \]  

6.3. SOLUTION OF THE PROBLEM

The governing equations (6.11)-(6.13), of the flow, momentum, temperature, and concentration respectively are coupled non-linear differential equations. Assuming \( \varepsilon \) to be very small, the perturbation parameter, we write:

\[ u = u_0(y) + \varepsilon u_1(y)e^{-\mu} + O(\varepsilon^2) \]

\[ \theta = \theta_0(y) + \varepsilon \theta_1(y)e^{-\mu} + O(\varepsilon^2) \]

\[ \phi = \phi_0(y) + \varepsilon \phi_1(y)e^{-\mu} + O(\varepsilon^2) \]  

By substituting the above equation (6.15) into set of equations (6.11)-(6.13), and equating the harmonic terms and neglecting the higher order terms of \( O(\varepsilon^2) \), we obtain the following pairs of equations for \((u_0, \theta_0, \phi_0)\) and \((u_1, \theta_1, \phi_1)\)

\[ u_0^{\prime\prime} + u_0^{\prime} - M_1 u_0 = -Gr\theta_0 - Gm\phi_0 \]  

\[ u_1^{\prime\prime} + u_1^{\prime} - M_1 u_1 = -Gr\theta_1 - Gm\phi_1 \]  

\[ N_1\theta_0^{\prime\prime} + Pr\theta_0^{\prime} = Pr Eu_0^{\prime\prime} - R_s\phi_1 \]  

\[ N_1\theta_1^{\prime\prime} + Pr\theta_1^{\prime} + N_1\theta_1 = 2Pr Eu_1^{\prime\prime} - R_s\phi_1 \]  

\[ \phi_0^{\prime\prime} + Sc\phi_0^{\prime} - Sc Kr\phi_0 = 0 \]  

\[ \phi_1^{\prime\prime} + Sc\phi_1^{\prime} + L_1\phi_1 = 0 \]
where the primes denote differentiation with respect to $y$.

The corresponding boundary conditions are

$$u_0 = 1, \ u_1 = 1, \ \theta_0 = 0, \ \theta_1 = 1, \ \phi_0 = 1, \ \phi_1 = 0, \ \text{as} \ \ y \to 0$$

$$u_0 \to 0, \ u_1 \to 0, \ \theta_0 \to 0, \ \theta_1 \to 0, \ \phi_0 \to 0, \ \phi_1 \to 0 \ \text{as} \ \ y \to \infty$$

Solving the equations (6.20) and (6.21) subject the corresponding boundary conditions, we obtain.

$$\phi_0 = e^{-\alpha y} \quad (6.23)$$

$$\phi_1 = 0 \quad (6.24)$$

The set of equations (6.16)-(6.19) are still coupled non-linear ordinary differential equations, whose exact solutions are not possible. To solve these equations, assuming the Eckert number $E$ to be small, we write.

$$u_0 = u_{01} + Eu_{02} + O(E^1)$$

$$u_1 = u_{11} + Eu_{12} + O(E^2)$$

$$\theta_0 = \theta_{01} + Eu_{02} + O(E^1) \quad (6.25)$$

$$\theta_1 = \theta_{11} + Eu_{12} + O(E^2)$$

Substituting the equations (6.25) in to equations (6.16)-(6.19), equating the coefficients of like powers of $E$ and neglecting the higher order terms of $O(E^2)$, we obtain

$$u_{01}^{11} + u_{01}^1 - M_1 u_{01} = -Gr \theta_{01} - Gm \phi_0 \quad (6.26)$$

$$u_{11}^{11} + u_{11}^1 - M_2 u_{11} = -Gr \theta_{11} - Gm \phi_0 \quad (6.27)$$

$$N_1 \theta_{01}^{11} + Pr \theta_{01}^1 = -R_s \phi_0 \quad (6.28)$$

$$N_1 \theta_{11}^{11} + Pr \theta_{11}^1 + N_2 \theta_{11} = -R_s \phi_1 \quad (6.29)$$
The corresponding boundary conditions are

\[ u_{01} = 1, \quad u_{02} = 0, \quad u_{11} = 1, \quad u_{12} = 0 \]
\[ \theta_{01} = 1, \quad \theta_{02} = 0, \quad \theta_{11} = 0, \quad \theta_{12} = 0 \quad \text{at} \quad y = 0 \] (6.34)

\[ u_{01} \to 0, \quad u_{02} \to 0, \quad u_{11} \to 0, \quad u_{12} \to 0 \]
\[ \theta_{01} \to 0, \quad \theta_{02} \to 0, \quad \theta_{11} \to 0, \quad \theta_{12} \to 0 \quad \text{as} \quad y \to \infty \]

The analytical solutions of equations (6.26)-(6.33) under the boundary conditions (6.34) are given by

\[ \theta_{01} = l_1 e^{-\alpha y} + l_2 e^{-\beta y} \] (6.35)

\[ u_{01} = l_3 e^{-\alpha y} + l_4 e^{-\beta y} + l_5 e^{-\gamma y} \] (6.36)

\[ \theta_{02} = l_6 e^{-\alpha y} + l_7 e^{-\beta y} + l_8 e^{-\gamma y} + l_9 e^{-\delta y} + l_{10} e^{-\epsilon y} + l_{11} e^{-\delta y} + l_{12} e^{-\epsilon y} \] (6.37)

\[ u_{02} = l_{13} e^{-\alpha y} + l_{14} e^{-\beta y} + l_{15} e^{-\gamma y} + l_{16} e^{-\delta y} + l_{17} e^{-\delta y} + l_{18} e^{-\epsilon y} + l_{19} e^{-\delta y} + l_{20} e^{-\epsilon y} \] (6.38)

\[ \theta_{11} = 0 \] (6.39)

\[ u_{11} = e^{-\beta y} \] (6.40)

\[ \theta_{12} = l_{21} e^{-\alpha y} + l_{22} e^{-\delta y} + l_{23} e^{-\delta y} + l_{24} e^{-\epsilon y} \] (6.41)

\[ u_{12} = l_{25} e^{-\alpha y} + l_{26} e^{-\beta y} + l_{27} e^{-\delta y} + l_{28} e^{-\delta y} + l_{29} e^{-\epsilon y} \] (6.42)

In view of the solutions (6.35)-(6.42), the expressions for velocity, temperature and concentration distributions in the boundary layer become
6.4. Skin-friction

\[
\tau = \left( \frac{\partial u}{\partial y} \right)_{y=0} = -[l_0 a_1 + l_1 a_2] - E[l_0 a_1 + l_1 a_2 + l_4 m_1 + l_5 m_1 + l_6 m_1 + l_7 m_4 + l_8 m_5 + l_9 m_6] - \varepsilon [a_0 - E(l_1 a_2 + l_2 a_2 - l_0 m_1 - l_9 m_5 - l_6 m_6)e^{-\alpha}] \\
\]  \hspace{1cm} (6.46)

6.5. Nusselt number

\[
\left( \frac{\partial \theta}{\partial y} \right)_{y=0} = -[l_0 a_1 + l_1 a_2] - E[l_0 a_1 + l_1 a_2 + l_4 m_1 + l_5 m_1 + l_6 m_1 + l_7 m_4 + l_8 m_5 + l_9 m_6] - \varepsilon [E(l_1 a_2 + l_2 m_1 + l_3 m_4 + l_0 m_5)e^{-\alpha}] \\
\]  \hspace{1cm} (6.47)

6.6. Sherwood number

\[
\left( \frac{\partial \phi}{\partial y} \right)_{y=0} = -a_1 \\
\]  \hspace{1cm} (6.48)

6.7. RESULTS AND DISCUSSION

In order to look into the physical insight of the problem, the expressions obtained in previous section are studied with help of graphs from figures 6.1 to 6.12. The effects of various physical parameters viz., the Schmidt number (Sc), the thermal Grashof number (Gr), the mass Grashof number (Gm), magnetic parameter (M), radiation parameter (R), radiation absorption parameter (Ra) and chemical reaction parameter (Kr) are studied numerically by choosing arbitrary values.
Fig. 6.1, depicts the variations in velocity profiles for different values of Schmidt number. From this figure it is noticed that, velocity decreases as Sc increases, physically it is true as the concentration increase the density of the fluid increases which results a decrease in fluid particles. In fig. 6.2, effect of thermal Grashof number on velocity is presented. As Gr increases, velocity also increases, this is due to the buoyancy which is acting on the fluid particles due to gravitational force that enhances the fluid velocity. A similar effect is noticed from fig. 6.3, in the presence of solute Grashof number, which also increases fluid velocity. In fig. 6.4, velocity profiles are displayed with the variation in magnetic parameter, from this figure it is noticed that velocity gets reduced by the increase of magnetic parameter. Because the magnetic force which is applied perpendicular to the plate, retards the flow, which is known as Lorentz force. Hence the presence of this retarding force reduces the fluid velocity. The effect of chemical reaction on velocity is presented in fig. 6.5, from which it is noticed that velocity decreases with an increase in chemical reaction parameter because of the presence of viscous dissipation. But it is quite interesting to notice that a reverse phenomenon near the plate, as usual the magnitude of velocity is high near the plate and it gradually decreases and reaches to free stream velocity.

Fig. 6.6, depicts the radiation parameter effect on velocity, as radiation increases, velocity also increases. This is because of the fluid considered here which is gray, emitting and absorbing radiation but non-scattering medium. Whereas reverse phenomenon is noticed in the case of radiation absorption parameter, from fig. 6.7 to 6.8 exhibits the velocity profiles for various values of Prandtl number. From these figures it is observed that velocity decreases with an increase in Prandtl number, this is physically true because, the Prandtl number is a dimensionless number which is the ratio of momentum diffusivity (kinematic viscosity) to thermal diffusivity. In many of the heat transfer problems, the Prandtl number controls the relative thickness of the momentum and thermal boundary layers. When Pr is small, it means that the heat diffuses very quickly compared to the velocity (momentum). This means that for liquid metals the thickness of the thermal boundary layer is much bigger than the velocity boundary layer. This is absolutely coincide with the result that is shown in fig. 6.9, where the thermal boundary layer shrinks for higher values of Prandtl number. The effect of radiation parameter and radiation absorption parameter on
temperature are studied from figures 6.10 and 6.11, from these figures it is noticed that temperature increases as radiation parameter and radiation absorption parameter increases.

This is because the thermal radiation is associated with high temperature, thereby increasing the temperature distribution of the fluid flow, the effect of chemical reaction parameter on temperature and concentration are presented in figures 6.12 and 6.13 respectively. From these figures it is noticed that both thermal boundary layer and concentration boundary layer shrink when the values of chemical reaction parameter increases. The influence of Schmidt number on concentration is shown in fig.6.14, from this figure it is noticed that concentration decreases with an increase in Schmidt number. Because, Schmidt number is a dimensionless number defined as the ratio of momentum diffusivity and mass diffusivity, and is used to characterize fluid flows in which there are simultaneous momentum and mass diffusion convection processes. Therefore concentration boundary layer decreases with an increase in Schmidt number.

The effect of various material parameters on Skin friction, Nusselt number and Sherwood number are presented in table 1. From this table it is noticed that both Skin-friction and as well as Nusselt number increase with an increase in Prandtl number. A similar effect is seen in the case of permeability parameter of the porous medium. Both Skin friction and Nusselt number decrease with an increase in radiation parameter, where as they increase in the presence of the radiation absorption parameter. Similar results are reported by Kesavaiah et al. [28], Babu and Narayana [29] and Venkateswarlu and Narayana [30]. When an increase in Grashof number, Skin friction and Nusselt number also increase. But they have shown opposite phenomenon in the case of modified Grashof number. When magnetic parameter increases Skin friction decreases but Nusselt number increases. When Schmidt number increases, Skin friction, Nusselt number and Sherwood number also decrease. Whereas the presence of chemical reaction parameter increases the Skin friction and Nusselt number and it decreases the Sherwood number.
6.8. GRAPHS

Fig. 6.1. Effect of Schmidt number (Sc) on velocity

Fig. 6.2. Effect of Grashof number (Gr) on velocity
Fig. 6.3. Effect of modified Grashof number (Gm) on velocity

Fig. 6.4. Effect of Magnetic parameter (M) on velocity
Fig. 6.5. Effect of chemical reaction (Kr) on velocity

Fig. 6.6. Effect of Radiation parameter (R) on velocity
Fig. 6.7. Effect of Radiation absorption parameter (Ra) on velocity

M=1;  
K=100;  
Pr=0.71;  
Sc=0.16;  
η=0.5;  
L=0.5;  
Kr=0.1;  
Gr=15;  
Gm=15;  
ε=0.1;  
R=0.1;  
E=0.1;  
t=0.1;

Fig. 6.8. Effect of Prandtl number (Pr) on velocity

Sc=0.16;  
M=1;  
K=100;  
Gm=0.15;  
R=0.1;  
η=0.5;  
L=0.5;  
Kr=0.1;  
Gr=15;  
ε=0.1;  
Ra=0.1;  
E=0.1;  
t=0.1;
Fig. 6.9. Effect of Prandtl number (Pr) on temperature

Fig. 6.10. Effect of Radiation parameter (R) on temperature
Fig. 6.11. Effect of Radiation absorption parameter (Ra) on temperature

Fig. 6.12. Effect of Schmidt number (Sc) on concentration
Fig. 6.13. Effect of chemical reaction (Kr) on concentration
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6.9. REFERENCES


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