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# Influence of SORET on Unsteady MHD of Kuvshinshiki Fluid Flow With Heat and Mass Transfer Past a Vertical Porous Plate With Variable Suction

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***Abstract--*** The objective of this paper is to study the influence of Soret on unsteady magnetohydrodynamic(MHD) of Kuvshinshin fluid taking visco-elastic and Soret terms into account and the constant permeability of the medium and neglecting induced magnetic field in comparison to an applied magnetic field. The dimensionless governing equations are solved using an implicit finite difference method of Crank-Nicolson type. The effects of various parameters on the velocity and temperature fields as well as the Coefficient of skin-friction, Nusselt and Sherwood number were presented graphically and in tabulated forms. It is observed that, when the heat source parameter increases, the velocity and temperature increases in the boundary layer.

**Keywords**: Soret, Unsteady, MHD, Kuvshinshiki Fluid Flow, Porous, Suction, Heat and transfer

**Subject Classification:** 76w05.

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## 1 INTRODUCTION

The study of non Newtonian fluid flow has gained the attention of engineers and scientist in recent times due to its important application in various branches of science, engineering and technology: particularly in chemical and nuclear industries, material processing, geophysics, and bio-engineering. In view of these applications an extensive range of mathematical models have been developed to simulate the diverse hydrodynamic behavior of these non- Newtonian fluids. In particular, different visco-elastic fluid model (like the Rivlin-Ericksen second order model. Oldroyd model, Johnson-Seagalman model). The fluid which exhibits the elasticity property of solids and viscous property of liquids are called viscoelastic fluid. These fluid flows are encountered in numerous areas of petrochemical, biomedical and environmental engineering including polypropylene coalescence sintering. Consequently, Ahmed, Sarma, and Baruna, (2012), investigated Magnetic field effect on free convective oscillatory flow between two vertical parallel plates with periodic plate temperature and dissipative heat. Idowu, Dada and Jimoh (2013) studied heat and mass transfer of magnetohydrodynamic (MHD) and dissipative fluid flow pass a moving vertical porous plate with variable suction. Alam , Rahman and Sattar (2009), looked at transient magnetohydrodynamic free convective heat and mass transfer flow with thermophoresis past a radiative inclined permeable plate in the presence of variable chemical reaction and temperature dependent viscosity. Chamkha, Takhar and Soundalgekar (2001), studied the radiation effect of free convection flow past a semi-infinite vertical plate with mass transfer. Devika, Satya Narayana and Yenkataramana (2013), investigated MHD oscillatory flow of a viscoelastic fluid in a porous channel with chemical reaction. Rushi, Kumar and Sivaraj (2012), studied MHD Visco-elastic fluid non-darcy flow along a moving vertical cone. Hady, Mohammed, Mahdy (2006), worked on MHD Free convection flow along a vertical wavy surface with heat generation or absorption effect. Gnaneshwara and Bhaskar (2009) investigated the radiation and mass transfer effects on an unsteady MHD free convection flow past a heated vertical porous plate with viscous dissipation. Vidyasagar and Raman (2013), reported a study on the radiation effect on MHD convection flow of Kuvshinshiki fluid with mass transfer past a vertical porous plate through porous medium. Kim and Fedorov (2004) studied transient mixed radiative convection flow of a micro polar fluid past a moving semi-infinite vertical porous plate, while, Vajravelu and Hadjinicolaou (1993) studied the heat transfer characteristics in the laminar boundary layer of a viscous fluid over a stretching sheet with viscous dissipation or frictional heating and internal heat generation.

The study of visco-elastic fluid through porous medial has become the basis of many scientific and engineering applications. This type of flow is of great importance in the petroleum engineering concerned with the movement of oil, gas and water through reserviour of oil or gas field to the hydrologist in the study of the migration of underground water and to the chemical engineering for the purification and filtration processes and in the case like drug permeation through human skin. The principles of this subject are very useful in recovering the water for drinking and irrigation purposes. Many research workers like Alam, et al.(2006) studied the problem of free convection heat and mass transfer flow past an inclined semi-infinite heated surface of an electrically conducting and steady viscous incompressible fluid in the presence of a magnetic field and heat generation. Abdus and Mohammed (2006) considered the thermal radiation interaction with unsteady MHD flow past a vertical porous plate immersed in a porous medium. The importance of radiation in fluid led Muthucumaraswamy and Chandrakala (2006) to study radiative heat and mass transfer effect on moving isothermal vertical plate in the presence of chemical reaction. Muthucumaraswamy and Senthih (2004) considered heat and mass transfer effect on moving vertical plate in the presence of thermal radiation.

In many chemical engineering processes, the chemical reaction do occur between mass and fluid in which plate is moving. These processes take place in numerous industrial applications such as polymer production, manufacturing of ceramics or glassware and food processing. In the light of the fact that, the combination of heat and mass transfer problems with chemical reaction are of importance in many processes, and have, therefore, received a considerable amount of attention in recent years. In processes such as drying, evaporation at the surface of a water body, energy transfer in a wet cooling tower and the flow in a desert cooler, heat and mass transfer occur simultaneously. Possible applications of this type of flow can be found in many industries. For example, in the power industry, among the methods of generating electricity is one in which electrical energy is extracted directly from the moving conducting fluid. Naving Kumar and Sandeep Gupta (2008) investigated the effect of variable permeability on unsteady two-dimensional free convective flow through a porous bounded by a vertical porous surface. Sandeep and Sugunamma (2013), analyzed the effect of inclined magnetic field on unsteady free convective flow of dissipative fluid past a vertical plate. Makinde and Mhone (2005), investigated the heat transfer to MHD oscillatory flow in a channel filled with porous medium. Sharma, Navin and Pooja (2011) have studied the influence of chemical reaction on unsteady MHD free convective flow and mass transfer through viscous incompressible fluid past a heated vertical plate immersed in porous medium in the presence of heat source. Muthucumaraswamy and Ganesan(2001) studied the effect of the chemical reaction and injection on flow characteristics in an unsteady upward motion of an isothermal plate. Mohammed (2009) studied double-diffusive convection-radiation interaction on unsteady MHD flow over a vertical moving porous plate with heat generation and Soret effects.
Base on these investigations and works that have been reported in the field; in particular, the study of heat transfer, heat radiation is of considerable importance in chemical and hydrometallurgical industries. Mass transfer processes are evaporation of water from a pound to the atmosphere the diffusion of chemical impurities in lakes, rivers and ocean from natural or artificial sources. Magnetohydrodynamic mixed convection heat transfer flow in porous plate and non-porous media is of considerable interest in the technical field due to its frequent occurrence in industrial technology and geothermal application, high temperature plasma application to nuclear fusion energy conversion, liquid metal fluid and MHD power generation systems combined heat mass transfer in natural convective flows on moving vertical porous plate. Das, Sarkar and Jana (2012), studied the MHD Natural Convection Vertical parallel Plates with Oscillatory Wall Temperature. Srinvasa Rao and Anand Babu.(2010), studied the finite element analysis of radiation and mass transfer flow past semi-infinite moving vertical plate with viscous dissipation.

In this study we consider the work of Vidyasagar ,et al (2013) with Kuvshinshiki fluid. The aim of the present investigation is to study the influence of Soret on unsteady MHD of Kkuvshinshiki fluid flow past a vertical porous plate with heat and mass transfer. The result of parametric study on the flow, heat and transfer characteristics are shown graphically and physical aspects are discussed in detail.

## 2 FORMULATION OF PROBLEMS

Consider unsteady two-dimensional heat mass transfer flow of an incompressible visco-elastic of kuvshinshiki type fluid past a semi-infinite vertical porous plate. According to the coordinate system, the x-axis is taken along the plate in upward direction and y-axis is normal to the plate. The fluid is assumed to be a gray, absorbing-emitting, but, non-scattering medium. The radiative heat flux in the x-direction is considered negligible in comparison with that in the y-direction Alam, et al(2009) . It is assumed that there is no applied voltage of which imp lies the absence of an electric field. The transversely applied magnetic field and magnetic Reynolds number are very small; hence, the induced magnetic field is negligible. Soret and visco-elastic terms are taken into account with the constant permeability porous medium. The MHD term is derived from an order-of-magnitude analysis of the full Navier-stokes equation. It is assumed here that the whole size of the porous plate is significantly larger than a characteristic microscopic length scale of the porous medium. The fluid properties are assumed to be constants except that the influence of density variation with temperature that has been considered in the body-force. Since the plate is semi-infinite in length, therefore all physical quantities are functions of y and t only. Hence, by the usual boundary layer approximations the governing equations for unsteady flow of a viscous incompressible fluid through a porous medium are:

Continuity Equation

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

Linear momentum equation is given as

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

Energy equation is given as

$$\frac{\partial T^*}{\partial t^*} + v^*\frac{\partial T^*}{\partial y^*} = \alpha\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{\upsilon}{C_P}\left(\frac{\partial u^*}{\partial y^*}\right)^2 - \frac{1}{\rho C_P}\frac{\partial q_r}{\partial y^*} \tag{3}$$

Concentration equation is

$$\frac{\partial C^*}{\partial t^*} + v^* \frac{\partial C^*}{\partial y^*} = D_m \frac{\partial^2 C^*}{\partial y^{*2}} + \frac{D_m K_T}{T_m}\frac{\partial^2 \theta^*}{\partial y^{*2}} - K_r (C^* - C_\infty^*) \quad (4)$$

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

$$t^* \le 0,\ u^* = 0,\ T^* \to T^*_\infty,\ C^* \to C^*_\infty \text{ for all } y^*$$

$$t^* > 0,\ u^* = 0,\ T^* \to T^*_\infty,\ C^* \to C^*_\infty \text{ for } y^* = 0 \quad (5)$$

$$u^* = 0,\ T^* \to T^*_\infty,\ C^* \to C^*_\infty \text{ as } y^* \to \infty$$

Where y is dimensions coordinates, u* and v* are dimensionless velocities, t* is dimensionless time, T* is the dimensional temperature, g- the acceleration due to gravity, β - the volumetric coefficient of thermal expansion, β* is the volumetric coefficient of thermal expansion with concentration, ρ - the density of the fluid, $C_p$ is the specific heat at constant pressure, θ- is the temperature, K* is the permeability of the porous medium, $q_r$ is the radiation heat flux, $B_0$- magnetic induction, ν- the kinematic viscosity, $T_w$* is wall dimensional temperature, $T_\infty$* -the free stream temperature far away from the plate, $K_0$ is the dimensional visco-elastic parameter, R is the radiation parameter, Pr is Prandlt number, U is velocity, n is the frequency, M is the Hartmann number, $D_m$ is the coefficient of mass diffusivity, $K_T$ is thermal diffusion ratio, $T_m$ is the mean fluid temperature, $K_c$ is chemical reaction, $K_r$ is mean absorption, K is the permeability parameter, η is the heat source, Gr is thermal Grashof number, α is the angle of inclination, and Ec is Eckert number, A is a real positive constant of suction velocity parameter, < ε, and εA<1 are small less than unity, i.e εA<<1, $V_0$ is the scale of suction velocity normal to the plate.

$$\frac{\partial q_r}{\partial y^*} = 4(T^* - T_\infty^*) - \int_0^\infty K\lambda\zeta \left(\frac{de_{b\lambda}}{dT^*}\right) d\lambda = 4I_1 (T^* - T_\infty^*) \quad (6)$$

Where $K\lambda\zeta$ is the absorption coefficient $e_{b\lambda}$ is the plank and the subscript $\zeta$ refers to the value at the wall.

From the continuity equation (1), it is clear that the suction velocity normal to the plate is a function of time only and we shall take it in the form:

$$v^* = -v_0^* \left(1 + \varepsilon A e^{nt}\right) \quad (7)$$

Introducing the following non-dimensional quantities

$$u = \frac{u^*}{U_0},\ y = \frac{U_0 y^*}{v},\ t = \frac{U_0^2 t^*}{v},\ \theta = \frac{T^* - T_\infty^*}{T_w^* - T_\infty^*}, C = \frac{C^* - C_\infty^*}{C_w^* - C_\infty^*}, Pr = \frac{v\rho C_p}{k} = \frac{v}{\alpha}, Gr = \frac{g\beta v (T_w - T_\infty)}{U_0^2},\ Gc = \frac{g\beta v (C_w - C_\infty)}{U_0^2}, Ec = \frac{U_0^2}{C_P (T_w - T_\infty)},$$

$$M = \frac{\sigma B_0^2 v}{\rho U_0^2},\ R = \frac{4I_1 v}{k U_0^2}, Sc = \frac{v}{D_m}, S_r = \frac{D_m K_T (T_w - T_\infty),}{T_m v (C_w - C_\infty)}\ and K_c = \frac{K_r v}{u_0^2} \quad (8)$$

into the equations (2) , (3) and (4) with equation (1) identically satisfied the following set of differential equations:

$$\left(1 + \frac{\lambda}{\partial t}\right)\frac{\partial u}{\partial t} - (1 + \epsilon A e^{nt})\frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} + Gr\theta + GcC - \left(\left(1 + \frac{\lambda}{\partial t}\right)(M + \frac{1}{k}\right) u \quad (9)$$

$$\frac{\partial \theta}{\partial t} - (1 + \epsilon A e^{nt})\frac{\partial \theta}{\partial y} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial y^2} - R\theta + Ec\left(\frac{\partial u}{\partial y}\right)^2 \quad (10)$$

$$\frac{\partial C}{\partial t} - (1 + \epsilon A e^{nt})\frac{\partial C}{\partial y} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} + \frac{1}{Sr}\frac{\partial^2 \theta}{\partial y^2} - K_r C \quad (11)$$

With the boundary conditions (4) given by the following dimensionless form

$$t^* \le 0,\ u^* = 0,\ \theta^* \to \theta^*_\infty,\ C^* \to C^*_\infty \text{for all } y^*$$

$$t^* > 0,\ u^* = 0,\ \theta^* \to \theta^*_\infty,\ C^* \to C^*_\infty \text{ for } y^* = 0 \quad (12)$$

$u^* = 0,\ \theta^* \to \theta^*_\infty,\ C^* \to C^*_\infty$ as $y^* \to \infty$

The dimensionless local value of skin friction ($\tau$), Nusselt number (Nu) and the Sherwood number (Sh) can be characterized in order by

$$\tau_x = -\left(\frac{\partial U}{\partial y}\right)_{y=0} \tag{13}$$

$$Nu_x = -X \left[\frac{\partial T}{\partial y}\right]_{y=0} \tag{14}$$

$$Sh_x = -X \left[\frac{\partial C}{\partial y}\right]_{y=0} \tag{15}$$

The average of: skin friction ($\tau$); Nusselt number (Nu); and Sherwood number (Sh) can be written in dimensionless form as

$$(\overline{\tau_x}) = -\int_0^1 \left[\frac{\partial u}{\partial y}\right]_{y=0} dX \tag{16}$$

$$(\overline{Nu_x}) = -\int_0^1 \left[\frac{\partial T}{\partial y}\right]_{y=0} dX \tag{17}$$

$$(\overline{Sh_x}) = -\int_0^1 \left[\frac{\partial C}{\partial y}\right]_{y=0} dx \tag{18}$$

## 3 METHOD OF SOLUTION

Solving the non-linear coupled equation s (9), (10) and (11) subject to the initial and boundary condition (12), Crank-Nicolson type of an implicit finite difference scheme was employed. The finite difference equations corresponding to equations (9), (10) and (11) are discretized as follows:

$$\left(1+\frac{\lambda}{\Delta t}\right)\frac{U_{i,j}^{n+1}-U_{i,j}^{n}}{\Delta t} - (1+\in Ae^{nt})\frac{U_{i,j+1}^{n+1}-U_{i,j-1}^{n+1}+U_{i,j+1}^{n}-U_{i,j-1}^{n}}{4\Delta y} = \frac{U_{i,j-1}^{n+1}-2U_{i,j}^{n+1}+U_{i,j+1}^{n+1}-U_{i,j-1}^{n}-2U_{i,j}^{n}+U_{i,j+1}^{n}}{2(\Delta y)^2} + Gr\left(\frac{\theta_{i,j}^{n+1}-\theta_{i,j}^{n}}{2}\right) + Gc\left(\frac{C_{i,j}^{n+1}-C_{i,j}^{n}}{2}\right) - \left(1+\frac{\lambda}{\Delta t}\right)(M+\frac{1}{k})\left(\frac{U_{i,j}^{n+1}-U_{i,j}^{n}}{2}\right) \tag{19}$$

$$\frac{\theta_{i,j}^{n+1}-\theta_{i,j}^{n}}{\Delta t} - (1+\in Ae^{nt})\frac{\theta_{i,j+1}^{n+1}-\theta_{i,j-1}^{n+1}+\theta_{i,j+1}^{n}-\theta_{i,j-1}^{n}}{4\Delta y} = \frac{\frac{1}{Pr}(\theta_{i,j-1}^{n+1}-2\theta_{i,j}^{n+1}+\theta_{i,j+1}^{n+1}+\theta_{i,j-1}^{n}-2\theta_{i,j}^{n}+\theta_{i,j+1}^{n}}{2(\Delta y)^2} - R\left(\frac{\theta_{i,j}^{n+1}-\theta_{i,j}^{n}}{\Delta t}\right) + Ec\frac{\left(U_{i,j+1}^{n}-U_{i,j-1}^{n}\right)^2}{2\Delta y} + \frac{\left(U_{i,j+1}^{n}-U_{i,j-1}^{n}\right)^2}{2\Delta y} \tag{20}$$

$$\frac{C_{i,j}^{n+1}-C_{i,j}^{n}}{\Delta t} - (1+\in Ae^{nt})\frac{C_{i,j+1}^{n+1}-C_{i,j-1}^{n+1}+C_{i,j+1}^{n}-C_{i,j-1}^{n}}{4\Delta y} = \frac{\frac{1}{Sc}(C_{i,j-1}^{n+1}-2C_{i,j}^{n+1}+C_{i,j+1}^{n+1}+C_{i,j-1}^{n}-2C_{i,j}^{n}+C_{i,j+1}^{n}}{2(\Delta y)^2} + \frac{\frac{1}{Sr}(\theta_{i,j-1}^{n+1}-2\theta_{i,j}^{n+1}+\theta_{i,j+1}^{n+1}+\theta_{i,j-1}^{n}-2\theta_{i,j}^{n}+\theta_{i,j+1}^{n}}{2(\Delta y)^2} - K_c\left(\frac{C_{i,j}^{n+1}-C_{i,j}^{n}}{2}\right) \tag{21}$$

with the following boundary conditions

t*≤ 0, u* = 0, θ= 0, C=0 for all y

t*>0, u =0, θ=1, T=1,C=1 for y = 0 (22)

u =0, θ = 0, T=0, C=0 as y →∞

where Δ is a dimensionless time-step, and Δy is a dimensionless finite difference grid size in the y- direction, i designate the grid point along the x-direction, j along the y- direction and n in the time variable t.

Here the region of integration is considered as a rectangle with max $Y_{max}$=26 where $Y_{max}$ corresponds to Y=∞ which lies well outside the momentum thermal layer, after some preminary numerical experiments such that the boundary conditions of (22) are satisfied within the tolerance limit $10^{-5}$. The mesh sizes have been fixed as Δ y =0.16 with time step Δt=0.01. The values of the velocity (u) and temperature (θ)at two consecutive time steps are less than $10^{-5}$ at all grid points. The scheme is unconditionally stable. The local truncation error is O $(\Delta t^2 + \Delta y^2)$ and it tends to zero as Δt and Δy tend to zero. It follows that the Crank-Nicolson Method is compatible. Stability and compatibility ensure the convergence.

## 4 Results and Discussions:

Numerical evaluation for the solutions of this problem is performed and the results are illustrated graphically in Fig.1-13, to the interesting features of significant parameters on velocity, temperature local skin friction and local Nusselt number. Throughout the computations we employ A=0.5, t=1.0, n=0.1 and ϵ=0.001, while R, $k_r^2$, Sc, Gr, M, Pr, η, and K are varied in order to account for their effects.

The velocity profiles for different values of Grashof number Gr are described in the fig.1. It is observed that an increasing in Gr leads to a rise in the values of velocity. Here the Grashof number represents the effect of the free convection currents. Physically, Gr >0 means heating of fluid of cooling of the boundary surface, Gr<0 means cooling of the fluid of heating of the boundary surface and Gr=0 corresponds to the absence of free convection current. In addition, the curves show that the peak value of velocity increases rapidly near the wall of the porous plate as Grashof number increases, and then decays to the relevant free stream velocity.Fig.13 shows that, as the value of Gr increase the temperature profiles decreases.

Fig.3. show that the effect of increasing values of M parameter results in decreasing velocity distribution across the boundary layer because of the application of transfer magnetic field will result a restrictive type force(Lorenz force) similar to drag force which tends to resist the fluid and this reducing its velocity.

It is observed from fig.4. that as velocity profiles for different values of the permeability K. Clearly, as K increases the peak value of velocity tends to increase. These results could be very useful in deciding the applicability of enhanced oil recovery in reservoir engineering.

The velocity profiles across the boundary layer for different values of prandtl number $Pr$ are plotted in Fig.5 and Fig 15. The results shows that the effect of increasing values of Pr results in a decreasing the velocity and temperature.

Fig.6. shows the effect of radiation R on velocity. It is observed that as the value of R increases, the velocity increases with an increasing in the flow boundary layer thickness. Thus, thermal radiation enhances the flow. The effect of radiation parameter R on the temperature profiles are presented in Fig.12. It shows that, as the value of R increases the temperature profiles increases, with an increasing in the thermal boundary layer thickness.

It is observed from Fig.7. that as velocity profile for different values of the visco-elastic fluid parameter ψ increases it results in a decreasing the thermal boundary layer thickness.

It is observed from Fig.8 that an increase in Soret parameter $S_r$ results in a decreasing the thermal boundary layer thickness and more uniform temperature distribution across the boundary layer.Fig.18.show that the effect of Soret parameter on the Sherwood profile. it shows that an increase in the Soret parameter it decreases in the Sherwood profile.

Fig.9 shows that the effect of increasing values of Sc parameter results in an increasing velocity distribution while it uniform in temperature distribution across the boundary layer. The effect of Sc parameter on Sherwood at Fig.17. it shows that an increasing the Schmit (Sc) parameter it decreases in the Sherwood number.

Fig.10and Fig.16. shows the effect of Eckert number on temperature and velocity, as Eckert number increases the temperature decreases also the concentration distribution across the boundary layer decreases

The velocity profiles across the boundary layer for different values of chemical reactions $K_r$ are plotted in Fig.11. The results show that the effect of increasing values of $K_r$ results in a decreasing the velocity and Sherwood number while the temperature does not change.

**Table-1. Effect of R on Velocity n=0.1, t=1 and A=1.**

| Fluid parameters | Velocity gradients | Nusselt numbers | Sherwood numbers |
|---|---|---|---|
| R =1 | 0.8095 | 4.7846 | 24.3541 |
| R=2 | 0.8205 | 5.4309 | 25.9742 |
| R=3 | 0.8307 | 5.9037 | 27.2893 |
| M=0.1 | 0.7555 | 3.7316 | 22.0748 |
| M=0.2 | 0.7076 | 3.7316 | 22.0746 |
| M=0.3 | 0.6639 | 3.7316 | 22.0750 |
| Gr=2 | 0.7972 | 3.7316 | 22.0747 |
| Gr=4 | 1.1958 | 3.7314 | 22.0738 |
| Gr=6 | 1.5943 | 3.7312 | 22.0726 |
| K=0.1 | 0.0671 | 3.7317 | 22.0755 |
| K=0.3 | 0.1873 | 3.7317 | 22.0754 |
| K=0.5 | 0.2856 | 3.7317 | 22.0754 |
| Pr=0.5 | 0.8481 | 3.8293 | 25.8066 |
| Pr=0.47 | 0.8145 | 3.6696 | 23.3055 |
| Pr=0.72 | 0.7967 | 3.7372 | 22.0445 |
| Ec=1 | 0.7969 | 3.7173 | 22.0030 |
| Ec=2 | 0.7966 | 3.7028 | 21.9306 |
| Ec=3 | 0.7963 | 3.6883 | 21.8581 |
| $S_r$=0.1 | 1.1360 | 3.7313 | 42.1010 |
| $S_r$=0.2 | 0.7972 | 3.7316 | 22.0747 |
| $S_r$=0.3 | 0.6609 | 3.7316 | 13.7374 |
| Sc=0.22 | 0.3763 | 3.7317 | 4.1528 |
| Sc=0.30 | 0.3781 | 3.7317 | 4.0389 |
| Sc=0.66 | 0.3866 | 3.7317 | 3.5047 |
| Kr=0.2 | 0.8428 | 3.7315 | 24.5766 |
| Kr=0.4 | 0.8349 | 3.7315 | 24.1485 |
| Kr=0.6 | 0.8274 | 3.7315 | 23.7387 |
| Φ= 0.1 | 4.9598 | 3.6932 | 21.9170 |
| Φ= 0.3 | 3.0196 | 3.7228 | 22.0342 |
| Φ= 0.5 | 2.3600 | 3.7277 | 22.0561 |

From the above result, the effects of the Permeability parameter, Grashof number for heat transfer, prandtl number, Schmidt number and the radiation on the skin- friction coefficient. It is observed from this table that as Permeability parameter, increases, the velocity gradient increases, also as magnetic field Parameter effect increases, Eckert number, Soret, chemical reaction and visco-elastic parameter velocity gradient decreases.

Also the Prandtl number parameter, Grashof number, Eckert number the Nusselt number decreases, increases in radiation for heat transfer, visco-elastic, the Nusselt number also increases. while the soret, Schmidt, chemical reaction, permeability, magnetic field remain unchanged.

The presence of Schmidt number, chemical reaction and Soret on Sherwood number also show significant effects in the result, as Schmidt number, chemical reaction and Soret increases the Sherwood number decreases.

It was generally observed from the above results that the presence Kuvshinshi fluid flow, Soret, permeability, viscous dissipation and radiation parameters in the fluid flow model played significant roles by influencing the behaviour of the natural velocity temperature and concentration of the fluid.

## 5 CONCLUSIONS

From the present study we can make the following conclusions:

The velocity increases with an increase in the permeability parameter, Grashof number.

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The velocity as well as temperature with an increase in the radiation, Soret and Schimidt parameter while the visco-elastic increases as temperature increases.

The velocity decreases with an increase in the magnetic parameter, visco-elastic, Eckert number, Pranditl number, chemical reaction.

The Sherwood number decreases as all the parameters increases except the radiation that is rising.

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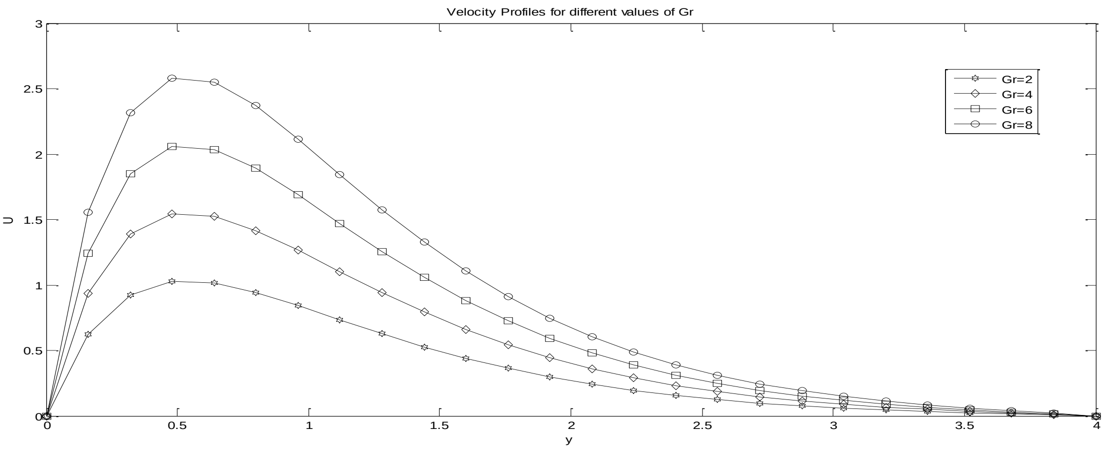
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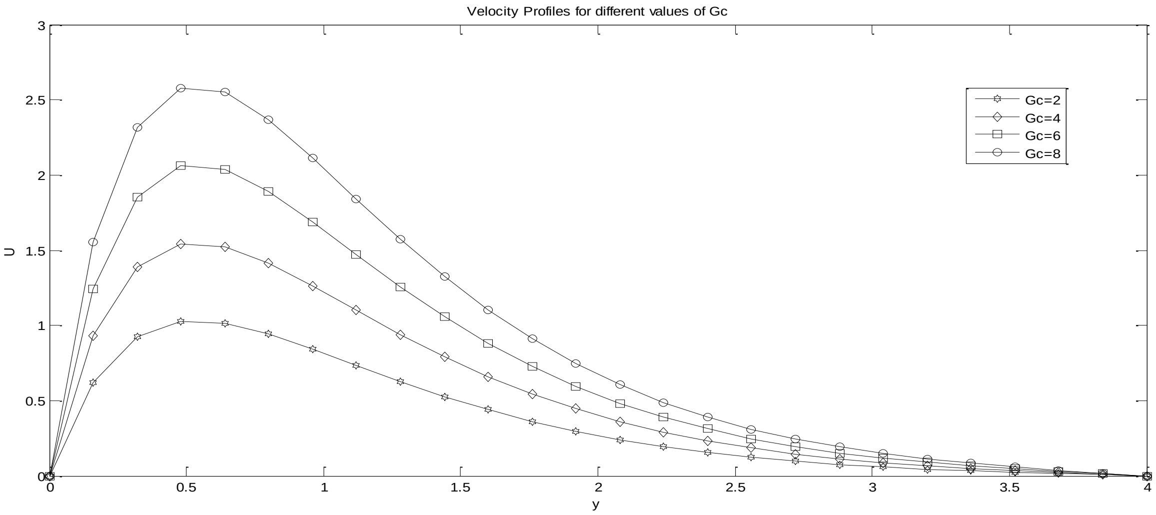
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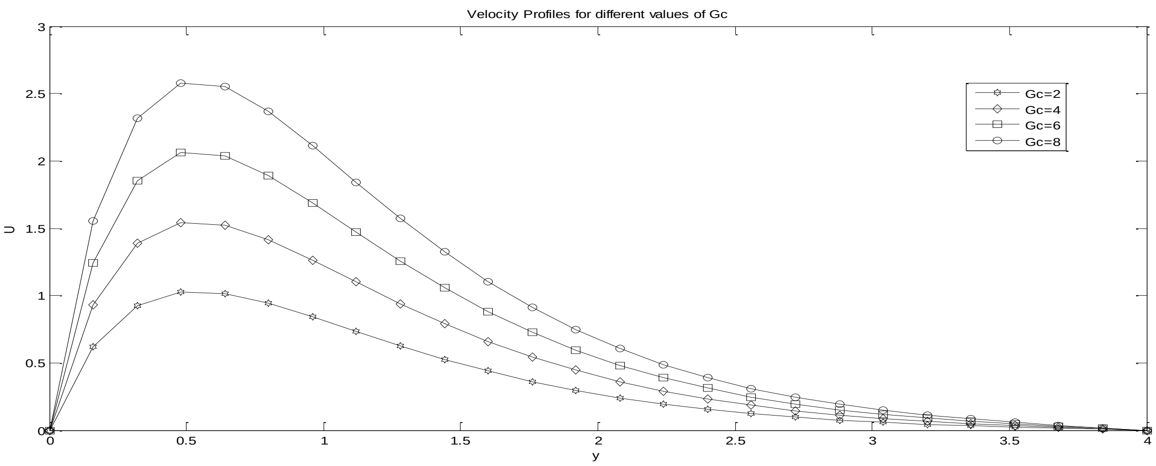
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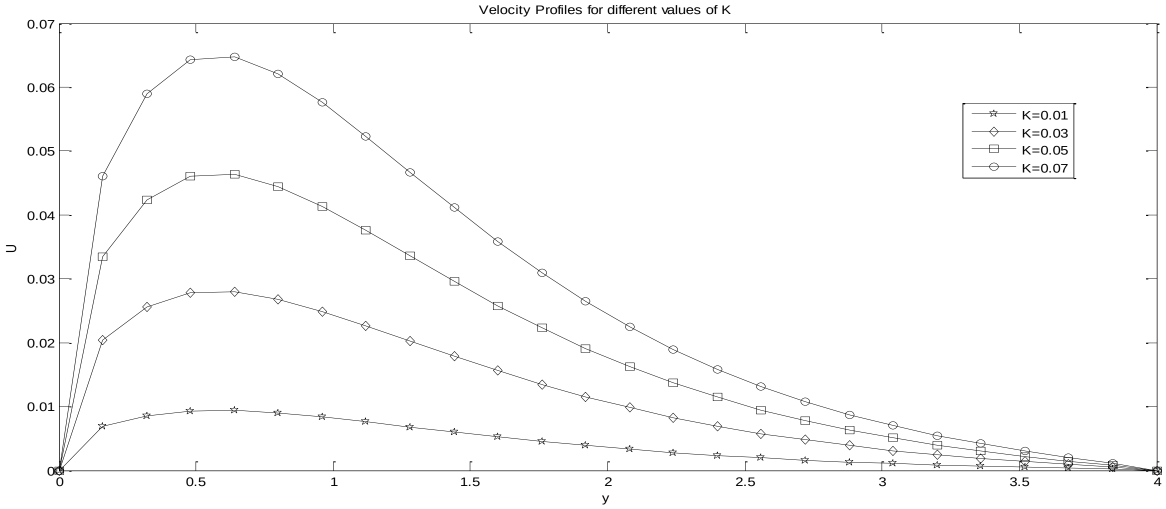
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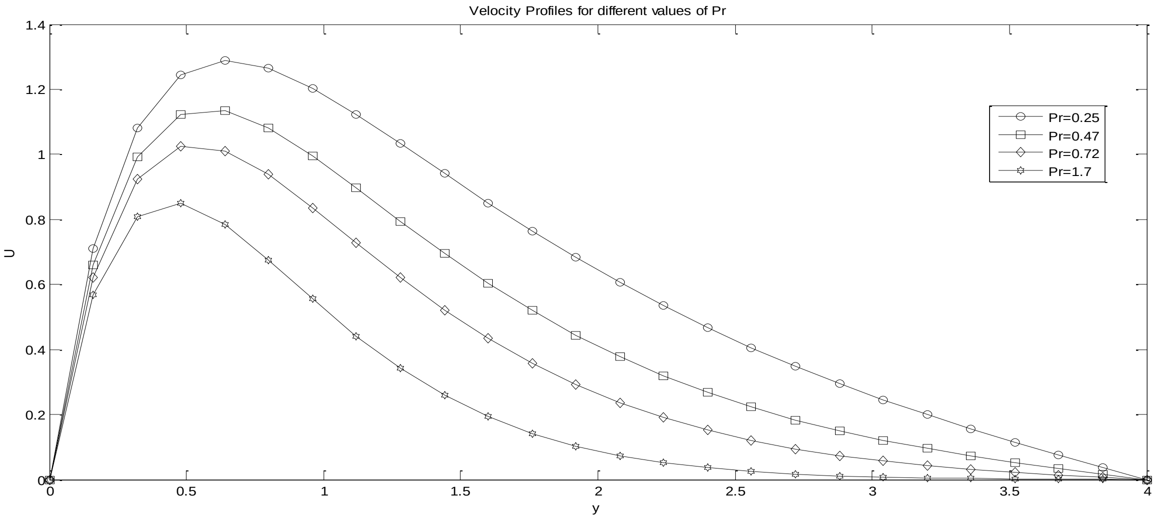
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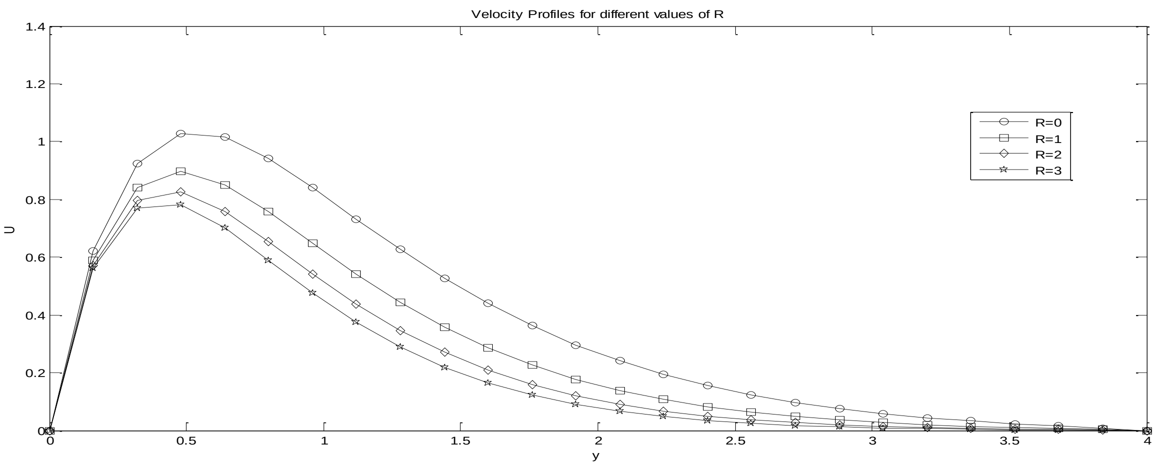
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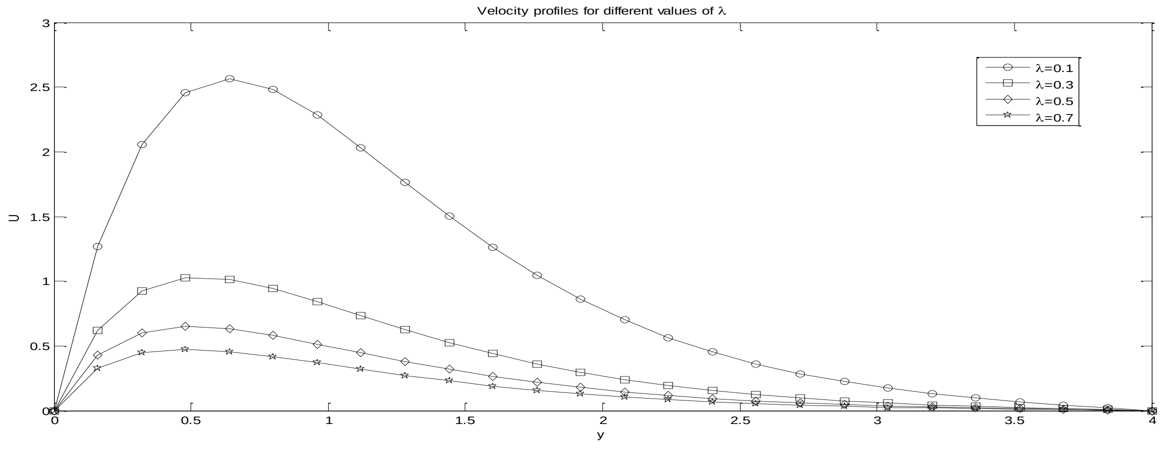


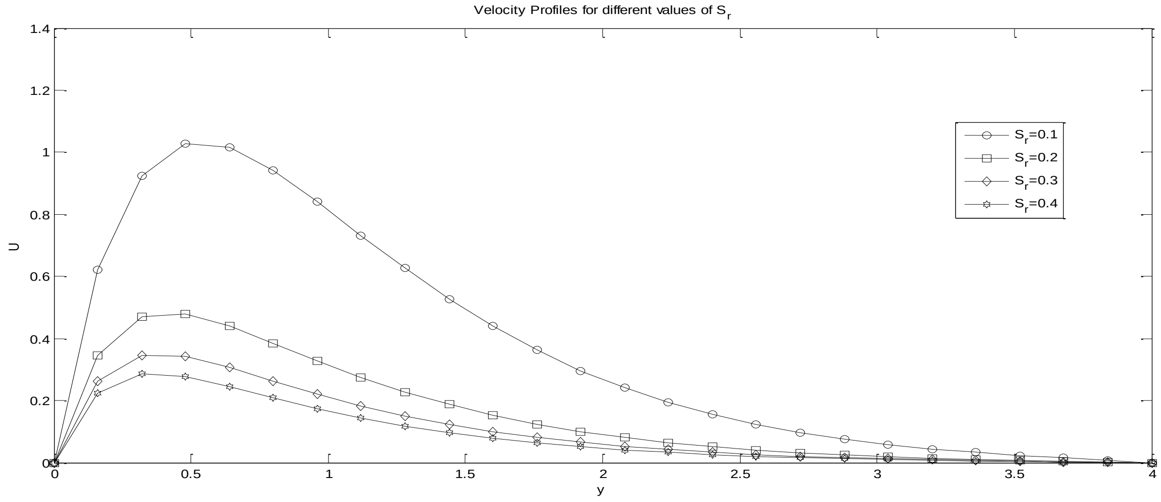


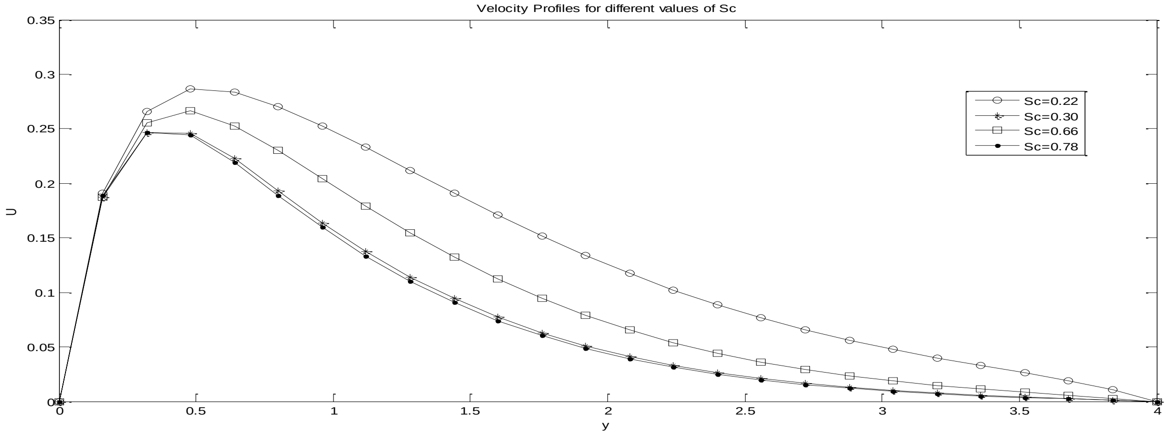

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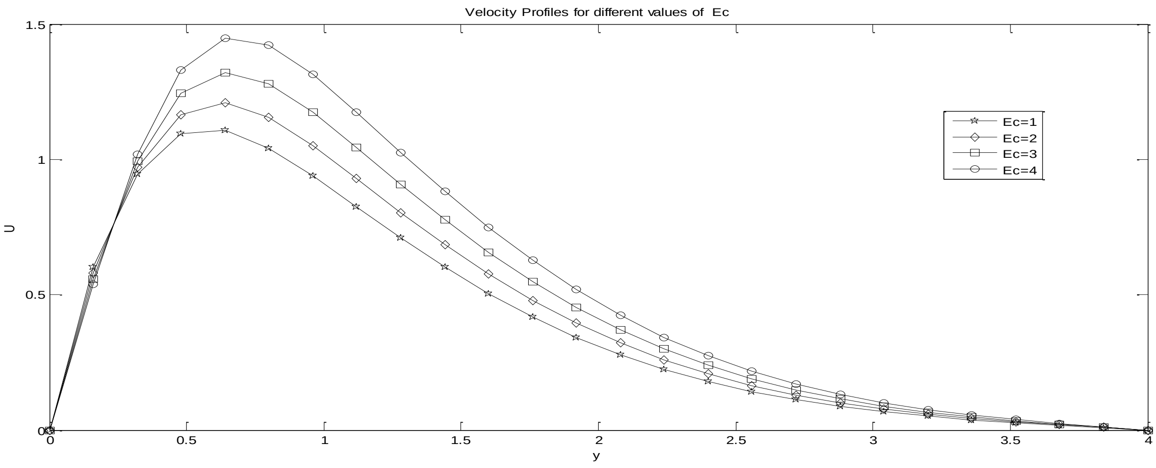


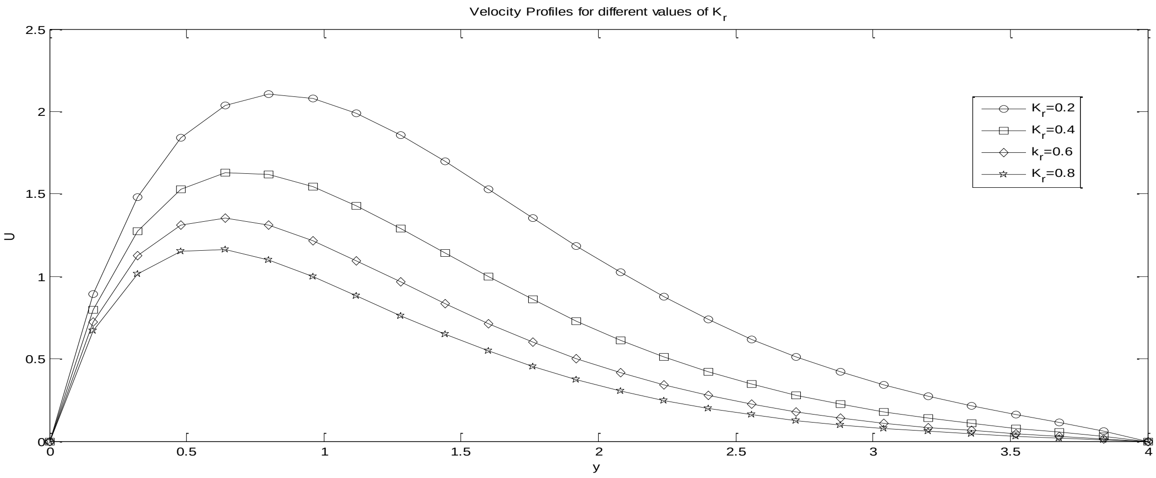


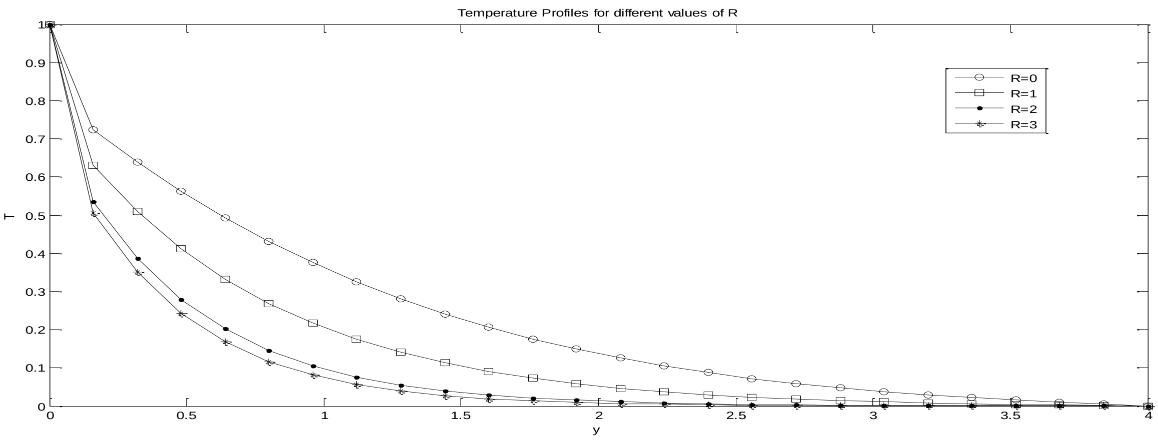

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