International Journal of Mathematical Analysis and Modelling

(Formerly Journal of the Nigerian Society for Mathematical Biology)

Volume 6, Issue 2 (Oct.-Nov.), 2023

ISSN (Print): 2682 - 5694
ISSN (Online): 2682 - 5708

International Journal of Mathematical Analysis and Modelling
Volume 6, Issue 2, October-November 2023, pages 159 – 192

Analysis of heat and mass transfer on magnetohydrodynamics (MHD) natural convective fluid flow over vertical and inclined porous media

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Abstract

Heat and mass transfer effects on MHD natural convective fluid flow over vertical and inclined porous media are analyzed in this paper, unsteadily. Non-dimensional differential equations are derived from the governing equations and are solved numerically using the fourth-order classical Runge-kutta method. First, we did a first-order reduction of the coupled ordinary differential equations. Furthermore, MATLAB was used to obtain and evaluate numerical expressions for the distributions of fluid velocities, temperatures, and concentrations. The Soret and dufour effects, or the impact of an inclination angle on the flow field, were the subject of an attempt at explanation. The equations for momentum, energy, and concentration are shown to be solvable as coupled second-order partial differential equations. The velocity, temperature, and concentration profiles in the flow domain are displayed graphically for a range of issue parameters. When the fluid's temperature, concentration, and velocity all rise due to the Grashof number (Gr), modified Grashof number (Gc), the Soret number (Sr), angle of inclination (α), Dufour number (Df), magnetic parameter (M) Increase and thus thickening the thermal boundary layer across the channel. There is a negative correlation between the Grasholf number (Gr) and fluid velocity, temperature, and concentration, However, the magnetic parameter (M), chemical reaction parameter (Kr), Schmidt number (Sc), Prandtl number (Pr), and the angle of inclination parameter (I) are all directly related to one another. Heat transfer at the wall is improved by a rise in the Prandtl number (Pr), radiation parameter (R), and Grasholf number (Gr), whereas mass transfer is sped up by an increase in the chemical reaction parameter (Q), the Schmidt number (Sc), the Grasholf number (Gr), and the heat source parameter (Q). While we used mat lab, an order-based computer program, and a traditional fourth-order Range-Kutta iteration technique to calculate the table, interested researchers are free to try out other order-based computer programs, such as maple, cubic, etc., to provide alternative solutions.

Keywords and phrases: MHD; heat source; heat transfer; mass transfer; porous medium; inclined angle; thermal radiation

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1 Introduction

As a result of its ubiquitous presence in many scientific and engineering disciplines, Magnetohydrodynamic (MHD) research in heat and mass movement has significant real-world applications for engineers and scientists. Unsteady MHD free convective flow over a vertical porous plate has been studied extensively for their effects on heat mass transport. Unsteady temperature with heat and mass change flows across a proliferating material at the control of a magnetic zone/edge with chemical reactions has attracted a growing number of researchers in recent years. Geothermal energy usage, cooling of reentry vehicles and rocket boosters, thermal energy storage, etc. are only a few examples of how this concept has been put into practice in other scientific and technological fields. [29] Studied the effects of unsteady MHD fluid flow over a vertically inclined porous plate on chemical reactions, aligned magnetic fields, radiation, and soret. [14] Investigate the convective heating of a vertical channel using a porous material and the resulting unsteady MHD free convection flow of an exothermic fluid. [17] Studied a generic solution for an unstable MHD natural convection flow involving an infinite vertical plate immersed in a porous medium and subject to random motion.

Heat and mass transfer effects on MHD flow over an inclined porous plate were investigated by [36] in the presence of a chemical reaction. [30] Investigated heat and mass transport in an unsteady MHD flow between two vertical porous plates. [41] Investigate Heat and mass transfer effects on unsteady MHD flow a past an inclined plate embedded in porous medium in the presence of hall current an viscous dissipation. [35] Studied Steady on MHD Heat and mass transfer flow of an inclined porous plate in the presence of Radiation and Chemical Reaction. [39] Investigate unsteady MHD Slip flow past a inclined porous plate with hall current and temperature gradient dependent heat source with fluctuating temperature and concentration in presence of radiation and Soret effect in a rotating system.

The porous medium in a horizontal channel with an inclination magnetic field is studied by [25] for its potential to facilitate both unsteady fluid flow and heat transfer. Using a periodic magnetic field and a constant pressure gradient, [1] investigated unsteady MHD flow and heat transfer through a porous medium between parallel plates. The regulation of micropolar fluid flow and heat transfer via porous media in a horizontal channel was investigated by [23]. Steady Magnetohydrodynamic Micropolar Fluid Flow and Heat and Mass Transfer in Permeable Channel with Thermal Radiation were studied by [3]. Researchers [15] looked at the effects of a chemical reaction on unsteady free convection MHD flow across a vertical cone in porous media.

The work in [27] investigated the free convection flow of magnetohydrodynamics (MHD) past an infinite sloping plate. Non-Newtonian fluid flow with heat transfer over a porous stretching/shrinking sheet is described by [46]. [28] Have taken into account the magneto-hydrodynamic (MHD) flow and heat transmission of a viscous incompressible fluid via a porous material. In the presence of a heat source, the Soret effect, and a chemical reaction influenced by viscous dissipation ohmic heating, [45] investigated MHD free convection flow across an inclined porous plate. Heat and mass transport of MHD for a non-stationary viscous oscillatory flow. Magnetohydrodynamic (MHD) study into the fundamentals of chemical reactions, such as heat and mass transfer, and unsteady viscous oscillatory flow, was given by [2].

Suction, viscous dissipation and thermal radiation were all factors in the transient magnetohydrodynamic natural convection boundary layer flow that [47] examined. (i) Ground water flow through soil and rocks, which is crucial for agriculture and pollution control, is an example of MHD fluid in a porous medium. (ii) Removing rock's natural gas and soil from it. Bone, cartilage, and muscle have all been established by [4] as functional tissues thanks to the steady stream of blood and nutrients that feed them. [5] Studied MHD heat and mass transfer in porous medium, with an emphasis on the quality of environmental cleanup and restoration. Heat and mass transfer in a permeable channel subjected to thermal radiation was investigated by [33]. Results of soret and douour analysis of Revlin-Erickson fluid's MHD free convective drift through a semi-endless vertical plate are reported. Using chemical reaction, an arbitrary shear stress, and exponential heating. [16] Investigated convection heat mass transfer and MHD flow over a vertical plate. Thermal radiation heat transfer has become so important at greater temperatures, as indicated by [20]. The significance of heat transmission via radiation has to be taken into account. With the addition of thermal radiation effects, the importance of MHD flow, mass, and heat transfer in industrial settings grows. High temperatures are required for many scientific and technical processes. For the purpose of modeling the appropriate instruments, the idea of heat transmission via thermal radiation stands out as particularly salient. The quality of the finished product is highly sensitive to heat and other regulating elements. Using radiative heat transfer in the process could lead to the desired end result.

Heat and mass transfer via MHD free convection with Dufour and chemical reaction effects were investigated by [12]. [38] Studied the dynamics of MHD and convective heat transfer over a vertical plate. The importance of mass transfer in the context of multi-phase, two-dimensional, oscillatory, suction-driven, and thermally-driven flows through a vertical porous plate in a porous medium.

Chaotic MHD In a rotary system featuring a hall current and temperature gradient dependent heat source with temperature and concentration changes, [39] Studied slip flow. [6] Studied the heat and mass transport in a porous medium between two vertical plates undergoing a chemical reaction in an unstable MHD convective flow, on a vertically stretched, permeable surface. [24] Studied the impact of heat production/absorption, thermal radiation, and chemical reaction on steady MHD flow and heat transfer.

The effect of chemical reactions and radiation absorption on convective flows in a porous vertical wavy channel transporting traveling thermal waves was studied by [22]. Unsteady MHD boundary layer flows with slip along an accelerating infinitized vertical plate with a ramping plate temperature were studied by [9]. Recent years have seen substantial progress in study into heat and mass transfer in magneto hydrodynamic flows due to their extensive application in devices like the MHD power generator and the Hall accelerator. Additionally applicable to studies of planetary atmospheres is the effect of a magnetic field on the motion of an electrically conducting viscous fluid undergoing mass transfer and radiation absorption. MHD free convection was investigated by [10] using a semi-infinite vertical porous plate and the diffusion-thermo effect. Unsteady MHD free convective mass transfer is investigated by passing a semi-infinite vertical porous plate through a fluid that is viscous, incompressible, and optically thin. [40] Examined the effects of heat and mass transfer on the flow of a chemically reactive and radiating fluid through a porous medium, through a vertically moving plate with an arbitrarily ramped temperature, in an unsteady MHD natural convection scenario. [32] Study Radiation and heat absorption effects on an unsteady MHD boundary layer flow along an accelerated infinite vertical porous plate with ramped plate temperature in existence of slip condition.

The work in [8] looked into the impact of radiation and chemical reactions on the dynamics of viscoelastic fluid flows in a porous medium. [43] Study effect of thermal radiation on MHD free convective flow via a vertical porous plate in the presence of chemical reaction-FEM, these studies investigate the impact of thermal radiation on the flow of fluids through such plate. [26] Analyzed the effects of thermal radiation on heat and mass transmission in a porous media. In a study published in [11]. looked at the effects of a chemical reaction on free convective MHD radiation flow through a porous vertical plate in a porous median. [44] Studied the impact of radiation and chemical reaction on MHD mixed convective flow and mass transfer using a vertical surface, ohmic heating, and viscous dissipation. Researchers [34] looked at how chemical reactions affected heat and mass transport in a magnetohydrodynamic (MHD) flow over a porous, inclined plate. Soret and Dufort effects on the MHD free convective flow behind an impulsively moving vertical plate in an oblique magnetic field were also investigated [42]. The effects of radiation and chemical reactions on the MHD free convective heat and mass transfer flow of a viscoelastic fluid across a porous heat source (sink) were studied by [37]. The effect of thermal radiation on unsteady magneto-convictive heat and mass transport through a vertical permeable sheet with a chemical reaction was studied by [19]. The slip MHd micro fluid float on a stretching sheet was analyzed by [13]. [21] Study Radiation effect on chemically reacting magnetohydrodynamics (MHD) boundary layer flow of heat and mass transfer through a porous vertical flat plate. [7] investigated Effects of variable transport properties on heat and mass transfer in MHD bioconvective nanofluid rheology with gyrotactic microorganisms. Convection heat mass transfer and MHD flow over a vertical plate with chemical reaction, arbitrary shear stress and exponential heating was study by [18]. Investigation of Steady MHD Natural Convection Heat and Mass Transfer Flow above a Vertical Porous Surface with Thermal Diffusion and Inclined Magnetic Field was done by [31].

In this work, we to determine the heat and mass transfer effects on unsteady MHD natural convective fluid flow over a vertical and inclined porous media. The numerical method is used to achieve our aim. We considered unsteady MHD flow of a viscous incompressible fluid which has the properties electrically conducting, chemically reacting and thermally radiating on limitless vertical porous media with periodical temperature with concentration in flow scheme. The Suction velocity v is of the form

$$v = -v_o(1 + \varepsilon A e^{i\omega t}) \quad (1)$$

where, $v_{o=}$ Suction velocity which is non-zero positive Constance. The suction is directed toward the plate, as shown by the negative sign; $\varepsilon =$ Small such that $A\varepsilon \ll 1$, $\omega =$ Frequency of oscillation, t= time and A= Positive real constant

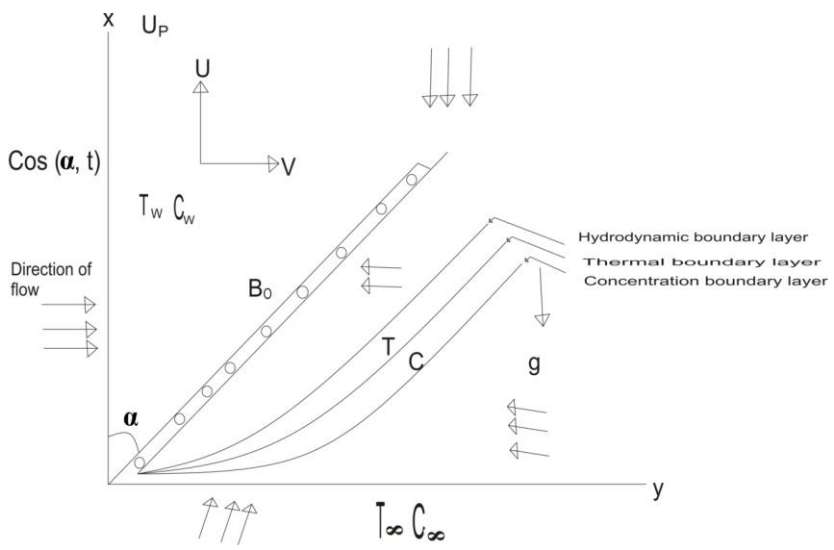

Figure 1: Physical Model and coordinate system of the problem.

The x-axis takes upward vertically alongside vertical porous plate and y-axis forming right angle to that A consistent magnetic force B_o is used perpendicular to the surface of the plate. Consider an infinite flat is in the x-direction so all value are independent of x. Assume the variables are dependent on y and t most effective.

The radiative heat flux is described using Rosseland's approximation, which assumes that the fluid is a gray absorbing emitting radiation but non scattering medium. When contrasted to the y-direction, the x-direction component is deemed to be insignificant. A homogeneous magnetic fluid was applied perpendicular to the surface of stretching. Since it was believed that both the magnetic Reynolds number and the transverse applied magnetic field were quite small, the x-axis is the direction along the stretching surface and indicates the direction of motion. The slant or inclined angle α and y-axis is perpendicular to it. At time $t > 0$ the plate is suddenly accelerated in the direction of flow, against gravity, along the x-axis with constant velocity U_p. Furthermore, it is believed that the suction velocity, wall temperature, and concentration all change exponentially with time, where u Is an inlet velocity component in x-direction, v Is an inlet velocity component in y-direction and w Is an inlet velocity component in z-direction. Therefore, the fluid element of length dx, dy, dz in the direction of x, y, z.

In this work, we assumed that: Induced magnetic is negligible because magnetic fields Reynolds number will be small. In between fluid and species concentration a first order chemical reaction exists. Heat generation throughout the chemical reaction negligible because the extend of species concentration could be very low. Liquid is grey and it absorbs and emits radiation in a non-scattering medium. A small velocity encountered in the free convective flow, so viscous dissipation and joule heating phrases will be neglected. No outside electric force will be carried out, thus electric field will be assumed to be zero. At constant temperature (T_w) the wall is maintained and concentration (C_w) higher than the ambient temperature (T_∞) and concentration (C_∞) respectively. A uniform magnetic field acts perpendicular to the porous plate, which absorbs the fluid with a suction velocity varying with time. The porous plate assumed to move with a constant velocity in the direction of the fluid flow.

Under the above assumption, the governing equations for the situation of the problem that describe the physical situation of the new equations are given by

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{2}$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} - v_0(1 + \varepsilon A e^{i\omega t})\frac{\partial u}{\partial y} = v\frac{\partial^2 u}{\partial y^2} + g\beta_T(T - T_\infty)\cos\alpha + g\beta_C(C - C_\infty)\cos\alpha - \left(\frac{\sigma\beta_0^2}{\rho} + \frac{v}{K}\right)u \tag{3}$$

$$\rho C_p\left[\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} - v_0(1 + \varepsilon A e^{i\omega t})\frac{\partial T}{\partial y}\right] = K\frac{\partial^2 T}{\partial y^2} + Q_0(T - T_\infty) + v\left(\frac{\partial u}{\partial y}\right)^2 - \frac{\partial q_r}{\partial y} + \frac{D_m K_T \partial^2 T}{T_m \partial y^2} \tag{4}$$

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} - v_0\left(1 + \varepsilon A e^{i\omega t}\right)\frac{\partial^2 C}{\partial y^2} = D\frac{\partial^2 C}{\partial y^2} - K_r(C - C_\infty) + \frac{DK_r \partial^2 T}{C_m \partial y^2} \tag{5}$$

The 2nd and 3rd terms on the right hand side of equation (3) denote thermal and concentration buoyancy effects respectively. Also the 4th and 5th terms on the right side of the equation (4) represents the radiative heat flux and the Dufour and Soret effects, with the following initial and boundary conditions;

$t \leq 0; u = 0, T = T_\infty, C = C_\infty, for$ all y

$$t > 0\{u = u_p, T = T_\infty + \varepsilon(T_w - T_\infty)e^{i\omega t}, C = C_\infty + \varepsilon(C_w - C_\infty)e^{i\omega t}, at y = 0\}$$
$$u \to 0, T \to 0, C \to 0 as y \to \infty \quad (6)$$

where T_w is the Temperature near to the wall, T_∞ is the Measures of temperature a long way from the wall or ambient temperature, C_w is the Species density near to the wall, C_∞ is the Species density a long way from the wall or ambient Species density, u is the velocity component in x-direction, v is the velocity component in y-direction, B_0 is the magnetic field strength, g is the acceleration due to gravity, D is the Chemical Molecular dispense, C is the Species density, T is the Temperature of fluid σ is the Electrical Conductibility, K is the Thermal Conductibility, C_p is the Specific Warmness at the consistent strain, v is the Kinematical Viscosity, β_T is the Constant of the volume elaboration for heat transfer, β_C is the Volumetric Constant of elaboration for mass transfer, K_r is the Chemical Reaction parameter, D_m is the Mass diffusivity q_r is the Radiative heat flow, D_k is the Darcy porosity parameter. Q is the Heat sources parameter, ρ is the Density of the fluid , α is the Inclined angle, U_p is the Plate velocity, ε is a positive constant, v_0 is the Suction velocity, K_T is the thermal diffusion effect, T_m is the mean temperature of the fluid, β_T and β_C are the thermal and mass expansion confidents respectively, Gr is Grashof number for heat transfer, Gc is Grahof number for mass transfer.

Using Rosseland diffusion approximation for radiation heat flux $q_r = -\frac{4\sigma}{3\delta k}\frac{\partial T^4}{\partial y^2}$ Using Taylor series to expand T^4 and the free stream T_∞ and neglecting higher order terms, this gives the approximation

$$T_\infty^4 \cong 4T_\infty^3 T - 3\delta k T_\infty^4 \quad (7)$$

Introducing the stream function (x,y)such that:

$$u = \frac{\partial \psi}{\partial y}, \quad v = -\frac{\partial \psi}{\partial x} \quad (8)$$

Using equation (8) into equation (2),(3),(4) and (5), Equation (2) its satisfiers, therefore (3) (4) and (5) becomes

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{9}$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\upsilon\frac{\partial^2 u}{\partial y^2}-\frac{\sigma B_0^2}{\rho}u-\frac{\upsilon}{K}u+g\beta_{\mathrm{T}}(T-T_\infty)\cos\alpha+g\beta_{\Gamma}(C-C_\infty)\cos\alpha \tag{10}$$

$$\frac{\partial T}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\frac{K}{\rho C_p}\frac{\partial^2 T}{\partial y^2}+\frac{Q_0}{\rho C_p}(T-T_\infty)-\frac{1}{\rho C_p}\frac{\partial q_r}{\partial y}+\frac{D_\kappa K_\tau}{T_\tau}\frac{\partial^2 T}{\partial y^2} \tag{11}$$

$$\frac{\partial C}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=D\frac{\partial^2 C}{\partial y^2}-K_r(C-C_\infty)+\frac{DK_\Gamma}{C_m}\frac{\partial^2 T}{\partial y^2} \tag{12}$$

Subject to the boundary condition below:

$$\left\{\begin{matrix} u=U_0\ell^{x/L},\ v=-U_0\ell^{x/L},\ C=C_\infty \quad @\,y=0 \\ y\to\infty,\quad u\to 0,\quad C\to C_\infty \quad @\,y=0 \end{matrix}\right\} \tag{13}$$

In order to solve equation (2) to (5) we introduce the following similarity transformations and diamentionaless concentration and temperature.

$$\psi(x,y)=(2t\,\mathrm{Re})^{1/2}\upsilon\ell^{x/2L}f(\eta) \tag{14}$$

$$\eta=\frac{y}{L}\left(\frac{\mathrm{Re}}{2t}\right)^{1/2}\ell^{x/2L} \tag{15}$$

$$\phi(\eta)=\frac{C-C_\infty}{C_w-C_\infty}=C=C_\infty+C_0\ell^{x/2L}\phi(\eta) \tag{16}$$

$$\theta(\eta)=\frac{T-T_\infty}{T_w-T_\infty}=T=T_\infty+T_0\ell^{x/2L}\theta(\eta) \tag{17}$$

$$T_0=T_w-T_\infty,C_0=C_w-C_\infty$$

where η is the similarity variable, $\psi(x,y)$ is the dimensionless stream function $\phi(\eta)$ is the dimensionless concentration and $\theta(\eta)$ is the dimensionless temperature. The equations are solving by their steps, by inserting (8) into (2) we have

$$\frac{\partial}{\partial x}\left(\frac{\partial\psi}{\partial y}\right)+\frac{\partial}{\partial y}\left(-\frac{\partial\psi}{\partial x}\right)=0$$

$$\frac{\partial^2\psi}{\partial x\partial y}-\frac{\partial^2\psi}{\partial y\partial x}=0 \tag{18}$$

It's satisfied the Cauchy-Riemann equation. Using (8) into (3), (4), and (5), we have

$$\frac{\partial}{\partial t}\left(\frac{\partial \psi}{\partial y}\right)+\frac{\partial \psi}{\partial y}\frac{\partial^2 \psi}{\partial x \partial y}-\frac{\partial \psi}{\partial x}\frac{\partial^2 \psi}{\partial y^2}=\upsilon\frac{\partial^2}{\partial y^2}\left(\frac{\partial \psi}{\partial y}\right)-\frac{\sigma\beta_0^2}{\rho}\frac{\partial \psi}{\partial y}-\frac{\upsilon}{k}\frac{\partial \psi}{\partial y}+g\beta_{\mathrm{T}}(T-T_\infty)\cos\alpha$$
$$+g\beta_c(C-C_\infty)\cos\alpha \quad (19)$$

$$\frac{\partial T}{\partial t}+\frac{\partial \psi}{\partial y}\frac{\partial T}{\partial x}-\frac{\partial \psi}{\partial x}\frac{\partial T}{\partial y}=\frac{K}{\rho C_p}(T-T_\infty)-\frac{\partial q_r}{\partial y}\frac{1}{\rho C_p}+\frac{D_\kappa K_{\mathrm{T}}}{T_\tau}\frac{\partial^2 T}{\partial y^2} \quad (20)$$

$$\frac{\partial \psi}{\partial y}\frac{\partial C}{\partial x}-\frac{\partial \psi}{\partial x}\frac{\partial C}{\partial y}=D\frac{\partial^2 T}{\partial y^2}+K_r(C-C_\infty)+\frac{DK_\Gamma}{C_m}\frac{\partial^2 T}{\partial y^2} \quad (21)$$

Non- dimensional quantities are defined by

$$M=\frac{4tL^3\sigma B_0^2}{\mathrm{Re}\,\rho\upsilon}\mathrm{Re}\,\ell^{-x/L} \quad Gr=\frac{4tL^3 g\beta_{\mathrm{T}}(T_0)}{(\mathrm{Re}\,\upsilon)^2}\ell^{-3x/2L} \quad Gc=\frac{4tL^3 g\beta_C(C_0)}{(\mathrm{Re}\,\upsilon)^2}\ell^{-3x/2L} \quad D_k=\frac{2L^2}{\mathrm{Re}\,K\upsilon}\mathrm{Re}\,\ell^{-x/L}$$
$$R=\frac{4\sigma T_\infty^3}{\delta k},\quad Q=\frac{Q_0\,2L^2\upsilon}{K\,\mathrm{Re}}\ell^{-x/L},\quad P_r=\frac{\upsilon\rho C_p}{K},\quad D_f=\frac{D_m K_{\mathrm{T}}}{T_m}\frac{\upsilon\rho C_p}{K}\ell^{-3x/2L},\left(\frac{\partial u}{\partial y}\right)_{y=0} \quad (22)$$

$$S_C=\frac{\upsilon}{D},\quad K_r=\frac{K_r}{\mathrm{Re}\,\upsilon}C_0\ell^{-3x/2L},\quad S_r=\frac{DK_\Gamma}{C_m}C_0\,\mathrm{Re}\,\ell^{x/L}$$

where Gr is the Grashof number, Gc is the modified Grashof number, M is the magnetic parameter, Kr is the Chemical Reaction parameter, Pr is the Prandtl number, Sc is the Schmidt number, D_k is the Darcy porosity parameter, Q is the Heat sources parameter, R is the radiation parameter, Sr is the Soret number, Df is the Dufour number respectively.

From equation (9) to (12), the following nonlinear equations (19) to (21) were obtained:

$$f'''+2tff''+2\eta f''-4tf'^2-(M+D_K)f'+Gr\theta\cos\alpha+Gc\phi\cos\alpha=0 \quad (23)$$

$$\left(1+\frac{4}{3}R\right)\theta''+P_r\left(f\theta'+\frac{\eta}{t}\theta'+Q\theta+D_f\theta''\right)=0 \quad (24)$$

$$\phi''+S_C\left(f\phi'+\frac{\eta}{2t}\phi'-K_r\phi+S_r\phi''\right)=0 \quad (25)$$

And the transform boundary conditions

$$f=f_w,\ f'(0)=0,\ \theta(0)=1,\phi'(1)=1\ \ at\ \eta=0 \quad (26)$$
$$f=0,\ f'(1)=0,\ \theta'(0)=1,\phi(0)=0\ \ at\ \eta=1$$

2 Method of solution

Non-linear ordinary differential equations are utilized for controlling the convection of heat and other physical substances via porous media. In order to control the convective motion of MHD fluids, these equations are used. With the shooting approach and a fourth-order Runge-Kutta scheme, non-linear ODE systems with boundary constraints can be numerically solved. The Runge-Kutta technique works well for such purposes. The method has been widely employed due to its efficacy in solving boundary layer equations, which appears to yield correct results (Ibrahim and Makinde, 2011). It seems to be the most flexible of the common methods. The scheme is also applicable to various types of boundary layer flow problems including the free and mixed connection flows. In the numerical system employed in solving the equation or models, that is the (BVP) boundary value problem. Shooting method reformulates the BVP to IVP by adding sufficient number of conditions at one end and adjusts these conditions until the giving conditions are satisfied at the other end while Runge-Kutta method solves the initial value problems. Here 4th order Runge-Kutta techniques where used to find the root and the scheme which is given below:

$$y_{n+1} = y_n + \frac{h}{6}\left(k_1 + 2k_2 + 2k_3 + k_4\right) \quad (27)$$

$$k_1 = hf\left(x_n, y_n\right) \quad (28)$$

$$k_2 = hf\left(x_n + \frac{h}{2}, y_n + \frac{k_1}{2}\right) \quad (29)$$

$$k_3 = hf\left(x_n + \frac{h}{2}, y_n + \frac{k_2}{2}\right) \quad (30)$$

$$k_4 = hf\left(x_n + h, y_n + hk_3\right) \quad (31)$$

n = 0, 1, 2…..

To apply the fourth order classical Runge-kutta method, for unsteady we first reduce the coupled ordinary differential equations in equation of order one

$$\begin{aligned}
&x_1 = f, x_2 = f', x_3 = f'', x_4 = \theta, x_5 = \theta', x_6 = \phi, x_7 = \phi' \\
&x_1' = f' = x_2, x_4' = \theta' = x_5, x_6' = \phi' = x_7 \\
&x_2' = f'' = x_3, x_5' = \theta'', x_7' = \phi' \\
&x_3' = f''' \quad (32)
\end{aligned}$$

$$x_3' = 4tx_2^2 + (M + D_k)x_2 - (2tx_1 + 2\eta)x_3 - G_r x_4 \cos\alpha - G_c x_6 \cos\alpha \quad (33)$$

$$x_5' = \frac{-P_r x_1 x_5 - P_r \frac{\eta}{t} x_5 - P_r Q x_4}{\left(1 + \frac{4}{3}R + P_r D_f\right)} \quad (34)$$

$$x_7' = \frac{S_c K_r x_6 - S_c x_1 x_6 - S_c \frac{\eta}{2t} x_7}{\left(1 + S_c S_r\right)} \quad (35)$$

3 Result and discussions

For the case of different values of the thermal Grashof number (Gr), the velocity profiles on the boundary layer are shown in figures 2, 3 and 4, it is observed that an increase in the Grashof number (Gr) the peak values of the velocity increase rapidly near the porous medium and then decay smoothly to the free stream velocity, temperatures and concentration.

The effect of the heat source (Q) on the velocity, temperature and concentration fields, it is visible that for the increase of the heat source parameter (Q), the velocity decreases but temperatures and concentration are both increasing for unsteady case. The profiles are presented in figures 5, 6 and 7.

Also the effect of the magnetic field on the velocity, temperature and concentration profiles. It is observed that the velocity, temperature and concentration decreases with an increasing magnetic parameter (M). This is because of the Lorentz force acting on the fluid flow. This type of resisting force slows down the fluid velocity as it is in figure. The effect of the permeability parameter in the velocity, temperature and concentration profile is depicted in figures 8, 9, 10. The effects of the modified Grashof number (Gc) on the velocity, temperatures and concentration profile. It is observed that as the modified Grashof number increases the velocity, temperatures and concentration profiles increases. The profiles are presented in figures 11, 12 and 13. The profiles are presented in figures. 14, 15, and 16 displayed the effect of various values of (Sr) on the velocity, temperature and concentration distribution for fixed values of Prandtl nuber Pr, Gr, M, and Q. It was observed, from the graph that increasing the (Sr) leads to increase in the velocity but has no effect on the temperature and the concentration distribution across the channel.

The effect of the Schmidt number (Sc) on the velocity, temperatures and concentration profiles, it is observed that as the Schmidt number increases the velocity, temperatures and concentration profiles also increases, due to the molecular diffusivity and boundary layer thickness. The profiles are presented in figures 16, 17, and 18. The influence of the radiation parameter (R) on the the velocity, temperatures and concentration profiles, it is observed that as the thermal radiation increases, the velocity, temperatures and concentration increases but without much effect on the profile due to the boundary layer getting thicker. The profile are presented in figures 19, 20, and 21. Figures 22, 23, and 24 represent the velocity, temperature and concentration profiles for different values of the Prandtl number $(\Pr)$. It is observed that the Prandtl number $(\Pr)$ increases the temperatures profiles increases but have no effect on velocity and concentration profiles due to the thermal boundary layer thickness. Because of the smaller values of the Prandtl numbers, the rate of heat transfer is reduced and the boundary layer is thicker. The effects of chemical reaction parameters and the velocity, temperatures and concentration profiles are presented in figures 25, 26, and 27 respectively. It is observed that on the velocity, temperatures and concentration profiles are decaying functions of amassed values of the chemical reaction parameter (Kr). Increased in values of chemical reaction parameter velocity and temperatures profiles increases but have no effect on concentration profile.

The effect of D_k the Darcy porosity parameter (D_k) on the velocity, temperatures and concentration profiles, it is observed that as the Darcy porosity parameter increases the velocity, temperatures and concentration profiles has no effect for. The profiles are presented in figures 28, 29 and 30. Figures 31, 32, and 33 displayed the effect of various values of (D_f) on the velocity, temperature and concentration distribution for fixed values of Prandtl nuber Pr, Gr, M, and Q. It was observed, from the graph that increasing the (D_f) leads to increase in the velocity, temperature and concentration distribution across the channel. Increase in Prandtl number (Pr), radiation parameter (R), Grasholf number (Gr), Increase the heat transfer at the wall and under the effect of the chemical reaction parameter(Q), Schmidt number (Sc), Grasholf number (Gr), and heat source parameter (Q), enhance the rate of mass transfer. Increase magnetic parameter (M), angle of inclination, decreases in velocity, temperature and concentration but has not much effect on Grasholf number (Gr).

Table 1: Numerical Results for different Parameter Values for unsteady

Parameters	Values	$f''(0)$	$-\theta'(0)$	$-\phi'(0)$
Gr	5.0	1.1823	1.7538	8.6844
	10.0	1.2773	1.7596	3.6852
	15.0	1.4447	1.7753	8.7298
	20.0	9.6917	1.7537	8.8700
Q	0.1	1.9892	5.6279	3.2117
	0.3	7.7893	5.6548	3.2144
	0.5	-2.5041	5.6563	3.2327
	0.7	-4.1751	5.6533	3.2419
M	1.0	5.6836	5.4372	2.3821
	3.0	7.4730	5.4571	2.4304
	5.0	-2.2493	5.3719	2.4516
	7.0	-8.0034	5.3738	2.3627
Gc	5.0	3.4097	-3.4713	-5.5462
	10.0	2.9211	-3.1122	-4.5580
	15.0	2.2377	-2.4820	-3.6644
	20.0	1.8517	-1.4852	-1.3344

Sr	0.2	2.5968	1.1017	1.7097
	0.4	3.1234	2.1018	2.7095
	0.6	4.5950	3.1234	4.2345
	0.8	5.2223	4.1011	4.7788
Sc	5.0	1.1823	1.7538	8.6844
	10.0	1.2773	1.7596	3.6852
	15.0	1.4447	1.7753	8.7298
	20.0	9.6917	1.7537	8.8700
R	1.0	5.6836	5.4372	2.3821
	3.0	7.4730	5.4571	2.4304
	5.0	-2.2493	5.3719	2.4516
	7.0	-8.0034	5.3738	2.3627
Pr	0.2	2.5968	1.1017	1.7097
	0.4	3.1234	2.1018	2.7095
	0.6	4.5950	3.1234	4.2345
	0.8	5.2223	4.1011	4.7788
Kr	0.1	1.9892	5.6279	3.2117
	0.3	7.7893	5.6548	3.2144
	0.5	-2.5041	5.6563	3.2327

	0.7	-4.1751	5.6533	3.2419
Dk	5.0	3.4097	-3.4713	-5.5462
	10.0	2.9211	-3.1122	-4.5580
	15.0	2.2377	-2.4820	-3.6644
	20.0	1.8517	-1.4852	-1.3344
Df	5.0	3.4097	-3.4713	-5.5462
	10.0	2.9211	-3.1122	-4.5580
	15.0	2.2377	-2.4820	-3.6644
	20.0	1.8517	-1.4852	-1.3344

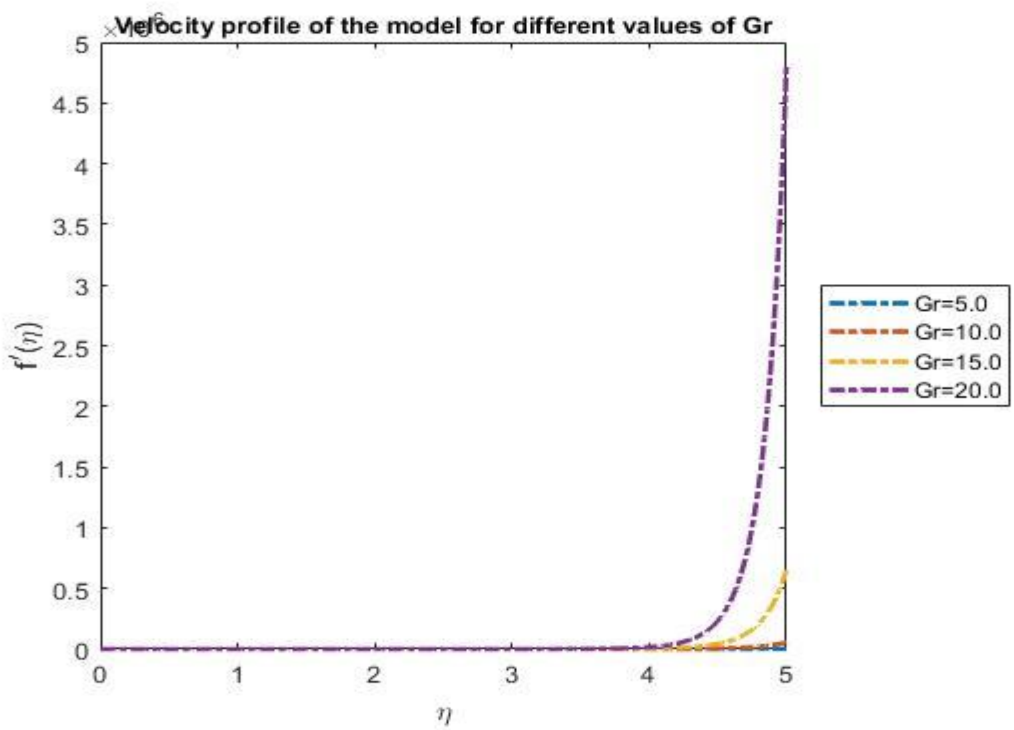

Figure 2: Velocity profile of the model for different values of Gr Number

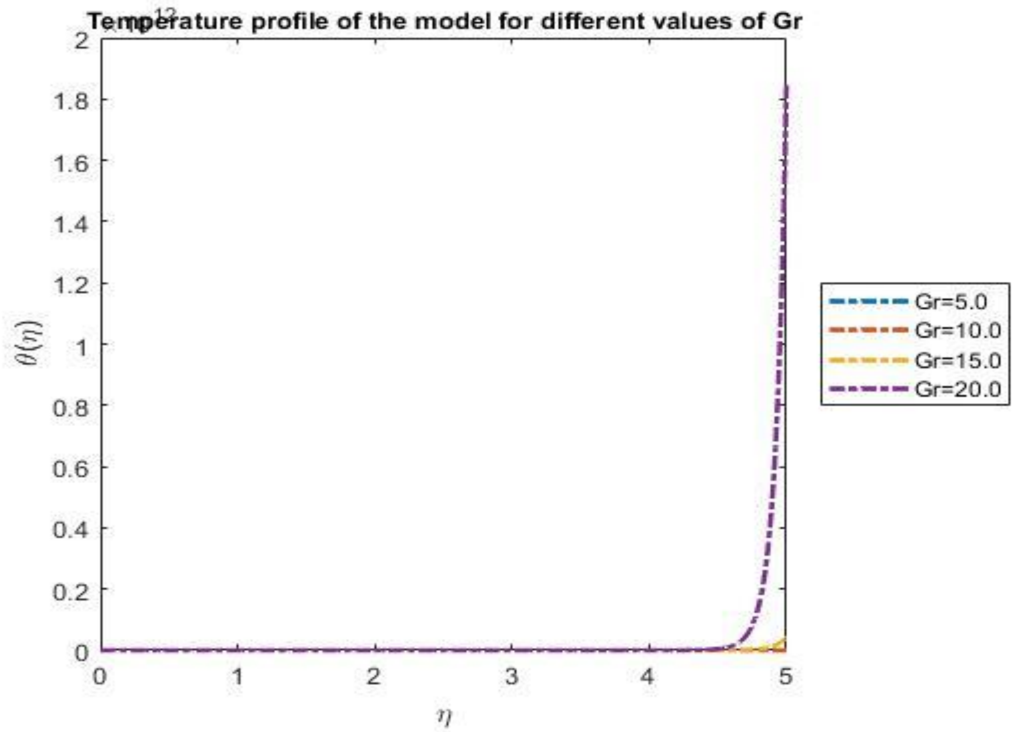

Figure 3: Temperature profile of the model for different values of Gr Number

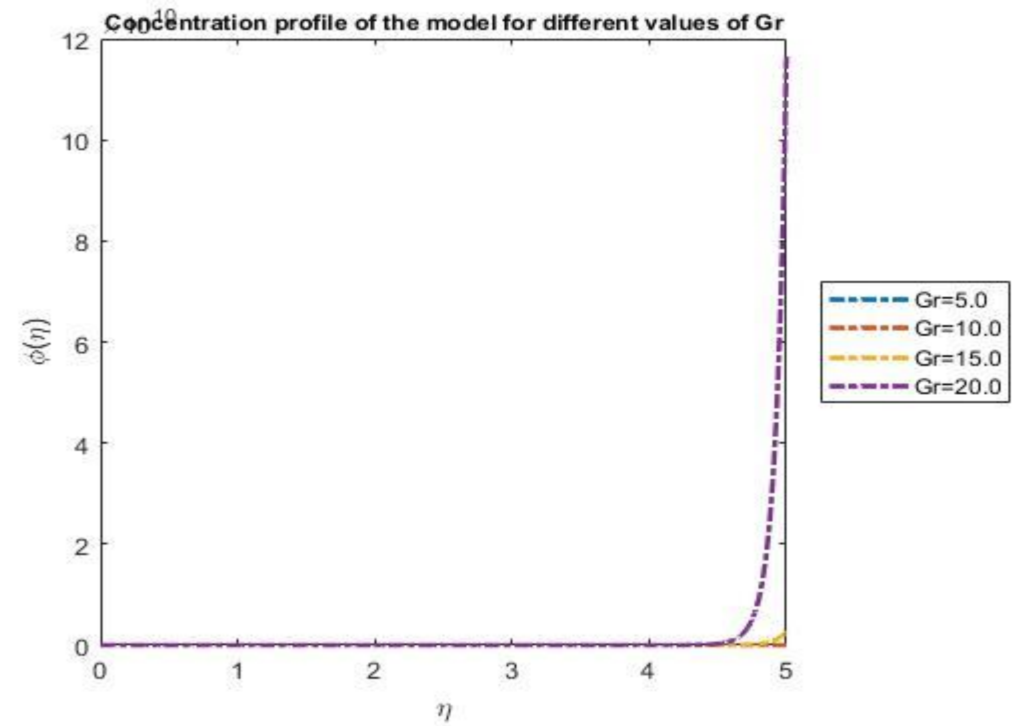

Figure 4: Concentration profile of the model for different values of Gr Number

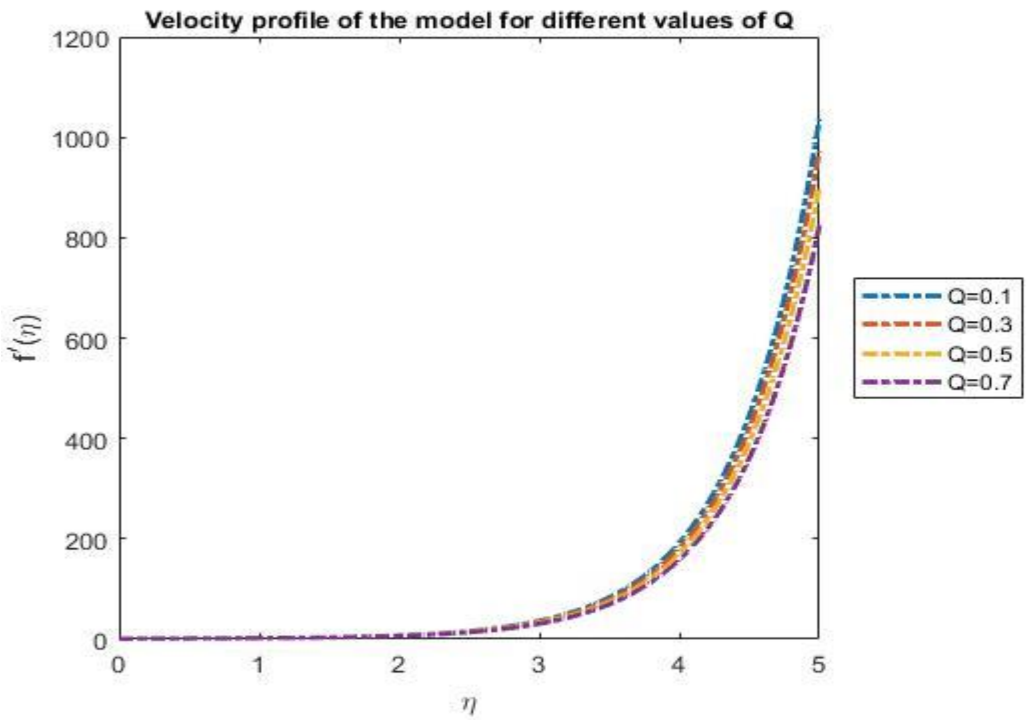

Figure 5: Velocity profile of the model for different values of Q Number

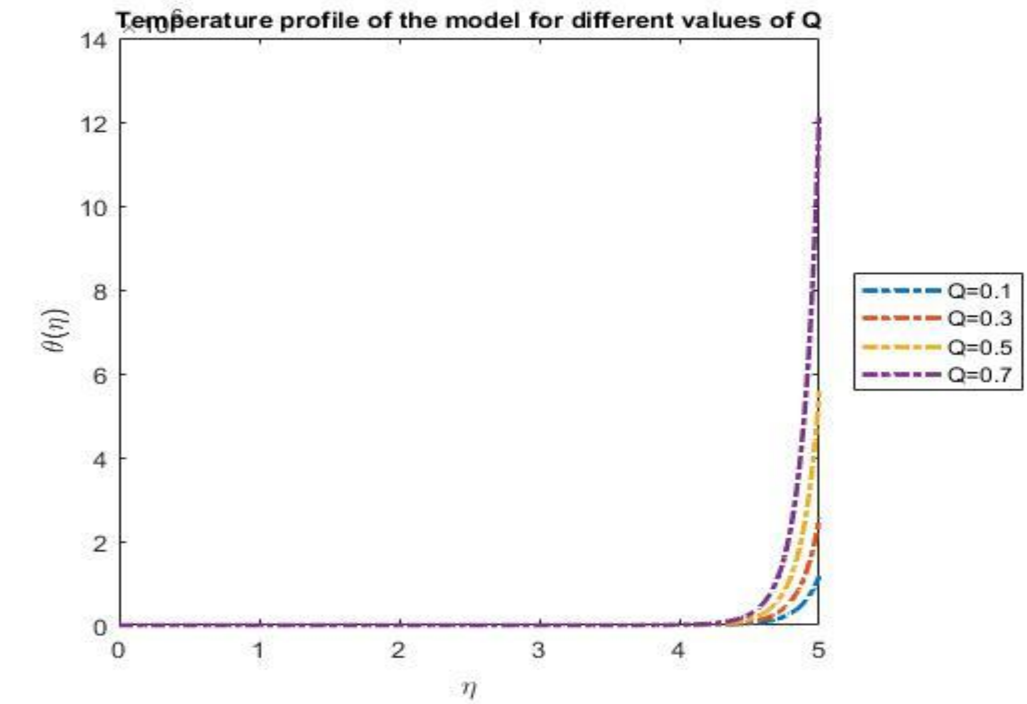

Figure 6: Temperature profile of the model for different values of Q Number

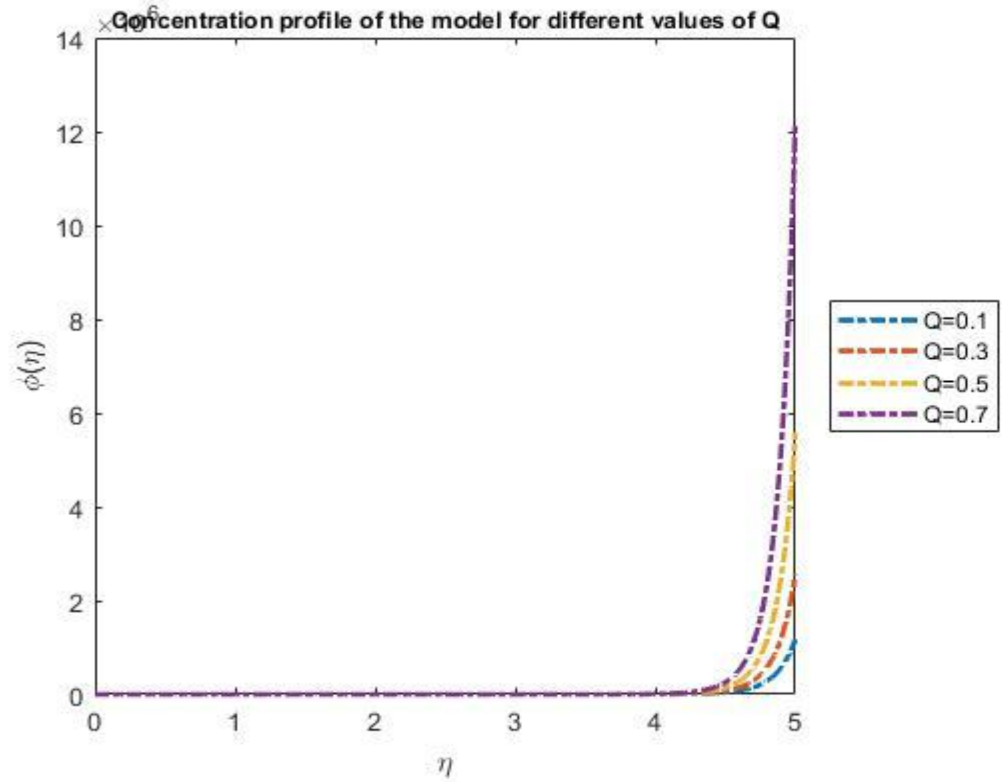

Figure 7: Concentration profile of the model for different values of Q Number

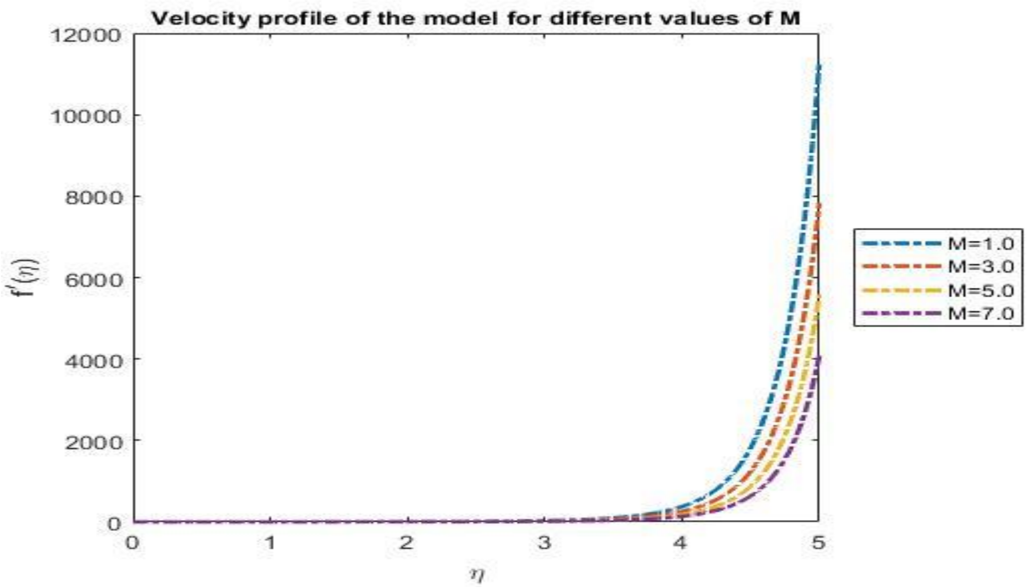

Figure 8: Velocity profile of the model for different values of M Number

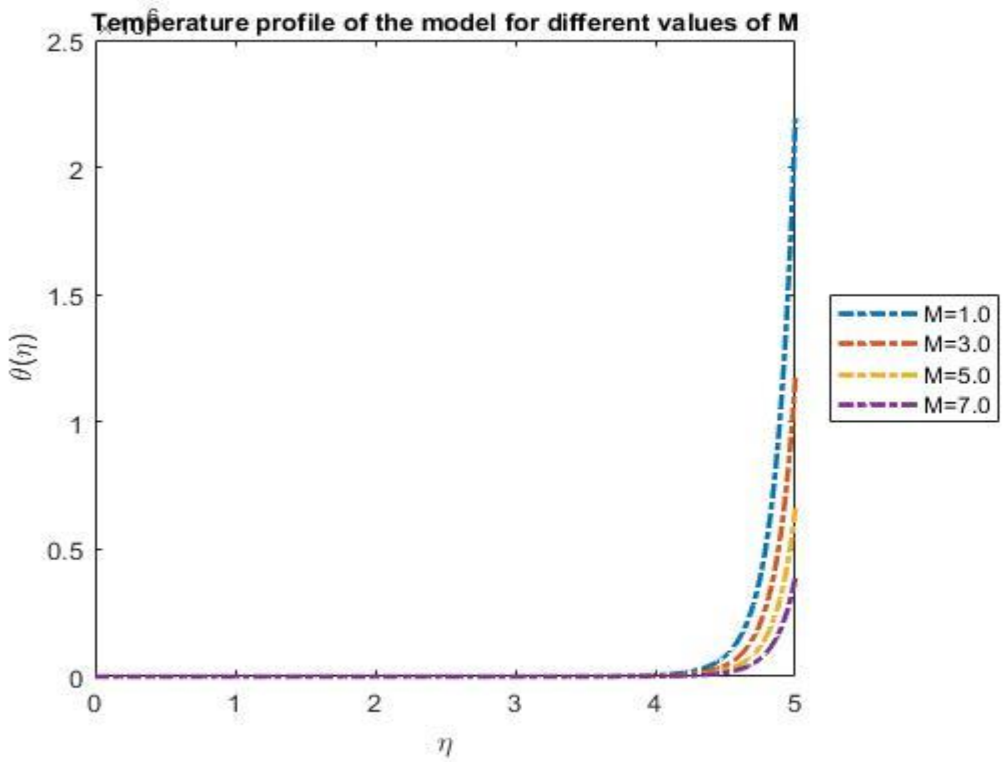

Figure 9: Temperature profile of the model for different values of M Number

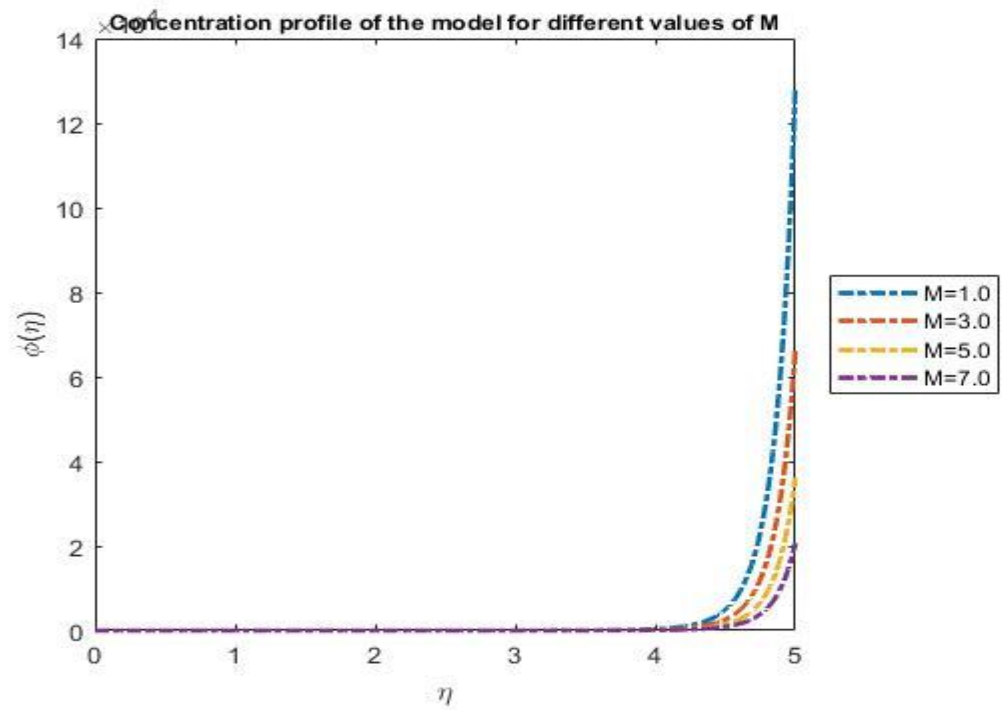

Figure 10: Concentration profile of the model for different values of M Number

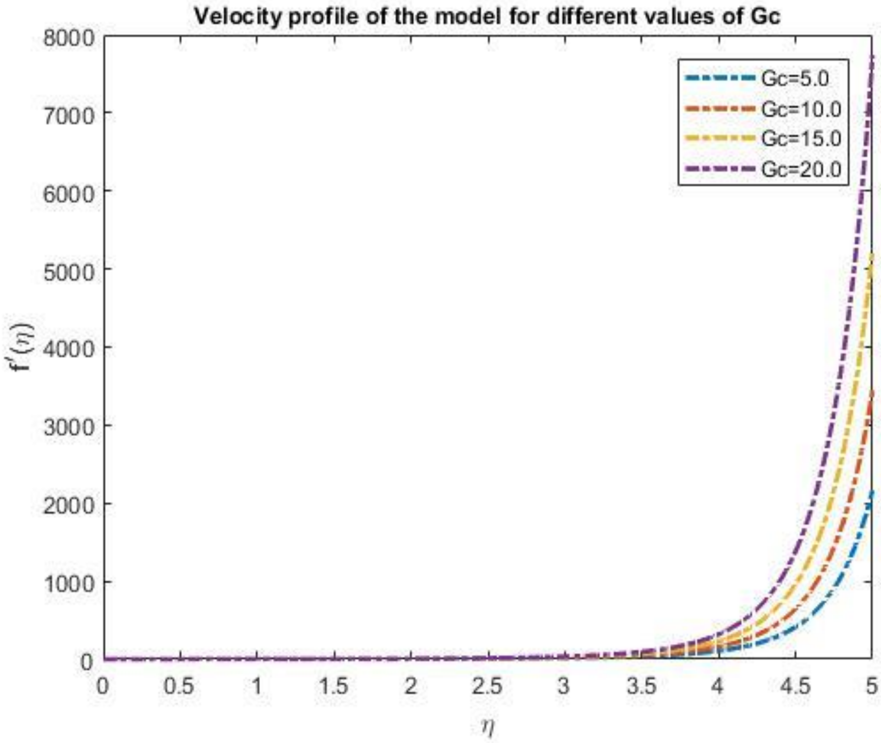

Figure 11: Velocity profile of the model for different values of Gc Number

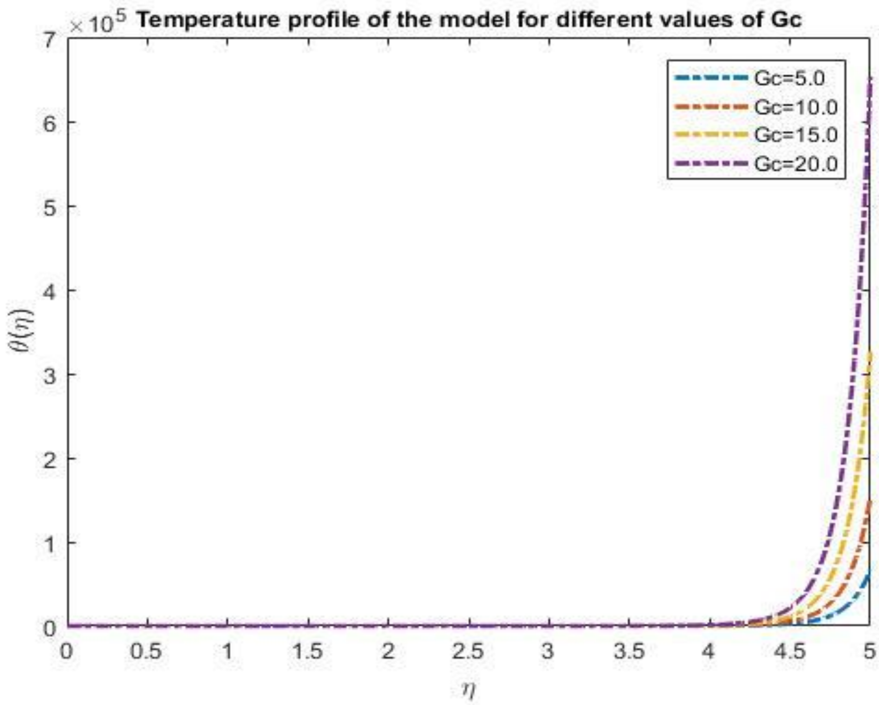

Figure 12: Temperature profile of the model for different values of Gc Number

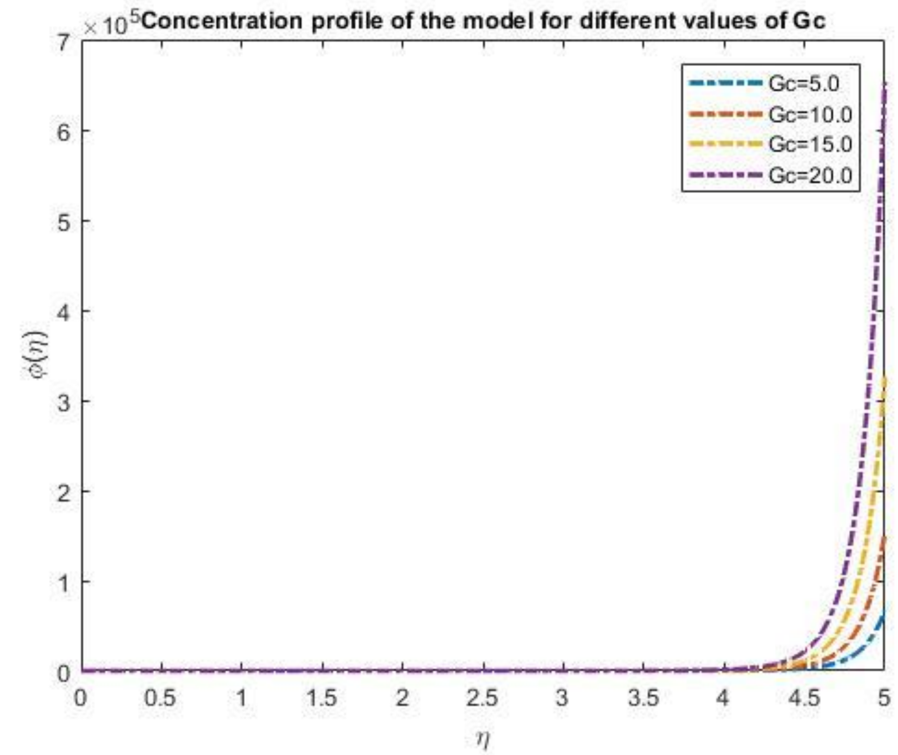

Figure 13: Concentration profile of the model for different values of Gc Number

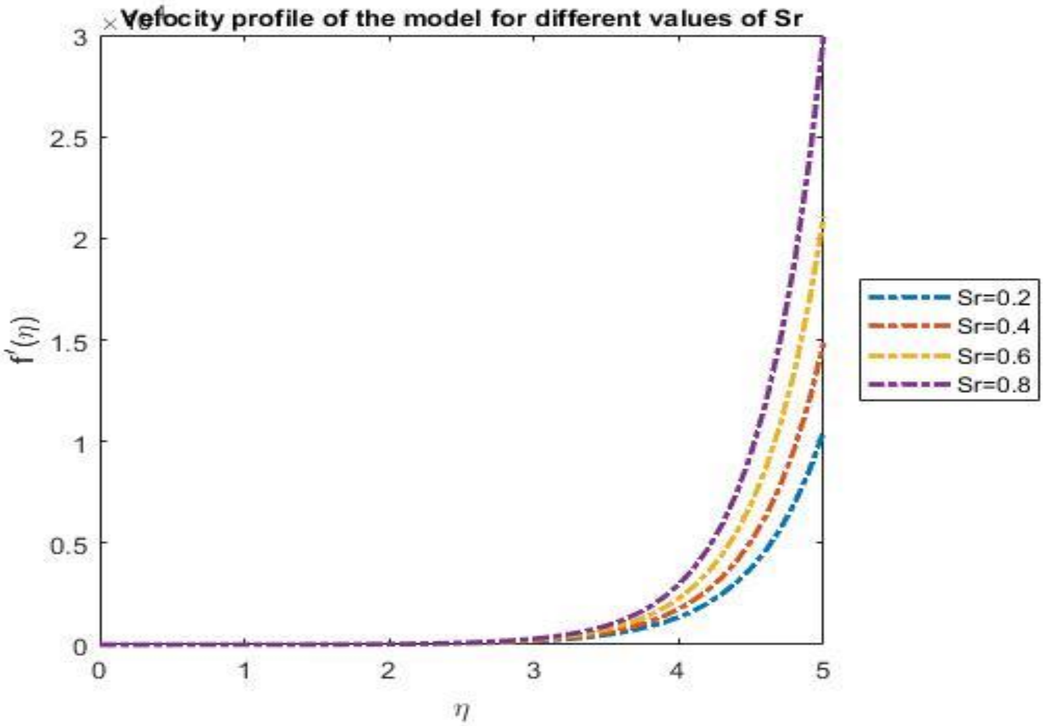

Figure 14: Velocity profile of the model for different values of Sr Number

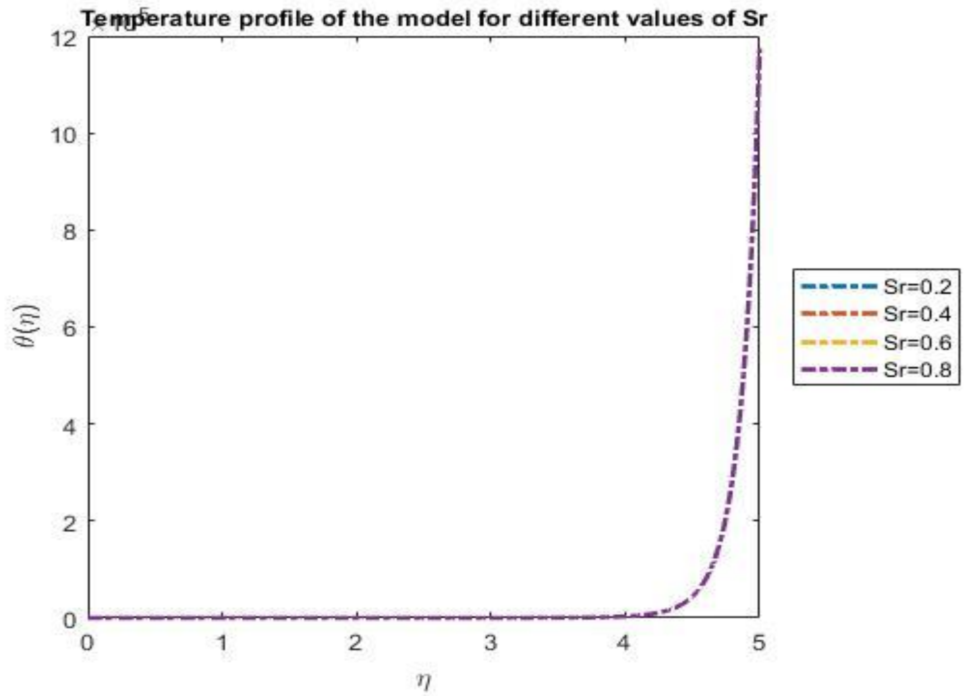

Figure 15: Temperature profile of the model for different values of Sr Number

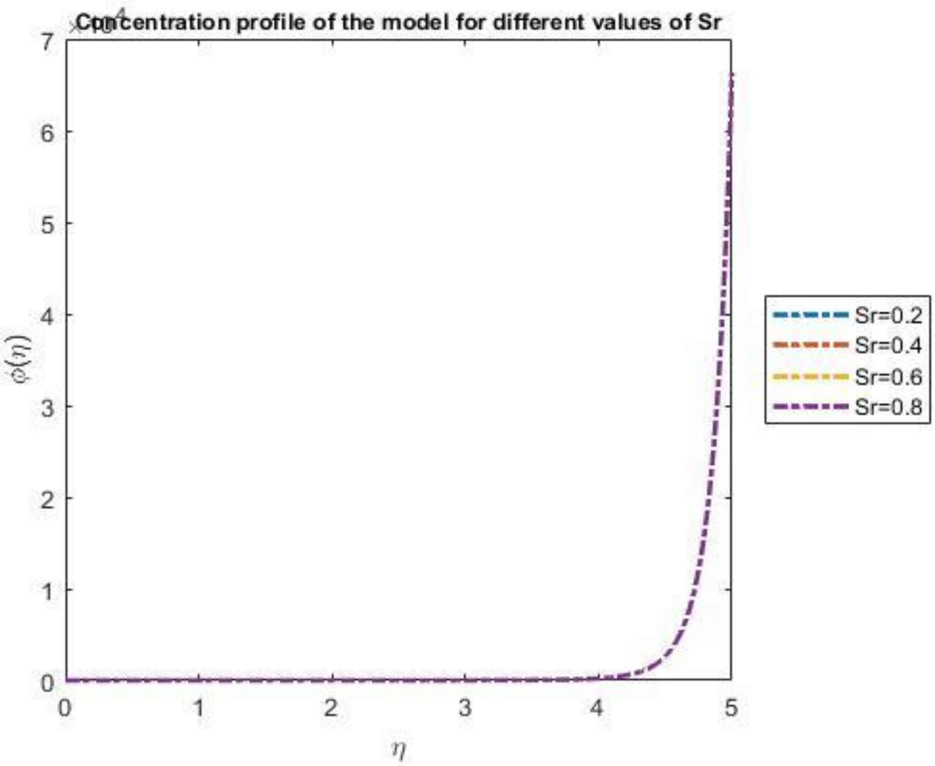

Figure 16: Concentration profile of the model for different values of Sr Number

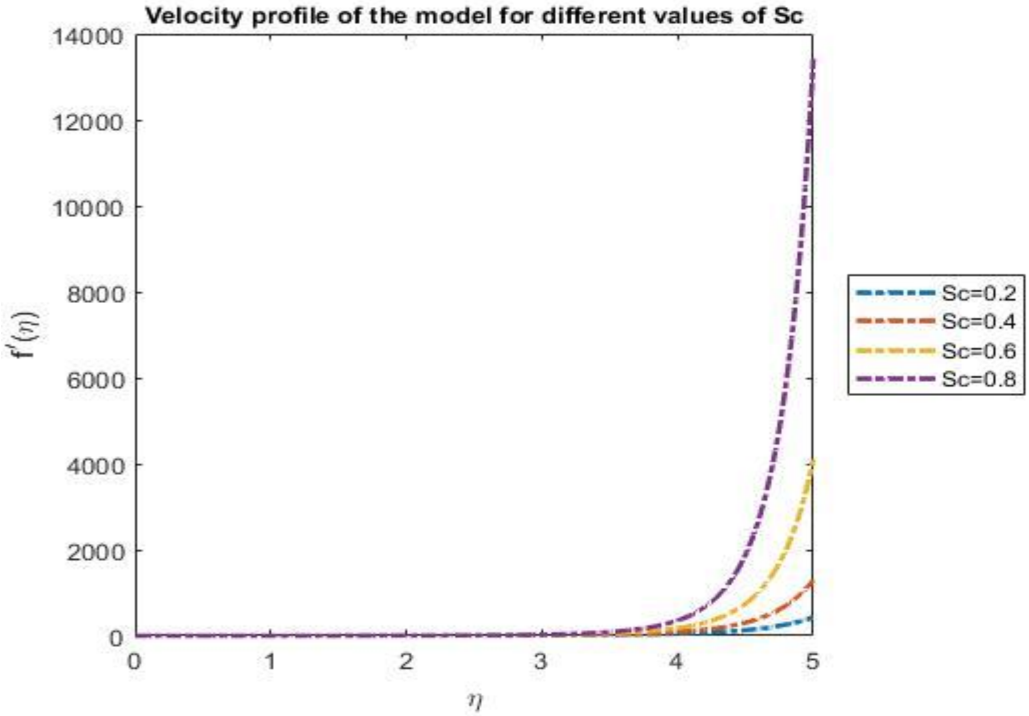

Figure 17: Velocity profile of the model for different values of Sc Number

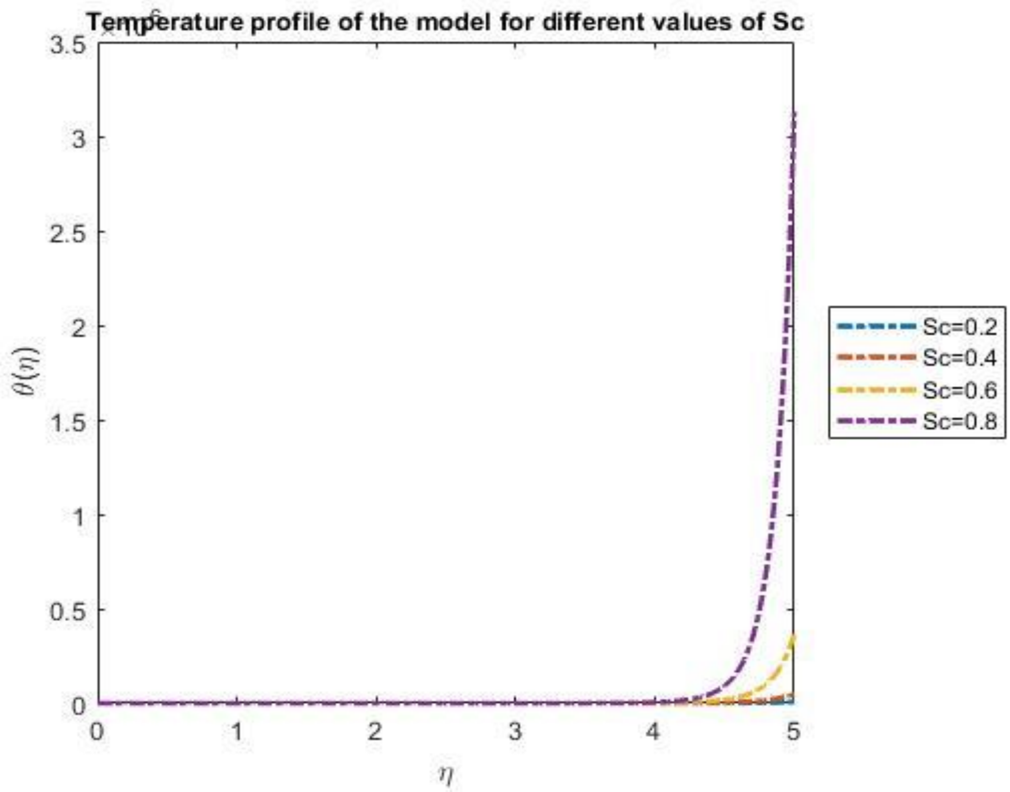

Figure 18: Temperature profile of the model for different values of Sc Number

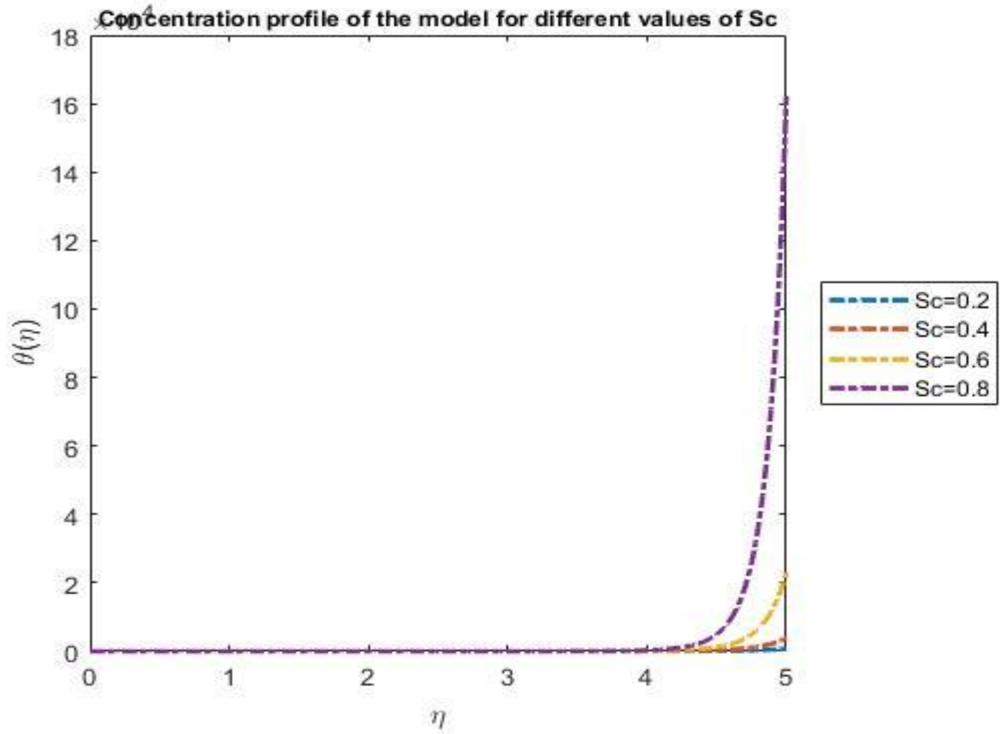

Figure 19: Concentration profile of the model for different values of Sc Number

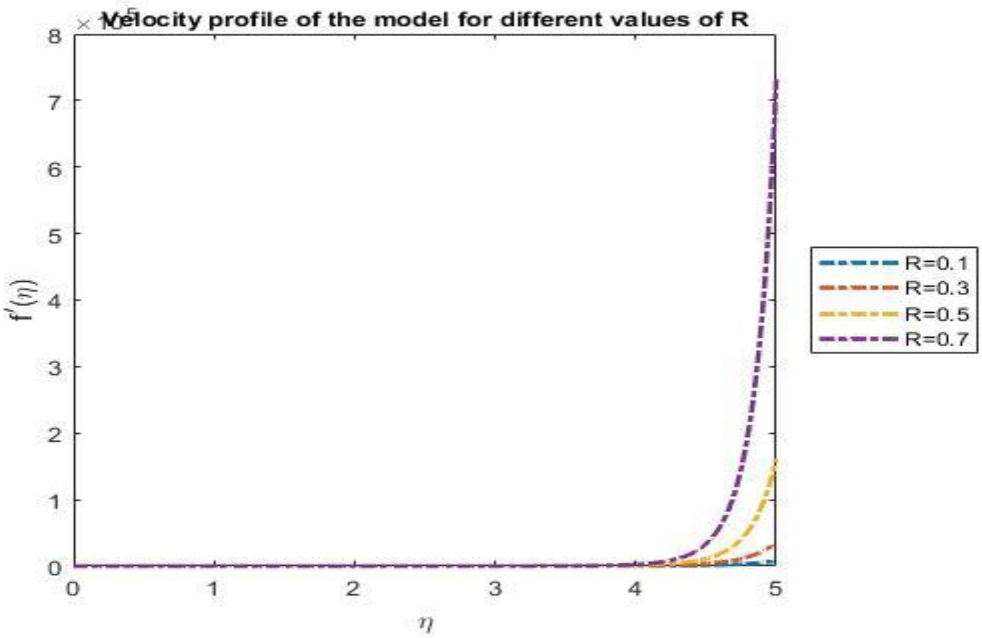

Figure 20: Velocity profile of the model for different values of R Number

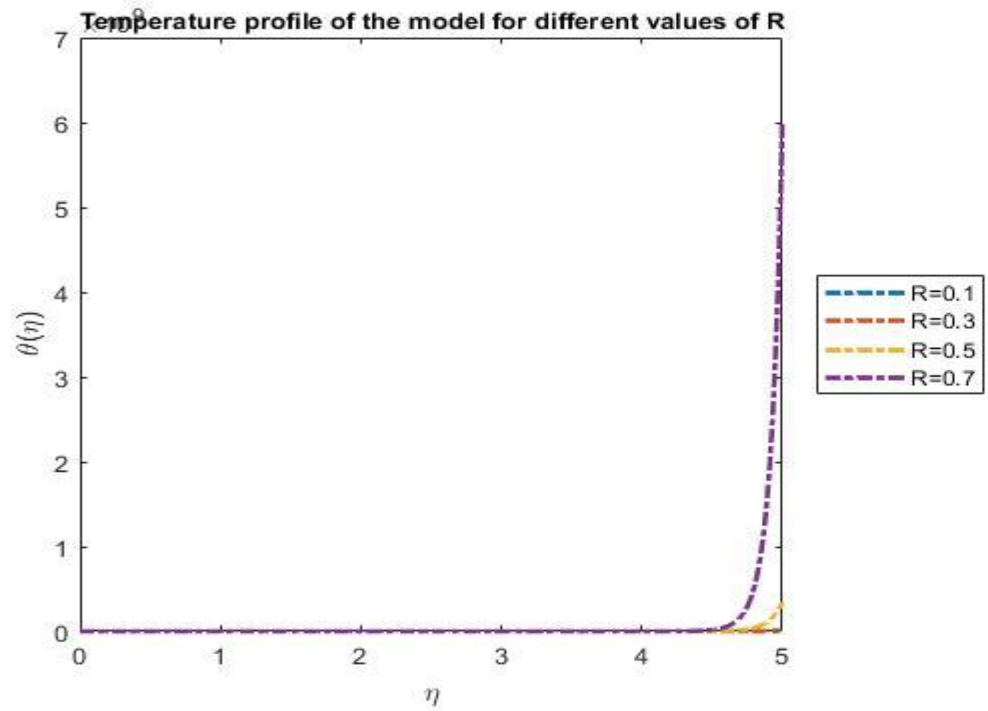

Figure 21: Temperature profile of the model for different values of R Number

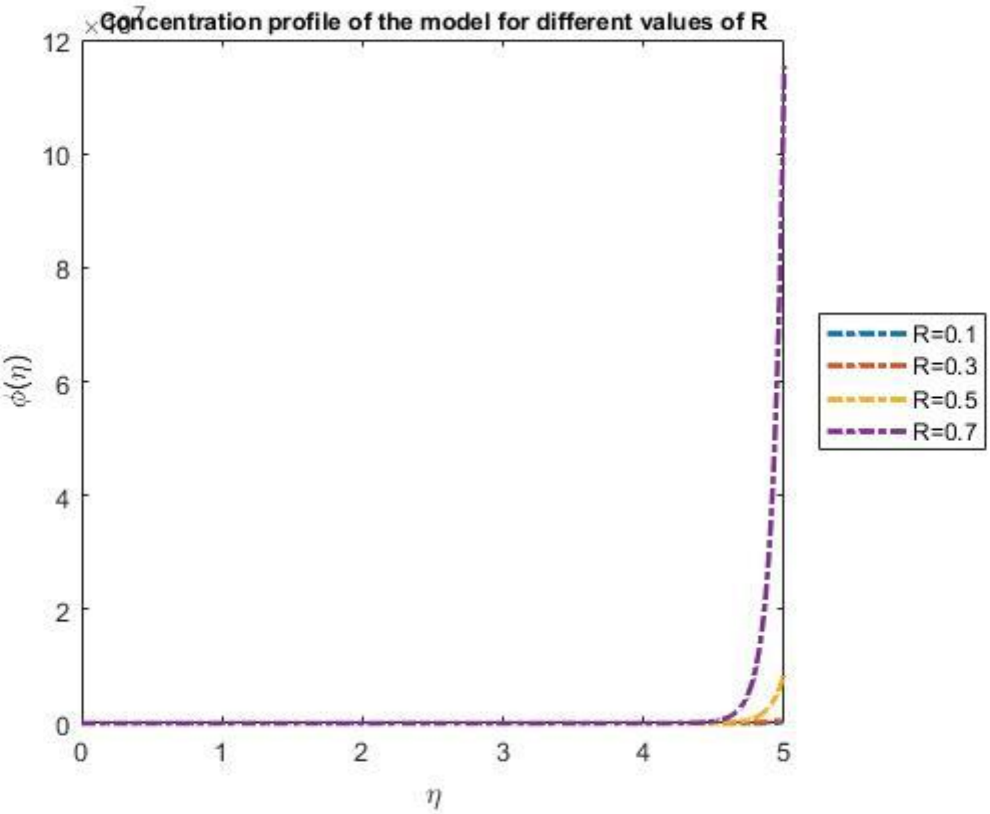

Figure 22: Concentration profile of the model for different values of R Number

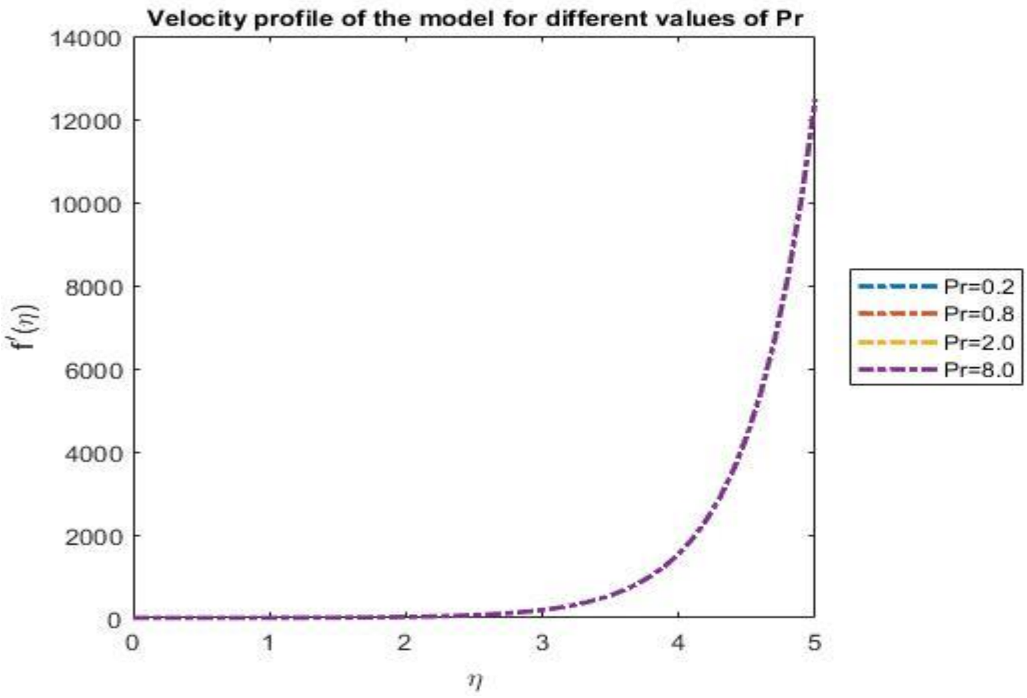

Figure 23: Velocity profile of the model for different values of Pr Number

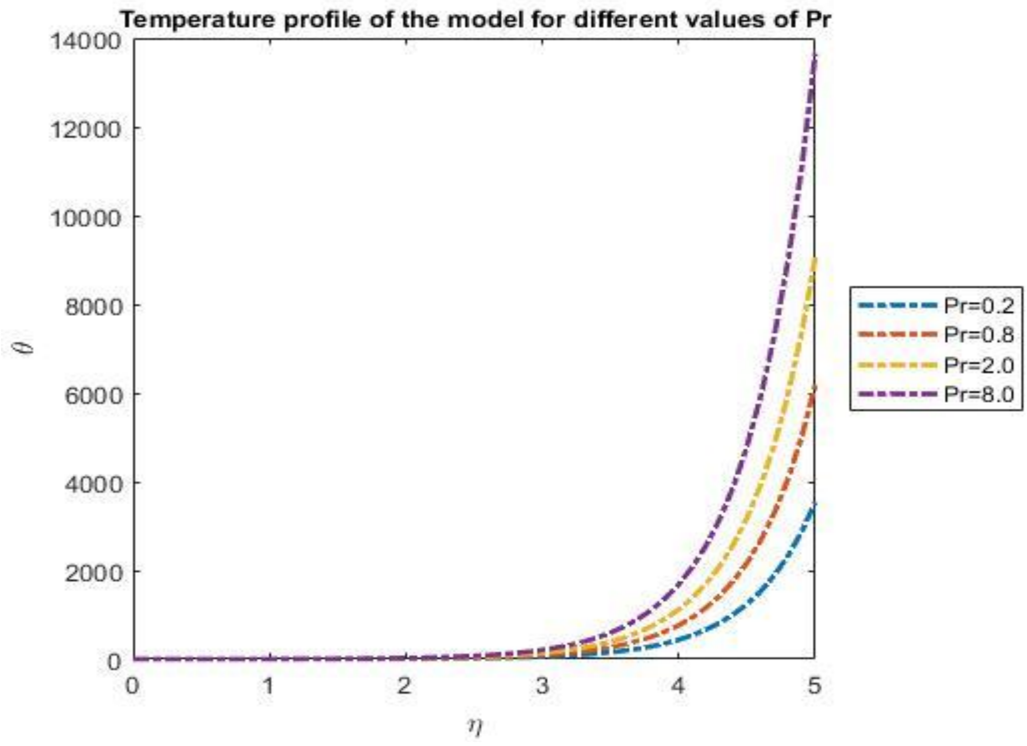

Figure 24: Temperature profile of the model for different values of Pr Number

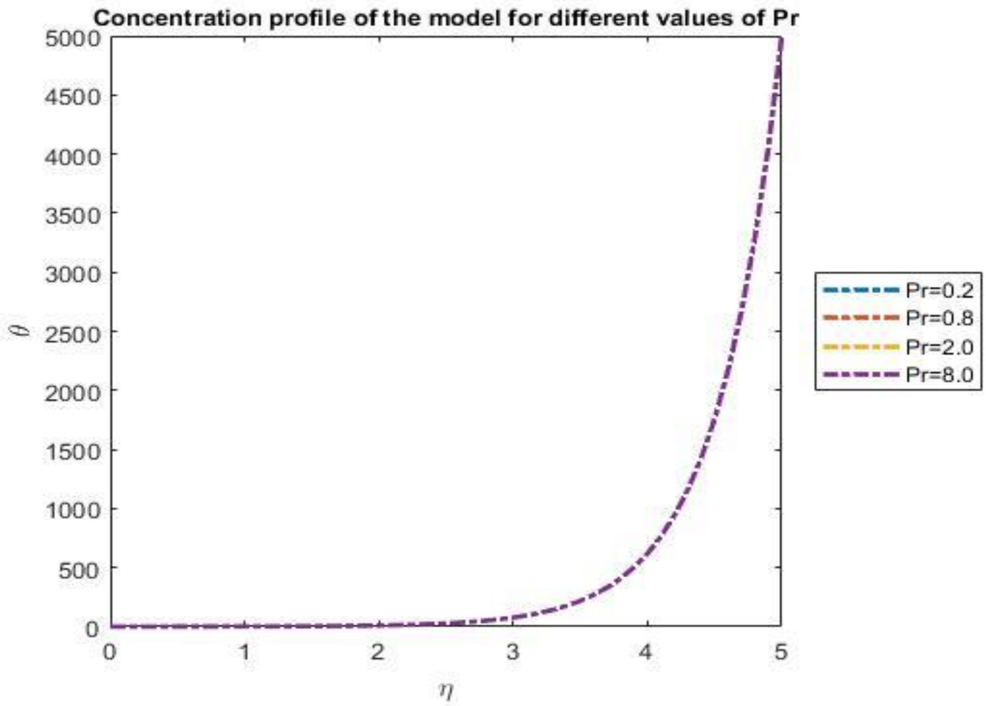

Figure 25: Concentration profile of the model for different values of Pr Number

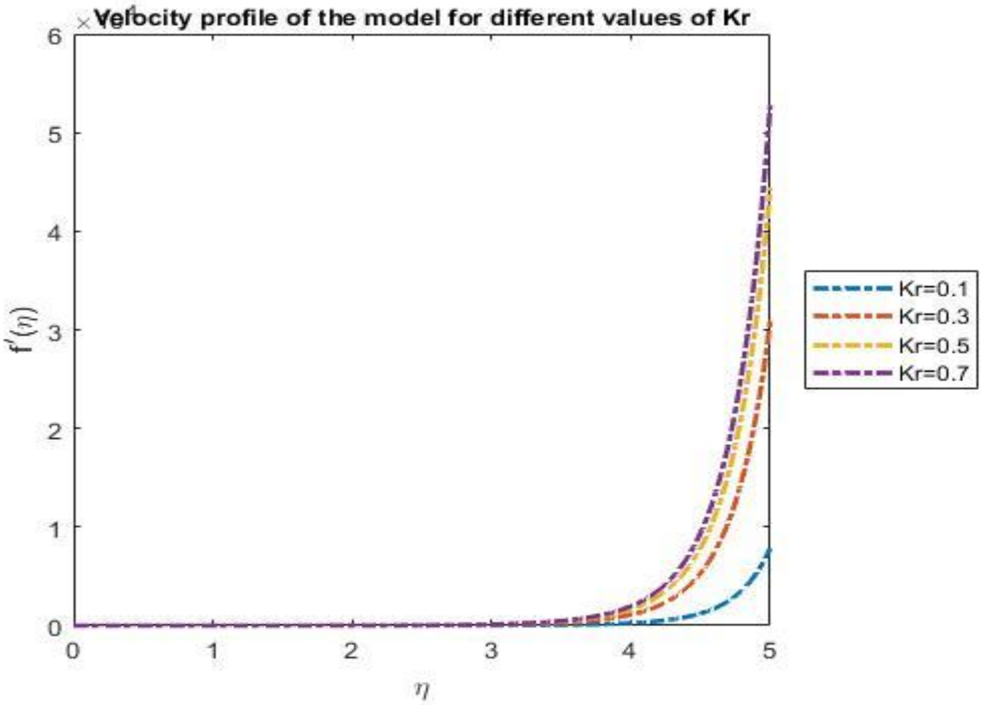

Figure 26: Velocity profile of the model for different values of Kr Number

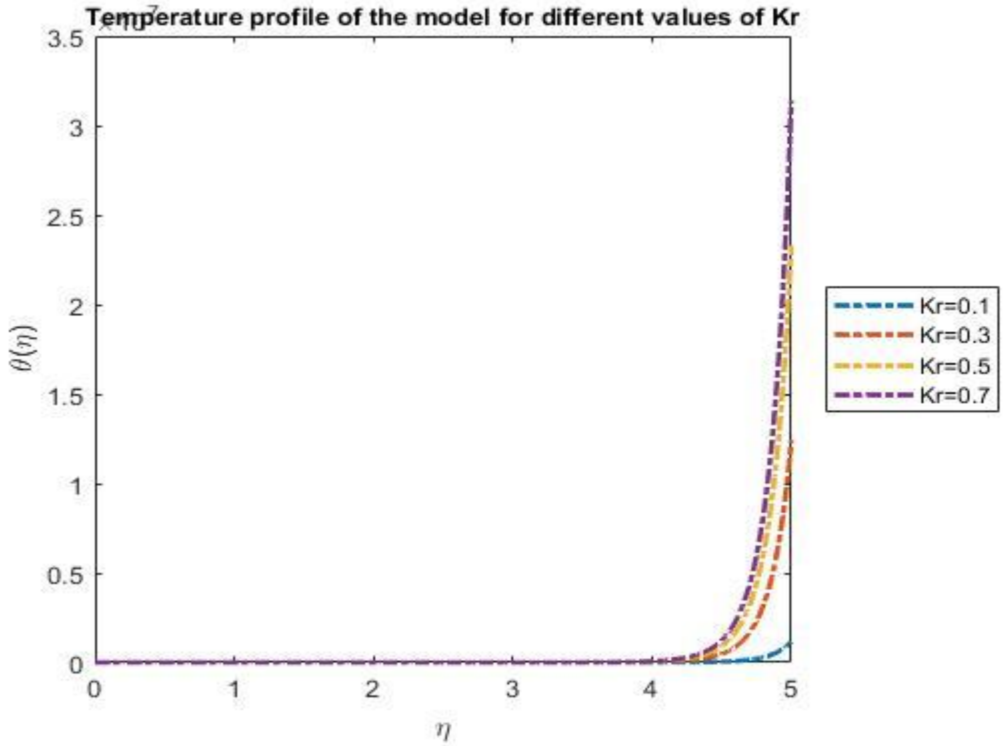

Figure 27: Temperature profile of the model for different values of Kr Number

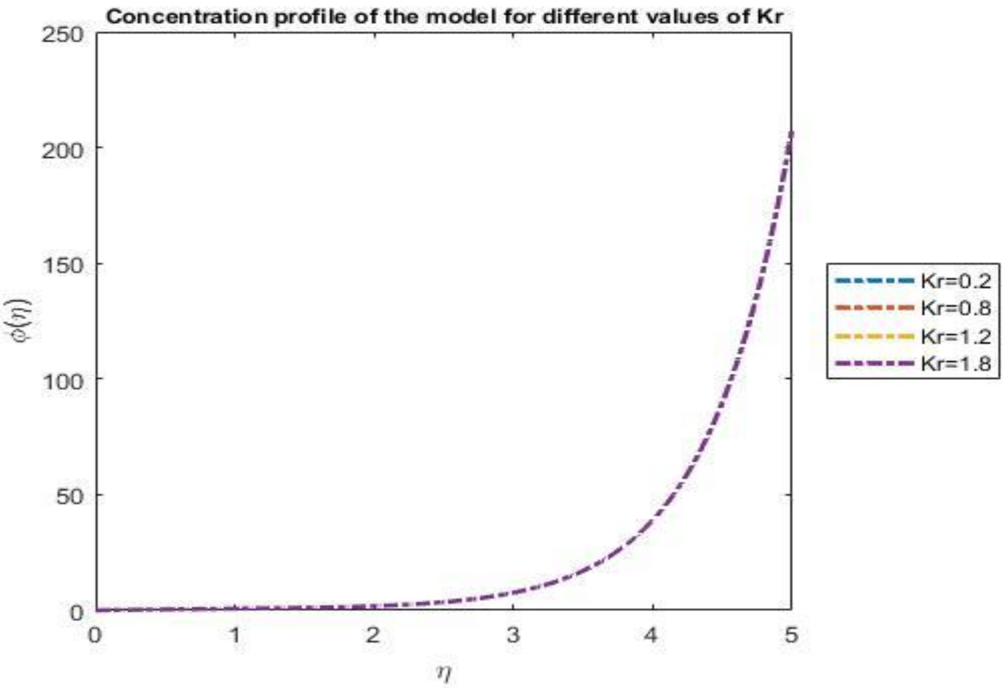

Figure 28: Concentration profile of the model for different values of Kr Number

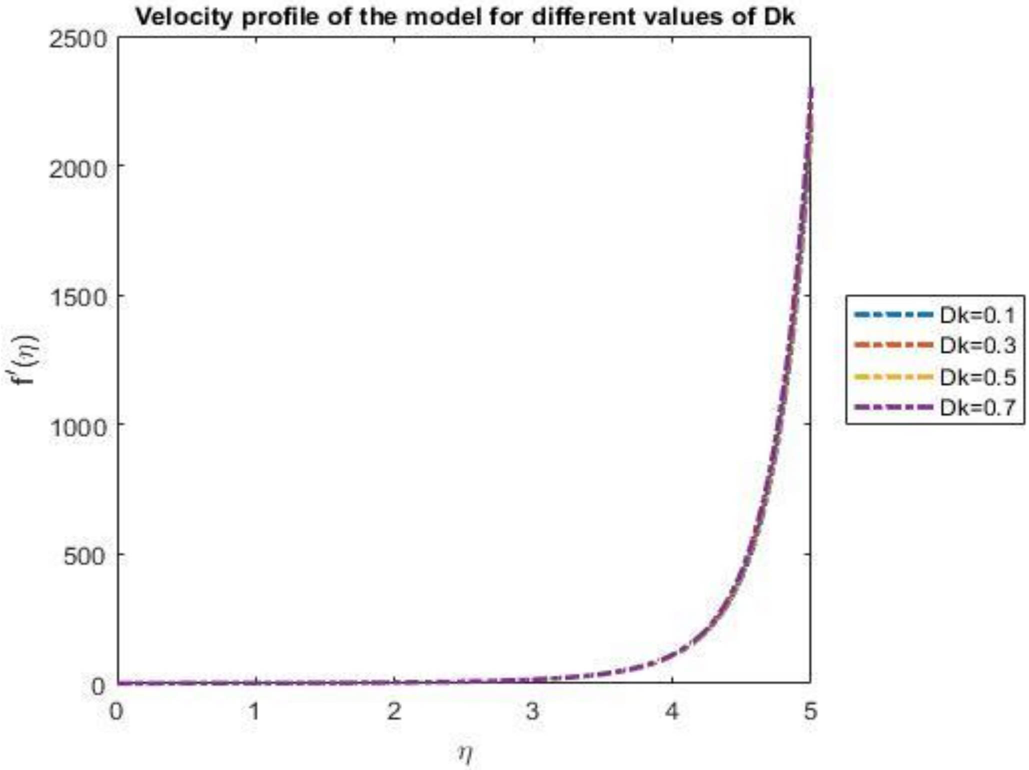

Figure 29: Velocity profile of the model for different values of Dk Number

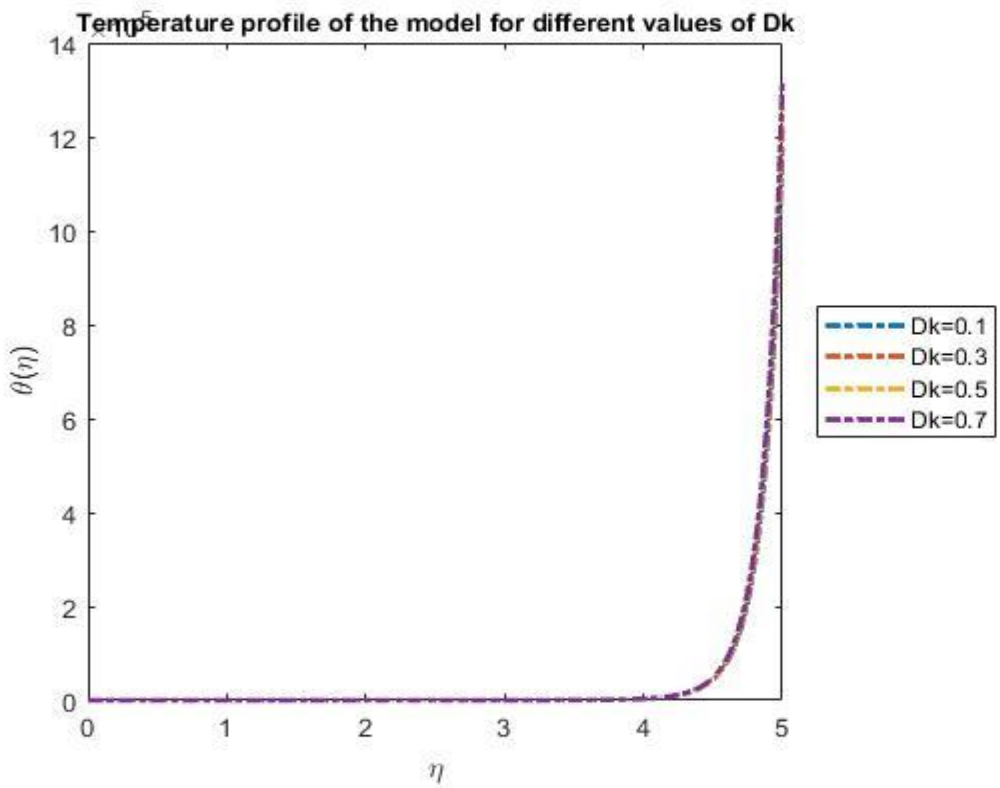

Figure 30: Temperature profile of the model for different values of Dk Number

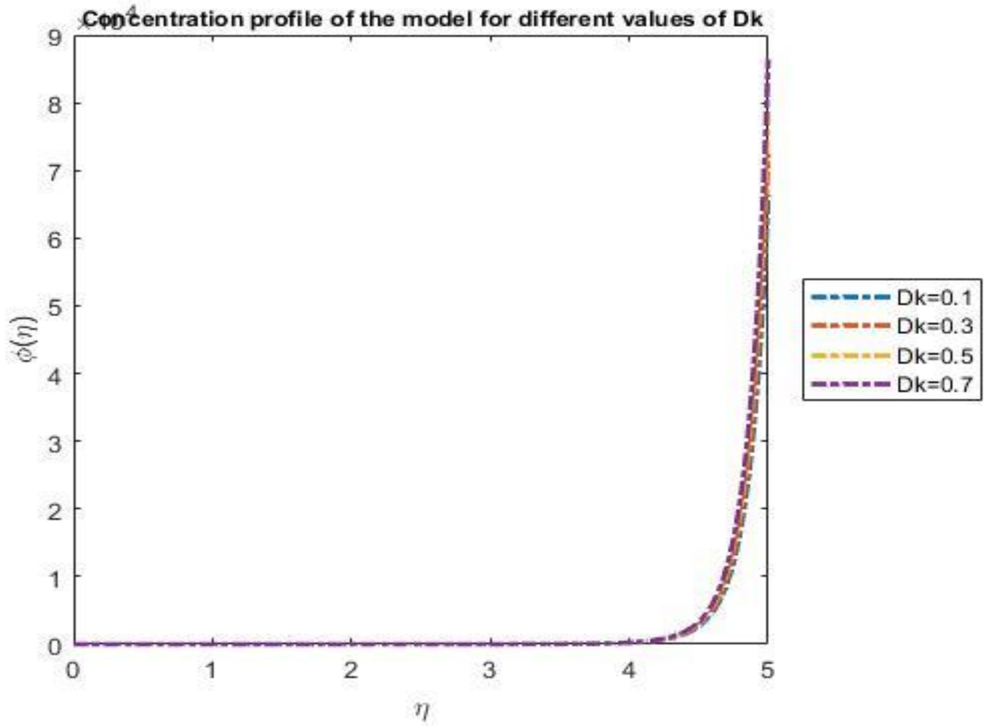

Figure 31: Concentration profile of the model for different values of Dk Number

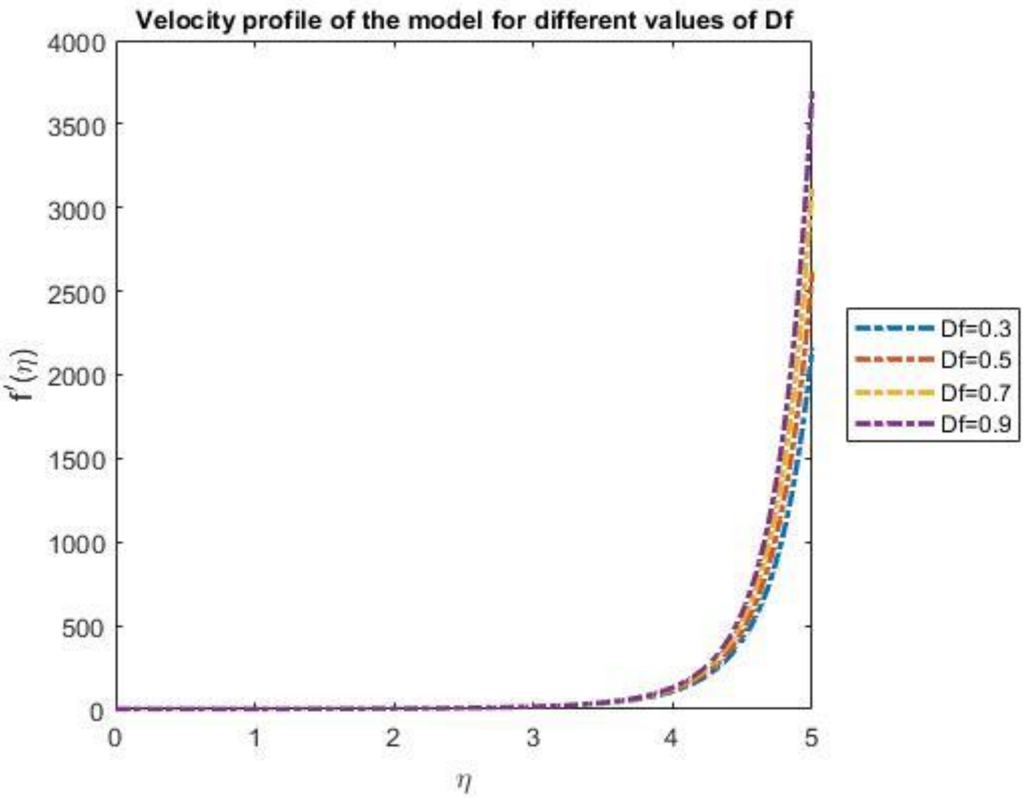

Figure 32: Velocity profile of the model for different values of Df Number

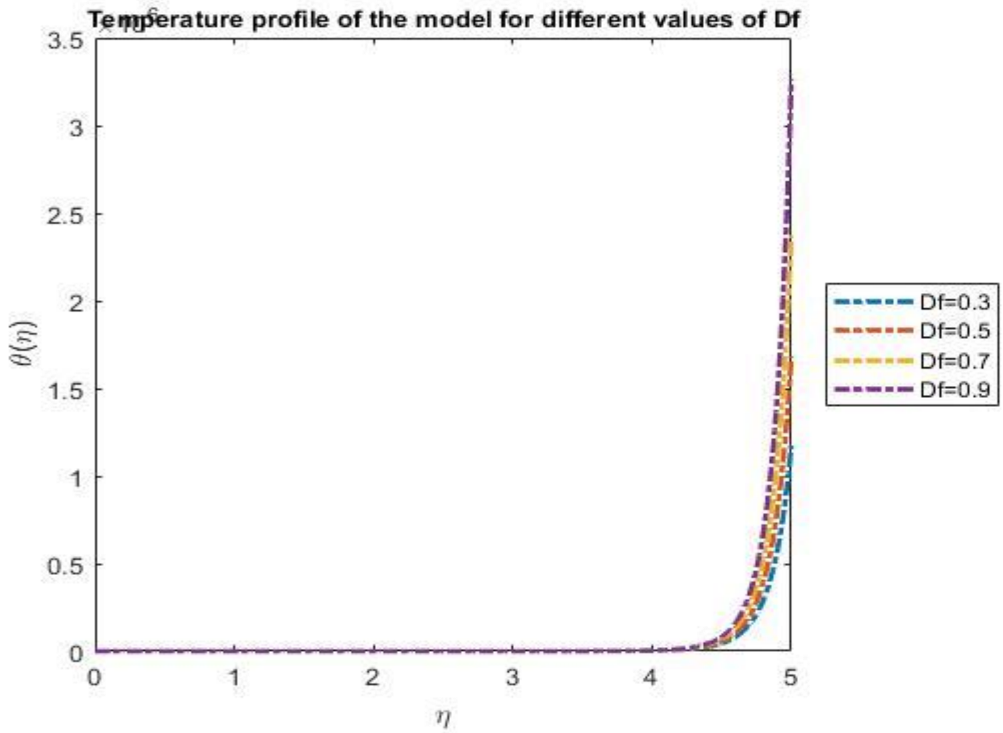

Figure 33: Temperature profile of the model for different values of Df Number

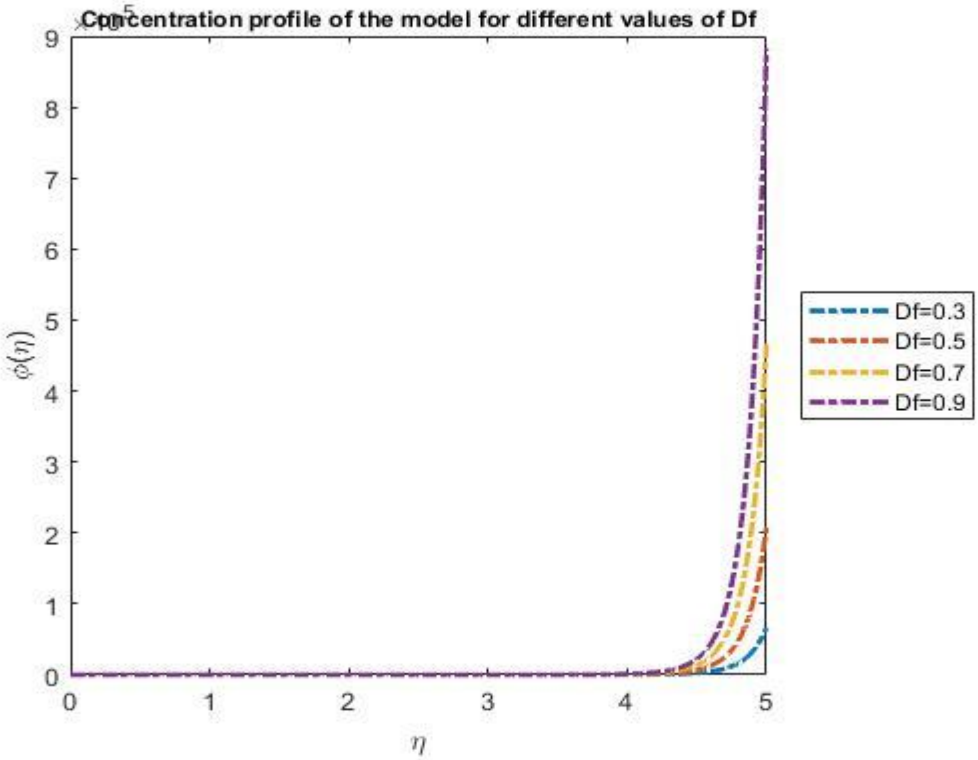

Figure 34: Concentration profile of the model for different values of Df Numbe

4 Conclusion

This Study Analyses heat and mass transfer effects on MHD natural convective fluid flow over a vertical and inclined porous media. Effects of various values of Grasholf number Gr on the thermal boundary layer for fixed values of M, Q, Gc, Pr. From the graph, it was discovered that:

- the fluid velocity, temperature and concentration increases when the Grashof number (Gr), modified Grashof number (Gc), the Soret number (Sr), angle of inclination (α), Dufour number (Df), magnetic parameter (M) Increase and thus thickening the thermal boundary layer across the channel.
- the fluid velocity, temperature and concentration decreases with an increase in magnetic parameter (M), chemical reaction parameter (Kr), Schmidt number (Sc), Prandtl number (Pr) and the angle of inclination parameter (α) but has not much effect on Grasholf number (Gr).
- increase in Prandtl number (Pr), radiation parameter (R), Grasholf number (Gr), Increase the heat transfer at the wall and under the effect of the chemical reaction parameter (Q), Schmidt number (Sc), Grasholf number (Gr), and heat source parameter (Q), enhance the rate of mass transfer.

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