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SORET AND DUFOUR EFFECTS ON CONVECTIVE HEAT AND MASS TRANSFER FLOW OF A VISCOUS FLUID IN THE PRESENCE OF THERMOPHORESIS PARTICLE DEPOSITION

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ABSTRACT

We analyze the combined influence of thermal radiation, Soret and Dufour effect on convective heat and mass transfer flow of a viscous incompressible fluid in the presence of suction\injection and thermophoresis deposition particle. The non-linear equations governing the momentum, temperature and concentration along with the boundary conditions are solved by using finite element method with Mathematica6.1 software.

Keywords: *Soret and Dufour effects, Thermophoresis, Non-Uniform Heat Source.*

1. INTRODUCTION

Thermophoresis phenomenon has many practical applications in removing small particles from gas streams, in determining exhaust gas particle trajectories from combustion devices, and in studying the particulate material deposition on turbine blades. It has been found that thermophoresis is the dominant mass transfer mechanism in the modified chemical vapor deposition process as currently used in the fabrication of optical fiber performs. Thermophoretic deposition on radioactive particles is considered to be one of the important factors causing accidents in nuclear reactors. Keeping the applications in view several researchers (Goren[12], Talbot *et al.* [25], Homsy *et al*. [14], Epstein *et al.* [10], Garg and Jayataj[11], Jia *et al.*[13 Chiou[8], Selim *et al.* [24], Chamkha *et al.* [5] Chamkha and Pop [6], Seddeek [23], Chamkha *et al.* [7], Partha [20], Partha [21], Beg *et al.* [4], PuviArasu*et et al.* [22], Kandasamy *et al.* [16] , Alam *et al.* [1], Alam *et al.* [2] Dulal Pal *et al.* [9]) have studied the effect of thermophoresis on convective heat and mass transfer flow in different configurations.

The effect of radiation on MHD flow and heat transfer problem has become more important industrially. At high temperature, radiation effect can be quite significant. Many processes in engineering areas occur at high temperature and knowledge of radiation heat transfer becomes very important for the design of the pertinent equipment. Nuclear power plants, gas turbines and the various propulsion devices for aircraft, missiles, satellites and space vehicles are examples of such engineering areas. Several authors (Bestman [3], Mankinde [19], Ibrahim *et al.* [15], Madhusudana *et al.* [18]) have investigated the effect of thermal radiation on heat and mass transfer flow under varied conditions.

In this paper we analyze the combined influence of thermal radiation, Soret and Dufour effect on convective heat and mass transfer flow of a viscous incompressible fluid in the presence of suction/injection and thermophoresis deposition particle. This problem has many applications, such as, technological and manufacturing engineering, radioactive particle deposition in nuclear reactors, deposition of silicon thin films and polymer extrusion process. The non-linear equations governing the momentum, temperature and concentration along with the boundary conditions are solved by using finite element method with Mathematica6.1 software.

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2. MATHEMATICAL FORMULATION

We consider the two-dimensional study mixed convective heat and mass transfer flow of a viscous incompressible, non-conducting, fluid through a porous medium in the presence of thermophoresis as shown in fig.1. The x-axis is directed along the vertical surface and the y-axis is perpendicular to this as shown in figure 1. The vertical surface and the fluid are maintained same temperature and concentration initially. Instantaneously they raised to a temperature $T_w (> T_\infty)$ and concentration $C_w (> C_\infty)$ which remain unchanged. The effects of thermophoresis are being taken in the diffusion equation to help in the understanding of the mass deposition variation on the surface. The temperature gradient in the y-direction is much larger than that in x-direction and hence thermophoretic velocity component normal to the surface is of more importance.

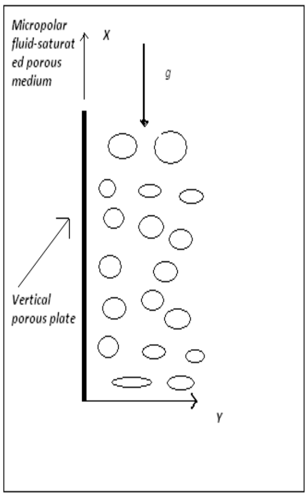

Figure-1: Physical Model of the Coordinate System

Under the above stated physical situation, the governing boundary-layer and Darcy-Boussinesq approximations, the basic equations are given by:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{1}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \nu\frac{\partial^2 u}{\partial y^2} + k_1\frac{\partial w}{\partial y} + \beta g(T - T_\infty) + \beta^* g(C - C_\infty) - \frac{\nu}{k}u - \frac{\sigma\mu_e^2 H_o^2}{\rho_o}u \tag{2}$$

$$u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} = \frac{k}{\rho j}\frac{\partial^2 w}{\partial y^2} - \frac{k}{\rho j}\left(2w + \frac{\partial u}{\partial y}\right) \tag{3}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{k_f}{C_p}\frac{\partial^2 T}{\partial y^2} + \frac{\nu}{C_p}\left(\frac{\partial u}{\partial y}\right)^2 + \frac{1}{C_p}q''' + \frac{D_m K_T}{C_s C_p}\frac{\partial^2 C}{\partial y^2} - \frac{1}{C_p}\frac{\partial (q_R)}{\partial y} \tag{4}$$

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D_m\frac{\partial^2 C}{\partial y^2} + \frac{D_m K_T}{T_m}\frac{\partial^2 T}{\partial y^2} - \frac{\partial (V_T C)}{\partial y} \tag{5}$$

The associated boundary conditions on the vertical surface are defined as follows,

$$\begin{aligned} & u = U_w = ax + L\frac{\partial u}{\partial y}, v = v_w(x), T = T_w, C = C_w \qquad at \quad y = 0 \\ & u \to 0, v \to 0, T \to T_\infty, C \to C_\infty \qquad as \quad y \to \infty \end{aligned} \tag{6}$$

In the above equations x and y represents coordinate axes along the continuous surface in the direction of motion and perpendicular to it, u and v are the velocity components along x and y directions, respectively. We note that $V_0 < 0$ represents suction while $V_0 > 0$ represents injection into the flow regime. Here we confine our attention to the suction (V_0>0) of fluid through the porous medium.

The effect of thermophoresis is usually prescribed by means of an average velocity acquired by small particles to the gas velocity when exposed to a temperature gradient. In boundary layer flow, the temperature gradient in y-direction is very much larger than in the x-direction and therefore only the thermophoretic velocity in y-direction is considered. As a consequence, the thermophoretic velocity V_T, which appears in equation (4), is expressed as

$$V_T = -\frac{k_1 \nu}{T_r}\frac{\partial T}{\partial y} \tag{7}$$

in which k_1 is the thermophoretic coefficient and T_r is the reference temperature. A thermophoretic parameter τ is given by the relation

$$\tau = -\frac{k_f (T_w - T_\infty)}{T_r} \tag{8}$$

Where the typical values of τ are 0.01, 0.1and 1.0 corresponding to approximate Values of *–k1 (Tw-T)* equal to 3, 30, 300K for a reference temperature of *T=300K.*

The non-dimensional heat/sink, q''' (19)is modeled as

$$q''' = \frac{k_f u_w(x)}{\nu x}(A1(T_w - T_\infty)u + B1(T - T_\infty)) \tag{9}$$

Where $A1$ and $B11$ are the coefficient of space and temperature dependent heat source/sink respectively. Here we make a note that the case $A1 > 0$, $B11 > 0$ corresponds to internal heat generation and that $A1 < 0$, $B1 < 0$ corresponds to internal heat absorption.

The energy equation with thermal radiation reduces in to

$$\rho C_p\left(u\frac{\partial T}{\partial x} + w\frac{\partial T}{\partial z}\right) = k_f\frac{\partial^2 T}{\partial y^2} + \mu\left(\frac{\partial u}{\partial y}\right)^2 + \frac{k_f U_0}{\nu x}(A1(T_w - T_\infty)u + B11(T - T_\infty)) + \frac{D_m K_T}{C_s C_p}\frac{\partial^2 C}{\partial y^2} + \frac{16\sigma^* T_\infty^3}{3\beta_R}\frac{\partial^2 T}{\partial y^2} \tag{10}$$

The mathematical analysis of the problem is simplified by introducing the following dimensionless functions f, h, θ, ϕ and the similarity variable η

$$\eta = \sqrt{\frac{U_w}{2\nu x}}\,y \;, \quad u = U_w f'(\eta)\;,\quad v = -\left(\frac{\nu U_w}{2x}\right)^{1/2}(f(\eta) + \eta f'(\eta)),$$
$$\theta = \frac{T - T_\infty}{T_w - T_\infty}\;,\quad \phi = \frac{C - C_\infty}{C_w - C_\infty}, W = -\sqrt{\frac{U_w}{2\nu x}}\,U_w h(\eta) \tag{11}$$

.
Substituting the equation (11) in equations (2), (3), (5) and (11)

We obtain

$$f''' + B_1 h' + ff'' + G_r(\theta + N\phi) - \left(\frac{D^{-1}}{R_e} + M^2\right)f' = 0 \tag{12}$$

$$\lambda h'' - 2\frac{\lambda}{G1}(2h + f'') + (fh' + f\hbar) = 0 \tag{13}$$

$$\theta'' + \Pr f\theta' + \Pr Du\phi'' + \frac{4Rd}{3}\theta'' + \Pr(A_1 f' + B_{11}\theta) + \Pr Ec(f'')^2 = 0 \tag{14}$$

$$\phi'' + Scf\phi' + ScSr\theta'' - \tau(\theta'\phi' + \theta''\phi) = 0 \tag{15}$$

Where

$$G_r = \frac{2\beta g x(T_w - T_\infty)}{U_w^2}(LocalGrashofNumber),\;\; N = \frac{\beta^*(C_w - C)}{\beta(T_w - T)}(Buoyancy\ ratio),$$

$D^{-1} = \frac{U_w k_p}{2\nu x}(Inverse\,Darcy\ parameter)$, $M^2 = \frac{2\sigma\mu_e^2 H_o^2 x}{\rho U_w}$ (Hartmann number)

$\mathrm{Re} = \frac{U_w L^2}{2\nu x}(Local\,\mathrm{Re}\,nolds\ number)$, $\mathrm{Pr} = \frac{\mu C_p}{k_f}(\mathrm{Pr}\,andtl\ Number)$,

$Sc = \frac{\nu}{D_m}(Schmidt\,number)$, $Du = \frac{D_m K_T (C_w - C_\infty)}{C_s C_p (T_w - T_\infty)}(Dufour\ parameter)$,

$Sr = \frac{D_m (T_w - T_\infty)}{\nu T_m (C_w - C_\infty)}(Soret\ parameter)$. $Ec = \frac{U_w^2}{C_p (T_w - T_\infty)}(Ec\,\mathrm{ker}\,t\ Number)$,

$Rd = \frac{4\sigma^* T^3}{\beta_R k_f}(Radiation\ parameter)$, $B1 = \frac{k_1}{\nu}$ (Coupling constant parameter)

$\lambda = \frac{\gamma}{\rho \nu j}$ (Micro polar parameter), $G1 = \frac{\gamma}{\nu k}$ (Micro polar parameter)

$\nu = \frac{\mu + k}{\rho}$ (Kinematic viscosity), $k_1 = \frac{k}{\rho}(k1 > 0)$ (Coupling constant)

$u = -\psi_y \qquad v = \psi_x$.

The corresponding transformed boundary conditions are

$$f'(0) = 1 + Af'',\ f(0) = V_0\sqrt{\frac{2x}{\nu U_w}} = fw, \theta(0) = 1, \phi(0) = 1 \quad at\,\eta = 1$$
$$f'(\infty) = 0, \theta(\infty) = 0, \phi(\infty) = 0 \qquad as\ \eta \to \infty \tag{16}$$

3. METHOD OF SOLUTION

The non linear coupled equations governing the flow have been solved by using FEM with quadratic approximation polynomials. The resulting local stiffness matrices are assembled by using inter element continuity, equilibrium and boundary conditions.

4. SHEAR STRESS, NUSSELT NUMBER AND SHERWOOD NUMBER

The major physical quantities of interest in this problem are the local skin friction coefficient C_f , the local Nusselt number Nu_x and the local Sherwood number Sh_x are defined, respectively by

$$C_f = \frac{f''(0)}{\mathrm{Re}_x^{1/2}} \quad , \quad Nux = -\frac{\theta'(0)}{\mathrm{Re}_x^{1/2}}, \quad Shx = --\frac{\phi(0)}{\mathrm{Re}_x^{1/2}}$$

The correctness of the current numerical method is checked with the results obtained by Loganathan *et al.* [2010] for the local skin friction coefficient C_f, local Nusselt number Nu_x and local Sherwood number Sh_x for various values of thermophoretic parameter τ and suction parameter V_0. Thus, it is seen from Table 1 that the numerical results are in close agreement with those published previously.

COMPARISION

Comparison of results of C_f, Nu_x, Sh_x with previously published data, Du = 0, Sr = 0, Ec = 0,. A1= 0, B11= 0, Rd = 0

Table-1

Du	Sr	Nu_x	Sh_x
0.5	0.5	-0.952739	-0.514925
	1.0	-0.981055	-0.439975
	1.5	-1.01065	-0.359391
	2.0	-1.04169	-0.2727
1	0.5	-0.870524	-0.521268
	1.0	-0.915672	-0.452475
	1.5	-0.966592	-0.373596
	2.0	-1.02494	-0.282221
1.5	0.5	-0.786301	-0.527484
	1.0	-0.844034	-0.465539
	1.5	-0.914626	-0.389352
	2.0	-1.00453	-0.292617
2	0.5	-0.700188	-0.53357
	1.0	-0.765569	-0.479223
	1.5	-0.852782	-0.407087
	2.0	-0.979596	-0.304151
2.5	0.5	-0.612292	-0.539526
	1.0	-0.679561	-0.49361
	1.5	-0.778022	-0.427486
	2.0	-0.94833	-0.317407

Table-2

Parameter		**Loganathan**		
		C_f	Nu_x	Sh_x
τ	1.0	6.034338	-2.580389	-5.260410
	2.0	6.034184	-2.580390	-5.804620
	3.0	6.034067	-2.580391	-8.366696
V_0	0.5			
	1.0			
	1.5			
	4.0	7.899134	-7.543495	-4.788675
	5.0	9.665340	-9.336595	-5.882326
	6.0	11.45915	-11.14177	-6.988321
Parameter		**Present results**		
		C_f	Nu_x	Sh_x
τ	1.0	6.034336	-2.580385	-5.260409
	2.0	6.034189	-2.580385	-5.804615
	3.0	6.034069	-2.580383	-8.366989
V_0	0.5	4.125482	-5.026587	-1.236587
	1.0	5.354135	-6.154873	-2.365989
	1.5	6.054877	-6.998514	-3.654871
	4.0	7.899139	-7.543493	-4.788673
	5.0	9.665336	-9.336592	-5.882322
	6.0	11.45919	-11.14169	-6.988319

Computed values of localNusselt number and local Sherwood number for

$$V_0 = 0.5; P_r = .71; S_c = 0.22; G_r = 5; G_m = 5; D_a = 0.1; r = 10; E_c = 0.01; \lambda = 0.1; s = 0.1; G1 = 0.5;$$
$$B1 = 0.5; \tau = 0.1.$$

5. DISCUSSION OF THE RESULTS

In this analysis we discuss the effect of thermal radiation, dissipation, Soret and Dufour on convective heat and mass transfer flow of a viscous, electrically conduction fluid past a stretching sheet in the presence of non-uniform heat source. The results are presented graphically in figures.2a-7a for different parametric variations. Comparison of the present results with previouslt works is performed and excellent agreements have been obtained. The non-linear coupled differential equations are solved by Galerkin finite analysis with three nodded line segments. In the absence of the results are compared with Loganathan [17].

Figs.2a-2d shows the influence of dissipation on the velocity, Angular velocity, temperature and concentration. It is pointed out that the presence of Eckert number increases the velocity, Angular velocity and temperature .This is due to the fact that the thermal energy is reserved in the fluid on account of friction heating. Hence the velocity and temperature rises in the entire boundary layer .However, the mass concentration is to reduce marginally with increase in Ec (fig.2c).

Figs.3a-3d and 4a-4d represents the variation of velocity, Angular velocity, temperature and concentration with space dependent heat source/temperature dependent heat source in the boundary layer. An increase in the space dependent /temperature dependent heat source increases the velocity, Angular velocity and temperature in the boundary layer. This may be attributed to the fact that the presence of the heat source generates energy in the boundary layer and as a consequence the velocity and temperature rises .In the case of heat absorption $A1 < 0$, $B11 < 0$, the velocity and temperature falls, owing to the absorption of energy in the boundary layer. In the case on concentration we find that it reduces with $A1 > 0$, $B11 > 0$ and increases with $A1 < 0$, $B11 < 0$ in the boundary layer.

Figs.5a-5d depicts the influence of Radiation parameter on the velocity, Angular velocity, temperature and concentration. It is observed that there is a significance rise in the velocity in the presence of thermal radiation throughout the boundary layer .Further increase in the values of thermal radiation parameter results in the increase of the boundary layer. The presence of the thermal radiation is very significant on the variation of temperature. It is seen that the temperature rapidly increases in the presence of thermal radiation parameter throughout the thermal boundary layer. This may be attributed to the fact as the Rosseland radiative absorption parameter R^* diminishes the corresponding heat flux diverges and thus rises the rate of radiative heat transfer to the fluid causing a rise in the temperature of the fluid. The thickness of the boundary layer also increases in the presence of Rd. The effect of Rd on concentration is to diminish it in the solutal boundary layer.

The effect of Soret and Dufour effects on the velocity, Angular velocity, temperature and concentration is exhibited in figs.6a-6d. From fig.6a and 6b we find that the velocity and Angular velocity profiles experience an enhancement with increasing values of Sr (or decreasing Dufour parameter (Du).This is due to the fact that an increase in Sr (or decrease in Du) increases the thickness of the boundary layer. From fig.6c we find that an increase in $Sr \leq 1.0$ (or $Du \leq 0.04$) increases the temperature and for higher $Sr \geq 1.5$ (or $Du \geq 0.05$) we notice a decrease in temperature in the thermal boundary layer. An increase in Sr (or decrease in Du) enhances the concentration. This may be attributed to the fact that the thickness of the solutal boundary layer increases with increase in Sr which in turn rises the concentration in the flow region (fig.6d).

Figs.7a-7d represents the influence of thermophoresis on velocity, Angular velocity, temperature and concentration. It is observed from fig.7a that increasing the values of thermophoresis parameter τ decreases the thickness of the momentum boundary layer while an increase in τ, increases the thickness of the thermal and solutal boundary layers (figs.7c-7d). From figure 7b we notice a reduction in angular velocity with increase in τ.

The skin friction (τ_1) at the wall $\eta=0$ is shown in tables 3 and 4 for different values of the parameters, A1, B11, Rd, Sr &Du, Ec. Here the thermo-diffusion smaller the skin friction .Increasing Soret parameter Sr(or decreasing Dufour parameter Du) smaller the skin friction. An increasing in the heat generating source enhances τ and reduces in the case heat absorbing source. An increase in micro polar parameter G1, B1 and λ leads to a reduction in τ_1.

The rate of heat transfer (Nusselt number) at the wall $\eta=0$ is shown in tables 3 and 4 evaluated for different parametric variation. Increasing Sr (or decreasing Du) leads to an enhancement Nu at the wall. Higher the dissipation/Radiative heat flux lesser the Nusselt number at the wall. With reference to the heat source parameter, we find that the rate of heat transfer reduces with increase in heat generating source and enhances with heat absorption source. Nu increases with G1 and decreases with B1 and λ.

The rate of mass transfer (Sherwood number) at the wall $\eta=0$ is shown in tables 3 and 4 evaluated with variations in different parameters. It can be seen from the tabular values that the rate of mass transfer increases with increase in Ec. Higher the radiative heat flux larger the rate of mass transfer at the wall. We noticed an enhancement in Sh increasing Sr (or Du) smaller the rate of mass transfer at the wall. The rate of mass transfer decreases with space dependent heat source and reduces with temperature dependent heat source. Sh experiences an enhancement with G1, B1 and λ

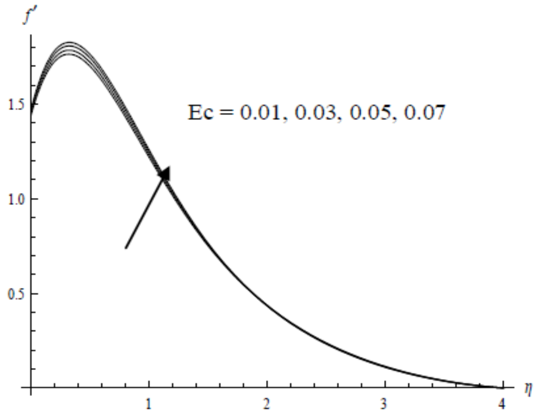

Figure-2a: Variation of f' with Ec

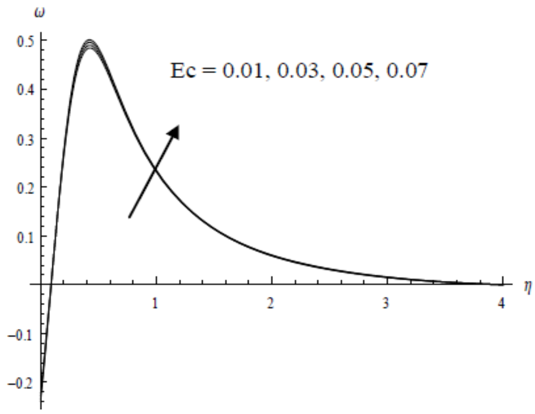

Figure-2b: Variation of ω with Ec

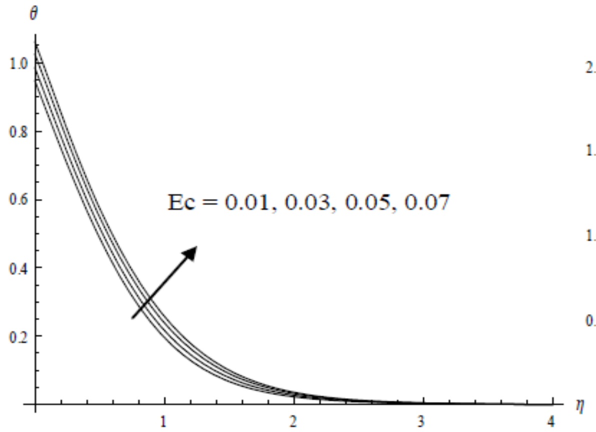

Figure-2c: Variation of θ with Ec

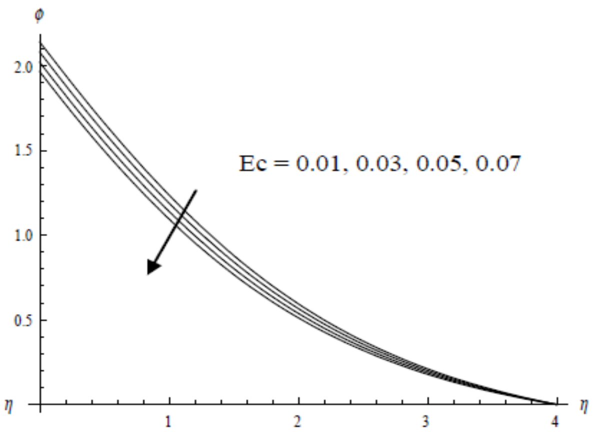

Figure-2d: Variation of ϕ with Ec

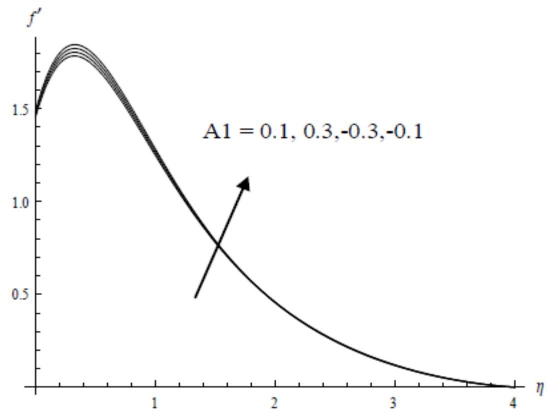

Figure-3a: Variation of ω with A1

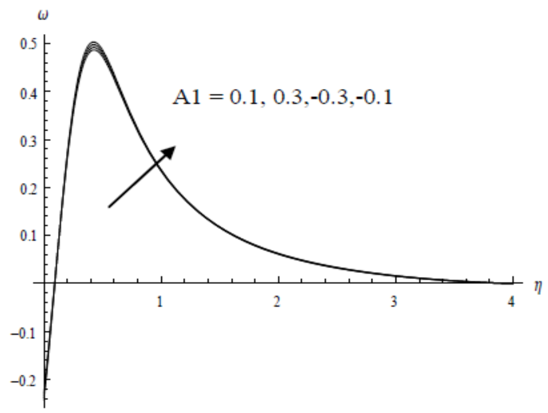

Figure-3b: Variation of ω with A1

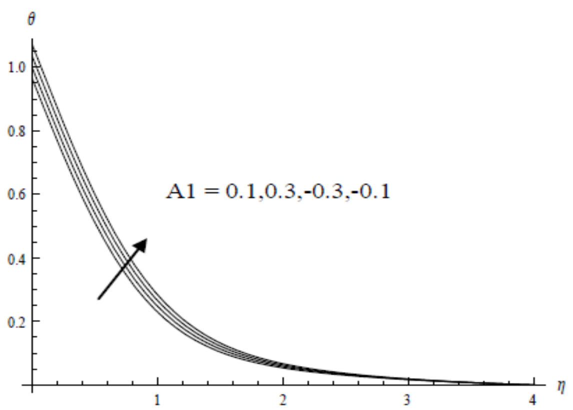

Figure-3c: Variation of θ with A1

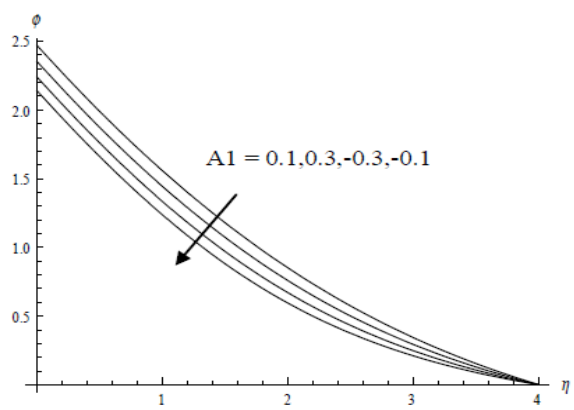

Figure-3d: Variation of ϕ with A1

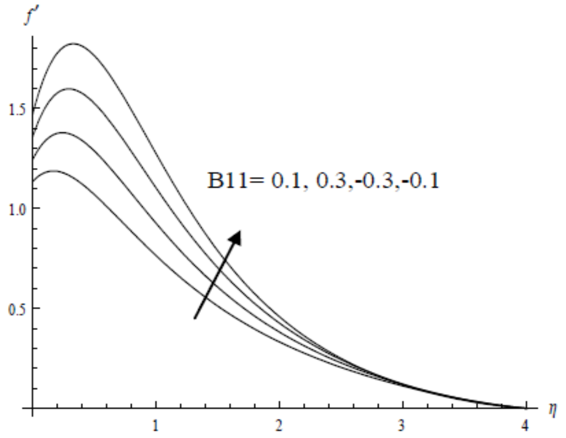

Figure-4a: Variation of f' with B_{11}

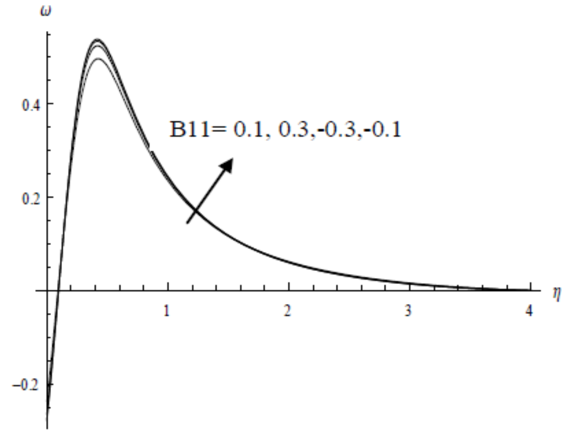

Figure-4b: Variation of ω with B_{11}

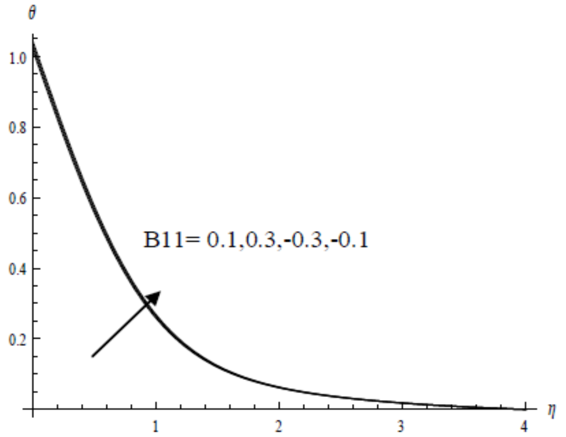

Figure-4c: Variation of θwith B_{11}

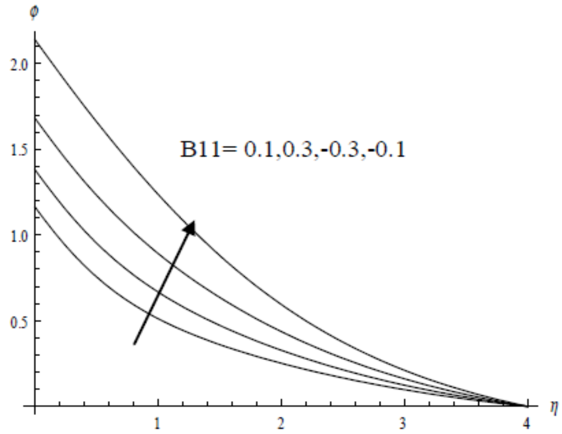

Figure-4d: Variation of ϕ with B_{11}

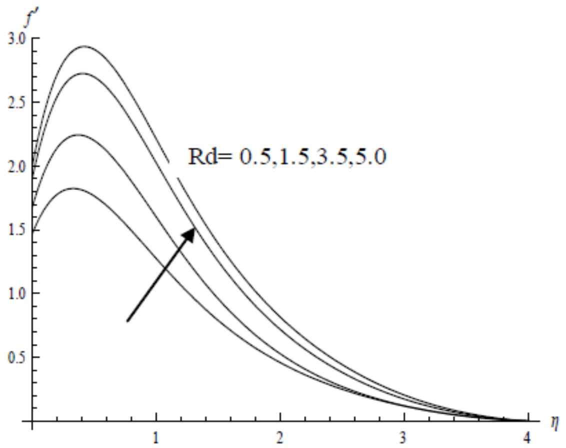

Figure-5a: Variation of f' with Rd

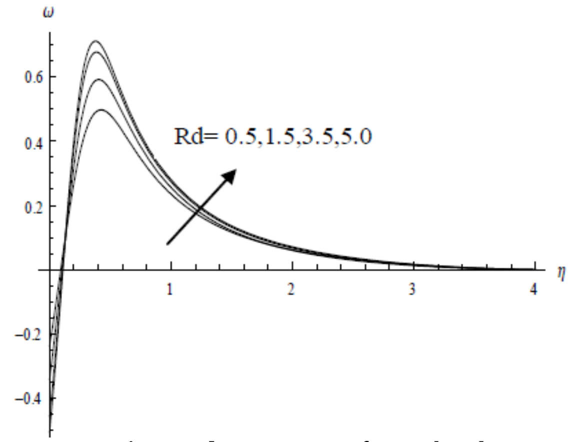

Figure-5b: Variation of ω with Rd

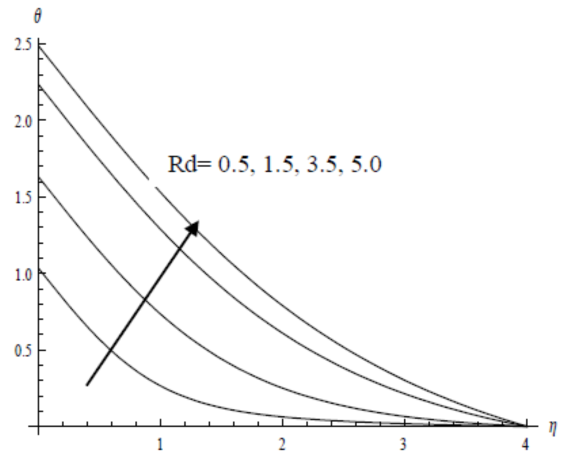

Figure-5c: Variation of θ with Rd

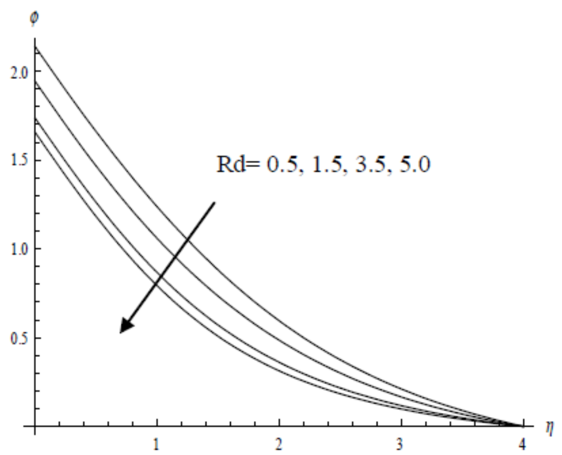

Figure-5d: Variation of ϕ with Rd

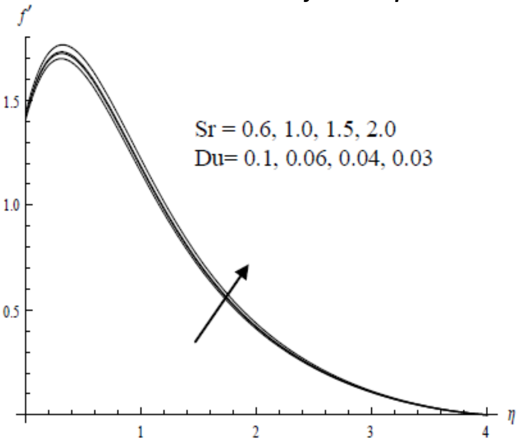

Figure-6a: Variation of f' with Sr &Du

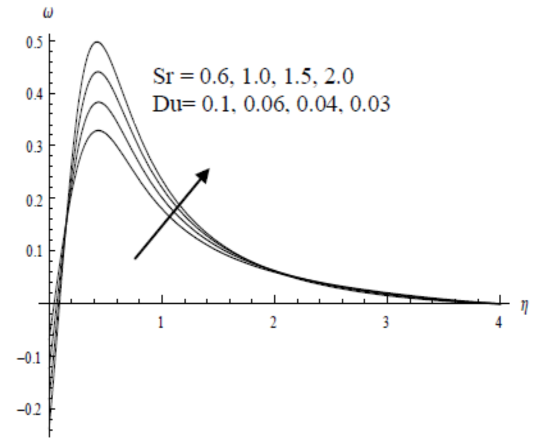

Figure-6b: Variation of ω with Sr &Du

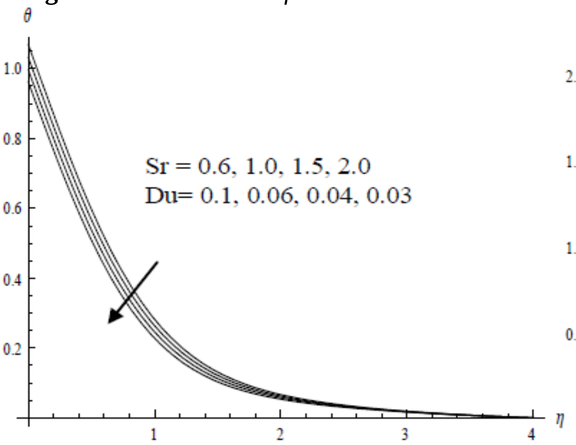

Figure-6c: Variation of θ with Sr &Du

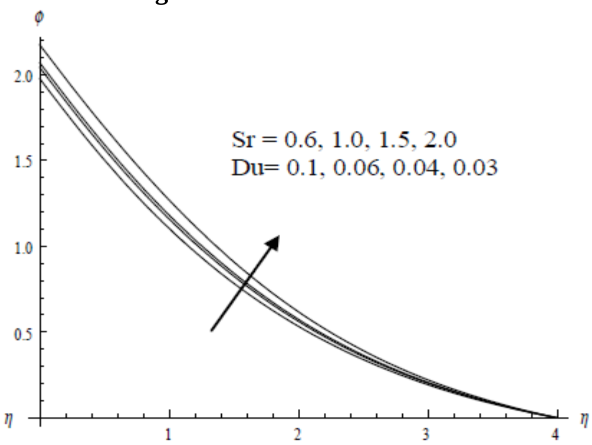

Figure-6d: Variation of ϕ with Sr &Du

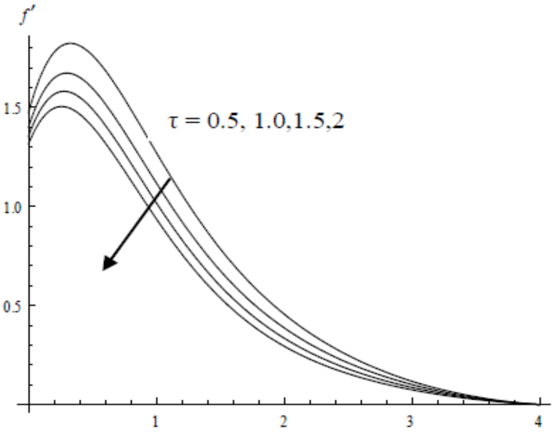

Figure-7a: Variation of f' with τ

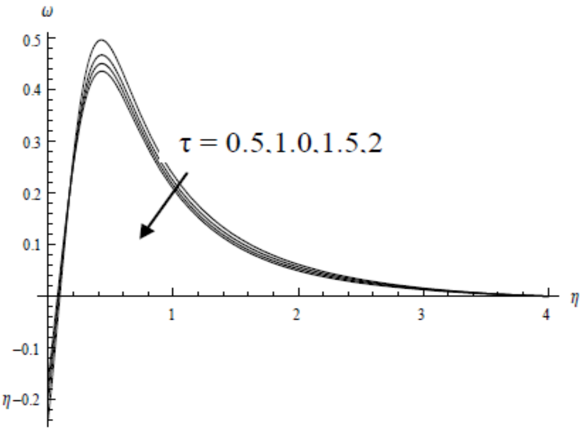

Figure-7b: Variation of ω with τ

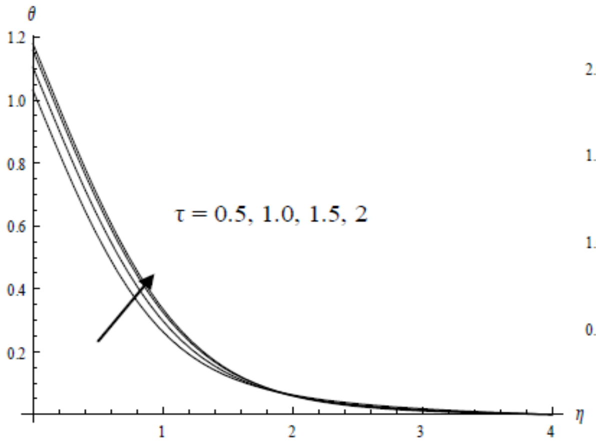

Figure-7c: Variation of θ with τ

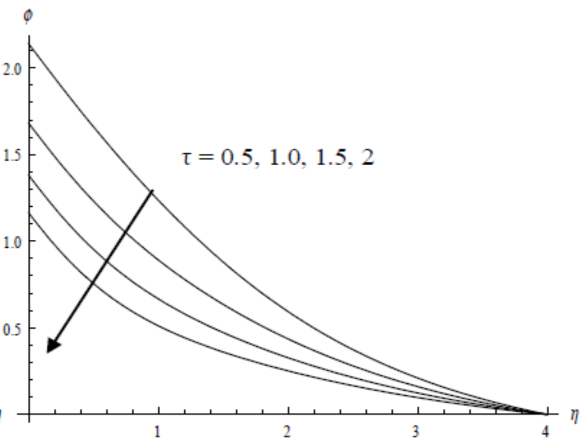

Figure-7d: Variation of ϕ with τ

Table-3

The local Skin-friction (Cf), couple stress (Cw), Nusselt number (Nu), Sherwood number (Sh) for different values of parameters

G1	B1	λ	A1	B11	Cf	Cw	Nu	Sh
0.2	0.2	0.1	0.1	0.1	2.60812	2.43688	0.96016	0.44462
0.4	0.2	0.1	0.1	0.1	2.42186	2.26287	0.97017	0.46738
0.6	0.2	0.1	0.1	0.1	2.41495	1.70187	0.97005	0.46779
0.8	0.2	0.1	0.1	0.1	2.41291	1.25982	0.96975	0.46821
0.2	0.4	0.1	0.1	0.1	2.65137	2.36947	0.97064	0.46728
0.2	0.6	0.1	0.1	0.1	2.72154	2.33368	0.96201	0.46732
0.2	0.8	0.1	0.1	0.1	2.89404	2.20645	0.95939	0.46737
0.2	0.2	0.3	0.1	0.1	2.34273	0.64294	0.97062	0.46771
0.2	0.2	0.5	0.1	0.1	2.32775	0.28926	0.97009	0.46792
0.2	0.2	0.7	0.1	0.1	2.31964	0.15369	0.96912	0.46802
0.2	0.2	0.1	0.3	0.1	2.48136	2.43469	1.04467	0.46349
0.2	0.2	0.1	-0.1	0.1	2.47821	2.40981	0.99816	0.46576
0.2	0.2	0.1	-0.3	0.1	2.50608	2.45126	1.02711	0.46426
0.2	0.2	0.1	0.1	0.3	2.46645	2.37855	0.9619	0.46772
0.2	0.2	0.2	0.1	-0.1	2.46575	2.40149	1.0066	0.46537
2	0.2	0.2	0.1	-0.3	2.48136	2.43469	1.04467	0.46349

Table-4

The local Skin-friction (Cf), couple stress (Cw), Nusselt number(Nu), Sherwood number(Sh) for different values of parameters

Sr/Du	Ec	Rd	Cf	Cw	Nu	Sh
0.6/0.1	0.01	0.5	2.57459	2.3752	1.00258	0.41944
1.0/0.06	0.01	0.5	2.60812	2.43688	0.96016	0.44462
1.5/0.04	0.01	0.5	2.6867	2.51777	0.89209	0.47532
2.0/0.03	0.01	0.5	2.91524	2.68375	0.79142	0.50812
1.0/0.06	0.03	0.5	2.61476	2.40956	0.93423	0.46953
1.0/0.06	0.05	0.5	2.65911	2.49736	0.91902	0.47032
1.0/0.06	0.07	0.5	2.74774	2.60834	0.88415	0.47246
1.0/0.06	0.01	1.5	3.51427	2.97518	0.61455	0.51444
1.0/0.06	0.01	3.5	4.78569	3.72434	0.44829	0.57619
1.0/0.06	0.01	5.0	5.44464	4.15775	0.40066	0.60583

6. CONCLUSIONS

The combined effects of suction and thermophoresis on the mixed convective heat and mass transfer of a fluid through a porous medium in the presence of Thermo-Diffusion and Diffusion-Thermo effects were investigated. Similarity transformations are used to transform the resulting partial differential equations into ordinary differential equations and numerically solved by using the Finite element method. The following conclusions have been made from the present problem.

1) Higher the radiative heat flux larger the velocity, angular velocity, temperature, Skin friction, Sherwood number and smaller the concentration and Nusselt Number.
2) Higher the dissipation larger the velocity, angular velocity, temperature and smaller the Concentration. The Skin friction and Sherwood number increases and Nusselt number reduces with increases Ec.
3) Increasing soret parameter Sr(or Decreasing Du) larger the Velocity, angular velocity, concentration, Nusselt number and smaller the Skin friction and Sherwood number.
4) The velocity, angular velocity, temperature, Skin friction, Sherwood number enhances , the Concentration, Nusselt number reduces, with increasing A1, B11>0,while a reversed effect is noticed with A1,B11<0.
5) An increase in thermophoresis parameter τ reduces the velocity, angular velocity, concentration and enhances the temperature.

7. REFERENCES

1. Alam, M..S,Ferdows, M., Ota, M, Maleque, M.A: Dufour and Soret effects on steady free convection and mass transfer flow past a semi-infinite vertical porous plate in a porous medium, *Int. J. Appl. Mech. Eng. 11* 535–545.(2006).
2. Alam, M.S. Rahman, M.M, Ferdows, M, Kaino,K, Mureithi,E, Postelnicu, A: Diffusion-thermo and thermal-diffusion effects on free convective heat and mass transfer flow on a porous medium with time dependent temperature and concentration, *Int. J. Appl. Eng. Res.*2 (1) 81–96(2007).

3. Bestman, A.R: Natural convection boundary layer with suction and mass transfer in a porous medium ,Int. J. Energy Res.,V.14,pp.389-396(1990) .
4. Beg O.A,Beg T.AQ ,Bakier A.Y and Prasad V.R: Chemically reacting mixed convective heat and mass transfer along inclined and vertical plates with Soret and Dufour effects: Numerical Solutions, Int. J. of Appl. Math and Mech,V.5 (2), pp.39-57(2009).
5. Chamkha, Ali. J and Camille Issa: Effects of heat generation/absorption and thermophoresis on hydromagnetic flow with heat and mass transfer over a flat surface, Int. J. Num. Methods for Heat and Fluid flow., V.10(4),pp.432-448(1990).
6. Chamkha, Ali.J and Camille Issa: Effects of heat generation/absorption and thermophoresis on hydromagnetic flow with heat and mass transfer over a flat surface., Int. J. Num. Methods for Heat &Fluid flow,V.10(4), pp.432-448(2000).
7. Chamkha, A.J. and Pop, I*:* Effect of thermophoresis particle deposition in free convection boundary layer from a vertical flat plate embedded in a porous medium. *Int.Comm. Heat Mass Transfer,* 31: 421-430. (2004).
8. Chiou, M.C , Cleaver, J.W: Effect of thermophoresis on sub micron particle deposition from a laminar forced convection boundary layer flow on to an isothermal cylinder, J. Aerosol Sci., 27, pp. 1155-1167(1996).
9. Dulal Pal, H.Mondal: MHD non-Darcian mixed convection heat and mass transfer over anon-linear stretching sheet with Soret and Dufour effects and chemical reaction, *International communications in heat and mass transfer* 463-467 (2011).
10. Epstein, M, Hauser,G.M, Henry, R.E: Thermophoretic deposition of particles in natural convection flow from a vertical plate, J. Heat Transfer, 107, pp.272-276(1985).
11. Garg, V.K, Jayaraj, S: Thermophoresis of aerosol particles in laminar flow over inclined plates,Int. J. Heat and Mass Transfer,31,pp. 875-890(1988).
12. Goren, S.L: Thermophoresis of aerosol particles in the laminar boundary layer on a flat plate. *J. Colloid Interface Sci.*, 61: 77-85, (1977).
13. Jia.G,Cipolla,J.W,Yener,Y: Thermophoresis of radiating aerosol in laminar boundary layer flow,J. Thermophy. Heat Transfer,6, pp. 476-482(1992).
14. Homsy,G.M,Geyling,F.T, Walke,K.L: Blasius series for theemophoretic deposition of small particles, J. Colloid Interface Sci., 83,pp.495-501(1981).
15. Ibrahim F.S , Hassanien I.A and Bakr, A.A: Non-classical thermal effects in Stokes second problem for mocropolar fluid ,ASME J.Appl Mech,V.72,pp.468-474(2005).
16. Kandasamy, R, Hayat,T and Obaidat,S: Group theory transformation for Soret and Dufour effects on free convective heat and mass transfer with the thermophoresis and chemical reaction over a porous stretching surface in the presence of heat source/sink.*Nuclear Eng. Design*, 241: 2155-2161.(2011).
17. Loganathan,P, PuviArasu.P: Thermophoresis effects on non-Darcy MHD mixed convective heat and mass transfer past aporous wedge in the presence of suction/ injection. *Theoret. Appl. Mech.*, Vol.37, No.3, pp. 203–227, Belgrade.(2010).
18. Madhusudhana,K,Dreenivasa Reddy,B and Sreedhara Babu, MLSoret and Dufour effects on convective heat and mass transfer flow of a micro polar fluid in the presence of thermophoresis deposition particle ,Int. J. Appl. Math and Physics,V.8(1),pp.87-104(2016.
19. Makinde, O.D: Free convection flow with thermal radiation and mass transfer past moving vertical porous plate., Int.Comm Heat Mass Transfer,V.32,pp.1411-1419(2005).
20. Partha,M.K: Thermophoresis particle deposition in a non-Darcy porous medium under the Influence of Soret, Dufour effects. *Heat and Mass Transfer*, 44: 969-977 (2008).
21. Partha, M.K: Suction/injection effects on thermophoresis particle deposition in a non- Darcy porous medium under the influence of Soret, Dufour effects. *Int. J. Heat Mass Transfer,* 52: 1971-1979(2009).
22. PuviArasu, P.. Loganathan, P, Kandasamy, R and Muhaimin, I: Lie group analysis for thermal-diffusion and diffusion-thermo effects on free convective flow over a porous stretching surface with variable stream conditions in the presence of thermophoresis particle deposition. *Nonlinear Analysis: Hybrid Systems,* 5:20-31(2011).
23. Seddeek, M.A.: Finite element method for the effects of chemical reaction, variable viscosity, thermophoresis and heat generation/absorption on boundary layer hydromagnetic flow with heat and mass transfer over a heat surface. *ActaMechanica*, 177: 1-18(2005).
24. Selim,A, Hossain, M.A., Ress, D.A.S :The effect of surface mass transfer on mixed convection flow past heated vertical flat permeable plate with thermophoresis, Int. JThermal Sci., 42,pp. 973-982(2003).
25. Talbot,L,. Cheng, R.K., Schafer, A.W, Wills, D.R.: Thermophoresis of particles in a Heated boundary layer, J. Fluid Mech., 101, pp.37-758(1980).

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