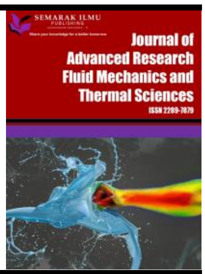
Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879




# Radiation Absorption and Diffusion Thermo Effects on Unsteady MHD Kuvshinski Fluid Flow Past an Inclined Porous Plate in the Presence of Thermal Radiation and Chemical Reaction

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**ARTICLE INFO**

***Article history:***
Received 7 June 2023
Received in revised form 17 August 2023
Accepted 28 August 2023
Available online 13 September 2023

***Keywords:***
Magnetohydrodynamic; radiation absorption; chemical reaction; porous media

**ABSTRACT**

The aim of the present paper is to investigate investigated the Radiation absorption and diffusion thermo on unsteady magneto hydrodynamic Kuvshinski fluid flow past an infinite vertical permeable moving plate in Presence of thermal radiation, heat absorption and homogenous chemical reaction, subjected to variable suction. The plate is assumed to be embedded in a uniform porous medium and Moves with a constant velocity in the flow direction in the presence of a transverse magnetic Field. The equations governing the flow are transformed into a system of nonlinear ordinary differential equations by using perturbation technique. Graphical results for the velocity distribution, temperature distribution and concentration distribution based on the numerical solutions are presented and discussed. Also discuss the effects of various parameters on the skin-friction coefficient and the rate of heat transfer in the form of Nusselt number and rate of mass transfer in the form of Sherwood number at the surface. Velocity and temperature distribution is observed to increase with an increase in Radiation absorption and Dufour parameter, whereas diminishes with enhances of Magnetic field, heat absorption coefficient, radiation parameter and chemical reaction parameter in respective velocity, temperature and concentration distributions.

## 1. Introduction

The fluid flow and heat transfer over a moving plate have a range of applications in applied science and engineering areas such as transportation, nuclear reactors, biomedicine and electronics. In present times, the convectional heat transfer fluid suffered different issues in engineering electronic devices due to relatively low thermal conductivity. Thus, some research focused on mixing nanometer-sized particles or micrometer-sized conducting dust particles in the base fluid to solve the defect in the fluid. The base fluid will become nanofluid when it is permeated with nanometer-

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https://doi.org/10.37934/arfmts.109.1.162176

sized particles while it will become dusty fluid when it is permeated with dust particles. These methods help to enhance the heat transfer performance of the fluid. The study of dusty fluid becomes necessary because of its importance in the applications such as sedimentation, blood rheology and environmental pollution and flow through packed bed. Saffman [1] was the first person who discuss the laminar flow of a dusty gas. Then, the characteristics of dusty gases at different conditions was analysed by Marble [2]. Madhura *et al.,* [3] studied the motion of the unsteady dusty fluid through porous media in an open rectangle channel. The convective heat transfer characteristics of an incompressible dusty fluid over a vertical stretching sheet was observed by Gireesha *et al.,* [4]. Sulochana and Sandeep [5] illustrated the flow of MHD dusty nanofluid toward a porous shrinking cylinder at different temperature. The natural convection flow of a two-phase dusty nanofluid along a vertical wavy frustum of a cone was examined by Siddiqa *et al.,* [6]. The gyrotactic bioconvection of dusty nanofluid along a vertical isothermal surface by using numerical method was studied by Begum *et al.,* [7]. Gireesha *et al.,* [8] analysed the Hall effects on dusty nanofluid two-phase transient flow past a stretching sheet. The MHD flow of a dusty fluid near the stagnation point over a permeable stretching sheet was studied by Ramesh *et al.,* [9] by considering the effect of non-uniform source. Sandeep *et al.,* [10] observed the unsteady MHD radiative flow of a dusty nanofluid over an exponentially pervious stretching surface. Mohana Ramana *et al.,* [11] have discussed Chemical reaction with aligned magnetic field effects on unsteady MHD Kuvshinski fluid flow past an inclined porous plate in the presence of radiation and Soret effects.

Now a days, magnetohydrodynamic (MHD) has been extended into wide areas of basic and applied research in sciences and engineering. The study of non-Newtonian fluid becomes very interested due to variety of technological applications like making of plastic sheets, lubricant's performance and motion of biological fluid. Raghunath [12] has studied Study of Heat and Mass Transfer of an Unsteady Magnetohydrodynamic Nanofluid Flow Past a Vertical Porous Plate in the Presence of Chemical Reaction, Radiation and soret Effects. Raghunath *et al.,* [13] has analyzed Diffusion Thermo and Chemical Reaction Effects on Magnetohydrodynamic Jeffrey Nanofluid over an Inclined Vertical Plate in the Presence of Radiation Absorption and Constant Heat Source. Maatoug *et al.,* [14] have expressed Variable chemical species and thermo-diffusion Darcy–Forchheimer squeezed flow of Jeffrey nanofluid in horizontal channel with viscous dissipation effects. Bafakeeh *et al.,* [15] have possessed Hall Current and Soret Effects on Unsteady MHD Rotating Flow of Second-Grade Fluid through Porous Media under the Influences of Thermal Radiation and Chemical Reactions. Deepthi *et al.,* [16] have discussed Recent Development of Heat and Mass Transport in the Presence of Hall, Ion Slip and Thermo Diffusion in Radiative Second Grade Material: Application of Micromachines.

Fluid flows through porous medium are seriously attracted by engineers and scientists. Now a days, due to their applications in the emerging trends in science and technology, namely in the field of agricultural engineering especially while studying water resources in the ground, to study the moment of natural gas, oil, and water through the reservoirs in the petroleum technology. Raghunath *et al.,* [17] have studied processing to pass unsteady MHD flow of a second-grade fluid through a porous medium in the presence of radiation absorption exhibits Diffusion thermo, hall and ion slip effects. Kodi *et al.,* [18] have studied Influence of MHD mixed convection flow for maxwell nanofluid through a vertical cone with porous material in the existence of variable heat conductivity and diffusion. Raghunath *et al.,* [19] Radiation absorption on MHD Free Conduction flow through porous medium over an unbounded vertical plate with heat source. Li *et al.,* [20] have studied Effects of activation energy and chemical reaction on unsteady MHD dissipative Darcy–Forchheimer squeezed flow of Casson fluid over horizontal channel**.** Suresh Kumar *et al.,* [21] have expressed Numerical analysis of magneto hydrodynamics Casson nanofluid flow with activation energy, Hall current and thermal radiation. Raju *et al.,* [22] have investigated the effect of radiation and mass transfer effects on a free convection flow past a porous medium bounded by a vertical surface. Seddek *et al.,* [23] have studied the effects of chemical reaction and variable viscosity on hydro magnetic mixed convection heat and mass transfer for Hiemenz flow through porous media with radiation. Ravikumar *et al.,* [24] have discussed the combined effect of heat absorption and MHD on convective Rivlin-Erichsen flow past a semi-infinite vertical porous plate with variable temperature and suction. Ibrahim *et al.,* [25] have analyzed the effect of the chemical reaction and radiation absorption on the unsteady MHD free convective flow past a semi-infinite vertical permeable moving plate with heat source and suction.

Combined heat and mass transfer problems with chemical reaction, are of importance in many processes and have, therefore, received a considerable amount of attention in recent years. In the processes such as drying, evaporation at the surface of a water body, energy transfer in a wet cooling tower and the flow in a desert cooler, heat and mass transfer occur simultaneously. Possible applications of this type of flow can be found in many industries. For example, in the power industry, among the methods of generating electric power is one in which, electrical energy is extracted directly from a moving conducting fluid. Very recently Raghunath and Mohanaramana [26] have studied Hall, Soret, and Rotational Effects on Unsteady MHD Rotating flow of A Second-Grade Fluid through a Porous Medium in the Presence of Chemical Reaction and aligned magnetic field. Kodi *et al.,* [27] have discussed Hall and Ion Slip Radiative Flow of Chemically Reactive Second grade through Porous Saturated Space via Perturbation approach. Raghunath *et al.,* [28] studied Effects of Soret, Rotation, Hall, and Ion Slip on unsteady MHD flow of a Jeffrey Fluid through a Porous Medium in the Presence of Heat absorption and chemical reaction. Theuri *et al.,* [29], studied unsteady double diffusive MHD boundary layer flow of chemically reacting fluid, over a flat permeable surface.

In spite of all the above studies, the aim of the present study is to analyze the effects of Radiation absorption and Diffusion thermo an unsteady MHD free convection Kuvshinski fluid flow immersed in a porous medium over an infinite vertical plate in the presence of thermal radiation and chemical reaction. The expressions are obtained for velocity, temperature and concentration and studied with the help of graphs in the presence of various physical parameters. The effects of various parameters on the skin-friction coefficient and the rate of heat and mass transfer at the surface are presented in the form of tables. Comparisons with previously published work performed and the results are found to be in the excellent agreement.

## 2. Mathematical Formulation

In this work, the combined effects of Radiation absorption and Chemical reaction on free convection flow of an incompressible and electrically conducting Kuvshinski fluid through porous medium with infinite vertical plates. A homogenous first order chemical reaction between fluid and the species concentration is considered, in which the rate of chemical reaction is directly proportional to the species concentration. The magnetic Reynolds number is so small that the induced magnetic field can be neglected. Also, no applied or polarized voltages exist so the effect of polarization of fluid is negligible. All the fluid properties except the density in the buoyancy force term are constants. The flow configuration of the problem is presented in Figure 1.

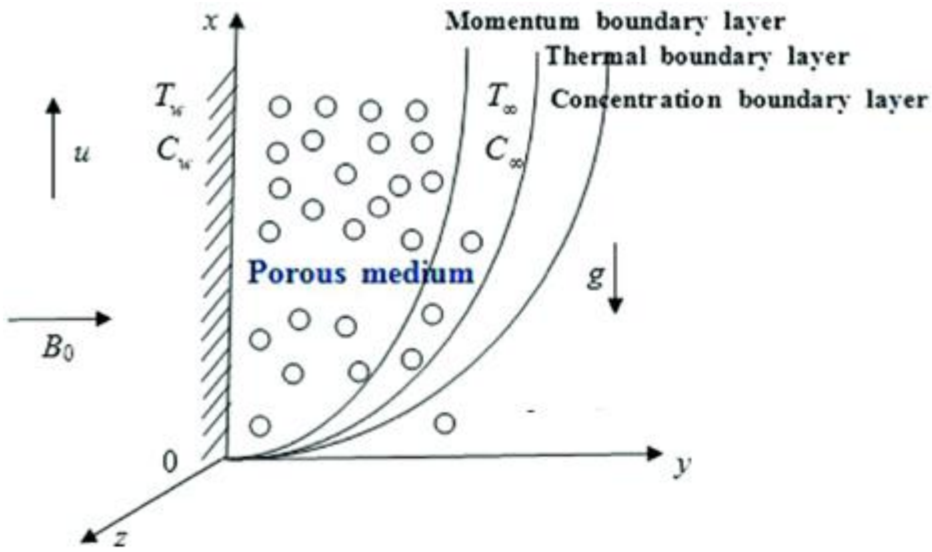


**Fig. 1.** The flow configuration of the problem

By considering the above assumptions, the governing equations are given by

$$\frac{\partial v^*}{\partial y^*} = 0 \rightarrow v^* = -v_0 (v_0 > 0) \quad \textbf{(1)}$$

$$\left[\left(1+\lambda^* \frac{\partial}{\partial t^*}\right)\frac{\partial u^*}{\partial t^*} + v^* \frac{\partial u^*}{\partial y^*}\right] = -\left(1+\lambda^* \frac{\partial}{\partial t^*}\right)\frac{1}{\rho}\frac{\partial p^*}{\partial x^*} + \vartheta \frac{\partial^2 u^*}{\partial y^{*2}} + g\beta_T (T^* - T_\infty^*) + g\beta_C (C^* - C_\infty^*) - \left(1+\lambda^* \frac{\partial}{\partial t^*}\right)\left(\frac{\sigma B_0^2}{\rho} u^* - \frac{\vartheta u^*}{k^*}\right) \quad (2)$$

$$\left(1+\lambda^* \frac{\partial}{\partial t^*}\right)\left[\frac{\partial T^*}{\partial t^*} + v^* \frac{\partial T^*}{\partial y^*}\right] = \frac{K}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}} - \frac{1}{\rho C_p}\frac{\partial q_r^*}{\partial y^*} - \frac{Q^*}{\rho C_p}(T^* - T_\infty^*) + Q_1 (C^* - C_\infty^*) + \frac{D K_T}{C_S C_P}\frac{\partial^2 C^*}{\partial y^{*2}} \quad \textbf{(3)}$$

$$\left[\left(1+\lambda^* \frac{\partial}{\partial t^*}\right)\frac{\partial C^*}{\partial t^*} + v^* \frac{\partial C^*}{\partial y^*}\right] = D\frac{\partial^2 C^*}{\partial y^{*2}} - K^* (C^* - C_\infty^*) \quad \textbf{(4)}$$

Under the above assumptions, the appropriate boundary conditions for the distributions of velocity, temperature and concentration are given by

$$u^* = u_p^*, \quad T^* = T_w^* + \varepsilon (T_w^* - T_\infty^*) e^{n^* t^*}, \; C^* = C_w^* + \varepsilon (C_w^* - C_\infty^*) e^{n^* t^*} \text{ at } y^* = 0 \quad (5)$$

$$u^* \rightarrow u_\infty^* = U_0 (1 + \varepsilon e^{n^* t^*}), \quad T^* \rightarrow T_\infty^* \quad C^* \rightarrow C_\infty^* \quad \text{as} \quad y^* \rightarrow \infty \quad \textbf{(6)}$$

where u* and v* are velocity components in x* and y* directions respectively, g is the acceleration due to gravity, β is the thermal expansion coefficient, T* is the temperature of the fluid, $T_\infty^*$ the temperature away from the plate, $T_w^*$ the temperature near the plate, β* is the mass expansion coefficient, C* is the concentration of the fluid, $C_\infty^*$ is the concentration away from the Plate, $C_w^*$ is the concentration near the plate, σ is the magnetic permeability of the fluid, $B_o$ is the Coefficient of magnetic field, $q_r *$ is the Radiation heat flux density, ρ is the density of the fluid, α is the inclined angle, ϑ is the kinematic viscosity, k* is the permeability of porous medium, $C_p$ is the specific heat at constant pressure, D is the chemical molecular diffusivity, $D_1$thermal diffusion coefficient, $K^*$ is the chemical reaction rate constant , ε is the scalar constant, n is the dimensionless exponential index.

Outside the boundary layer, Eq. (2) gives

$$-\left(1+\lambda^*\frac{\partial}{\partial t^*}\right)\frac{1}{\rho}\frac{\partial p^*}{\partial x^*}=\frac{\partial U_\infty}{\partial t^*}+\frac{\upsilon}{k^*}U_\infty^*+\left(1+\lambda^*\frac{\partial}{\partial t^*}\right)\left(\frac{\sigma B_0^2}{\rho}U_\infty^*\right) \tag{7}$$

We consider a mathematical model, for an optically thin limit gray gas near equilibrium in the form given by Cramer and Pai [30]. Later Grief *et al.,* [31].

$$\frac{\partial q_r^*}{\partial y^*}=4\left(T^*-T_w^*\right)I \tag{8}$$

where $I=\int_0^\infty K_{\lambda\omega}\left(\frac{\partial_{eb\lambda}}{\partial T}\right)_\omega d\lambda,\ K_{\lambda\omega}$ the absorption coefficient at the wall and ebλ is Planck's function.

To normalize the mathematical model of the physical problem, introduce the following non-dimensional quantities and parameters

$$U_\infty=\frac{U_\infty^*}{U_0},U_p=\frac{U_p^*}{U_0},u=\frac{u^*}{U_0},y=\frac{U_0y^*}{\vartheta},n=\frac{n^*\vartheta}{U_0^2},v=\frac{v^*}{U_0},\theta=\frac{T^*-T_\infty^*}{T_w^*-T_\infty^*},\phi=\frac{C^*-C_\infty^*}{C_w^*-C_\infty^*},Sc=\frac{\vartheta}{D},$$
$$\Pr=\frac{\mu C_p}{K_T},Q_1=\frac{\vartheta Q_1^*}{U_0^2}\frac{C_w^*-C_\infty^*}{T_w^*-T_\infty^*},Gr=\frac{\vartheta g\beta_T(T_w^*-T_\infty^*)}{U_0^3},Gm=\frac{\vartheta g\beta_c^*(C_w^*-C_\infty^*)}{U_0^3},\ Du=\frac{DK_T}{\vartheta C_S C_P}\frac{(C_w^*-C_\infty^*)}{(T_w^*-T_\infty^*)}$$

$$M=\frac{\sigma B_0^2\vartheta}{\rho U_0^2},K=\frac{U_0^2K_0^*}{\vartheta^2},t=\frac{t^*U_0^2}{4\vartheta},K=\frac{\vartheta K^*}{U_0^2},Q=\frac{Q_1 v}{U_0^2},\lambda_1=\frac{\lambda_1^* v_0^2}{\vartheta}F=\frac{4I_1\upsilon}{\rho C_p v_0^2} \tag{9}$$

The non-dimensional form of the Eq. (2) to Eq. (4) are

$$\left[\left(1+\lambda_1\frac{\partial}{\partial t}\right)\frac{\partial u}{\partial t}-(1+A\varepsilon e^{nt})\frac{\partial u}{\partial y}\right]=\left(1+\lambda_1\frac{\partial}{\partial t}\right)\frac{dU_\infty}{dt}+\frac{\partial^2 u}{\partial y^2}+Gr\,\theta+ Gm\,\phi+(M+1/k)\left(1+\lambda_1\frac{\partial}{\partial t}\right)(U_\infty-u) \tag{10}$$

$$\left[\left(1+\lambda_1\frac{\partial}{\partial t}\right)\frac{\partial\theta}{\partial t}-(1+A\varepsilon e^{nt})\frac{\partial\theta}{\partial y}\right]=\frac{1}{\Pr}\frac{\partial^2\theta}{\partial y^2}-(F+Q)\,\theta+Q_1\,\phi+Du\frac{\partial^2\phi}{\partial y^2} \quad (11)$$

$$\left[\left(1+\lambda_1\frac{\partial}{\partial t}\right)\frac{\partial\phi}{\partial t}-(1+A\varepsilon e^{nt})\frac{\partial\phi}{\partial y}\right]=\frac{1}{Sc}\frac{\partial^2\phi}{\partial y^2}-K\,\phi \quad (12)$$

The corresponding boundary conditions are given by

$$\begin{aligned}&u=U_p \qquad \theta=1+\varepsilon\,e^{nt} \quad \phi=1+\varepsilon\,e^{nt}, \qquad at \quad y=0\\&U\to U_\infty=1+\varepsilon\,e^{nt}, \qquad \theta\to 0, \quad \phi\to 0 \quad as \quad y\to\infty\end{aligned} \quad (13)$$

## 3. Method of Solution

The set of Eq. (10) to Eq. (12) are partial differential equations which cannot be solved in closed form. However, these can be solved by reducing them into a set of ordinary differential equations using the following perturbation method. Now represent the velocity, temperature and concentration distributions in terms of harmonic and non-harmonic functions as

$$\begin{aligned}u(y,t)&=u_0(y)+\varepsilon\,u_1(y)e^{nt}+O(\varepsilon^2)\\\theta(y,t)&=\theta_0(y)+\varepsilon\,\theta_1(y)e^{nt}+O(\varepsilon^2)\\\phi(y,t)&=\phi_0(y)+\varepsilon\,\phi_1(y)e^{nt}+O(\varepsilon^2)\end{aligned} \quad (14)$$

Substituting Eq. (14) into Eq. (10) to Eq. (12), and equating the harmonic and non-harmonic terms, and neglecting the higher order terms of ε, obtain the following pairs of equations of order zero and order one.

$$u_0''+u_0' - (M+1/k)\,\mathrm{u}_0 = -\mathrm{Gr}\,\theta_0 - \mathrm{Gm}\,\phi_0-(M+1/k) \quad (15)$$

$$\theta_0''+\Pr\theta_0' - (F+Q)\Pr\theta_0=-Q_1\Pr\phi_0-\Pr Du\,\phi_0'' \quad (16)$$

$$\varphi_0^{ll}+Sc\;\;\varphi_0^{l}-\mathrm{Sc}\,\mathrm{K}\varphi_0=0 \quad (17)$$

$$u_1''+u_1' - \left((M+1/k)+n+\lambda_1 n^2\right)\mathrm{u}_1 = -\mathrm{Gr}\,\theta_1 - \mathrm{Gm}\,\phi_1 - Au_0^{\prime}-\left((M+1/k)+n+\lambda_1 n^2\right) \quad (18)$$

$$\theta_1''+\Pr\theta_1'-(n+\lambda_1 n^2+F+Q)\Pr\theta_1 = -\Pr\mathrm{A}\,\theta_0' - \mathrm{Q}_1\Pr\phi_1'-\Pr Du\,\phi'' \quad (19)$$

$$\varphi_1^{ll}+Sc\;\;\varphi_1^{l}-\mathrm{Sc}\;(\mathrm{K}+n+\lambda_1 n^2)\,\varphi_1 = -\mathrm{A}\,\mathrm{Sc}\,\varphi_0^{1} \quad (20)$$

The corresponding boundary conditions are

$$\begin{aligned} &u_0 = U_p, u_1 = 0, \theta_0 = 1, \theta_1 = 1, \quad C_0 = 1, \quad C_1 = 1 \qquad at \quad y = 0 \\ &u_0 = 1, \quad u_1 = 1, \theta_0 \to 0, \theta_1 \to 0, C_0 \to 0, C_1 \to 0 \qquad as \quad y \to \infty \end{aligned} \tag{21}$$

Solving Eq. (15) to Eq. (20) under the boundary conditions (21), the following solutions are obtained

$$u_0 = 1 + B_9 \exp(-m_1 y) + B_{10} \exp(-m_3 y) + B_{11} \exp(-m_5 y) \tag{22}$$

$$\begin{aligned} u_1 = 1 &+ B_{12} \exp(-m_1 y) + B_{13} \exp(-m_2 y) + B_{14} \exp(-m_3 y) + B_{15} \exp(-m_4 y) \\ &+ B_{16} \exp(-m_5 y) + B_{17} \exp(-m_6 y) \end{aligned} \tag{23}$$

$$\theta_0 = B_3 \exp(-m_1 y) + B_4 \exp(-m_3 y) \tag{24}$$

$$\theta_1 = B_5 \exp(-m_1 y) + B_6 \exp(-m_2 y) + B_7 \exp(-m_3 y) + B_8 \exp(-m_4 y) \tag{25}$$

$$\phi_0 = \exp(-m_1 y) \tag{26}$$

$$\phi_1 = B_1 \exp(-m_1 y) + B_2 \exp(-m_2 y) \tag{27}$$

Substituting Eq. (22) to Eq. (27) in Eq. (14), obtain the velocity, temperature and concentration distribution in the boundary layer as follows

$$u = 1 + B_9 \exp(-m_1 y) + B_{10} \exp(-m_3 y) + B_{11} \exp(-m_5 y) + \varepsilon e^{nt} \begin{pmatrix} 1 + B_{12} \exp(-m_1 y) + \\ B_{13} \exp(-m_2 y) + \\ B_{14} \exp(-m_3 y) + \\ B_{15} \exp(-m_4 y) + \\ B_{16} \exp(-m_5 y) + \\ B_{17} \exp(-m_6 y) \end{pmatrix} \tag{28}$$

$$\theta = B_3 \exp(-m_1 y) + B_4 \exp(-m_3 y) + \varepsilon e^{nt} \begin{pmatrix} B_5 \exp(-m_1 y) + B_6 \exp(-m_2 y) + \\ B_7 \exp(-m_3 y) + B_8 \exp(-m_4 y) \end{pmatrix} \tag{29}$$

$$\phi = \exp(-m_1 y) + \varepsilon e^{nt} \left( B_1 \exp(-m_1 y) + B_2 \exp(-m_2 y) \right) \tag{30}$$

### *3.1 Skin Friction*

Very important physical parameter at the boundary is the skin friction which is given in the non-dimensional form and derives as

$$\tau = \left(\frac{\partial u}{\partial y}\right)_{y=0} = -\left(B_9 m_1 + B_{10} m_3 + B_{11} m_5\right) - \varepsilon e^{nt}\begin{pmatrix} B_{12} m_1 + B_{13} m_2 + B_{14} m_3 + \\ B_{15} m_4 + B_{16} m_5 + B_{17} m_6 \end{pmatrix} \quad \textbf{(31)}$$

*3.2 Nusselt Number*

In Another physical parameter like rate of heat transfer in the form of Nusselt number expressed by

$$Nu = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0} = B_3 m_1 + B_4 m_3 + \varepsilon e^{nt}\left(B_5 m_1 + B_6 m_2 + B_7 m_3 + B_8 m_4\right) \quad \textbf{(32)}$$

*3.3 Sherwood Number*

The rate of mass transfer in the form of Sherwood number are also derived by

$$Sh = -\left(\frac{\partial C}{\partial y}\right)_{y=0} = m_1 + \varepsilon e^{nt}\left(B_1 m_1 + B_2 m_2\right)$$

$$Sh = m_1 A_3 + m_3 A_4 + \varepsilon\, e^{nt}(m_1 A_5 + m_2 A_6 + m_4 A_7 + m_5 A_8) \quad \textbf{(33)}$$

**4. Results and Discussion**

In this paper, the unsteady magneto-hydrodynamic mixed convection flow over an inclined permeable moving plate in presence of aligned magnetic field, thermal radiation, heat absorption and homogenous chemical reaction, subjected to the variable suction are discussed in detail through graphs from Figure 1 to 13. The governing equations are having non- linear nature and have been solved by analytical method. The objective of this section is to analyze the behaviour of various involved parameters such as visco-elastic parameter (λ), Magnetic field parameter (M), Permeability of porous medium (k), Grashof number (Gr), modified Grashof number (Gm), Heat absorption coefficient (Q), Prandtl number (Pr), radiation parameter (F), Schmidt number (Sc), Diffusion thermo Parameter (Du), chemical reaction parameter (K), on the velocity, temperature and concentration profiles. As well as the variation of skin friction, rate of heat and mass transfers in term of Nusselt and Sherwood numbers for various values of the involved parameters are shown in Table 1.

Figure 2 depicts the influence of the Hartmann number on velocity with a rise in the Hartmann number, the velocity falls. It's because the introduction of a transverse magnetic field produces a resistive type force (Lorentz force) that acts like a drag force, resisting fluid flow and lowering its velocity. In addition, when the Hartmann number raises, the thickness of the boundary layer decreases. The influence of the permeability of the porous media parameter on the velocity distribution is shown in Figure 3. As can be seen, the velocity rises as the dimensionless porous media parameter rises. Physically, this outcome may be obtained by ignoring the holes in the porous substance. Figure 4 and 5, effects of thermal and solute buoyancy on velocity are presented, in which it is noticed that velocity increases in both the cases as both the parameters namely Grashof number and modified Grashof number increase. It can be seen in Figure 6 that the angle of inclination (α) decreases the effect of the buoyancy force due to thermal diffusion. Consequently, the driving force to the fluid decreases as a result velocity of the fluid decreases. Figure 7 presents the velocity profiles for different values of visco-elastic parameter (λ). Velocity is observed to be increasing with the increase in visco-elastic parameter.

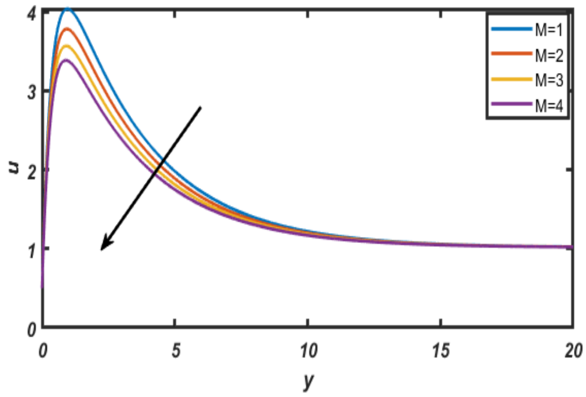


**Fig. 2.** The Influence of Magnetic field parameter (M) on velocity profiles

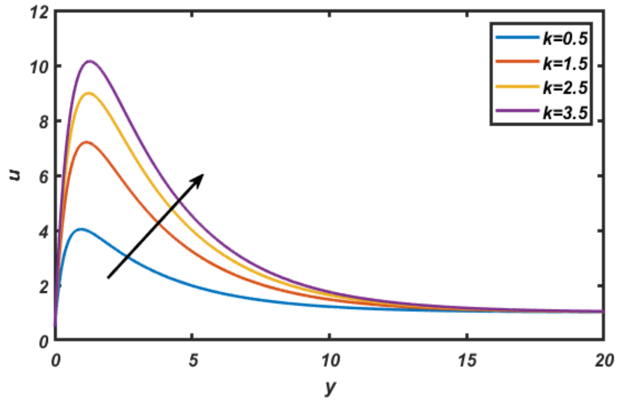


**Fig. 3.** The Influence of Permeability of porous media (k) on velocity profiles

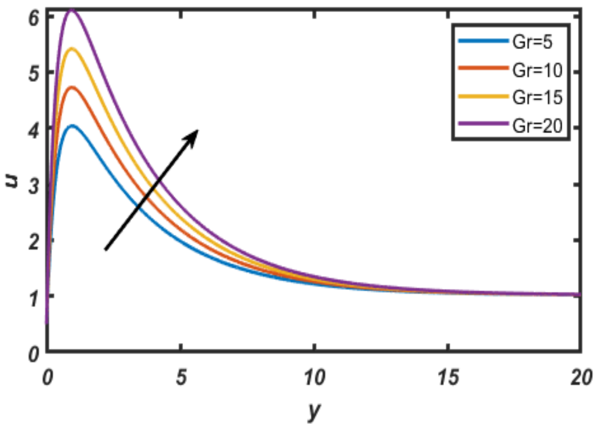


**Fig. 4.** The Influence of thermal Grashof number (Gr) on velocity profiles

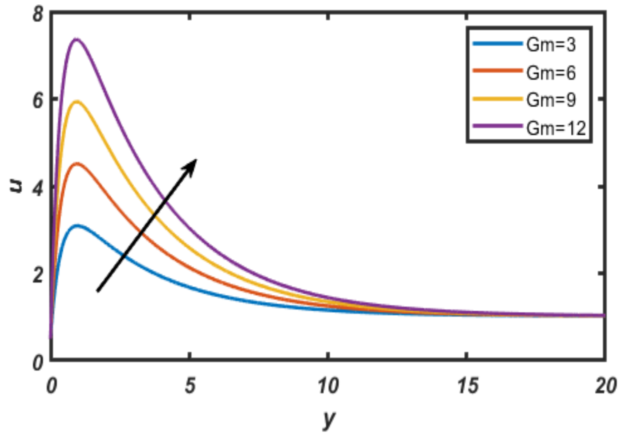


**Fig. 5.** The Influence of mass Grashof number (Gm) on velocity profiles

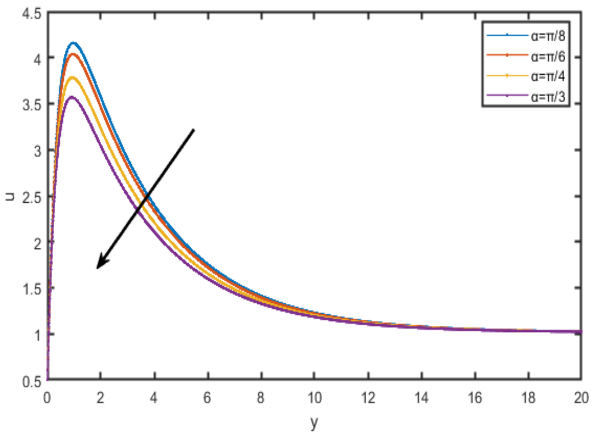


**Fig. 6.** The Influence of Inclined angle (α) parameter on velocity profiles

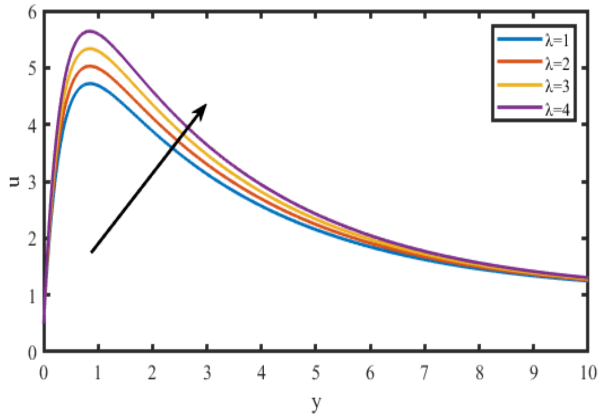


**Fig. 7.** The Influence of visco-elastic parameter (λ) on velocity profiles

Figure 8 and 9 show the effect of the radiation absorption parameter on velocity and temperature respectively. It is clear from these graphs that both velocity and temperature raise as the radiation absorption parameter rises. Because thermal radiation is linked with high temperature. Figure 10 illustrates the influence of the heat absorption coefficient *Q* on the temperature profile. Physically speaking, the presence of heat absorption (thermal sink) effects has the tendency to reduce the fluid temperature. Figure 11 depicts the effect of Prandtl number (Pr) on temperature profiles in presence of some selected fluids such as Hydrogen (Pr = 0.68), Air (Pr = 0.71), Carbon dioxide (Pr = 0.76) and Electrolytic solution (Pr = 1). From this figure, observed that, an increase in the Prandtl number decreases the temperature of the flow field at all points. Due to the ratio of momentum diffusivity (kinematic viscosity) to thermal diffusivity.

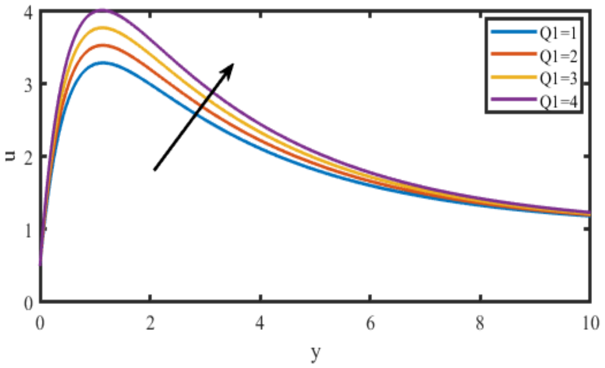


**Fig. 8.** The Influence of Radiation absorption ($Q_1$) parameter on velocity profiles

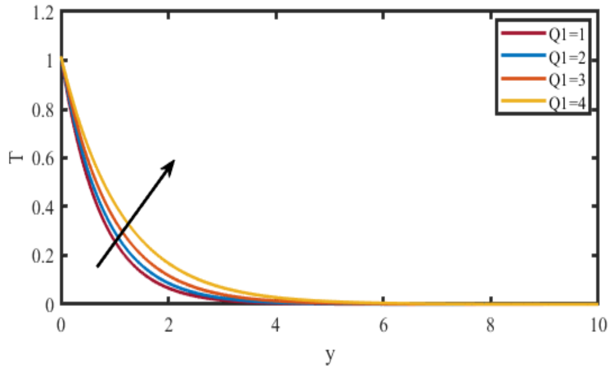


**Fig. 9.** The Influence of Radiation absorption ($Q_1$) parameter on Temperature profiles

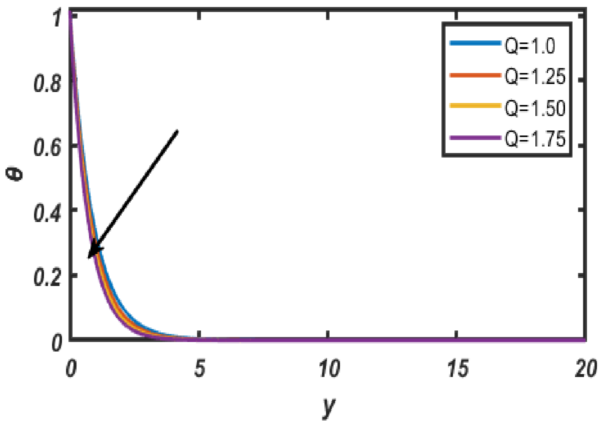


**Fig. 10.** The influence of Heat absorption coefficient (Q) on Temperature profiles

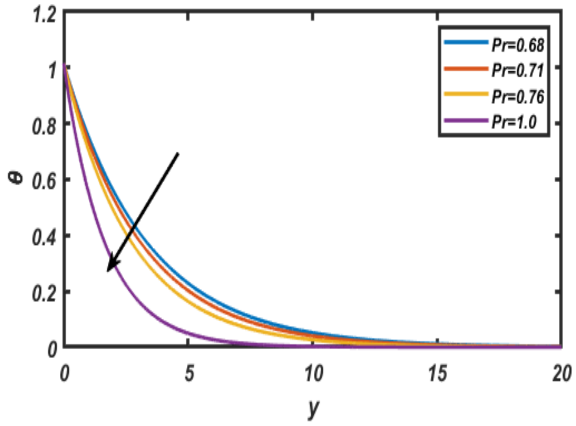


**Fig. 11.** The influence of Prandtl number (Pr) on Temperature profiles

Figure 12 and 13 illustrate the velocity and temperature profiles for different values of the Dufour number Du. The analytical results show that the effect of increasing values of Dufour number results in an increases velocity and temperature. Causes influence of Dufour number controls the influence of chemical concentration on fluid temperature. The Dufour effect is the reciprocal phenomenon, i.e., the rate of a heat flux owing to a chemical potential gradient.

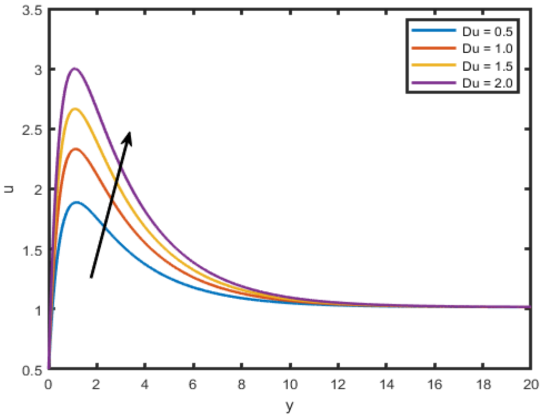


**Fig. 12.** The Influence of Dufour specification ($D_u$) on velocity profiles

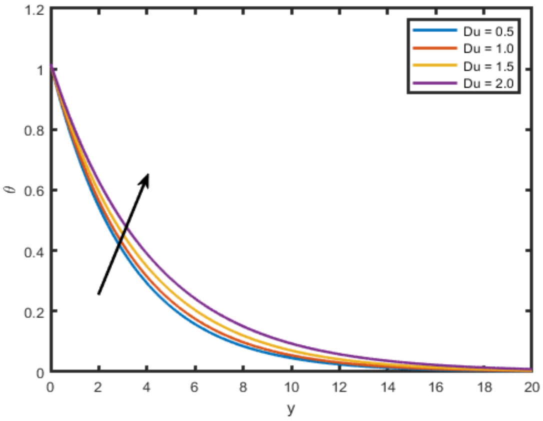


**Fig. 13.** The influence Dufour specification ($D_u$) on Temperature profiles

The influence of Schmidt number (Sc) on the velocity and concentration profiles is shown in Figure 14. Graphical result of concentration profile for different values of Schmidt number Sc shows that with an increase in Sc, decreases the concentration profile. Physically this is true because of the fact that the water vapors can be used for maintaining normal concentration field whereas hydrogen can be used for maintaining effective concentration field. Figure 15, depicts the influence of chemical reaction effect on concentration. This figure witness that concentration decreases with an increase in the values of chemical reaction parameter.

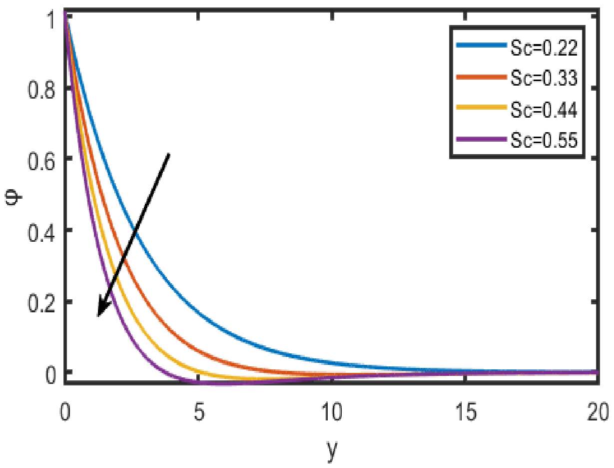


**Fig. 14.** The influence of Schmidt number (Sc) on Concentration profiles

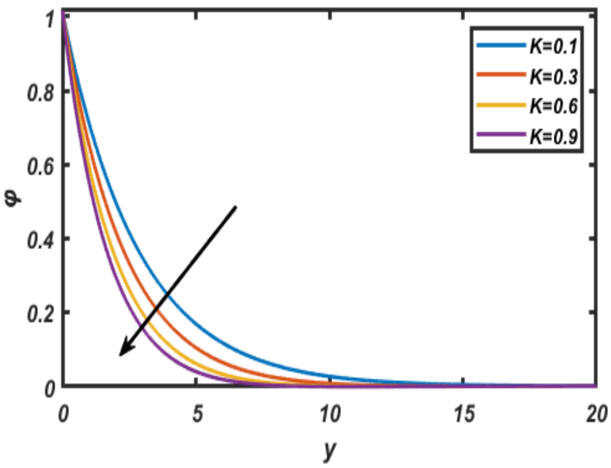


**Fig. 15.** The influence of Chemical reaction parameter (K) on Concentration profiles

The variation in skin-friction coefficient, the rate of heat transfer in the form of Nusselt number and the rate of mass transfer in the form of Sherwood number for various parameters are studied through Table 1 to Table 3. For the validity of our work to compared our results with the existing results of Vaddemani *et al.,* [32]. Our result appears to be in excellent agreement with the existing results.

Table 1 shows numerical values of skin-friction for several of Grashof number (Gr), modified Grashof number (Gm), Magnetic parameter (M), and Porosity parameter (k). From Table 1, we observe that the skin-friction increases with an increase in Grashof number (Gr), modified Grashof number (Gm), Porosity parameter (K), Heat source parameter (Q), and Thermal Radiation (F), whereas it decreases under the influence of magnetic parameter (M), Radiation absorption (Q1), Diffusion thermo parameter (Du) and Chemical Reaction (K). Table 2 demonstrates the numerical values of Nusselt number (Nu) for different values of Prandtl number (Pr), Radiation parameter (R), Heat source parameter (Q). From Table 2, we notice that the Nusselt number increases with an increase in Prandtl number, Radiation parameter and Heat source parameter. Table 3 shows numerical values of Sherwood number (Sh) for the distinction values of Schmidt number (Sc), Chemical reaction parameter (K) and Dufour parameter (Du). It can be noticed from Table 3 that the Sherwood number enhances with rising values of Schmidt number, chemical reaction parameter where as it decreases under the influence of Dufour parameter.

**Table 1**
The consequence of numerous quantities on the skin friction for Sc=0.22, Pr=0.71, Gr=5, k=0.5, K=0.1, M=1, Q=0.1, E=0.01, A=0.5, F=0.5, Gm=5, t=0.5, n=1, Up=0.5, $Q_1$=0.5, Du=0.5

| Gr | Gm | M | k | $Q_1$ | K | Du | F | Q | T |
|---|---|---|---|---|---|---|---|---|---|
| 4.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 0.7874 |
| 6.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 0.8875 |
| 12.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 1.3144 |
| 4.0 | 5.0 | 1.0 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 0.8745 |
| 4.0 | 10.0 | 1.0 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 1.3452 |
| 4.0 | 15.0 | 1.0 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 2.0012 |
| 4.0 | 3.0 | 0.5 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 1.1247 |
| 4.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 0.8965 |
| 4.0 | 3.0 | 1.5 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 0.6987 |
| 4.0 | 3.0 | 1.0 | 1.0 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 0.6456 |
| 4.0 | 3.0 | 1.0 | 2.0 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 0.8012 |
| 4.0 | 3.0 | 1.0 | 0.5 | 1.0 | 0.1 | 0.5 | 1.0 | 0.3 | 0.9175 |
| 4.0 | 3.0 | 1.0 | 0.5 | 2.0 | 0.1 | 0.5 | 1.0 | 0.3 | 0.8562 |
| 4.0 | 3.0 | 1.0 | 0.5 | 0.5 | 1.0 | 0.5 | 1.0 | 0.3 | 0.7903 |
| 4.0 | 3.0 | 1.0 | 0.5 | 0.5 | 3.0 | 0.5 | 1.0 | 0.3 | 0.8674 |
| 4.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.1 | 1.0 | 1.0 | 0.3 | 0.9745 |
| 4.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.1 | 1.5 | 1.0 | 0.3 | 0.8464 |
| 4.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 0.3 | 0.7894 |
| 4.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.1 | 0.5 | 1.5 | 0.3 | 0.8467 |
| 4.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 1.0 | 0.7356 |
| 4.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.1 | 0.5 | 1.0 | 1.25 | 0.8176 |

**Table 2**
The consequence of numerous quantities on the Nusselt number for Pr=0.71, λ=0, Q=0.1, E=0.01, A=0.5, F=0.01, t=0.5, Du=0, F=0

| Pr | F | $Q_1$ | Nu | Nu |
|---|---|---|---|---|
| | | | Present Values | Vaddemani *et al.*, [32] |
| 0.4 | | | 1.1373 | 1.2478 |
| 0.7 | | | 1.6283 | 1.8521 |
| 0.9 | | | 1.9182 | 1.8999 |
| | 2.0 | | 1.8972 | 1.8874 |
| | 3.0 | | 2.1124 | 2.0124 |
| | 4.0 | | 2.3092 | 2.4521 |
| | | 1.5 | 1.7726 | 1.7854 |
| | | 2.5 | 2.0093 | 2.0147 |
| | | 3.0 | 2.1163 | 2.9785 |

**Table 3**
The consequence of numerous quantities on the Sherwood Number for Sc=0.22, Pr=0.71, K=0.1, Q=0.1, E=0.01, A=0.5, F=0.01, t=0.5, n=1, Up=0.5

| Sc | K | $D_u$ | Sh |
|---|---|---|---|
| 0.16 | | | 0.2834 |
| 0.22 | | | 0.3205 |
| 1 | | | 0.4673 |
| | 0.5 | | 0.1684 |
| | 2..0 | | 0.4784 |
| | 4.0 | | 0.0484 |
| | | 2.0 | 0.0994 |
| | | 3.0 | -0.1284 |
| | | 4.0 | -0.3384 |

## 5. Conclusion

In the present investigation have studied analytically Radiation absorption and Chemical Reaction effects on Unsteady MHD Kuvshinski fluid flow past an inclined porous plate. From the present investigation the following conclusions can be drawn.

i. The fluid velocity increases when the Visco velocity parameter (λ), the Grashof number (Gr), modified Grashof number (Gm), the porous media (k) increase. Whereas it has reverse effect on fluid velocity with enhances magnetic field parameter (M).
ii. Both resultant velocity and Temperature enhances with increasing diffusion thermo and Radiation absorption.
iii. The fluid temperature decreases with the effect of the Prandtl number, radiation parameter, and heat source parameter.
iv. Both velocity and temperature enhance with increasing Radiation absorption and Dufour Parameters.
v. The fluid temperature decreases with the effect of the Prandtl number (Pr), radiation parameter (F) and heat source parameter (Q).
vi. The concentration level of the fluid diminishes increasing chemical reaction parameter (K) and the Schmidt number (Sc).

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