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DUAL SOLUTION OF A JEFFREY FLUID BOUNDARY LAYER FLOW ACROSS A STRETCHING/SHRINKING SHEET EMBEDDED IN A POROUS MEDIUM

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Abstract

Heat transfer is very important factor to consider in heat exchangers, electric coolers, solar collectors, and nuclear reactors. The use of an appropriate non-Newtonian fluid as an active liquid can accelerate heat transfer. We explored the typical Jeffery fluid stream past a plane with both scenario with a magnetic field, non-uniform heat source/sink, and a porous medium in this regard. With the relevant method, the constrained non-linear differential equation of the flow field is rehabilitated into nonlinear differential equations with convenient transformations. These enormously nonlinear systems are solved by the Runge-Kutta 4th-order method in aggregation with an efficient shooting method. Effects of physical parameters like, Pr - "Prandtl number", e_1-"thermal stratification". λ_1- "Jeffery Parameter", λ_2- "Porous Parameter" M - "Magnetic field" and "heat generation / absorpton"- "γ" and "a &b are non-uniform heat source" on $f'(\eta)$ and $\theta(\eta)$ (velocity profile & temperature profile) have been discussed graphically. The density of the boundary layer is discussed in both the cases as shrinking and stretching. According to our findings, it is detected that for higher values in "e_1"the thermal stratification parameter led to enhance in fluid velocity as well as temperature profile, whereas, in the case of the heat source/sink parameters, the opposite impact is detected. In the assessment of the results with the experimental data from the literature, a reasonable agreement between them is found. From the results, it is concluded that the fluid flow over a stretching/shrinking sheet in a porous media can be studied in terms of hydromagnetic characteristics using the model that has been described.

Keywords: Dual solution, Porous medium, Thermal Stratification, λ_1 −Jeffery parameter, stretching/shrinking sheet.

1. Introduction

Several industrial fluids, namely dye, shampoo, adhesives, blood, slurries, food materials, printing inks, cleanser, and dissolved polymers, are non-Newtonian in their physical state. The stated fluids have viscous and viscoelastic properties and are fundamentally nonlinear. The integral equations for aforementioned fluids are naturally more advanced than those for typical Newtonian (Navier-Stokes) fluids. The classical momentum equations of the majority of non-Newtonian models, such as the Maxwell, Walters-B, Oldroyd-B, Eyring-Powell, and Jeffrey models, have been enhanced to varied degrees. The Jeffrey model, which has excessive shear viscosity, yield stress, and shear decreasing properties, is the most practical one-fee type non-Newtonian model. Many researchers have been drawn to it due to its versatility and numerous uses in science and engineering. Choi [1] who announced the perception of nanofluid through submerging the nanometre sized debris into the base fluid. Chen [2] thought about how a non-Newtonian fluid would transfer heat across a nonlinear stretching surface with viscous dissipation. Sajid et al. [3] used the stagnation factor to validate the Oldroyd-B fluid over a stretched surface in porous media. The temperature profiles of the Oldroyd-B fluid increase as the radiation restriction increases, according to Hayat et al. [4], who considered diffusive heat transfer in two-dimensional peripheral layer glide of an Oldroyd-B fluid across a stretching floor. The Brownian-motion-enabled Jeffrey nanofluid MHD glides across a stretching floor, and the thermophoresis outcomes are studied by Abbasi et al. [5]. The physical characteristics of thermophoresis and Brownian motion were found to be predisposed to thickening the thermal boundary layer in this observation. The impact of nonlinear thermal energy on Jeffrey fluid drift when homogeneous-heterogeneous processes are present was examined by Raju et al. [6]. Sandeep and Raju [7] expanded this examination of non-Newtonian bio-convection drift and examined the warm-up and mass-transfer processes involved in non-Newtonian bio-convection drift across a spinning cone/plate. Sandeep and Sulochana [8] granted a micro polar fluid over a stretching or contracting sheet with a non-uniform heat source/sink and an erratic combined convection. Raju et al. [9] explored the outcomes of radiation and associated magnetic pitches on flow throughout a stretching surface and discovered that the radiation parameter has an inclination to grow the temperature profiles of the stream. Mehmood et al[10] .'s consideration of the heat-switch ability and stagnation aspect breeze of micropolar second-grade fluid across a stretched surface. Baris and Dokuz [11] considered the stagnation factor float of a second-grade fluid past an impacting vertical plate. Nadeem et al. [12] noted the impact of Jeffrey fluid stream on the stagnation aspects of a stretching floor below convective boundary conditions. Nadeem and Akbar [13] were used to characterise the temperature and mass transport of a Jeffrey fluid in a halo. Illustration of a non-Newtonian fluid flowing erratically across a flooded porous medium by Makinde et al. [14] under convective boundary conditions. Thermal radiation and viscous dissipation cause a standard two-dimensional MHD Jeffrey nanofluid to waft over a stretched sheet, and Hussain et al. [15] found that the existence of the growth inside the viscous dissipation parameter causes a scrambling within the thermal boundary layer. Drawings of the dual solutions from Heat Source/ Sink in a Magneto-Hydrodynamic Non-Newtonian fluid stream in a Porous Medium [16] have been changed by Hayat et.al. The effects of heat switch during the nonlinear peristaltic transport of a Jeffrey fluid across a finite vertical porous conduit were assessed by Vajravelu et al. [17]. Eswara RE and Sreenadh [18] investigated the MHD boundary layer flow of Jeffrey's fluid through a stretch/shrink sheet via a porous medium. Narayana et al. [19] evaluated the effects of viscous dissipation on the Jeffrey fluid glide generated by the use of a stretchy sheet. ThirupatiThumma and S R Mishra [20] investigated the final results of warmth source/sink Joule dissipation on a 3D MHD radiating Eyring-Powell nanofluid with convective situations passing via a stretched. Cracked ode by means of semi analytical, ADM (Adomain decomposition approach K Avinash, Dr. N Sandeep, and colleagues [21] used the Jeffery fluid mode to observe the drift and heat transmission behaviour of an ethylene glycol liquid layer in the presence of a non-uniform warmness supply/sink. MHD Stagnation point waft across a stretching/shrinking sheet via porous medium changed into discussed by means of Eswara Rao M1 and Krishna Murthy M2* [22]. Bhattacharyya [23] explored the Dual solution in boundary layer stagnation factor flow and mass switch with chemical response past a stretching/shrinking sheet. Dulal Pal and Gopinath Mandal [24] investigated the effect of thermal radiation on Jeffery nanofluid warmness and mass transfer in the presence of a non-uniform warmness source/sink and suction. Ramanahalli's Konduru Sarada J. Punith Gowda et al. [25] investigated the character of MHD (magneto hydrodynamics) in a porous media using the LTNE (nearby thermal non equilibrium conditions) version, that's based totally on energy equations and distinguishes between fluid and stable levels. Reddy et al. [26] investigated the float of nanofluid fashions together with Maxwell, Oldroyd-B, and Jeffery with a warmness supply/sink thru a cone. Almakki et al. [27] used Maxwell, Oldroyd-B, and Jeffery nanofluid models to analyse entropy formation with Brownian motion and thermophoresis diffusions. Sandeep, N. et al. [28] have discussed the heat transfer and momentum behaviour of non-uniform heat source/sink Jeffery, Maxwell, and Oldroyd-B nanofluids. The writers of [29-30] worked on stretching and shrinking.

With the aid of graphs for special parameters, the main topic is intended to influence the magnetic area and nonuniform heat source/sink of the boundary layer float of a Jeffrey fluid over a stretching/shrinking sheet in porous material.

2. Formulation of mathematical model

A stream of incompressible liquid moving in two dimensions across a stretching/shrinking sheet is known as the MHD Jeffrey fluid flow. Following is a typical notation representation of the temperature and fluid flow equations.

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

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\left(\frac{v}{1+\lambda_1}\right)\frac{\partial^2 u}{\partial y^2}-\frac{\sigma {B^2}_0}{\rho}u-\frac{v}{k}u \tag{2}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y} = \frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2}+\frac{Q}{\rho C_p}(T-T_\infty)+\frac{q'''}{\rho C_p} \tag{3}$$

velocity components u & v,

'"$\nu=\frac{\mu}{\rho}$"- Kinematic fluid viscosity,"ρ"- *fluid density* and "μ"- coefficient of fluid viscosity expresses Jeffery parameter, "Cp" and "k"- Specific heat &thermal conductivity at constant pressure and γ- heat generation/absorption.'

The conditions for existing studies of boundary are

$$\left.\begin{aligned} &u=U_w,\quad v=-v_w\,,T=T_w=T_0+b_1x \quad at \quad y=0\\ &u\to\ 0\ \Rightarrow\ T\to T_\infty=T_0+b_2x,\ \ y\to\infty,\ \ as y\to\infty \end{aligned}\right\} \tag{4}$$

"U_w" $=cx$ Stretching Sheet case and

"U_w" $=-cx$ with e > 0 being for shrinking sheet case

"v_w" > 0 &"v_w" < 0 mass suction and mass injection.

correspondence transformations are,

$$\left.\begin{aligned} \psi = \sqrt{c\nu}\, x f(\eta) \qquad and \qquad \eta = y\sqrt{c/\nu} \\ \theta(\eta) = T - T_\infty / T_w - T_0 \Longrightarrow T = (T_w - T_o)\theta(\eta) + T_\infty \end{aligned}\right\} \quad (5)$$

"Stream functions are defined as "

$$u = \partial\psi/\partial y \; and \; v = -\partial\psi/\partial x \quad (6)$$

"ψ" - Stream function, and "η" - similarity variable.

Also $T = b_1 x\theta(\eta)$& $\quad T_\infty = T_0 + b_2$ (7)

Where $q''' = \frac{KU_w}{x}[a(T_w - T_0)f' + (T - T_\infty)b]$

Using equation (5), the equations (2)-(3) takes the forms,

$$\left(\frac{1}{1+\lambda_1}\right)f''' + ff'' - f'^2 - (M + \lambda_2)f' = 0 \quad (8)$$

$$\theta'' + Pr\theta' f - Pr\theta f' - Pre_1 f' + Pr\gamma\theta + \Pr(af' + b\theta) = 0 \quad (9)$$

2.1 Consistent boundary conditions of

a) Stretching sheet

$$f(\eta) = S, f'(\eta) = 1, \theta(0) = 1 - e_1 at\eta = 0; \; f'(\eta) \to 0,$$
$$\theta(\infty) \to 0, as\eta \to \infty \quad (10)$$

b) Shrinking sheet

$$f(\eta) = S, f'(\eta) = -1, \theta(0) = 1 - e_1 at\eta = 0; \; f'(\infty) \to 0,$$
$$\theta(\infty) \to 0, as\eta \to \infty \quad (11)$$

$S = \frac{v_w}{(c\nu)^{\frac{1}{2}}}$'With "S>0 (i.e.,$v_w > 0$) and S <0 (i.e.,$v_w < 0$) for wall mass suction" &

Wall mass injection, S represents wall mass constraint.

Where, $M = \frac{\sigma {B^2}_0}{\rho c}$, $\lambda_2 = \frac{\nu}{ck}$, $pr = \frac{\mu C_p}{K}$. $e_1 = {}^{b_2}/_{b_1}$ and $\gamma = \frac{Q}{\rho C_p a}$

2.2 Solution Framework

To deal emphasizes with the BVPs, the firing system Runge-Katta 4th order method are used to solve the governing equation. The modified ODEs are converted into the following system using Equations (8) and (11).

$$\frac{df_0}{d\eta} = f_1, \frac{df_1}{d\eta} = f_2, (1+\lambda)\frac{df_2}{d\eta} = \left({f_1}^2 + M + \lambda_2\right)f_1 - f_0 f_2), \tag{12}$$

$$\frac{d\theta_0}{d\eta} = \theta_1, \quad \frac{d\theta_1}{d\eta} = \Pr[f_1\theta_0 + e_1 f_1 + \gamma\theta_0 - \theta_1 f_o - (af_1 + b\theta_0] \tag{13}$$

An equation (10) and (11) illustrates the boundary conditions after that as stretching and shrinking, respectively.$f_o = \mathrm{S}$, $f_1(0) = -1, f_1(\infty) = 0, \theta_0(0) = 1 - e_1, \theta_0(\infty) = 0;$

$f_o = f(\eta) and \theta_0 = \theta(\eta),$ The aforementioned BVP is first transformed into an IVP by accurately measuring the slopes that were ignored. To solve the created IVPs, MATLAB's bvp4c module is employed.

3. Results and discussion:

Figures 1 and 2 show how Prandtl no 'Pr' influences the $f'$and $\theta(\eta)$) for both scenarios as Pr (Prandtl no) surges, the fluid becomes denser and the speed profile declines. The increase in Prandtl broad variety (pr) is especially vulnerable to energy diffusion for frequent values of Pr drops due to dimensionless variety is inversely related to thermal conductivity. A rise in Pr causes a significant drop in fluid temperature, resulting in a thinner thermal boundary layer. When a sheet is shrunk, a large Pr (Prandtl number) fluid causes thermal unsteadiness on the surface, but this is not the case when the sheet is stretched, contrary to what is predicted in fig (2). "e_1"-Thermal stratification is predicted in figures (3) - (4) for stretching and shrinking on velocity and temperature profiles, respectively. "e_1" Declines fluid velocity because there is a concentrated convective potential sandwiched between the aspect of the sheet and the surrounding temperature. Temperature drops enhance the "e_1"stratification parameter. Figures (5) and (6) show the effects of heat generation/absorption "γ" as the heat generation parameter"γ" for velocity"f'"and Nusselt no "θ" is increased, the velocity and temperature of the fluid rise, as revealed in Figures (5) and (6). Due to the Lorentz effect, the velocity drops as M increases for frequent values of "M" magnetic parameter. When "M" grows, the Lorentz force enhances, and the boundary layer thickness declines in the stretching scenario. Parameter M in shrinking case, dissimilar values of "M" the velocity increases with growing in "M" which is exposed in Fig- (7). The motivation of the magnetic field constraint "M" on stream "θ" temperature profiles. It is obvious that rise in the magnetic field parameter" increases the "θ" (temperature profile) of the flow which is depicted in the Figure (8) for both the scenario. The fluctuation in velocity "f'" for various values of the "λ_1"--Jeffrey parameter is depicted in Figure (9). In the stretching scenario, as the "λ_1" rises and the viscosity of the frontier layer rises, the velocity falls. When there is shrinkage, the velocity falls as the Jeffrey parameter "λ_1" surges and the thickness of the peripheral layer rises. The Jeffery parameter

"λ_1" and its effect on the temperature profile for each situation are shown in Figure (10). The temperature profile declines as the Jeffery parameter - "λ_1"improves because of the advanced temperature and thicker thermal border layer, which causes an increase in moderation time and a decrease in obstruction time. The temperature profile $\theta(\eta)$ and the porous parameter- ("λ_2") graphs for the stretching and contracting situations are shown in Figures (11) and (12). In both situations, the porous parameter increases as velocity decreases. Different values of the porosity parameter in the $\theta(\eta)$ temperature profile surge as the temperature declines in the stretching case, but they decrease as the temperature increases in the shrinking case. Figure (13) & (14) parade the impact of 'a' non uniform heat source parameter for both the cases stretching /shrinking for skin friction and Nusselt no it increases in stretching where as in other hand decreases in shrinking. Also, for "b" nonuniform heat source parameter it enhances for velocity and temperature profile in stretching& declines in shrinking in both the profiles which are plotted in figure (15) and (16).

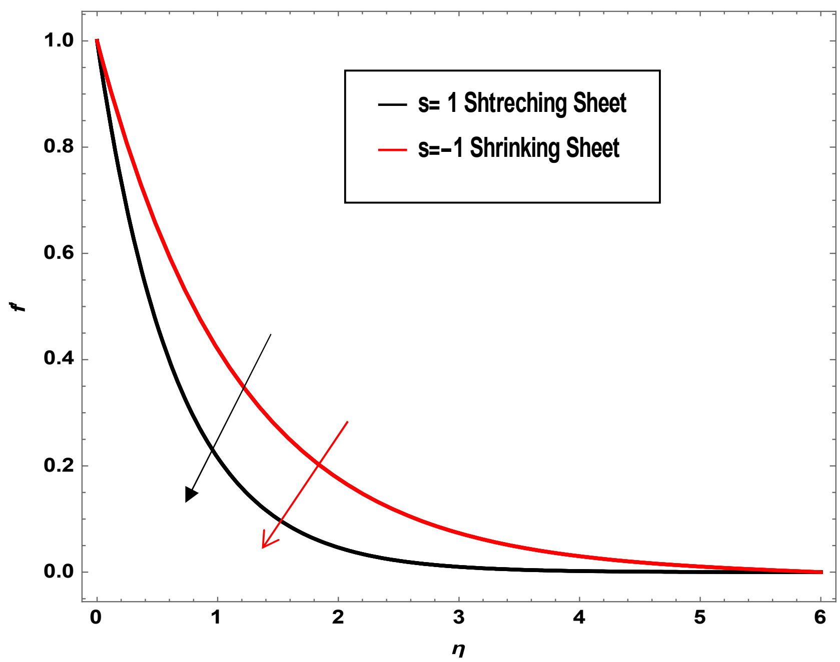

Fig.1 Plots *Pr* on the Velocity profile

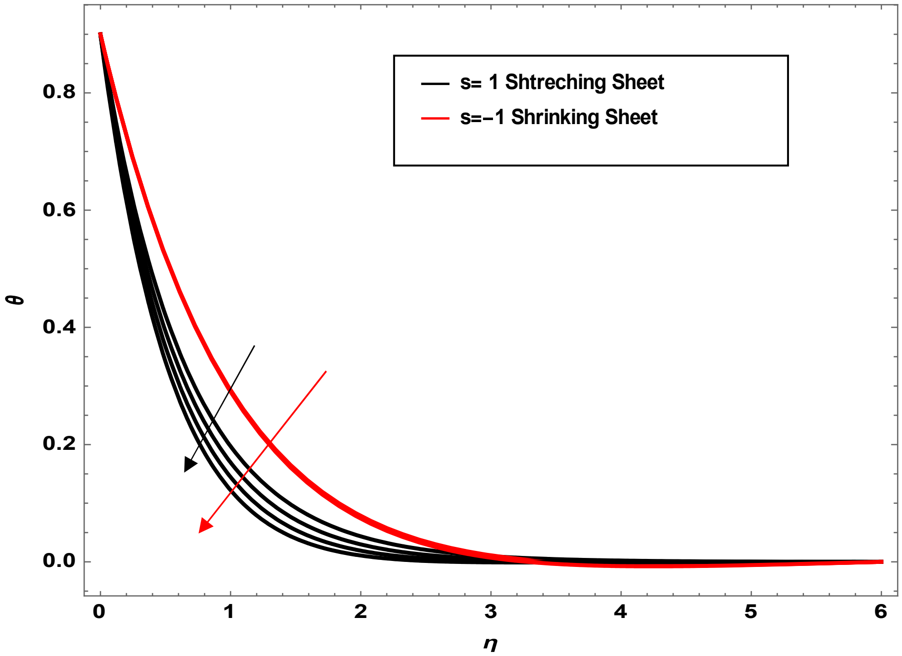

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Fig.2 Influence of Pr on $\theta(\eta)$

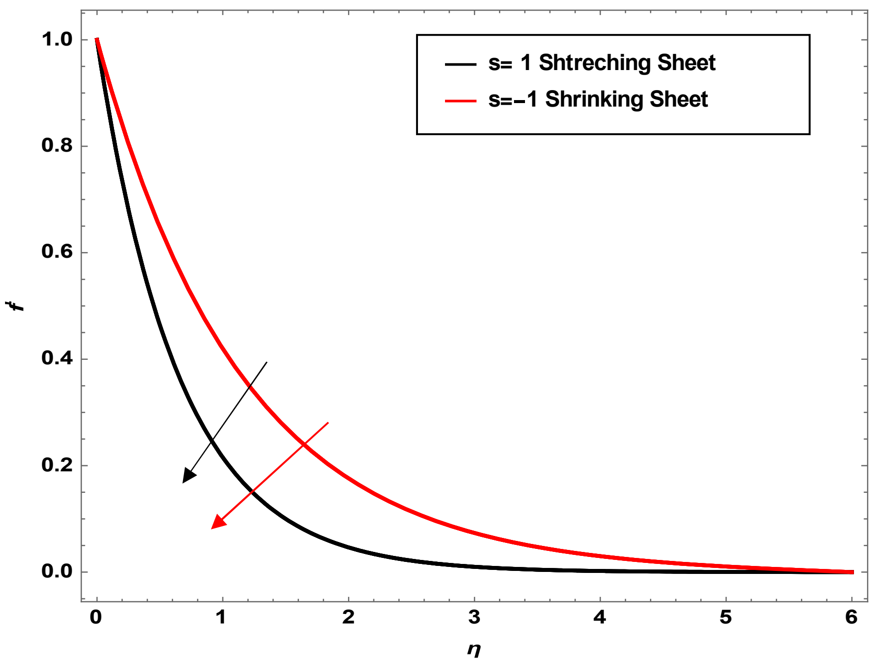

Fig.3.Influence of e_1 on the Velocity profile

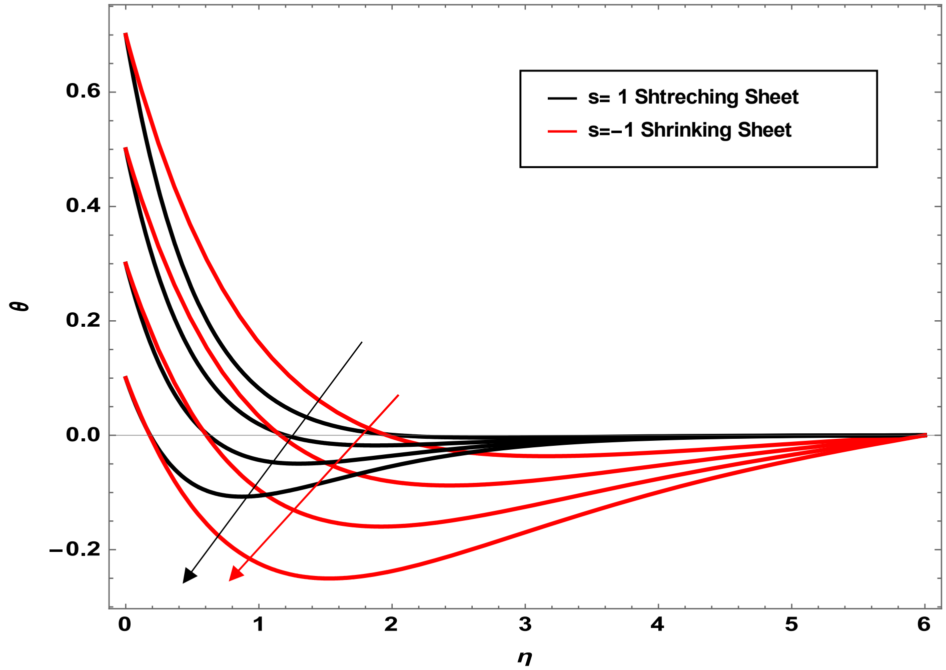

Fig.4 Influence of “e_1” on the “θ”

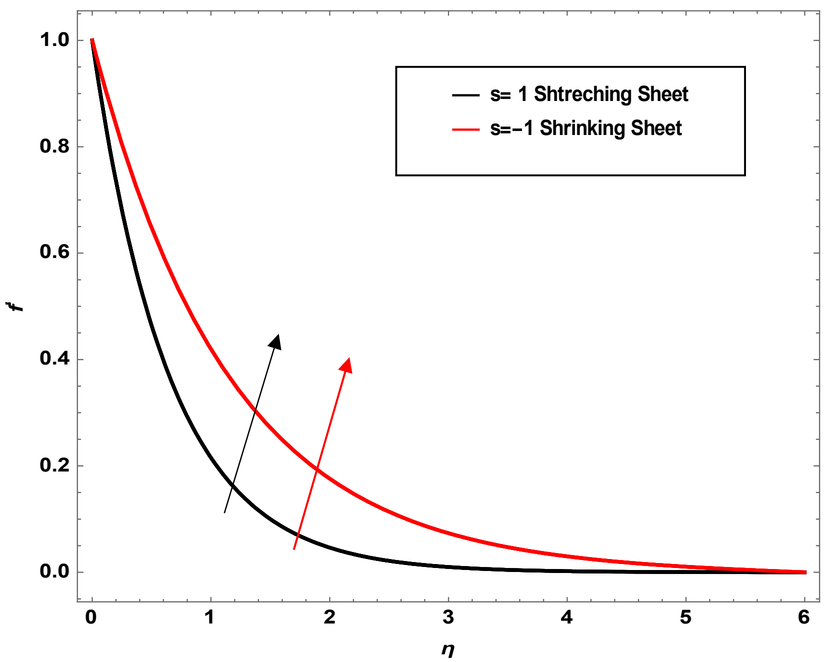

Fig.5 Influence of “γ” on f'

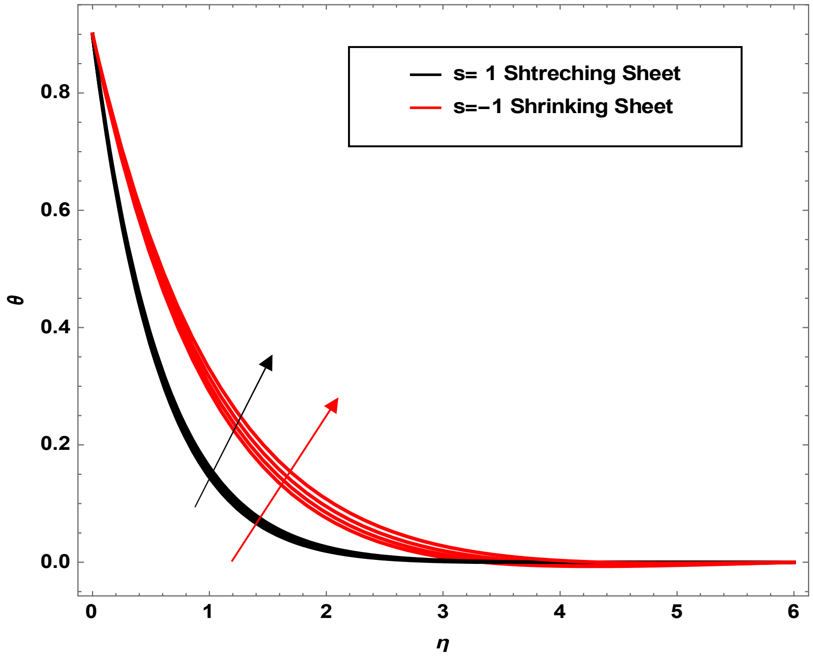

Fig.6 Influence of "γ "on "θ"

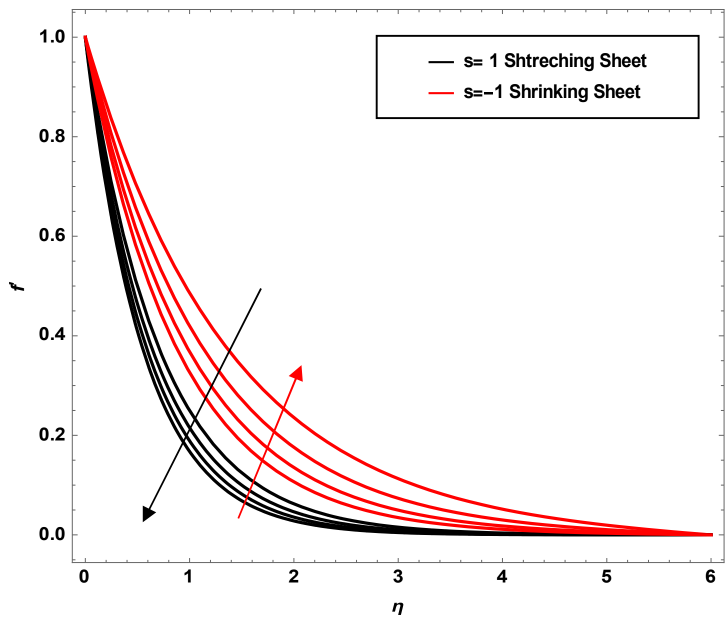

Fig.7 Influence of "M" on f'

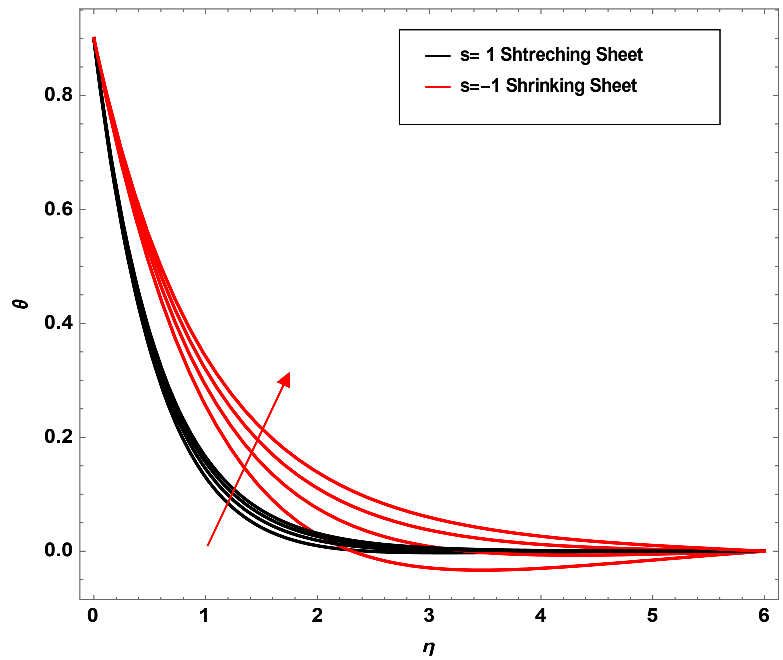

Fig.8 Influence of “M” on “θ”

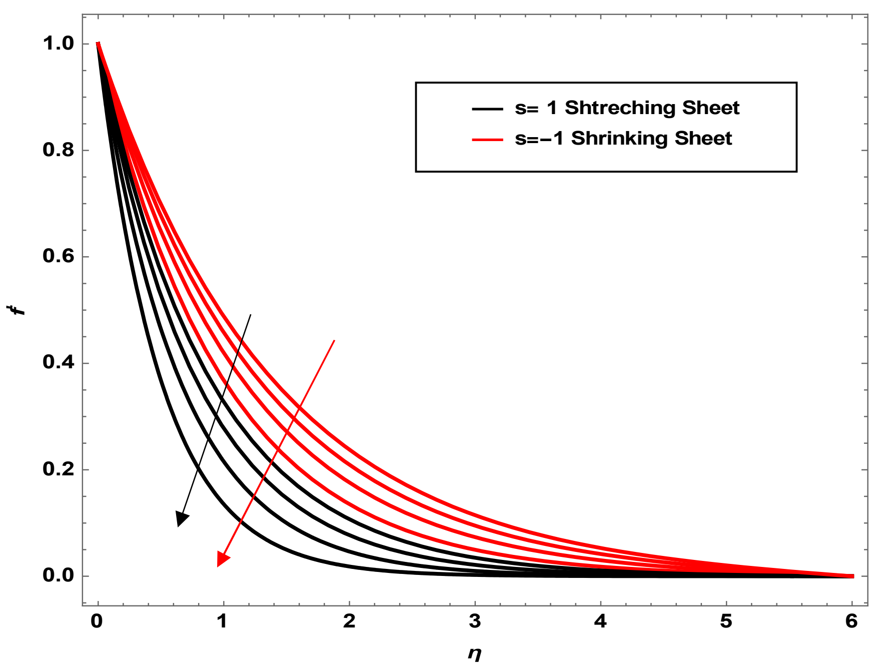

Fig.9 Influence of “λ_1"on the Velocity profile

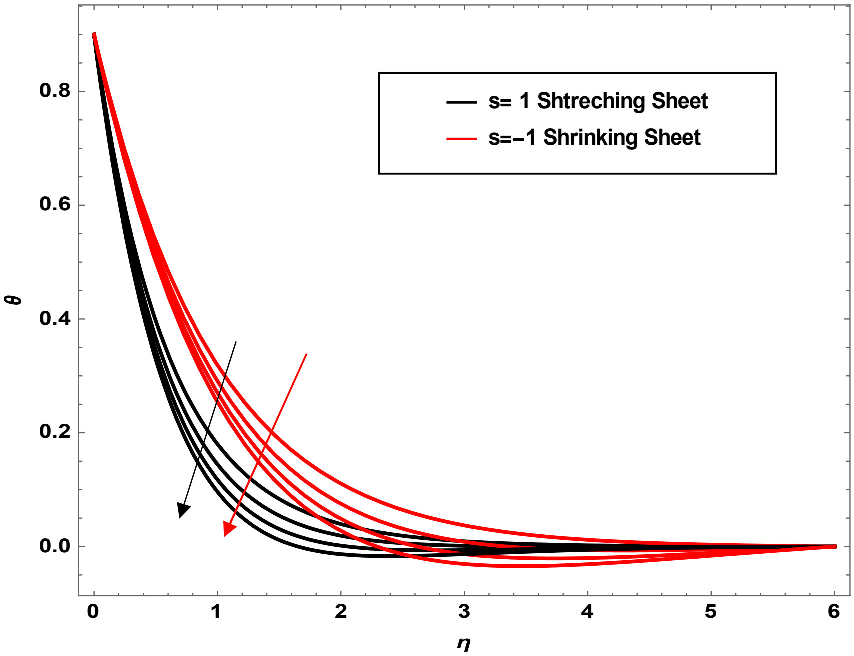

Fig.10 Impact of "λ_1" on $\theta(\eta)$

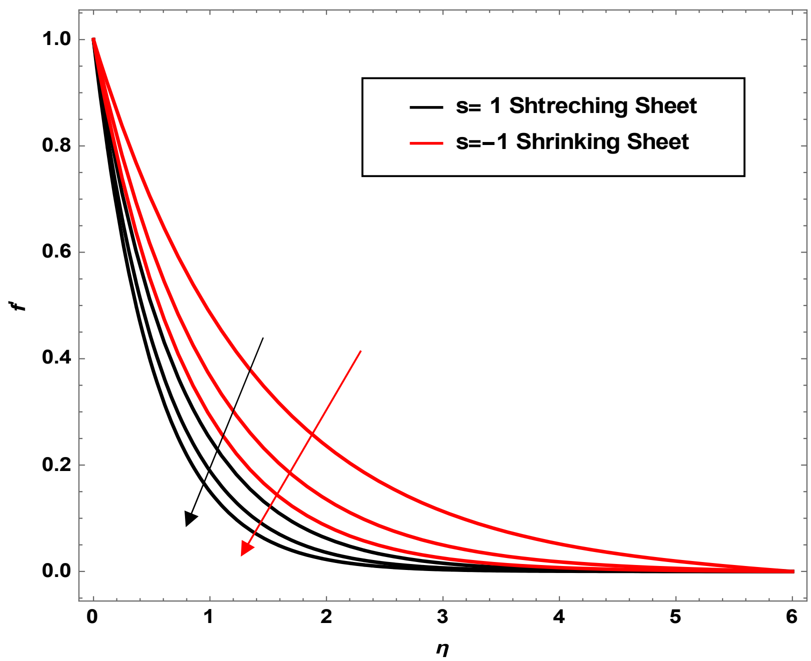

Fig.11 Influence of "λ_2" on the Velocity profile

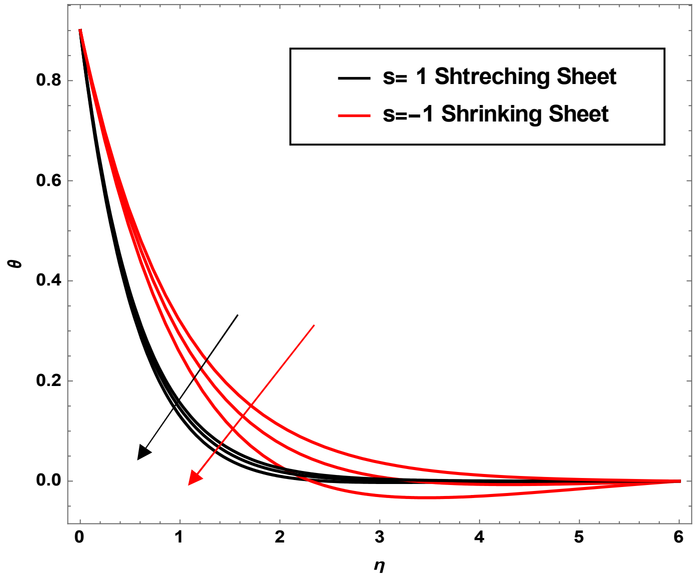

Fig.12 Influence of "λ_2"on the Velocity profile

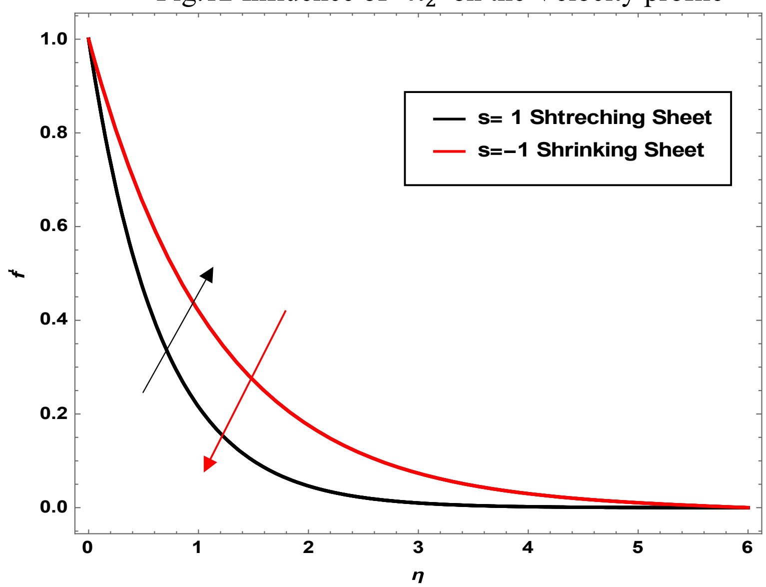

Fig.13 Influence of "a" on the f'

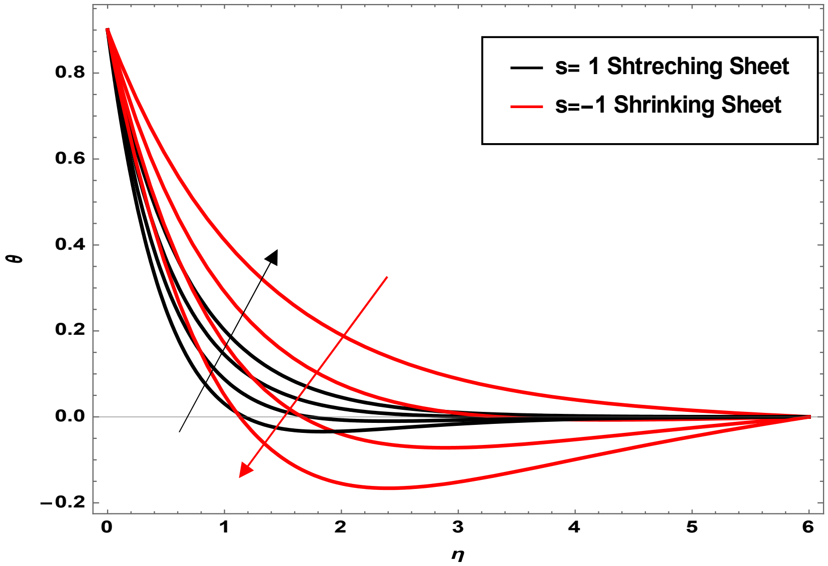

Fig.14 Influence of “a” on the Temperature profile

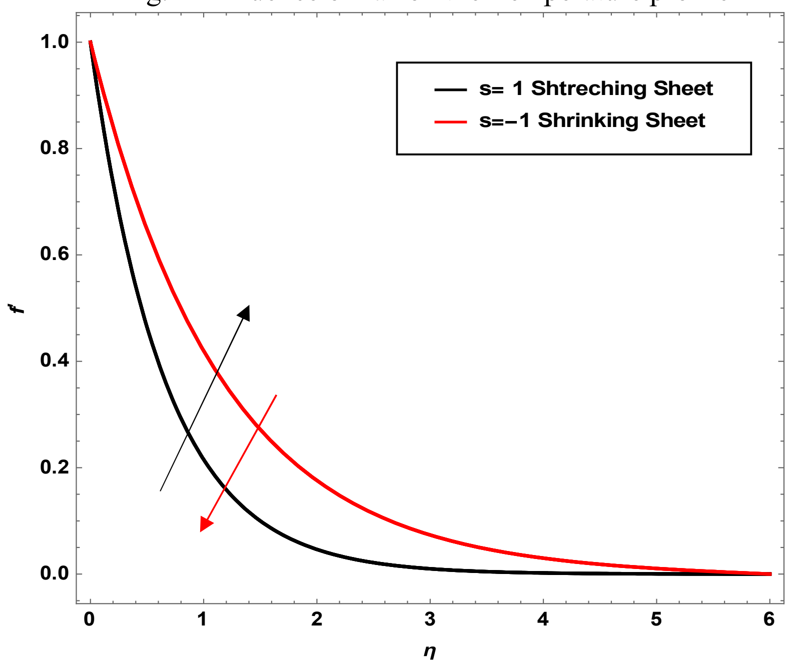

Fig.15 Influence of “b” on the Velocity profile

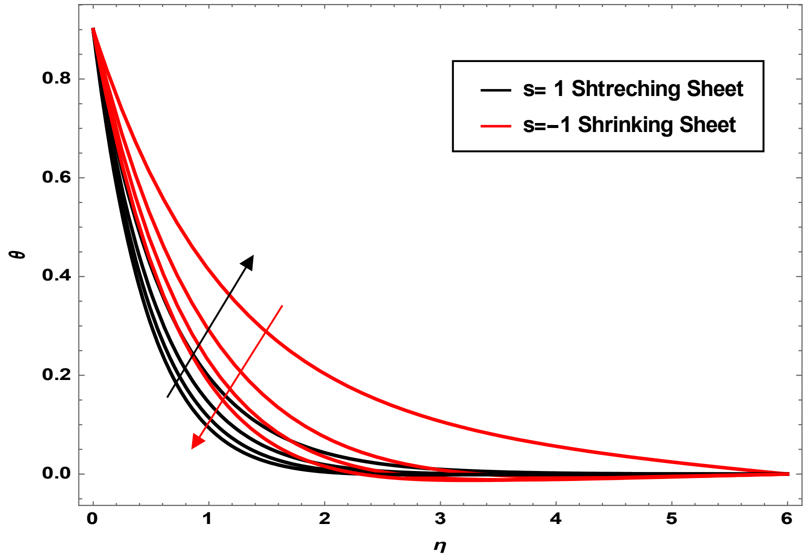

Fig.16 Influence of "b" on $\theta(\eta)$Temperature profile

4. Conclusion:

In addition to considering heat transmission, an important aspect of this exertion is to consider frontier layer fluid flow of a "λ_1"Jeffery constraint in a porous physical across a contracting and expanding (stretching /shrinking) pane. The dimensionless velocity and temperature are also discovered. We can make the following findings for different ideals of the specified bodily constraints,$f'$and '$\theta(\eta)$' (velocity and temperature profile) from the existing investigation:

- Increment in the Pr Prandtl no constraint of "f'"and "θ" (Velocity and temperature profile) of the fluid drops.
- The difference in velocity f for various Jeffrey parameter λ_1 values When the Jeffrey constraintλ_1 is increased, the velocity falls and the boundary layer width Flourishes, but when the Jeffrey parameter λ_1 is augmented, the velocity rises and the boundary layer width rises.
- Controlling fluid velocity and temperature can be aided by the thermal stratification Parameter "e_1" strength.
- In both situations, the porous parameter -"λ_2"rises as "f'"(velocity) profiles declines. In stretching, porous parameter-"λ_2" upsurges as the $\theta(\eta)$(Temperature profile) drops, In shrinking , porous parameter-"λ_2"enhances as the $\theta(\eta)$(Temperature profile) drops.
- Elaborating the values of the "γ" - heat generation/ absorptionparameter consequences in an upsurge in both velocity and temperature profiles.
- Increment in non-uniform heat enhances temperature profile.

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