Mhd Fluid Flow over A Vertical Plate With Dufour and Soret Effects

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ABSTRACT
MHD fluid flow is examined over a vertical plate in the presence of Dufour and Soret effects. The governing equations are solved using perturbation technique. The velocity, temperature, and concentration profiles are studied for different values of Dufour Du and Soret Sr numbers, Grashof number Gr, mass Grashof number Gc, Prandtl number Pr, Magnetic parameter M and thermal radiation conduction number k_1. It is observed that the velocity increases with increase in Gc, Gc and ε. but the trend is reversed with respect to Du, Sr, Sc, M, k_1, Pr, and t. it is also observed that temperature and concentration increases with decrease in Du, Sr and k_1.

General Terms
Asogwa et. al.

Keywords
MHD flow, vertical plate, Dufour and Soret effects.

1. INTRODUCTION
The magnetic hydrodynamics (MHD) continues to attract the interest of engineering science and applied Mathematics researches owing to extensive applications of such flows in the context of aerodynamics, engineering, geophysics and aeronautics . The magnetic hydrodynamic flow of a viscous incompressible fluid past an impulsively started infinite horizontal plate was studied by stokes [18], and because it's practical importance. In light of the above applications many researchers studied the effects of mass transfers on magnetohyhydrodynamics (MHD) free convection flow; some of them are Aboeldahab et al. [1], Raptis and Kafousias [16] and Megahead et al. [12]. In the above stated papers, the diffusion-thermo and thermal-diffusion term were neglected from the energy and concentration equations respectively. But when heat and mass transfer occurs simultaneously in a moving fluid, the relation between the fluxes and the driving potentials are of intricate nature. It has been found that an energy flux can be generated not only by temperature gradient but by composition gradients as well. The energy flux caused by composition gradient is called the Dufour or diffusion-thermal effect. The diffusion-thermo (Dufour) effect was found to be of considerable magnitude such that it cannot be ignored Eckert and Drake [8]. In view of the importance of this diffusion-thermo effect, Jha and Singh [19] studied the free convection and mass transfer flow about an infinite vertical flat plate moving impulsively in its own plane, Ibrahim et al. [9] very recently reported computational solutions for transient reactive magnetohydrodynamic heat transfer with heat source land wall mass flux effects. These studies did not consider transfer over an inclined plate or Soret and Dufour effects, Chen [6] has studied magnetohydrodynamic free convection from an inclined surface with suction effects. The Soret effect refers to mass flux produce by a temperature gradient and the Dufour effect refers to heat flux produced by a concentration gradient. Very recently, Alam and Rahmam [2] studied the Dufour and Soret effects on study MHD free convective heat and mass transfer flow past a semi-infinite vertical porous plate embedded in a porous medium. Sedeek [17] has considered thermal-diffusion and diffusion-thermo effects on mixed free-forced convective flow and mass transfer over accelerating surface with a heat source in the presence of suction and blowing in the case of variable viscosity. Dufour and Soret effects on steady MHD free convection and mass transfer fluid flow through a porous medium in a rotating system were studied recently by Nazmul and Mahmud [13]. Kafoussias and Williams [10] presented thermal-diffusion and diffusion-thermo effects on mixed free forced convective and mass transfer boundary layer flow with temperature dependent. Ananda et al. [3] studied thermal diffusion and chemical effects with simultaneous thermal and mass diffusion in MHD mixed convection flow with ohmic heating. Oladapo [14] obtained the numerical solution of Dufour and Soret effects of a transient free convective flow with radiative heat transfer past a flat plate moving through a binary mixture. Anghel et al. [4] investigated Dufour and Soret effects on free convection boundary layer over a vertical surface embedded in a porous medium.

Very recently, Postelnicus [15] studied numerically the influence of a magnetic field on heat and mass transfer by natural convection from vertical surfaces in porous media considering Soret and Dofour effects. Dursunkaya et al. [7] analyzed diffusion-thermo and thermal-diffusion effects in transient and steady natural convection from vertical surface. Mansour et al. [11] studied the effects of chemical reaction and thermal stratification on magnetohydrodynamics free convective heat and mass transfer over a vertical stretching surface embedded in a porous media. Anwar Beg and Ghosh [5] Studied the steady and unsteady magnetohydrodynamic (MHD) free and forced convective flow of electrically, conducting, Newtonium fluid in the presence of appreciable thermal radiation heat transfer and surface temperature oscillation. Hence it is proposed to study MHD fluid flow over a vertical plate with Dufour and Soret effects.

2. FORMULATION OF THE PROBLEM
Considering MHD fluid flow of a viscous, incompressible, electrically-conducting fluid over a vertical plate moving with constant velocity with Dufour and soret effects is considered. The surface temperature of the plate oscillates with small amplitude about a non-uniform mean temperature. The system representation is such that the x-axis is taken along the plate and y-axis is normal to the plate.

The governing equations for the momentum, energy and concentration are as follows;

$$\frac{\partial u'}{\partial t'} = \nu \frac{\partial^2 u'}{\partial y'^2} + g\beta(T' - T'_\infty) - \frac{\sigma \beta_0^2 u'}{\rho} + g\beta^*(C' - C'_\infty) \quad (1)$$

$$\frac{\partial T'}{\partial t'} = \frac{k}{\rho C_\rho} \frac{\partial^2 T'}{\partial y'^2} - \frac{1}{\rho C_\rho} \frac{\partial q_r}{\partial y} + \frac{D_m k_T}{C_s C_p} \frac{\partial^2 C'}{\partial y'^2} \quad (2)$$

$$\frac{\partial C'}{\partial t'} = D \frac{\partial^2 C'}{\partial y'^2} + \frac{D_m k_T}{T_m} \frac{\partial^2 T'}{\partial y'^2} \quad (3)$$

where u' is the velocity of the fluid, t' is time, ν is the kinematics viscosity, g is the gravitational constant, β and β^* are the thermal expansions of fluid and concentration, T' is the temperature of the fluid, k is thermal conductivity, ρ is density, C_ρ is the specific heat capacity at constant pressure, C_s is the concentration susceptibility, k_T is the thermal diffusion, T_m is the mean fluid temperature, C' is the mass concentration, y' is distance, q_r is the radiative heat flux, β_0 is the magnetic field, D is the molecular diffusivity and D_m is the coefficient of mass diffusivity. The mathematical formulation is an extension of Anwar Beg and Ghosh [5], Dufour and Soret effects were added to the existing equations. The fluid is assumed to have constant properties except for the influence of the density variations with temperature and concentration, which are considered only in the body force term. under the above assumptions the physical variables are functions of y and t.

The initial and boundary conditions are:

$$\left.\begin{array}{l} u' = u, \quad T' = T'_\omega + \varepsilon(T'_\omega - T'_\infty)e^{i\omega t}, C' = C'_\omega + \varepsilon(C'_\omega - C'_\infty)e^{i\omega t}, at\ y = 0 \\ u' \to 0, \quad \theta' \to 0, T' \to 0 \quad C' \to 0 \quad as \quad y \to \infty \end{array}\right\} \quad (4)$$

Introducing the dimensionless quantities

$$\left.\begin{array}{l} u = \frac{u'}{U}, y = \frac{y'U}{\nu}, t = \frac{t'U^2}{\nu}, \\ Gr = \frac{g\beta\nu(T'_\omega - T'_\infty)}{U^3}, M = \frac{\sigma\beta_0^2\nu}{\rho U^2}, Du = \frac{D_m k_T}{C_s C_p}\frac{(C'_\omega - C'_\infty)}{\nu(T'_\omega - T'_\infty)} \\ k_1 = \frac{16a\sigma^*\nu^2 T'^3}{kU^2}, \Pr = \frac{\mu C_\rho}{K}, Sc = \frac{\nu}{D}, Sr = \frac{D_m k_T(T'_\omega - T'_\infty)}{T_m \nu(C'_\omega - C'_\infty)} \\ \theta = \frac{T' - T'_\infty}{T'_\omega - T'_\infty}, C = \frac{C' - C'_\infty}{C'_\omega - C'_\infty}, Gc = \frac{g\beta^*\nu(C'_\omega - C'_\infty)}{U^3} \end{array}\right\} \quad (5)$$

The thermal radiation flux gradient smay be expressed as follows

$$-\frac{\partial q_r}{\partial y'} = 4a\sigma^*(T'^4_\infty - T'^4) \quad (6)$$

. Considering the temperature difference by assumption within the flow are sufficiently small such that T'^4 may be expressed as a linear function of the temperature.this is attained by expanding in T'^4 taylor series about T'_∞ and ignoring higher orders terms.

$$T'^4 = 4T'^3_\infty T' - 3T'^4_\infty \quad (7)$$

(3)

Substituting the dimensionless variables (5) into (1) to (3) and using equation (6) and (7) equation (2) reduces to (9)

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + Gr\theta - Mu + GcC \quad (8)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2} - k_1\theta + Du\frac{\partial^2 C}{\partial y^2} \quad (9)$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} + Sr\frac{\partial^2 \theta}{\partial y^2} \quad (10)$$

Where
$$\left.\begin{array}{l} u = 1, C = 1 + \varepsilon e^{i\omega t}, \theta = 1 + \varepsilon e^{i\omega t}, y = 0 \\ u \to 0, C \to 0, \theta \to 0, y \to \infty \end{array}\right\} \quad (11)$$

Where Gr is thermal Grashof number, M is the Hartmann number, Gc is the mass Grashof number, k_1 is the thermal radiation conduction number ,Sc is the Schmidt number, Pr is the Prandtl number, Sr *and* Du represent the Soret and Dufour numbers respectively

3. METHOD OF SOLUTION

Analytical Solution, We assume that ε is small, therefore, we seek the solutions to (12), (13) and (14) having the form (3)

$$u(y,t) = u_0(y) + \varepsilon u_1(y)e^{i\omega t} \quad (12)$$

$$\theta(y,t) = \theta_0(y) + \varepsilon\theta_1(y)e^{i\omega t} \quad (13)$$

$$C(y,t) = C_0(y) + \varepsilon C_1(y)e^{i\omega t} \quad (14)$$

Where $u_0(y), C_0(y), \theta_0(y), u_1(y), C_1(y)$ and $\theta_1(y)$ are to be determined.

$$u_0'' - Mu_0 = -GcC_0 - Gr\theta_0 \quad (15)$$

$$\theta_0'' - \Pr k_1\theta_0 = D_3^* C_0'' \quad (16)$$

$$C_0'' = D_2^*\theta_0'' \quad (17)$$

$$u_1'' - (M + i\omega)u_1 = -GcC_1 - Gr\theta_1 \quad (18)$$

$$\theta_1'' - (k_1 + i\omega)\Pr\theta_1 = D_3^* C_1'' \quad (19)$$

$$C_1'' - Sci\omega C_1 = D_2^* \theta'' \quad (20)$$

All primes denote differentiation with respect to y

The boundary conditions are:

$$\left.\begin{array}{ll} u_0 = 1, \theta_0 = 1, C_0 = 1 & \text{on } y = 0 \\ u_1 = 0, \theta_1 = 1, C_1 = 1 & \text{on } y = 0 \\ u_0 \to 0, \theta_0 \to 0, C_0 \to 0 & \text{as } y \to \infty \\ u_1 \to 0, \theta_1 \to 0, C_1 \to 0 & \text{as } y \to \infty \end{array}\right\} \quad (21)$$

Solving equation (15) to (17) subject to the boundary conditions (21) we obtain

$$u_0(y) = \left(1 + \frac{Gr}{(\Omega_1 - M)} + \frac{Gc}{(\Omega_1 - M)}\right) e^{-y\sqrt{M}} - \frac{Gr}{(\Omega_1 - M)} e^{-y\sqrt{\Omega_1}} - \frac{Gc}{(\Omega_1 - M)} e^{-y\sqrt{\Omega_1}} \quad (22)$$

$$\theta_0(y) = e^{-y\sqrt{\Omega_1}} \quad (23)$$

$$C_0(y) = e^{-y\sqrt{\Omega_1}} \quad (24)$$

Solving equation (18) to (20) subject to the boundary conditions (21) we obtain

$$\begin{aligned} \therefore u_1(y) = & \left[1 + Gr\left(\frac{1}{a^2 - (M + i\omega)} + \frac{1}{b^2 - (M + i\omega)}\right)\right. \\ & \left. + Gc\left(\frac{1}{c^2 - (M + i\omega)} + \frac{1}{d^2 - (M + i\omega)}\right)\right] e^{-(M + i\omega)^{\frac{1}{2}} y} \\ & - Gc\left(\frac{1}{c^2 - (M + i\omega)} e^{-cy} + \frac{1}{d^2 - (M + i\omega)} e^{-dy}\right) \\ & - Gr\left(\frac{1}{a^2 - (M + i\omega)} e^{-ay} + \frac{1}{b^2 - (M + i\omega)} e^{-by}\right) \end{aligned} \quad (25)$$

$$\theta_1(y) = e^{-ay} + e^{-by} \quad (26)$$

$$C_1(y) = e^{-cy} + e^{-dy} \quad (27)$$

where

$$D_2^* = -ScSr,\ D_3^* = -\Pr Du,\quad \Omega_1 = \frac{\Pr k_1}{1 - D_3^* D_2^*},$$

,

$$\lambda_1 = \frac{(k_1 + i\omega)\Pr + Sci\omega}{1 - D_2^* D_3^*},\quad \lambda_2 = \frac{(k_1 + i\omega)Sci\omega\Pr}{1 - D_2^* D_3^*}$$

$$a = \left(\frac{\lambda_1}{2} + \lambda_3\right)^{\frac{1}{2}},\quad b = \left(\frac{\lambda_1}{2} - \lambda_3\right)^{\frac{1}{2}},$$

$$\eta_1 = \frac{Sci\omega + (k_1 + i\omega)\Pr}{1 - D_2^* D_3^*},\quad \eta_2 = \frac{(k_1 + i\omega)Sci\omega\Pr}{1 - D_2^* D_3^*}$$

$$c = \left(\frac{\eta_1}{2} + \eta_3\right)^{\frac{1}{2}} \quad and \quad d = \left(\frac{\eta_1}{2} - \eta_3\right)^{\frac{1}{2}}$$

Substituting equation (22) and (25) into (12) gives

$$\begin{aligned} u(y,t) = & \left(1 + \frac{Gr}{(\Omega_1 - M)} + \frac{Gc}{(\Omega_1 - M)}\right) e^{-y\sqrt{M}} - \frac{Gr}{(\Omega_1 - M)} e^{-y\sqrt{\Omega_1}} \\ & - \frac{Gc}{(\Omega_1 - M)} e^{-y\sqrt{\Omega_1}} + \varepsilon\left[\left[Gr\left(\frac{1}{a^2 - (M + i\omega)} + \frac{1}{b^2 - (M + i\omega)}\right)\right.\right. \\ & \left. + Gc\left(\frac{1}{c^2 - (M + i\omega)} + \frac{1}{d^2 - (M + i\omega)}\right)\right] e^{-(M + i\omega)^{\frac{1}{2}} y} - Gr\left(\frac{1}{a^2 - (M + i\omega)} e^{-ay} + \frac{1}{b^2 - (M + i\omega)} e^{-by}\right) \\ & \left. - Gc\left(\frac{1}{c^2 - (M + i\omega)} e^{-cy} + \frac{1}{d^2 - (M + i\omega)} e^{-dy}\right)\right] e^{i\omega t} \end{aligned} \quad (28)$$

The skin friction is obtain from equation (28) when differentiated at y=0

$$\begin{aligned} u'(y)\big|_{y=0} = & -M - \frac{MGr}{(\Omega_1 - M)} - \frac{MGc}{(\Omega_1 - M)} + \frac{\sqrt{\Omega_1} Gr}{(\Omega_1 - M)} + \frac{\sqrt{\Omega_1} Gc}{(\Omega_1 - M)} \\ & + \varepsilon\left[-(M + i\omega)^{\frac{1}{2}} Gr\left(\frac{1}{a^2 - (M + i\omega)} + \frac{1}{b^2 - (M + i\omega)}\right)\right. \\ & - (M + i\omega)^{\frac{1}{2}} Gc\left(\frac{1}{c^2 - (M + i\omega)} + \frac{1}{d^2 - (M + i\omega)}\right) \\ & \left. + \frac{aGr}{a^2 - (M + i\omega)} + \frac{bGr}{b^2 - (M + i\omega)} + \frac{cGc}{c^2 - (M + i\omega)} + \frac{dGc}{d^2 - (M + i\omega)}\right] e^{i\omega t} \end{aligned} \quad (29)$$

Substituting equation (23) and (26) in (13)

$$\theta(y) = e^{-y\sqrt{\Omega_1}} + \varepsilon\left(e^{-ay} + e^{-by}\right) e^{i\omega t} \quad (30)$$

The nusselt number is obtain from equation (31).when differentiated at y=0

$$\theta'(y)\big|_{y=0} = -\sqrt{\Omega_1} + \varepsilon\left(-a - b\right) e^{i\omega t}$$

(31)

Substituting (24) and (27) in (14)

$$C(y) = e^{-y\sqrt{\Omega_1}} + \varepsilon\left(e^{-cy} + e^{-dy}\right) e^{i\omega t} \quad (32)$$

The Sherwood number is obtain from equation (32). when differentiated at y=0

$$C'(y)\big|_{y=0} = -\sqrt{\Omega_1} + \varepsilon\left(-c-d\right)e^{i\omega t} \qquad (33)$$

4. RESULTS AND DISCUSSION

MHD fluid flow over a vertical plate with Dufour and Soret effects has been formulated,analysed and analytically. In order to understand the nature of the flow problem, computations are performed for different parameters such as Hartmann number M, Dufour number Du, Soret number Sr,thermal radiation conduction k_1, Prandtl number Pr Schmidtl number Sc, frequency oscillation ω, and perturbation parameter ε .

Figures 1-11 represent the velocity profiles with varying parameters, while figures 12-17 and 18-23 represent temperature and concentration distributions respectively.

The effect of velocity for different values of Hartmann number (M = 0.5, 1.0, 1.5, 2.0) is presented in Figure 1. The graph shows velocity increases with increasing M. The effect of velocity for different values of Dufour number (Du = 0.03, 0.06, 0.15, 0.3) is presented in Figure 2. The graph shows that velocity increases with increasing Du. The effect of velocity for different values of thermal radiation conduction (k_1 = 0.2, 0.5, 0.8, 1.0) is presented in Figure 3. The graph shows that velocity increases with decreasing k_1

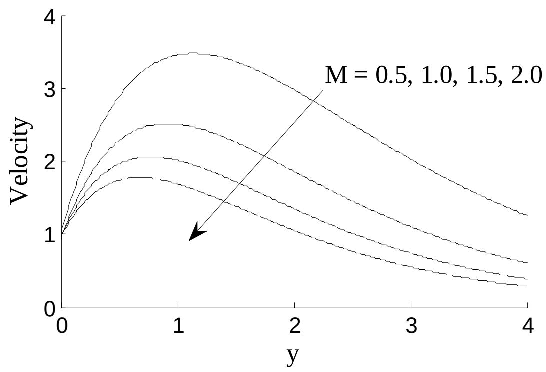

Figure 1. Velocity profiles for different values of M

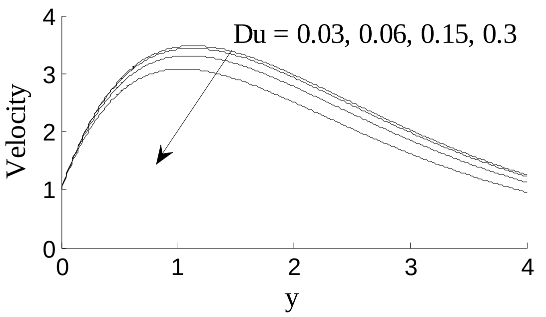

Figure 2. Velocity profiles for different values of Du

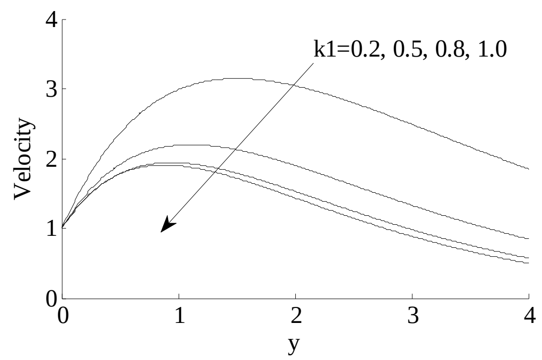

Figure 3. Velocity profiles for different values of k_1

The velocity profiles is studied for different values of mass and thermal Grashof number (Gc = 2, 5, 10) and (Gr = 3, 5, 10) are presented in Figure 4 and 5 respectively. It is observed that velocity increases with increasing Gc. and Gr. respectively. The velocity profiles is studied for various values of Prandtl number (Pr =0.71, 0.85, 1, 7) and is presented in Figure 6 It is observed that velocity increases with decreasing values of Pr.

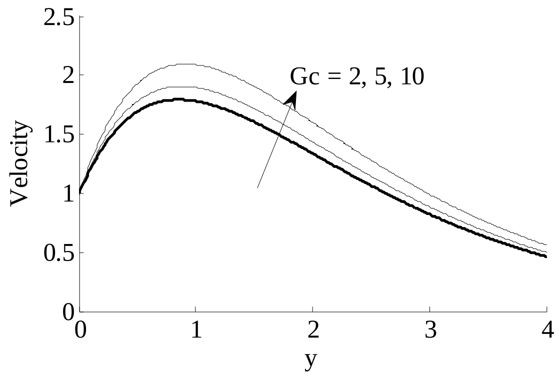

Figure 4. Velocity profiles for different values of Gc

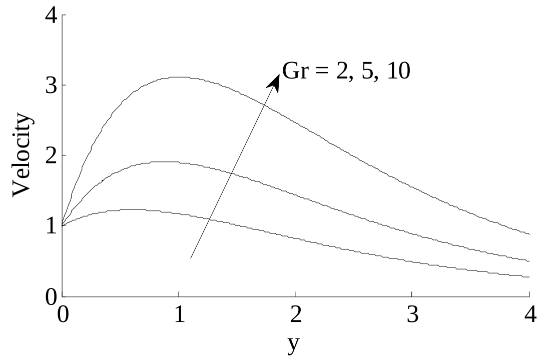

Figure 5. Velocity profiles for different values of Gr

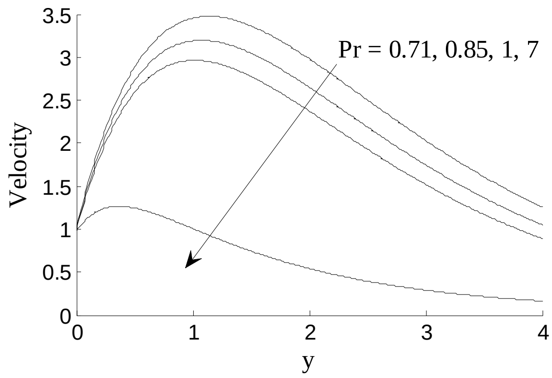

Figure 6. Velocity profiles for different values of Pr

The velocity profiles is studied for various values of frequency oscillation (ω =0.1, 0.5, 0.8, 1) and is presented in Figure 7. It is observed that velocity increases with decreasing values of ω. The velocity profiles is studied for different values of perturbation parameter (ε = 0.001, 0.002, 0.003, 0.004) is presented in Figure 8. It is observed that velocity increases with increasing values of ε. The velocity profiles is studied for different values of time (t = 0.1, 0.5, 1, 2) is presented in Figure 9. It is observed that velocity increases with decreasing values of t.

The effects of velocity for different values of Soret number (Sr = 0.1, 0.4, 1, 2) is presented in Figure 10. From the graph it shows that velocity increases with decreasing Sr. The velocity profiles is studied for various values of Schmidt number (Sc = 0.16, 0.3, 0.6, 2.01) and is presented in Figure 11. It is observed that velocity increases with decreasing values of Sc

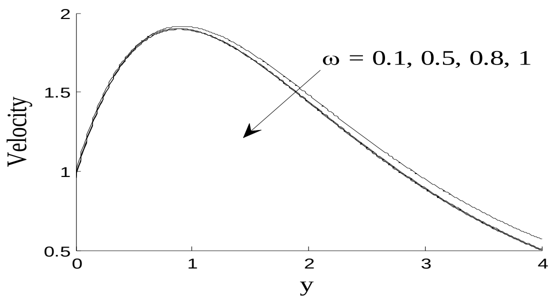

Figure 7. Velocity profiles for different values of ω.

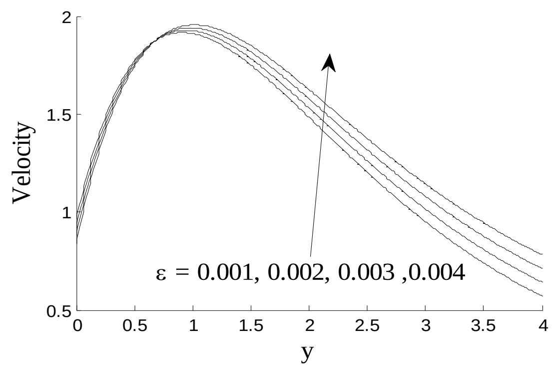

Figure 8. Velocity profiles for different values of ε

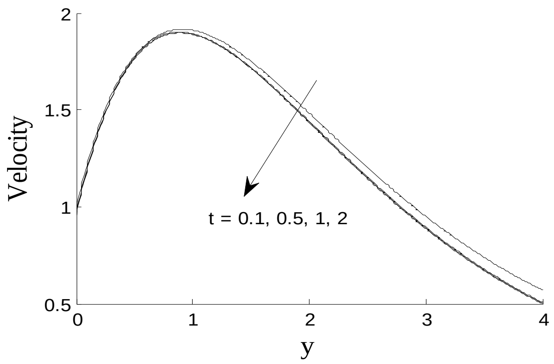

Figure 9. Velocity profiles for different values of t

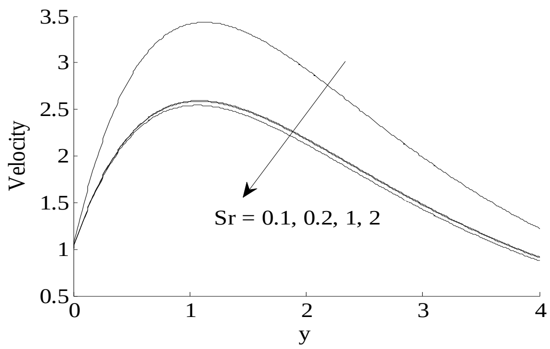

Figure 10. Velocity profiles for different values of Sr

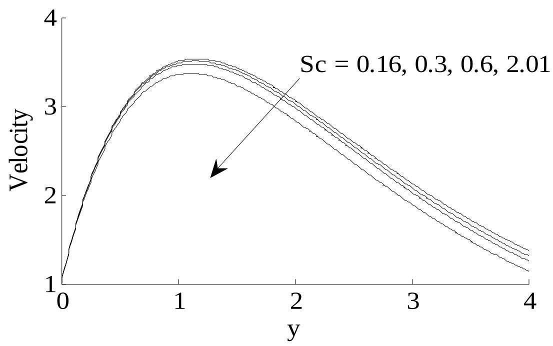

Figure 11. Velocity profiles for different values of Sc

The effects of temperature for different values of Dufour number (Du = 0.03, 0.06, 0.15, 0.3) is presented in Figure 12 From the graph it shows that temperature increases with decreasing Du. The effects of temperature for different values of thermal radiation conduction (k_1 = 0.2, 0.5, 0.8, 1.0) is presented in Figure 13 From the graph it shows that temperature increases with decreasing k_1. The temperature profiles is studied for different values of perturbation parameter (ε = 0.001, 0.002, 0.003, 0.004) is presented in Figure 14. It is observed that temperature increases with increasing values of ε. The effects of temperature for different values of Soret number (Sr = 0.1, 0.4, 1, 2) is presented in Figure 15 From the graph it shows that temperature increases with decreasing Sr. The temperature profiles is studied for various values of Prandtl number (Pr =0.71, 0.85, 1, 7) and is presented in Figure 4.3.16 It is observed that velocity increases with decreasing values of Pr.

The temperature profiles is studied for various values of Schmidt number (Sc = 0.16, 0.3, 0.6, 2.01) and is presented in Figure 17. It is observed that velocity increases with decreasing values of Sc

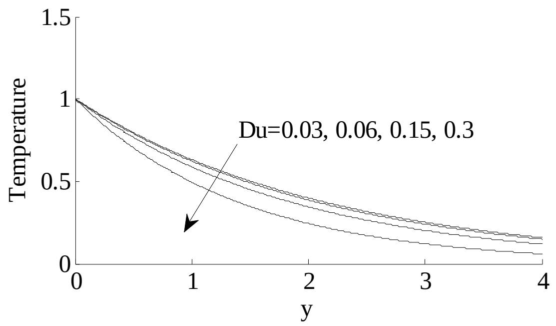

Figure 12. Temperature profiles for different values of Du

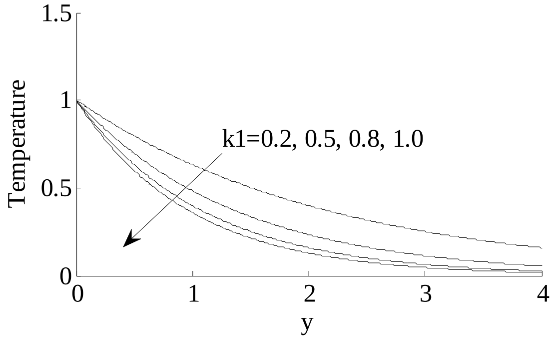

Figure 13. Temperature profiles for different values of k_1

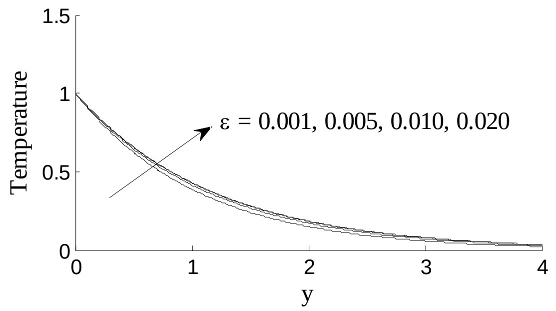

Figure 14. Temperature profiles for different values of ε

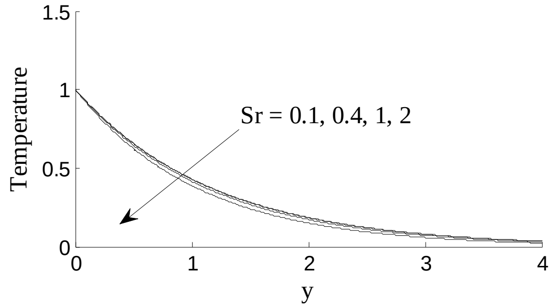

Figure 15. Temperature profiles for different values of Sr

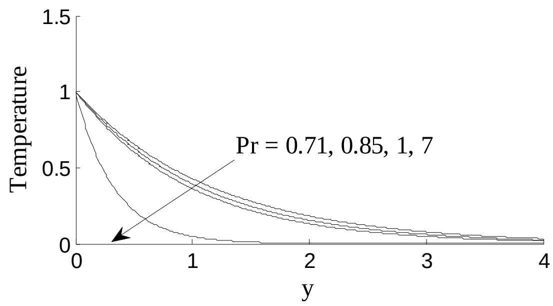

Figure 16. Temperature profiles for different values of Pr

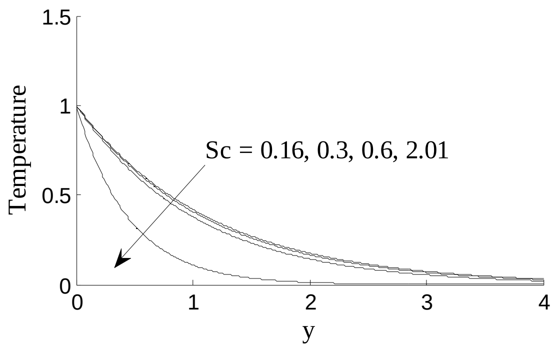

Figure 17. Temperature profiles for different values of Sc

The concentration profiles for different values of Dufour number (Du = 0.03, 0.06, 0.15, 0.3) is presented in Figure 18. It is observed that the concentration increases with decreasing Du. the concentration profiles for different values of thermal radiation conduction (k_1 = 0.2, 0.5, 0.8, 1.0) is presented in Figure 19. It is observed that the concentration increases with decreasing k_1. The concentration profiles is studied for different values of perturbation parameter (ε = 0.001, 0.002, 0.003, 0.004) is presented in Figure 20. It is observed that temperature increases with increasing values of ε .

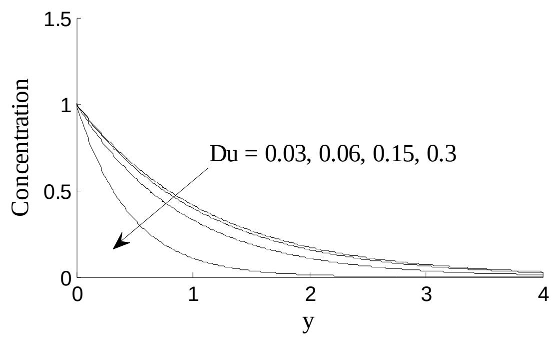

Figure 18. Concentration profiles for different values of Du

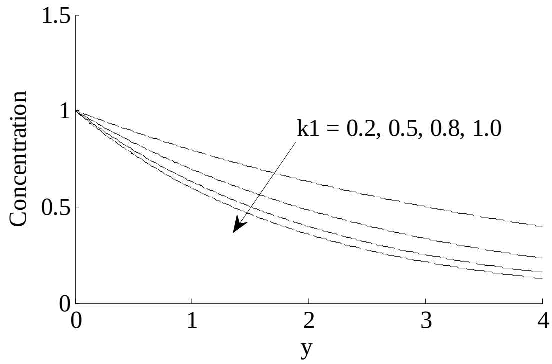

Figure 19. Concentration profiles for different values of k_1

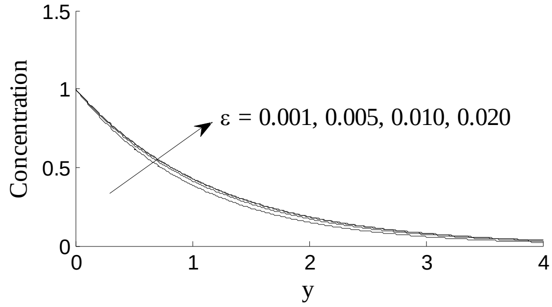

Figure 20. Concentration profiles for different values of ε

The effects of concentration for different values of Soret number (Sr = 0.1, 0.4, 1, 2) is presented in Figure 21. From the graph it shows that concentration increases with decreasing Sr. The concentration profiles for different values of Prandtl number(Pr = 0.71, 0.85, 1, 7) is presented in Figure 22. It is observed that the concentration increases with decreasing Prandtl number. The concentration profiles for different values of Schmidt number (Sc = 0.16, 0.3, 0.6, 2.01) is presented in Figure 23. It is observed that the concentration increases with decreasing Schmidt number.

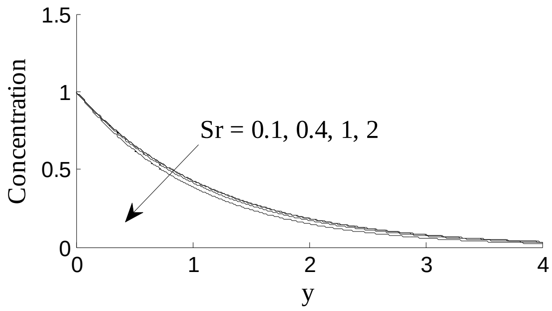

Figure 21. Concentration profiles for different values of Sr

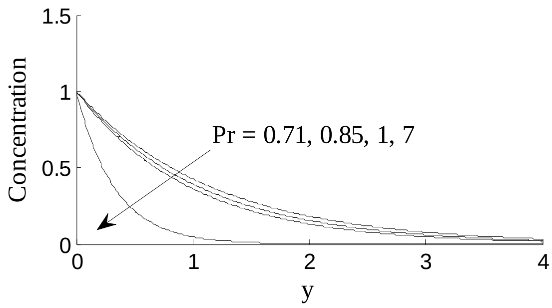

Figure 22. Concentration profiles for different values of Pr

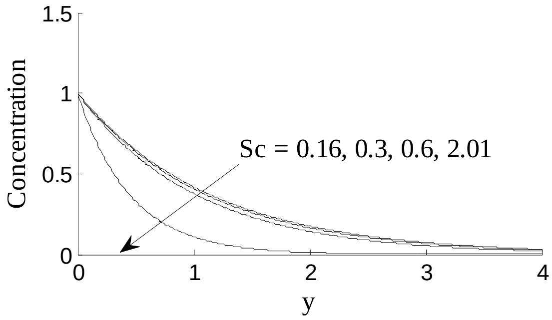

Figure 23. Concentration profiles for different values of Sc

Tables 1 to 3 gives the Skin friction, Nusselt number and Sherwood number respectively.

Table 1 shows the effect of physical parameters Gr, Gc, M, Du, Sr, Sc, ε, ω, k_1 and Pr on the skin friction.its observed that the shear stress increases when Gr, Gc, M, Du, Sr, Sc, ε, ω, k_1 and Pr increases.

Table 2 represents the variation of physical parameters Du, Sr, Sc, ε, ω, k_1 and Pr on the nusselt number which determines the rate of heat transfer.its observed that rate of heat transfer increases Du, Sr, Sc, ε, ω, k_1 and Pr increases.

Table 3 gives the effect of physical parameters Du, Sr, Sc, ε, ω, k_1 and Pr on the Sherwood number.its observed that mass transfer increases when Du, Sr, Sc, ε, ω, k_1 and Pr increases.

Table 1 Skin friction τ

Gr	Gc	M	Du	Sr	ε	ω	Pr	Sc	k_1	τ
2	3	0.5	0.03	0.1	0.001	0.1	0.71	0.6	0.5	-3.8183
2	5	0.5	0.06	0.4	0.001	0.1	0.71	0.6	0.5	-5.3840
3	5	0.	0.15	1	0.0	0.1	0.7	0.6	0.	-8.1571

		5			01		1		5	
3	5	0.5	0.3	2	0.001	0.1	0.71	0.6	0.5	-66.4684
5	5	1	0.03	0.1	0.001	0.1	0.71	0.3	0.5	4.4380
5	5	1	0.06	0.4	0.002	0.1	0.71	0.3	0.5	5.2902
5	5	1	0.15	1	0.002	0.1	7	0.3	1	1.3940

Table 2 Nusselt number Nu

ε	Du	Sr	ω	Pr	Sc	k_1	Nu
0.001	0.03	0.1	0.1	0.71	0.6	0.5	-0.5970
0.001	0.06	0.4	0.1	0.71	0.6	0.5	-0.5997
0.001	0.15	1	0.1	0.71	0.6	0.5	-0.6166
0.001	0.3	2	0.1	0.71	0.6	0.5	-0.6914
0.002	0.03	5	0.1	0.71	0.6	0.5	-0.6051
0.002	0.06	0.1	0.1	0.71	0.3	0.5	-0.5976
0.002	0.15	0.4	0.1	7	0.3	0.5	-2.0052
0.002	0.06	1	0.1	7	0.3	1	-2.8356

Table 3 Sherwood number Sh

ε	Du	Sr	ω	Pr	Sc	k_1	Sh
0.001	0.03	0.1	0.1	0.71	0.6	0.5	-0.8442
0.001	0.06	0.4	0.1	0.71	0.6	0.5	-0.8480
0.001	0.15	1	0.1	0.71	0.6	0.5	-0.8719
0.001	0.3	2	0.1	0.71	0.6	0.5	-0.9777
0.002	0.03	0.1	0.1	0.71	0.6	0.5	-0.8452
0.002	0.06	0.4	0.1	0.71	0.3	0.5	-0.8467
0.002	0.15	2	0.1	0.71	0.3	1	-0.8728
0.002	0.06	5	0.1	7	0.3	1	-4.3553

5. SUMMARY AND CONCLUSION

MHD fluid flow over a vertical plate with Dufour and Soret effects has been formulated, analysed and solved analytically. The dimensional governing equations are solved by perturbation technique. In order to point out the effects of physical parameters namely; Hartmann number M, Dufour number Du, Soret number Sr, thermal radiation conduction k_1, Schmidt number, Prandtl number Pr, frequency oscillation ω, and perturbation parameter ε .It is observed that velocity profile increases with decreasing Du and Sr.

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