Available online at http://scik.org
J. Math. Comput. Sci. 4 (2014), No. 5, 915-939
ISSN: 1927-5307

# EFFECT OF JEFFERY FLUID ON HEAT AND MASS TRANSFER PAST A VERTICAL POROUS PLATE WITH SORET AND VARIABLE THERMAL CONDUCTIVITY

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**Abstract.** This present study examines the effect of Jeffery fluid on heat and mass transfer past a vertical porous plate with Soret and variable thermal conductivity. The equations in dimensionless form have been solved numerically by implicit finite difference schemes of Crank – Nicolson type. Results are shown graphically for the velocity profiles, the temperature profiles, and the concentration profiles with different values of physical parameters like Jeffery parameter, radiation, chemical reaction, thermal Grashof number, solutal Grashof number, Schmidt number, Prandtl number, magnetic parameter, Dufour number, Soret number, permeability parameter, suction parameter, heat generation parameter, and Eckert number. It is observed that the velocity becomes higher as Gr, Gc, Ec, Du, Sr, S, K, $\gamma$ , and t increased but decreases for Pr, Sc, M, R, and $\lambda_1$. The temperature profile increases due to the presence of heat generation, Dufour number, and time but reduces for increased values of Prandtl number and suction. Similarly, concentration rises with Soret number and time, and decreases with increasing values of Schmidt number Sc and suction.

**Keywords:** Soret and Dufour effect; heat and mass transfer; Jeffery fluid; porous medium and variable thermal conductivity.

**2010 AMS Subject Classification:** 80A20.

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Received May 5, 2014

## INTRODUCTION

Flow through a porous medium has numerous engineering and geophysical applications, for example, in chemical engineering for filtration and purification process; in agriculture engineering to study the underground water resources; in petroleum technology to study the movement of natural gas, oil and water through the oil reservoirs Alam *et al.* (2006)*. Heat and mass transfer in porous medium are known to have applications in industrial, chemical engineering, nuclear reactors, geophysical and in petroleum industries. Recent developments in binary flow of mixtures and the determination of molecular weights, separation of isotopes, food processing, filtration process lead to increased investigations on understanding such flow Alam *et al.* (2006),

There are industrial applications of flows of electrically conducting fluids in the fields of geothermal systems, nuclear reactors, filtration, etc. where the conducting fluid flows through a porous medium which also rotates about an axis. There is one subclass of non – Newtonian fluids called Jeffery fluid, the fluid model is capable of describing the characteristics of relaxation and retardation times Hayat *et al.* (2008).

Hayat *et al.* (2012) studied Soret and Dufour effects on the magnetohydrodynamics (MHD) flow of Casson fluid over a stretched surface. They obtained series solution by homotropic procedure and examined the convergence of series solutions. Hayat *et al.* (2012) investigated radiative flow of a Jeffery fluid in a porous medium with power law heat flux and heat source. Dufour and Soret effects on unsteady MHD convective heat and mass transfer flow due to rotating disk is examined by Maleque (2010).

Sravan *et al.* (2012) analyzed the effect of Soret parameter on the set of double diffusive convection on Darcy porous medium saturated with couple stress fluid. Dufour and Soret effects on mixed convection flow past a vertical porous flat plate with variable Suction is presented by Alam and Rahman (2006). Anghil *et al.* (2000) investigated Dufour and Soret effects on free convection boundary- layer over a vertical surface embedded in a porous medium. Influence of a magnetic field on heat and mass transfer by natural convection from vertical surfaces in a porous media considering Soret and Dufour effects is studied by Postelnicu (2004).

Madhusudhana and Viswanatha (2012) examined Soret and Dufour effects on hydromagnetic heat and mass transfer over a vertical plate in a porous medium with convective surface boundary condition and chemical reaction. Dufour and Soret effects on unsteady MHD free convection and mass transfer flow past a vertical porous plate in a porous medium is investigated by Alam *et al.* (2006)*. Alam and Rahman (2005) studied Dufour and Soret effects on MHD free convective heat and mass transfer flow past a vertical flat plate embedded in a porous medium.

Afsar Khan *et al.* (2012) investigated the peristaltic flow of Jeffery fluid with variable viscosity through porous medium in an asymmetric channel. They obtained analytic solutions for stream function velocity, pressure gradient, and pressure rise by regular perturbation. The effect of linear thermal stratification in stable stationary ambient fluid on steady MHD convective flow of a viscous incompressible electrically conducting fluid along a moving, non- isothermal vertical plate in the presence of mass transfer, Soret and Dufour effects and heat generation or absorption is investigated by Subhakar *et al.* (2012). Shateyi and Motsa (2011) studied unsteady magnetohydrodynamics convective heat and mass transfer past an infinite vertical plate in a porous medium with thermal radiation, Heat generation /absorption and chemical reaction. The effects of variable viscosity and thermal conductivity on the flow and heat transfer in a laminar liquid on a horizontal shrinking / stretching sheet is analyzed by Khan *et al.* (2011). Aruna Kumari *et al.* (2012) studied the effects of magnetic field on free convective flow of Jeffery fluid past an infinite vertical porous plate with constant heat flux. Sreedharamalle *et al.* (2012) examined unsteady flow of a Jeffery fluid in an elastic tube with stenosis numerically. Kavita *et al.* (2012) analyzed influence of heat transfer on MHD oscillatory flow of a Jeffery fluid in a channel. Oscillatory flow of a Jeffery fluid in an elastic tube of variable cross- section was examined numerically by Bandari Narayana *et al.* (2012). Sharma and Singh (2009) discussed effects of variable thermal conductivity and heat source/ sink on flow of a viscous incompressible electrically conducting fluid in the presence of uniform transverse magnetic field and variable free stream near stagnation point on a non – conducting stretching sheet numerically using shooting method. Uwanta (2012) studied numerically the steady two dimensional flow of an incompressible viscous fluid with heat and mass transfer and MHD radiation past an infinite vertical plate in a porous medium using fourth order Runge – Kutta method and shooting technique. Uwanta and Omokhuale (2012) analyzed viscoelastic fluid flow in a fixed plane with heat and mass transfer analytically.

Prasad et al. (2007) used Crank-Nicolson scheme to analyse the transient convective heat and mass transfer with thermal radiation effects along a vertically impulsively started plane. Dada and Adefolaju (2012) studied dissipative, MHD and radiation effects on an unsteady convective heat and mass transfer in a Darcy-Forcheimer porous medium. Among other authors that used this method is Sangapatnam *et al.* (2009) who investigated the thermal radiation and mass transfer effects on MHD free convection dissipative fluid flow past impulsively- stated vertical plate.

In view of the importance of Soret effect and variable thermal conductivity, in this paper, effect of Jeffery fluid on heat and mass transfer past a vertical porous plate with Soret and Variable thermal conductivity is investigated. This work is an extension of Soundalgekar *et al.* (2004). The equations have been solved numerically by implicit finite difference schemes of Crank – Nicolson type. The results obtained show that the velocity field rise as Gr, Gc, Ec, Du, Sr, S, K, $\gamma$, and t increased but decreases for Pr, Sc, M, R, and $\lambda_1$. The temperature profile increases due to the presence of heat generation, Dufour number, and time but reduces for increased values of Prandtl number and suction. Similarly, concentration rises with Soret number and time, and decreases with increasing values of Schmidt number Sc, radiation and suction.

## PROBLEM FORMULATION

Consider an unsteady two–dimensional heat and mass transfer flow of an electrically conducting incompressible viscous fluid past an infinite vertical porous plate moving with Jeffery fluid. As the plate is infinite in extent, the physical variables are functions of $y'$ and $t'$ where $y'$ is taken normal to the plate and the $x'$ -direction is taken along the plate in the vertical upward direction, where fluid suction or injection and magnetic field are imposed at the plate surface. The temperature and concentration of the fluid are raised to $T'_w$ and $C'_w$ respectively and are higher than the ambient temperature and that of fluid. In addition, the Soret and variable thermal conductivity effect is taken into account. It is assumed that induced magnetic field is negligible, viscous dissipation and the heat generated are not neglected.

The governing equations of the flow under the usual Boussinesq and boundary-layer approximation can be written as (See Soundalgekar *et al.* (2004) and Aruna Kumari *et al.* (2012)):

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

$$\frac{\partial u'}{\partial t'} + v'\frac{\partial u'}{\partial y'} = \frac{\nu}{1+\lambda_1}\frac{\partial^2 u'}{\partial y'^2} + g\beta\left(T' - T'_\infty\right) + g\beta^*\left(C' - C'_\infty\right) - \frac{\sigma B_0^2}{\rho}u' - \frac{\nu}{K^*}u' \tag{2}$$

$$\frac{\partial T'}{\partial t'}+v'\frac{\partial T'}{\partial y'}=\frac{k}{\rho Cp}\frac{\partial}{\partial y'}\left\{\left[1+m\left(T'-T'_\infty\right)\right]\frac{\partial T'}{\partial y'}\right\}+\frac{Q}{\rho Cp}\left(T'-T'_\infty\right)$$
$$+\frac{D_m K_T}{C_S Cp}\frac{\partial^2 C}{\partial y^2}+\frac{\mu}{Cp}\left(\frac{\partial u'}{\partial y'}\right)^2 \tag{3}$$

$$\frac{\partial C'}{\partial t'}+v'\frac{\partial C'}{\partial y'}=D_m\frac{\partial^2 C'}{\partial y'^2}+\frac{D_T K_T}{T_S}\frac{\partial^2 T'}{\partial y'^2} \tag{4}$$

with the following initial and boundary conditions:

$$\left.\begin{array}{l} t'\le 0, u'=0, T'\to T'_\infty, C'\to C'_\infty \ for\, all\ y' \\ t'>0, u'=0, \dfrac{\partial T'}{\partial y'}=-\dfrac{q}{k}, C'=C'_\omega at\ y'=0 \\ u'\to 0, T'\to T'_\infty, C'\to C'_\infty, as\ y'\to\infty \end{array}\right\} \tag{5}$$

where $u$ and $v$ are velocity components in $x'$ and $y'$ directions respectively, $T$ is the temperature, $t$ is the time, g is the acceleration due to gravity, $\beta$ is the thermal expansion coefficient, $\beta^*$ is the concentration expansion coefficient, $\upsilon$ is the kinematic viscosity, $D_m$ is the chemical molecular diffusivity, $C_p$ is heat capacity at constant pressure, $B_0$ is a constant magnetic field intensity, $\sigma$ is the electrical conductivity of the fluid, $k$ is the thermal conductivity, $\rho$ is the density, $\lambda_1$ is the Jeffery fluid, $q$ is the constant heat flux per unit area at the plate, $T_S$ is the mean fluid temperature, $T_w$ is the wall temperature, $D_T$ is the coefficient of temperature diffusivity, $T_\infty$ is the free stream temperature, $C_w$ is the species concentration at the plate surface, $C_\infty$ is the free stream concentration, $Q$ is the heat generation coefficient.

$v_0>0$ is the suction parameter and $v_0<0$ is the injection parameter. On introducing the following non-dimensionless quantities:

$$\left.\begin{array}{l} u=\dfrac{u'}{u_0}, y=\dfrac{u_0 y'}{\nu}, t=\dfrac{t' u_0}{\nu}, \theta=\dfrac{\left(T'-T'_\infty\right)ku_0}{q\nu}, C=\dfrac{\left(C'-C'_\infty\right)ku_0}{q\nu} \\ \Pr=\dfrac{\nu\rho Cp}{k}, M=\dfrac{\sigma B_0^2\nu}{\rho {u_0}^2}, K=\dfrac{\nu^2}{K^* {u_0}^2}, Gr=\dfrac{g\beta q\nu^2}{k{u_0}^4} \\ Gc=\dfrac{g\beta^* q\nu^2}{k{u_0}^4}, Sc=\dfrac{\nu}{D}, Du=\dfrac{D_m K_T}{C_S C_P \nu}, S=\dfrac{Q\nu}{\rho Cp{u_0}^2} \\ Ec=\dfrac{k\mu}{\rho Cpqu_o}, Sr=\dfrac{D_T K_T}{T_S \nu}, \gamma=\dfrac{v_0}{u_0}, \eta=\dfrac{mq\nu}{ku_0} \end{array}\right\} \tag{6}$$

where

$u_0$ and $t_0$ are reference velocity and time respectively.

Using (1) and (6), equations (2) - (5) are transformed to the following:

$$\frac{\partial u}{\partial t}-\gamma\frac{\partial u}{\partial y}=\frac{1}{1+\lambda_1}\frac{\partial^2 u}{\partial y^2}+Gr\theta+GcC-Mu-Ku \tag{7}$$

$$\frac{\partial \theta}{\partial t}-\gamma\frac{\partial \theta}{\partial y}=\frac{1}{\Pr}\left(1+\eta\theta\right)\frac{\partial^2 \theta}{\partial y^2}+\frac{\eta}{\Pr}\frac{\partial \theta}{\partial y}+S\theta+Du\frac{\partial^2 C}{\partial y^2}+Ec\left(\frac{\partial u}{\partial y}\right)^2 \tag{8}$$

$$\frac{\partial C}{\partial t}-\gamma\frac{\partial C}{\partial y}=\frac{1}{Sc}\frac{\partial^2 C}{\partial y^2}+Sr\frac{\partial^2 \theta}{\partial y^2} \tag{9}$$

The corresponding boundary conditions are:

$$\left.\begin{array}{l} u=0, T\to T_\infty, C\to C_\infty,\ for\, all\, y: t\le 0 \\ u=u_p, \dfrac{\partial\theta}{\partial y}=-1, C=C_\omega, at\; y=0 \\ u\to 0, \theta\to 0, C\to 0, as y\to\infty \end{array}\right\} \tag{10}$$

Here $\lambda_1$ is the Jeffery parameter, $Gr$ is the thermal Grashof number, $Gc$ is the mass Grashof number, $Sc$ is the Schmidt number, $\Pr$ is the Prandtl number, $M$ is the magnetic parameter, Du is the Dufour number, Sr is the Soret number, $K$ is the permeability parameter, $\gamma$ is the suction parameter, $S$ is the heat generation parameter, $Ec$ is the Eckert number. $\eta$ is a constant. Also, $u_0$ and $t_0$ .

Equations (7) to (10) are now solved by implicit finite difference schemes of Crank – Nicolson type. The finite difference approximations of these equations are as follows:

$$\left(\frac{u_{i,j+1}-u_{i,j}}{\Delta t}-\gamma\frac{u_{i+1,j}-u_{i,j}}{\Delta y}\right)=\frac{1}{\left(1+\lambda_i\right)}\left[\frac{u_{i+1,j}+u_{i-1,j}-2u_{i,j}+u_{i+1,j+1}+u_{i-1,j+1}-2u_{i,j+1}}{2\left(\Delta y\right)^2}\right]$$
$$+\frac{Gr}{2}\left(\theta_{i,j+1}+\theta_{i,j}\right)+\frac{Gc}{2}\left(C_{i,j+1}+C_{i,j}\right)-\frac{M}{2}\left(u_{i,j+1}+u_{i,j}\right)-\frac{K}{2}\left(u_{i,j+1}+u_{i,j}\right) \tag{11}$$

$$\left(\frac{\theta_{i,j+1}-\theta_{i,j}}{\Delta t}-\gamma\frac{\theta_{i+1,j}-\theta_{i,j}}{\Delta y}\right)=\frac{1}{\Pr}\cdot\left[1+\frac{\eta}{2}\left(\theta_{i,j+1}+\theta_{i,j}\right)\right]\left[\frac{\theta_{i+1,j}-\theta_{i-1,j}-2\theta_{i,j}+\theta_{i+1,j+1}+\theta_{i-1,j+1}-2\theta_{i,j+1}}{2\left(\Delta y\right)^2}\right]$$

$$+\frac{\eta}{\Pr}\left(\frac{\theta_{i+1,j}-\theta_{i,j}}{\Delta y}\right)+\frac{S}{2}\left(\theta_{i,j+1}+\theta_{i,j}\right)+Du\left(\frac{C_{i+1,j}-C_{i-1,j}-2C_{i,j}+C_{i+1,j+1}+C_{i-1,j+1}-2C_{i,j+1}}{2\left(\Delta y\right)^{2}}\right)$$
$$+Ec\left(\frac{u_{i+1,j}-u_{i,j}}{\Delta y}\right)^{2} \tag{12}$$

$$\left(\frac{C_{i,j+1}-C_{i,j}}{\Delta t}-\gamma\frac{C_{i+1,j}-C_{i,j}}{\Delta y}\right)=\frac{1}{Sc}\left[\frac{C_{i+1,j}-C_{i-1,j}-2C_{i,j}+C_{i+1,j+1}+C_{i-1,j+1}-2C_{i,j+1}}{2\left(\Delta y\right)^{2}}\right]$$
$$+\frac{Sr}{2}\left[\frac{\theta_{i+1,j}-\theta_{i-1,j}-2\theta_{i,j}+\theta_{i+1,j+1}+\theta_{i-1,j+1}-2\theta_{i,j+1}}{2\left(\Delta y\right)^{2}}\right] \tag{13}$$

The initial and boundary conditions become:

$$u_{i,0}=0,\theta=0,C_{i,0}=0 \; for \; all \; i \; except \; i=0$$
$$u_{i,0}=0,\frac{\theta_{i+1,j}-\theta_{i,j}}{\Delta y}=-1,C_{i,0}=1 \tag{14}$$
$$u_{L,0}=0,\theta_{L,0}=0,C_{L,0}=0$$

where L corresponds to $\infty$. The suffix i corresponds to y and j is equals to t. consequently, $\Delta t=t_{j+1}-t_j$ and $\Delta y=y_{i+1}-y_i$ .

## COMPUTATIONAL PROCEDURE

In order to access the effects of parameters on the flow variables namely; Jeffery parameter, thermal Grashof number, mass Grashof number, Schmidt number, Prandtl number, magnetic parameter, Soret number, Dufour number, permeability parameter, suction parameter, heat generation parameter, and Eckert number on the velocity, temperature and concentration, and have grips of the physical problem, the unsteady coupled non-linear partial differential equations (7) – (9) with boundary conditions (10) have been solved by implicit finite difference schemes of Crank – Nicolson type. This method has been extensively developed in recent years and remains one of the best reliable methods for solving partial differential equation because it converges fast and is unconditionally stable. The finite difference approximations of these equations were solved by using the values for Gr = Gc = M = $\eta$ = S = 1, $\lambda_1=0.5$, *Pr* = 0.71, *Sc* = 0.6, Ec = 0.2, Du = 0.03, Sr = 0.5, K= 0.5, $\gamma=0.5$ except where they are varied. A step size of

$\Delta Y$ = 0.01 is used for the interval $Y_{min}$ = 0 to $Y_{max}$ = 5 for a desired accuracy and a convergence criterion of $10^{-6}$ is satisfied for various parameters.

## RESULTS AND DISCUSSION

For values of C, $\theta$, u at time t, the values at a time $t+\Delta t$ obtained for $i=1,2,...,L-1$ in (3). Similarly, calculating $\theta$ and u from (2) and (1).

If $\lambda_1 = M = m = K = Gc = S = Du = Sr = 0$, and Gr = 1, the results of Soundalgekar *et al.* (2004) are obtained. Also, at $\frac{\partial u}{\partial t} = \frac{\partial \theta}{\partial t} = \frac{\partial C}{\partial t} = 0, \gamma = -1,\ \lambda_1 = Gc = Gr = S = Du = Sr = 0$ , $\eta = 1$ , the results of Aruna Kumari *et al.* (2012) are gotten.

### Velocity profiles

Figures 1 to 14 represent the velocity profiles with varying parameters respectively.

Figure 1 shows the effect of Prandtl number on the velocity. It is observed that, the velocity decreases with increasing Prandtl number. Influence of Hartmann number M on the velocity is shown in figure 2. It is found that, the velocity decreases with the increase in magnetic parameter. Figure 3 depicts variation of Schmidt number on the velocity profile. It is noted that, the velocity decreases with decrease in Schmidt number. Dufour number on the velocity profile is depicted in figure 4. It is observed that, the velocity decreases with increasing Dufour number. Figure 5 illustrates different values of constant $\eta$ on the velocity. It is found that, the velocity increases with the increase of the constant. Effect of Jeffery parameter on the velocity is illustrated in figure 6. It is clear that, the velocity decreases with increase in Jeffery parameter. Figure 7 shows that with the increase in heat generation, the velocity of the fluid increases. Influence of suction parameter on the velocity is demonstrated in figure 8. It is seen that, the velocity is higher with due to an increase in suction parameter. Figure 9 represents different values of thermal Grashof number on the velocity, it is noted that, the velocity rises with increasing thermal Grashof number. In figure 10, the effect of mass Grashof number on the velocity is presented. It is observed that, the velocity increases with increase in mass Grashof number. The influence of

Soret number on the velocity is given in figure 11. It is noticed that, the velocity rises with an increase in Soret number. Figure 12 shows that for an increase in time, the velocity rises. Figure 13 illustrates the variation of permeability parameter on the velocity. It is shown that, the velocity falls with increase of permeability parameter. In figure 14, it is observed that, the velocity increases with for different values of Eckert number.

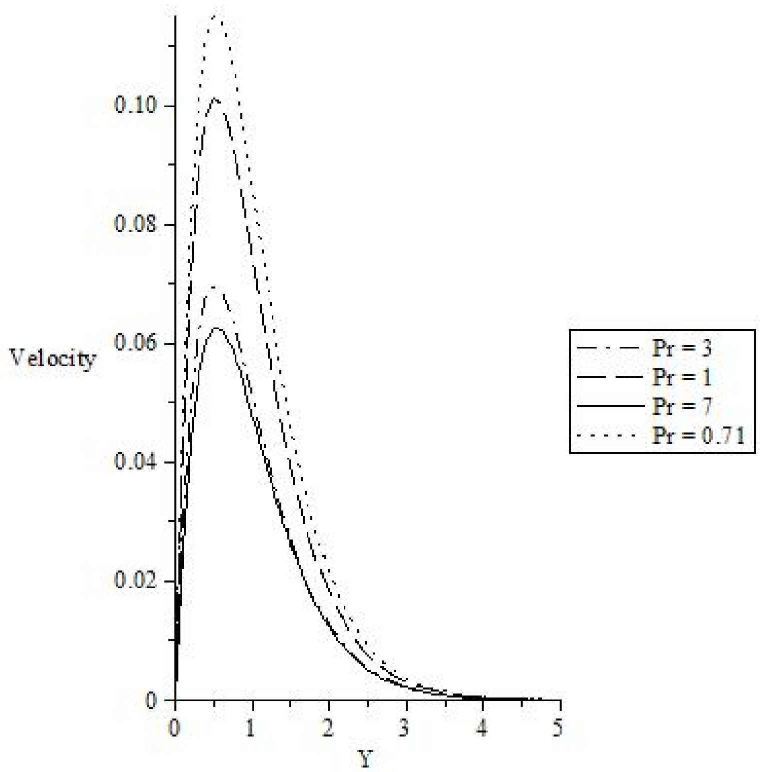


Figure 1.Velocity profiles for different values of Pr.

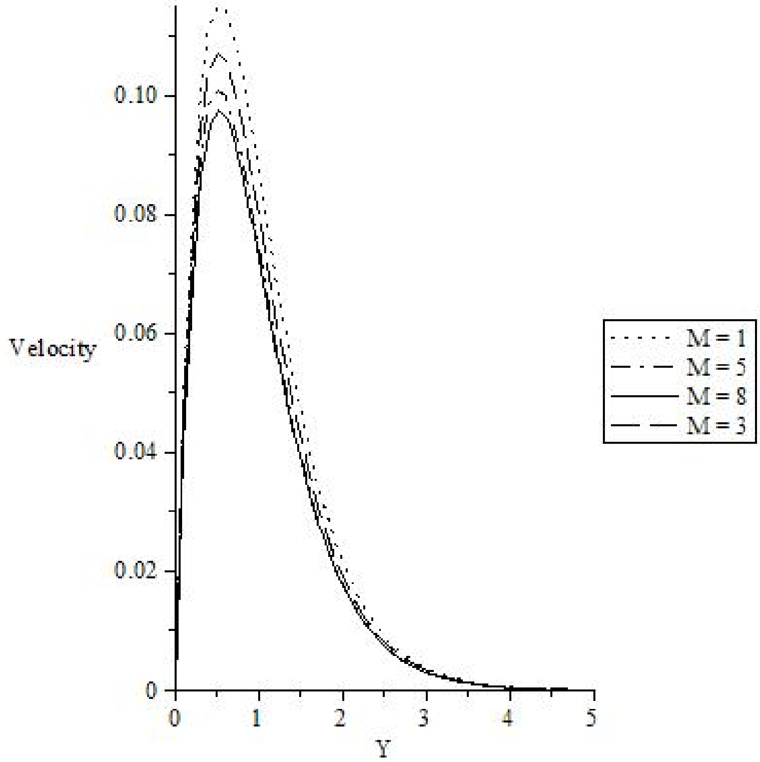


Figure 2.Velocity profiles for different values of M.

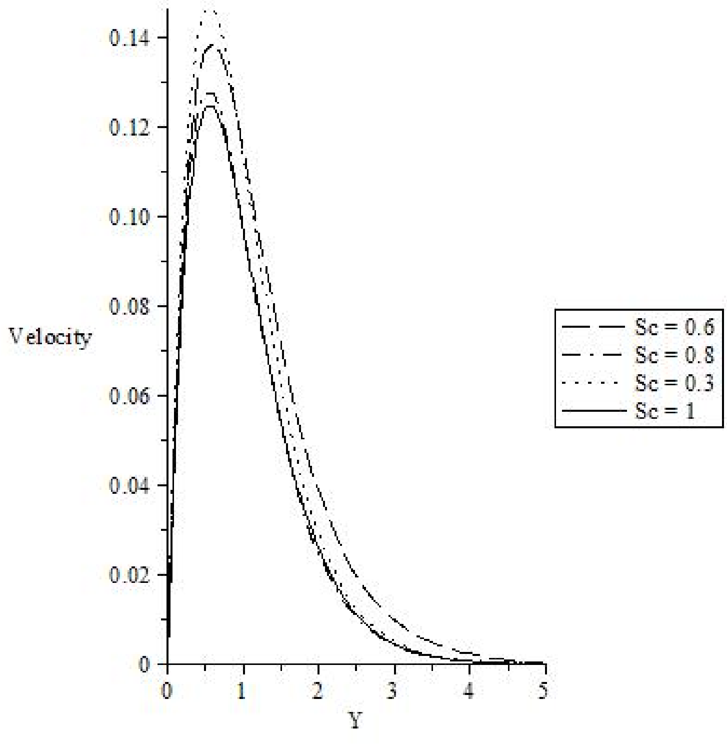


Figure 3.Velocity profiles for different values of Sc.

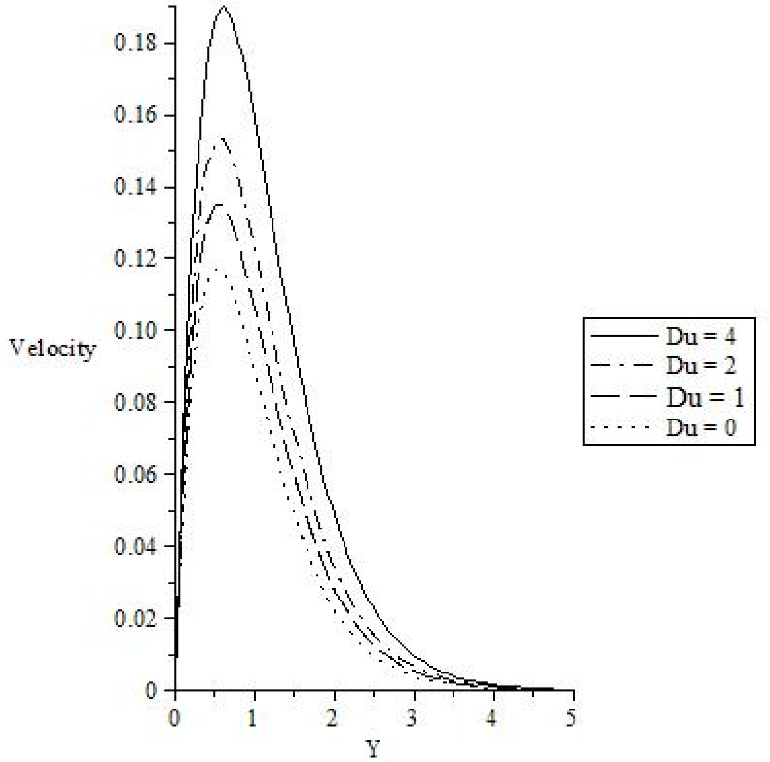


Figure 4.Velocity profiles for different values of Du .

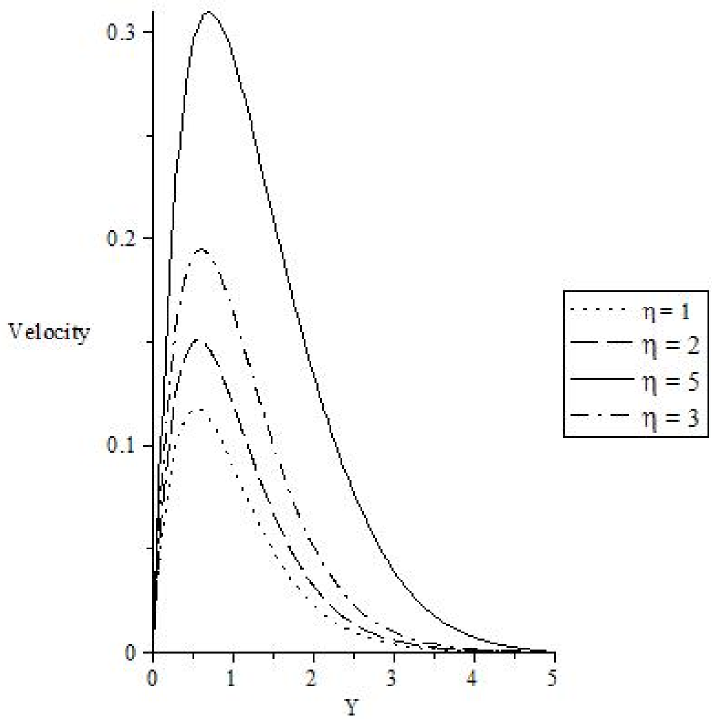


Figure 5.Velocity profiles for different values of $\eta$ .

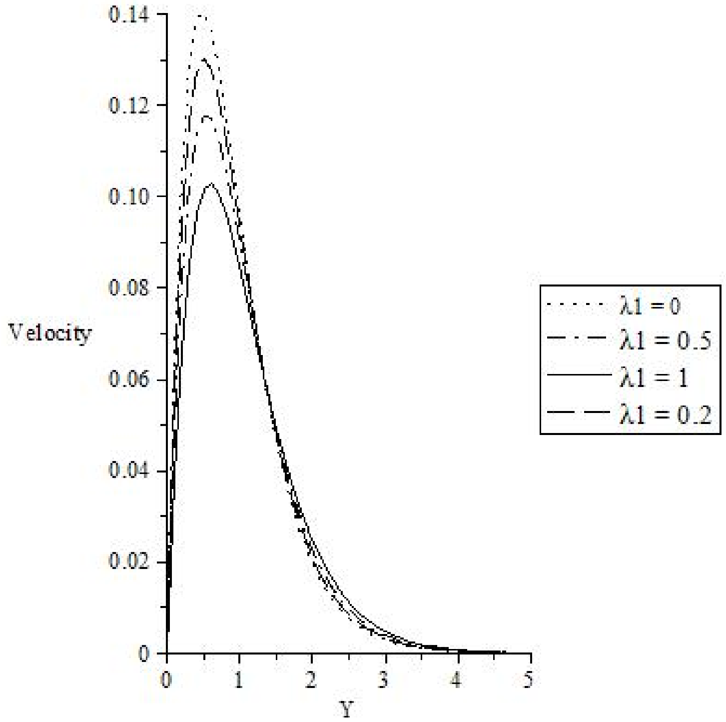


Figure 6.Velocity profiles for different values of $\lambda_1$.

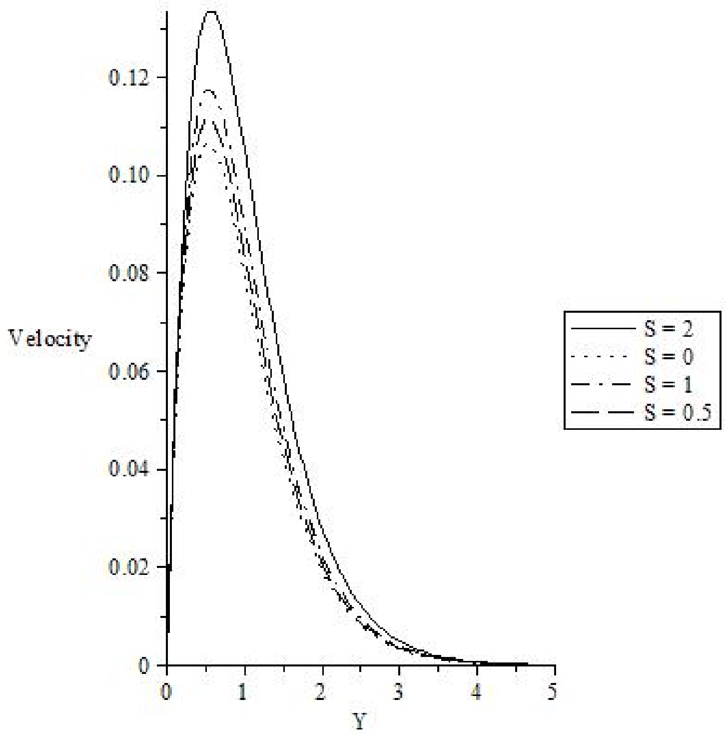


Figure 7.Velocity profiles for different values of S.

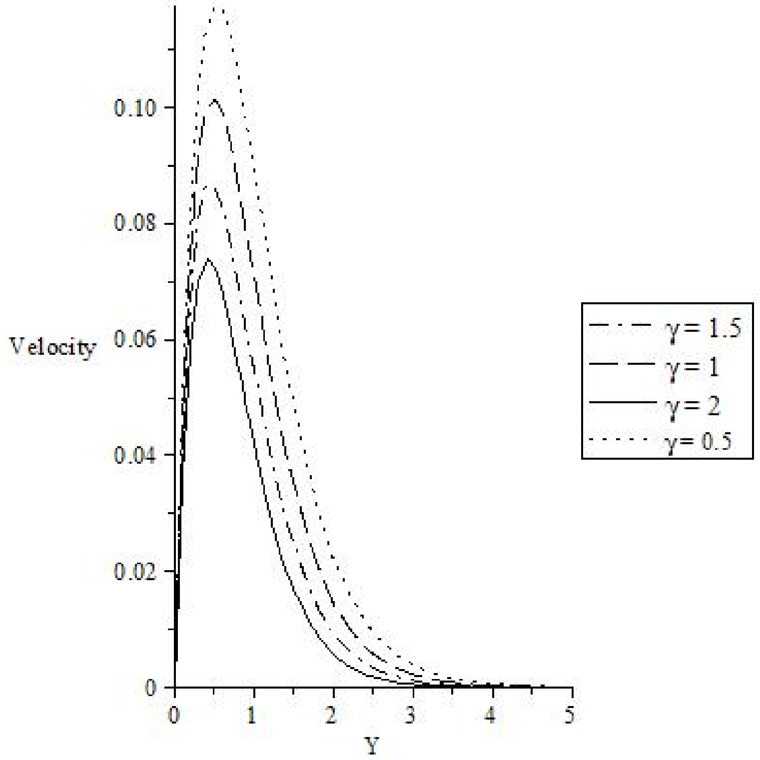


Figure 8.Velocity profiles for different values of $\gamma$ .

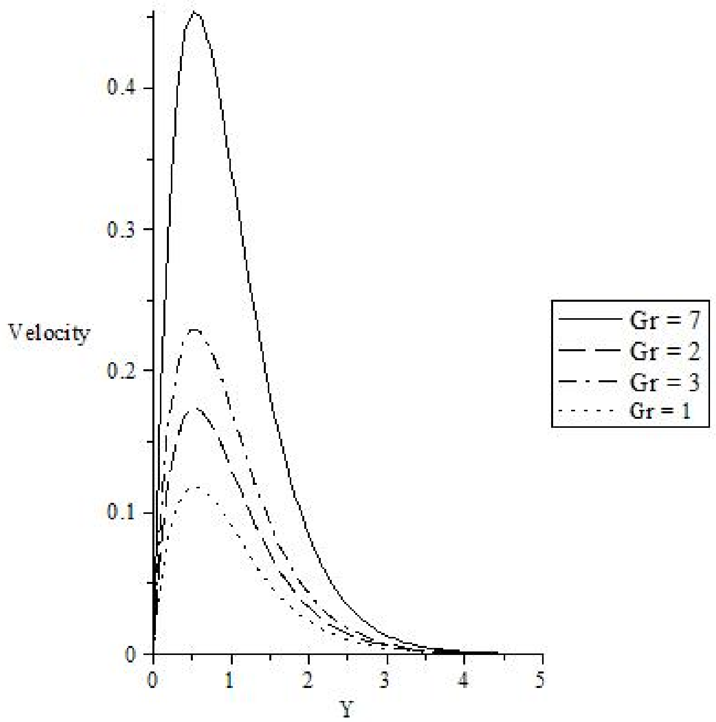


Figure 9.Velocity profiles for different values of Gr.

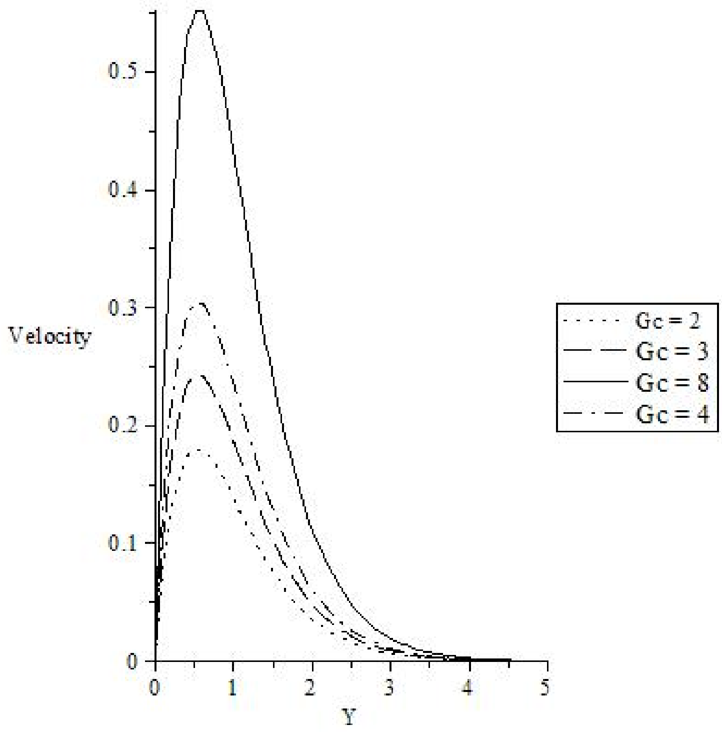


Figure 10.Velocity profiles for different values of Gc.

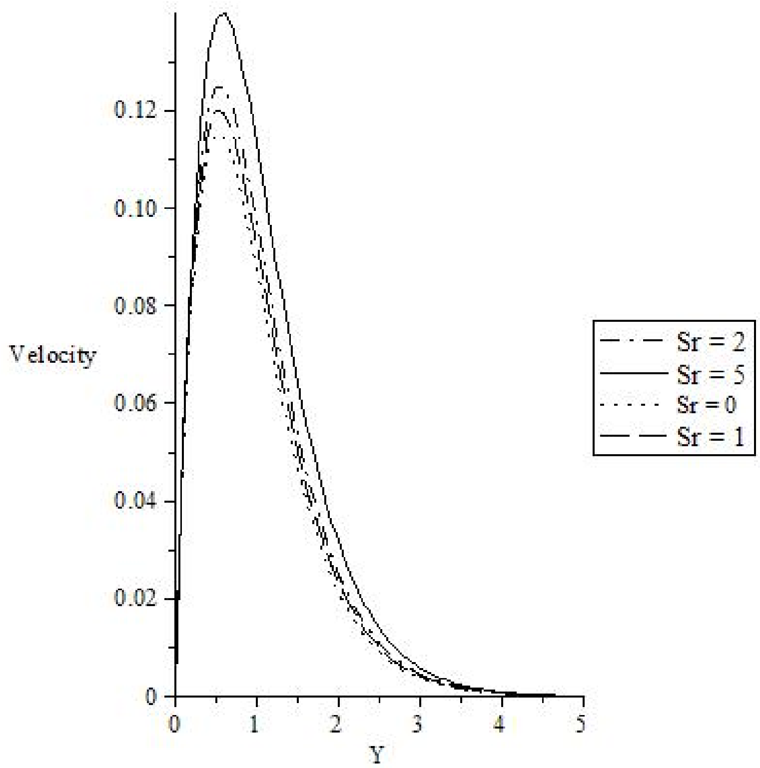


Figure 11.Velocity profiles for different values of Sr.

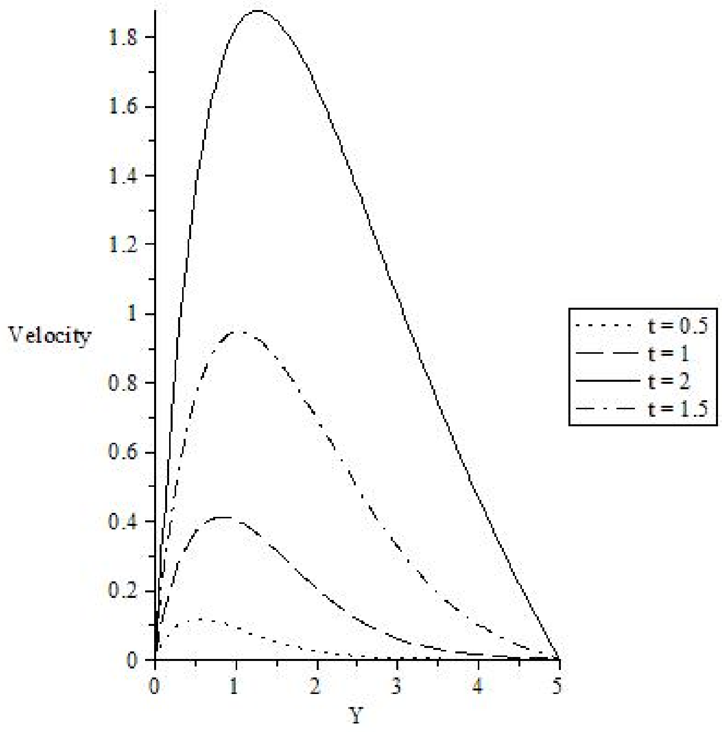


Figure12. Velocity profiles for different values of t.

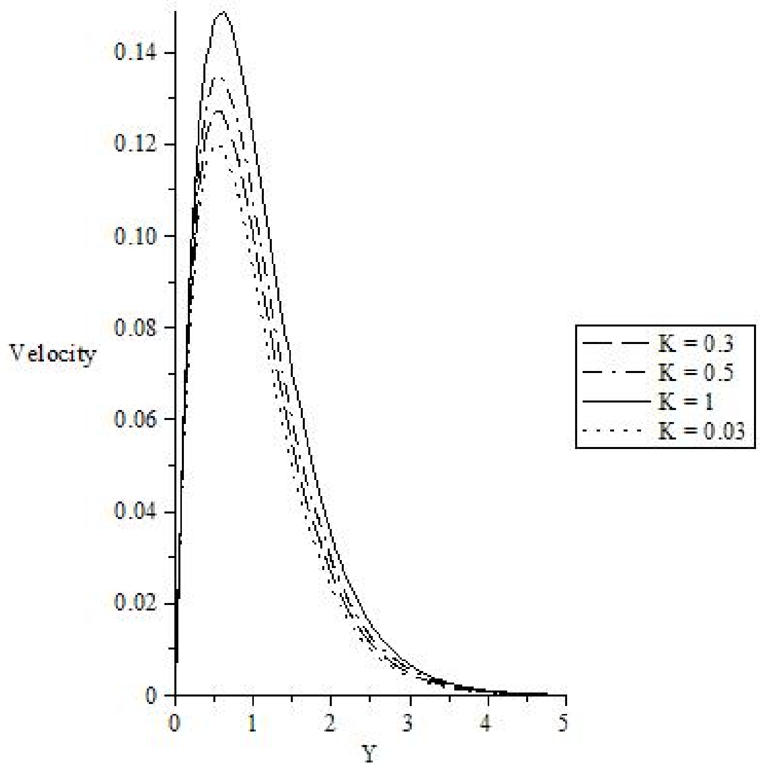


Figure 13.Velocity profiles for different values of K.

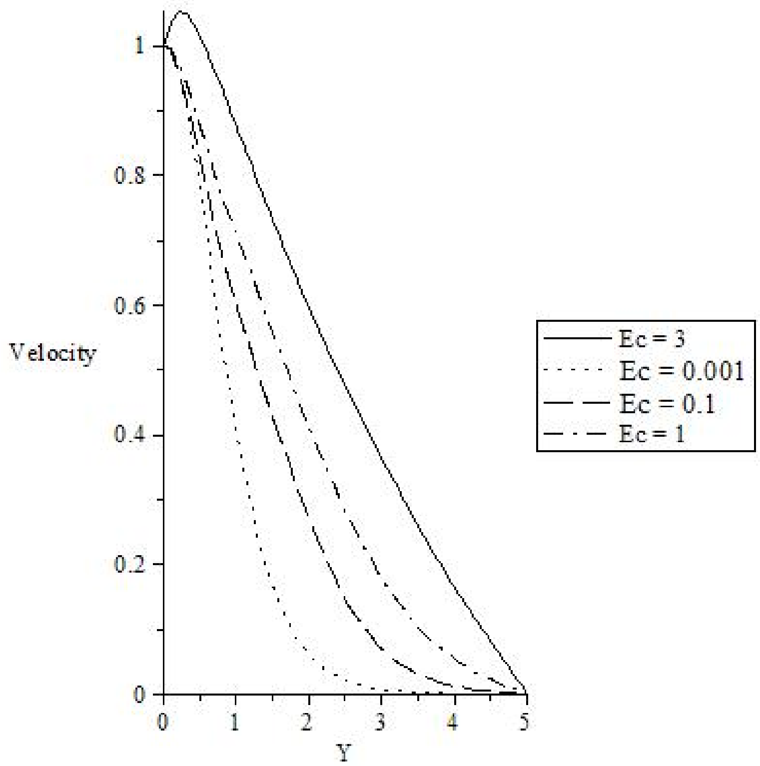


Figure 14.Velocity profiles for different values of Ec.

## 4.2 Temperature profiles

Figures 15 to 20 demonstrate the temperature profiles.

In figure 15, the influence of Prandtl number on the temperature is shown. It is seen that, the temperature decreases when the Prandtl number is reduced. Figure 16 represents effect of heat generation on the temperature. It is depicted that, the temperature increases with increase in heat generation. Variation of suction parameter on the temperature is illustrated in figure 17. It is observed that, the temperature decreases with decrease in the suction parameter. Figure 18 depicts the effect of constant $\eta$ on the temperature. It is noted that, the temperature rises when the constant is higher. In figure 19, it is presented that, the temperature increases with increasing time. Figure 20 shows the variation of temperature for different values of Dufour number, it is clear that the temperature increases with increase in Du.

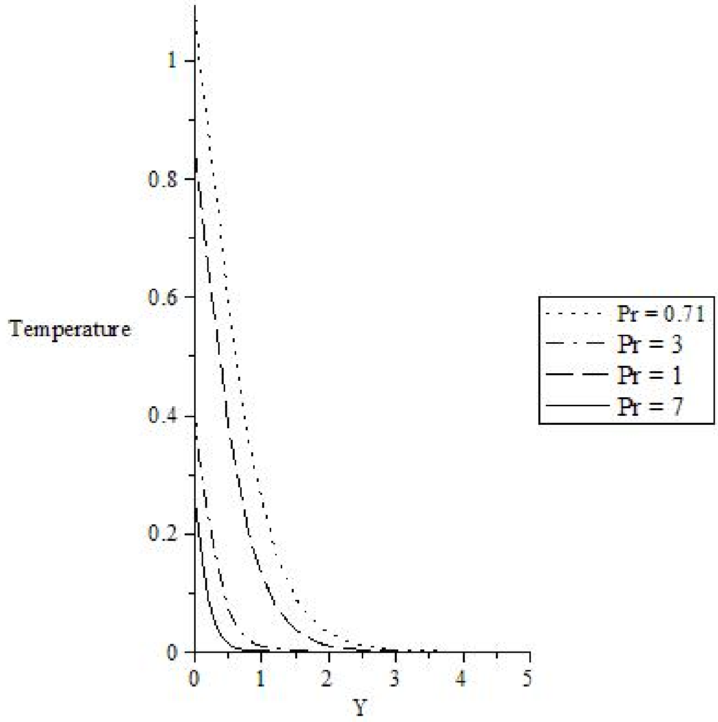


Figure 15.Temperature profiles for different values of Pr.

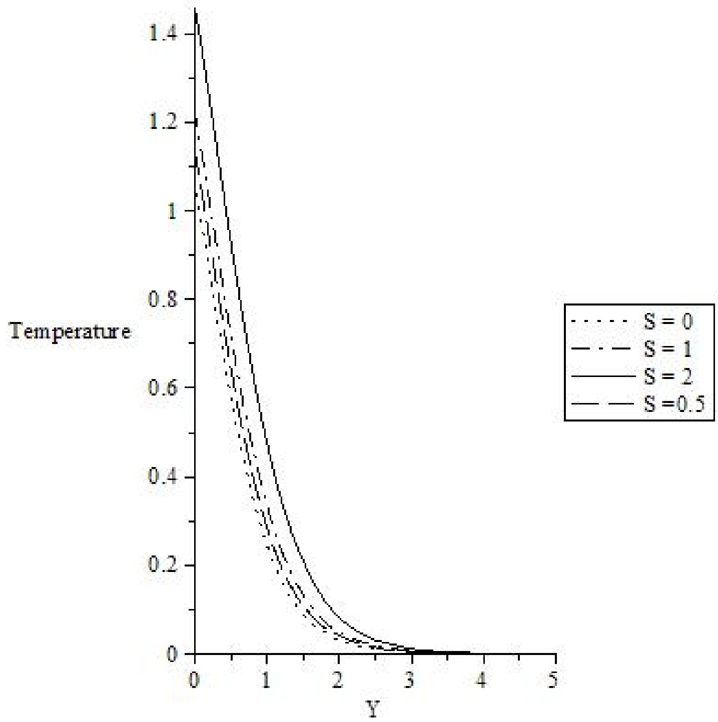


Figure 16.Temperature profiles for different values of S.

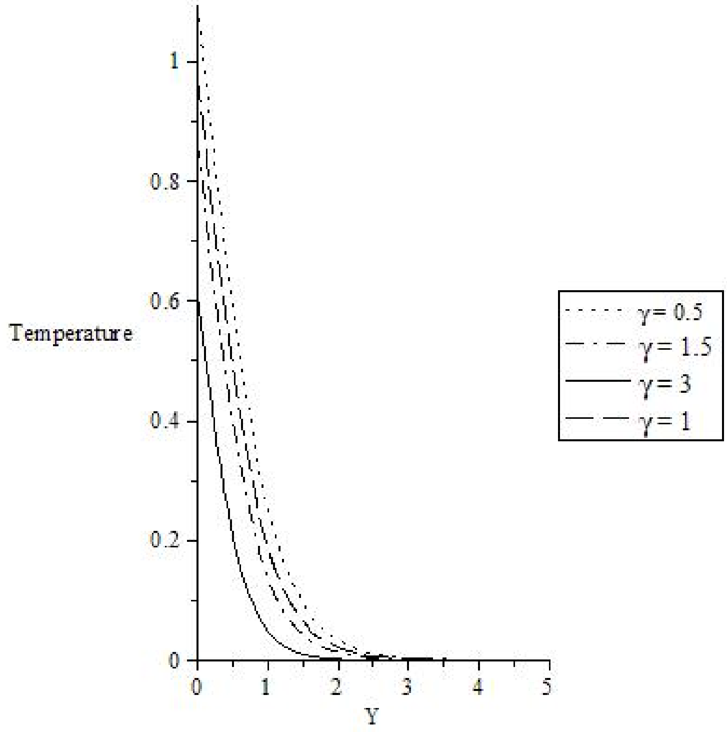


Figure 17.Temperature profiles for different values of $\gamma$.

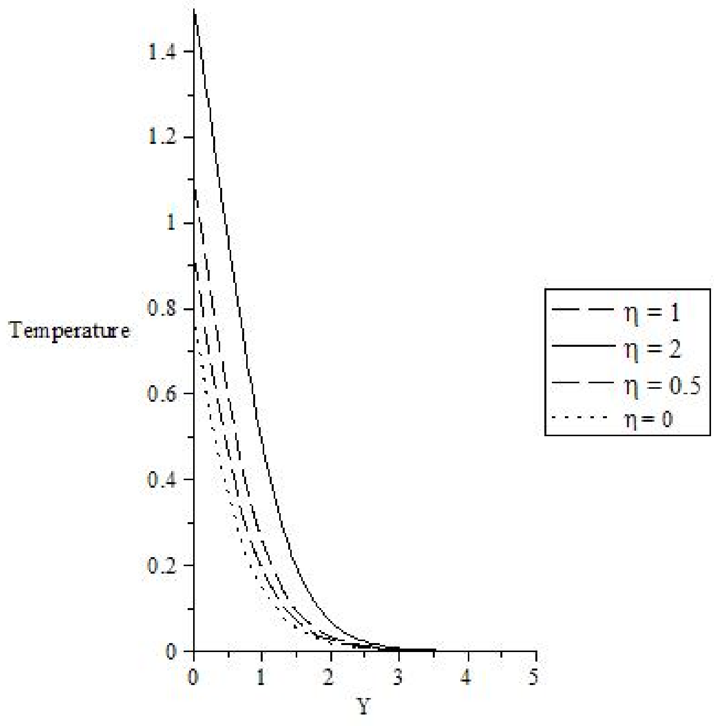


Figure 18.Temperature profiles for different values of $\eta$.

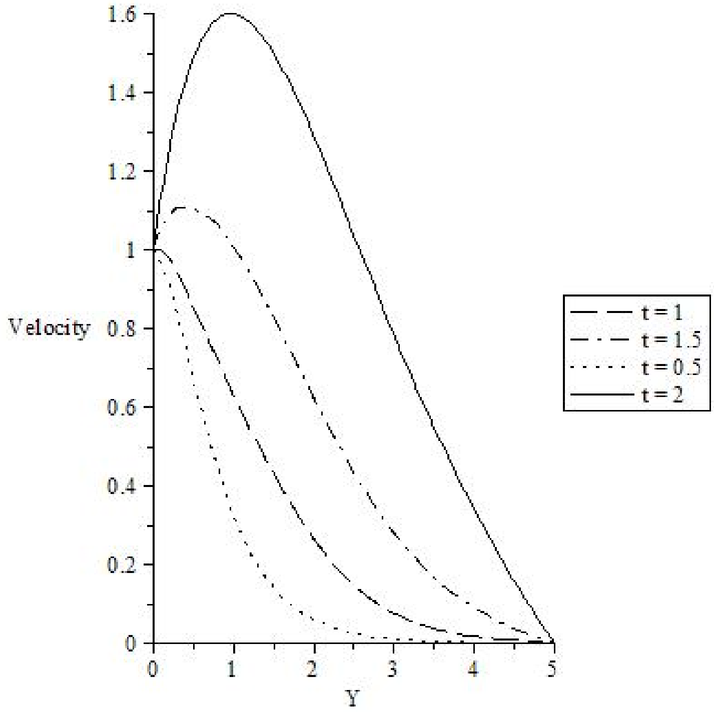


Figure 19.Temperature profiles for different values of t.

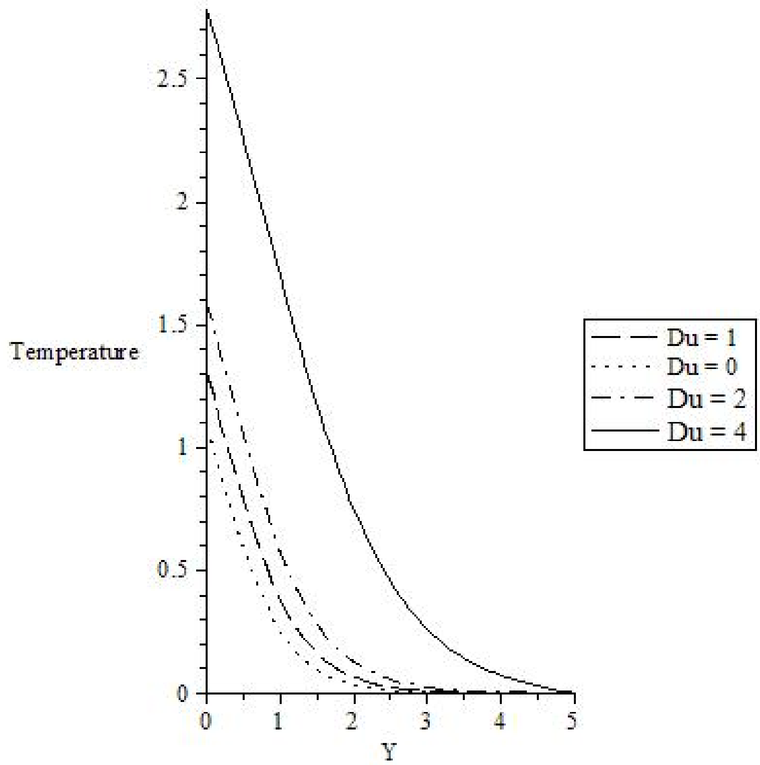


Figure 20.Temperature profiles for different values of Du.

### 4.3 Concentration profiles

Figures 21 to 24 illustrate the concentration profiles.

Effect of Schmidt number on the concentration is presented in figure 21. It is noted that, the concentration is lower due to increasing Schmidt number. In figure 22, the influence of Soret number on the concentration is shown. It is demonstrated that, the concentration is higher as the Soret number is increased. Figure 23 displays the variation of suction parameter on the concentration. It is seen that, the concentration deceases with decreasing suction parameter. In figure 24, It is observed that the concentration rises with an increase in the time.

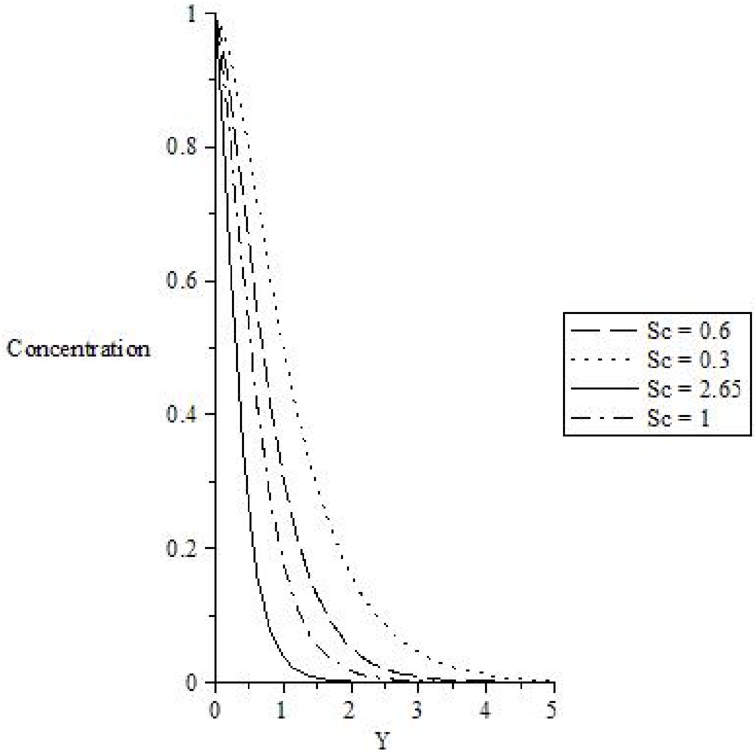


Figure 21.Concentration profiles for different values of Sc.

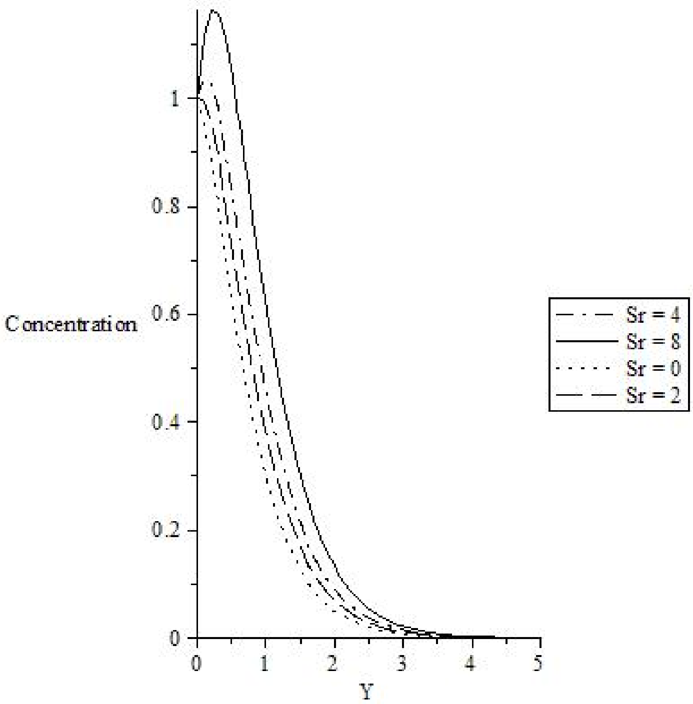


Figure 22.Concentration profiles for different values of Sr.

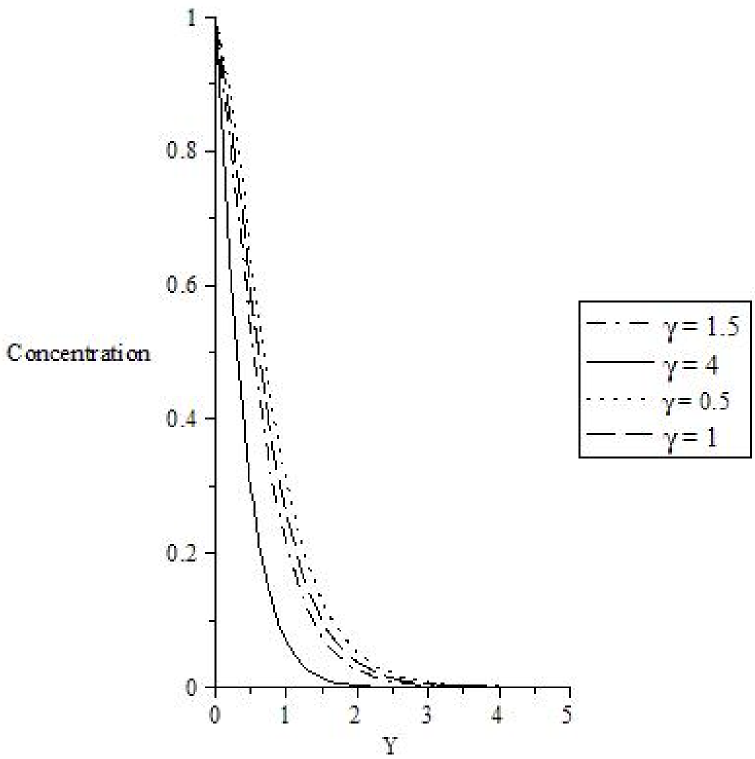


Figure 23.Concentration profiles for different values of $\gamma$.

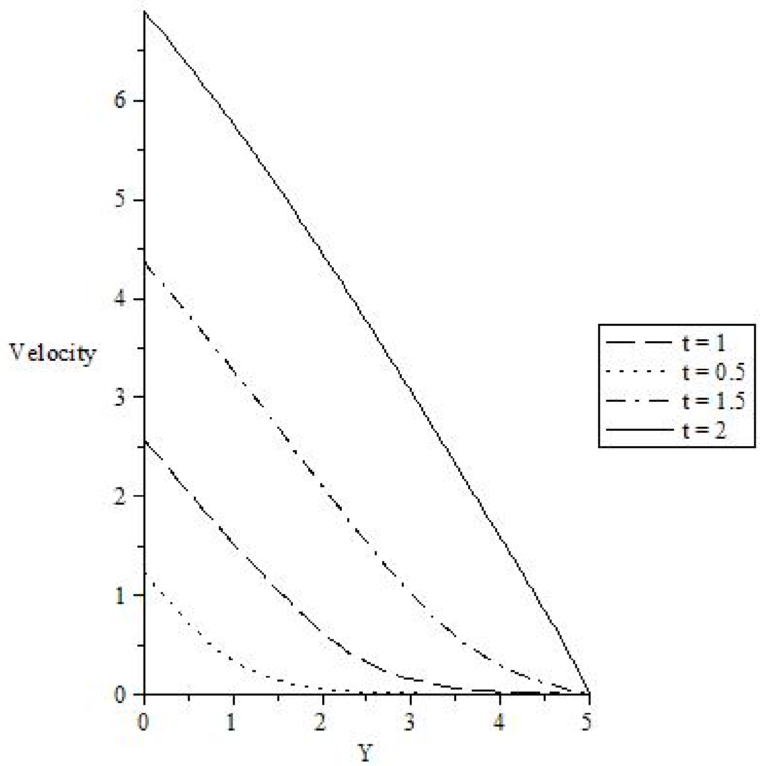


Figure 24.Concentration profiles for different values of t.

**CONCLUSIONS**

Effect of Jeffery fluid on heat and mass transfer past a vertical porous plate with Soret and variable thermal conductivity has been studied. A set of non-linear coupled differential equations governing the fluid velocity, temperature and chemical species concentration is solved numerically for various material parameters. The velocity becomes higher when Gr, Gc, Ec, S, Du, Sr, K, $\eta$ , $\gamma$ , and t is increased. Also, decreases of Pr, Sc, M, and $\lambda_1$ lead to sharp fall in the velocity of the boundary layer. The temperature profile increases in the presence of heat generation, Dufour number, and time but reduces for increased values of Prandtl number and suction. Similarly, concentration rises with Soret number and time, and decreases with increasing values of Schmidt number and suction.

**Conflict of Interests**

The authors declare that there is no conflict of interests.

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