Middle-East Journal of Scientific Research 24 (10): 3212-3225, 2016
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2016.3212.3225

# Radiation Absorption and Thermal Diffusion Effects on Conducting Fluid past an Exponentially Accelerated Vertical Plate with Exponentially Varying Temperature and Concentration

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**Abstract:** In this paper investigated the hydro magnetic effects of a uniform transverse magnetic field electrically conducting fluid past an exponentially varying temperature and concentration influence on conducting fluid past an exponentially accelerated infinite vertical plate in conducting field. This problem is governed by coupled non linear partial differential equations. Here the plate temperature is increasing linearly with time and the concentration level near the plate is increased. Among the effects of various physical parameters in going into the problem, the velocity, Skin friction, Nusselt number and Sherwood number are broadly discussed with the help of graphs.

**Key words:** Vertical plate · Soret number · Unsteady · Explicit finite difference method · Heat source · Porous medium and electrically conducting fluid

## INTRODUCTION

The majority common type of body force on a fluid is gravity defined in magnitude and direction by the corresponding acceleration vector. Magneto hydrodynamic is the branch of continuum mechanics which deals with the flow of electrically conducting fluids. Many natural phenomena and engineering problems are important being subjected to a magneto hydrodynamic analysis. Sometimes, electromagnetic effects are important. The electric and magnetic fields themselves obey a locate of physical laws, if they are expressed by Maxwell's equations. The solution of such problems requires the simultaneous result of the equations of fluid mechanics and of electromagnetism. One special case of this type of coupling is the field known as magneto hydrodynamics. The hydro magnetic flows and heat transfer have become more important in recent years because of its varied applications in farming engineering and petroleum industries. Recently, considerable attention has also been focused on new applications of magneto hydrodynamics and heat transfer such as metallurgical processing. Melt refining involves magnetic field applications to control excessive heat transfer rate. Other applications of MHD heat transfer include MHD generators, plasma propulsion in astronautics, nuclear reactor thermal dynamics and ionized-geothermal energy systems. Magneto hydrodynamic has drawn the attention of a broad number of scholars due to its variant applications. In engineering it finds its applications in pumps. Magneto hydrodynamic bearing etc. Free convection flows are of a great attention in a number of industrial applications like as fiber and granular insulation; geothermal systems etc. convection in porous media has application on geothermal energy recovery, oil extraction, thermal energy storage and flow throughout

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filtering devices. The occurrences of mass transfer are also very general in theory of stellar structure and remarkable erects are detectable, at least on the solar surface. The study of influence of magnetic field on free convection flow is main in liquid metal, electrolytes and ionized gases. Mondal *et al*. [1] discussed free convection and mass transfer flow through a porous medium with variable temperature. Chamkha [2] studied unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption. Hayat *et al*. [3] investigated MHD flow and heat transfer over permeable stretching sheet with slip conditions. Cortell *et al*. [4] discussed MHD flow and mass transfer of an electrically conducting fluid of second grade in a porous medium over a stretching sheet with chemically reactive species. Kandasamy *et al*. [5] studied lie group analysis for the effect of temperature dependent fluid viscosity with thermophoresis and chemical reaction on MHD free convective heat and mass transfer over a porous stretching surface in the presence of heat source / sink. Khan *et al*. [6] investigated MHD boundary layer flow of a nanofluids containing gyro tactic microorganisms past a vertical plate with navier slip. Kandasamy *et al*. [7] discussed chemical reaction, heat and mass transfer on MHD flow over a vertical stretching surface with heat source and thermal stratification effects. Kaprawi [8] discussed analysis of transient natural convection flow past an accelerated infinite vertical plate. Kim [9] discussed unsteady MHD convective heat transfer past a semi-infinite vertical porous moving plate with variable suction. Muthucumaraswamy *et al*. [10] discussed MHD and radiation effects on moving isothermal vertical plate with variable mass diffusion. Mishra *et al*. [11] investigated mass and heat transfer effect on MHD flow of a visco-elastic fluid through porous medium with oscillatory suction and heat source. Ravi kumar *et al*. [12] analyzed MHD double diffusive and chemically reactive flow through porous medium bounded by two vertical plates. Muthucumaraswamy *et al*. [13] discussed natural convection on a moving isothermal vertical plate with chemical reaction. Pal *et al*. [14] analyzed hall current and MHD effects on heat transfer over an unsteady stretching permeable surface with thermal radiation. Prakash *et al*. [15] discussed diffusion-thermo and radiation effects on unsteady MHD flow through porous medium past an impulsively started infinite vertical plate with variable temperature and mass diffusion. Pal and Chatterjee [16] analyzed heat and mass transfer in MHD non-darcian flow of a micro polar fluid over a stretching sheet embedded in a porous media with non-uniform heat source and thermal radiation. Patil *et al*. [17] analyzed chemical reaction effects on unsteady mixed convection boundary layer flow past a permeable slender vertical cylinder due to a nonlinearly stretching velocity. Raptis *et al*. [18] studied viscous flow over a non-linearly stretching sheet in the presence of a chemical reaction and magnetic field. Seth *et al*. [19] discussed MHD natural convection flow past an impulsively moving vertical plate with ramped wall temperature in the presence of thermal diffusion with heat absorption. Seini *et al*. [20] discussed boundary layer flow near stagnation-points on a vertical surface with slip in the presence of transverse magnetic field. Seth *et al*. [21] analyzed MHD natural convection flow with radiative heat transfer past an impulsively moving plate with ramped wall temperature. Ravi kumar *et al*. [22] discussed combined effects of heat absorption and MHD on convective Rivlin-Ericksen flow past a semi-infinite vertical porous plate with variable temperature and suction. Seth *et al*. [23] studied effects of hall current and rotation on unsteady MHD natural convection flow with heat and mass transfer past an impulsively moving vertical plate in the presence of radiation and chemical reaction. Anjalidevi *et al*. [24] discussed effects of a chemical reaction heat and mass transfer on MHD flow past a semi-infinite plate. Chamkha *et al*. [25] MHD flow of a uniformly stretched vertical permeable surface in the presence of heat generation/absorption and a chemical reaction. Singh *et al*. [26] analyzed MHD free convection and mass transfer flow with heat source and thermal diffusion. Sonth *et al*. [27] discussed heat and mass transfer in a visco-elastic fluid flow over an accelerating surface with heat source/sink and viscous dissipation. Takhar *et al*. [28] studied flow and mass transfer on a stretching sheet with a magnetic field and chemically reactive species. Vajravelu *et al*. [29] discussed unsteady convective boundary layer flow of a viscous fluid at a vertical surface with variable fluid properties. Ravi Kumar *et al*. [30] analyzed theoretical investigation of an unsteady MHD free convection heat and mass transfer flow of a non-Newtonian fluid flow past a permeable moving vertical plate in the presence of thermal diffusion and heat sink. Seth *et al*. [31] discussed hydro magnetic natural convection flow with radiative heat transfer past an accelerated moving vertical plate with ramped temperature through a porous medium.

Mathematical formulation

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

$$\rho C_p \frac{\partial \bar{T}}{\partial \bar{t}} = \kappa\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} + Q_l\left(\bar{C}-\bar{C}_\infty\right) \quad (2)$$

$$\frac{\partial \bar{C}}{\partial \bar{t}} = D\frac{\partial^2 \bar{C}}{\partial \bar{y}^2} + D_1\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} \quad (3)$$

The boundary conditions related with the problem are

$$\begin{aligned} &\bar{t}\le 0; \bar{u}=0, \bar{T}=\bar{T}_\infty, \bar{C}=\bar{C}_\infty, \quad \text{for all } \bar{y} \\ &\bar{t}>0; \bar{u}=u_0 e^{\bar{a}\bar{t}}, \bar{T}=\bar{T}_\infty+\left(\bar{T}_w-\bar{T}_\infty\right)e^{\bar{a}\bar{t}}, \bar{C}=\bar{C}_\infty+\left(\bar{C}_w-\bar{C}_\infty\right)e^{\bar{a}\bar{t}} \quad \text{for all } \bar{y}=0 \\ &\bar{u}=0, \bar{T}-\bar{T}_\infty, \bar{C}=\bar{C}_\infty \text{ as } \bar{y}\to\infty \end{aligned} \quad (4)$$

Where $\bar{u}$ is the velocity of the fluid in $\bar{x}$ directions, $\bar{T}$ is the temperature and $\bar{C}$ is the concentration of the fluid respectively, g is the acceleration due to gravity, $\bar{C}_\infty$ is the concentration in the fluid far away from the plate, $\bar{C}_w$ is the concentration of the plate, $\bar{y}$ is coordinate axis normal the plate, B0 is the external magnetic field, Q is the radiation absorption parameter, $C_p$ is specific heat at constant pressure, $\bar{T}_\infty$ is the temperature of the fluid far away from the plate, $\bar{T}_w$ is the temperature of the plate, M is the magnetic parameter, $a$ is the acceleration parameter, $D_1$ is the thermal diffusivity, $u_0$ is the velocity of the plate, K Porous permeability, $D$ is the chemical molecular diffusivity, $K$ is the permeability parameter, $\rho$ is the density, $\nu$ is kinematic viscosity and $\bar{t}$ is the corresponding time, $\beta$ is the volumetric coefficient of thermal expansion and $\bar{\beta}$ is the volumetric coefficient of expansion with concentration respectively.

Here $A=\frac{u_0^2}{\nu}$, since the solutions of the governing equations under the boundary conditions will be based on the finite difference method so it is necessary to make the equation dimensionless. For this reason now we introduce the following dimensionless quantities.

$$\begin{aligned} &u=\frac{\bar{u}}{u_0}, y=\frac{\bar{y}u_0}{\nu}, \theta=\frac{\bar{T}-\bar{T}_\infty}{\bar{T}_w-\bar{T}_\infty}, Gr=\frac{g\beta\nu\left(\bar{T}_w-\bar{T}_\infty\right)}{u_0^3}, Gm=\frac{g\beta'\nu\left(\bar{C}_w-\bar{C}_\infty\right)}{u_0^3}, \\ &\Pr=\frac{\mu C_p}{\kappa}, Sc=\frac{\nu}{D}, M=\frac{\sigma B_0^2\nu}{\rho u_0^2}, K=\frac{u_0^2\bar{K}}{\nu^2}, C=\frac{\bar{C}-\bar{C}_\infty}{\bar{C}_w-\bar{C}_\infty}, a=\frac{\bar{a}\nu}{u_0^2}, t=\frac{\bar{t}u_0^2}{\nu}, \\ &S_0=\frac{\left(\bar{T}_w-\bar{T}_\infty\right)D_1}{\left(\bar{C}_w-\bar{C}_\infty\right)\nu}, Sc=\frac{\nu}{D}, Q=\frac{\nu\left(\bar{C}_w-\bar{C}_\infty\right)Q_l}{u_0^2\left(\bar{T}_w-\bar{T}_\infty\right)\rho C_p} \end{aligned} \quad (5)$$

Then equation (1)-(3) and boundary conditions (4) leads to

$$\frac{\partial u}{\partial t} = Gr\theta + GmC + \frac{\partial^2 u}{\partial y^2} - Mu - \frac{u}{K} \quad (6)$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} + S_0\frac{\partial^2 \theta}{\partial y^2} \quad (7)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2} + QC \quad (8)$$

With the initial and boundary conditions

$$\begin{aligned} &t\le 0: u=0, \quad \theta=0, \quad C=0 \quad \text{for all } y \\ &t>0: u=e^{at}, \theta=e^{at}, C=e^{at} \quad \text{for all } y=0 \end{aligned} \quad (9)$$

**Method of Solution:** Several physical phenomena in applied science and engineering when formulated into mathematical models fall into a category of systems know as non-linear coupled partial differential equations. Most of these problems can be formulated as second order partial differential equations. A system of non-linear coupled partial differential equations with the boundary conditions is very complicated to solve analytically. For obtaining the solution of such problems we adopt advanced numerical methods. Governing equations of our problem contain a system of partial differential equations which are transformed by normal transformations into a non-dimensional system of non-linear coupled partial differential equations with initial and boundary conditions. Hence the solution of the problem would be based on advance numerical methods. The finite difference method formula will be used for solving our obtained non-similar coupled partial differential equations. From the concept of the above discussion, for simplicity the explicit finite difference method has been used to solve from equations (6) to (8) subject to the boundary condition by (9). To obtain the difference equations the region of the flow is separated into a grid or mesh of lines parallel to $X$ and $Y$ axis is taken along the plate and Y-axis is normal to the plate. Here, the suffix i refer to y and j to time. The mesh system is divided by taking $\Delta y = 0.1$. From the initial condition in (9), we have the following equivalent:

$$u(i,0)=0, \theta(i,0)=0, C(i,0)=0 \quad \text{for all } i \quad (10)$$

The boundary conditions from (9) are expressed in finite-difference form as follows

$$u(0,j)=e^{a(j-1)\Delta t},\theta(0,j)=e^{a(j-1)\Delta t},C(0,j)=e^{a(j-1)\Delta t} \text{ for all } j$$
$$u(i_{max},j)=0,\theta(i_{max},j)=0,C(i_{max},j)=0 \text{ for all } j \qquad (11)$$

(Here $i_{max}$ was taken as 200)

First the velocity at the end of time step viz, u (i, j+1)(i=1 to200) is computed from (6) in terms of velocity, temperature and concentration at points on the earlier time-step. Then θ (i, j +1) is computed from (7) and C (i, j +1) is computed from (8). The procedure is repeated until t = 0.5 (i.e. j = 500). During computation Δt was chosen as 0.001.

Using the explicit finite difference approximation, the following appropriate set of finite difference equations are obtained as;

$$\theta_{i,j+1}-\theta_{i,j}=\frac{\Delta t}{\Pr}\left(\frac{\theta_{i-1,j}-2\theta_{i,j}+\theta_{i+1,j}}{(\Delta y)^2}\right)+\Delta t\,Q\,C(i,j) \qquad (13)$$

$$C_{i,j+1}-C_{i,j}=\frac{\Delta t}{Sc}\left(\frac{C_{i-1,j}-2C_{i,j}+C_{i+1,j}}{(\Delta y)^2}\right)+\Delta t\,(S_0) \qquad (14)$$

$$U_{i,j+1}-U_{i,j}=\Delta t\,Gr\,\theta(i,j)+\Delta t\,Gm C(i,j)+\Delta t\left(\frac{U_{i-1,j}-2U_{i,j}+U_{i+1,j}}{(\Delta y)^2}\right)-\Delta t\,MU(i,j)-\frac{\Delta t}{K}U(i,j) \qquad (15)$$

The following equations (13) to (15) are as follows finite differences equations are obtained.

$$\theta_{i,j+1}=\theta_{i,j}+\frac{\Delta t}{\Pr}\left(\frac{\theta_{i-1,j}-2\theta_{i,j}+\theta_{i+1,j}}{(\Delta y)^2}\right)+\Delta t\,QC(i,j) \qquad (16)$$

$$C_{i,j+1}=C_{i,j}+\frac{\Delta t}{Sc}\left(\frac{C_{i-1,j}-2C_{i,j}+C_{i+1,j}}{(\Delta y)^2}\right)+\Delta t\,(S_0) \qquad (17)$$

$$_{i,j+1}=U_{i,j}+\Delta t\,Gr\,\theta(i,j)+\Delta t\,Gm C(i,j)+\Delta t\left(\frac{U_{i-1,j}-2U_{i,j}+U_{i+1,j}}{(\Delta y)^2}\right)-\Delta t\,MU(i,j)-\frac{\Delta t}{K}U(i,j) \qquad (18)$$

**Skin-Friction:** The skin-friction in non-dimensional form is given by

$$\tau=\left(\frac{\partial u}{\partial y}\right)_{y=0}$$

**Rate of Heat Transfer:** The dimensionless rate of heat transfer is given by

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

**Rate of Mass Transfer:** The dimensionless rate of mass transfer is given by

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

## RESULTS AND DISCUSSIONS

In order to get a physical insight into the problem, extensive computations have been performed to study the effects of various influencing parameters on the dimensionless velocity, temperature and concentration profiles and also on the Skin-friction, Nusselt number and Sherwood number. The effects of various physical parameters viz., the Schmidt number (Sc), Soret number ($S_0$), radiation absorption parameter (Q), Grashof number (Gr), the modified Grashof number (Gm), magnetic parameter (M), magnetic parameter (M), Prandtl number (Pr), Porous permeability (K) are exhibited in the figures 1-20.

In fig. 1, it is noticed that temperature decrease in the boundary layer is clearly observed from this figure for an increase in the Prandtl number. Fig. 2, depicts the effect of radiation heat absorption parameter on temperature. It is noticed that the temperature increases as an increase in the radiation absorption parameter. The central reason behind this effect is that the radiation absorption parameter causes an increase in the kinetic energy as well as thermal energy of the fluid. The momentum and thermal boundary layers get thinner in case of radiation absorbing fluids. It shows reverse effect in the case of heat generation parameter. Fig.3, from this figure it is noticed that concentration decreases with an increase in Schmidt number. Because, Schmidt number is a dimensionless number defined as the ratio of momentum diffusivity and mass diffusivity and is used to characterize fluid flows in which there are simultaneous momentum and mass diffusion convection processes. Therefore, concentration boundary layer decreases with an increase in Schmidt number. From Fig.4, it is clear that the concentration increases with an increasing of Soret number. The influence of modified Grashof number on the velocity field is illustrated graphically in Fig. 5. Modified Grashof number is increase, in general the fluid velocity increases and also reverse effect is observed when modified Grashof number and velocity. The effect of Prandtl number on the velocity field is shown in Fig.6. As the Prandtl number increases the velocity field is found to be decreasing. As we move away from the plate it is noticed that at higher values of Prandtl number does not contribute much on the velocity field but a smaller values contributes to the increase in the velocity. Figures 7 and 8 it is noticed that radiation absorption parameter and Soret number is increases, in general the fluid velocity increases and also reverse effect is observed when radiation absorption parameter, Soret number and velocity.

The effects of some of the above parameters on Nusselt number, Sherwood number and Skin friction with the help of the graphs. The effects of Prandtl number increases as Nusselt number increases in figure 9. Fig. 10 depicts the effect of radiation absorption parameter on Nusselt number. It is noticed that the Nusselt number decreases as an increase in the radiation absorption parameter. The contribution of Schmidt number on the Sherwood number profiles is shown in Fig.11. It is noticed that increase in the Schmidt number contributes to the increase in the Sherwood number of the fluid media. It is observed that relatively for the smaller values of the Schmidt number the Sherwood number is perfectly linear. Increase in the Schmidt number contributes to the parabolic nature of the profiles. Fig. 12 depicts the effect of Soret number on Sherwood number. It is noticed that the Sherwood number decreases as an increase in the Soret number.

Fig. 13 and 14 shows the effect of Grashof number and modified Grashof number on Skin-friction. It is noticed that Skin-friction decreases as increase in Grashof number and modified Grashof number. From the figure (15) it is observed that the increasing of Prandtl number resulting the decreases of Skin friction. Fig. 16 depicts the effect of radiation absorption parameter on Skin friction. It in noticed that the Skin friction decreases as an increase in the radiation absorption parameter. In figure 17, Skin friction is displayed with variation in Schmidt number. From this figure it is notice that Skin friction increases as an increase in the Schmidt number. Figures 18 to 20 show the effect of Soret number, Magnetic parameter and Porous permeability on Skin friction. It is noticed that Skin friction decreases an increase in Soret number, Magnetic parameter and porous permeability

- Temperature decreases with an increase in Prandtl number while it increases with increase in radiation absorption parameter.
- Concentration decreases with an increase in Schmidt number while it increases with increase in Soret number.
- Velocity increases with an increase in modified Grashof number while it decreases with increase in modified Grashof number.
- Velocity decreases with an increase in Prandtl number.
- Velocity increases with increase in radiation absorption parameter and Soret number and also reverse effect is observed when radiation absorption parameter, Soret number and velocity.
- Nusselt number increases with increase in Prandtl number, where as it has reverse effect in the case of radiation absorption parameter.
- Sherwood number increases with increase in Schmidt number, where as it has reverse effect in the case of Soret number.
- Skin friction increases within increase in Grashof number, modified Grashof number, radiation absorption parameter, Soret number, magnetic parameter and Porous permeability, where s it has reverse effect in the case of Prandtl number and Schmidt number.

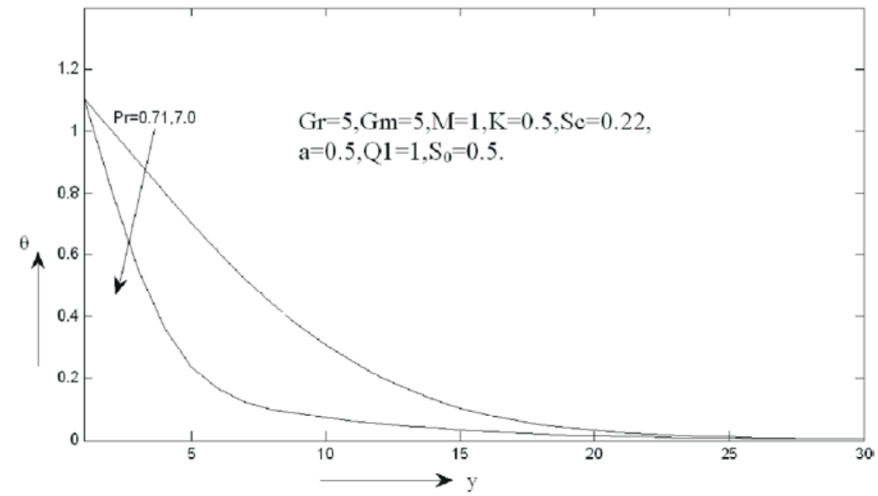


Fig. 1: Effect of Prandtl number on Temperature

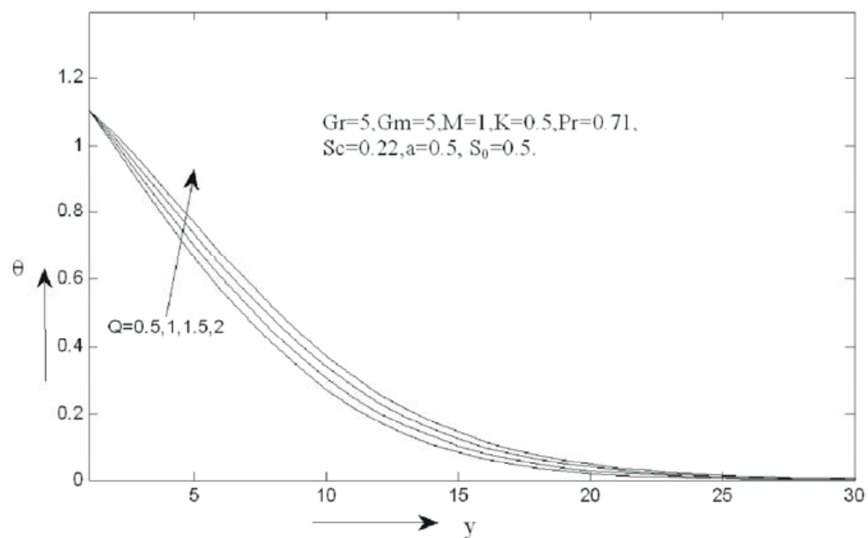


Fig. 2: Effect of radiation absorption parameter on Temperature

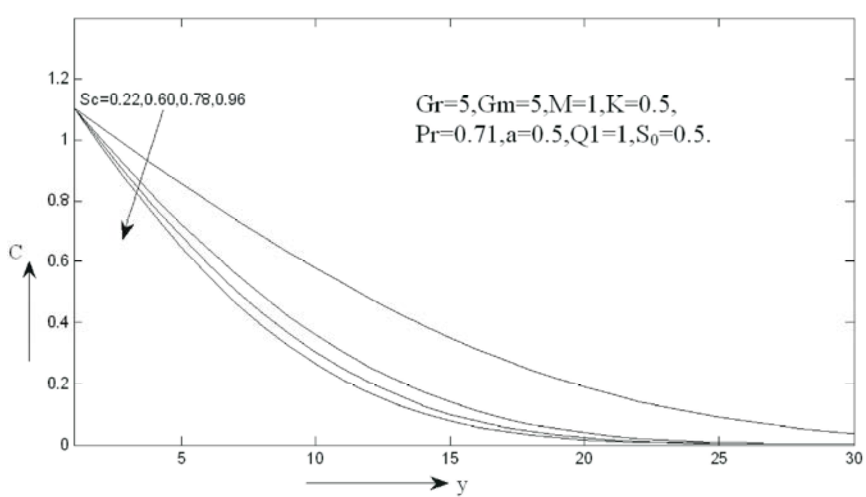


Fig. 3: Effect of Schmidt number on Concentration

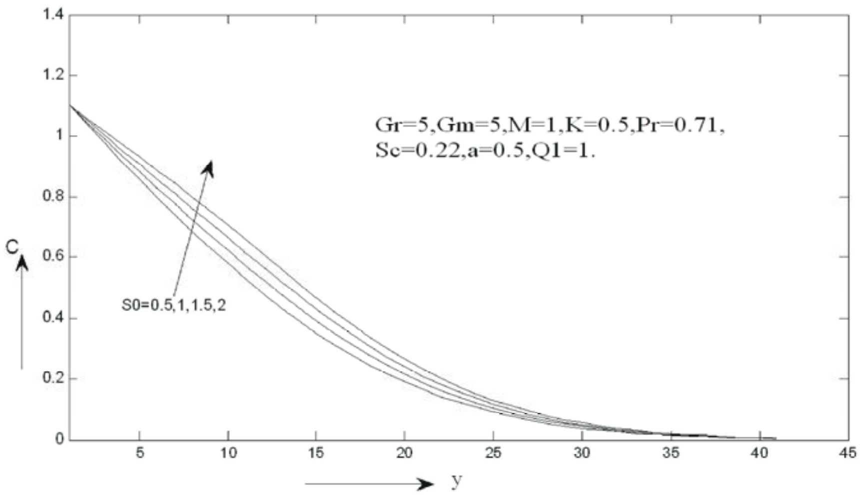


Fig. 4: Effect of Soret number on Concentration

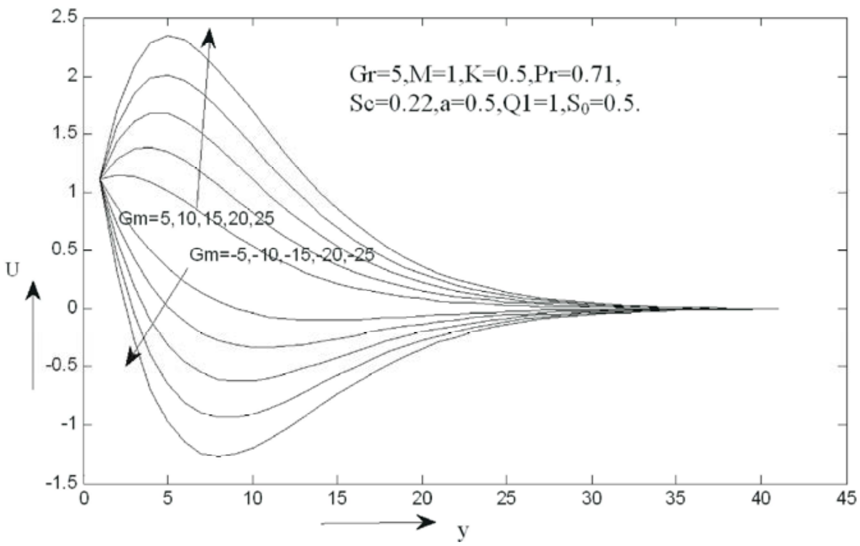


Fig. 5: Effect of modified Grashof number on velocity

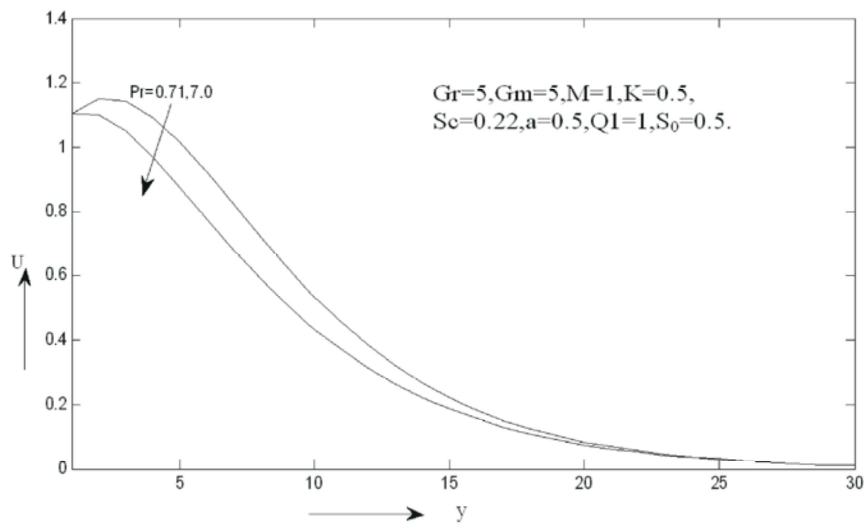


Fig. 6: Effect of Prandtl number on velocity

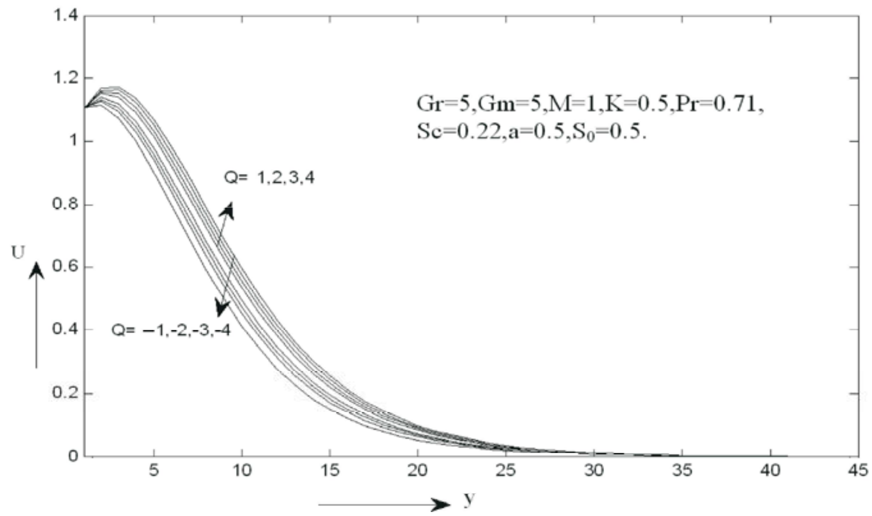


Fig. 7: Effect of radiation absorption on velocity

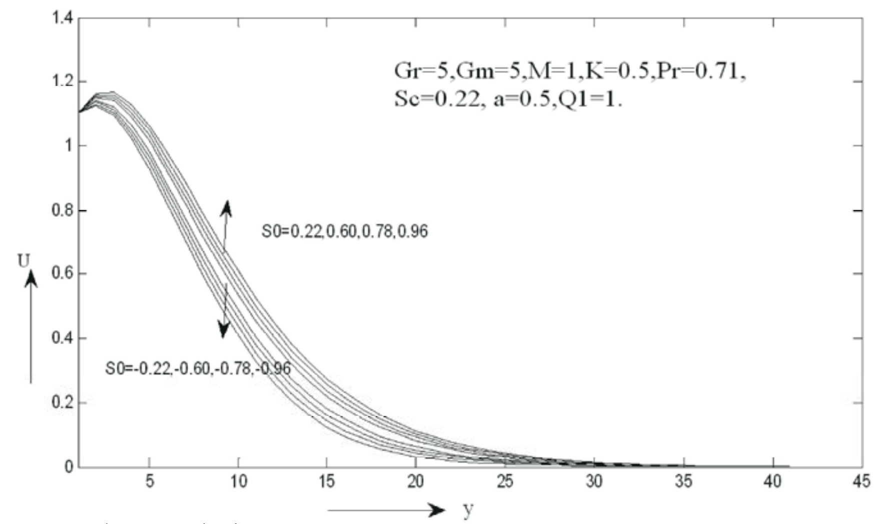


Fig. 8: Effect of Soret number on velocity

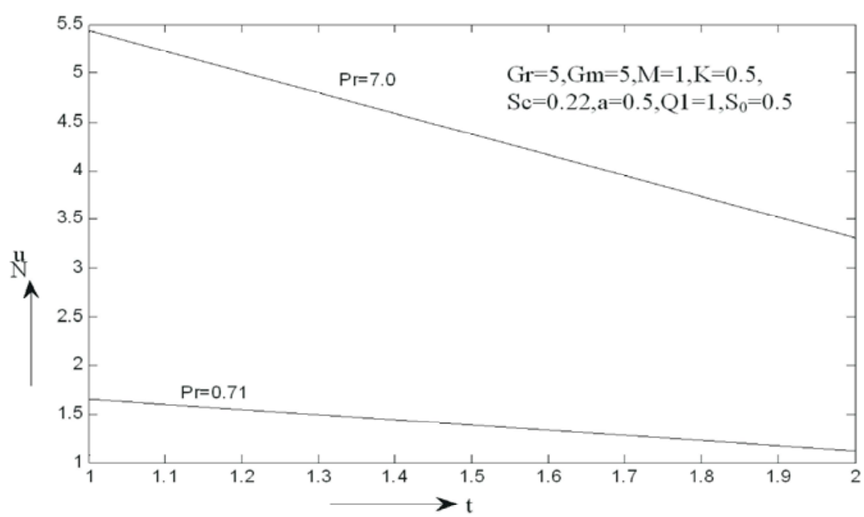


Fig. 9: Effect of Prandtl number on Nusselt number

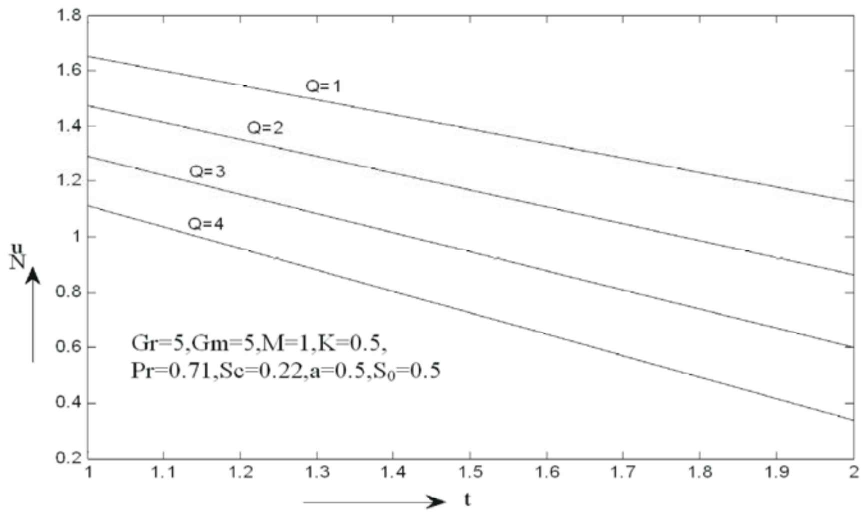


Fig. 10: Effect of Prandtl number on Nusselt number

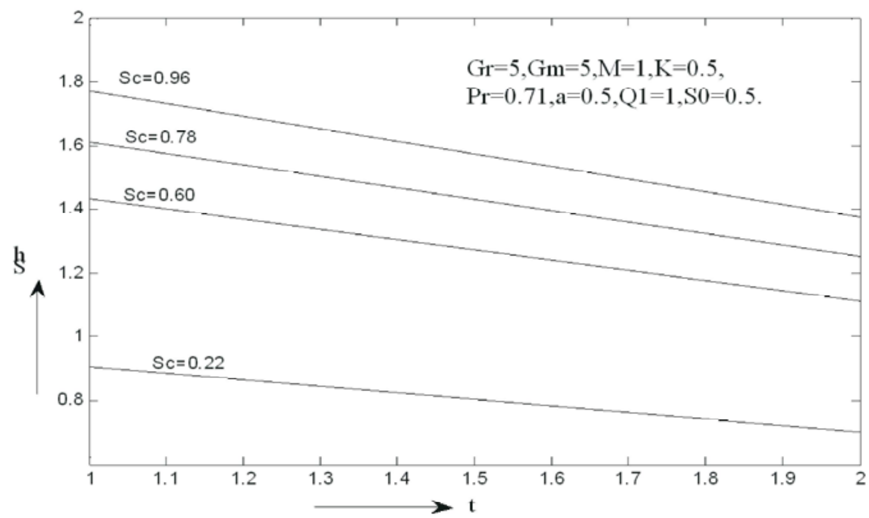


Fig. 11: Effect of Schmidt number on Sherwood number

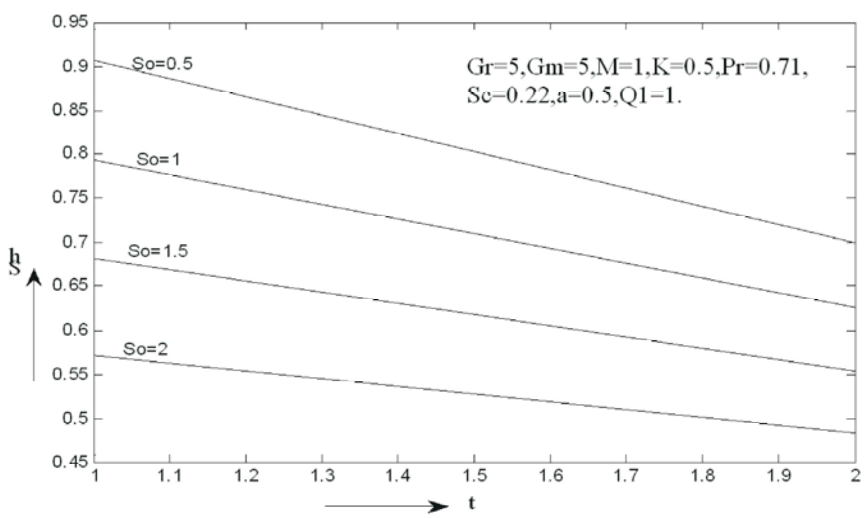


Fig. 12: Effect of Soret number on Sherwood number

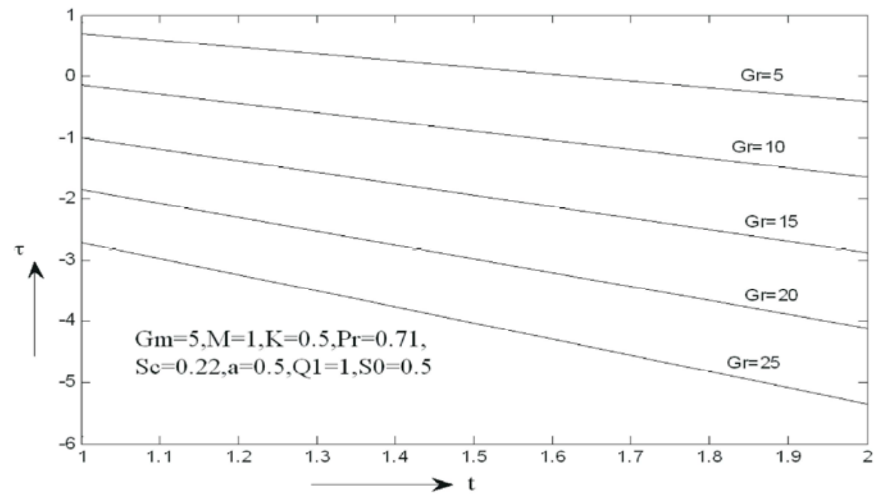


Fig. 13: Effect of Grashof number on Skin friction

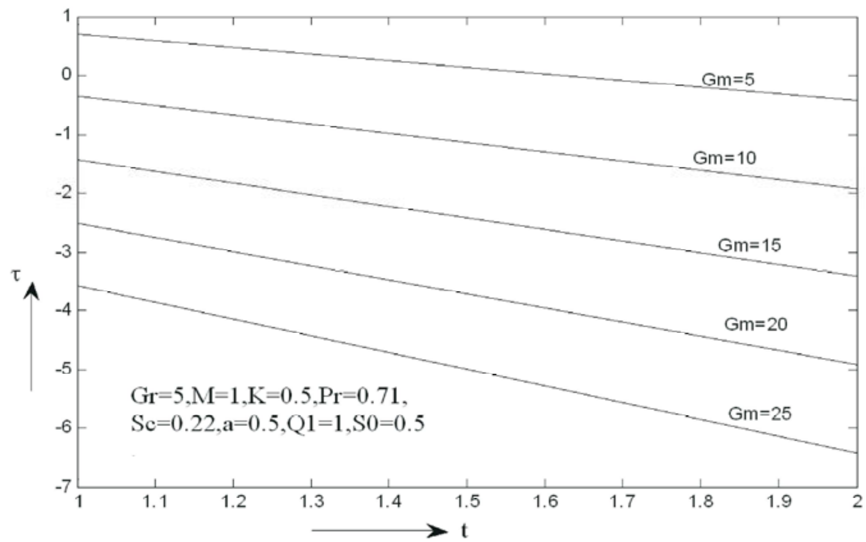


Fig. 14: Effect of modified Grashof number on Skin friction

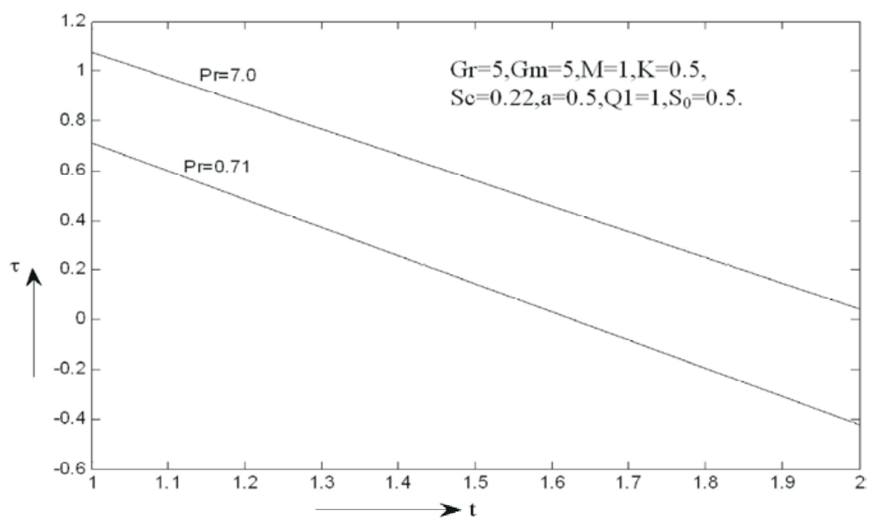


Fig. 15: Effect of Prandtl number number on Skin friction

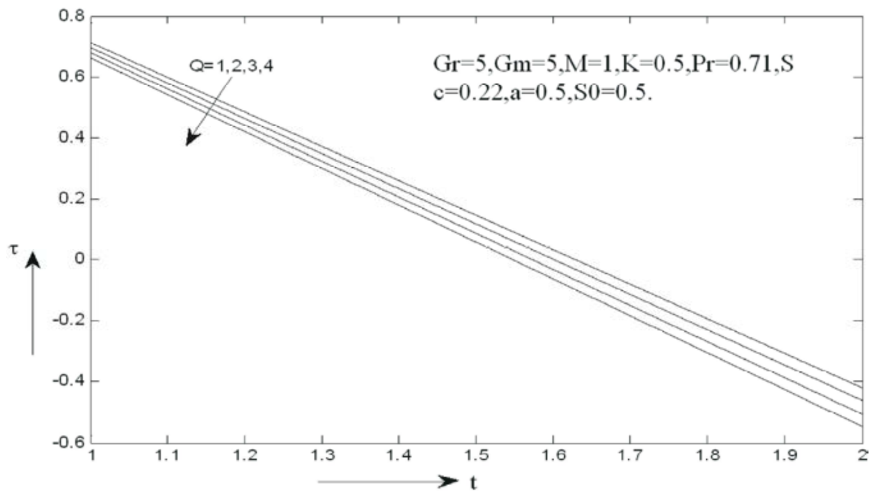


Fig. 16: Effect of radiation absorption parameter on Skin friction

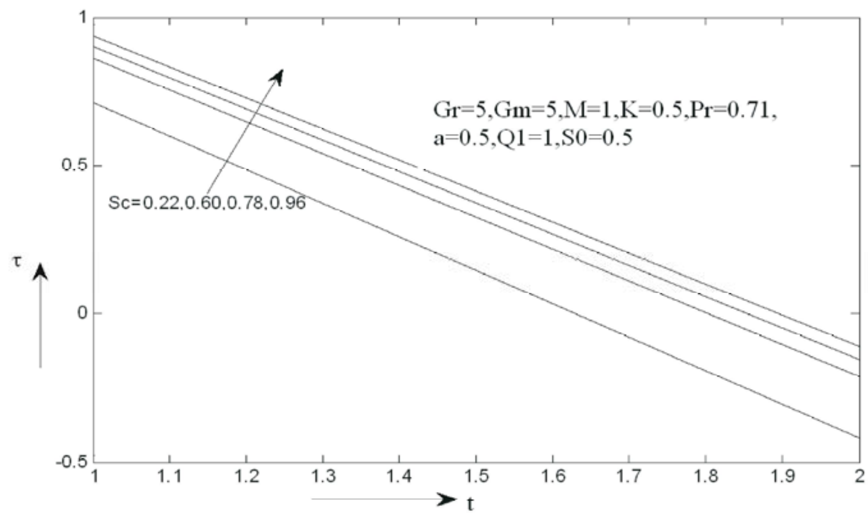


Fig. 17: Effect of Schmidt number on Skin friction

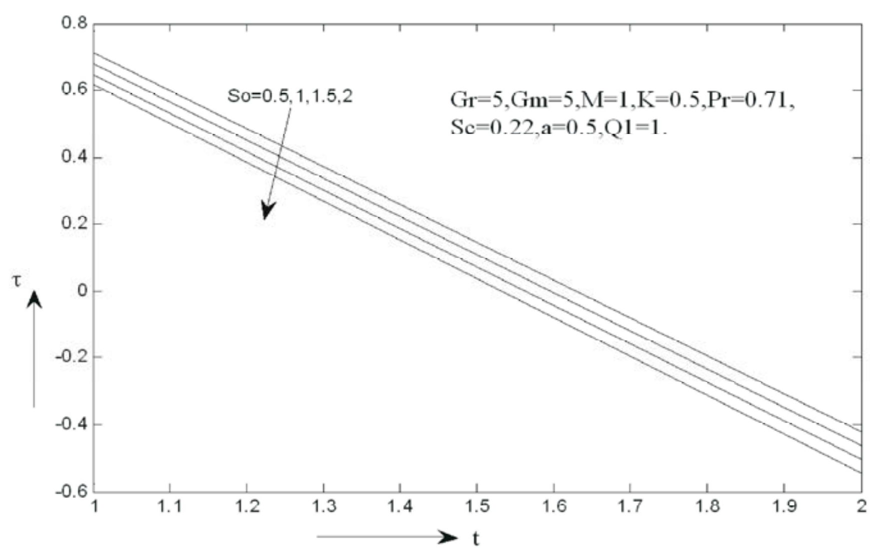


Fig. 18: Effect of Soret number on Skin friction

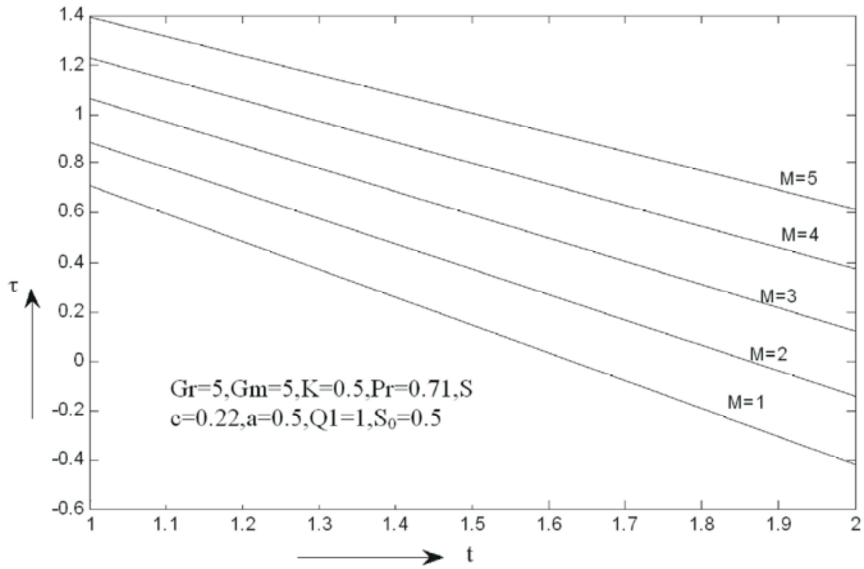


Fig. 19: Effect of Magnetic parameter on Skin friction

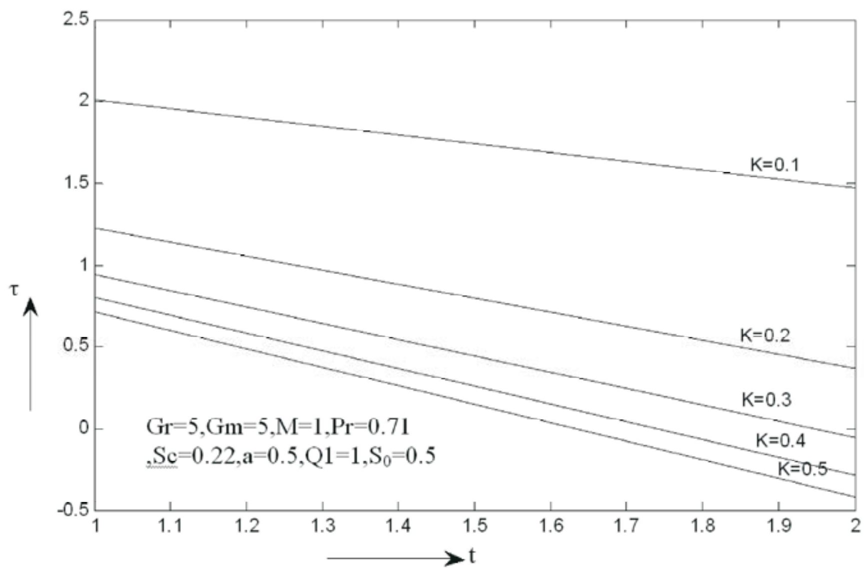


Fig. 20: Effect of Porous permeability on Skin friction

## CONCLUSION

We investigated the exponentially varying temperature and concentration on conducting fluid past an exponentially accelerated vertically plate in conducting field. The governing boundary equations are simplified and non-dimensionalized. The dimensionless equations are solved using the finite difference method. The effects of various physical parameters which are Prandtl number, Radiation absorption parameter, Schmidt number, Soret number, Grashof number, modified Grashof number, Porous permeability, magnetic parameter are considered on the dimensionless velocity, temperature and concentration. Computations on the variation of Skin friction, Nusselt number and Sherwood number are also discussed through the graphs.

## REFERENCE


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