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Stagnation Point Flow Of Nan fluid Over a Linear Stretching Surface with the Effect of Non Uniform Heat Source/Sink.

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Abstract: *The present study is totally concentrated on the numerical solution of stagnation point flow of nano fluid due to a linear stretching surface with the effect of non uniform heat source/sink. A system of coupled ordinary differential equations was obtained by applying similarity transformation on the governing partial differential equations. The system of coupled ordinary differential equations was solved using the fourth order Runge-Kutta method with shooting technique. The role of various parameters involved in the system such as the velocity ratio parameter λ, the Prandtle number Pr, the Lewis number Le, the Brownian motion parameter Nb, the thermophoresis parameter Nt, the space dependent heat source/sink parameters A^* and temperature dependent heat source/sink parameter B^* are sketched graphically and discussed. The skin friction Cf, the local Nusselt number Nu, the local Sherwood number Sh, were determined for different cases and analyzed.*

Key Words: *Linear stretching surface, Stagnation point flow, Nanofluid and non uniform heat source/sink.*

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Nomenclature

a	Velocity of the stretching surface
b	Free Stream velocity
T	Temperature of the fluid in the boundary layer
C	Concentration of the fluid in the boundary layer
T_w	Stretching surface temperature
C_w	Stretching surface concentration
T_∞	Ambient fluid temperature
C_∞	Ambient fluid concentration
u	Velocity component along the x- axis
v	Velocity component along the y- axis
u_w	Velocity component at the wall
v_w	Velocity component at the wall
υ	Kinematic viscosity
τ	The effective heat capacity of the Nano particle to the heat capacity of the fluid
$(\rho c)_p$	Effective heat capacity of Nano particle material
$(\rho c)_f$	Effective heat capacity of the Fluid
α	Thermal diffusivity
D_B	Brownian diffusion coefficient
D_T	Thermophoresis diffusion coefficient
k	Thermal conductivity
Pr	Prandtl number
Nb	Brownian motion parameter
Nt	Thermophoresis parameter
A^*	The space dependent heat source/sink Parameter
B^*	The Temperature dependent heat source/sink Parameter
Le	Lewis number
λ	Velocity ratio parameter
Cf_x	Local skin friction
Nu_x	Local Nusselt number
Sh_x	Local Sherwood number

I. Introduction

Nanofluids are two phase fluids involving base fluid and nano sized (1-100 nm) particles (nano particles) suspended within them. Some of the base fluids are water, oil, glycol, polymeric solutions etc. Examples of the materials used for nanoparticles are like alumina, silica, diamond graphite, Alo3, Cuo, Ag, and Cu. A properly and efficiently synthesized nanofluid provides high specific surface area that allows to have more heat transfer surface between particles and fluids, more stable dispersions of the nanoparticles, minimized particles clogging, adjustable properties such as thermal conductivity by varying particle concentration, the collision and interaction among particles, the surface of the flow passage and base fluids are intensified.

The stagnation point flow of nanofluid over a linear stretching surface is the most applicable study in technology and manufacturing industries. Some of the applications are saving power using nanofluid in closed loop cooling cycles, in the extraction of Geothermal power nanofluids used to cool the pipes exposed to high temperature, extrusion, melting spinning, the hot rolling, wire drawing, glass fiber production, manufacturing of plastic and rubber sheets, cooling of large metallic plate in bath, polymer sheets and filaments are manufactured by continuous extrusion of the polymer from a die to a mind up roller.

Khan and Pop [1] have investigated the effect of stretching flat surface on a laminar fluid flow of nanofluid numerically. Hazem [2] has studied the role of heat generation/absorption on the steady hydro magnetic laminar three dimensional stagnation point flow of an incompressible viscous fluid impinging on a permeable stretching sheet numerically. Makinde and Aziz [3] have analyzed the numerical study on the boundary layer flow induced in a nanofluid over a linearly stretching sheet with the influence of various parameters involved. Krishnendu [4] has reported the contribution of non uniform heat flux on heat transfer in a boundary layer stagnation point flow over a shrinking sheet. Mohanty et al. [5] have presented the combined effect of heat and mass transfer in Jeffrey fluid due to a stretching sheet to transverse magnetic field in the presence of heat source/sink. Thommaandru et al. [6] have explored the role of MHD and heat source/sink on free convection boundary layer flow of nanofluid over a non linear stretching sheet. Vijendra and Shweta [7] have explained the contribution of non uniform heat source/sink with variable thermal conductivity on MHD flow and heat transfer for Maxwell fluid over exponentially stretching sheet through a porous medium. Gireesha et al. [8] have examined the influence of non uniform heat generation/absorption and chemical reaction on MHD casson fluid boundary layer flow over a permeable stretching sheet. Sarojamma and Vendabai [9] have analyzed the effect of magnetic field and heat source/sink on the steady boundary layer flow and heat transfer of Casson nano fluid over an exponentially stretching vertical cylinder a long its radial direction. Ramesh [10] has investigated the role of temperature dependent heat generation/absorption on the flow of Jeffrey nanoliquid near stagnation point towards a permeable stretching sheet. Dulalpal et al. [11] have studied the influence of thermal radiation and internal heat generation /absorption on heat transfer in a nano fluid stagnation point flow over a stretching/shrinking sheet embedded in a porous medium. Chenna and Shankar [12] have presented the influence of radiation and heat source/sink on the casson fluid over a non linear stretching sheet. Ananth et al. [13] have explained the contribution of thermal radiation on a stagnation point flow of casson fluid towards a stretching sheet. Sandeep et al. [14] have examined the role of radiation and magnetic field on an unsteady mixed convection flow over a vertical stretching/shrinking sheet with suction/injection. Sulochana and Sandeep [15] have reported the stagnation point flow and heat transfer behavior of Cu-water nano fluid towards an exponentially stretching/shrinking horizontal permeable cylinder in the presence of suction/injection. Renuka et al.[16] have analyzed the influence of radiation and heat source/sink on MHD slip flow past a stretching sheet with variable viscosity. Sreenivasulu et al. [17] have explored the effect of viscous dissipation on MHD boundary layer flow of a radiating nanofluid over a non linear stretching sheet with uniform heat source. Hayat et al. [18] have presented the contribution of thermal radiation and heat source/sink on the mixed convection flow of Non Newtonian nano fluid over a stretching surface. Elsayed et al. [19] have examined the contribution of radiation, heat generation and dissipation on a steady two dimensional boundary layer MHD stagnation point flow and heat transfer of incompressible micro polar fluid over stretching sheet. Saidulu and Venkata [20] have presented the influence of thermal radiation, suction/blowing, viscous dissipation, heat source/sink and chemical reaction on the boundary layer flow of a non Newtonian casson fluid with heat and mass transfer towards a porous exponentially stretching sheet with velocity slip and thermal slip conditions. Raju et al. [21] have studied the role of heat source/sink on MHD two dimensional ferro fluid flows past a cone and a vertical plate in the presence of volume fraction of ferrous nano particles. Kishan et al. [22] have investigated the steady MHD boundary layer flow of an electrically conducting nano fluid due to an exponentially permeable stretching sheet with heat source/sink in the presence of thermal radiation. Mohan et al. [23] have explored the effect of non linear thermal radiation on MHD casson fluid flow over a non-linearly stretching sheet. Dodda et al. [24] have examined the influence of velocity, temperature concentration slips on the steady two dimensional flows of a viscous nano fluid MHD and heat transfer for the boundary layer flow over non-linear stretching sheet. Mohamed and Tarek [25] have reported the effect of nonlinear thermal radiation and convective boundary conditions on the hydro magnetic nanofluid boundary layer flow over a moving surface with variable thickness. Madasi et al.[26] have explained the role of non-uniform heat source/sink on a stagnation point flow of MHD casson nano fluid over exponentially stretching sheet with heat and mass transfer. Mahatha et al. [27] The influence of nonuniform heat generation/absorption and Newtonian heating on the steady two dimensional laminar stagnation point boundary layer nano fluid flow past a stretching sheet in the presence of an external uniform magnetic field is investigated. Auradha and Yegammai [28] The influence of the n^{th} order chemical reaction on the free convective unsteady MHD boundary layer flow of nano fluid over a permeable shrinking sheet is studied. Shakhaoath et al.[29] explored the effect of magnetic field of thermal radiation-diffusion, heat generation and viscous dissipation on a two dimensional flow of an incompressible Williamson fluid of Cattaneo-christov heat flux type over a linearly stretched surface. Jain et al. [30] have clearly put the different numerical methods specifically the Runge -Kutta method.

On the bases of above literatures, it is known that a number of investigations have been conducted on the stagnation point flow of nanofluid over a linear stretching surface. However to the best of the author's knowledge the problem of stagnation point flow of nanofluid over a linear stretching surface with the effect of non uniform heat source/sink has not yet addressed. Therefore in the present paper, we have dealt with the stagnation point flow of nanofluid over a linear stretching surface with the effect of non uniform heat source/sink. The governing equations are transformed into Non-linear ordinary differential equations using suitable similarity transformation and the results are solved numerically using the fourth Range-Kutta method. We investigated the effect of the relevant parameters using several set of values of the parameters and the results are analyzed for the flow and heat transfer characteristics.

II. Mathematical Formulation:

Let us assume that the flow is steady two dimensional stagnation point flow of nanofluid due to a linear stretching sheet. Consider the velocity of the stretching sheet to be $u_w(x) = ax$ and the velocity of the free stream flow to be $u(x) = bx$, where a, b are constants and x is the coordinate measured along the stretching sheet. The flow is carried out at $y \geq 0$, where y is the coordinate measured normal to the stretching sheet. Assume that T_w is the temperature at the stretching sheet while T_∞ to be the temperature of the nanofluid. Moreover it is assumed that the base fluid and the nano particles are in thermal equilibrium and no slips occur between them.

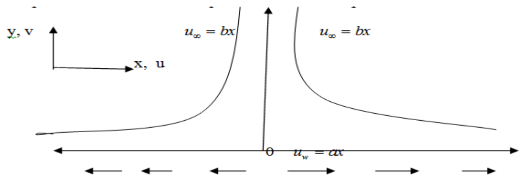


Figure 1 physical sketch of the problem

With the above assumptions the governing equations for the boundary layer motion, energy and concentration in the presence of non uniform heat source/sink and viscous dissipation are as follows.

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

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \upsilon\frac{\partial^2 u}{\partial y^2} + u_\infty\frac{\partial u_\infty}{\partial x} \tag{2}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2} + \tau\left[D_B\frac{\partial C}{\partial y}\frac{\partial T}{\partial y} + \frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)^2\right] + \frac{q'''}{\rho c_p} \tag{3}$$

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D_B\frac{\partial^2 C}{\partial y^2} + \frac{D_T}{T_\infty}\frac{\partial^2 T}{\partial y^2} \tag{4}$$

q''' is the space and temperature dependent heat source/sink that is given [8] as;

$$q''' = \frac{k u_w}{x\upsilon}[A^*(T_w - T_\infty) f' + B^*(T - T_\infty)]$$

Boundary conditions are

$$\left.\begin{array}{l} u = U_w = ax,\ v = 0,\ T = T_w,\ C = C_w \quad at\ \ y = 0 \\ u = U_\infty = bx, \qquad T \to T_\infty\ ,C \to C_\infty \qquad\qquad as\ \ y \to \infty \end{array}\right\} \tag{5}$$

Where u and v are the velocity components along x and y directions respectively, υ is the kinematic viscosity, α is the thermal diffusivity, τ is the effective heat capacity of nanoparticle to the heat capacity of the fluid i.e. $\tau = \frac{(\rho c)_p}{(\rho c)_f}$, D_B is the Brownian motion coefficient, D_T is the thermophoresis diffusion coefficient.

With the help of the similarity transformation below, we have transformed the coupled partial differential equations into a system of ordinary differential equations.

$$\left.\begin{array}{l} \psi = (a\upsilon)^{\frac{1}{2}} x f(\eta), \qquad \theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty},\ \ \phi(\eta) = \frac{C - C_\infty}{C_w - C_\infty} \\ \eta = \left(\frac{a}{\upsilon}\right)^{\frac{1}{2}} y, \quad u = \frac{\partial \psi}{\partial y} = axf', \quad v = -\frac{\partial \psi}{\partial x} = -(a\upsilon)^{\frac{1}{2}} f(\eta) \end{array}\right\} \tag{6}$$

Substituting equation (6) in Equations (2), (3) and (4) we have

$$f''' + ff'' - f'^2 + \lambda^2 = 0 \tag{7}$$

$$\theta'' + \Pr[\mathrm{Nb}\,\theta'\phi' + f\theta' + Nt\theta'^2] + [A^* f' + B^*\theta] = 0$$

(8)

$$\phi'' + Le\phi' f + \frac{Nt}{Nb}\theta'' = 0 \tag{9}$$

With associated boundary conditions;

$$\left.\begin{array}{l} f(0) = 0, \qquad f'(0) = 1, \quad \theta(0) = 1, \quad \phi(0) = 1 \qquad at\ \eta = 0 \\ f'(\infty) = \lambda, \quad \theta(\infty) \to 0, \qquad \phi(\infty) \to 0, \quad as\ \ \eta \to \infty \end{array}\right\} \tag{10}$$

Where Pr is the Prandtl number, Le is the Lewis Number, Nb is the Brownian motion parameter , Nt is the thermophoresis parameter, A* and B* are the space dependent, temperature dependent heat source/sink parameters respectively . A*>0 and B*>0 represent heat source and A*< 0 and B*< 0 indicate heat sink. We know that Nb and Nt involve the x-coordinate and therefore we look for the variability of the local similarity solution that gives chances to investigate the behavior of these parameters at affixed location above the sheet. The skin friction coefficient Cf_x, the local Nusselt number Nu_x and the local Sherwood number Sh_x are given by

$$Cf_x = \frac{\mu\left(\frac{\partial u}{\partial y}\right)_{y=0}}{\rho u_w^2}, \quad Nu_x = \frac{-x\left(\frac{\partial T}{\partial y}\right)_{y=0}}{T_w - T_\infty}, \quad Sh_x = \frac{-x\left(\frac{\partial C}{\partial y}\right)_{y=0}}{C_w - C_\infty} \tag{11}$$

Substituting equations (6) into equations (11), the reduced form will be

$$\mathrm{Re}_x^{\frac{1}{2}}\, Cf_x = f''(0), \quad \frac{Nu_x}{\mathrm{Re}_x^{\frac{1}{2}}} = -\theta'(0), \quad \frac{Sh_x}{\mathrm{Re}_x^{\frac{1}{2}}} = -\phi'(0) \tag{12}$$

III. Method Of Solution

Using the fourth order Runge-Kutta method along with shooting technique, we solve the coupled ordinary differential equations (7) (8) and (9), with their respective boundary condition equations (10). The system of the ordinary differential equations (7),(8) and(9) are highly non linear higher order differential equations. To solve these equations using the indicated method, first we transform them into a system of first order differential equations by applying the following notations.

Let

$$\left.\begin{array}{lll} f = f(1), & f' = f(2), & f'' = f(3) \\ \theta = f(4), & \theta' = f(5) & \\ \phi = f(6), & \phi' = f(7) & \end{array}\right\} \tag{13}$$

Using equations (13) in equations (7),(8) and(9) we have

$$\left.\begin{array}{l} f''' = -ff'' + f'^2 - \lambda^2 \\ \quad = -f(1)*f(3) + f(2)*f(2) - \lambda^2 \\ \theta'' = -\Pr[Nb\phi'\theta' + f\,\theta' + Nt\theta'^2] - [A^* f' + B^*\theta] \\ \quad = -\Pr[\mathrm{Nb}*f(7)*f(5) + f(1)*f(5) + \mathrm{Nt}*f(5)*f(5)] - [A^{*}*f(2) + B^{*}*f(4)] \\ \phi'' = -Le\phi' f - \frac{Nt}{Nb}\theta'' \\ \quad = -Le*f(7) - \frac{Nt}{Nb}*[-\Pr[\mathrm{Nb}*f(7)*f(5) + f(1)*f(5) + \mathrm{Nt}*f(5)*f(5)] - [A^{*}*f(2) + B^{*}*f(4)]] \end{array}\right\}$$

The boundary conditions are

$$\left.\begin{array}{l} f_a(1) = 0,\ f_a(2) = 1,\quad f_a(4) = 1,\ f_a(6) = 1 \\ f_b(2) \to 0,\quad f_b(4) \to 0 \quad f_b(6) \to 0 \\ where\ \ a = 0 \quad and \quad b = \infty \end{array}\right\}$$

(15)

The boundary conditions $f''(0), \theta'(0)\, and\, \phi'(0)$ are not included in the system of the ordinary differential equations. Therefore, we calculate the approximate values $f''(0), \theta'(0)\, and\, \phi'(0)$ using the shooting technique first and then we apply the fourth order Runge-Kutta method to get f, $\theta\, and\ \phi$ as it is clearly indicated in Jain et al. [30]. We choose the step size to be $\Delta h = 0.01$ with accuracy of 10^{-5}.

IV. Results And Discussions

The role of various parameters involved in the coupled ordinary differential equations such as the velocity ratio λ, the prandtl number Pr, the Brownian motion parameter Nb, the thermophoresis parameter Nt, the space dependent and temperature dependent heat source/sink parameters respectively A^* and B^* and the Lewis number Le on the stagnation point flow of nano fluid over a linear stretching surface have been drawn their graphs and discussed.

Table 1 Comparison of results for the reduced Nusselt number -$\theta'(0)$

Pr	Present result of - $\theta'(0)$	Khan and Pop [1] results of - $\theta'(0)$
0.7	0.4544	0.4539
2.0	0.9114	0.9113
7.0	1.8954	1.8954
10.0	3.3540	3.3539
70.0	6.4622	6.4621

Table 2 Variation of Nu_x with Nb and Nt where Pr=Le=10

	Nb=0.1		Nb=0.2		Nb=0.3		Nb=0.4		Nb=.05	
Nt	Present	Khan and Pop [1]	Present	Khan and Pop [1]	Present	Khan and Pop [1]	Present	Khan and Pop [1]	Present	Khan and Pop [1]
0.1	0.9524	0.9524	0.5056	0.5056	0.2521	0.2522	0.1138	0.1194	0.0542	0.0543
0.2	0.6932	0.6932	0.3653	0.3654	0.1816	0.1816	0.0859	0.0559	0.0393	0.0390
0.3	0.5201	0.5201	0.2731	0.2731	0.1355	0.1355	0.0641	0.0641	0.0291	0.0291
0.4	0.4026	0.4026	0.2110	0.2110	0.1046	0.1046	0.0495	0.0495	0.0225	0.0225
0.5	0.3211	0.3211	0.1681	0.1681	0.0833	0.0833	0.0392	0.0394	0.0179	0.0394

Table 3 Variation of Sh_x with Nb and Nt, for Le=Pr=10

	Nb=0.1		Nb=0.2		Nb=0.3		Nb=0.4		Nb=.05	
Nt	Present	Khan and Pop [1]	Present	Khan and Pop [1]	Present	Khan and Pop [1]	Present	Khan and Pop [1]	Present	Khan and Pop [1]
0.1	2.1294	2.1294	2.3819	2.3819	2.4100	2.4100	2.3997	2.3997	2.3836	2.3836
0.2	2.2740	2.2740	2.5153	2.5152	2.5150	2.5150	2.4808	2.4807	2.4468	2.4468
0.3	2.5287	2.5286	2.6554	2.6555	2.6088	2.6088	2.5486	2.5486	2.4984	2.4984
0.4	2.7952	2.7952	2.7818	2.7818	2.6876	2.6876	2.6039	2.6038	2.5399	2.5399
0.5	3.0352	3.0351	2.8884	2.8883	2.7519	2.7519	2.6483	2.6483	2.5711	2.5731

The present results for the considered Prandtl numbers in table1 above agree to three decimal places with the results of Khan and Pop [1]. The results of table 1 clearly illustrate that the Nusselt number increases as the prandtl number increases and this is analogous to the result obtained in a natural convection from a vertical plate in a regular fluid.

In tables 2 and 3 above, for the given values of the Brownian motion parameter Nb and the thermophoresis parameter Nt the present result coincides with the results presented by Khan and Pop [1].

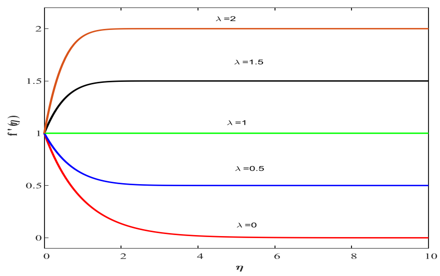
Table 4

Numerical results of $f''(0), -\theta'(0), and -\phi'(0)$ for different values of λ, Pr, Nb, Nt, A^*, B^* &Le

λ	Pr	Nb	Nt	A^*	B^*	Le	Skin friction $f''(0)$	$-\theta'(0)$	$-\phi'(0)$
0.1	4.5	0.01	0.01	0.01	0.01	10	-0.9694	1.4095	1.6974
0.3							-0.8494	1.4409	1.7340
0.6							-0.5563	1.5048	1.8057
0.9							-0.1547	1.5761	1.8855
0.2	1	0.01	0.01	0.01	0.01	10	-0.9181	0.5954	2.1575
	3						-0.9181	1.1419	1.8817
	4						-0.9181	1.3366	1.7673
	6						-0.9181	1.6544	1.5662
0.2	4.5	0.1	0.01	0.01	0.01	10	-0.9181	1.0896	2.2957
		0.3					-0.9181	0.5721	2.3320
		0.5					-0.9181	0.2832	2.3353
		0.6					-0.9181	0.1957	2.3353
0.2	1	0.1	0.1	0.001	0.001	1	-0.9181	0.5732	0.2880
			0.3				-0.9181	0.5382	0.2992
			0.5				-0.9181	0.5054	0.7828
			0.6				-0.9181	0.4899	0.9896
0.2	6.4	0.01	0.01	0.1	0.01	10	-0.9181	1.6425	1.5717
				0.3			-0.9181	1.4922	1.6660
				0.5			-0.9181	1.4170	1.7132
				0.6			-0.9181	1.3416	1.7605
0.2	6.4	0.01	0.01	0.01	0.1	10	-0.9181	1.7100	1.5294
					0.3		-0.9181	1.7049	1.5335
					0.4		-0.9181	1.7024	1.15356
					0.5		-0.9181	1.6971	1.5422
0.2	1	0.01	0.01	0.01	0.01	1	-0.9181	0.5983	0.2661
						3	-0.9181	0.5966	0.9291
						5	-0.9181	0.5960	1.3698
						6	-0.9181	0.5958	1.5534

As Nb varies from 0.1 to 0.5 taking Nt constant the reduced Nusselt number decreases. Because increasing Brownian motion enforces a large extent of the fluid to wedge together so that the thermal boundary layer thickness increases however the Nusselt number diminish. The Sherwood number increases considerably with the increase of Nb from 0.1 to 0.3 and approaches to plateau beyond Nb=0.3. Table 2 and 3 show that the thermophoresis parameter has the same contribution as the Brownian motion parameter on the Nusselt number but the Sherwood number increases with the increase thermophoresis. This due to the fact that the thermophoresis diffusion perforates deeper in to the fluid and makes to move nano particles from hot to cold areas as Nt increases. This cause both the thermal boundary layer and concentration boundary layers thicken and hence the Nusselt number decreases as well as the Sherwood number increases.

In the first part of table 4 above one can easily understand that as the velocity ratio $\lambda = \frac{b}{a}$ <1(i.e. the velocity of the stretching surface is greater than the free stream velocity) increases then the velocity of the fluid and the boundary layer thickness increase. The second, third and fourth parts of table 4 have analogous results for Pr, Nb and Nt as table1, 2, 3. In the fifth and sixth parts of table 4 increasing A* and B* result in the increase of the generation of thermal energy. So that the nanofluid temperature enlarged and this causes the reduced Nusselt number to descend and the Sherwood number to ascend. In the last part of table 4 the Nusselt number decreases and the Sherwood number increases with the increase of Lewis number. Because the larger the Lewis number the weaker molecular diffusivity and the thinner concentration boundary layer.



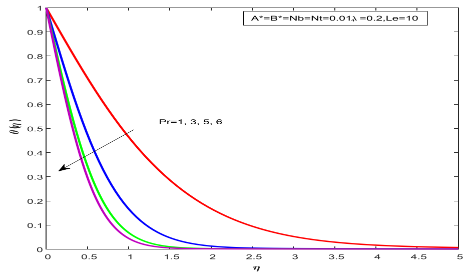
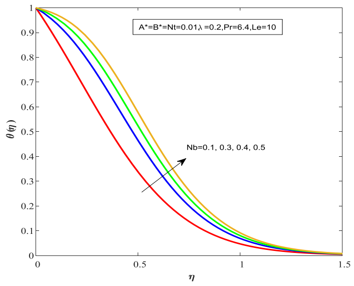


Figure 2 the effect of λ on the velocity profile. **Figure 3** the influence of Pr on the temperature profile.



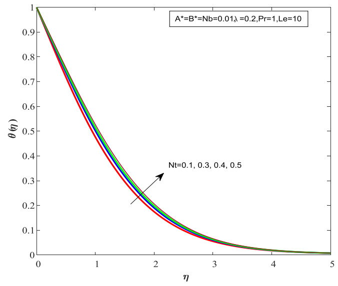
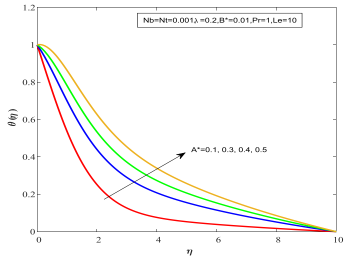


Figure 4 the contribution of Nb on the temperature profile. **Figure 5** the effect of Nt on the temperature profile.



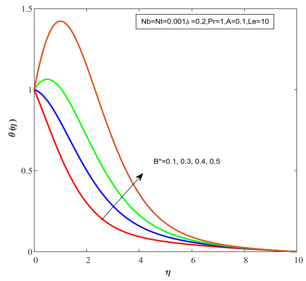


Figure 6 the influence of A^* on the temperature profile **Figure 7** the contribution of B^* on the temperature profile.

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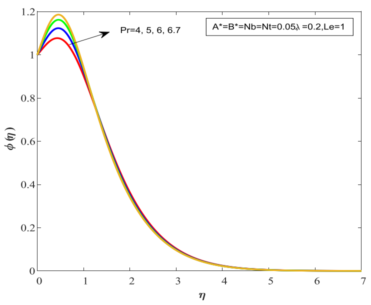


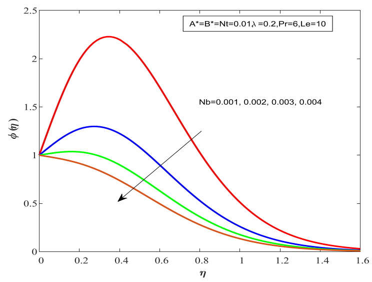
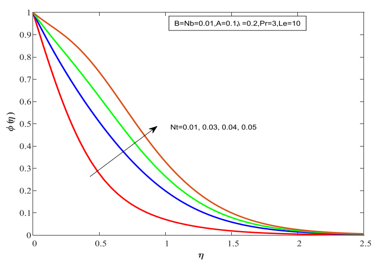


Figure 8 the effect of Pr on the concentration profile. **Figure 9** the influence of Nb on the concentration profile.



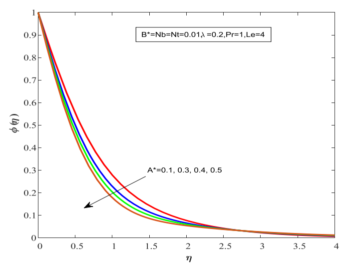


Figure 10 the contribution of Nt on the concentration profile. **Figure 11** the effect of A^* on the concentration profile

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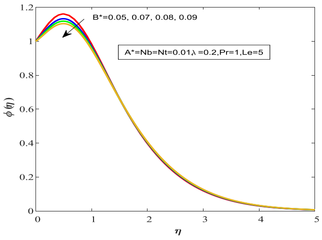

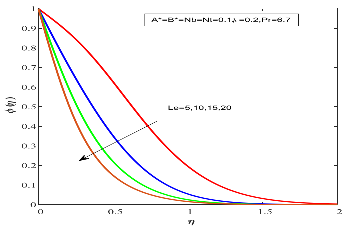

Figure 12 the influence of B^*on the concentration Profile.

Figure 13 the contribution of Le on the concentration profile.

Figure 2 indicates that the velocity of the fluid and the boundary layer thickness increase with the increase of λ as the velocity of the stretching surface is greater than the free stream velocity (i.e. $\lambda = \frac{b}{a} < 1$) , where as the flow velocity increases and the boundary layer thickness decreases with the increase of λ when the free stream velocity is larger than the velocity of the stretching surface(i.e. $\lambda = \frac{b}{a} > 1$). In the case where the velocity of the stretching surface is equal to the free stream velocity, there is no boundary layer thickness of the nanofluid near the surface. Increasing the Prandtl number as in Figure 3 reduces the thermal boundary layer thickness; it is because of the smaller the thermal diffusivity for the larger the Pradntl number. In Fig 4 the enhancement of the Brownian motion parameter make the thermal boundary layer thicken it is due to the increased Brownian motion enforce a large extent of fluid to wedge together and make the thermal boundary layer thicken. Figure5 shows that the increment of the thermophoresis parameter make the thermal boundary layer thickens. Because as Nt increases the thermophoresis diffusion enforce the nanoparticles to move from hot to cold area which enlarges the thermal boundary layer thickness. In Figure 6 and 7, it is revealed that the thermal boundary layer thickness increases with the enlargement of the space and temperature dependent of non uniform heat source/sink parameters A^* and B^* which corresponds to the internal heat generation that raises the temperature profiles.

Figure 8 indicates that as Prandtl number increases the boundary layer thickness of the concentration increases. The concentration boundary layer reduces as the Brownian motion parameter increases that is revealed in Figure 9, as Nb increases the Brownian motion of the nanoparticles transfers the surface heat to the fluid and the nanoparticles gain higher kinetic energy that contributes to the thermal energy of the fluid and cause the movement of the nano particles from hot to the cold region. However the concentration boundary layer increases with the increase of Nt as it is shown in Figure 10, increasing the thermophoresis diffusion creates the movement of the nanoparticles from a region of high temperature to a region of low temperature. Figures 11and 12 show that as the space dependent A^* and the temperature dependent B^* heat source/sink parameters increases the concentration boundary layer decreases; as the nanofluid temperature increase with the increase of A^* and B^* diffusion of the nanoparticles takes place from high to low temperature regions and hence the concentration boundary layer decrease. The molecular diffusivity becomes weaker as the Lewis number increases and the concentration boundary layer becomes thinner as it is illustrated in Figure 13 so that as Le increases the concentration boundary layer decreases.

V. Conclusions

Stagnation point flow of nanofluid over a linear stretching surface is studied in the presence of non uniform heat source/sink. Numerical solutions of the governing equations are obtained that permit the computation of the flow, heat and mass transfer behaviors for various values of the velocity ratio λ , the Prandtl number Pr, the Brownian motion parameter Nb, the thermophoresis parameter Nt, the non uniform heat source/sink space and temperature dependent parameters A^* and B^* as well as the Lewis Number Le. The results have been found that

1. The velocity boundary layer thickness increases with the increase of the velocity ratio parameter λ .
2. Increasing Prandtl number reduces the thermal boundary layer thickness.
3. The thermal boundary layer thickness increases with the increase of the space dependent (A^*) and temperature dependent (B^*) parameters and similar results have been found for the Brownian motion and thermophoresis effects.
4. The concentration boundary thickness increases with the increase of the prandtl number Pr and the thermophoresis parameter Nt

5. The enhancement of the space dependent (A^*) parameter and the Brownian motion parameter Nb reduces the concentration boundary layer thickness.
6. The concentration Boundary layer thickness decreases as the Lewis number increases.

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