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An exact analysis on transient radiative chemically reactiveflow in porous media with soret effect

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ABSTRACT
An analysis is carried out to study the parametric influences of thermal radiation and first order chemical reaction on a two dimensional unsteady heat and mass transfer flow of Newtonian viscous incompressible fluid past an oscillating plate with Soret effect. It is observed that, the temperature and the fluid velocity decrease due to increase in Peclet number (*Pe*), whereas the concentration as well as the velocity is found to decrease as mass transfer Peclet number (Pe_m) increases. It is also seen that, the vorticity vector of fluid particles increases due to increase in frequency parameter and time but found to decrease as mass transfer Peclet number increases.

Introduction

In recent years, considerable attention has been devoted to the study of combined heat and mass transfer characteristic of a Newtonian viscous fluid because of its significant applications in various fields of science and technology. Many natural problems, chemical processes such as food, polymer production etc. and various transport processes exist where the transfer of heat and mass phenomena are taking place simultaneously. It is interesting to observe that, when heat and mass transfer occur simultaneously in a moving fluid, the relations between the fluxes and the driving potentials are of more complicated in nature. It is observed that, the mass fluxes can also be created not only by concentration gradients alone but by temperature gradients as well and is popularly known as Soret or thermal-diffusion effect. For the fluids with very light molecular weight as well as medium molecular weight, the importance of Soret (thermal-diffusion) effect is enormous and as such many investigators have studied and reported significant results for these flows of whom Eckert and Drake [1], Dursunkaya and Worek [2], Postelnicu [3], Ahmed et al. [4] etc. are worth mentioning. Recently, Sengupta and Sen [5] investigated the thermo-diffusion (Soret) effect on free convective heat and mass transfer flow of Newtonian incompressible viscous fluid with heat generation and thermal radiation. On the other hand combined heat and mass transfer problems with chemical reaction are of importance in many chemical industrial processes and have, therefore, received a considerable amount of attention in recent years. In processes such as drying, evaporation at the surface of a water body, energy transfer in a wet cooling tower and theflow in a desert cooler etc. Chamkha [6] considered the effect of chemical reaction on the MHD flow of a uniformly stretched vertical permeable surface in the presence of heat generation/absorption. Kandasamy et al. [7] studied the effects of chemical reaction on heat and mass transfer flow along a wedge in the presence of suction orinjection. Of late, Sengupta [8] investigated free convective flow of chemically absorbing fluid through porous media with heat sink. In contrary, radiative heat and mass transfer flow with chemical reaction play an important role in manufacturing industries for the design of fins, steel rolling, nuclear power plants, gas turbines and various propulsion device for aircraft, combustion and furnace design, food processing and cryogenic engineering, as well as numerous agricultural, health and military applications. Seddek et al. [9] investigated the combined effects of chemical reaction and thermal radiation on hydromagnetic mixed convective heat and mass transfer Hiemenz flow through porous media. Mohamed and Abo-Dahab [10] studied the influence of chemical reaction and thermal radiation on the heat and mass transfer flow of MHD micropolar fluid with heat generation.

The objective of the present paper is to study theoretically the influence of thermal radiation, first order chemical reaction and Soret effect on the unsteady heat and mass transfer flow of Newtonian viscous incompressible fluid through an impulsively oscillating plate immersed in porous media with consideration of uniform heat and mass fluxes.

Formulation of the Problem:

An unsteady two-dimensional flow of Newtonian incompressible viscous fluid is considered for study, while the fluid and the porous media are supposed to be in local thermo-dynamical equilibrium. Also, the fluid flow and the permeability of the medium are considered to be moderate and as such, the Forchheimer flow model is not applicable for this discussion. A co-ordinate system $(\bar{x},\bar{y})$ has been introduced, with$\bar{x}$-axis along the length of the plate in the upward vertical direction and $\bar{y}$-axis perpendicular to the plate towards the fluid region. The plate oscillates about$\bar{y}$axis and is subjected to a constant suction velocity. Using Boussinesq approximations, a two- dimensional fluid model is thus developed as:

Continuity Equation

$$\frac{\partial \bar{v}}{\partial \bar{y}} = 0 \qquad (1)$$

Momentum Equation

$$\frac{\partial \bar{u}}{\partial \bar{t}} + \bar{v}\frac{\partial \bar{u}}{\partial \bar{y}} = \nu \frac{\partial^2 \bar{u}}{\partial \bar{y}^2} + \beta(\bar{T} - \bar{T}_\infty) + \beta^*(\bar{C} - \bar{C}_\infty) - \frac{\nu}{\bar{K}}\bar{u} \qquad (2)$$

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Energy Equation

$$\frac{\partial \bar{T}}{\partial \bar{t}} + \bar{v}\frac{\partial \bar{T}}{\partial \bar{y}} = \frac{k}{\rho c_p}\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} - \frac{1}{\rho c_p}\frac{\partial \bar{q}_{r\bar{y}}}{\partial \bar{y}} \quad (3)$$

Species Continuity Equation

$$\frac{\partial \bar{C}}{\partial \bar{t}} + \bar{v}\frac{\partial \bar{C}}{\partial \bar{y}} = D_M\frac{\partial^2 \bar{C}}{\partial \bar{y}^2} + D_T\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} - \bar{K}_l(\bar{C} - \bar{C}_\infty) \quad (4)$$

The relevant initio-boundary conditions:

$\bar{u} = 0$, $\bar{T} = \bar{T}_\infty$, $\bar{C} = \bar{C}_\infty$, for every $\bar{y}$, when $\bar{t} \le 0$ (5.1)

$\bar{u} = \bar{u}_0 \exp(i\bar{\omega}\bar{t})$, $\frac{\partial \bar{T}}{\partial \bar{y}} = -\frac{q}{k}$, $\frac{\partial \bar{C}}{\partial \bar{y}} = -\frac{m}{D_M}$, at $\bar{y} = 0$, when $\bar{t} > 0$ (5.2)

$\bar{u} \to 0$, $\bar{T} \to \bar{T}_\infty$, $\bar{C} \to \bar{C}_\infty$, for $\bar{y} \to \infty$, when $\bar{t} > 0$ (5.3)

The constant suction velocity can be considered as:

$\bar{v}(t) = -V_0$, $(V_0 > 0)$ (6)

Assuming that the medium is optically thin with relatively low density and following Cogly – Vincentine – Gillies [11] equilibrium model, the heat flux is quantified as,

$$\frac{\partial \bar{q}_{\bar{y}}}{\partial \bar{y}} = 4(\bar{T} - \bar{T}_\infty)\int_0^\infty (k_{\lambda^{**}})_{w^*}\left(\frac{\partial e_{b\lambda^{**}}}{\partial \bar{T}}\right)_{w^*} d\lambda^{**} = 4I^*(\bar{T} - \bar{T}_\infty) \quad (7)$$

Where, $I^* = \int_0^\infty (k_{\lambda^{**}})_{w^*}\left(\frac{\partial e_{b\lambda^{**}}}{\partial \bar{T}}\right)_{w^*} d\lambda^{**}$ and $k_{\lambda^{**}}$ is the absorption co-efficient, $e_{b\lambda^{**}}$ is the Plank's constant, λ^{**} represents wave length.

We now introduce the following non-dimensional quantities as:

$y = \frac{\bar{y}}{L}$, $t = \frac{\bar{t}V_0}{L}$, $u = \frac{\bar{u}}{V_0}$, $v = \frac{\bar{v}}{V_0}$, $K = \frac{\bar{K}V_0}{L\nu}$, $\mathrm{Re}_L = \frac{V_0 L}{\nu}$

$Gr = \frac{g\beta q L^3}{\nu k V_0 \mathrm{Re}_L}$, $Gm = \frac{g\beta^* m L^3}{\nu D_M V_0 \mathrm{Re}_L}$, $\omega = \frac{\omega^* L}{V_0}$, $\theta = \frac{(\bar{T} - \bar{T}_\infty)k}{qL}$,

$\phi = \frac{(\bar{C} - \bar{C}_\infty)D_M}{mL}$, $\Pr = \frac{\nu\rho c_p}{k}$, $Sc = \frac{\nu}{D_M}$, $Pe = \mathrm{Re}_L\, Pr$, $u_0 = \frac{\bar{u}_0}{V_0}$

$Pe_m = \mathrm{Re}_L\, Sc$, $Sr = \frac{D_M D_T q}{V_0 k m L}$, $R = \frac{4I^* L}{k}$, $F = \frac{K_l L}{V_0}$.

The non-dimensional form of equation (1) on assuming constant plate suction gives,

v =-1. (8)

Also, the non-dimensional form of equations (2) to (4) is,

$$\frac{\partial u}{\partial t} - \frac{\partial u}{\partial y} = \frac{1}{\mathrm{Re}_L}\frac{\partial^2 u}{\partial y^2} + Gr\theta + Gm\phi - \frac{u}{K} \quad (9)$$

$$\frac{\partial \theta}{\partial t} - \frac{\partial \theta}{\partial y} = \frac{1}{Pe}\frac{\partial^2 \theta}{\partial y^2} - R\theta \quad (10)$$

$$\frac{\partial \phi}{\partial t} - \frac{\partial \phi}{\partial y} = \frac{1}{Pe_m}\frac{\partial^2 \phi}{\partial y^2} + Sr\frac{\partial^2 \theta}{\partial y^2} - F\phi \quad (11)$$

With non-dimensional boundary conditions as,

$u = u_0 \exp(i\omega t)$, $\frac{\partial \theta}{\partial y} = -1$, $\frac{\partial \phi}{\partial y} = -1$, at $y = 0$ (12.1)

$u \to 0$, $\theta \to 0$, $\phi \to 0$, for $y \to \infty$ (12.2)

Method of Solution:

To, solve the system of equations (9) – (11), the normal mode method has been preferred to obtain exact closed form of solutions supported by the boundary condition (12.1) and to do so we consider the exponentially oscillating form of solutions as:

$$u(y,t) = U_0(y)\sum_{r=0}^{\infty}\frac{(i\omega t)^r}{r!},\quad \theta(y,t) = \theta_0(y)\sum_{s=0}^{\infty}\frac{(i\omega t)^s}{s!},\quad \phi(y,t) = \phi_0(y)\sum_{m=0}^{\infty}\frac{(i\omega t)^m}{m!}$$

On using the prescribed form, the equations (9) – (11) give,

$$\frac{d^2 U_0}{dy^2} + \mathrm{Re}_L\frac{dU_0}{dy} - \left(\frac{1}{K} + i\omega\right)\mathrm{Re}_L U_0 = -Gr\theta_0 - Gm\phi_0 \quad (13)$$

$$\frac{d^2\theta_0}{dy^2} + Pe\frac{d\theta_0}{dy} - (R + i\omega)Pe\,\theta_0 = 0 \quad (14)$$

$$\frac{d^2\phi_0}{dy^2} + Pe_m\frac{d\phi_0}{dy} - (F + i\omega)Pe_m\,\phi_0 = -SrPe_m\frac{d^2\theta_0}{dy^2} \quad (15)$$

With boundary conditions as:

$U_0 = u_0$, $\frac{d\theta_0}{dy} = -1$, $\frac{d\phi_0}{dy} = -1$, at y=0 (16.1)

$U_0 \to 0$, $\theta_0 \to 0$, $\phi_0 \to 0$, for $y \to \infty$ (16.2)

The real part of expressions for non-dimensional temperature, concentration and velocity of the flow field finally obtained as:

$$\theta_R(y,t) = \frac{\exp(-\alpha_1 y)}{\alpha_1^2 + \beta_1^2}[\{\alpha_1\cos(\beta_1 y) - \beta_1\sin(\beta_1 y)\}\cos(\omega t) + \{\alpha_1\sin(\beta_1 y) + \beta_1\cos(\beta_1 y)\}\sin(\omega t)] \quad (17)$$

$$\phi_R(y,t) = [\exp(-\alpha_2 y)\{\gamma_3\cos(\beta_2 y) + \gamma_4\sin(\beta_2 y)\} + \exp(-\alpha_1 y)\{\delta_1\cos(\beta_1 y) + \delta_2\sin(\beta_1 y)\}]\cos(\omega t)$$
$$-[\exp(-\alpha_1 y)\{\delta_2\cos(\beta_1 y) - \delta_1\sin(\beta_1 y)\} + \exp(-\alpha_2 y)\{\gamma_4\cos(\beta_2 y) - \gamma_3\sin(\beta_2 y)\}]\sin(\omega t) \quad (18)$$

$$u_R(y,t) = [\exp(-\alpha_1 y)\{\delta_7\cos(\beta_1 y) + \delta_8\sin(\beta_1 y)\} + \exp(-\alpha_2 y)\{\gamma_5\cos(\beta_2 y) + \gamma_6\sin(\beta_2 y)\} +$$
$$\exp(-\alpha_3 y)\{(u_0 - \delta_7 - \gamma_5)\cos(\beta_3 y) - (\gamma_6 + \delta_8)\sin(\beta_3 y)\}]\cos(\omega t) - [\exp(-\alpha_1 y)\{\delta_8\cos(\beta_1 y) -$$
$$\delta_7\sin(\beta_1 y)\exp(-\alpha_2 y)\} + \exp(-\alpha_2 y)\{\gamma_6\cos(\beta_2 y) - \gamma_5\sin(\beta_2 y)\} - \exp(-\alpha_3 y)\{(\gamma_6 + \delta_8)\times$$
$$\cos(\beta_3 y) + (u_0 - \delta_7 - \gamma_5)\sin(\beta_3 y)\}]\sin(\omega t) \quad (19)$$

Skin – friction co-efficient:

The real part of the skin-friction co-efficient exerted by the fluid particles on the plate is,

$$\tau_R(t) = -\frac{1}{\mathrm{Re}_L}\left(\frac{\partial u_R}{\partial y}\right)_{y=0} = \frac{1}{\mathrm{Re}_L}[\alpha_1\delta_7 + \alpha_2\gamma_5 + \alpha_3(u_0 - \delta_7 - \gamma_5) - \beta_1\delta_8 - \beta_2\gamma_6 + \beta_3(\delta_8 + \gamma_6)]\cos(\omega t) -$$
$$[\alpha_1\delta_8 + \alpha_2\gamma_6 + \alpha_3(\delta_8 + \gamma_6) + \beta_1\delta_7 + \beta_2\gamma_5 + \beta_3(u_0 - \delta_7 - \gamma_5)]\sin(\omega t) \quad (20)$$

Vorticity of the motion:

$$\left|\vec{\Omega}_R(y,t)\right| = \frac{\partial u_R}{\partial y} = [\exp(-\alpha_1 y)\{-\alpha_1(\delta_7\cos(\beta_1 y) + \delta_8\sin(\beta_1 y)) + \beta_1(\delta_8\cos(\beta_1 y) - \delta_7\sin(\beta_1 y))\} +$$
$$\exp(-\alpha_2 y)\{-\alpha_2(\gamma_5\cos(\beta_2 y) + \gamma_6\sin(\beta_2 y)) + \beta_2(\gamma_6\cos(\beta_2 y) - \gamma_5\sin(\beta_2 y))\} + \exp(-\alpha_3 y)\times$$
$$\{-\alpha_3(u_0 - \delta_7 - \gamma_5)\cos(\beta_3 y) + \alpha_3(\gamma_6 + \delta_8)\sin(\beta_3 y) - \beta_3(u_0 - \delta_7 - \gamma_5)\sin(\beta_3 y) - \beta_3(\gamma_6 + \delta_8)\cos(\beta_3 y)\}]\times$$
$$\cos(\omega t) - [\exp(-\alpha_1 y)\{-\alpha_1(\delta_8\cos(\beta_1 y) - \delta_7\sin(\beta_1 y)) - \beta_1(\delta_7\cos(\beta_1 y) + \delta_8\sin(\beta_1 y))\} +$$
$$\exp(-\alpha_2 y)\{-\alpha_2(\gamma_6\cos(\beta_2 y) - \gamma_5\sin(\beta_2 y)) - \beta_2(\gamma_5\cos(\beta_2 y) + \gamma_6\sin(\beta_2 y))\} + \exp(-\alpha_3 y)\times$$
$$\{\alpha_3(\gamma_6 + \delta_8)\cos(\beta_3 y) + \alpha_3(u_0 - \delta_7 - \gamma_5)\sin(\beta_3 y) + \beta_3(\gamma_6 + \delta_8)\sin(\beta_3 y) - \beta_3(u_0 - \delta_7 - \gamma_5)\cos(\beta_3 y)\}]\times$$
$$\sin(\omega t) + \quad (21)$$

Results and Discussion:

The present paper deals with the exact analysis of unsteady freeconvective flow of viscous incompressible fluid past anoscillating plate in presence of thermal radiation, chemical reaction and Soret effect. The exact closed form of solutions for velocity, temperature and concentrations as well as skin-friction and vorticity vector have been obtained for various physical parameters involved in the study such as Peclet number (*Pe*), mass transfer Peclet number (Pe_m), thermal Grashoff number (*Gr*), solutalGrashoff number (*Gm*),radiation parameter (*R*), local Reynolds number (*Re*), chemical reaction parameter (*F*), Soret number (*Sr*), permeability parameter (*K*), frequency of oscillation parameter (ω), mean plate velocity (u_0) normal distances (*y*)andtime variable (*t*).

Figure 1 reflects the influence of parameter *R* on the temperature profiles (θ_R, *y*) for fixed values of *Pe*=0.71, $\omega = 0.05$ and *t*=0.1. It is observed that, due to an increase in values of *R*, the thermal diffusivity decrease, which decreases the thickness of the thermal boundary layer and thus decrease the value of θ_R. Figure 2 shows the effect of *Pe* on the temperature profiles (θ_R, *y*) for fixed values of *R*=2.0, $\omega = 0.05$ and *t*=0.1. Due to increase in values of *Pe*, the diffusion mode of heat transfer becomes prominent in comparison to convection mode, results of which minimizes the thermal boundary layer thickness and thus decreases the value of θ_R.

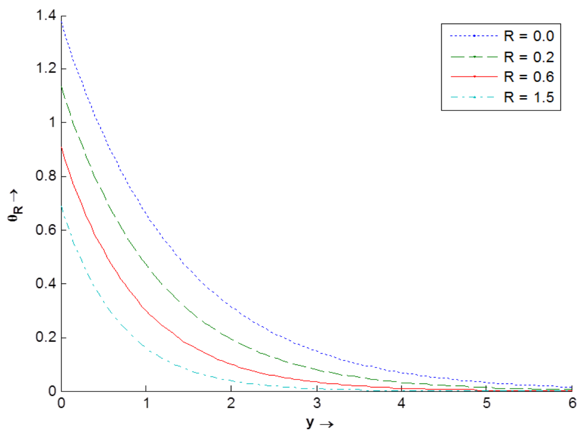

Figure1.Variations of temperature against normal distances relative to thermal radiation.

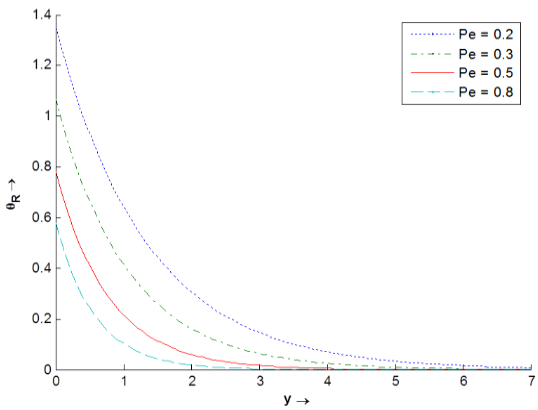

Figure2.Variations of temperature against normal distances relative to Peclet number.

Figure 3 exhibits the influence of mass transfer Peclet number Pe_m on the concentration profiles (ϕ_R, *y*) for a set of fixed values of *R* = 0.375, *F*=0.5, *t*=0.1, $\omega = 0.05$, *Pe*=0.71, *Sr*=0.5. As the values of Pe_m increase, the diffusion mode of mass transfer becomes more significant than the convective mode of mass transfer, results of which the thickness of the solutal boundary layer decreases and thus reducing the value of ϕ_R.Figure 4 depicts the effect of *F* on the concentration profiles (ϕ_R, *y*) for a set of fixed values of *R* = 0.375, Pe_m=0.74, *Sr*=0.5, *t*=0.1, $\omega = 0.05$, *Pe*=0.71. Due to increase in values of *F*, the higher concentration species near the plate surface approach towards the lower concentration species of the free stream region as a result, the concentration near the plate drops and this decrease the value of ϕ_R.

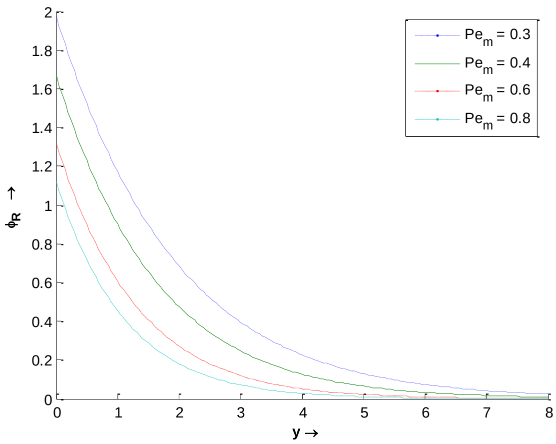

Figure 3. Variations of concentration against normal distances relative to mass transfer Pecletnumber.

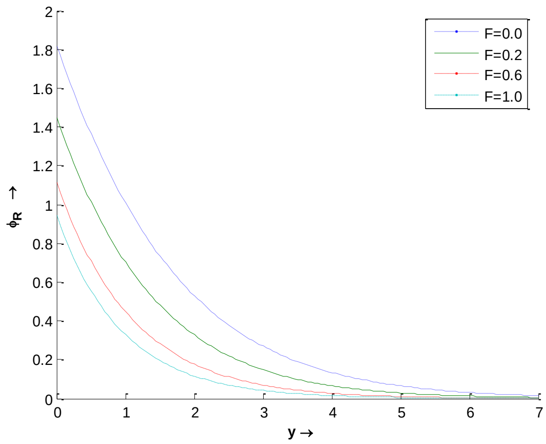

Figure 4.Variations of concentration against normal distances relative to chemical reaction paramter.

The influence of physical parameter *Sr* on the concentration profiles (ϕ_R, *y*) has shown in fig. 5 for fixed values of *R* = 0.375, Pe_m=0.74, *F* =0.5, *t*=0.1, $\omega = 0.05$, *Pe*=0.71. The increase in valuesof *Sr*increases the thickness of concentration boundary layer thus raising the concentration near the plate.

Figures 6 and 7 depict the parametric effects of Pe_m and *Pe*on the velocity profiles (u_R, *y*) for fixed values of *Pe* = 0.71 (for fig. 6), Pe_m = 0.74 (for fig. 7),*Re*=1.0, Sr=0.5, *Gr*=10.0, *Gm*=5.0,*F*=0.5, *K*=2.0,*R*=0.375, $u_0 = 1.0$ *t*=0.1, $\omega = 0.05$. Due to increase in values of Pe_m, the concentration near the plate reduces, which minimizes the effect of mass buoyancy force and thus the rate of flow decelerates and this decreases the value of u_R.Again, an increase in *Pe*decreases the temperature near the plate surface results of which decreases the thermal buoyancy forces and thus the values of u_R get decrease. The effects of Soret number *Sr* and chemical reaction parameter *F* on the velocity profiles (u_R,*y*) are shown respectively in fig. 8 and fig. 9 and for a set of fixed values of Pe_m = 0.74,*Pe*=0.71,*Re*=1.0, *Gr*=10.0, *Gm*=5.0,*F*=0.5, *K*=2.0, *F*=0.5(for fig. 8), Sr=0.5 (for fig. 9), *R*=0.375, $u_0 = 1.0$, $\omega = 0.05$, *t*=0.1. Due to increase in values of *Sr*, the mass buoyancy force increases, which accelerate the flow rate and this increase the value of u_R.

On the other hand it is observed that, the flow velocity decreases due to increase in values of *F*. This is obvious due to the fact that, the increase in *F* decreases the concentration near the plate thus decelerates the flow rate and decrease the value of u_R.

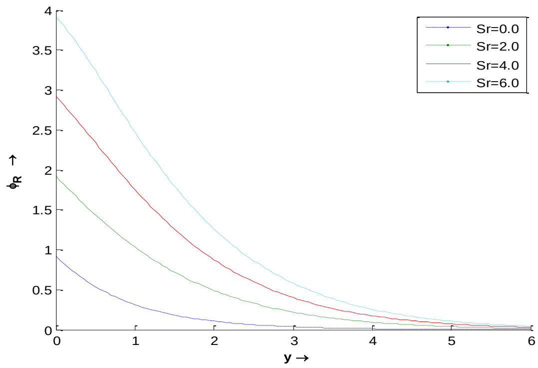

Figure5.Variations of concentration against normal distances relative to Soret number

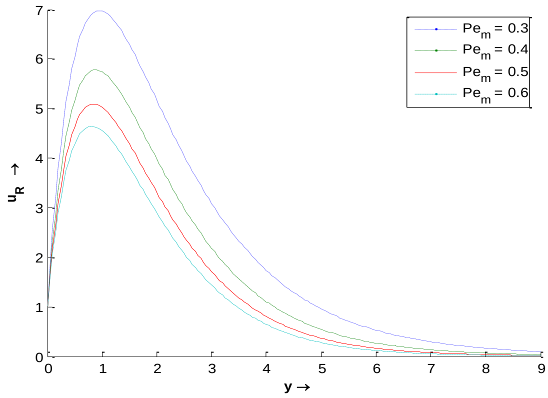

Figure6. Variations of velocity against normal distances relative to mass transfer Peclet number.

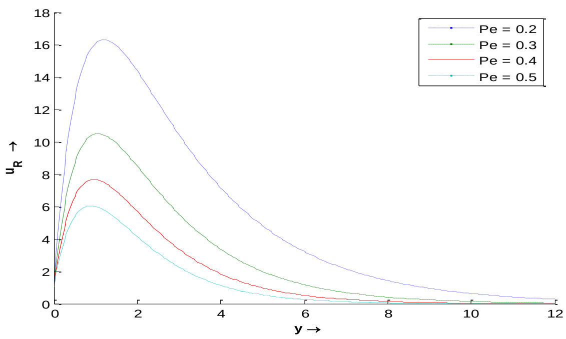

Figure7.Variations of velocity against normal distances relative to Peclet number.

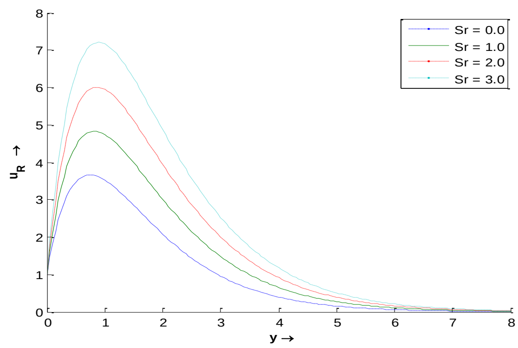

Figure8.Variations of velocity against normal distances relative to Soret number.

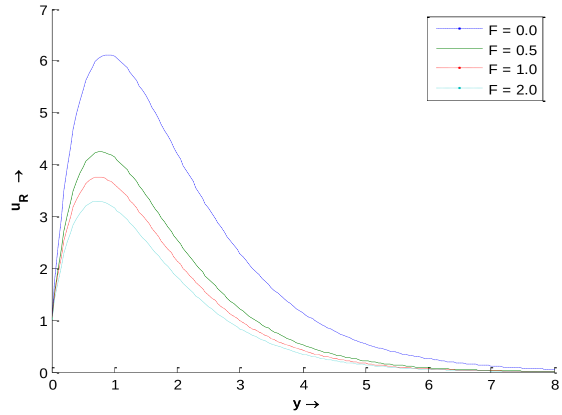

Figure9.Variations of velocity against normal distances relative to chemical reaction parameter.

Figure 10 shows the effect of thermal radiation *R* on the velocity profiles (u_R, *y*) for certain fixed values of Pe_m = 0.74,*Pe*=0.71,*Re*=1.0, *Gr*=10.0, *Gm*=5.0,*F*=0.5, *K*=2.0, *F*=0.5, Sr=0.5, *t*=0.1,$u_0 = 1.0$, $\omega = 0.05$. The increase in values of R is found to decrease the temperature near the plate and as such the thermal buoyancy effect automatically decreases which, results in decreasing the value of u_R.

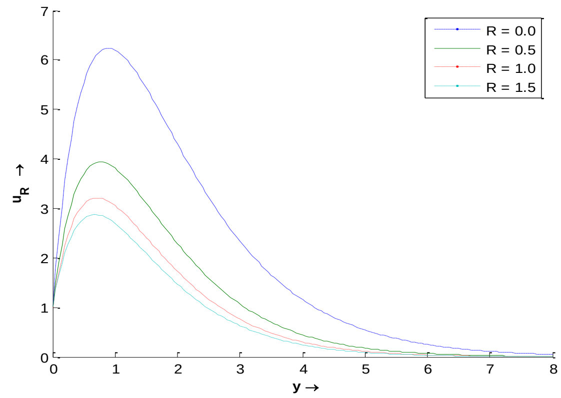

Figure10.Variations of velocity against normal distances relative to thermal radiation parameter.

Figure 11 depicts the parametric influence of *R* on the skin-friction profiles (τ_R, *t*) for a set of fixed values of Pe_m = 0.74,*Pe*=0.71,*Re*=1.0, *Gr*=10.0, *Gm*=5.0,*F*=0.5, *K*=2.0, *F*=0.5, Sr=0.5, *t*=0.1,$u_0 = 1.0$, $\omega = 0.05$. It is observed that, the skin frictional effect increases gradually due to increase in values of *R* as well as *t*. Figure 12 presents graphically the effect of *Pe* on the skin-friction profiles (τ_R, *t*) relative to a set of fixed values of Pe_m = 0.74,*Re*=1.0, *Gr*=10.0, *Gm*=5.0, *R*=0.375, *F*=0.5, *K*=2.0, *F*=0.5, *Sr*=0.5, *t*=0.1,$u_0 = 1.0$, $\omega = 0.05$. It is clearly observed that, the value of τ_R increases due to increase in values of *Pe*as well as *t*.The influence of mass transfer Peclet number Pe_m on the skin-friction profiles (τ_R, *t*) for a set of fixed values of*Pe*=0.71,*Re*=1.0, Sr=0.5, *Gr*=10.0, *Gm*=5.0,*F*=0.5,*K*=2.0,*F*=0.5, Sr=0.5, *t*=0.1,$u_0 = 1.0$, $\omega = 0.05$ is demonstrated in figure 13. Due to increase in values of Pe_m and *t*, the value of τ_R is found to be increased gradually.

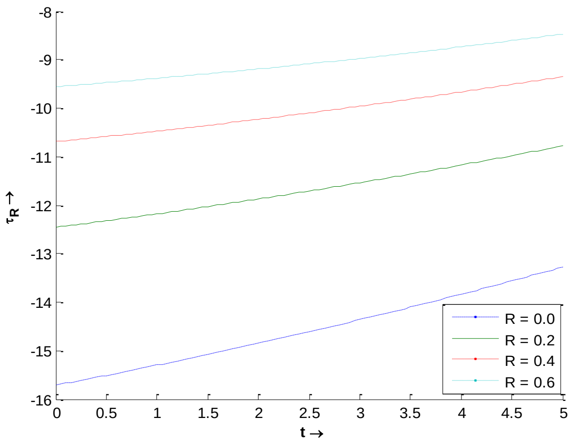

Figure11. Variations of skin-friction against time scales variable relative to thermal radiation parameter

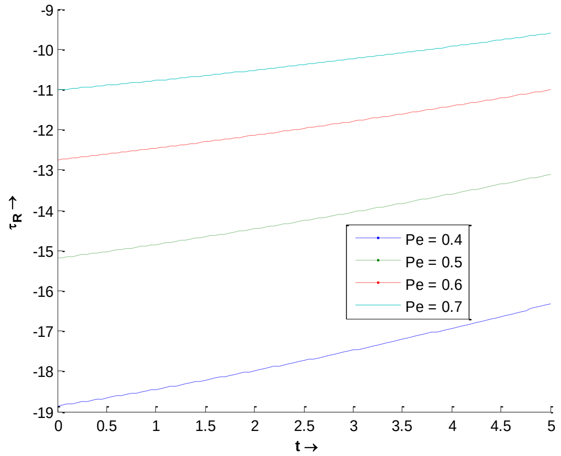

Figure12. Variations of skin-friction against time scales variable relative to Peclet number.

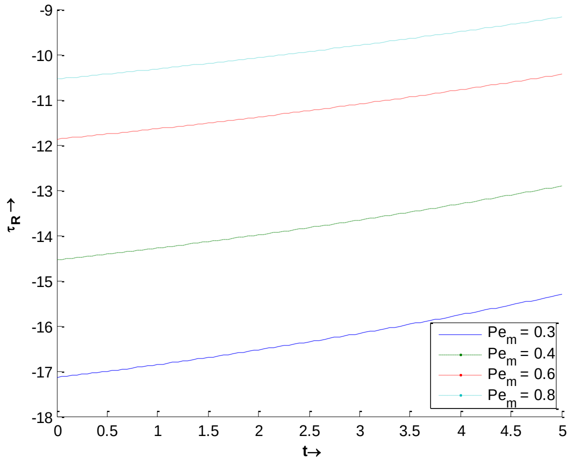

Figure13. Variations of skin-friction against time scales variable relative to mass transfer Peclet number.

Table 1 highlights numerically the variation of frequency of oscillation parameter ω against time t on the magnitude of the vorticity vector $\left|\vec{\Omega}_R(y,t)\right|$. It is observed that, the magnitude of the vorticity vector increases due to increase in values of ω, while an opposite trend has been observed as time propagates.

Table 1. Numerical values of Ω_R for different values of ω against arbitrary values of *t*.

t	ω = 0.005	ω = 0.01	ω = 0.05	ω = 0.1
0.0	2.2782	2.2789	2.3004	2.3665
0.5	2.2778	2.2773	2.2605	2.2099
1.0	2.2774	2.2756	2.2192	2.0479
1.5	2.2770	2.2739	2.1764	1.8807
2.0	2.2765	2.2721	2.1323	1.7089
2.5	2.2761	2.2703	2.0869	1.5327
3.0	2.2756	2.2684	2.0402	1.3528
3.5	2.2751	2.2664	1.9922	1.1694
4.0	2.2746	2.2644	1.9429	0.9831
4.5	2.2741	2.2624	1.8924	0.7944
5.0	2.2736	2.2603	1.8408	0.6037

Table 2 represents the change in values of vorticity vector $\left|\vec{\Omega}_R(y,t)\right|$ due to arbitrary change in mass transferPeclet number Pe_m against time *t*. It is clearly seen that, the vorticity vector of fluid particles decreases as the values of Pe_m increase.

Table 2. Numerical values of Ω_R for different values of Pe_m against arbitrary values of *t*.

t	Pe_m = 0.1	Pe_m = 0.3	Pe_m = 0.5	Pe_m = 0.7
0.0	13.9382	6.7718	5.0943	4.3628
0.5	13.8976	6.7518	5.0788	4.3486
1.0	13.8484	6.7276	5.0601	4.3316
1.5	13.7904	6.6991	5.0382	4.3120
2.0	13.7239	6.6665	5.0131	4.2896
2.5	13.6488	6.6297	4.9849	4.2646
3.0	13.5651	6.5888	4.9536	4.2369
3.5	13.4730	6.5437	4.9192	4.2065
4.0	13.3724	6.4946	4.8818	4.1736
4.5	13.2635	6.4414	4.8413	4.1380
5.0	13.1463	6.3841	4.7977	4.0998

Conclusions:

The significant outcome of the discussion is highlighted as:

●The temperature decreases due to increase in values of thermal radiation parameter and Peclet number.

●The concentration decreases due to increase in values of mass transfer Peclet number and chemical reaction parameter while due to increase in Soret number the concentration is found increasing.

●The increase in parametric values of Peclet number, mass transfer Peclet number, thermal radiation and chemical reaction parameters decreases the fluid velocity, while the velocity increases due to increase in Soret number.

●The skin-friction is found to increase as thermal radiation parameter, Peclet number and mass transfer Peclet number increase.

●The vorticity vector decreases due to increase in mass transfer Peclet number and time, while an opposite effect has been observed due to increase in frequency parameter.

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