JOURNAL LA MULTIAPP

VOL. 03, ISSUE 02 (068-083), 2022
DOI: 10.37899/journallamultiapp.v3i2.583

# Effect of Variable Thermal Conductivity and Viscosity on MHD Casson Nanofluid Flow Vertical Plate through Thermal Radiation Convective Temperature along with Velocity Slip

**M. Ramanuja[1,2], A. Sudhaker[1], V. Nagradhika[2]**

[1]*Department of Mathematics, Marri Laxman Reddy Institute of Technology & Management (Autonomous), Dundigal, Medchal Dist, Hyderabad-500043, India*
[2]*Department of Mathematics, GITAM University, Bangalore, 562163, India*

**Corresponding Author: M. Ramanuja*
*Email:* mramanuja09@gmail.com

Article Info

*Article history:*
Received 2 March 2022
Received in revised form 24 March 2022
Accepted 29 March 2022

*Keywords:*
MHD
Casson
Dufour Number
Prandtl Number
Radiation

**Abstract**

*This article presents the influences of connected variable thickness with created conductivity, nanofluid flow over a vertical level plate through convective smooth, with velocity slip boundary surroundings. The controlling vehicle nonlinear divided differential stipulations with the interrupt surroundings are non- dimensionalized. The reachable path of motion of certain existing differential conditions is then diminished to a set of joined nonlinear quintessential differential conditions utilizing convenience modify. Numerical outcomes are getting for dimensionless velocity, temperature, and nanoparticle quantity. It is discovered that the velocity increments, while each temperature and nanoparticle extent partrot with improved estimations of variable maximum conductivity and consistency. At the same time as the Dufour range and Soret, comprehensive range augmentation with working up the relative and the thing subject decompose as the Schmidt range tendencies while the temperature area decreases with extending Prandtl number and Dufour number correlations are executed with scattered facts virtually taking parent proper now the numerical outcomes. Surprising consideration is seen. Taking the entirety into account, the effects of essential parameters on fluid velocity, temperature, and focus on dispersion moreover as on the partition total mass, heat, and mass exchange figures are audited in detail. Also, this existing consideration can determine purposes in the method, which include nanofluid works out.*

## Introduction

Nanofluid grabbed the concentration of particular researchers outstanding to its brilliant outcomes in as long as grabbed the focus of specific researchers excellent to its good effects in so long as the extra exceptional efficiency mainly in advance of heat transfers. When the nanoparticles additional right coarse fluid, set aside put into the first-rate charge of heat switch as of coolants. This selection of nanofluid has by way of them phenomenal for various styles of functions in heat transfer. The sun, coil, biomass, and hydropower form significant sources of renewable power. Scientists, engineers, and theoretical mathematicians have explored these additional novel energy sources to develop new energy technologies that maintain clean and sustainable energy sources and contest climate change. There is a significant organization within the non-Newtonian (nanofluid) fluids fitting to, including and region of reasonable and made sciences. For instance, designed oils, exhausting attitudes, ensured oils and paints, coarseness courses of action, land increase, or common mollified kind of run through are the straightforward shared cases regarding non-Newtonian fluids. The Navier-Stokes ideal conditions can't quickly represent the properties concerning preserving discipline concerning non-Newtonian fluid's reasonable incongruity with the unpredictability between the rational structures in a sprint with the flow issue. Plenteous styles for non-Newtonian fluids are portrayed as figuring rheological qualities for illustration. Eyring To the best of the author's knowledge, despite the frequently mentioned literature, the focus of the present work is to study the combined effect of the effect of variable thermal conductivity and viscosity on MHD Casson nanofluid flow vertical plate through thermal radiation convective temperature and velocity slip. This investigation investigates the impact of induced magnetic field on flow formulation and heat transfer in combined pressure and driven flow of conducting Casson nanofluid fluid in a vertical flow plate. The function of working non-conducting plate on the velocity of heat transfer is extensively discussed. A similar problem is discussed by J.A Gbadeyan et al.in the absence of induced magnetic field., Powell, Bulky, Seely, Oldroyd-B, Maxwell, Oldroyd-A, Carreau, Casson, Burger, Jeffrey, etc.

Jawali & Chamkha (2015) explore the united impact of variable thickness and cool conductivity on the free convection pass easily of a viscous fluid in a vertical channel. he used Attia's (2006) interpretation for each temperature-subordinate consistency and cool conductivity. It was once noticed that the fluid waft and heat move enlarge because the variable consistency parameter increases. The trend in factor moderate conductivity reduces each the flame goes and the fluid flow. Bagai & Nishad (2014) used a numerical implement (for instance, shooting procedure) to analyze the impact of temperature-subordinate thickness on the trademark convective breaking reason layer goes with the flow over a quantity plate embedded in a nanofluid doused porous medium. The consistency of the fluid is recounted to falter exponentially with temperature. The moderate conductivity was as soon as the customary regular and radiation period is overpassed. It was once considered that the flame and mass exchange scale expand as the thickness parameter increases. Casson fluid slide along with variable thermo-physical houses alongside exponentially expanding sheet with points of interest and exponentially decaying inner heat time using the homotopy examination approach (HAM) used to be idea by way of Animasaun et al. (2016) have pondered the radiation term used was once immediate. The effect of porosity was no longer put into thought. Moreover, Casson fluid, instead of Casson nanofluid, used to be thinking at the current time. They determined that improvement in Casson fluid's variable plastic novel consistency parameter prompts an addition in velocity profile and a diminishing in temperature profile all via the breaking factor layer. Inspected the flame and mass alternate waft of as distant as possible layer float in the direction of an expanding sheet with manufactured response was represented with the aid of Mabood & Khan (2015) investigated the impact of the appealing subject on the two-dimensional movement of nanofluid with and without slip situation used to be mentioned by way of Khan et al. (2016) examined Mohyud-Din et al. (2016) independently. Khan et al. (2016) analyzed two-dimensional electrically driving the motion of nanofluid on the explanation of the broadening sheet influenced by way of convective breaking factor conditions. The impact of first-demand mixture reaction two-dimensional motion of thick fluid in the proximity and nonappearance of interesting subject Khan et al. (2016) and Mohyud-Din et al. (2016) examined continuing considering its application, the impact of moderate radiation on the gooey stream of a micropolar nanofluid interior seeing the horny self- was as soon as made by way of Mohamud-commotion et al. (2015) researched, on the other hand, non-Newtonian fluids have gotten involved in light of its wide range software in various ventures, for instance, the shape of solid cross-section heat, nuclear fritter away evacuation, compound synergist reactors, geothermal imperativeness creation, groundwater hydrology, transpiration cooling, oil storehouses, etc. These fluids are step by step jumbled when diverged from Newtonian fluids in light of nonlinear associations among uneasiness rates. A couple of fashions have been proposed for the examination of non-Newtonian fluids, in any case. Still, no longer singular model is developed that suggests all houses of non-Newtonian fluids.

Recorded as a difficult facsimile, the clearest mannequin is the Maxwell model. Among special non-Newtonian fluids, there is every other fluid acknowledged as Casson fluid. Casson fluid is a shear-decreasing fluid required to have a perpetual consistency at zero paces of shear, yield stress under which no flow occurs, and a zero thickness at a never-ending sheer pace. Saidulu & Venkata et al. (2016) used a numerical technique (Keller box system) to research the impact of slip-on MHD waft of a Casson fluid over an exponentially broadening sheet inside, seeing moderate radiation, warmness source/sink, and manufactured reaction. It was once situated that the temperature and obsession profile extend when the Casson parameter increases. However, the inverse has been the circumstance for the tempo profile. difficult MHD slip flow of a Casson fluid resulting from a rising sheet with attractions or leaving behind Mahdy (2016) examined it was seen that establishing the slip parameter constructs the fluid flow, and so far as conceivable layer will get little by little skinny if there must emerge a match of attractions or blowing. Nadeem et al. (2013) used the area deterioration instrument to obtain the answer for a great distance as a viable layer goes with the waft of a Casson fluid over an exponentially contracting sheet. it's miles seen that their anxiety diminished to the Newtonian case after the fluid parameter methods limitlessness. Mukhopadhyay et al (2-16) Nadeem et al. (2013) are discussed in like manner dismembered the third-dimensional hydromagnetic float of Casson fluid in a porous medium. Numerical plans of the electrically riding the slipstream of Casson nanofluid made at some point of the increasing sheet influenced by way of convective breaking factor conditions the use of closeness modifications have been presented by using. Using its functions with charming features, Benazir et al. (2016) regarded unstable Casson circulate past a vertical cone and quantity sheet inner seeing a desirable field. As of late, Oyelakin et al. (2016) explored the unreliable electrically riding movement of Casson nanofluid inside, seeing slip and convective cutoff conditions. A numerical document used by Jagdish Prakash et al. (2014) inspected the qualities of warmness and mass change on insecure mixed convective magnetohydrodynamic fluid glide outdated a brought about vertical wavy plate, issue to quite a lot of temperature and mass dispersal, with the influence of moderate radiation, daintiness and Dufour sway. Anand et al. (2012) indicated short glide previous a rashly started ceaseless degree porous plate in a turning fluid in the closeness of appealing discipline with Hall present day the usage of the constrained phase structure. Anand Rao et al. (2012) had been inquired about the merged effects of heat and mass trade on unsteady MHD circulate past a vertical oscillatory plate points of interest speed using constrained section methodology. The joined results of heat and mass change on uncertain MHD frequent convective flow past a boundless vertical plate encased through the porous medium in the closeness of temperate radiation and Hall Current was once inquired about utilizing Ramana Murthy et al. (2015) Researched the sensitive magnetohydrodynamic infrequent movement of a non-Newtonian fluid through penetrable channel coherently has been investigated with the aid of Taklifi and Aliabadi (2012). Zueco et al. (2009) reviewed the effect of combination response on the hydromantic heat and mass exchange boundary layer goes with the flow starting a level chamber in a Darcy-Forchheimer with shape proliferation.

To one of the author's knowledge, despite the repeatedly talked about literature, the point of interest of the current exertion is to check the mixed impact of the impact of variable thermal conductivity and viscosity on the MHD Casson nanofluid waft vertical plate by way of thermal radiation convective temperature and velocity slip. The investigation for this investigation is to investigate the impression of brought on the magnetic subject on glide formula and heat switch in mixed stress and pushed go with the of conducting Casson nanofluid fluid in a vertical glide plate, the objective of working non-conducting plate on the velocity of heat switch is broadly discussed. The same concern is mentioned by J.A Gbadeyan et al.in the absence of prompted magnetic field.

## Mathematical Formation of the Problem:

Let us think concerning the two-dimensional constant laminar standard convective enhancement of massive electrically utilizing incompressible Casson nanofluid in far more than a vertical stage, the plate is the idea that of. the entire properties of the liquid are common to be regular then to the thickness, consistency, and unruffled conductivity of the fluid. It is predicted that the outer base of the plate is exposed to convective temperate with temperature $T_f$, $\vec{x}$ is the distance along with the plate, while $y$ in the distance perpendicular to the plate. A local magnetic field $M_0\ (\bar{x})$ is assumed to be positioned in a slanting route to the fluid flow. The fluid temperature and nanoparticle quantity fraction (concentration) is denoted with the support of T and C respectively. It is in a similar fashion accepted that the actuated putting focus is unobserved due to the fact of a little attractive Reynolds quantity. The nanoparticle quantity fraction at the wall is taken as $C_w$ at the same time as the temperature and nanoparticle volume fraction far commencing the wall is denoted through $T_\infty$ and $C_\infty$ correspondingly

$$\tau_{ij} = \begin{cases} 2\left(\mu_B + \dfrac{p_y}{\sqrt{2\pi}}\right)e_{ij} & \pi > \pi_c \\ 2\left(\mu_B + \dfrac{p_y}{\sqrt{2\pi_c}}\right)e_{ij} & \pi < \pi_c \end{cases} \quad (1)$$

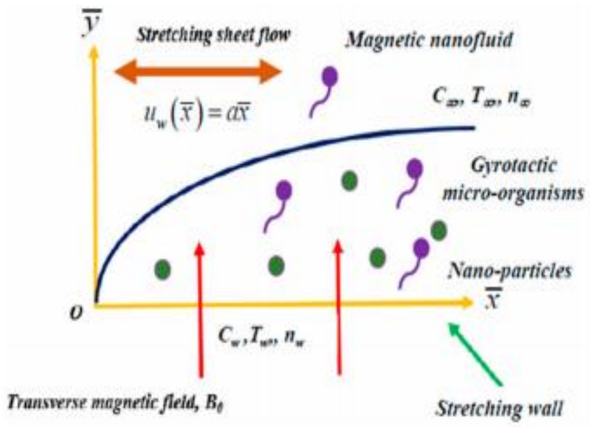


*Figure 1. Intention pattern and systematize system (Nanofluid growing quantity flow)*

The stable two-dimensional MHD flow of an electrically conducting non-Newtonian Casson nanofluid over a stretching sheet placed at y = 0. The flow is proscribed in the region y>0. The equal through contradictory forces is functional along the x-axis so that the wall is long-drawn-out with the origin fixed. $p_y = \dfrac{\mu_B\sqrt{2\pi}}{\beta}$ , $e_{ij}e_{ij} = \dfrac{1}{2}\left(\dfrac{\partial u_i}{\partial x_j} + \dfrac{\partial u_j}{\partial x_i}\right)$ Rate of strain tenor, $\pi = e_{ij}e_{ij}$ and $e_{ij}$ is the $(i, j)$th element of deformation rate, n is the effect of deformation rate utilizing itself, $\pi_c$ is a critical value of this product based under the non-Newtonian model, $\beta$ Casson parameter, $\mu_B + \dfrac{P_Y}{\sqrt{2\pi}}$ be real the plastic dynamic viscosity $(\mu_f)$ of the non-Newtonian fluid and $p_y$ be the yield stress of the fluid. The kinematic viscosity $v_f = \dfrac{\mu_B}{\rho_f}\left(1 + \dfrac{1}{\beta}\right)$ the continuity, momentum, and energy equations governing such type of flow are given as

$$\frac{\partial u'}{\partial x}+\frac{\partial v'}{\partial y}=0 \quad (2)$$

$$\frac{\partial u'}{\partial t}+u'\frac{\partial u'}{\partial x}+v'\frac{\partial u'}{\partial y}=v\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u}{\partial y^2}-\left(\frac{\sigma M_0^2(x,t)}{\rho}+\frac{v\varphi}{k_1}\right)$$
$$\pm g\beta_T(T-T_\infty)\pm g\beta_c(C-C_\infty) \quad (3)$$

$$\frac{\partial T}{\partial t}+u'\frac{\partial T}{\partial x}+v'\frac{\partial T}{\partial y}=\frac{k}{\rho c_p}\frac{\partial^2 T}{\partial y^2}-\frac{1}{\rho c_p}\frac{\partial q_r}{\partial y}+\frac{v}{c_p}\left(1+\frac{1}{\beta}\right)\left(\frac{\partial u'}{\partial y}\right)^2$$
$$+\frac{\sigma M_0{}^2(x,t)}{\rho c_p}u^2+\frac{Q(x,t)}{\rho c_p}(T-T_\infty), \quad (4)$$

$$\frac{\partial c}{\partial t}+u\frac{\partial c}{\partial x}+v\frac{\partial c}{\partial y}=D\frac{\partial^2 c}{\partial y^2}-k_c(C-C_\infty). \quad (5)$$

$$u'\frac{\partial T}{\partial x}+v'\frac{\partial T}{\partial y}=\alpha_{nf}\frac{\partial^2 T}{\partial y^2} \quad (6)$$

Where $u'$ and $v'$ be the velocity apparatus in the $x$ and $y$ directions, respectively. $v_{nf}$ Be the kinematic viscosity, $\rho_{nf}$ is the Casson fluid density,

$\beta=\mu_B\sqrt{\frac{2\pi_c}{p_y}}$ be the parameter of Casson fluid, $\sigma$ is the electrical conductivity of the fluid, $\alpha_{nf}$ is the thermal diffusivity, $T$ is the temperature, and $k_0$ is the permeability of the porous medium. $k_0=k_1(1-\gamma t)/\mathrm{x}^{(\mathrm{m}-1)}$ exist the variable permeability of the porous medium, g be the induced gravitational force due to acceleration, $\beta_T$ be the volumetric coefficient of thermal expansion, $\beta_C$ the coefficient of concentration expansion, $k$ is the thermal conductivity of the Casson fluid, $q_r$ is the radioactive heat flux,

$Q(x,t)=\frac{Q_0 x^{m-1}}{(1-\gamma\,\mathrm{t})}$ is high-temperature generation/absorption coefficient, D is the mass diffusivity and $k_c$ is the rate of the chemical effect. The material properties of nana fluid such at the same time as $\rho_{nf}$, $\mu_{nf}$, $(\rho C_P)_{nf}$ and $k_{nf}$ are given as Abu-Nada (2008), Zhang et al. (2015).

$$\mu_{nf}=\frac{\mu_f}{(1-\phi)^{2.5}},\quad \rho_{nf}=(1-\phi)p_f+\phi p_s,$$
$$(\rho C_P)_{nf}=(1-\phi)(\rho C_P)_f+\phi\left(\rho C_P\right)_S \quad (7)$$
$$\frac{k_{nf}}{k_f}=\frac{k_S+2k_f-2\phi(k_f-k_s)}{k_S+2k_f+\phi(k_f-k_s)}$$

Where $\rho_f$ be the density of the stranded fluid, $\rho_s$ be the density of the nanoparticle, $\mu_f$ be the viscosity of the base fluid, whereas the nanoparticle $\phi$ by the volume of the function of nanoparticles, $(\rho C_p)_f$, $(\rho C_p)_s$ is the heat capacitance of the base fluid and nanoparticle respectively and $k_f, k_s$ are thermal conductivities of the base fluid and nanoparticle respectively. Different states of nanoparticles and various equations for temperate conductivity and dynamic consistency can be found in the referenced referred to thus. The successful temperate conductivity of the nanofluid given by Hamilton, which is of the structure the thermophysical property of various base liquids and nanoparticles, has appeared in

Table 1. Numerical Values of Nanoparticles and Water

| **Thermophysical properties** | **Fluid phase water** | **Cu** | **$Al_2O_3$** | **Ni** |
|---|---|---|---|---|
| $C_p$(Þ j=kg) K | 4178 | 384 | 764 | 445 |
| ρ (kg/m³) | 997.2 | 8934 | 3971 | 8901 |
| k (w/m K) | 0:614 | 401 | 41 | 90.6 |

The appropriate boundary conditions for the problem are given by

$$u = u'_w = bx$$
$$T = T_w = T_\infty + A\left(\frac{x}{l}\right)^2 \qquad at\ y = 0$$
$$u = u_w(x) + Nv\left(1+\frac{1}{\beta}\right)\frac{\partial u'}{\partial y} \qquad k\frac{\partial T}{\partial y} = -h_f(T_f - T)_x$$
$$a_{nf}\frac{\partial c}{\partial y} = -h_f(\mathrm{C}_f - C) \qquad \text{at y} = 0$$
$$\mathrm{u}' \to 0 \ ,\ \mathrm{T} \to \mathrm{T}_\infty, \qquad C \to C_\infty$$
$$u \to 0 \ ,\ \mathrm{T} \to \mathrm{T}_\infty \qquad as\ \ y \to \infty$$

(8)

Now $N_1(X_x, t) = N_0 x^{-(\mathrm{m}-1)/2}(1-\gamma t)^{1/2}$ denotes velocity slip dynamic with constant $N_0$. $h_f(x,t) = h_0 x^{(\mathrm{m}-1)/2}(1-\gamma t)^{-1/2}$ And $h_s(x,t) = h_1 x^{(\mathrm{m}-1)/2}(1-\gamma t)^{-1/2}$ correspond to the convective heat and mass transfer with $h_0$, $h_1$ being constants, $T_f(\mathrm{x,t}) = \mathrm{T}_\infty + T_0 x^n (1-\gamma t)^{-n}$ during which $T_0$ being position temperature and $n = 2m-1$ $C_s(x,t) = C_\infty + C_0 x^n (1-\gamma t)^{-n}$ with $C_0$ being reference concentration. The radioactive heat flux $q_r$ describes according be give as we take up the Rosseland approximation for radioactive flux writhe energy equation in Eq.

$$q_r = \frac{-4\sigma^*}{3k_1^*}\frac{\partial T^4}{\partial y} \qquad (9)$$

Where $\sigma^*$ is the Stefan--Boltzmann constant and $k_1^*$ is the mean absorption coefficient. $T^4$ can exist expressed as the linear function of temperature. By expanding $T^4$ in a Taylor series about $\mathrm{T}_\infty$ and neglecting higher terms we can inscribe

$$T^4 \cong 4T_\infty^3 T - 3T_\infty^4. \qquad (10)$$

IncorporateEq(6)andEq(7)inEq(4),we obtain

$$\frac{\partial T}{\partial r} + u'\frac{\partial T}{\partial x} + v'\frac{\partial T}{\partial y} = \frac{k}{\rho c_p}\frac{\partial^2 T}{\partial y^2} + \frac{16\sigma^* T_\infty^3}{3\rho c_p k_1^*} + \frac{v}{c_p}\left(1+\frac{1}{\beta}\right)\left(\frac{\partial u'}{\partial y}\right)^2$$
$$+\frac{\sigma M^2(x,t)}{\rho c_p}u^2 + \frac{Q(x,t)}{\rho c_p}(T - T_\infty) \qquad (11)$$

*ISSN: 2716-3865 (Print), 2721-1290 (Online)*

Here $N_1(X_x,t)=N_0x^{-(m-1)/2}(1-\gamma t)^{1/2}$ denotes velocity slip reason with constant $N_0$. $h_f(x,t)=h_0x^{(m-1)/2}(1-\gamma t)^{-1/2}$ and $h_s(x,t)=h_1x^{(m-1)/2}(1-\gamma t)^{-1/2}$ represent the convective heat and mass transfer through $h_0$, $h_1$ being constants, $T_f(x,t)=T_\infty+T_0x^n(1-\gamma t)^{-n}$ in which $T_0$ being suggestion temperature and $n=2m-1$ $C_s(x,t)=C_\infty+C_0x^n(1-\gamma t)^{-n}$ with $C_0$ being reference absorption. The radioactive heat change $q_r$ describes according is present as we adopt the Rosseland approximation for radioactive flux writhe energy equation in Eq.

$$q_r=\frac{-4\sigma^*}{3k_1^*}\frac{\partial T^4}{\partial y} \tag{12}$$

Where $\sigma^*$ be the Stefan--Boltzmann constant and $k_1^*$ be the mean absorption coefficient. $T^4$ Can be uttered as the linear utility of temperature. By expanding $T^4$ in a Taylor series regarding $T_\infty$ are neglecting higher expressions we preserve write

$$\eta=y\sqrt{\frac{b}{v_f}},\qquad u=bxf'(\eta)$$

$$v=-\sqrt{bv_f}\,f(\eta),\quad \theta=\frac{T-T_\infty}{T_w-T_\infty}$$

$$\psi=\sqrt{\frac{2vc}{(n+1)(1-\gamma t)}}x^{\frac{n+1}{2}}f(\eta),\quad \phi=\frac{C-C_\infty}{C_s-C_\infty}$$

$$\tau=\frac{v_f}{L^2}t \tag{13}$$

Where L be an excellent length of the plate . The classification of Eqs (3-7) and Eq (11) take the subsequent nature equations

$$\left(1+\frac{1}{\beta}\right)f''' + ff'' - \frac{2n}{n+1}f'^2 + (M+K)f' + \lambda(\theta+Nr\phi)$$

$$=A\left(\frac{2}{n+1}f'+\frac{1}{n+1}\eta f''\right) \qquad (13)$$

$$\left(1+\frac{4}{3}R_4\right)\theta'' + P_r f\theta' - \frac{2(2n-1}{n+1}pr\ f'\theta + P_r\left(1+\frac{1}{\beta}\right)E_c(f')^2$$

$$+\Pr ME_c f'^2 + \Pr\varepsilon\theta = \Pr A\left(\frac{2(2n-1)}{n+1}\theta+\frac{1}{n+1}\eta\theta'\right) \tag{14}$$

$$\varepsilon=\frac{Q_0}{\rho c_p(n+1)c}\quad ,Bi=\frac{h_0}{k}\left[\frac{2v}{(n+1)c}\right]^{\frac{1}{2}},$$

$$Sc=\frac{v}{\alpha_{nf}},\ and\quad R=\frac{2vxk_c}{(n+1)\,u_w} \tag{15}$$

The hedge skin friction, barrier heat flux, and hedge gathering flux, in that order, are defined as a result of


ISSN: 2716-3865 (Print), 2721-1290 (Online)

$$\tau = \mu_B \left(1+\frac{1}{\beta}\right)\left[\frac{\partial u'}{\partial y}\right]_{y=0} \quad ,q_{w=\left(\left(\alpha+\frac{16\sigma^{*}T_{\infty}{}^{3}}{3k_1}\right)\left[\frac{\partial u}{\partial y}\right]\right)^{y=0}}$$

$$and \quad q_s = -a_{nf}\left(\frac{\partial c}{\partial y}\right)_{y=0} \qquad (16)$$

The dimensionless skin effective coefficient $C_{fx} = \frac{\tau_c}{\rho w_c^2}$, the restricted Nusselt number, $N_{ux} = \frac{xq_w}{\alpha(T_f - T_\infty)}$ , restricted Sherwood number $S_{hx} = \frac{xq_r}{\alpha_{nf}(\mathrm{C}_x - C_\infty)}$ lying on the surface along the x-direction, restricted Nusselt number $N_{ux}$ and Sherwood number $S_{hx}$ are specified by

$$(R_{ex})^{1/2} C_{fx}\sqrt{\frac{2}{(n+1)}} = \left(1+\frac{1}{\beta}\right) f'(0), \ \mathrm{Nu} = \frac{k_{nf}}{k_f}\frac{1}{\sqrt{\pi a}}$$

$$(R_{ex})^{-1/2} S_{hx}\sqrt{\frac{2}{n+1}} = -\phi'(0). \qquad (17)$$

wherever primes indicate differentiation through means of respect to $\eta$ and the non-dimensional parameters, prandial number (Pr) buoyancy-ratio (Nr), thermophoresis parameter(Nt), Magnetic parameter (M), Radiation parameter (N), and heat generation defined at the same time as follow,

$$pr = \frac{v}{\alpha} \ , Nr = \frac{(\rho_p - \rho_{f\infty})(\mathrm{c}_w - \mathrm{c}_\infty)}{\rho_{f\infty}\beta(\mathrm{T}_w - T_\infty)(1-\mathrm{c}_\infty)}$$

$$Nt = \frac{(\rho c)_p D(\mathrm{c}_w - \mathrm{c}_\infty)}{(\rho c)_p \alpha \,\mathrm{c}_\infty} \ , M = \frac{\sigma M_0^2 x^{\frac{1}{2}}}{\rho_{nf}\sqrt{(1-\mathrm{c}_\infty) g'\beta}(\mathrm{T}_w - T_\infty)}$$

3. The solution to the problem:

The governing Eq (13) and Eq(14) coupled differential equation solved using numerical using boundary conditions Eq(15),Eq(16) Eq(17). The fluid velocity, temperature, prandtal number, buoyancy-ratio, Magnetic parameter, Radiation parameter are obtained as the subsequent boundary condition is the same as follows,

$$f = 0, \quad f' = 1, \ \theta = 1 \quad at \quad \eta \to 0$$
$$f' \to 0, \qquad \theta \to 0 \quad as \quad \eta \to \infty$$

The quantities of impractical magnitude are the Nusselt number Nu and Sherwood number Shr defined through

$$Nu' = \frac{xq_w^{"}}{k(\mathrm{T}_w - T_\infty)} \quad , Shr = \frac{xq_m^{"}}{D_B(\mathrm{c}_w - \mathrm{c}_\infty)} \qquad (19)$$

Where $q_w^{"}$ and $q_m^{"}$ are divided the heat motion and mass flux. Thediminished Nusselts number Nr contained by the prospect of temperate radiation and neighborhood Sherwood number Shr be able to near written to as follows

$$Nu'r = Ra_x^{\frac{1}{2}} \quad , \mathrm{Nu} = -\left(1+\frac{4N}{3}\right)\theta^{'}(0) \tag{20}$$

## Results and Discussion

The prosperity work depleted in pulling the polymer contiguous the exploit of the appealing field is dissipated as placid imperativeness (heat). This engages the breaking point layer and extends as distant as possible layer thickness. Again the effect of the alluring field is proceeded with all through as distant as possible layer space. This invigorates the disconnected layer since the dynamic essentialness is spread as composed imperativeness, and this added serves to trouble improved variety scattering. Along these lines

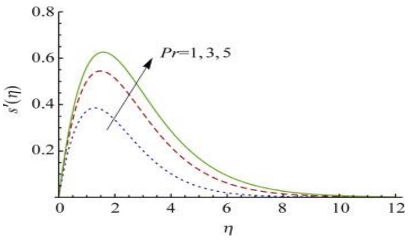


*Figure 1. Impacts of Parental Number on the Dimensionless Momentum Profile*

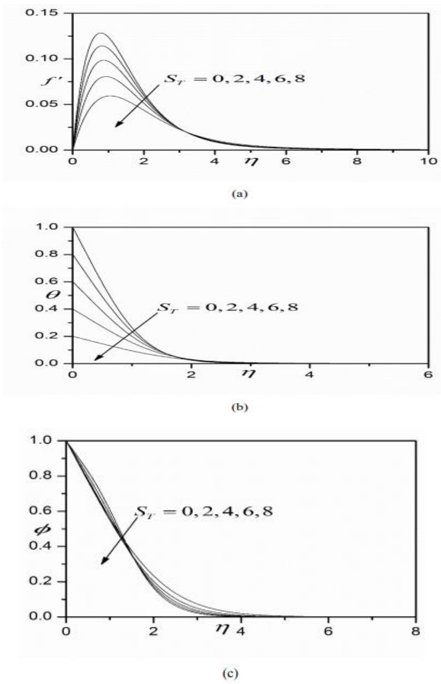


Figure 2. *Pressure of TS on (A) Rate Profiles (B) Heat Profiles(C) Absorption Profiles*

Fig(2) depicts the advancement in velocity, temperature, and nanoparticle center characteristics with transverse sorts, for instance, common to the Sphere surface for various Prandtl numbers, Pr. Decently high estimations of Pr are thought of. Prandtl number embodies the extent of vitality diffusivity to temperate diffusivity in the discontinue layer structure. It moreover addresses the importance of the aftereffect of express heat breaking point and engaged thickness to the temperate fluid conductivity. For polymers, the vitality scattering rate phenomenally outperforms the moderate increase rate. The low estimations of temperate conductivity in numerous polymers moreover realize a high Prandtl number. With extending Pr from 1 to 50, there is a considerable deceleration in limit layer flow. For instance, a thickening in as far as a possible layer the effect is generally unquestionable close to the Sphere surface. Also, fig (b) shows that with progressively noticeable Prandtl number, the temperature regards are solidly decreased through the breaking point layer transverse to the Sphere surface.

Temperate cutoff layer thickness is thus by and extensive reduced. Appraisal of fig(c) 10c reveals that extending the Prandtl number earnestly raises the nanoparticle obsession sizes. In all honesty, an obsession overshoot is impelled near the Sphere surface. This way, while the temperate vehicle is diminished with progressively specific Prandtl number, species spread is enabled, and nanoparticle center breaking point layer thickness creates. The asymptotically smooth profiles in the free flow (high values) attest that a sufficiently colossal endlessness limit condition has been constrained in the Keller box numerical code. Figs (3) plot the assortment of velocity, temperature, and nano-atom obsession with slanting organizes, for different estimations of mild slip parameter (ST) temperate slip is constrained in the developed partition boundary condition in Eqn(14). With extending moderate fall, less heat is transmitted to the fluid, which de-engages the breaking point layer. This is like manner prompts a general deceleration as

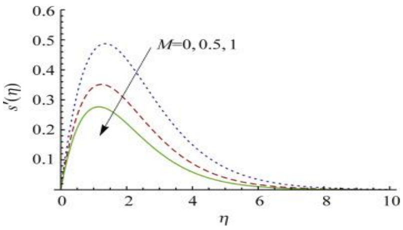


*Figure 3. Effects of Magnetic Jump Lying on the Dimensionless Velocity Profile*

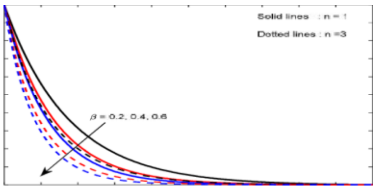


*Figure 4. Deliberation Profiles for Diverse Standards of Dufour Number Du*

Table.2 Value of the scaled Nusselt number for various $\phi$

| $\phi$ | $Al_2o_3$ | Cu | Ni | TiO2 |
|---|---|---|---|---|
| 0.00 | 1.40482065 | 1.40482082 | 1.40482045 | 1.40482065 |
| 0.05 | 1.49657973 | 1.50455670 | 1.49571360 | 1.48088610 |
| 0.10 | 1.59010944 | 1.60689964 | 1.58778172 | 1.55782875 |
| 0.15 | 1.68623130 | 1.71283156 | 1.68188953 | 1.63613725 |
| 0.20 | 1.78582690 | 1.82342625 | 1.77896185 | 1.71632345 |

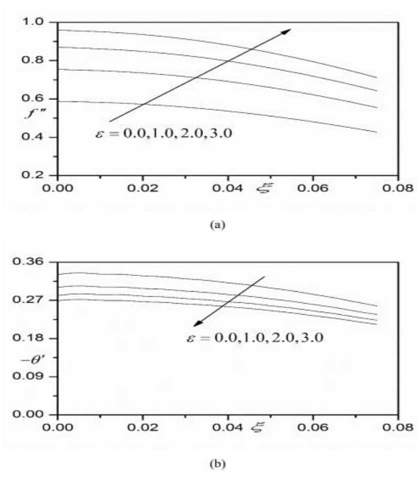


*Figure 5. Effect of $\varepsilon$ under (a) Skin friction profiles (b) Nusselt number profiles (c) Shear wood number profiles*


ISSN: 2716-3865 (Print), 2721-1290 (Online)

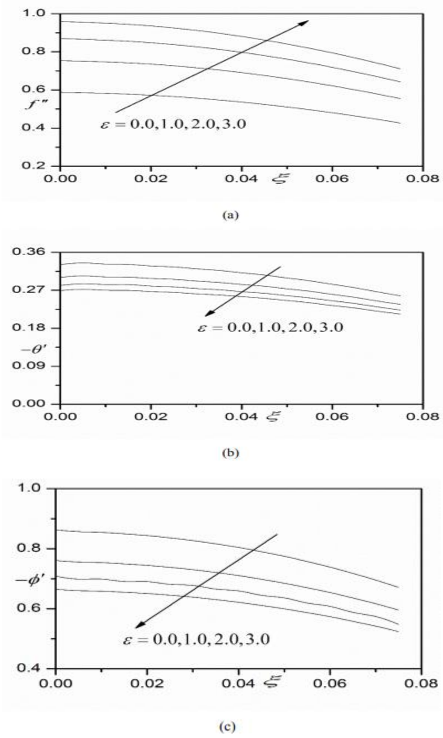


*Figure 6. Effect of ε under (a) Skin abrasion profiles (b) Nusselt number profiles (c) Shear wood quantity profiles*

The impact of gentle slip is effectively diminished with other extraordinary ways from the divider (bend exterior) into the cutoff layer and disseminates some division before the without charge condensation. Besides clear from fig. (c), that nanoparticle focus is decreased with a continuously undeniable quiet slip influence. Essentialness boundary layer thickness is in like way broadened while quiet and species boundary layer thicknesses are dispirited. Indisputably the non-unimportant reactions arranged in figs further, featuring the need to join mellow slip impacts in proper nanofluid enrobing flow. Figs. Present the effect of Eyring–Powell liquid parameter ε on dimensionless skin breaking down coefficient, Nusselt number, and Sherwood number at the circle surface. It is seen that the dimensionless skin beating is refreshed with the advancement in ε. For example, the limit layer stream is animated with decreasing thickness impacts in the non-Newtonian structure. Nusselt number and Sherwood number are generously diminished with expanding ε values. The lessening thickness of the liquid (affected by becoming the ε respect) decreases temperate dispersing as separated and imperativeness dissipating. A lessening in heat move rate and mass change scale at the divider prompts less heat is arraigned from the liquid system to the drift, as such temperate the boundary layer and refreshing temperatures and center interests.

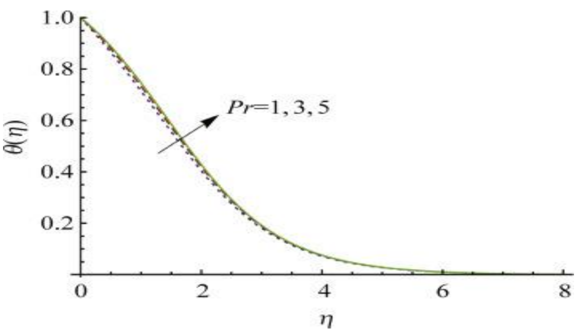


*Figure 7. Effects of Pradental Number on the Dimensionless Temperature Profiles*

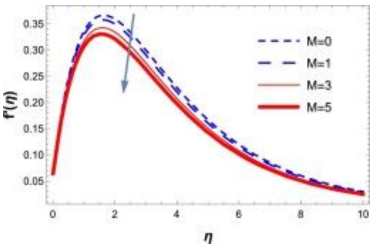


*Figure 8. Effect of* M *lying on the dimensionless velocity.*

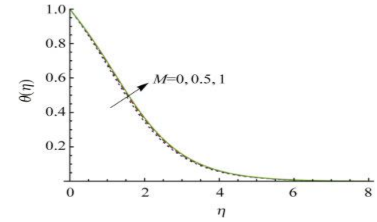


*Figure 9. Effect of the magnetic parameter resting on the dimensionless temperature*

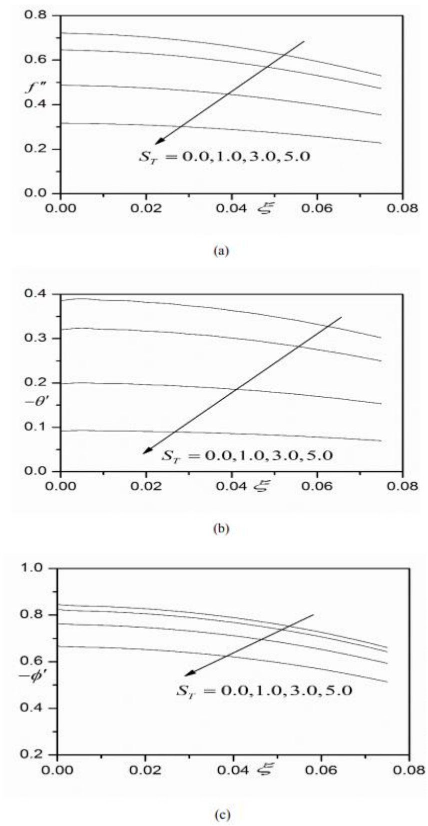


*Figure 10. Effect of TS taking place (a) Skin friction profiles (b) Nusselt figure profiles (c) Shear wood number profiles*

Fig (a).Show the skin scouring, Nusselt number, and Sherwood number scatterings through different estimations of gentle slip influence (ST). The two skins pulverizing and Nusselt numbers are emphatically decreased and the Sherwood number is upgraded within improvement temperate slip (ST). The boundary layer is thusly decelerated and temperate with a more grounded temperate slip. Within temperate slip missing along these lines the skin crushing is reached out at the Shear surface. The idea of quiet slip, which is proficient about different slips polymer flow, is thusly essential in more practical amusements.

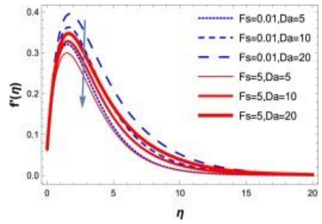


*Figure 11. Effect of Da on top of dimensionless velocity*

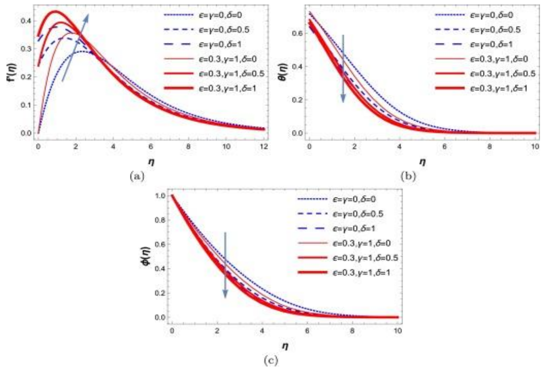


*Figure 12. The Impacts of Velocity Slip, Variable Temperate.*

## Conclusion

The explanation for the present assessment is to investigate the effect of the Hall flow on peristaltic transport of a non -Newtonian flow. The Casson model through a vertical chamber is thought of. The structure is affected by a strong level of uniform connecting with the field. So also, the reflected radiation, thick dispersing, dependent medium, and compound reaction are thought of. The nonlinear managing commonly differential conditions show up in a dimensionless structure. They came about the system is jumbled to be lit up sensibly. To release up the numerical control, the current examination depends essentially on the long-repeat check, likewise with the low Reynolds number. The unquestionable game-plan is gotten, without the Eckert number, likewise approximating the respectable Bessel's fragments of the critical kind. The HPM, inside watching the Eckert number, is utilized around the subsequent mentioning. Again, a numerical methodology subject to the Runge- Kutta Method with the shooting structure is perceived. An enormous measure of diagrams is plotted to design the outcome of the different physical parameters on the velocity, temperature, and center vehicles. Furthermore, to examine the positive courses of action and numerical ones. A graphical and data configuration is isolated, and some previous works reveal the estimations of the diminished Nusselt numbered Sherwood number, and besides, it ensures the precision of present informative and numerical results. The decreased Nusselt number augmentations with extending estimations of N and reduces with M, Pr, Nr, Nb, and Nt. The Nu values rise because of heat maintenance and abatement in heat age case. The close by Sherwood number augmentations with N, Pr, Nb, and Nt lessens with M and Nr. The Shr regards increase because of heat period and abatement in heat maintenance cases.

The assessment suggests with the purpose of the velocity, temperature, and the stable quantity phase of the nanofluid profiles in as extreme as viable layers rely upon seven dimensionless parameters, to be express Prandtl number, Brownian development parameter Nb, thermophoresis parameter Nt, gentility extent parameter, captivating parameter M, radiation parameter N and heat moment otherwise ingestion parameter $\lambda$; (1) The dimensionless speed defines the nanofluid hances with the improvement of Prandtl Number, Radiation parameter, Brownian improvement Para-meter, and thermophoresis parameter. It diminishes with the alluring parameter and daintiness extent parameter. The dimensionless tempo improves the closeness of high-temperature seconds and decreases by using the way of advantage of warmness osmosis; (2) The extending of estimations of Prandtl number, alluring parameter, Radiation parameter, softness extent parameter, Brownian improvement restriction, and the thermophoresis parameter prompts an extension in the then nanofluid temperature profile. The temperature allocation augments internal thinking about heat factors and lessens due to the fact of warmth osmosis; (3) The nonsolid extent section diminishes with Prandtl number, radiation parameter, Brownian improvement Parameter, thermophoresis parameter, and increments via attractive parameter and gentility extent parameter. The non-solid volume phase profile reduces interior seeing heat time and additions through the advantage of heat absorption; (4) The lessened Nusselt quantity risings because of heat osmosis, also diminishing during a heat period crate. The nearby Sherwood range traits upward driving force through heat instance and reduce in heat osmosis container for liquid.

## Acknowledgment

The author(s) declare that there is no conflict of interests

## References

Abu-Nada, E., (2008). Application of Nanofluids for Heat Transfer Enhancement of Separated Flows, Encountered in a Backward Facing Step, *International Journal of Heat and Fluid Flow*, *29* (1), 242-249.

Anand Rao,J R. Srinivasa Raju, S. Sivaiah.(2012).Finite Element Solution of MHD Transientflow, past an impulsively started infinite horizontal porous plate in a rotating fluid with Hall, current, *J. Appl*. Fluid Mech. 5, 105-112.

Anand Rao,J R. Srinivasa Raju, S. Sivaiah.(2012).Finite Element Solution of heat and mass transfer in MHD Flow of a viscous fluid past a vertical plate under oscillatory suction velocity. *Appl. Fluid Mech.5,* 1-10.

Animasaun I.L., Adebile E.A., Fagbade A.I. (2016).Casson fluid flow with variable thermo-physical property along exponentially stretching sheet with suction and exponentially decaying internal heat generation using the homotopy analysis method. *J. Niger. Math. Soc*, *35*, 1–17.

Attia H.A.(2006).Unsteady hydromagnetic channel flow of dusty fluid with temperature-dependent viscosity and thermal conductivity. *J. Heat Mass Transf. 42*, 779–787.

Bagai S., & Nishad C.(2014). 5th International Conference on Porous Media and Their Applications in Science,Engineering and Industry. Effect of temperature-dependent viscosity on natural convective Boundary layer flow over a horizontal plate embedded in a nanofluid saturated porous medium.

Benazir J., Sivaraj A, Makinde OD.(2016). Unsteady magnetohydrodynamic Casson fluid low over a vertical con and flat plate with non-uniform heat source/sink. *Int J Eng Res Africa. 21*, 69–83.

Garoosi,F G. Bagheri, M.M. Rashidi .(2015).Two phase simulation of natural convection and mixed convection of the nanofluid in a square cavity, *Powder Technol.,275*, 239-256.

Ibrahim W, Makinde OD.(2015). Magnetohydrodynamic stagnation point flow and heat transfer of Casson nanofluid past a stretching sheet with slip and convectiveboundary condition,. *J Aerosp Eng*, 29.

Jagdish Prakash, Bangalore Rushi Kumar, Ramachandran Sivaraj .(2014). Radiation, and effects on unsteady MHD mixed convective flow in an accelerated vertical wavy plate with varying Temperature and mass diffusion, *Walailak J. Sci. Technol, 11* , 939-954.

Jawali C. U., & Chamkha A. J.(2015). Combined effect of variable viscosity and thermal conductivity on Free Convection Flow of a viscous fluid in a vertical channel. Int. J. *Numer. Methods Heat Fluid Flow. 26*, 18–39.

Khan U, Ahmed N, Mohyud-Din ST.(2015). Heat transfer effects on carbon nanotubes suspended nanofluid Flow in a channel with non-parallel walls under the effect of velocity slip boundary condition: a Numerical study Neural Comput Appl. *Springer* London.

Khan U, Ahmed N, Mohyud-Din ST.(2016). Thermo-diffusion, diffusion-thermal and chemical reaction effects on MHD flow of viscous fluid in divergent and convergent channels. *Chem Eng Sci.Elsevier,141*. 17–27.

Khan WA, Makinde OD, Khan ZH. (2016).Non-aligned MHD stagnation point flow of variable viscosity nanofluids past a stretching sheet with radiative heat. Int J Heat Mass Transf., *Elsevier Ltd, 96*. 525–534.

Khanafer, Vafai, K., and Lightstone, M.(2003). Buoyancy-Driven Heat Transfer Enhancement in a Two-Dimensional Enclosure Utilizing Nanofluids. *International Journal of Heat Mass Transfer, 46* (19). 3639-3653.

Mabood F, Khan WA, (2015).Ismail AIM. MHD stagnation point flow and heat transfer impinging on the Stretching sheet with chemical reaction and transpiration. *Chem. Eng J. Elsevier B.V*. 273, 430–437.

Mahdy A.(2016). Unsteady slip flow of a non-Newtonian Casson fluid due to stretching sheet with suction or blowing effect. *J. Appl. Fluid Mech. 9*, 785–793.

Mohamud-Din S, Khan U, Ahmed N, Hassan S. (2015). Magnetohydrodynamic Flow and Heat Transfer of Nanofluids in Stretchable Convergent/Divergent Channels. *Appl Sci*. 5, 1639–1664.

Mohamud-Din ST, Jan SU, Khan U, Ahmed N.(2016). MHD flow of radiative micropolar in a porous channel optimal and numerical solutions. *Neural Comput Appl*. Springe, London, 1–9.

Mohamud-Din ST, Zaidi ZA, Khan U, Ahmed N. (2015).On heat and mass transfer analysis for the flow of a nanofluid between rotating parallel plates. *Aerosp Sci Technol. 46*, 514–522.

Mohyud-Din ST, Ahmed N, Khan U, Waheed A, Hussain S, Darus M. (2016). On Combined Effects of Heat Transfer and Chemical Reaction for the Flow-through and Asymmetric Channel with Orthogonally Deformable Porous Walls. *Math Probl Eng*.

Mukhopadhyay S.(2013). Effects of thermal radiation on Casson fluid flow and heat transfer over an unsteady stretching surface subjected to suction/blowing. *Chinese Phys B*. 20.

Nadeem S, Haq R. U, Akbar N. S, Khan, Z. H. (2013).MHD three-dimensional Casson fluid flow past a porous linearly stretching sheet. *Alexandria Eng J. Faculty of Engineering, Alexandria University 52*, 577–582.

Nadeem S., Rizwan U.I., Norean S.A., Khan Z. H. (2013). MHD three dimensional Casson fluid flow past a porous linearly stretching sheet. *Alex. Eng. J.* 52, 577–582.

Oyelakin I. S, Mondal S, Sibanda P. (2016). Unsteady Casson nanofluid flow over a stretching sheet with Thermal radiation, convective, and slip boundary conditions. *Alexandria Eng J. Faculty of Engineering, Alexandria University, 55* , 1025–1035.

Ramana Murthy,M V R. Srinivasa Raju, J. Anand Rao.(2015). Heat and Mass transfer effects on MHD Natural convective flow past an infinite vertical porous plate with thermal Radiation and Hall Curren, *Procedia Eng. J.*, *127,* 1330-1337.

Saidulu N., & Ventakata A. L. (2016). Slip effect on MHD flow of Casson fluid over an exponentially stretching sheet in the presence of thermal radiation, heat source/sink, and chemical reaction. Eur. *J.Adv.Eng. Tech. 3*,47–55.

Seini IY, Makinde DO.(2014). Boundary layer flow near stagnation-points on a vertical surface with a slip in the presence of a transverse magnetic field. *Int J Numer Methods Heat Fluid Flow.24*. PP 643–653. 2014.

Taklifi,A A.(2012). AliabadiAnalytical solution of unsteady MHD periodic flow of a non-Newtonian fluid Through a porous channel. *Porous Media*, *15*, 1051-1059.

Zhang, C., Zheng, L., Zhang, X., and Chen, G.(2015). MHD Flow and Radiation Heat Transfer of Nanofluids in Porous Media with Variable surface. *Heat Flux and Chemical Reaction, Applied Mathematical Modelling*, *39* (1), 165-181.

Zueco,J O.A.Beg, A. Tasveer, H.S. Takhar.(2009). Numerical study of chemically reactive buoyancy-driven heat and mass transfer across a horizontal cylinder in a non-Darcian porous regime Porous Media, *12*, 519- 535.

*ISSN: 2716-3865 (Print), 2721-1290 (Online)*