

# Transient Magnetohydrodynamic of Kuvshinshiki Fluid Flow past a Vertical Porous Medium with Variable Suction and Chemical Reaction

**Idowu, A.S.**

Department of Mathematics  
University of Ilorin  
Ilorin, Nigeria  
Email: asidowu@gmail.com

**Jimoh, A.**

Nigerian Communications Satellite Limited  
Airport Road  
Abuja, Nigeria  
E-mail: abdulwaheedjimoh@gmail.com2

## ABSTRACT

This work aimed at studying the influence of Soret on transient Magnetohydrodynamic (MHD) of Kuvshinshiki fluid. Visco-elastic and Soret terms were considered as well as the chemical reaction. The model equations were 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 numbers were presented graphically and in tabular form. It is observed that, when the heat source parameter increases, the velocity and temperature increases in the boundary layer.

**Keywords:** Transient MHD, Visco-elastic, Soret, chemical reaction and Kuvshinshiki fluid.

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### Aims Research Journal Reference Format:

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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 visco-elastic fluid. These fluid flows are encountered in numerous areas of petrochemical, biomedical and environmental engineering including polypropylene coalescence sintering. Consequently, 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.

Chamkha, Takhar and Soundalgekar (2001), studied the radiation effect of free convection flow past a semi-infinite vertical plate with mass transfer. Kim and Fedorov (2004) studied transient mixed radiative convection flow of a micro polar fluid past a moving semi-infinite vertical porous plate. 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. Alam, Rahman and Sattar (2009), looked at transient MHD 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. 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. Rushi, Kumar and Sivaraj (2012), studied MHD Visco-elastic fluid non-darcy flow along a moving vertical cone. Idowu, Dada and Jimoh (2013) studied heat and mass transfer of MHD and dissipative fluid flow past a moving vertical porous plate with variable suction. Devika, SatyaNarayana and Yenkataramana (2013), investigated MHD oscillatory flow of a visco-elastic fluid in a porous channel with chemical reaction. 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.

The study of visco-elastic fluid through porous media 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 reservoir 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 water for drinking and irrigation purposes. Many researchers 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 Senthil (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) studied the influence of chemical reaction of 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 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 pond to the atmosphere the diffusion of chemical impurities in lakes, rivers and ocean from natural or artificial sources.

Magneto hydrodynamic 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 AnandBabu.(2010), studied the finite element analysis of radiation and mass transfer flow past semi-infinite moving vertical plate with viscous dissipation.

The aim of the present investigation is to study the influence of soret on unsteady MHD of Kuvshinshiki fluid flow past a vertical porous plate with heat and mass transfer with variable suction. The result of parametric study on the flow, heat and transfer characteristics are shown graphically and physical aspects are discussed in details.

## 2. FORMULATION OF PROBLEM

Consider the transient two-dimensional heat and 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 implies 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 transient flow of a viscous incompressible fluid through a porous medium are:

$$\frac{\partial v^*}{\partial y} = 0 \quad (1)$$

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

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

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

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

$$t^* \leq 0, u^* = 0, T^* \rightarrow T_\infty^*; C^* \rightarrow C_\infty^*, \text{ for as } y^*$$

$$t^* > 0, u^* = 0, T^* \rightarrow T_\infty^*, C^* \rightarrow C_\infty^* \text{ as } y^* = 0$$

$$u^* = 0, T^* \rightarrow T_\infty^*, C^* \rightarrow C_\infty^* \text{ as } y^* \rightarrow \infty \quad (5)$$

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,  $\beta$  - the volumetric coefficient of thermal expansion,  $\beta^*$  is the volumetric coefficient of thermal expansion with concentration,  $\rho$  - the density of the fluid,  $C_p$  is the specific heat at constant pressure,  $\theta$ - is the temperature,  $K^*$  is the permeability of the porous medium,  $q_r$  is the radiation heat flux,  $B_0$ - magnetic induction,  $\nu$ - 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,  $KT$  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,  $\eta$  is the heat source,  $Gr$  is thermal Grashof number,  $\alpha$  is the angle of inclination, and  $Ec$  is Eckert number,  $A$  is a real positive constant of suction velocity parameter,  $\epsilon$ , and  $\epsilon A < 1$  are small less than unity, i.e  $\epsilon A \ll 1$ ,  $V_0$  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 theform:

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

0

Introducing the following non-dimensional quantities

$$u = \frac{u^*}{U_0}, y = \frac{U_0 y^*}{\nu}, t = \frac{U_0^2 t^*}{\nu}, \theta = \frac{T' - T_\infty'}{T_w' - T_\infty'}, C = \frac{C' - C_\infty'}{C_w' - C_\infty'}, \text{Pr} = \frac{\nu \rho C \rho}{k} = \frac{\nu}{\alpha},$$

$$Gr = \frac{g \beta \nu (T_w - T_\infty)}{U_0^2}, Gc = \frac{g \beta \nu (C_w - C_\infty)}{U_0^2}, Ec = \frac{U_0^2}{C_p (T_w - T_\infty)}, M = \frac{\sigma B_0^2 \nu}{\rho U_0^2}, R = \frac{4 I_1 \nu}{k U_0^2},$$

$$Sc = \frac{\nu}{Dm}, Sr = \frac{Dm K_T (T_w - T_\infty)}{T_m \nu (C_w - C_\infty)}, \text{and } KC = \frac{k_r \nu}{U_0^2}, \quad (8)$$

into the equations (2),(3)and(4); equation(1) is identically satisfied, we obtain the following set of differential equations:

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

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

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

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

$$t^* \leq 0, u^* = 0, \theta^* \rightarrow \theta^*_{\infty}, C^* \rightarrow C^*_{\infty} \text{ for } y^* = 0$$

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

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

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

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

$$Nu_x = -X \left[\frac{\partial \tau}{\partial y}\right]_{y=0} \quad (14)$$

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

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

$$(\bar{\tau})_x = - \int_0^1 \left[ \frac{\partial u}{\partial y} \right]_{y=0} dX \quad (16)$$

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

$$(\overline{Sh})_x = - \int_0^1 \left[ \frac{\partial C}{\partial y} \right]_{y=0} dX \quad (18)$$

### 3. NUMERICAL SOLUTION

The non-linear coupled equations (9), (10) and (11) subject to the initial and boundary condition (12), was solved by Crank-Nicolson type of an implicit finite difference scheme. This method has been extensively developed in recent years and remains one of the best reliable methods for solving partial differential equations because it converges faster. The finite difference equations corresponding to equations (9), (10) and (11) are discretized as follows:

$$\left(1 + \frac{\lambda}{\Delta t}\right) \frac{(u_{i,j}^{n+1} - u_{i,j}^n)}{\Delta t} - (1 + \epsilon A e^{nt}) \frac{(u_{i,j+1}^{n+1} - u_{i,j-1}^{n+1} + u_{i,j+1}^n - u_{i,j-1}^n)}{4\Delta y} = \frac{u_{i,j-1}^{n+1} - 2u_{i,j}^{n+1} + u_{i,j+1}^{n+1} - u_{i,j-1}^n - 2u_{i,j}^n + u_{i,j+1}^n}{2(\Delta y)^2} + Gr \frac{(\theta_{i,j}^{n+1} - \theta_{i,j}^n)}{2} + Gc \frac{(c_{i,j}^{n+1} - c_{i,j}^n)}{2} - \left(1 + \frac{\lambda}{\Delta t}\right) \left(M + \frac{1}{K}\right) \frac{(u_{i,j}^{n+1} - u_{i,j}^n)}{2} \quad (19)$$

$$\frac{(\theta_{i,j}^{n+1} - \theta_{i,j}^n)}{\Delta t} - (1 + \epsilon A e^{nt}) \frac{(\theta_{i,j+1}^{n+1} - \theta_{i,j-1}^{n+1} + \theta_{i,j+1}^n - \theta_{i,j-1}^n)}{4\Delta y} = \frac{\theta_{i,j-1}^{n+1} - 2\theta_{i,j}^{n+1} + \theta_{i,j+1}^{n+1} - \theta_{i,j-1}^n - 2\theta_{i,j}^n + \theta_{i,j+1}^n}{(2Pr\Delta y)^2} - R(\theta_{i,j+1}^n - \theta_{i,j}^n)^2 - Ec \frac{(u_{i,j}^{n+1} - u_{i,j}^n)^2}{2\Delta y} + Du \frac{(c_{i,j-1}^{n+1} - 2c_{i,j}^{n+1} + c_{i,j+1}^{n+1} - c_{i,j-1}^n - 2c_{i,j}^n + c_{i,j+1}^n)}{2(\Delta y)^2} \quad (20)$$

$$\frac{(c_{i,j}^{n+1} - c_{i,j}^n)}{\Delta t} - (1 + \epsilon A e^{nt}) \frac{(c_{i,j+1}^{n+1} - c_{i,j-1}^{n+1} + c_{i,j+1}^n - c_{i,j-1}^n)}{4\Delta y} = \frac{c_{i,j-1}^{n+1} - 2c_{i,j}^{n+1} + c_{i,j+1}^{n+1} - c_{i,j-1}^n - 2c_{i,j}^n + c_{i,j+1}^n}{25c(\Delta y)^2} + \frac{(c_{i,j-1}^{n+1} - 2c_{i,j}^{n+1} + c_{i,j+1}^{n+1} - c_{i,j-1}^n - 2c_{i,j}^n + c_{i,j+1}^n)}{25r(\Delta y)^2} - Kr \frac{(c_{i,j}^{n+1} - c_{i,j}^n)}{2} \quad (21)$$

With the following boundary conditions

$$t^* \leq 0, u = 0, \theta = 0, C = 0 \text{ for all } y$$

$$t^* > 0, u = 0, \theta = 1, T = 1, C = 1 \text{ for } y = 0 \quad (22)$$

$$u = 0, \theta = 0, T = 0, C = 0 \text{ as } y \rightarrow \infty$$

Where  $\Delta$  is a dimensionless time-step, and  $\Delta y$  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.

Here the region of integration is considered as a rectangle with max  $Y_{\max}=26$  where  $Y_{\max}$  corresponds to  $Y=\infty$  which lies well outside the momentum thermal layer, after some preliminary numerical experiments such that the boundary conditions of (22) are satisfied within the tolerance limit  $10^{-5}$ . The mesh sizes have been fixed as  $\Delta y = 0.16$  with time step  $\Delta t=0.01$ . The values of the velocity ( $u$ ) and temperature ( $\theta$ ) 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  $\Delta t$  and  $\Delta y$  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  $\epsilon=0.001$ , while  $R$ ,  $kr^2$ ,  $Sc$ ,  $Gr$ ,  $Gc$ ,  $M$ ,  $Pr$ ,  $\eta$ , 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  $\psi$  increases it results in a decreasing the thermal boundary layer thickness. It is observed from Fig.8 that an increase in Soret parameter  $Sr$  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.10 and 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.

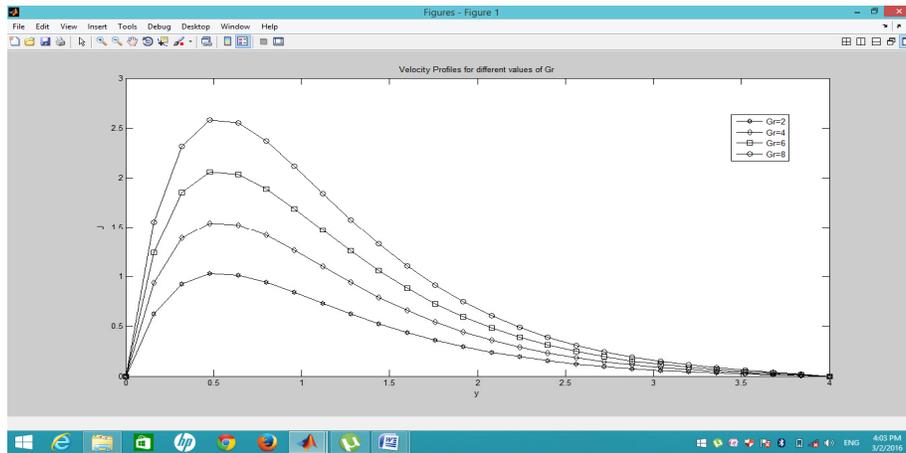


Figure 1: Effect of Gr on Velocity

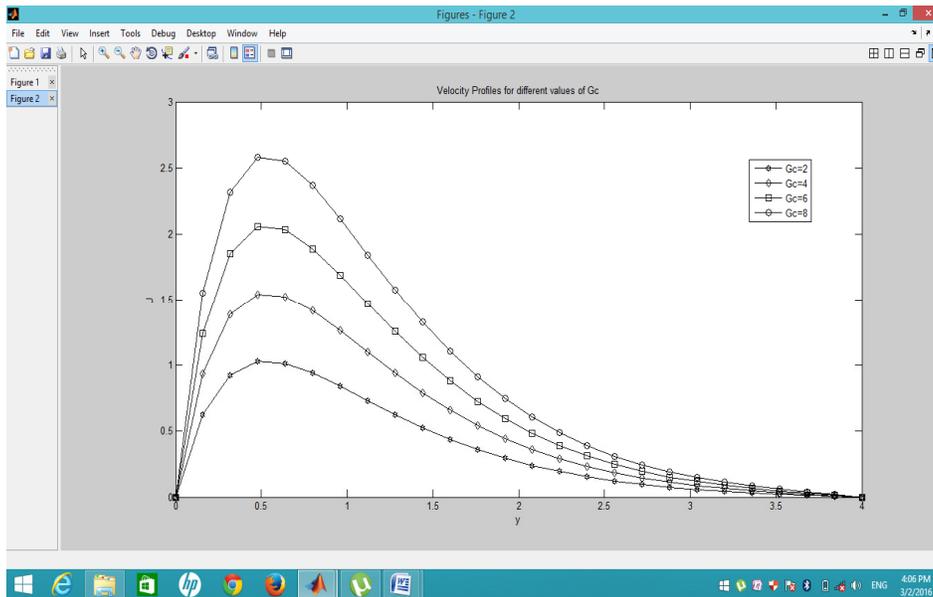


Figure 2: Effect of Gc on Velocity

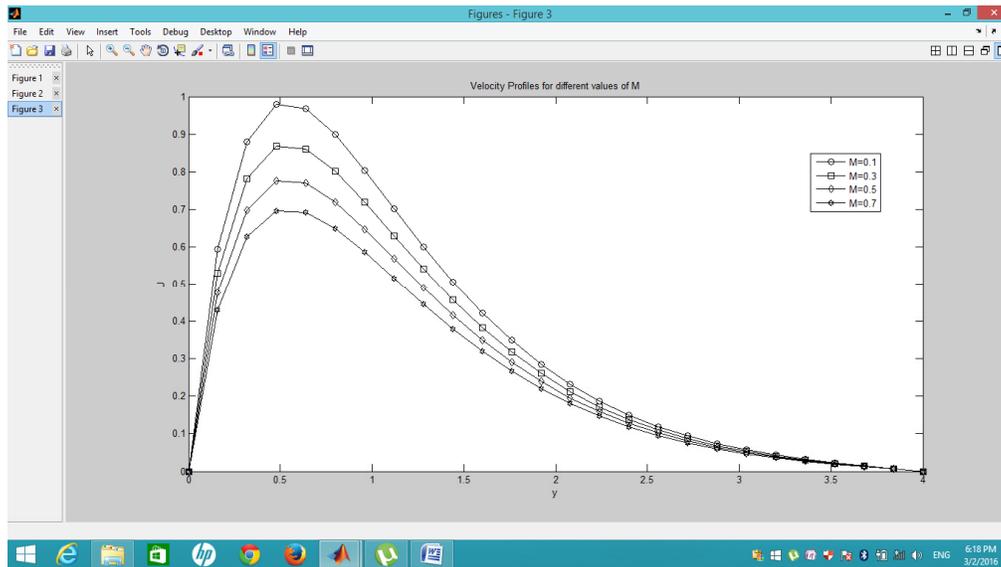


Figure 3: Effect of M on Velocity

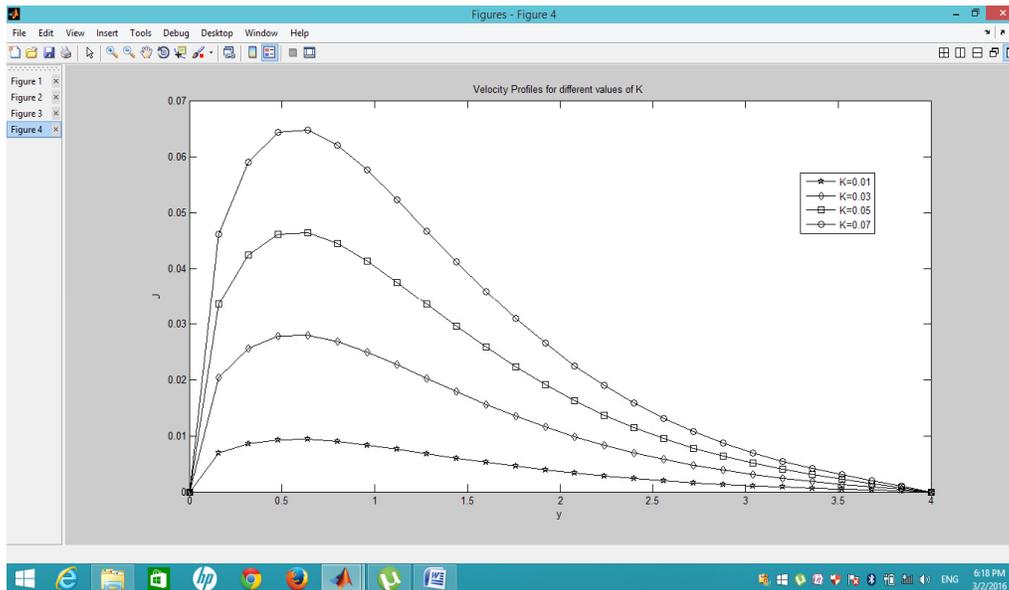


Figure 4: Effect of K on Velocity

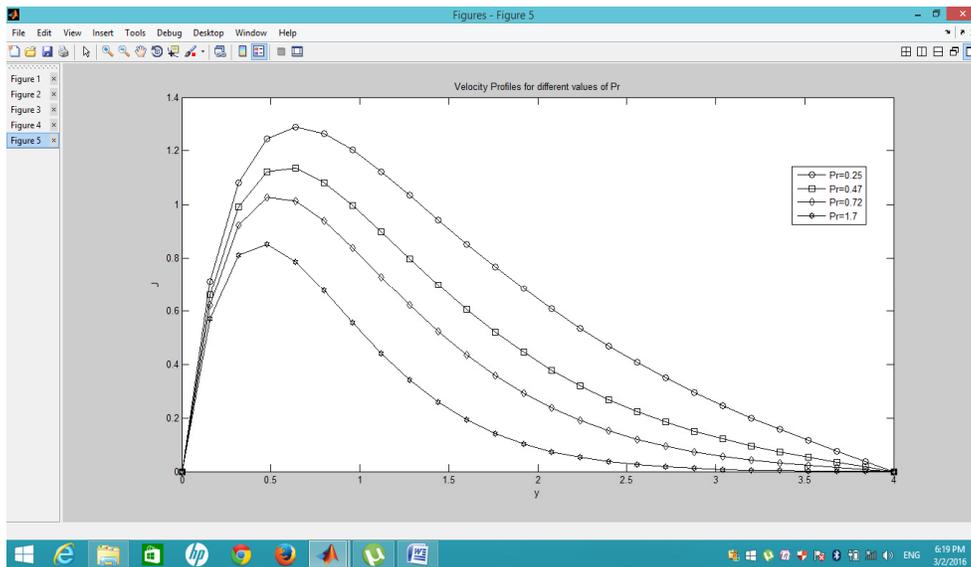


Figure 5: Effect of Pr on Velocity

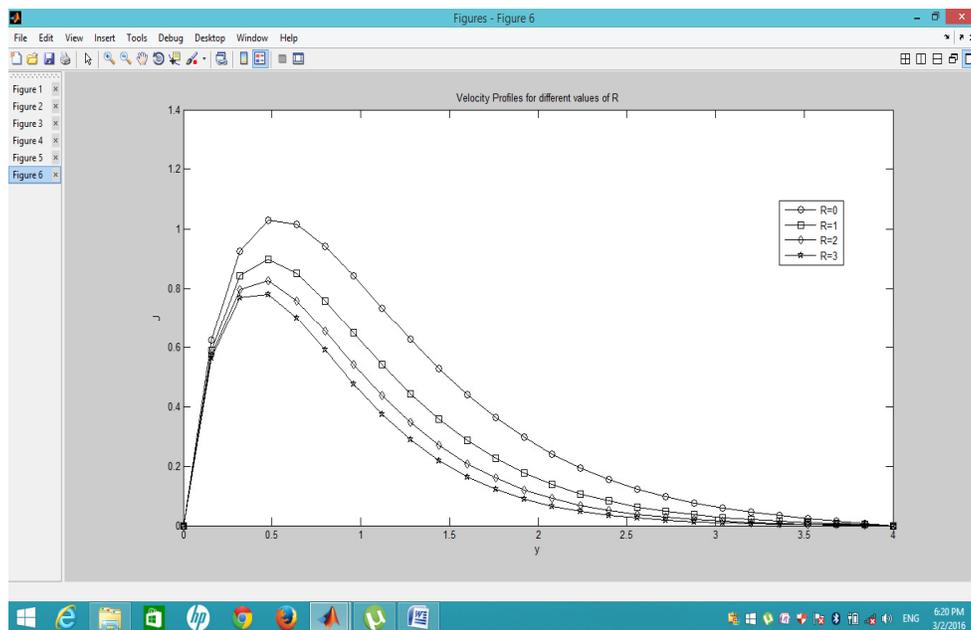


Figure 6: Effect of R on Velocity

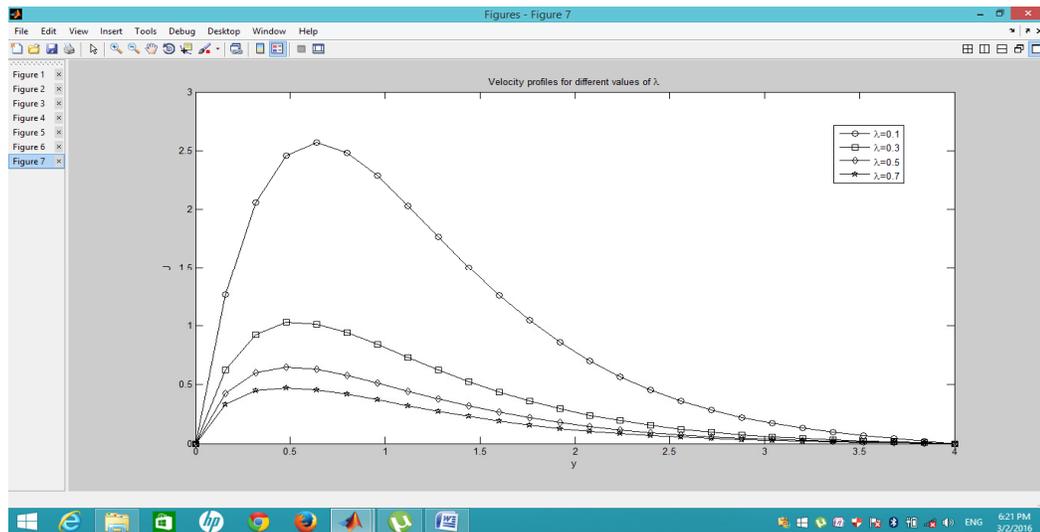


Figure 7: Effect of  $\lambda$  on Velocity

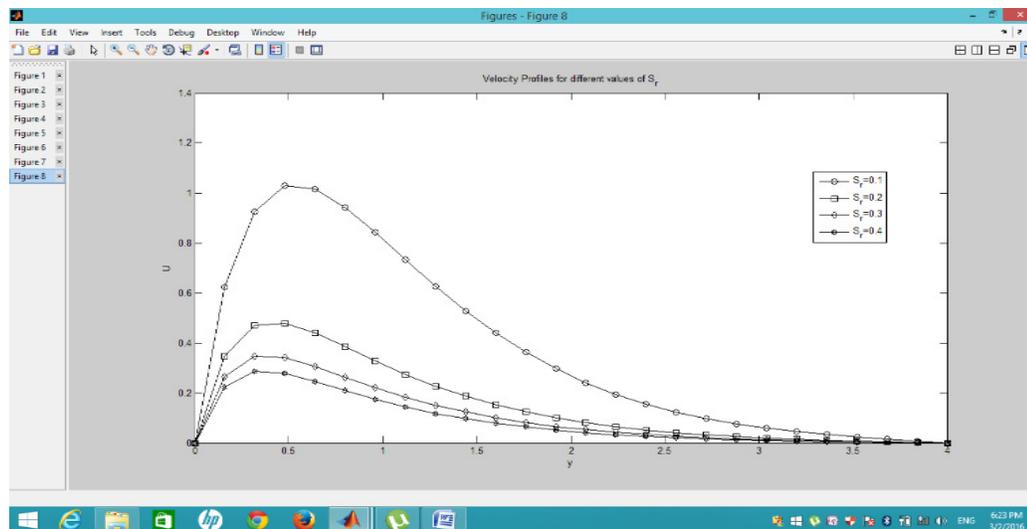


Figure 8: Effect of  $S_r$  on Velocity

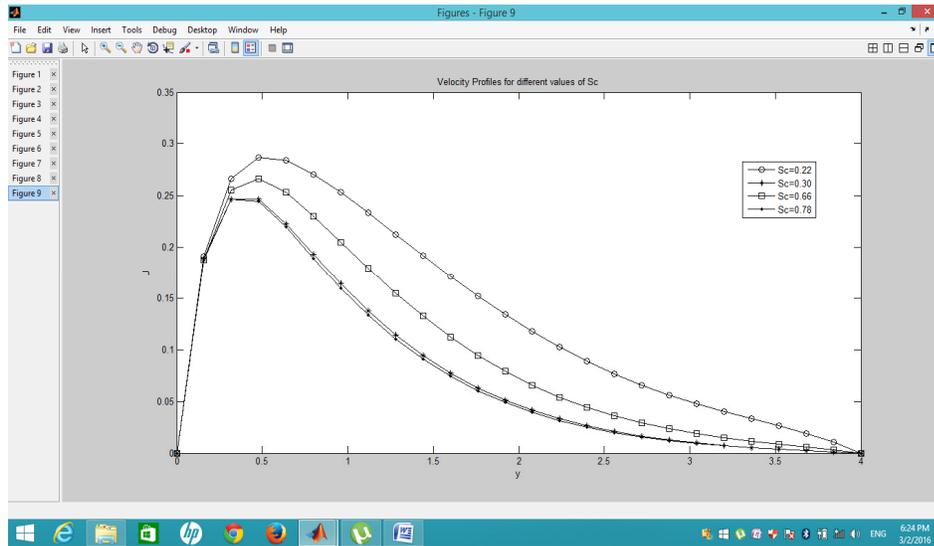


Figure 9: Effect of Sc on Velocity

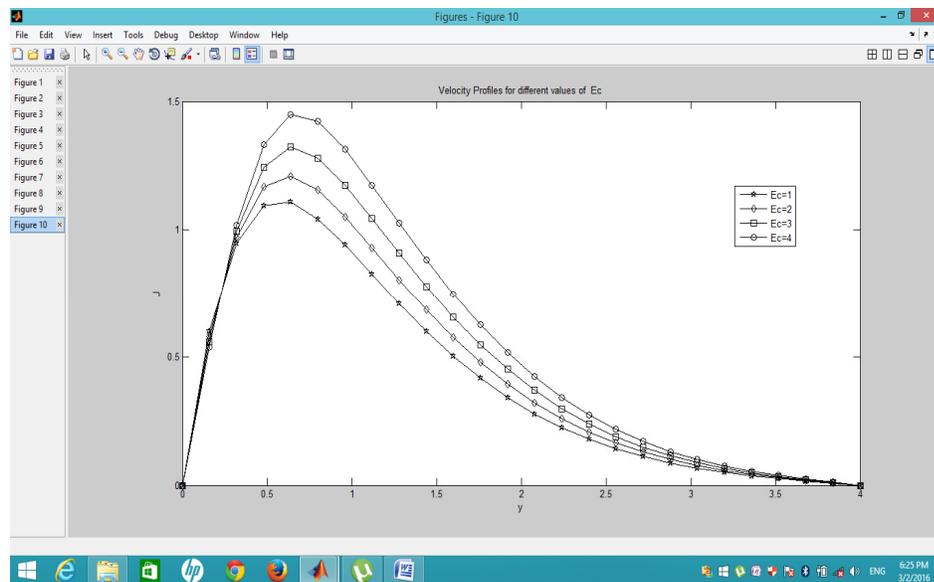


Figure 10: Effect of Ec on Velocity

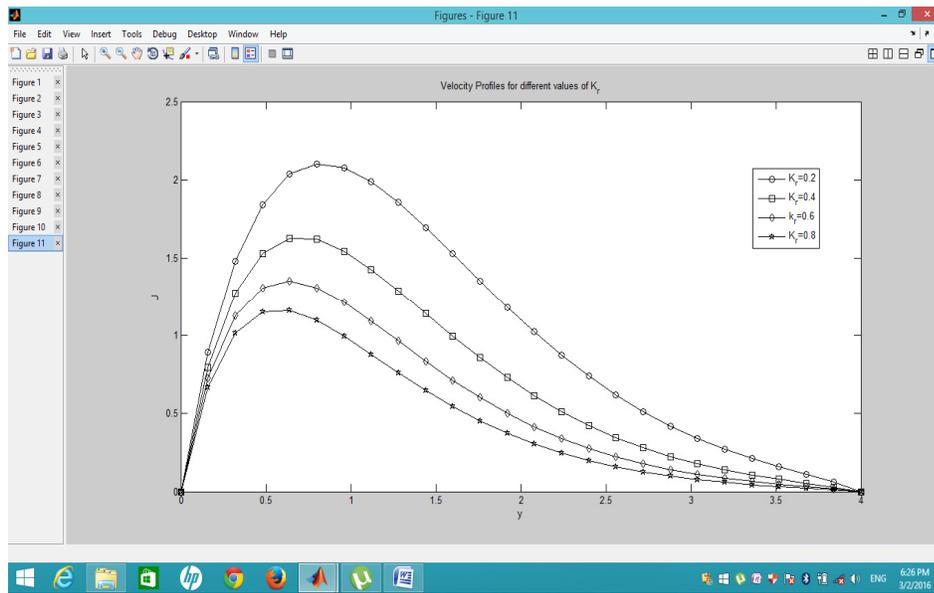


Figure 11: Effect of  $K_r$  on Velocity

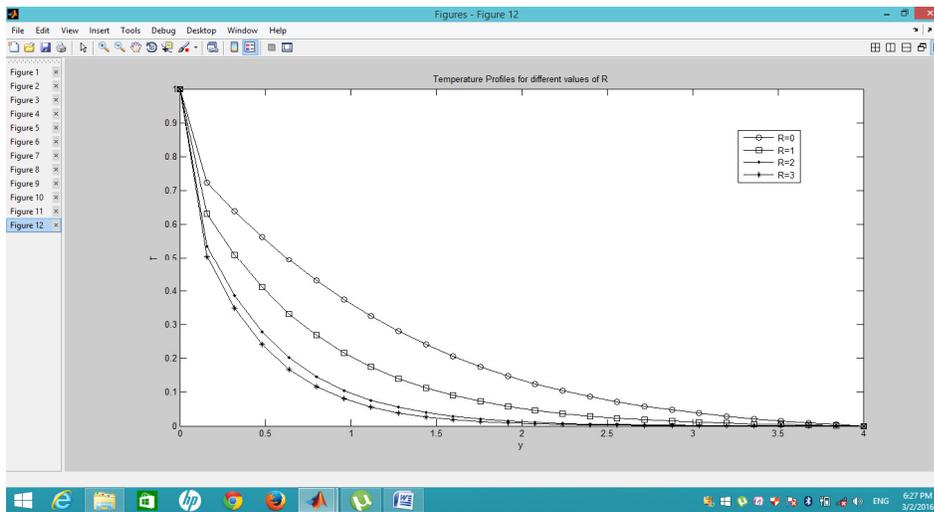


Figure 12: Effect of  $K_r$  on Temperature

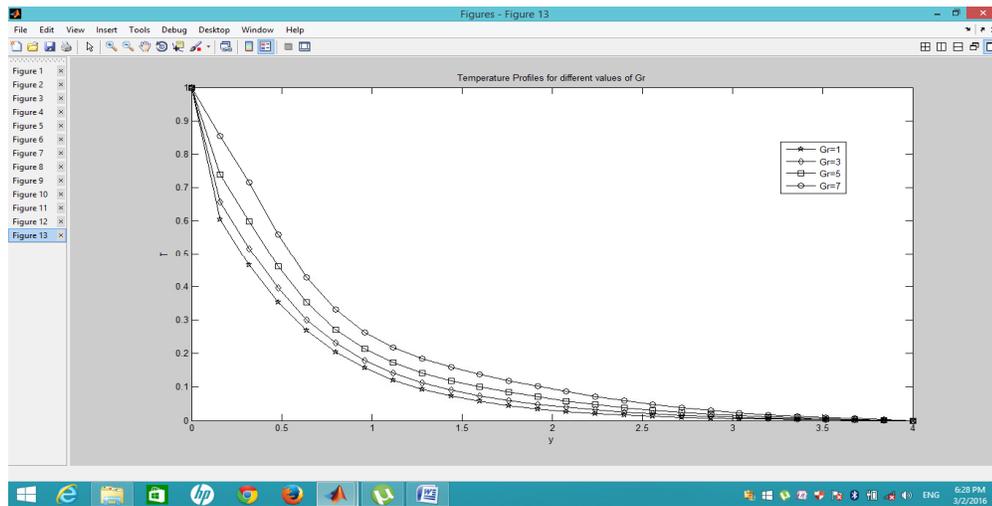


Figure 13: Effect of Gr on Temperature

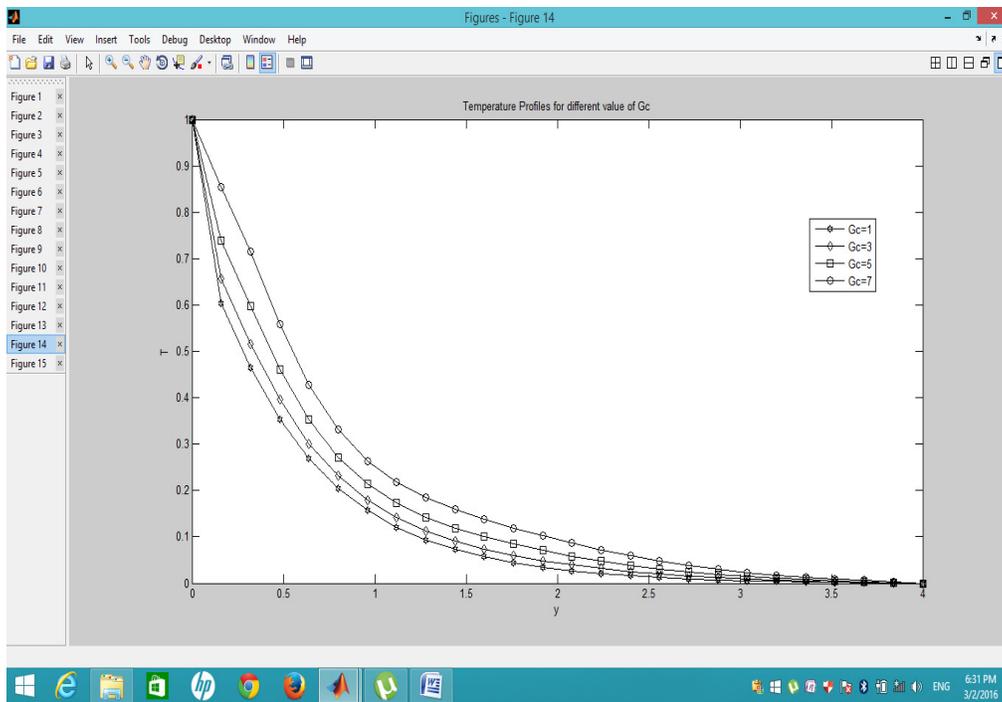


Figure 14: Effect of Gc on Temperature

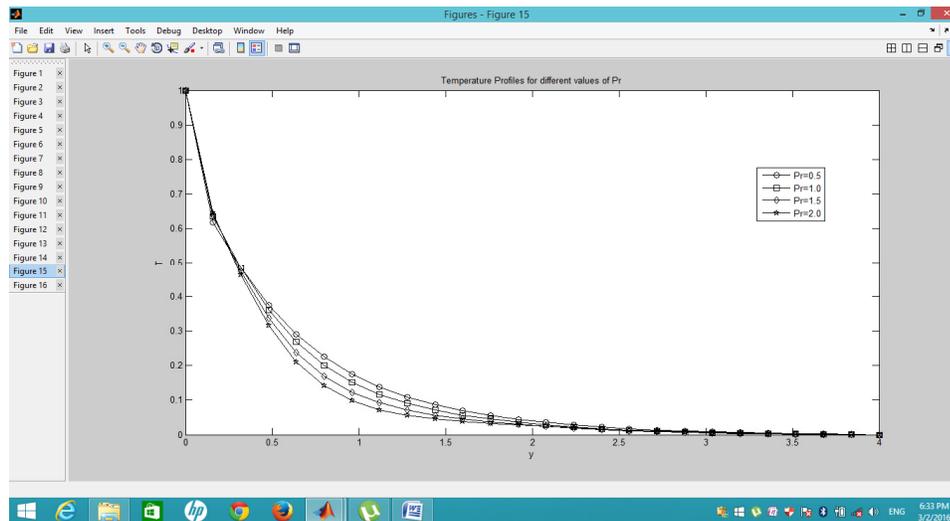


Figure 15: Effect of Pr on Temperature

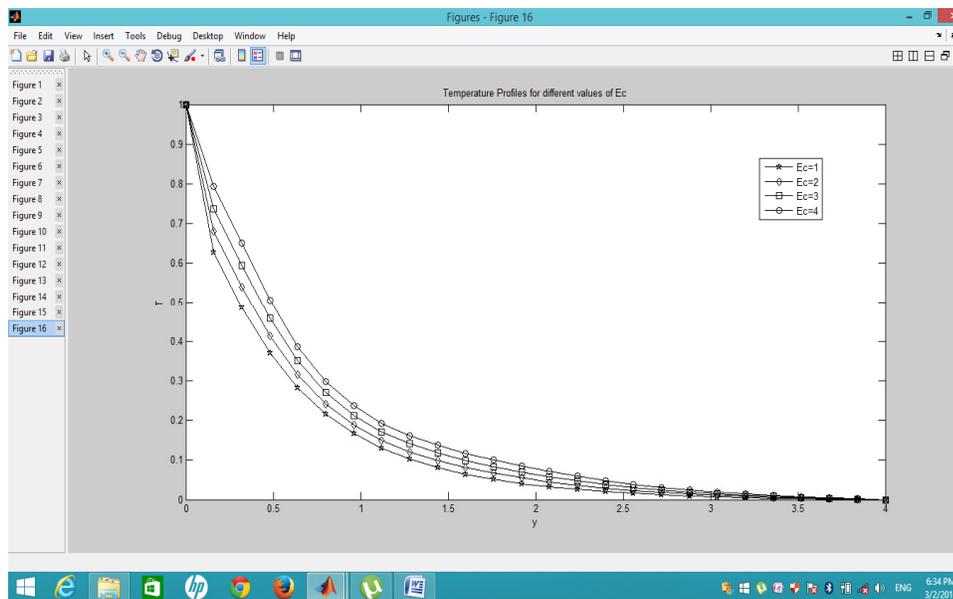


Figure 16: Effect of Ec on Temperature

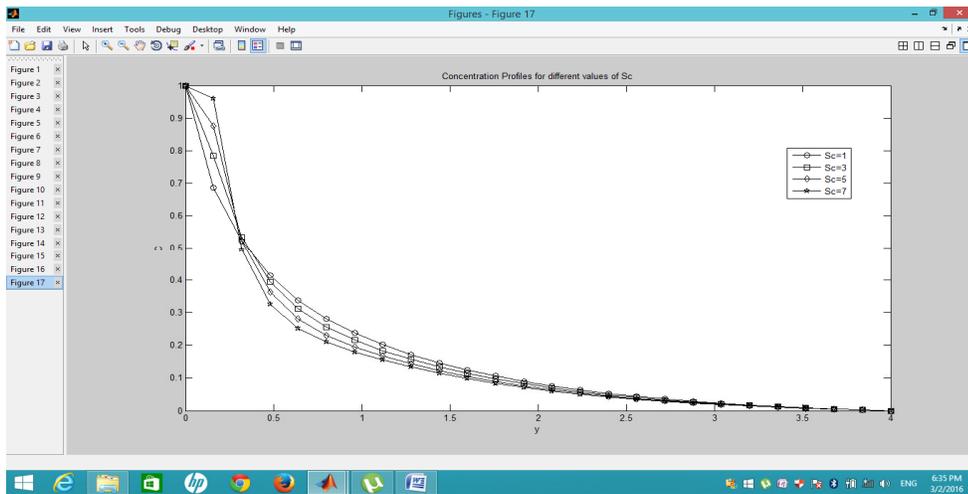


Figure 17: Effect of Sc on Concentration

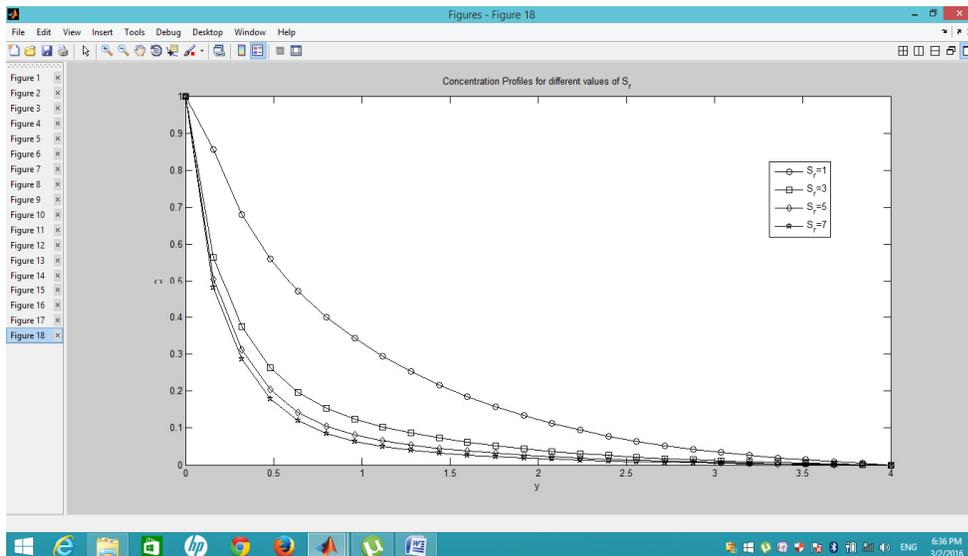


Figure 18: Effect of Sc on Concentration

**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
Sr=0.1	1.1360	3.7313	42.1010
Sr=0.2	0.7972	3.7316	22.0747
Sr=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
$\Phi=0.1$	4.9598	3.6932	21.9170
$\Phi=0.3$	3.0196	3.7228	22.0342
$\Phi=0.5$	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 shows 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 behavior of the natural velocity temperature and concentration of the fluid.

## 5. CONCLUSIONS

From the present study we can make the following conclusions:

1. The velocity increases with an increase in the permeability parameter, Grashof number.
2. The velocity as well as temperature with an increase in the radiation, Soret and Schmidt parameter while the visco-elastic increases as temperature increases.
3. The velocity decreases with an increase in the magnetic parameter, visco-elastic, Eckert number, Prandtl number, chemical reaction.
4. The Sherwood number decreases as all the parameters increases except the radiation that is rising.

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