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Convective Heat Flux Characteristics of MHD Fluid with Oscillatory Suction and Variable Electroconductivity over a Vertical Plate Provoked by Radiation

P. O. Nwabuzor[1*] and A. T. Ngiangia[1]

[1]Univesity of Port-Harcourt, Choba, Port-Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This article presents the effects of thermal radiation, Soret and Duffour terms on MHD fluid (which is the study of an electrically conducting fluid and its interaction with magnetic field) with oscillatory suction over a vertical plate. The solution of the dimensionless equation is obtained analytically using collocation weighted residual method. Using the wolfram 9 software, graphs were plotted to obtain the effects of the various material parameters on the velocity, temperature and concentration field within the boundary layers and they are separately discussed. The suction term and the Dufour parameter improves the temperature of the fluid but it receives and opposition from the Prandtl parameter. Also, the suction term, Soret and the Schmedit all improves the concentration of the fluid. Finally the effects of material parameters on the shear stress, Nusselt number and Sherwood are also presented graphically. In addition the results obtained showed that the material parameters have significant influence on the flow, heat and mass transfer.

Keywords: Soret; Dufour; heat flux; collocation weighted residual method; MHD.

**Corresponding author: E-mail: peter_nwabuzor@yahoo.com;*

NOMENCLATURES

ρ	: Fluid density
u'	: Fluid velocity
P	: Fluid pressure
μ	: Absolute viscosity
g	: Acceleration due to gravity
t	: Dimensionless time
t'	: Dimensional time
T	: Fluid temperature
C	: Dimensionless fluid concentration
a	: Thermal diffusivity
q_z	: Radiative term
Sc	: Schmidt number
y'	: Coordinate
σ	: Electrical conductivity
σ_∞	: Mean electrical conductivity
C_p	: Specific heat at constant pressure
C_o	: Initial concentration
β_c	: Coefficient of volume expansion for concentration
β_T	: Coefficient of volume expansion for temperature
T_∞	: Reservoir temperature
$\wedge$	: Planck's function
α_{K^*}	: Absorption coefficient
κ^*	: Frequency of radiation
ρ_∞	: Reservoir density
Sr	: Soret term
θ	: Dimensionless temperature
Gr_c	: Free convection parameter due to concentration
Gr_T	: Free convection parameter due to temperature
Du	: Dufour number
Y	: Dimensionless coordinate
υ	: Kinematic viscosity
C'	: Fluid concentration
R	: Dimensionless radiation term
T_m	: Mean fluid temperature
U	: Dimensionless fluid velocity
M	: Hartmann number
Nu	: Nusselt number
Sh	: Sherwood number
$\sigma_{x,y}$	: Shear stress
MHD	: Magnetohydrodynamics

1. INTRODUCTION

Heat flux characteristics has be widely studied by various scholars basically because of its wide range of application in the field of engineering and science. It's application include, removal of heat in nuclear reactors, processes of drying, exchanges of heat recovery of oil and geothermal construction of building, solar collector and others.

Radiation activities is also important in engineering and science, some industrial application such as aerodynamics, rocket propulsion system, science of plasma and others uses the concept for radiation for their operations. Cogley et al. [1].

Ahmed and Kalita [2] studied non-linear MHD flow with heat and mass transfer characteristics of an incompressible viscous electrically conducting and Newtonian fluid over a vertically oscillating porous plate. They applied the finite difference scheme of the Crank-Nicolson type as well as the Laplace transform technique to solve the modeling equation. Mebine [3] investigated the effect of radiation on MHD Couette flow with heat transfer between two parallel plates. Also, soundalgekar [4] examined free convection effects on the oscillating flow past an infinite vertical porous plate with constant suction. In another study, Isreal-Cookey and Sigalo [5] complemented the study of Soundalgekar [4], by investigating the simultaneous effect of viscous dissipation and radiation to the problem of unsteady MHD flow past an infinite vertical heated plate in a porous medium with time dependent suction. In a later study Isreal-Cookey et al. [6] worked on influence of viscous dissipation and radiation on the problem of unsteady MHD free convection past an infinite vertical heated plate in an optically thin environment with dependent suction Kayalvizhi and Anjali [7] examined radiation on linear MHD boundary layer of a fluid past a stretching porous sheet with prescribe heat flux. Prasannakumara et al. [8] investigated the effect of melting on flow and heat transfer of incompressible viscous dusty fluid near two dimensional stagnation point flow over a stretching surface in the presence of thermal radiation non-uniform heat source/sink and applied magnetic field. They found out that the temperature profile decreases with an increase in radiation. This is so because the large radiation values correspond to an increased dominance of conduction over radiation, thereby decreasing buoyancy force and thickness of thermal boundary layer. In another study Makinda and Animasaun [9] examined the combine effect buoyancy force, Brownain motion, thermophoresis and quartic autocatalytic kind of chemical reaction on bioconvection of nano fluid containing gyrotactic microorganism over an upper horizontal surface of a paraboliod of revolution. Boricic et al. [10] examined MHD universal equations of time dependent incompressible fluid flow with variable electroconductivity on heated moving plate. In another study Ngiangia [11] worked on the flow of viscous incompressible MHD fluid over an accelerated plate with electroconductivity and chemical reaction which is provoked by radiation. Sivaiah and Srinivasa, [12] investigated hall current effect and heat sipation with the infinite element technique. The hydro-magnetic heat and mass transfer in MHD flow of an incompressible electrically conducting viscous fluid past an infinite vertical porous plate of time dependent permeability under oscillatory suction velocity normal to the plate has been established by Anand et al. [13].

The unsteady MHD free-convection flow governed by the impact of suction or injection is one of the distinguished present day themes. For instance the process of blowing or suction is extremely important in the activities of engineering, these activities are design of thrust bearing, radial diffuses and thermal oil recovery. Suction is applied to chemical processes to remove reactant while injection is used to add reactant. Suction is also used for surface cooling and corrosion prevention Labrapala et al. [14].

Altia [15] illustrated the effect of suction and injection on Couette flow with properties. Ahmed and Khatin [16] carried out a theoretical analysis on MHD oscillatory flow in a planer porous channel with suction and injection.

Fourier [17] reported that energy flux can be generated by composition gradients, pressure gradients or the force produce by a body. In 1875 Henri Dufour discovered the energy flux caused by composition gradient and this was referred to as Dufour effect. Also, mass flux can be created by the gradient of temperature and this was established by Charles Soret. In practical sense energy flux due to mass concentration gradient tends to occur as a coupled effect of irreversible processes in the industry when buoyancy and impulsion are needed to instigate the flow. An example can be observed when species are injected at a surface in fluid domain with different (lower) density than the surrounding fluid. The Soret and Dufour effect tends to be significantly influential. This encounter is often noticed in chemical engineering processes according to Fourier [17], Alam, et al. [18], Mosta and Animisaun [19]. It is pertinent to note that the effect of the Dufour term and its reciprocal phenomenon (Soret effect) are considered together in most studies on mass and heat transfer. Aruna et al. [20] in their study of the combine influence of Dufour and Soret on a unsteady mixed convection MHD heat and mass transfer flow in an accelerated plate embedded in a porous medium discovered that the flux of energy can be generated from temperature gradient and fro concentration gradient. In another study Pattanayak and Mohipatra [21] examined the Dufour and Radiation effect on MHD boundary layer flow past a wedge with heat source and chemical reaction. Mosta and Animasaun [22] examined unsteady boundary layer flow over a vertical surface due to impulsive and buoyancy in the presence of thermal-diffusion and diffusion-themo using bivariate spectral relaxation method.

In the studies mentioned above the suction term together with the Soret and Dufour term have not been considered from the equation of energy and concentration. Hence, this article seeks to examine critically the characteristics of heat flux of MHD with variable electroconductivity and oscillatory suction over a vertical plated with radiation influence.

2. MATHEMATICAL FORMULATION

We considered a flow of an incompressible viscous, electrically conducting and heat absorbing fluid in a two dimensional coordinate system and subjected them to a varying temperature and concentration.

We made the following assumptions

- The fluid is assumed to be conducting slightly, and hence the magnetic Reynolds number is much less than unity also the magnetic induced field is negligible in comparison with the applied magnetic field.
- The Hall Effect of magnetohydrodynamics and the magnetic dissipation (Joule heating of the fluid) are neglected.
- It is assumed also that all the fluid properties are constant except that of the

influence of the density variation with temperature and concentration in the body force term
- The governing equations for this investigation are based on the balance of mass, linear momentum, energy and concentration species

Since the plate is situated in an infinite fluid and the length of the plate is large enough, the pressure gradient must be constant everywhere and the governing equations become

$$(1 + Ae^{iwt})\frac{\partial u'}{\partial y} = \mu'\frac{\partial^2 u'}{\partial y'^2} + \beta_T g(T - T_0) + \beta_c g(C - C_0) - \frac{\sigma B_o^2 u}{\rho} - \frac{\sigma_\infty u'}{U} \tag{1}$$

Where following Ngiangia [16], the fluid electro conductivity is assumed to be of the form $\sigma_\infty\left(1-\frac{u'}{U}\right)$ but for physical exigency and mathematical amenability, it is approximated to the form in (1)

$$\frac{\partial T}{\partial t'} + (1 + Ae^{iwt'})\frac{\partial T}{\partial y'} = a\frac{\partial^2 T}{\partial y'^2} - \frac{\partial q_r}{\rho C_p \partial y'} + \frac{D_m K_T \partial^2 C'}{C_p \partial y'^2} \tag{2}$$

$$\frac{\partial C}{\partial t'} + (1 + Ae^{iwt'})\frac{\partial C'}{\partial y'} = \frac{D_m K_T \partial^2 T}{T_m \partial y'^2} + \frac{D_m \partial^2 C'}{\partial y'^2} \tag{3}$$

$$\frac{\partial^2 q_z}{\partial y'^2} - 3\sigma^2 q_z - 16\sigma T_\infty^3 \frac{\partial T}{\partial y'} = 0 \tag{4}$$

For optically thin medium with relatively low density in the spirit of Isreal-Cookey et al. [6], equation (4) reduces to

$$\frac{\partial q_z}{\partial y'} = 4\delta^2\left(T - T_\infty\right) \tag{5}$$

where $\delta^2 = \int_0^\infty (\alpha_{K^*}\frac{\partial \wedge}{\partial T})dk^*$

subject to the boundary and initial conditions

$$u' = 0 \text{ when } t' \le 0,\ T = T_\infty, C' = C_\infty \text{ for all } y' \tag{6}$$

$$u'(0) = U,\quad u'(\infty) = U_\infty \tag{7}$$

$$T(\infty) = T_\infty,\ \frac{\partial T}{\partial y'}(\infty) = T_\infty \tag{8}$$

$$C'(\infty) = C'_\infty \quad \frac{\partial C'}{\partial y'}(\infty) = C'_\infty \tag{9}$$

2.1 Dimensionless Variables

For dimensional homogeneity of the governing fluid equations, we substitute the following dimensionless quantities or expressions of the fluid variables

$$u = \frac{u't}{y'}, M = \frac{\sigma B_0^2 y'^2}{\rho\mu\upsilon}, R = \frac{4\delta^2\rho_\infty C_\infty y'^2}{\rho C_p \upsilon}, C = \frac{C' - C_o}{C' - C_\infty}, \sigma_0 = \frac{\sigma_\infty t'}{\sigma u' y'}, Sc = \frac{\upsilon}{D_m}$$

$$\Pr^{-1} = \frac{\upsilon}{a}, g' = \frac{gy'}{u'^2}, \theta = \frac{T - T_o}{T - T_\infty}, U' = \frac{U}{u}, Sr = \frac{D_m k_T\left(T - T_\infty\right)}{\upsilon U T_m\left(C - C_\infty\right)}, n = \frac{\omega'\upsilon}{U^2}, \mu' = \frac{\mu}{\rho}$$

$$t = \frac{u'y'}{t'}, Gr_T = \frac{g\beta_T\left(T - T_o\right)y'^3}{u'^3}, Gr_c = \frac{g\beta_c\left(C' - C_o\right)y'^3}{u'^3}, k = \frac{\kappa_r^2 T_\infty \upsilon}{\alpha u'^2}$$

Using the dimensionless quantities, equations (1) – (9) can be rewritten as

$$(1 + Ae^{iwt})\frac{\partial u}{\partial y} = \frac{\mu'\partial^2 u}{\partial y^2} + Gr_T\theta + Gr_c C - Mu - \sigma_o u \tag{10}$$

$$(1 + Ae^{iwt})\frac{\partial \theta}{\partial y} = \Pr^{-1}\frac{\partial^2\theta}{\partial y^2} - R\theta + Du\frac{\partial^2 C}{\partial y^2} \tag{11}$$

$$(1 + Ae^{iwt})\frac{\partial C}{\partial y} = Sc^{-1}\frac{\partial^2 C}{\partial y^2} + Sr\frac{\partial^2\theta}{\partial y^2} \tag{12}$$

Subject to the boundary and initial conditions from Aruna et al. [20].

$u = 0, \theta = 0, C = 0$ for all y (13)

$u(0) = 1, \quad u(1) = 0$ (14)

$\theta(0) = 1 \quad \frac{\partial \theta}{\partial y}(0) = 1$ (15)

$C(0) = 1 \quad \frac{\partial C}{\partial y}(0) = 1$ (16)

3. METHOD OF SOLUTION

The problem posed in equations (10) – (12) are highly nonlinear equations and will be solved using the collocation weighted residual method

$L(u) - P(x) = U_B + \sum_{k=1}^{N} \alpha_k \emptyset_k$

If $U_B = o$

$L(u) - P(x) = \sum_{k=1}^{N} \alpha_k \emptyset_k$

Let

$\frac{1}{(1+Ae^{iwt})}$ = h

We assume our solution for equation 10 to be in the form

U(y)= $a_0 + a_1 y + a_2 y^2 + a_3 y^3 + a_4 y^4 + a_5 y^5 + a_6 y^6 + a_7 y^7 + a_8 y^8$ (17)

θ(y)= $b_0 + b_1 y + b_2 y^2 + b_3 y^3 + b_4 y^4 + b_5 y^5 + b_6 y^6 + b_7 y^7 + b_8 y^8$ (18)

C(y)= $c_0 + c_1 y + c_2 y^2 + c_3 y^3 + c_4 y^4 + c_5 y^5 + c_6 y^6 + c_7 y^7 + c_8 y^8$ (19)

Put equations 17 – 19 into equation 10 and collect like terms we have

$(2a_2 h\mu + hGr_T b_0 + hGr_c c_0 - h(m + \sigma)a_0 - a_1) + y(6a_3 h\mu + hGr_T b_1 + hGr_c c_1 - h(m + \sigma)a_1 - 2a_2) + y^2(12a_4 h\mu + hGr_T b_2 + hGr_c c_2 - h(m + \sigma)a_2 - 3a_3) + y^3(20a_5 h\mu + hGr_T b_3 + hGr_c c_3 - h(m + \sigma)a_3 - 4a_4) + y^4(30a_6 h\mu + hGr_T b_4 + hGr_c c_4 - h(m + \sigma)a_4 - 5a_5) + y^5(42a_7 h\mu + hGr_T b_5 + hGr_c c_5 - h(m + \sigma)a_5 - 6a_5) + y^6(56a_8 h\mu + hGr_T b_6 + hGr_c c_6 - h(m + \sigma)a_6 - 7a_6) + y^7(hGr_T b_7 + hGr_c c_7 - h(m + \sigma)a_7 - 8a_8) + y^8(hGr_T b_8 + hGr_c c_8 - h(m + \sigma)a_8)$

Therefore from the above equation we can get

$\alpha_1 = 2a_2 h\mu + hGr_T b_0 + hGr_c c_0 - h(m + \sigma)a_0 - a_1$ (20)

$\alpha_1 + \alpha_2 y + \alpha_3 y^2 + \alpha_4 y^3 + \alpha_5 y^4 + \alpha_6 y^5 + \alpha_6 y^6 + \alpha_7 y^7 + \alpha_8 y^8$

Form the collocation residual formula $\emptyset_k$ comes from a complete sequence defined by

$\emptyset_1 = y(1-y)$ (21a)

$\emptyset_2 = y(1-y)y$ (21b)

$\emptyset_3 = y(1-y)y^2$ (21c)

We collocate with only two points from equations (21a-21c)

$U_{(y)}$ = y(1 – y) (α_1 + α_2y)

$U_{(y)} = \alpha_1 y - \alpha_1 y^2 + \alpha_2 y^2 - \alpha_2 y^3$ (22)

From equation 21a and 21b we have

$\frac{\partial^2}{\partial y^2}(y - y^2) = -2$ (23)

$\frac{\partial^2}{\partial y^2}(y^2 - y^3)$ = 2 – 6y (24)

Put equations (23 and 24) into equations (22) and apply the boundary conditions in equation 14 we have

$\alpha_2 = \frac{1}{6}$ (25)

$\alpha_1 = -\frac{1}{3}$ (26)

Put equations (23-26) in equations 22 we have

U(y) = $-\frac{1}{3}$ (-2 + y - y^2) + $\frac{1}{6}$ (2– $6y + y^2 - y^3$) (27)

From equations (20) let

a_2 = 0, b_0 = 1, c_0 = 1, a_0 =1, a_1 = 0

Therefore equations (20) becomes

$\alpha_1 = 2h\mu + hGr_T + hGr_c - h(m + \sigma)$ (28)

Therefore equation (27) can be written as

(-2 + y - y^2) $(2h\mu + hGr_T + hGr_c - h(m + \sigma))$ + $\frac{1}{6}$ (2– $6y + y^2 - y^3$) (29)

U(y) = $-\frac{y^3}{6} + y^2$ (-$2h\mu - hGr_T + hGr_c + h(m + \sigma) + \frac{1}{6}$) + $y\left(2h\mu + hGr_T - hGr_c - h(m + \sigma) - 1\right)$ + $\frac{1}{3}$-4$h\mu$-2 $hGr_T + 2hGr_c + 2h(m + \sigma)$ (30)

Substitute equation (18) and its derivative into equation (11) and collect like terms we have

β_1 = 2h$Pr^{-1}b_2$ + hRb_0 + 2hDu$c_2 - b_1$ (31)

We collocate with only two points from equations (21a-21c)

$\theta(y)$= y(1 – y) (β_1 + β_2y)

$\theta(y)$ = ($y - y^2$) β_1 + (y^2 - y^3) β_2 (32)

Add equations (23 and 24) to equations 36 and apply the boundary conditions in equation (15) we have

$\beta_1 = -\frac{4}{5}$

$\beta_2 = -\frac{3}{10}$

Let $b_0 = 1$, $b_1 = 0$, $b_2 = 1$, $c_2 = 1$, we have

β_1 = 2hPr^{-1} + hR + 2hDu (33)

Equation (31) can be written as

$\theta(y) = (-2 + y - y^2)$ (2hPr^{-1} + hR + 2hDu) - $\frac{3}{10}$ $(2 - 6y + y^2 - y^3)$ (34)

Therefore equation (34) gives

$\theta(y) = \frac{3y^3}{10} - y^2(\frac{3}{10}$ + 2hPr^{-1} + hR + 2hDu) + $y(\frac{9}{5}$ + 2hPr^{-1} + hR + 2hDu) - $\frac{6}{10}$ - 4hPr^{-1} + 2hR + 4hDu (35)

Substituting the derivatives of equation (18) and (19) into equation (12) and collecting like terms we have

γ_1 = 2h$Sc^{-1}c_2$ + 2h$Sr^{-1}b_2$ - c_1 (36)

We collocate with only two points from equations (21a-21c)

$$C(y) = y(1 - y)(\gamma_1 + \gamma_2 y)$$

$$C(y) = (y - y^2)\gamma_1 + (y^2 - y^3)\gamma_2 \quad (37)$$

Add equations (27 and 28) to equations 40 and apply the boundary conditions in equation (16) we have

$$\gamma_1 = -\frac{4}{5}$$

$$\gamma_2 = -\frac{3}{10}$$

From equation (36) let $b_0 = 1, \quad b_1 = 0, \ b_2 = 1, \ c_2 = 1$, we have

$$\gamma_1 = 2hSc^{-1} + 2hSr^{-1} \quad (38)$$

Equation (37) can therefore be written as

$$C(y) = (-2 + y - y^2)(2hSc^{-1} + 2hSr^{-1}) - \frac{3}{10}(2 - 6y + y^2 - y^3)$$

$$C(y) = \frac{3y^3}{10} - y^2(\frac{3}{10} + 2hSc^{-1} + 2hSr^{-1}) + y(-\frac{9}{5} + 2hSr^{-1} + 2hSc^{-1}) - \frac{6}{10} - 4hSr^{-1} - 4hSc^{-1} \quad (39)$$

The shear stress is given as

$$\sigma_{xy} = \mu\frac{du}{dy} = \mu[(-\frac{y^2}{2} + 2y\,(-2h\mu - hGr_T + hGr_c + h(m + \sigma) + \frac{1}{6}) + (2h\mu + hGr_T - hGr_c - h(m + \sigma) - 1)] \quad (40)$$

The Nusselt number is given as

$$Nu = -\frac{dT}{dy} = -[\frac{9y^2}{10} - 2y(\frac{3}{10} + 2hPr^{-1} + hR + 2hDu) + (\frac{9}{5} + 2hPr^{-1} + hR + 2hDu)] \quad (41)$$

The Sherwood number is given by

$$S_h = -\frac{dc}{dy} = -[\frac{9y^2}{10} - 2y(\frac{3}{10} + 2hSc^{-1} + 2hSr^{-1}) + (-\frac{9}{5} + 2hSr^{-1} + 2hSc^{-1})] \quad (42)$$

4. RESULTS AND DISCUSSION

For a clear physical understanding and validation of the problem, results which were obtained from the collocation weighted residual method are explained graphically in the system of equations (10)-(12) with the boundary conditions in equations (14) –(16). The results are also given graphically which are represented in Figs. 1 to 24. For the graphical solution an approximate value of viscosity μ = 1.002N.s/$m^2$was used. The other parameter values used for this work are

Sc = 0.94, 1.94, 2.94, 3.94, 4.94
Sr = 0.31, 0.62, 0.93, 1.24, 1.55
R = 1.23, 2.23, 3.23, 4.23, 5.23
Du = 0.9, 1.8, 2.7, 3.6, 4.5
Gr_T = 0.7, 1.4, 2.1, 2.8, 3.5
Gr_c= 0.8, 1.6, 2.4, 3.2, 4.0
σ_0 = 0.25, 0.75, 1.25, 1.75, 2.25
M = 0.5, 1.5, 2.5, 3.5, 4.5
h = 0.73, 1.46, 2.19, 2.92, 3.65
Pr = 0.31, 0.41, 0.51, 0.61, 0.71

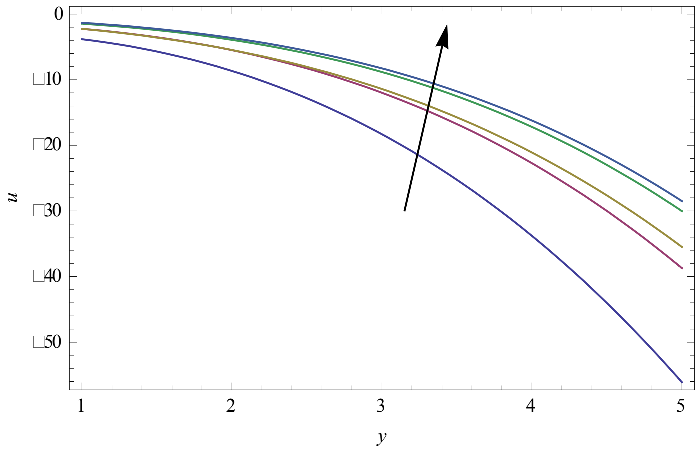

Fig. 1. Effect of velocity profile on varying suction term (h)
h = 0.73, 1.46, 2.19, 2.92, 3.65

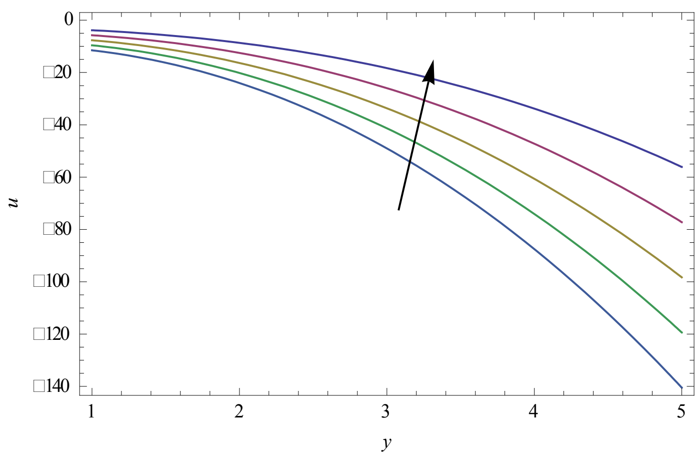

Fig. 2. Effect of velocity profile on varying thermal Grashof number (Gr_T)
G_T = *0.7, 1.4, 2.1, 2.8, 3.5*

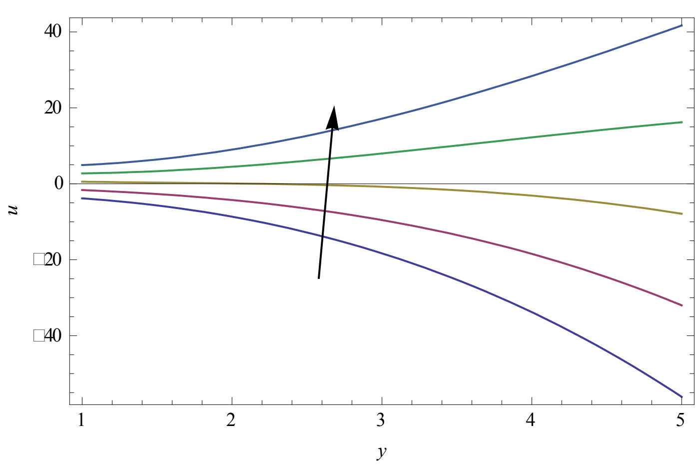

Fig. 3. Effect of velocity profile on varying solutal Grashof number (Gr_c)
G_c = *0.8, 1.6, 2.4, 3.2, 4.0*

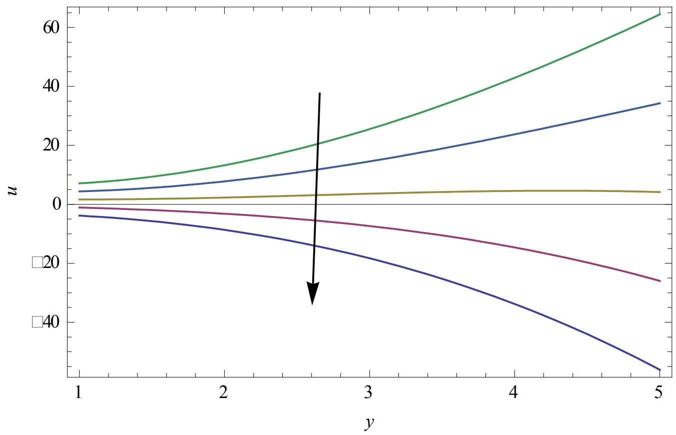

Fig. 4. Effect of velocity profile on varying magnetic number (M)
M = 0.5, 1.5, 2.5, 3.5, 4.5

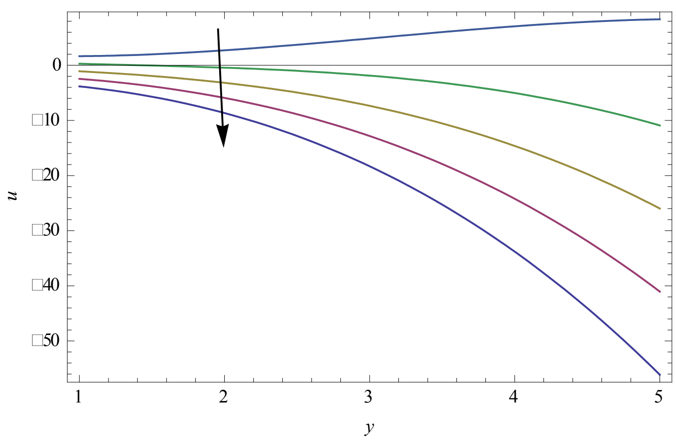

Fig. 5. Effect of velocity profile on varying electroconductivity (σ_0)
σ_0 = 0.25, 0.75, 1.25, 1.75, 2.25

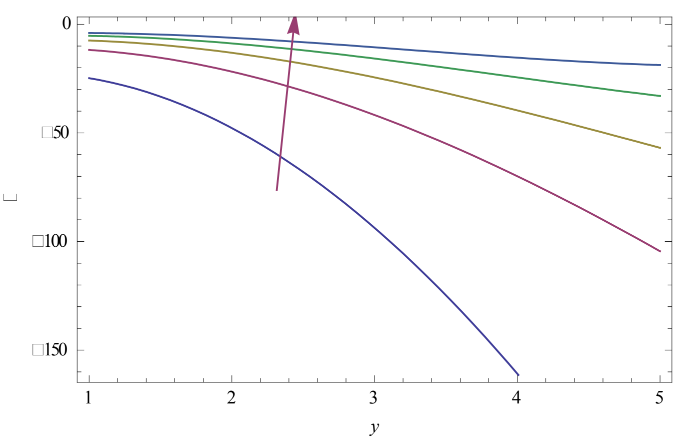

Fig. 6. Effect of temperature profile on varying suction term (h)
h = 0.73, 1.46, 2.19, 2.92, 3.65

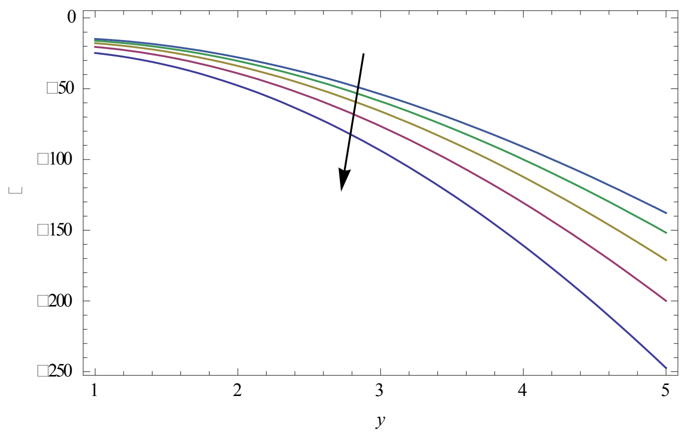

Fig. 7. Effect of temperature profile on varying Prandtl number
Pr = 0.31, 0.41, 0.51, 0.61, 0.71

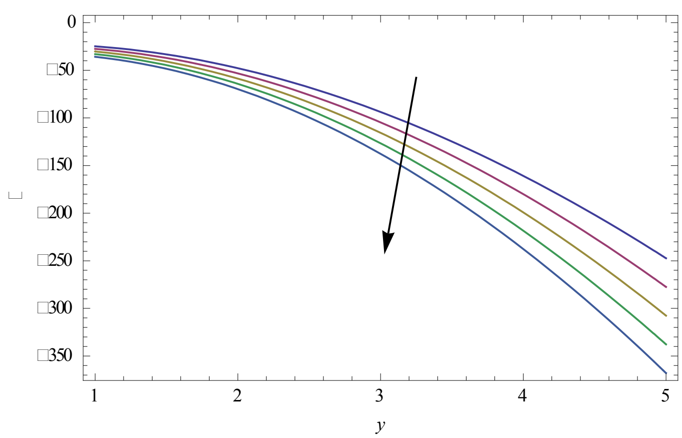

Fig. 8. Effect of temperature profile on varying radiation number (R)
R = 1.23, 2.23, 3.23, 4.23, 5.23

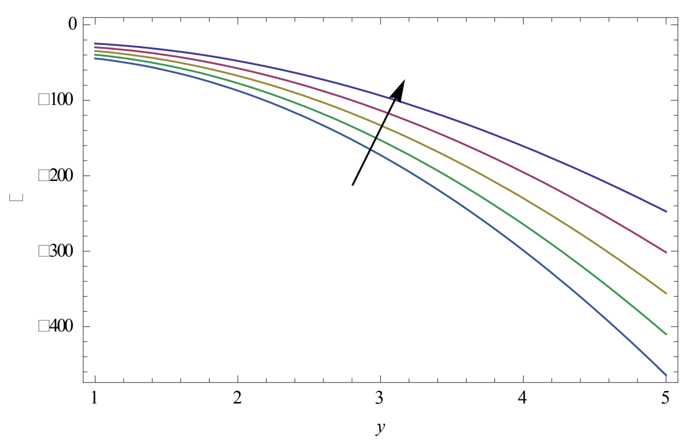

Fig. 9. Effect of temperature profile on varying Dufuor number (Du)
Du = 0.9, 1.8, 2.7, 3.6, 4.5

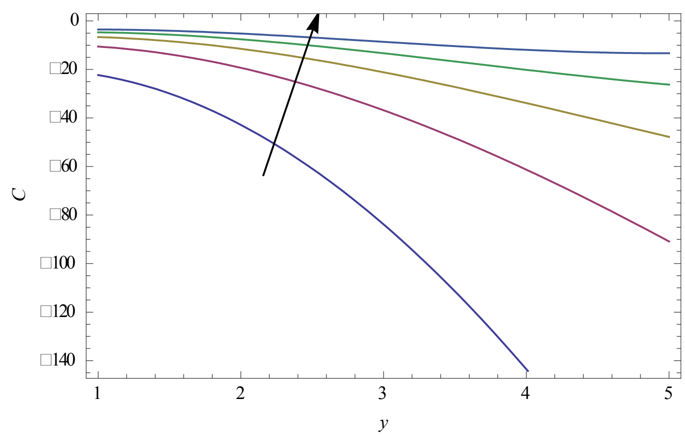

Fig. 10. Effect of concentration profile on varying suction term number (h)
h = 0.73, 1.46, 2.19, 2.92, 3.65

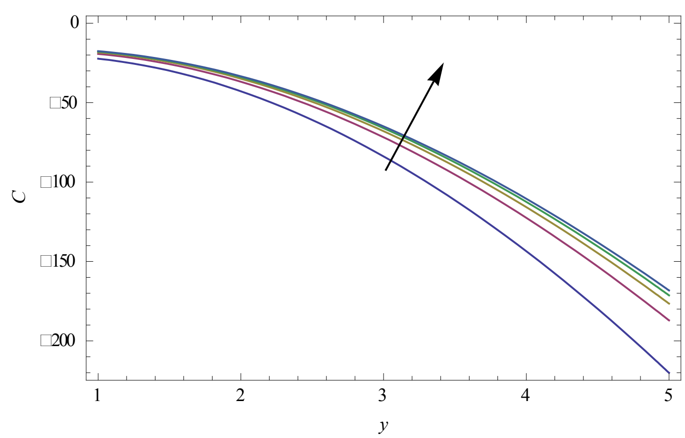

Fig. 11. Effect of concentration profile on varying Schmdit number (Sc)
Sc = 0.94, 1.94, 2.94, 3.94, 4.94

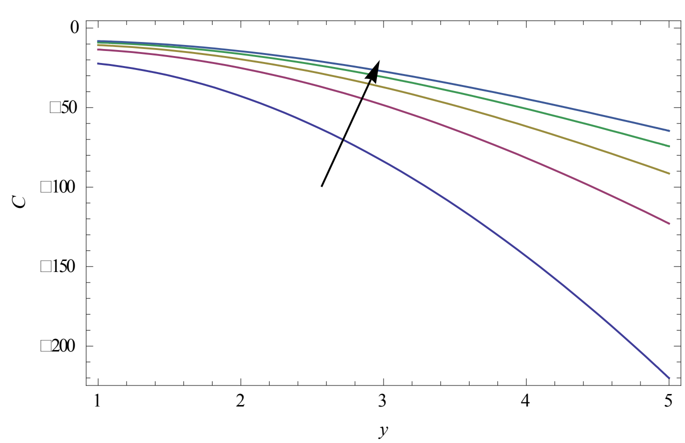

Fig. 12. Effect of concentration profile on varying Soret number (Sr)
Sr = 0.31, 0.62, 0.93, 1.24, 1.55

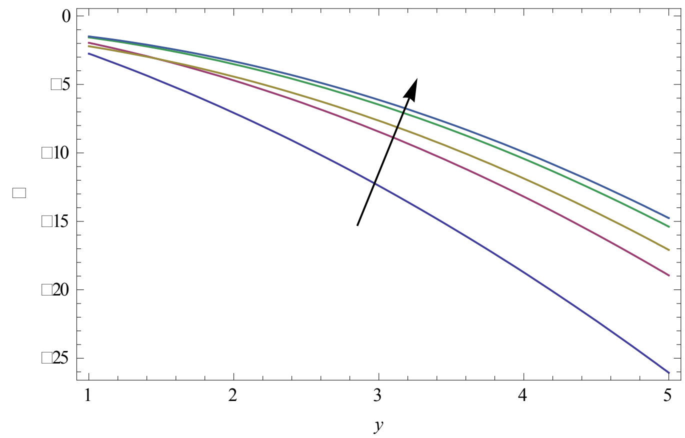

Fig. 13. Effect of shear stress profile on varying suction term (h)
h = 0.73, 1.46, 2.19, 2.92, 3.65

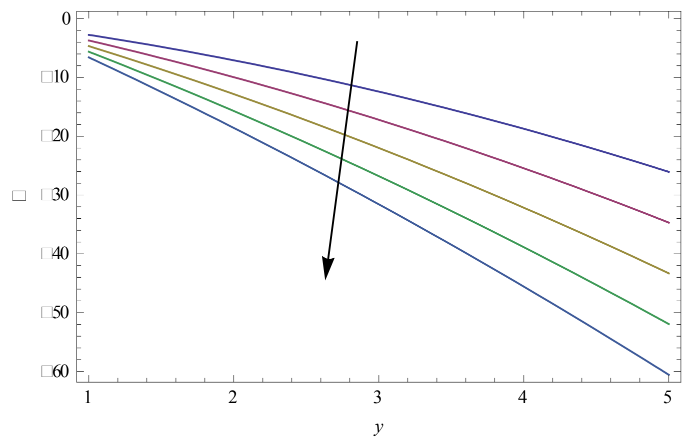

Fig. 14. Effect of shear stress profile on varying thermal Grashof number (Gr_T)
G_T *= 0.7, 1.4, 2.1, 2.8, 3.5*

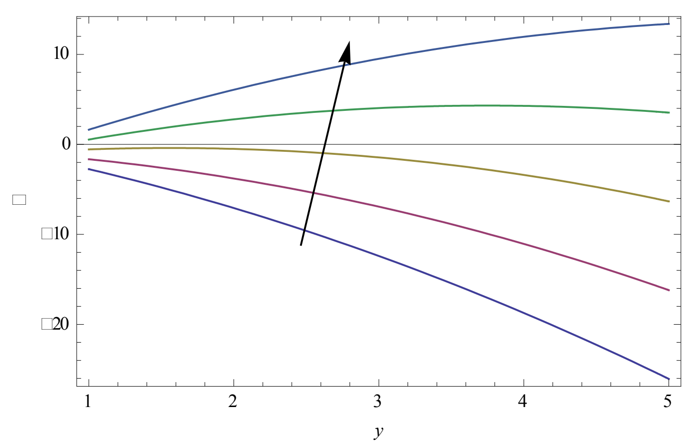

Fig. 15. Effect of velocity profile on varying solutal Grashof number (Gr_c)
G_c *= 0.8, 1.6, 2.4, 3.2, 4.0*

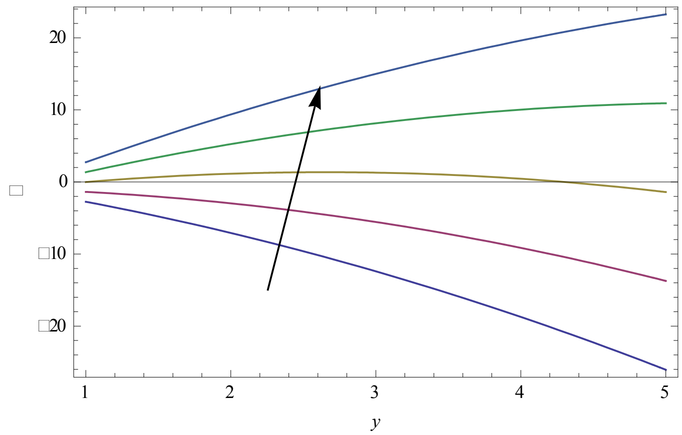

Fig. 16. Effect of shear stress profile on varying magnetic number (M)
M = 0.5, 1.5, 2.5, 3.5, 4.5

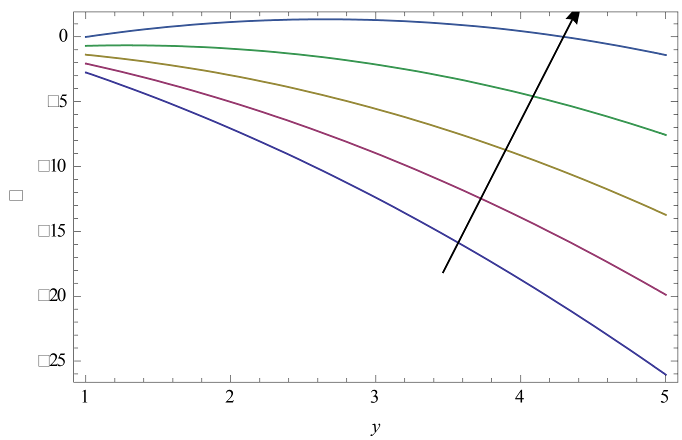

Fig. 17. Effect of shear stress profile on varying electroconductivity (σ_0)
σ_0 = 0.25, 0.75, 1.25, 1.75, 2.25

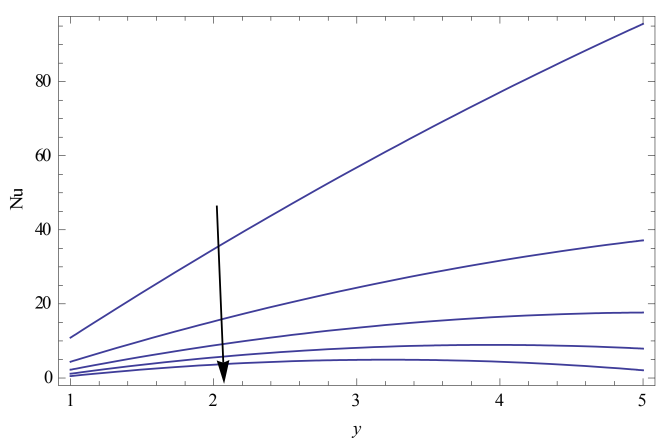

Fig. 18. Effect of Nusselt number on varying suction term (h)
h = 0.73, 1.46, 2.19, 2.92, 3.65

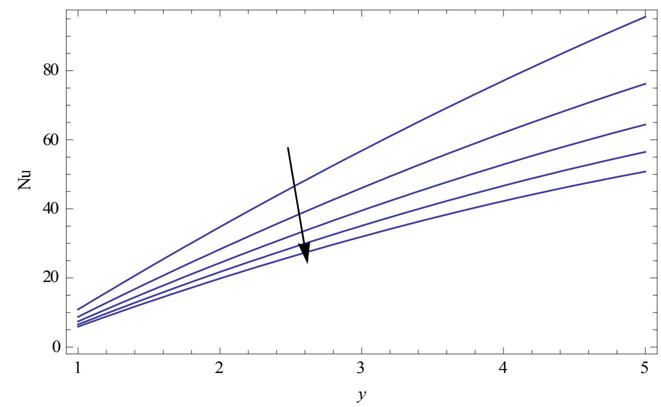

Fig. 19. Effect of Nusselt number on varying Prandtl number
Pr = 0.31, 0.41, 0.51, 0.61, 0.71

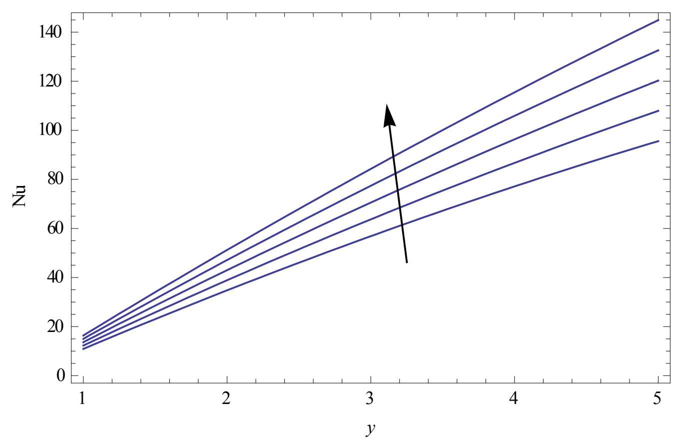

Fig. 20. Effect of Nusselt number on varying radiation number (R)
R = 1.23, 2.23, 3.23, 4.23, 5.23

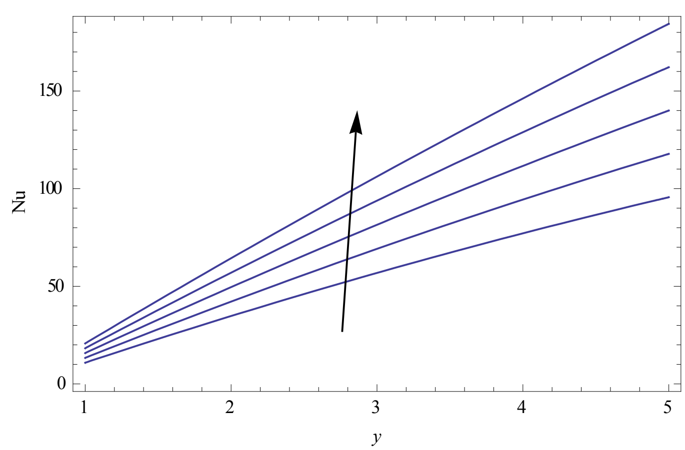

Fig. 21. Effect of temperature profile on varying Dufuor number (Du)
Du = 0.9, 1.8, 2.7, 3.6, 4.5

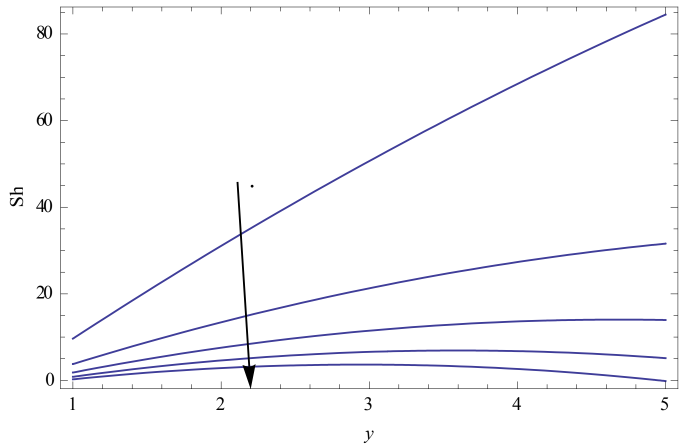

Fig. 22. Effect of sherwood on varying suction term number (h)
h = 0.73, 1.46, 2.19, 2.92, 3.65

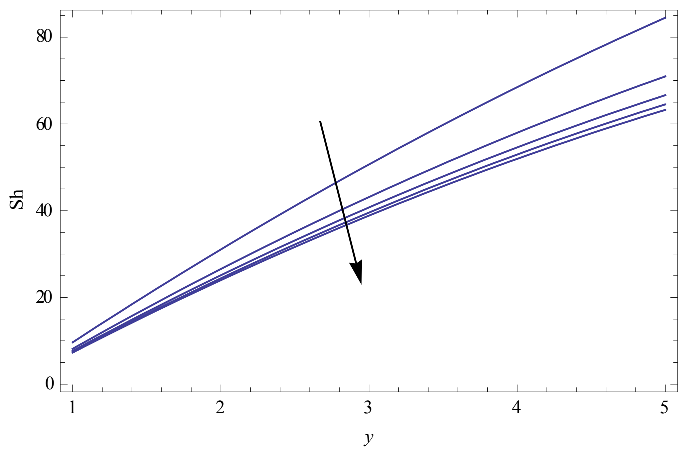

Fig. 23. Effect of Sherwood on varying Schmdit number (Sc)
Sc = 0.94, 1.94, 2.94, 3.94, 4.94

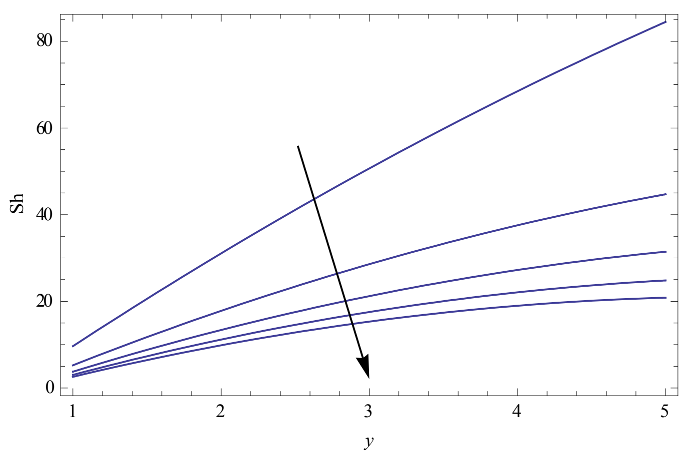

Fig. 24. Effect of Sherwood on varying Soret number (Sr)
Sr = 0.31, 0.62, 0.93, 1.24, 1.55

Fig. 1, illustrate the variation of the velocity profile with various values of the suction term. It can be seen that an increase in the suction term leads to an increase in the velocity profile of the fluid. Fig. 2 represents the importance of the grashof parameters due to temperature which is the thermal grashof number to the velocity profile. We observe that the velocity of the flow is accelerated as a result of an increase in the thermal grashofs parameter. Fig. 3 presents typical velocity profile for values of the solutal grashofs numbers Gr_c. We noticed clearly that there is an increase in the velocity profile when the soluital grashof number increases. This result is consistent with the study of Aruna et al. [20].

From Fig. 4 it is observed that an increase in the magnetic field parameter will lead to a decrease in the velocity profile. This observation is in tandem Mebine, [3]. Fig. 5 displays increase in electroconductivity and a corresponding decrease in the velocity profile of the flow of the fluid; this shows that the conductivity produces a resistive force which act in the opposite direction to the fluid motion. The effect of the suction term on the temperature profile is shown in Fig. 6, it can be observed that the temperature profile increases with a corresponding increase in the suction term.

Fig. 7 exhibits the effects of Prandtl number on the temperature of the fluid, increasing the Prandtl number results in a decrease in the temperature profile. This result agrees with the findings of Mohammed and Suneetha, [23]. From Fig. 8, increase in the radiation number results in decrease in the temperature profile. This is so because larger radiation values correspond to an increased dominance of thermal radiation over conduction. As such thermal radiation supplement the thermal diffusivity of the regime since the local radiation conductivity to the convectional thermal conductivity as a result the temperature in the fluid regime are significantly increased. This is in agreement with Onwugbute et al. [24] and Ahmed and Kalita [2].

In Fig. 9, the Dufour parameter which signifies the contribution of the concentration gradient to the thermal energy flux in the flow and it showed that when the Dufuor parameters are increased the temperature profile will increase.

Figs. 10 – 12 shows the effects of suction term (h), Schmdit (Sc) and the Soret (Sr) on the concentration of the fluid. It shows that when Sr, Sc and h are increased there will be an increase in the concentration of the fluid.

Fig. 13 gives the variation with increasing suction term (heat absorption). It is observed that increasing the suction term increases the shear stress. In Fig. 14 it is observed that an increase in the thermal grashof number leads to a decrease in the shear stress of the plate. Furthermore from Fig. 15 it can be observed that when the solutal grashof number is increases the shears stress. Fig. 16 shows that magnetic field parameter when increase will increase the shear stress. Fig. 17 shows that an increase in the conductivity will increase the shear stress.

Fig. 18 depicts the Nusselt profiles for different values of the suction term (h) it can be noticed that when the suction term increase the Nusselt number will decrease.

Fig. 19 presents typical Nusselt number in the boundary layer for various values of Prandtl's number. It is noticed that the Nusselt profile decreases with an increase in the Prandtl number. From Fig. 20 the Nusselt number increases with an increase in the radiation parameters.

Fig. 21 shows that increasing the Dufuor term will lead to an increase in the Nusselt number. Fig. 22 and Fig. 23 show that increase in the suction term and schemdit will lead to decrease in the Sherwood number (Sh). Fig. 24 is plotted to display the effect of soret number on Sherwood number (Sh). The Sherwood number decreases for higher values of soret number.

5. CONCLUSION

In this article we have theoretically studied the effect of thermal radiation and electroconductivity on convective heat flux characteristic of MHD fluid with oscillatory suction over a vertical plate. The method of solution applied is collocation weighted residual method which can be applied for solving second order differential equations and other related mathematical problems. The result gotten were illustrated through a graph and discussed. The results obtained showed that parameters such as Soret, Dufour, Magnetic number Grashof Prandtl, Suction terms and others used have significant influence on heat and mass transfer. The findings can be summarized as.

1. The suction term, thermal Grashof number solutal Grashof number and electroconductivity promotes the flow of the fluid while the magnetic parameter opposes the flow.

2. The suction term and the Dufour parameter improves the temperature of the fluid but the Prandtl number works against it.
3. The suction term, the soret and the schemdit all improves the concentration of the fluid.
4. Results for the above listed parameter were also used to determined their effects on the Nusselt number the shear stress and the Sherwood and results were obtained.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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