MAGNETIC FIELD AND CHEMICAL REACTION EFFECTS ON UNSTEADY FLOW PAST A STIMULATE ISOTHERMAL INFINITE VERTICAL PLATE

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Abstract
An exact analysis ofradiation and magnetic field effects on unsteady flow past an accelerated isothermal infinite vertical platein the presence of chemical reaction and heat source. It is assumed that the effect of viscous dissipation in the energy equation and there is a first order chemical reaction between the diffusing species and the fluid cannot negligible. The fluid considered here is a gray, absorbing emitting radiation but a non-scattering medium.The dimensionless governing equations are solved using perturbation technique. The velocity, temperature and concentration profiles are discussed through graphically for different physical parameters.

Keywords: Magnetic field, Infinite vertical plate, Radiation, Radiation absorption, Chemical reaction,
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INTRODUCTION
Meanwhile, it is well known that for a simultaneous occurrence of heat and mass transfer in a moving fluid, the relationships between the driven potential and the corresponding fluxes are of important. Also it is noticed that the energy flux (rate of energy transfer per unit area) and mass flux (rate of

mass flow per unit area) can be generated by temperature gradients as well as composition gradients. The energy caused or generated by composition gradients is known as Dufour or diffusion-thermo effect and is considered useful in isotope separation. The mass flux created or generated by temperature gradients is known as Soret or thermal-diffusion effect which is considered useful in mixture of gases with very light molecular weight (hydrogen–helium) and medium molecular weight (nitrogen–air). In view of the above some of the authors studies, (Chenna Kesavaiah et al, 2021) point out on radiative MHD Walter's Liquid-B flow past a semi-infinite vertical plate in the presence of viscous dissipation with a heat source, ((Rajaiah and Sudhakaraiah, 2015) action is an idea an unsteady MHD free convection flow past an accelerated vertical plate with chemical reaction and Ohmic heating, (Rami Reddy et al, 2021) communicated on Hall effect on MHD flow of a viscoelastic fluid through porous medium over an infinite vertical porous plate with heat source, (Chenna Kesavaiah Venkateswarlu, 2020) carried out the research work on chemical reaction and radiation absorption effects on convective flows past a porous vertical wavy channel with travelling thermal waves, (Mallikarjuna Reddy et al, 2019) expressed the radiation and diffusion thermo effects of viscoelastic fluid past a porous surface in the presence of magnetic field and chemical reaction with heat source,(Haranth and Sudhakaraiah, 2015) has been studied the viscosity and Soret effects on unsteady hydromagnetic gas flow along an inclined plane, (Srinathuni Lavanya and Chenna Kesavaiah, 2017) explained on heat transfer to MHD free convection flow of a viscoelastic dusty gas through a porous medium with chemical reaction, (Mallikarjuna Reddy et al, 2018) has motivated study on effects of radiation and thermal diffusion on MHD heat transfer flow of a dusty viscoelastic fluid between two moving parallel plates.

The Soret effect, for instance, has been utilized for isotope separation, and in mixtures between gases with very light molecular weight (H_2, He). For medium molecular weight (N_2, air), the Dufour effect was found to be of a considerable magnitude such that it cannot be neglected. For the temperature interval employed by Soret the ratio of concentration in the cold end to that in the warm end should therefore be 1. 250. This ratio proved to be approximately correct for cupric sulphate; for potassium, sodium and lithium chlorides, however, the average observed ration were, respectively, 1.069, 1.054, and 1.006. The supposition that these solutions might not have a higher rate of diffusion than copper sulphate. When heat and mass transfer occurs simultaneously between the fluxes, the driving potential is of more intricate nature, as energy flux can be generated not only by temperature gradients but by composition gradients as well. The energy flux caused by a composition gradient is called the Dufour or diffusion-thermo effect. Temperature gradients can also create mass fluxes, and this is the Soret or thermal-diffusion effect. Generally, the thermal-diffusion and the diffusion-thermo effects are of smaller-order magnitude than the effects prescribed by Fourier's or Fick's laws and are often neglected in heat and mass transfer processes. There are, however, exceptions. The Soret effect, for instance, has been utilized for isotope separation, and in mixtures between gases with very light molecular weight (H_2, He). For medium molecular weight (N_2, air), the Dufour effect was found to be of a considerable magnitude such that it cannot be neglected, (Chenna Kesavaiah and Sudhakaraiah, 2014) has been considered the effects of heat and mass flux to MHD flow in vertical surface with radiation absorption, (Yeddala et al, 2016) revealed that the finite difference solution for an MHD free convective rotating flow past an accelerated vertical plate,(Chenna Kesavaiah et al, 2013) shows that the natural convection heat transfer oscillatory flow of an elastico-viscous fluid from vertical plate, (Chenna Kesavaiah and Satyanarayana, 2013) has been studied MHD and Diffusion Thermo effects on flow accelerated vertical plate with chemical reaction,(Rajaiah et al, 2015) explained on chemical and Soret effect on MHD free convective flow past an accelerated Vertical plate in presence of inclined magnetic field through porous medium.

When heat and mass transfer occurs simultaneously between the fluxes, the driving potential is of more intricate nature, as energy flux can be generated not only by temperature gradients but by composition gradients as well. The energy flux caused by a composition gradient is called the Dufour or diffusion-thermo effect. Temperature gradients can also create mass fluxes, and this is the Soret or thermal-diffusion effect. Generally, the thermal-diffusion and the diffusion-thermo effects are of smaller-order magnitude than the effects prescribed by Fourier's or Fick's laws and are often neglected in heat and mass transfer processes. There are, however, exceptions.(ChennaKesavaiah et al, 2013) has been consideredradiation and Thermo - Diffusion effects on mixed convective heat and mass transfer flow of a viscous dissipated fluid over a vertical surface in the presence of chemical reaction with heat source,(Karunakar Reddy et al,2013) carried out of the work MHD heat and mass transfer flow of a viscoelastic fluid past an impulsively started infinite vertical plate with chemical reaction,(Rajaiah and Sudhakaraiah, 2015) depicted on radiation and Soret effect on unsteady MHD flow past a parabolic started vertical plate in the presence of chemical reaction with magnetic dissipation through a porous medium, (Ch Kesavaiah et al, 2013)has been considered the effects of radiation and free convection currents on unsteady Couette flow between two vertical parallel plates with constant heat flux and heat source through porous medium,(Rajaiah et al, 2014) explained in detailed on unsteady MHD free convective fluid flow past a vertical porous plate with Ohmic heating in the presence of suction or injection, (ChKesavaiah et al, 2012) revealed on radiation and mass transfer effects on moving vertical plate with variable temperature and viscous dissipation,(Satyanarayana et al, 2011) shown viscous dissipation and thermal radiation effects on an unsteady MHD convection flow past a semi-infinite vertical permeable moving porous plate, ChKesavaiah et al, 2011) expressed their view on effects of the chemical reaction and radiation absorption on 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. (Chenna Kesavaiah, 2022) explained heat and mass transfer effects over isothermal infinite vertical plate of Newtonian fluid with chemical reaction,(Chenna Kesavaiah, 2022) motivated study on influence of joule heating and mass transfer effects on MHD mixed convection flow of chemically reacting fluid on a vertical surface, (Bal Reddy, 2022) observed Anote on heat transfer of MHD Jeffrey fluid over a stretching vertical surface through porous plate.

In view of the above the objective of the present paper is radiation and magnetic field effects on unsteady flow past an accelerated isothermal infinite vertical plate in the presence of chemical reaction and heat source. The plate temperature is raised to T_w and the concentration level near the plate is also raised to C_w. The dimensionless governing equations are solved using perturbation technique. The velocity, temperature and concentration profiles are studied for different physical parameters by using MATLAB.

FORMULATION OF THE PROBLEM

We consider unsteady radiative flow of a viscousincompressible fluid past a uniformly acceleratedisothermal infinite vertical plate with uniform massdiffusion and magnetic field in the presence of chemical reaction which takes place in the flow is assumed to be homogeneous and of first order with uniform magnetic field. Unsteady flow of a viscousincompressible fluid which is initially at rest andsurrounds an infinite vertical plate with temperature T_∞ and concentration C_∞. The x-axis is taken along the platein the vertically upward direction and the y-axis is takennormal to the plate. At time $t' \le 0$, the plate and fluid areat the same temperature T_∞. At time $t' > 0$, the plate isaccelerated with a velocity $u = \frac{u_0^3 t'}{\nu}$ in its own plane andthe temperature from the plate is raised to T_w *w*and theconcentration levels near the plate are also raised to C_w.It is assumed that the effect of viscous dissipation isnegligible in the energy equation and there is a first orderchemical reaction between the diffusing species and thefluid. The fluid considered here is a gray, absorbing emitting radiation but a non-scattering medium. Thenunder usual Boussinesq's approximation the unsteadylow is governed by the following equations:

$$\frac{\partial u^*}{\partial t^*} = g\beta\left(T^* - T_\infty^*\right) + g\beta^*\left(C^* - C_\infty^*\right) + \nu\frac{\partial^2 u^*}{\partial y^{*2}} - \frac{\sigma B_0{}^2}{\rho}u^* \quad (1)$$

$$\rho C_p \frac{\partial T^*}{\partial t^*} = k\frac{\partial^2 T^*}{\partial y^{*2}} + \mu\left(\frac{\partial u^*}{\partial y^*}\right)^2 - \frac{\partial q_r}{\partial y^*} - Q_0\left(T^* - T_\infty^*\right) \quad (2)$$

$$\frac{\partial C^*}{\partial t^*} = D_M\frac{\partial^2 C^*}{\partial y^{*2}} - Kr^*\left(C^* - C_\infty^*\right) + D_T\frac{\partial^2 T^*}{\partial y^{*2}} \quad (3)$$

The initial and boundary conditions for the velocity, temperature and concentration fields are

$$u^* = 0, T^* = T_\infty^*, C^* = C_\infty^* \Big\} \quad for \;\; all\, t' > 0$$

$$\left.\begin{array}{l} t^* > 0 : u = \frac{u_0{}^3 t'}{\nu}, \\ \quad T^* = T_w^*, C^* = C_w^* \end{array}\right\} \quad at \quad y = 0 \quad (4)$$

$$\left.\begin{array}{l} u^* \to 0, \;\; T^* \to T_\infty^* \\ \quad C^* \to C_\infty^* \end{array}\right\} \quad as \quad y \to \infty$$

where u' is the velocity of the fluid along the plate in the x' - direction, t' is the time, g is theacceleration due to gravity, β is the coefficient of volume expansion, β^* is the coefficient ofthermal expansion with concentration, T_∞ is the temperature of the fluid near the plate, C' is thespecies concentration in the fluid near the plate, C'_∞ is the species concentration in the fluid faraway from the plate, ν is the kinematic viscosity, σ is the electrical conductivity of thefluid, B_0 is the strength of applied magnetic field, ρ is thedensity of the fluid, C_p is the specific heat at constant pressure, K is the thermal conductivity ofthe fluid, μ is the viscosity of the fluid, D is the molecular diffusivity.

The local radiant for the case of an optically thin gray gas is expressed by

$$\frac{\partial q_r}{\partial y^*} = -4a^*\sigma\left(T_\infty^4 - T^4\right) \quad (5)$$

It is assume that the temperature differences within the flow are sufficiently small such that T^4 may be expressed as a linear function of the temperature. This is accomplished by expanding T^4 in a Taylor series about T_∞ and neglecting higher-order terms, thus

$$T^4 \cong 4T_\infty^3 T - 3T_\infty^4 \quad (6)$$

By using equations (5) and (6), equation (2) reduces to

$$\rho C_p \frac{\partial T^*}{\partial t^*} = k\frac{\partial^2 T^*}{\partial y^{*2}} + \mu\left(\frac{\partial u^*}{\partial y^*}\right)^2 + 16a^*\sigma T_\infty^3\left(T^* - T_\infty^*\right) - Q_0\left(T^* - T_\infty^*\right) \quad (7)$$

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On introducing the following non-dimensional quantities:

$$U=\frac{u^*}{u_0}, Y=\frac{u_0 y^*}{\nu},\ t=\frac{t^* u_0{}^2}{\nu},\ Sc=\frac{\nu}{D}$$

$$\phi=\frac{\left(C^*-C_\infty^*\right)}{C_w^*-C_\infty^*}, Gc=\frac{\nu\beta^* g\left(C_w^*-C_\infty^*\right)}{u_0{}^3}$$

$$Gr=\frac{\nu\beta g\left(T_w^*-T_\infty^*\right)}{u_0{}^3}, \Pr=\frac{\mu C_p}{k}$$

$$Kr=\frac{Kr^*\nu}{u_0{}^2},\ Q=\frac{\nu^2 Q_0}{ku_0{}^2},\ M=\frac{\sigma B_0{}^2\nu}{\rho u_0{}^2} \quad (8)$$

$$Ec=\frac{u_0^2}{k\left(T_w^*-T_\infty^*\right)},\quad R=\frac{16a^*\nu^2\sigma T_\infty^3}{ku_0^2}$$

$$S_0=\frac{D_T\left(T_w^*-T_\infty^*\right)}{\nu\left(C_w^*-C_\infty^*\right)},\quad \theta=\frac{\left(T^*-T_\infty^*\right)_\infty}{T_w^*-T_\infty^*}$$

where Gr is the thermal Grashof number, Gc is modifiedGrashof Number, $\Pr$ is Prandtl Number, M is the magnetic field, Sc is Schmdit number, Kr is Chemical Reaction, S_0 is Soret number, ϕ is Heat source parameter respectively.

Introducing the above non dimensional quantities in equations (1) - (3) and using equation (7) reduces to

$$\frac{\partial U}{\partial t}=Gr\,\theta+Gc\,C+\frac{\partial^2 U}{\partial Y^2}-M\,U \quad (9)$$

$$\frac{\partial\theta}{\partial t}=\frac{1}{\Pr}\frac{\partial^2\theta}{\partial Y^2}+\frac{Ec}{\Pr}\left(\frac{\partial U}{\partial Y}\right)^2 -\frac{1}{\Pr}\left(R+Q\right)\theta+Q_l C \quad (10)$$

$$\frac{\partial\phi}{\partial t}=\frac{1}{Sc}\frac{\partial^2\phi}{\partial Y^2}-Kr\,\phi+S_0\frac{\partial^2\theta}{\partial Y^2} \quad (11)$$

The negative sign of Kr in the last term of the equation (11) indicates that the chemical reaction takes place from higher level of concentration to lower level of concentration.

The initial and boundary conditions in non-dimensional quantities are

$$U=0,\ \ \theta=0,\ \phi=0\ \ for\ all\ Y,\ t\le 0$$
$$t>0: U=t,\ \ \theta=1,\ \ \phi=1\quad at\ \ Y=0 \quad (12)$$
$$U\to 0, \theta\to 0, \phi\to 0\quad as\quad Y\to\infty$$

SOLUTION OF THE PROBLEM:

Equations (9) – (11) are coupled, non – linear partial differential equations and these cannot be solved in closed – form using the initial and boundary conditions (12). However, these equations can be reduced to a set of ordinary differential equations, which can be solved analytically. This can be done by representing the velocity, temperature and concentration of the fluid in the neighbourhood of the fluid in the neighbourhood of the plate as

$$U=U_0\left(y\right)+\varepsilon e^{nt}U_1\left(y\right)\ +o\left(\varepsilon^2\right)$$
$$\theta=\theta_0\left(y\right)+\varepsilon e^{nt}\theta_1\left(y\right)\ +o\left(\varepsilon^2\right) \quad (13)$$
$$\phi=\phi_0\left(y\right)+\varepsilon e^{nt}\phi_1\left(y\right)+o\left(\varepsilon^2\right)$$

Substituting (13) in equation (9) – (11) and equating the harmonic and non – harmonic terms, and neglecting the higher order terms of $0\left(\varepsilon^2\right)$, we obtain

$$U_0''-MU_0=-Gr\,\theta_0-Gc\,C_0 \quad (14)$$
$$U_1''-\left(M+n\right)U_1=-Gr\,\theta_1-Gc\,C \quad (15)$$
$$\theta_0''-\left(R+Q\right)\theta_0=-Ec\,U_0'^2 \quad (16)$$
$$\theta_1''-\left(R+Q+n\Pr\right)\theta_1=-2Ec\,U_0'U_1' \quad (17)$$
$$\phi_0''-Sc\,Kr\,\phi_0=-ScS_0\theta_0'' \quad (18)$$
$$\phi_1''-\left(Kr+n\right)Sc\phi_1=-ScS_0\theta_1'' \quad (19)$$

The corresponding boundary conditions can be written as

$$\left.\begin{array}{l}U_0=t, U_1=0, \theta_0=1\\ \theta_1=1,\ \phi_0=1,\ \phi_1=0\end{array}\right\}\quad at\quad y=0$$
$$\left.\begin{array}{l}U_0\to 0, U_1\to 0, \theta_0\to 0\\ \theta_1\to 0,\ \phi_0\to 0,\ \phi_1\to 0\end{array}\right\}\ as\ y\to\infty \quad (20)$$

The equations (14) - (19) are still coupled and non-linear, whose exact solutions are not possible. So we expand $U_0, U_1, \theta_0, \theta_1, \phi_0, \phi_1$ in terms $\left(f_0, f_1\right)$ of Ec in the following form, as the Eckert number is very small for incompressible flows.

$$f_0(y) = f_{01}(y) + Ec\ f_{02}(y)$$
$$f_1(y) = f_{11}(y) + Ec\ f_{12}(y) \quad (21)$$

Substituting (21) in Equations (14) - (19), equating the coefficients of Ec to zero and neglecting the terms in Ec^2 and higher order, we get the following equations.

$$U_{01}'' - MU_{01} = -Gr\,\theta_{01} - Gc\,\phi_{01} \quad (22)$$
$$U_{02}'' - MU_{02} = -Gr\,\theta_{02} - Gc\,\phi_{02} \quad (23)$$
$$U_{11}'' - (M+n)U_{11} = -Gr\,\theta_{11} - Gc\,\phi_{11} \quad (24)$$
$$U_{12}'' - (M+n)U_{12} = -Gr\,\theta_{12} - Gc\,\phi_{12} \quad (25)$$
$$\theta_{01}'' - (R+Q)\theta_{01} = 0 \quad (26)$$
$$\theta_{02}'' - (R+Q)\theta_{02} = -U_{01}'^2 \quad (27)$$
$$\theta_{11}'' - (Q+R+n\Pr)\theta_{11} = 0 \quad (28)$$
$$\theta_{12}'' - (R+Q+n\Pr)\theta_{12} = -2U_{01}'U_{11}' \quad (29)$$
$$\phi_{01}'' - Sc\,Kr\,\phi_{01} = -ScS_0\theta_{01}'' \quad (30)$$
$$\phi_{02}'' - Sc\,Kr\,\phi_{02} = -ScS_0\theta_{01}'' \quad (31)$$
$$\phi_{11}'' - (Kr+n)Sc\phi_{11} = -ScS_0\theta_{11}'' \quad (32)$$
$$\phi_{12}'' - (Kr+n)Sc\phi_{12} = -ScS_0\theta_{12}'' \quad (33)$$

The respective boundary conditions are

$$\left.\begin{array}{lll} U_{01}=t, & U_{02}=0, & \theta_{01}=1 \\ \theta_{02}=0, & \phi_{01}=1, & \phi_{02}=0 \\ U_{11}=0, & U_{12}=0, & \theta_{11}=0 \\ \theta_{12}=0, & \phi_{11}=0, & \phi_{12}=0 \end{array}\right\} y=0 \quad (34)$$

$$\left.\begin{array}{l} U_{01}\to U_{02}\to\theta_{01}\to\theta_{02}\to 0 \\ \phi_{01}\to\phi_{02}\to U_{11}\to U_{12}\to 0 \\ \theta_{11}\to\theta_{12}\to\phi_{11}\to\ \phi_{12}\to 0 \end{array}\right\} y\to\infty$$

Solving equations (22) - (33) under the boundary conditions (34)we obtain the velocity, temperature and concentration distributions in the boundary layer as

$$\begin{aligned} U(y,t) &= A_1 e^{m_1 y} + A_2 e^{m_1 y} + A_3 e^{m_2 y} + A_4 e^{m_3 y} \\ &+ Ec\Big\{A_5\ e^{m_1 y} + A_6\ e^{2m_3 y} + A_7 e^{2m_1 y} \\ &+ A_8\ e^{2m_1 y} + A_9 e^{2m_2 y} + A_{10}\ e^{(m_1+m_3)y} \\ &+ A_{11} e^{2m_1 y} + A_{12} e^{(m_1+m_3)y} + A_{13} e^{(m_2+m_3)y} \\ &+ A_{14} e^{(m_1+m_2)y} + A_{15} e^{(m_1+m_3)y} + A_{16} e^{m_2 y} \\ &+ A_{17} e^{m_1 y} + A_{18} e^{2m_3 y} + A_{19} e^{2m_1 y} \\ &+ A_{20} e^{2m_1 y} + A_{21} e^{2m_2 y} + A_{22} e^{2m_1 y} \\ &+ A_{23} e^{2m_1 y} + A_{24} e^{2m_1 y} + A_{25} e^{(m_1+m_2)y} \\ &+ A_{26} e^{(m_1+m_2)y} + A_{27}\, e^{(m_1+m_2)y}\Big\} \end{aligned}$$

$$\begin{aligned} \theta(y,t) &= e^{m_1 y} + Ec\Big\{ J_1 e^{2m_3 y} + J_2 e^{2m_1 y} \\ &+ J_3 e^{2m_1 y} + J_4 e^{2m_2 y} + J_5 e^{(m_1+m_3)y} \\ &+ J_6 e^{2m_1 y} + J_7 e^{(m_1+m_3)y} + J_8 e^{(m_2+m_3)y} \\ &+ J_9 e^{(m_1+m_2)y} + J_{10} e^{(m_1+m_2)y} + J_{11} e^{m_1 y}\Big\} \end{aligned}$$

$$\begin{aligned} \phi(y,t) &= B_1 e^{m_1 y} + B_2 e^{m_2 y} + Ec\Big\{B_{14} e^{m_2 y} \\ &+ B_3 e^{m_1 y} + B_4 e^{2m_3 y} + B_5 e^{2m_1 y} \\ &+ B_6 e^{2m_1 y} + B_7 e^{2m_2 y} + B_8 e^{2m_1 y} \\ &+ B_9 e^{2m_1 y} + B_{10} e^{(m_1+m_3)y} + B_{11} e^{(m_1+m_2)y} \\ &+ B_{12} e^{(m_1+m_2)y} + B_{13} e^{(m_1+m_2)y}\Big\} \end{aligned}$$

Skin-friction:

We now calculate skin-friction from the velocity field. It is given in non-dimensional form as:

$\tau = -\left(\dfrac{\partial U}{\partial y}\right)_{y=0}$, where $\tau = -\dfrac{\tau'}{\rho U_0^{\,2}}$

$$= A_1 m_1 + A_2 m_1 + A_3 m_2 + A_4 m_3 + Ec\{A_5 m_1 + 2A_6 m_1 + 2A_7 m_1 + 2A_8 m_1 + 2A_9 m_2 + A_{10}(m_1+m_3) + 2A_{11} m_1 + (m_1+m_3)A_{12} + (m_2+m_3)A_{13} + (m_1+m_2)A_{14} + (m_1+m_3)A_{15} + + A_{16} m_2 + A_{17} m_1 + 2A_{18} m_3 + 2A_{19} m_1 + 2A_{20} m_1 + 2A_{21} m_2 + 2m_1 A_{22} + 2A_{23} m_1 + 2A_{24} m_1 + A_{25}(m_2+m_1) + A_{26}(m_1+m_2) + A_{27}(m_1+m_2)\}$$

Rate of heat transfer:

The dimensionless rate of heat transfer is given by

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

$$= m_1 + Ec\{2J_1 m_3 + 2J_2 m_1 + 2J_3 m_1 + 2J_4 m_2 + (m_1+m_3)J_5 + 2J_6 m_1 + (m_1+m_3)J_7 + (m_2+m_3)J_8 + (m_1+m_2)J_9 + (m_1+m_2)J_{10} + J_{11} m_1\}$$

Sherwood number:

The dimensionless Sherwood number is given by

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

$$= B_1 m_1 + B_2 m_2 + Ec\{B_{14} m_2 + B_3 m_1 + 2B_4 m_3 + 2B_5 m_1 + 2B_6 m_1 + 2B_7 m_2 + 2m_1 B_8 + 2B_9 m_1 + (m_1+m_3)B_{10} + (m_1+m_2)B_{11} + (m_1+m_2)B_{12} + (m_1+m_2)B_{13}\}$$

RESULTS AND DISCUSSION

The results for various parameters were discussed for the dimensionless governing equations. The velocity, temperature and concentration profiles are studied for different physical parameters through graphically.We assigned the following values for various parameters involving in flow problem, $\Pr = 0.72$, $Q = 1.0$, $Kr = 1.0$, $R = 1.0$, $M = 1.0$, $n = 0.5$, $S_0 = 1.0$, $Gr = 5.0$, $Gc = 5.0$, $t = 0.2$, $Sc = 0.84$, $Ec = 0.01$. The effect of thermal Grashof number on the velocity profiles is shown in figure (1). Form the plot increase in Grashof numbercontributes to the increase in velocity. Also it is noticed that as we move away from the plate the influence of Grashof number is not that significant.As shown in figure (2),as the mass Grashof number increases the velocity profiles is seen to be increasing. Also, it is seen that as we move far away from the plate it is seen that the effect of mass Grashof number is found to be not that significant.The effect of chemical reaction parameter decreases the velocity of the boundary layer thickness with increasing various values of chemical reaction parameter shown in figure (3). The influence of Magnetic field on the velocity profiles has been plot in figure (4). It is seen that the increase in the applied magnetic intensity contributes to the decrease in the velocity. Further, it is seen that the magnetic influence does not contribute significantly as we move away from the bounding surface.From figures(5) – (6), it is observedthat increases the radiation parameter and heat source parameter produces significant decrease. This is attributed to the thermal state of the fluid causing its velocity to decreases. The contribution of Soret number on the velocity profiles is noticed in figure (7), from this figure we observed that an increase in Soret number contributes the increase in the velocity field. This is due to that increase in the fluid temperature induces through the effect of thermal buoyancy more flow in the boundary layer causing the velocity of the fluid there to increase. Further, it is noticed that the velocity decreases as we move away from the plate which is found to be independent of Soret number. The influence of Schmidt number on velocity profiles has been illustrated in figure (8). It is observed that, while all other participating parameters are held constant and Schmidt numberis increased, it is seen that the velocity decreases in general. Further, it is noticed that as we move far away from the plate, the fluid velocity goes down. The velocity profiles for different values oftime studied and presented in figure (9). It is observed that the velocity increases with increasing values of the time. The temperature profiles decreases with increase in the value of the internal heat source parameter and radiation parameter increases the thermal boundary layer thickness shown in figures (10) & (11). Figure (12) show the influence of the chemical reaction parameter. Increasing the chemical reaction parameter produces a decrease in the species concentration. In turn, this causes the concentration buoyancy effects to decrease as chemical reaction parameter increases. The influence of Schmidt number on the concentration is illustrated in figure (13). It is observed that increase in Schmidt numbercontributes to decrease of concentration of the fluid medium. Further, it is seen that Schmidt numberdoes not contributes much to the concentration field as we move far away from the bounding surface. Knowing the velocity, temperature and concentration profiles, it is customary to study the skin-friction, Nusselt number and Sherwood number. The local as well as average values of skin-friction, Nusselt number and Sherwood number in dimensionless form are as follows: The Local values of the skin-friction, Nusselt number and Sherwood number for fixed parameters and are shown in tables (1) – (3), with the values of $\Pr = 0.72$, $Q = 1.0$, $Kr = 1.0$, $R = 1.0$, $M = 1.0$, $n = 0.5$, $S_0 = 1.0$, $Gr = 5.0$, $Gc = 5.0$, $t = 0.2$, $Sc = 0.57$, $Ec = 0.01$. Local skin-friction as function of the axial coordinate for different values of Soret number versus Grashof number. It is observed that with increasing values of Soret number the results increases, the Nusselt number shown for various values of radiation parameter versus Grashof numberwe observed that there is a fall down in Nusselt number with increasing radiation parameter, finally the Sherwood number for various values of chemical reaction parameter versus Grashof number, it is clear that an increasing values of chemical reaction parameter the results are decreases.

CONCLUSIONS:

The main conclusions of this study are as follows:

- Velocity profiles increases with increasing values of Grashof number, modified Grashof number, Soret number and time.
- The velocity profiles decreases with increasing values of magnetic field. So magnetic field can effectively be used to control the flow as well as chemical reaction parameter, heat source parameter, radiation parameter and Schmidt number.
- Temperature profiles decreases with increases in heat source parameter and radiation parameter.
- Concentration profiles decreases with increasing values of Schmidt number and chemical reaction parameter.
- The plate temperature is raised to T_w and the concentration level near the plate is also raised to C_w.

Table (1): Skin friction	
S_0	τ
1.0	0.5412
2.0	0.6523
3.0	1.2532
4.0	1.5701

Table (2): Nusselt number	
R	Nu
1.0	-2.6235
2.0	-3.1524
3.0	-3.5256
4.0	-4.6452

Table (3): Sherwood number

Kr	Sh
1.0	-0.64587
2.0	-0.89586
3.0	-0.95892
4.0	-1.52546

Appendix:

$$m_1 = -\sqrt{R+Q},\ m_2 - \sqrt{KrSc},\ m_3 = -\sqrt{M}$$

$$m_4 = -\sqrt{Q+R+n\Pr},\ m_5 = -\sqrt{(Kr+n)Sc}$$

$$m_6 = -\sqrt{M+n},\ A_1 = -\frac{Gr}{m_2^2 - M}$$

$$A_2 = -\frac{GcB_1}{m_2{}^2 - M},\ A_3 = -\frac{GcB_2}{m_4{}^2 - M}$$

$$A_4 = (t - A_1 - A_2 - A_3),\ A_5 = -\frac{GrJ_{11}}{m_8^2 - M}$$

$$A_6 = -\frac{GrJ_1}{4m_6{}^2 - M},\ A_7 = -\frac{GrJ_2}{4m_2{}^2 - M}$$

$$A_8 = -\frac{GrJ_3}{4m_2{}^2 - M},\ A_9 = -\frac{GrJ_4}{4m_4{}^2 - M}$$

$$A_{10} = -\frac{GrJ_5}{(m_2+m_6)^2 - M},\ A_{11} = -\frac{GrJ_6}{4m_2{}^2 - M}$$

$$A_{12} = -\frac{GrJ_7}{(m_2+m_6)^2 - M}$$

$$A_{13} = -\frac{GrJ_8}{(m_4+m_6)^2 - M}$$

$$A_{14} = -\frac{GrJ_9}{(m_2+m_4)^2 - M}$$

$$A_{15} = -\frac{GrJ_{10}}{(m_2+m_4)^2 - M},\ A_{16} = -\frac{GcB_{14}}{m_{12}{}^2 - M}$$

$$A_{17} = -\frac{GcB_3}{m_8{}^2 - M},\ A_{18} = -\frac{GcB_4}{4m_6{}^2 - M}$$

$$A_{19} = -\frac{GcB_5}{4m_2{}^2 - M},\ A_{20} = -\frac{GcB_6}{4m_2{}^2 - M},$$

$$A_{21} = -\frac{GcB_7}{4m_4{}^2 - M},\ A_{22} = -\frac{GcB_8}{(m_2+m_8)^2 - M}$$

$$A_{23} = -\frac{GcB_9}{4m_2{}^2 - M},\ A_{24} = -\frac{GcB_{10}}{(m_2+m_6)^2 - M}$$

$$A_{25} = -\frac{GcB_{11}}{(m_4+m_8)^2 - M}$$

$$A_{26} = -\frac{GcB_{12}}{(m_2+m_4)^2 - M}$$

$$A_{27} = -\frac{GcB_{13}}{(m_2+m_4)^2 - M}$$

$$A_{28} = -\begin{pmatrix} A_5 + A_6 + A_7 + A_8 + A_9 + A_{10} + A_{11} \\ +A_{12} + A_{13} + A_{14} + A_{15} + A_{16} + A_{17} \\ +A_{18} + A_{19} + A_{20} + A_{21} + A_{22} + A_{23} \\ +A_{24} + A_{25} + A_{26} + A_{27} \end{pmatrix}$$

$$J_1 = -\frac{m_6^2 A_4^2}{4m_6^2 - (R+Q)},$$

$$J_2 = -\frac{m_2^2 A_1^2}{4m_2^2 - (R+\phi)}$$

$$J_3 = -\frac{m_2^2 A_2^2}{4m_2^2 - (R+Q)},$$

$$J_4 = -\frac{m_4^2 A_3^2}{4m_4^2 - (R+Q)}$$

$$J_5 = -\frac{2m_2 m_6 A_1 A_4}{(m_2+m_6)^2 - (R+Q)}$$

$$J_6 = -\frac{2m_2^2 A_1 A_2}{4m_2^2 - (R+Q)}$$

$$J_7 = -\frac{2m_2 m_6 A_2 A_4}{(m_2+m_6)^2 - (R+Q)}$$

$$J_8 = -\frac{2m_4 m_6 A_3 A_4}{(m_4+m_6)^2 - (R+Q)}$$

$$J_9 = -\frac{2m_2 m_4 A_1 A_3}{(m_2+m_4)^2 - (R+Q)}$$

$$J_{10} = -\frac{2m_2 m_4 A_2 A_3}{(m_2+m_4)^2 - (R+Q)}$$

$$J_{11} = -\begin{pmatrix} J_1 + J_2 + J_3 + J_4 + J_5 \\ +J_6 + J_7 + J_8 + J_9 + J_{10} \end{pmatrix}$$

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$$B_1 = -\frac{ScS_0}{m_2^2 - KrSc} \quad B_2 = (1 - B_1),$$

$$B_3 = -\frac{ScS_0 m_8{}^2 J_{11}}{m_8{}^2 - ScKr}, B_4 = -\frac{4ScS_0 m_6{}^2 J_1}{4m_6{}^2 - ScKr}$$

$$B_5 = -\frac{4ScS_0 m_2{}^2 J_2}{4m_2{}^2 - ScKr} \quad B_6 = -\frac{4ScS_0 m_2{}^2 J_3}{4m_2{}^2 - ScKr}$$

$$B_7 = -\frac{4ScS_0 m_4{}^2 J_4}{4m_4{}^2 - ScKr}$$

$$B_8 = -\frac{ScS_0 (m_2 + m_8)^2 J_5}{(m_2 + m_8)^2 - ScKr}$$

$$B_9 = -\frac{4ScS_0 m_2{}^2 J_6}{4m_2{}^2 - ScKr}$$

$$B_{10} = -\frac{ScS_0 (m_2 + m_6)^2 J_7}{(m_2 + m_6)^2 - ScKr}$$

$$B_{11} = -\frac{ScS_0 (m_4 + m_6)^2 J_8}{(m_4 + m_6)^2 - KrSc}$$

$$B_{12} = -\frac{ScS_0 (m_2 + m_4)^2 J_9}{(m_2 + m_4)^2 - KrSc}$$

$$B_{13} = -\frac{ScS_0 (m_2 + m_4)^2 J_{10}}{(m_2 + m_4)^2 - KrSc}$$

$$B_{14} = -\begin{pmatrix} B_3 + B_4 + B_5 + B_6 + B_7 + B_8 \\ +B_9 + B_{10} + B_{11} + B_{12} + B_{13} \end{pmatrix}$$

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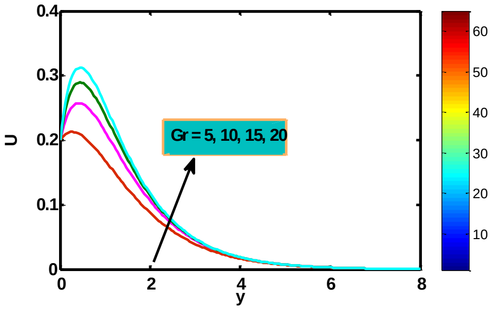

Fig. (1): Velocity Profiles for Gr

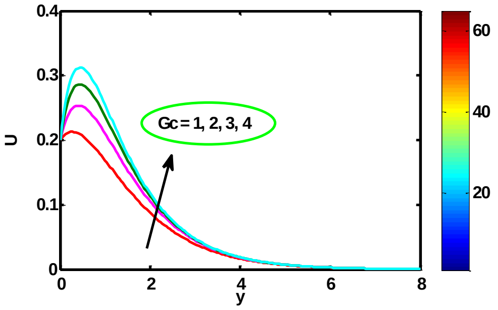

Fig. (2): Velocity Profiles for Gc

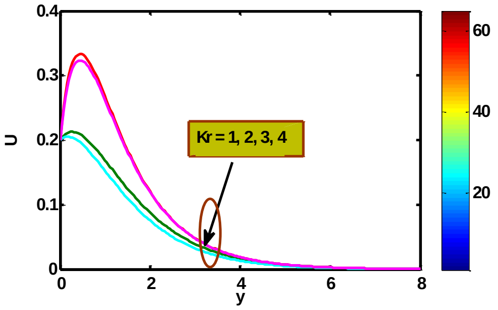

Fig. (3): Velocity Profiles for Kr

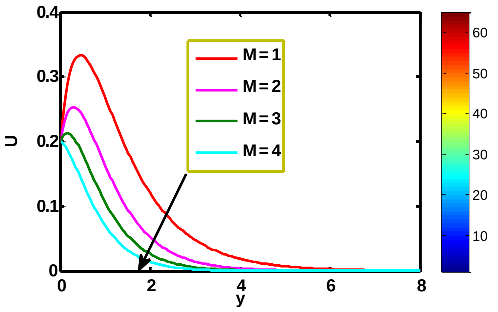

Fig. (4): Velocity Profiles for M

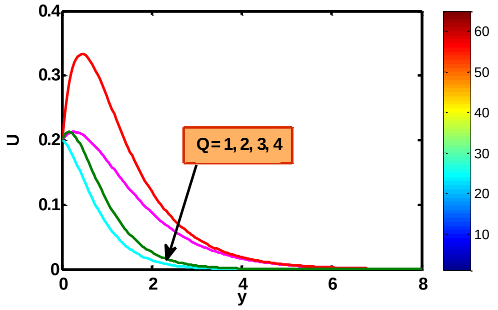

Fig. (5): Velocity Profiles for Q

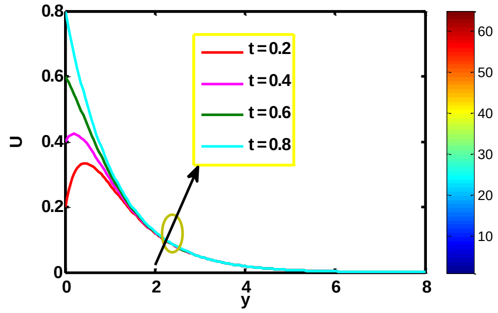

Fig. (9): Velocity Profiles for t

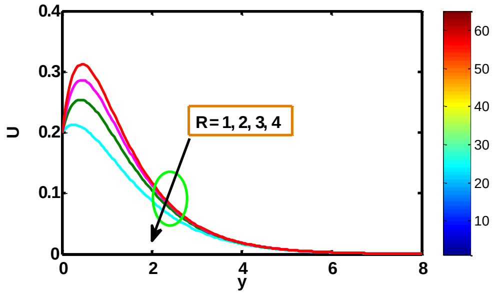

Fig. (6): Velocity profiles for R

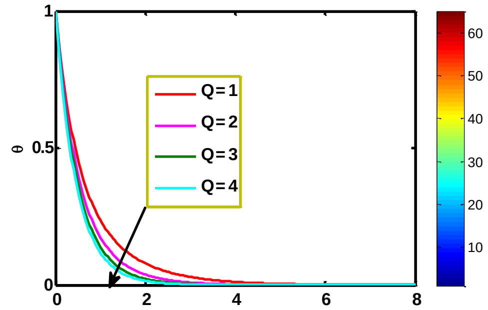

Fig. (10): Temperature Profiles for Q on y axis

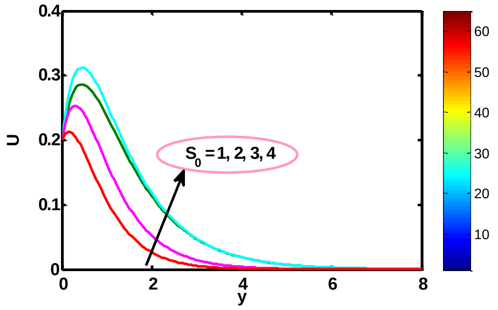

Fig. (7): Velocity Profiles for S_0

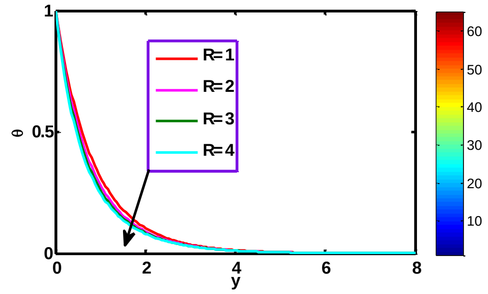

Fig. (11): Temperature Profiles for R

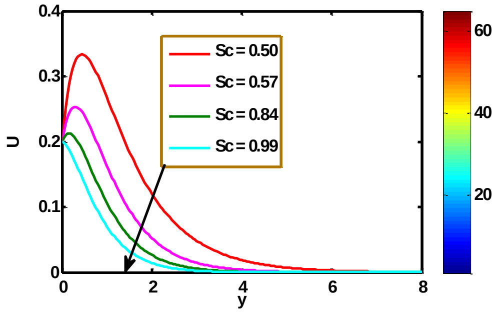

Fig. (8): Velocity Profiles for Sc

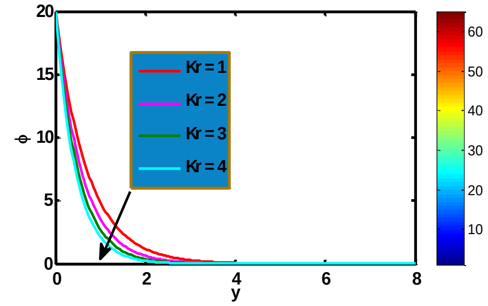

Fig. (12): Concentration Profiles for Kr

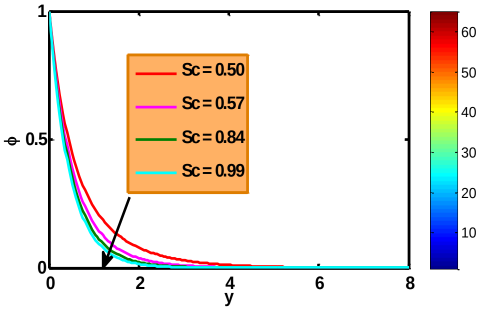

Fig. (13): Concentration Profiles for Sc