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Effect of Variable Properties on Heat and Mass Transfer Flow of Nanofluid over a Vertical Cone Saturated by Porous Medium under Enhanced Boundary Conditions

B. Kalavathamma [1]* and C. Venkata Lakshmi [2]

[1, 2]Department of Mathematics, Sri Padmavati Mahila Visvavidyalayam (Women's University) Tirupati, Andhra Pradesh-517502, India

**Corresponding Author E-mail: kalajasmine707@gmail.com*

ABSTRACT

We have investigated the impact of variable viscosity and thermal conductivity on MHD boundary layer flow, heat and mass transfer of nanofluid over a vertical cone saturated by porous medium with thermal radiation and chemical reaction. Further, the viscosity and thermal conductivity are considered as the function of nanoparticle volume fraction (ϕ). By using suitable similarity variables the governing equations represents the velocity, temperature and volume fraction of nanoparticles are transformed into the set of ordinary differential equations. These equations together with associated boundary conditions are solved numerically by using an optimized, extensively validated, variational Finite element method. Effects of different parameters such as variable viscosity, Buoyancy, magnetic, radiation, variable thermal conductivity, thermophoresis, Brownian motion, Lewis number and chemical reaction parameters on velocity, temperature and concentration profiles are examined and the results are presented in graphical from. Furthermore, the skin-friction coefficient, Nusselt number and Sherwood number are also investigated and are shown in tabular form.

Keywords: Nanofluid, Vertical cone, Variable viscosity, Variable thermal conductivity, Chemical reaction, Thermal radiation.

NOMENCLATURE

k_m	Thermal conductivity	Nu_x	Nusselt number
ϕ	Nanoparticle volume fraction	ϕ_w	Nanoparticle volume fraction on the plate
ϕ_∞	Ambient nanoparticle volume fraction	(x, y)	Cartesian coordinates
T_w	Temperature at the plate	T_∞	Ambient temperature attained
T	Temperature on the plate	Ra_x	Rayleigh number
q_w	Wall heat flux	J_w	Wall mass flux
D_B	Brownian diffusion	D_T	Thermophoretic diffusion coefficient
β_0	Strength of magnetic field	g	Gravitational acceleration vector
Nt	Thermophoresis parameter	Le	Lewis number
P	Pressure	Nb	Brownian motion parameter
q_r	Thermal radiation	M	Magnetic parameter
Sh_x	Local Sherwood number	Nv	Variable viscosity parameter
		K_r	Rate of chemical Reaction
Nc	Variable thermal conductivity parameter	Cr	Chemical reaction parameter
Nr	Buoyancy ratio	K	Permeability of the porous medium

Greek symbols:

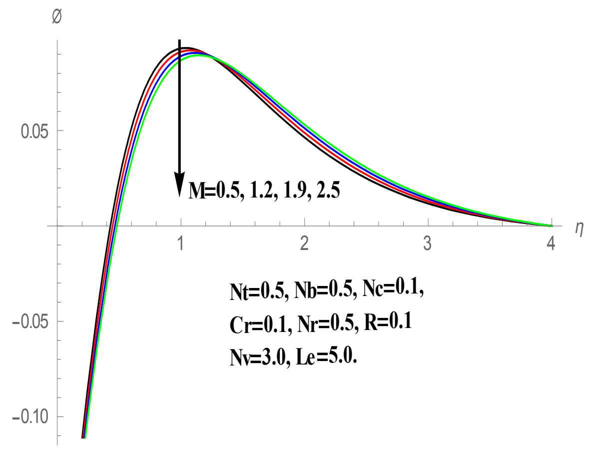

Fig.10: Effect of M on Concentration profiles.

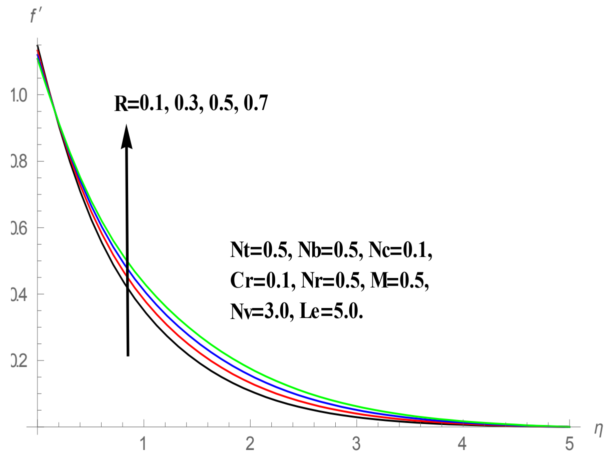

Fig.11: Effect of R on Velocity profiles.

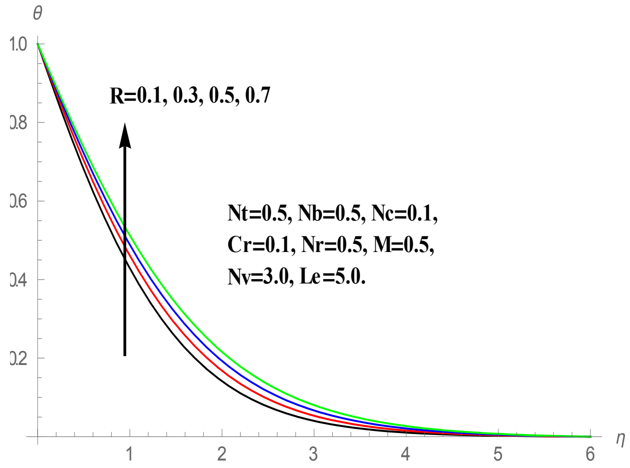

Fig.12: Effect of R on Temperature profiles.

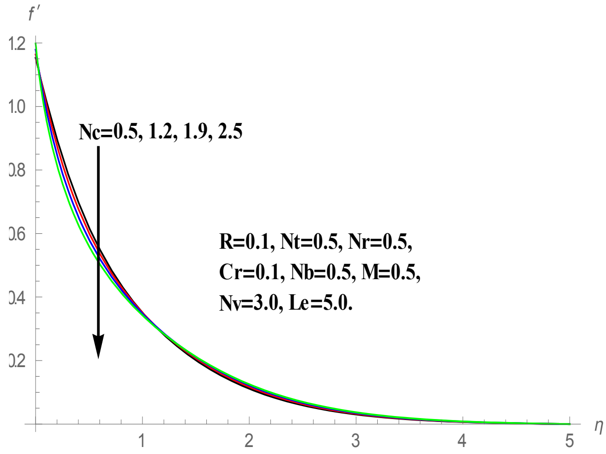

Fig.13: Effect of Nc on Velocity profiles.

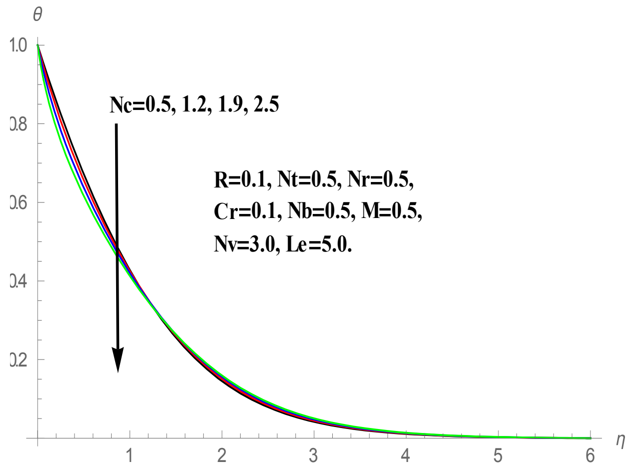

Fig.14: Effect of Nc on Temperature profiles.

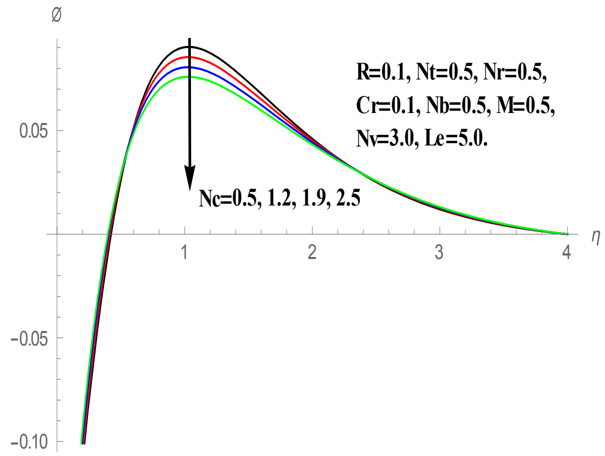

Fig.15: Effect of Nc on Concentration profiles.

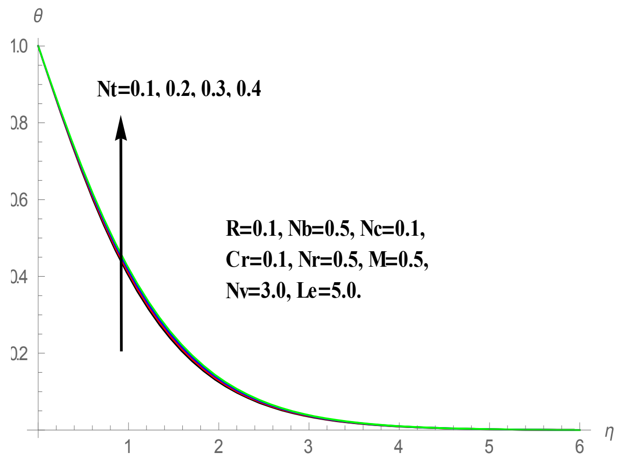

Fig.16: Effect of Nt on Temperature profiles.

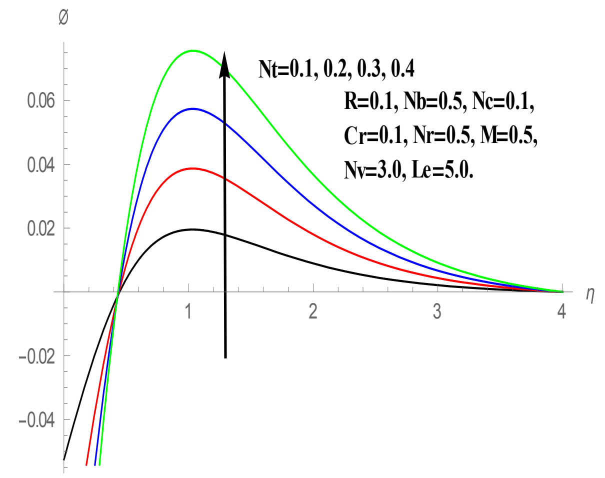

Fig.17: Effect of Nt on Concentration profiles.

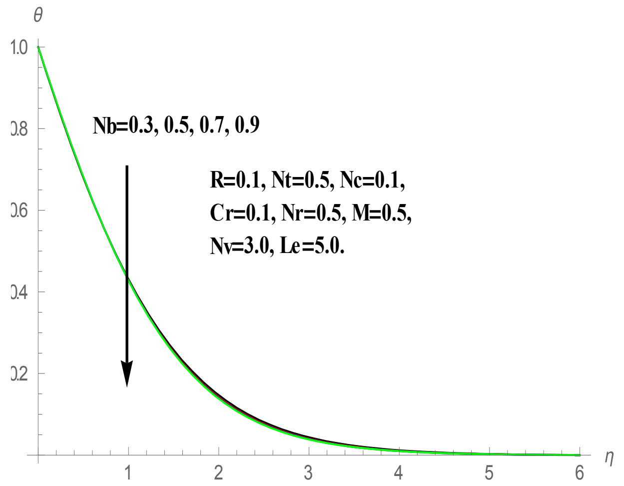

Fig.18: Effect of Nb on Temperature profiles.

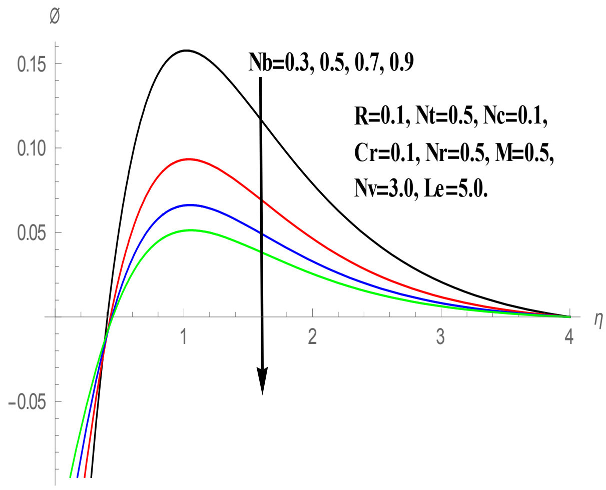

Fig.19: Effect of Nb on Concentration profiles.

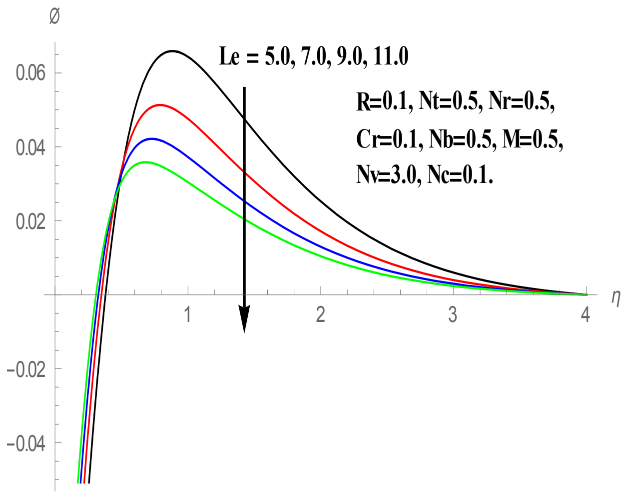

Fig.20: Effect of Le on Concentration profiles.

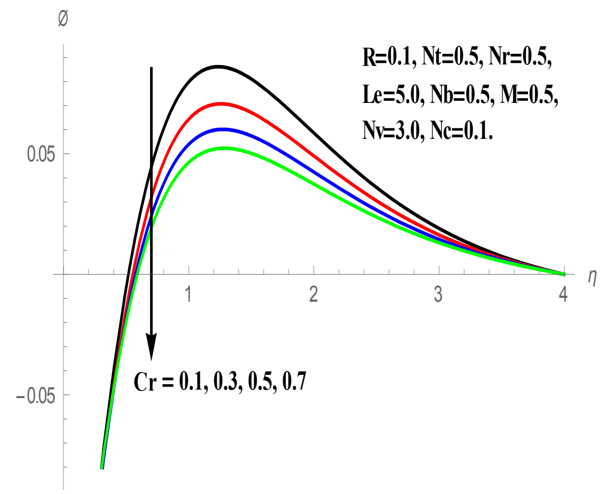

Fig.21: Effect of Cr on Concentration profiles.

It is observed from fig. 20 that concentration distributions decelerate with the increasing values of the Lewis number (Le) in the entire boundary layer region. By definition, the Lewis number represents the ratio of thermal diffusivity to the mass diffusivity. Increasing the Lewis number means a higher thermal diffusivity and a lower mass diffusivity, and this produces thinner thermal and concentration boundary layers. It is noticed from Fig.21 that concentration profiles are highly influenced by the chemical reaction parameter and declines in the fluid region.

It is noticed from table 2 that the magnitude of skin-friction coefficient, Nusselt and Sherwood numbers are amplified in the fluid regime as the values of variable viscosity parameter (*Nv*) increases. The non-dimensional velocity and heat transfer rates upsurges, whereas, mass transfer rate diminishes with the higher values of (*Nc*). It is obvious from table 2 that the dimensionless rates of velocity escalates, whereas, rates of heat and mass transfer are both deteriorates with the higher values of (*Nt*). It is also seen from this table that the values of skin-friction coefficient and Nusselt number decelerates, whereas, Sherwood number values enhances in the fluid region as the values of (*Nb*) rises. Higher the values of chemical reaction parameter (*Cr*) lower the values of non-dimensional velocity, heat and mass transfer rates.

Table 2: Effect of various parameters on local skin-friction co-efficient (C_f), local Nusselt number (Nu_x) and local Sherwood number (Sh_x).

Parameters					$-f''(0)$	$-\theta'(0)$	$-\varphi'(0)$
Nv	*Nc*	*Nt*	*Nb*	*Cr*			
1.0	0.1	0.5	0.5	0.1	0.891364	0.569568	-0.502992
3.0	0.1	0.5	0.5	0.1	1.117950	0.662561	-0.815183
5.0	0.1	0.5	0.5	0.1	1.133760	0.691567	-0.937933
7.0	0.1	0.5	0.5	0.1	1.120990	0.691253	-0.992331
3.0	0.5	0.5	0.5	0.1	1.152860	0.742135	-0.484589
3.0	1.2	0.5	0.5	0.1	1.163740	0.897660	-0.603443
3.0	1.9	0.5	0.5	0.1	1.178620	1.186630	-1.891771
3.0	2.5	0.5	0.5	0.1	1.198130	1.815350	-1.998438
3.0	0.1	0.1	0.5	0.1	0.988353	0.708372	-0.141674
3.0	0.1	0.2	0.5	0.1	1.029980	0.701997	-0.280799
3.0	0.1	0.3	0.5	0.1	1.070410	0.695130	-0.417078
3.0	0.1	0.4	0.5	0.1	1.109660	0.687843	-0.550274
3.0	0.1	0.5	0.3	0.1	1.279170	0.691365	-1.152280
3.0	0.1	0.5	0.5	0.1	1.147720	0.680198	-0.680198
3.0	0.1	0.5	0.7	0.1	1.090000	0.674447	-0.481748
3.0	0.1	0.5	0.9	0.1	1.057610	0.670993	-0.372774
3.0	0.1	0.5	0.5	0.1	0.896364	0.574568	-0.299253
3.0	0.1	0.5	0.5	0.3	0.893576	0.572239	-0.311181
3.0	0.1	0.5	0.5	0.5	0.886547	0.570990	-0.466227
3.0	0.1	0.5	0.5	0.7	0.876047	0.568162	-0.562668

5. CONCLUSIONS

MHD natural convection boundary layer flow, heat and mass transfer characteristics over a vertical cone embedded in a porous medium saturated by a nanofluid under the impact of variable viscosity, variable thermal conductivity, thermal radiation and chemical reaction is investigated in this research. The hydrodynamic, thermal and solutal boundary layers thickness were analyzed for various values of the pertinent parameters and the results are shown in figures. Furthermore, the impact of these parameters on Nusselt number and Sherwood number are also calculated. The important findings of the present study are summarized as follows.

(i) The hydrodynamic boundary layer thickness heightens, whereas, the thickness of thermal boundary layer decelerates as the values of (*Nv*) rises.
(ii) With the increasing values of (*Nc*) the values of skin-friction coefficient and Nusselt number elevates in the fluid region.
(iii) Both the temperature and concentration profiles elevates in the boundary layer regime as the values of (*Nt*) increases.
(iv) With increase in the values (*Nb*) the temperature and concentration distributions of the fluid, deteriorates.

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