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RADIATION ABSORPTION EFFECTS ON MHD JEFFREY FLUID FLOW PAST A VERTICAL PLATE THROUGH A POROUS MEDIUM IN CONDUCTING FIELD

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Abstract: The present research aims to examine the radiation absorption effects on MHD Jeffrey fluid flow past a vertical plate through a porous medium in conducting field. The equations that governed the fluid flow are solved using the perturbation technique and the expressions for the velocity, temperature, and concentration distributions have been obtained. Investigating, the obtained numerical values for Dimensionless velocity, temperature and concentration profiles are displayed graphically for different values of the parameters entering into the problem have been investigated. The effects of different parameters on the physiological quantities of interest are captured with the assistance of MATLAB programming. Also the expressions for physical quantities such as the skin friction, Nusselt number and Sherwood have been derived. Our sketches illustrate that the induced magnetic field is perceived to be downward with intensification in magnetic parameter. Temperature profile is accelerated by rising heat absorption and concentration distribution is decelerated by enhancing the chemical reaction and Schmidt number. The effect of all of the parameters involved with the help of tables, graphs and reports.
Keywords: MHD, chemical reaction, radiation, radiation absorption, Jeffrey parameter, skin–friction

1. INTRODUCTION

MHD is a fluid dynamics of plasma which can carry an electric current. The interaction with this current and the magnetic field generated by the current, as well as externally imposed magnetic fields, give MHD its rich character which adds to underlying fluid dynamics. Although the plasma can carry a current, it remains electrically neutral throughout the course of its dynamics. Unsteady MHD Convective flow of Rivlin–Ericksen fluid over an infinite vertical porous plate with absorption effect and variable suction was studied by VeeraSankar et al. [1]and Sharmilaa et al. [2] Steadied MHD mixed convective flow in presence of inclined magnetic field and thermal radiation with effects of chemical reaction and Soret embedded in a porous medium. Unsteady MHD mixed convection flow of Jeffrey fluid past a radiating inclined permeable moving plate in the presence of the thermophoresis heat generation and chemical reaction was discussed by Venkateswararaju et al. [3]. Unsteady MHD free convection flow of a visco elastic fluid past a vertical porous plate. International journal of dynamics of fluids was studied by Gurivi Reddy et al. [4]. Reddy et al. [5] studied MHD boundary layer flow, heat and mass transfer analysis over a rotating disk through porous medium saturated by Cu–water and Ag–water Nano fluid with chemical reaction. Magneto hydrodynamic (MHD) mixed convection flow of micro polar liquid due to nonlinear stretched sheet with convective condition was discussed by Waqas et al. [6]. Rashad et al, [7] studied by MHD mixed convection of localized heat source/sink in a Nano fluid–filled lid–driven square cavity with partial slip. The porous debris could be saturated sodium coolant and heat generation will result from the radioactive decay of the fuel particulate. Chemical reaction and radiation absorption effects on MHD convective heat and mass transfer flow of a visco–elastic fluid past an oscillating porous plate with heat generation / absorption was studied by Ramaiah et al. [8]. Recently researchers [9–11] showed interest in this area. K Raghunath et al. [12] have studied Heat and mass transfer on Unsteady MHD flow of a second grade fluid through porous medium between two vertical plates. Raghunath K et al. [13] Discussed Hall Effects on MHD Convective Rotating Flow of Through a Porous Medium past Infinite Vertical Plate. Raghunath, et al. [14] have discussed Heat and mass transfer on an unsteady MHDflow through porous medium between two porous vertical plate. This paper is an extension work to the paper of Obulesu and Sivaprasad [15] by considering Hall current effects on MHD convective flow past a porous plate with thermal radiation, chemical reaction and heat generation/absorption, along with thermal diffusion.

2. FORMULATION OF THE PROBLEM

Let x^* –axis is taken along the porous plate in the upward direction and y^* –axis is normal to it. The fluid is assumed to be gray, absorbing–emitting but non–scattering medium. The radiative heat flux in the x^* –

direction is considered negligible in comparison with that in the y* –direction. It is assumed that there is no applied voltage of which implies the absence of an electric field. The transversely applied magnetic field and magnetic Reynolds number are very small and hence the induced magnetic field is negligible. The MHD term is derived from an order of magnitude analysis of the full Navier–stokes equation. It is assumed that the whole size of the porous plate is significantly larger than characteristics microscopic length scale of the porous medium. We regard the porous medium as an assemblage of small identical spherical particles fixed in space. The chemical reactions are taking place in the flow and all thermo physical properties are assumed to be constant of the linear momentum equation, which is approximation. The fluid properties are assumed to be constant except that the influence of density variation with temperature and concentration has been considered in the body force term. The magnetic and viscous dissipations are neglected. Due to the assumption that the plate in x* –direction is of infinite length, all the flow variables except pressure are functions of y* and t* only.

Continuity equation:

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

Momentum equation:

$$\frac{\partial u^*}{\partial t^*}+V^*\frac{\partial u^*}{\partial y^*}=\left(\frac{\vartheta}{1+\alpha}\right)\frac{\partial^2 u^*}{\partial y^{*2}}+g\beta\ (T^*-T_\infty)+gB^*(C^*-C_\infty)$$
$$-K_1{}'\frac{\partial^3 u^*}{\partial y^{*2}\,\partial t^*}-\frac{\sigma B_0^2}{\rho}u^*-\frac{\vartheta}{K_0}u^* \tag{2}$$

Energy equation:

$$\frac{\partial T^*}{\partial t^*}+V^*\frac{\partial T^*}{\partial y^*}=\frac{K}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}}+\frac{1}{\rho C_p}\frac{\partial q_r}{\partial y^*}-\frac{S^*}{\rho C_p}(T^*-T_\infty)-\frac{R^*}{\rho C_p}(C^*-C_\infty) \tag{3}$$

Concentration equation

$$\frac{\partial C^*}{\partial t^*}+V^*\frac{\partial C^*}{\partial y^*}=D\frac{\partial^2 C^*}{\partial y^{*2}}-K^*(C^*-C_\infty) \tag{4}$$

The relevant boundary conditions are given as follows

$$u^*=U_0(1+\varepsilon e^{i\omega^* t^*}),\quad T^*=T_w+\varepsilon(T_w-T_\infty)e^{i\omega^* t^*},\quad C^*=C_w+\varepsilon(C_w-C_\infty)e^{i\omega^* t^*},\quad \text{at}\quad y^*=0$$
$$u^*\to 0,\ T^*\to T_\infty,\quad C^*\to C_\infty\quad \text{as } y^*\to\infty \tag{5}$$

where U_0 is the plate velocity, T_w and C_∞ are the wall dimensional temperature and concentration, respectively, T_∞ and C_∞ are the free stream dimensional temperature and concentration, respectively, ω–the constant.

Eq. (1) gives that

$$V^* = \text{Constant} = -V_0. \tag{6}$$

where V_0 is the constant suction velocity normal to the plate.

Introducing the following non–dimensional quantities,

$$u=\frac{u^*}{U_0},w=\frac{\upsilon w^*}{U_0^2},\lambda_1=\frac{U_0^2K_1{}'}{\rho\upsilon^2},\ y=\frac{U_0\ y^*}{\vartheta},\ t=\frac{t^*U_0{}^2}{\vartheta}\ T=\frac{T^*-T_\infty}{T_w-T_\infty},\quad C=\frac{C^*-C_\infty}{C_w-C_\infty},$$
$$\Pr=\frac{\mu C_p}{K},\ Sc=\frac{\vartheta}{D},\ M^2=\frac{\sigma_e B_0^2\vartheta}{\rho U_0{}^2},Gr=\frac{\vartheta g\beta\ (T_w-T_\infty)}{U_0^3},\quad Gm=\frac{\vartheta g\beta^*(C_w-C_\infty)}{U_0^3}$$
$$K_p=\frac{K_0U_0^2}{\vartheta^2},V_0=\frac{v_0}{U_0},\ K_r=\frac{\vartheta K^*}{U_0^2},R=\frac{4I^*\vartheta^2}{KU_0^2},\ S=\frac{S^*v^2}{KU_0^2},R_1=\frac{R^*\vartheta^2(C_w-C_\infty)}{KU_0^2(T_w-T_\infty)}, \tag{7}$$

In view of the above non–dimensional quantities and the equation (6) the equations (2) to (4) after dropping the asterisks reduce to the following dimensionless form.

$$\frac{\partial u}{\partial t}-V_0\frac{\partial u}{\partial y}=\beta\frac{\partial^2 u}{\partial y^2}+GrT+GmC-M_1u-\lambda_1\frac{\partial^3 u}{\partial y^2\partial t} \tag{8}$$

$$\Pr\frac{\partial T}{\partial t}-\Pr V_0\frac{\partial T}{\partial y}=\frac{\partial^2 T}{\partial y^2}+LT-R_1C \tag{9}$$

$$Sc\frac{\partial C}{\partial t}-ScV_0\frac{\partial C}{\partial y}=\frac{\partial^2 C}{\partial y^2}-ScK_rC \tag{10}$$

where $M_1=M^2+\frac{1}{K_p}$, $L=R-S$, $\beta=\frac{1}{1+\alpha}$

The corresponding boundary conditions are:

$$\begin{aligned} &u=1+\varepsilon e^{i\omega t},\ T=1+\varepsilon e^{i\omega t}, C=1+\varepsilon e^{i\omega t} \quad \text{at} \quad y=0 \\ &u\to 0, \quad T\to 0, \quad C\to 0 \quad s \quad y\to\infty \end{aligned} \tag{11}$$

3. SOLUTION OF THE PROBLEM

To solve the nonlinear equations (8) to (10) with the boundary conditions (11)Substituting equation (12) into the equations (8), (9) and (10) and equating the harmonic and non–harmonic terms, neglecting the terms of $\in^2$, we get

$$\begin{aligned} u(y,t) &= u_o(y)+\varepsilon u_1(y)e^{i\omega t} \\ T(y,t) &= T_o(y)+\varepsilon T_1(y)e^{i\omega t} \\ C(y,t) &= C_o(y)+\varepsilon C_1(y)e^{i\omega t} \end{aligned} \tag{12}$$

Zero order terms:

$$\beta u_0''+V_0u_0' = -Gr\,T_0 - Gm\,C_0 + M_1u_0 \tag{13}$$

$$T_0''+Pr\,V_0T_0'+\alpha T_0 = R_1\,C_0 \tag{14}$$

$$C_0'' + Sc\ V_0C_0'-ScK_rC_0 = 0 \tag{15}$$

First order terms:

$$N_1u_1''+V_0u_1' = -Gr\,T_1 - Gm\,C_1 + N_2u_1 \tag{16}$$

$$T_1''+Pr\,V_0T_1'+(\alpha - Pr(i\omega)\,T_1 = R_1\,C_1 \tag{17}$$

$$C_1''+ScV_0C_1'-Sc(K_r+i\omega)C_1=0 \tag{18}$$

where $N_1=\beta-\lambda_1(i\omega)$, $N2=M_1+i\omega$

The corresponding boundary conditions are

$$\begin{aligned} &u_0=1,\ u_1=1,\quad T_0=1,\ T_1=1,\ C_0=1,\ C_1=1 \qquad \text{at } y=0 \\ &u_0\to 0,\ u_1\to 0,\quad T_0\to 0,\ T_1\to 0,\quad C_0\to 0,\ C_1\to 0 \qquad \text{at } y\to\infty \end{aligned} \tag{19}$$

Solving equations (14) – (18) under the boundary conditions (19), the following solutions are obtained

$$u_0(y)=b_5e^{-m_1y}+b_6e^{-m_3y}+b_7e^{-m_5y} \tag{20}$$

$$u_1(y)=b_8e^{-m_2y}+b_9e^{-m_4y}+b_{10}e^{-m_6y} \tag{21}$$

$$\theta_0(y)=b_1e^{-m_1y}+b_2e^{-m_3y} \tag{22}$$

$$\theta_1(y)=b_3e^{-m_2y}+b_4e^{-m_4y} \tag{23}$$

$$\phi_0(y)=e^{-m_1y} \tag{24}$$

$$\phi_1(y)=e^{-m_3y} \tag{25}$$

Substituting equations (20) – (25) in equation (12) we obtain the velocity temperature and concentration field

$$u(y,t)=(b_5e^{-m_1y}+b_6e^{-m_3y}+b_7e^{-m_5y})+\varepsilon(b_8e^{-m_2y}+b_9e^{-m_4y}+b_{10}e^{-m_6y})e^{i\omega t} \tag{26}$$

$$T(y,t)=(b_1e^{-m_1y}+b_2e^{-m_3y})+\varepsilon(b_3e^{-m_2y}+b_4e^{-m_4y})e^{i\omega t} \tag{27}$$

$$C(y,t)=e^{-m_1y}+\varepsilon\,e^{-m_2y}e^{i\omega t} \tag{28}$$

— **Skin friction**

The non–dimensional skin friction at the surface is given by

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

$$\tau=[m_1b_5+m_3b_6+m_5b_7]+\varepsilon[m_2b_8+m_4b_9+m_6b_{10}]e^{i\omega t} \tag{29}$$

— **Nusselt number**

The rate of heat transfer in terms of the Nusslelt number is given by

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

$$Nu = [m_1 b_1 + m_3 b_2] + \varepsilon [m_2 b_3 + m_4 b_4] e^{i\omega t} \quad (30)$$

— **Sherwood number**

The rate of mass transfer on the wall in terms of Sherwood number is given by

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

$$Sh = m_1 + \varepsilon m_2 e^{i\omega t} \quad (31)$$

4. RESULTS AND DISCUSSION

In order to get a physical insight into the problem numerical calculations are carried out for the Velocity, Temperature and concentration profiles and the following discussion is set out. Throughout the computations we employ, V0 =1, Sc=0.22, Pr=0.71, Gr=1, Gm=1, S=2, Kr=1, Kp =1, M=1, E=0.01, t=3, R=1, R1=1, ω=π/6, λ=1.

In order to reveal the effects of various parameters on the dimensionless velocity fields, temperature field, concentration field, skin friction, Nusselt number and Sherwood number and the effect of the various physical parameters such as the Grashof number (Gr), the modified Grashof number (Gm),Magnetic parameter (M), Permeability parameter(K_p),Jeffrey parameter(α), Prandtl number (Pr), Heat absorption parameter(S), Radiation Parameter (R), Radiation absorption Parameter (R_1), Schmidt number(Sc) and Chemical reaction parameter(K_r) on velocity, temperature and concentration we draw a number of figures marked as Figures 1–11 and study these by choosing arbitrary values. The influence of these parameters on skin friction, Nusselt number and Sherwood number is also shown in Tables 1–3.

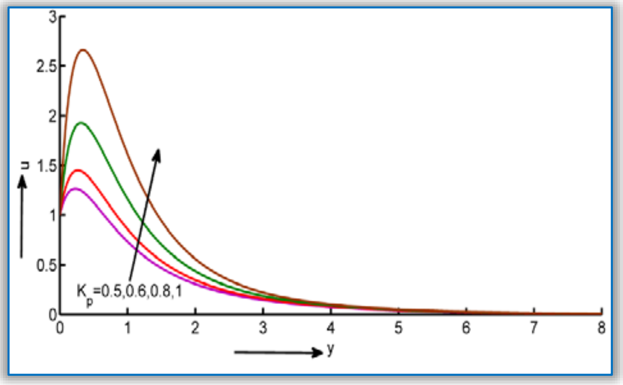

Figure 1: Effect of Permeability parameter on Velocity

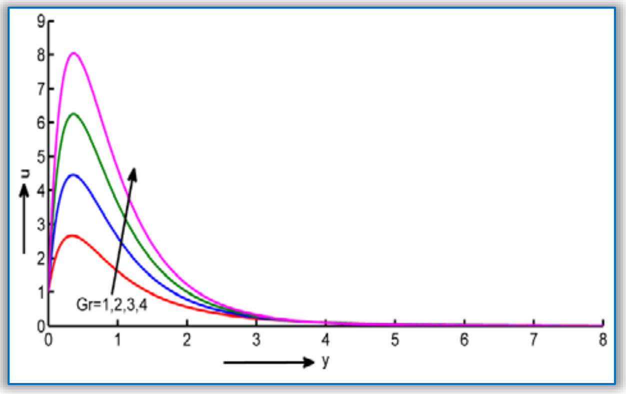

Figure 2: Effect of Thermal Grashof number on Velocity

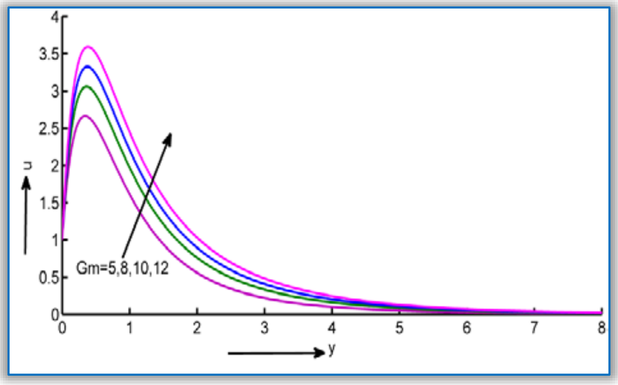

Figure 3: Effect of Modified Grashof number on Velocity

Figures 1–5 demonstrate the variations of the fluid velocity under the effects of different parameters. Figure 1 depicts the variations in velocity profiles for different values of permeability parameter (K_p). From where it is noticed that, velocity increases as K_p increases. In Figure 2, we represent the velocity profile for different values of Grashof number (Gr). From this figure it is noticed that, velocity increases with increases in Gr. In Figure 3 the effect of modified Grashof number (Gm) on velocity is presented. As Gm increases, velocity also increases. In Figure 4, velocity profiles are displayed with the variation in magnetic parameter (M). From this figure it is noticed the velocity gets reduced by the increase of magnetic parameter (M). Figure 5 depicts the variations in velocity profiles for different values of Jeffreyparameter (α) which shows that velocity increases asαincreases.

Figures 6–9, display the variations of the fluid temperature under the effects of different parameters. From Figures 6–7, it is clear that temperature decreases with the increase in Radiation absorption Parameter (R_1) and Prandtl number (Pr). In Figures 8–9, the effect of Heat absorption parameter(s) and Chemical reaction parameter (K_r) are shown on the temperature profile. From these figures are observed that temperature increases with an increase values in S and K_r.

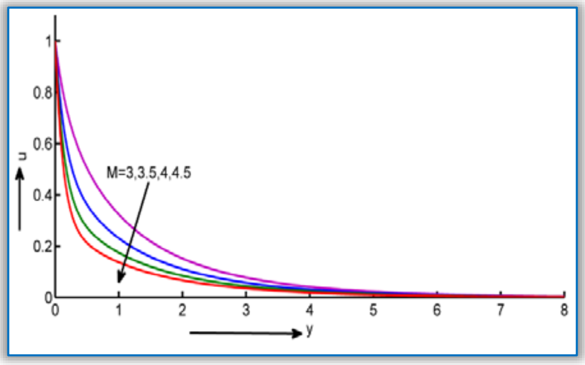

Figure 4: Effect of Magnetic parameter on Velocity

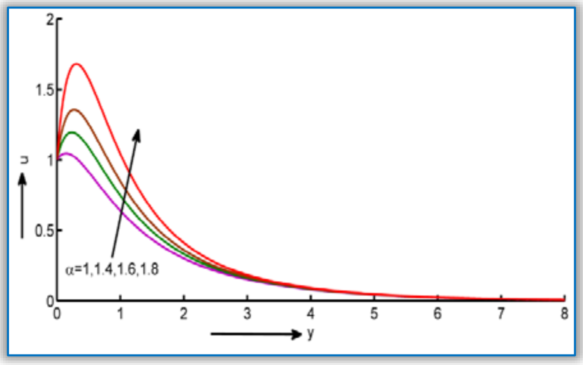

Figure 5: Effect of Jeffrey parameter on Velocity

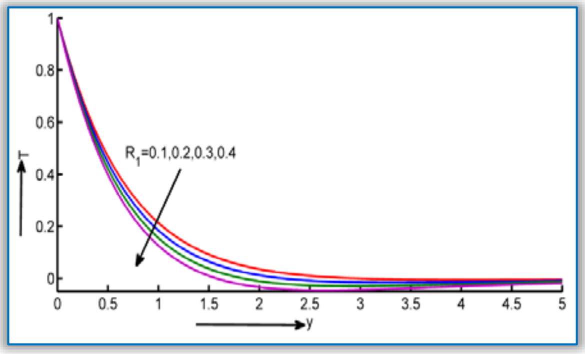

Figure 6: Effect of Radiation absorption parameter on Temperature

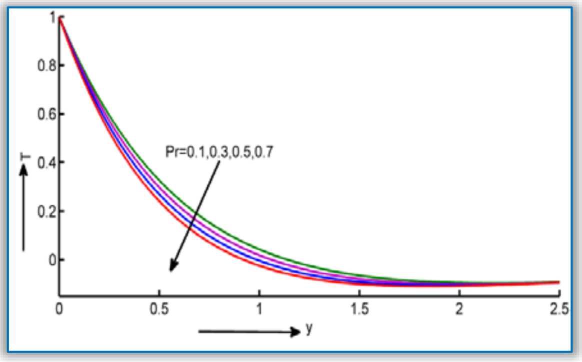

Figure 7: Effect of Prandtl number on Temperature

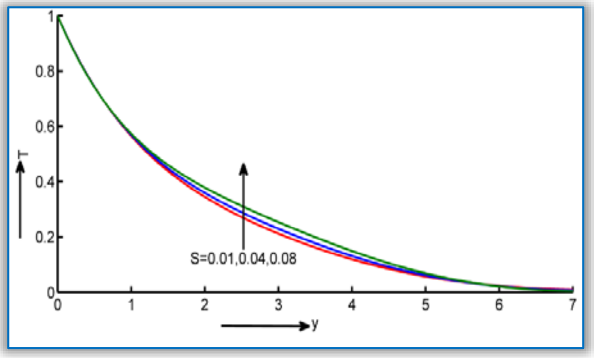

Figure 8: Effect of Heat absorption parameter on Temperature

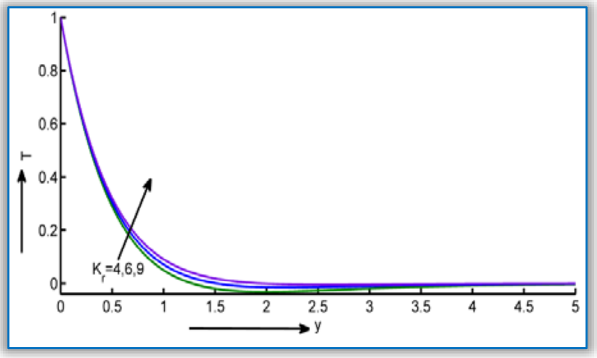

Figure 9: Effect of Chemical Reaction Parameter on Temperature

To analyze the effect of Schmidt parameter (Sc) on the concentration profile in Figure10. The result shows that the concentration field decreases when increases Sc. Figure11 depict the variations in Concentration profile for different values of Chemical Reaction Parameter (K_r). From this figure it is noticed that, Concentration decreases when K_r increases.

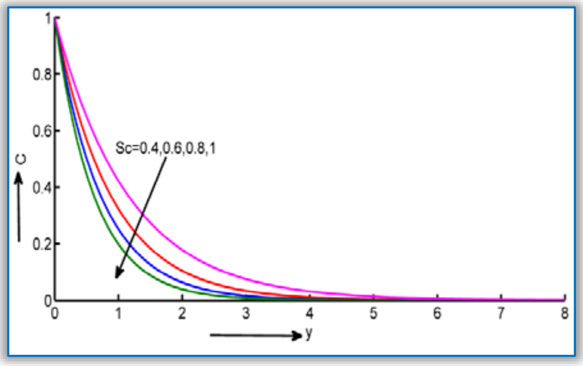

Figure 10: Effect of Schmidt number on Concentration

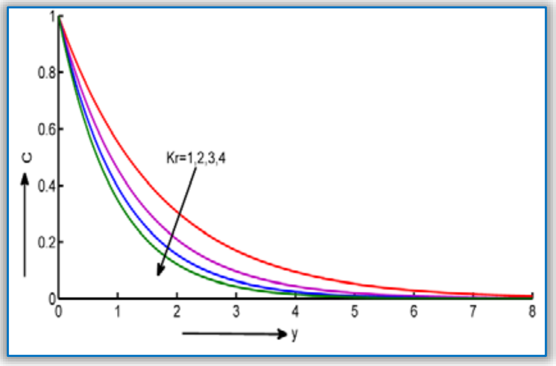

Figure 11: Effect of Chemical Reaction Parameter on Concentration

Table 1. Skin Friction (τ)

Gr	Gm	M	K_p	λ_1	A	τ
1						3.5483
2						4.2090
3						6.8697
4						8.5304
	5					1.8803
	7					0.2124
	10					−2.2896
		1.5				1.4749
		2				3.5483
		2.5				9.7475
			0.5			5.0077
			1.2			3.3460
			1.5			3.1488
				1.2		3.5483
				3		3.5441
				4		3.5329
					1.5	4.5923
					2.5	3.2503
					3	3.0956

Table 2. Nusselt number (NU)

Pr	R	S	R_1	Nu
0.1				1.9758
0.2				2.0416
0.5				2.2498
0.7				2.3975
	3			2.4024
	4			0.6150
	5			0.4870
		2.5		2.2935
		2.7		2.3380
		2.9		2.3827
			3	3.5815
			4	4.1698
			5	4.7580

Table 3. Sherwood number (SH)

Sc	Kr	Sh
0.1		0.3722
0.5		1.0045
0.7		1.2622
	2	0.7848
	3	0.9319
	4	1.0563

Table 1 shows numerical values of skin–friction for various of Grashof number (Gr), modified Grashof number (Gm), Magnetic parameter (M), Permeability parameter (K_p) and Visco elastic parameter (λ_1) From table 1, we observe that the skin–friction decreases with an increase in Grashof number (Gr), modified Grashof number (Gm), Permeability parameter (K_p) where as it increases under the influence of magnetic parameter and visco elastic parameter.

Table 2 demonstrates the numerical values of Nusselt number (Nu) for different values of Prandtl number (Pr), Radiation parameter (R), Heat absorption parameter (S) and Radiation absorption parameter (R_1). From table 2, we notice that the Nusselt number increases with an increase in Prandtl number, Heat absorption parameter (S) and Radiation absorption parameter (R_1) where as it decreases under the influence of Radiation parameter (R).

Table 3 shows numerical values of Sherwood number (Sh) for the distinction values of Schmidt number (Sc), Chemical reaction parameter (K_r). It can be noticed from Table 3 that the Sherwood number enhances with rising values of Schmidt number, and the Chemical reaction parameter.

5. CONCLUSIONS

In this problem, we have studied the radiation absorption effects on MHD Jeffrey fluid flow past a vertical plate through a porous medium in conducting field. In the analysis of the flow the following conclusions are made:

— Velocity increases with an increase in Grashof number and as well as modified Grashof number, Permeability parameter and Jeffrey parameter of the porous medium while, it decreases in the existence of magnetic parameter.
— Temperature increases in the presence of chemical reaction parameter and heat absorption parameter while it decreases in the presence of radiation absorption parameter and Prandtl number.
— Concentration decreases with an increase in Schmidt number and chemical reaction parameter.
— As significant decrease in seen in skin friction for Grashof number, modified Grashof number and permeability parameter while an increase is seen in the presence of magnetic parameter and visco–elastic parameter.
— The rate of heat transfer increases with Prandtl number, heat absorption parameter and radiation absorption parameter where as it decreases with an increase in radiation parameter.
— The rate of mass transfer increases with Schmidt number and chemical reaction parameter.

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