BOUNDARY LAYERED FLOW OF MHD CASSONIAN LIQUID THROUGH MEANS OF STRETCHED PLATES IN RELATION TO PERMEABLE MEDIUM

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ABSTRACT

Through means of this specific paper, the work identifying with "Boundary layered MHD flow through Cassonian liquid dependent on a penetrable extending/contracting plate in relation with permeable medium is likely being attempted. Further, endeavors will consequently be made towards contemplating similar changes, for which partial differential equations are changed into ordinary differential equations, which are being solved logically.

The "impacts pertaining to magnetic boundary, porousness boundary and Casson boundary are specifically introduced through graphs on various velocity attributes while the neighborhood skin friction coefficient is introduced through graphs", respectively. As a result, this work will subsequently uncover the fact that, in situations wherein there exists increment of Casson boundary, resulting velocity tends to diminish and furthermore lessen the limit layer thickness, gradually.

Keywords: MHD, Casson parameter, permeability parameter, boundary layer, stretching/shrinking sheet.

1. INTRODUCTION

Based on previous few years, there has been observed a continuous expanding interest in progressions of Newtonian as well as non-Newtonian liquids over extending/contracting sheet as a result of their applications in preparing ventures, for example- polymer handling, glass fiber creation along with numerous others industries, as well. In consideration to this, its thereby being studied about MHD stream, which is quite significant on grounds that the works because of attractive field on electrically directing liquid is pertinent in numerous mechanical interactions, like that of magnetic materials handling cleansing of unrefined petroleum and magneto hydrodynamic electrical force. Moreover, since the conduct of mechanical liquids is unpredictable, it got important to undertake utilization of "non-Newtonian liquid models so as for portraying actual wonders substances like- Jelly, tomato sauce, organic product, juices and so forth having a place with the class of non-Newtonian liquids and they might be clarified well through basic model, wherein human blood is additionally be treated as a Casson liquid". As a result, "Casson liquid" can subsequently be determined as form of a shear diminishing fluid that is expected for having endless thickness corresponding to zero pace of shear, having a yield pressure beneath which no stream happens, resulting in zero consistency of limit-less pace in relation to that shear, considerably.

A large number of works on similar aspects are being done in past few years, based on which upcoming works can be undertaken. Therefore, a spearheading work on consistent limit layering stream because of direct extending sheet was being contemplated by "Crane" [1], while a definite examination for ascertaining "impacts of heat dissemination relating MHD and radiation Marangoni limit layer Nano liquid stream past a surface inserted in a permeable medium is concentrated by Emad H. Aly et al.", [2] considerably. Further, Turkyilmazoglu[3] covered progression of a miniature polar liquid because of permeable extending plate along dissemination of heat. "Shalini Jain et al." [4] moreover examined about impacts pertaining to "MHD on limit layer stream in permeable medium due to dramatically contracting sheet with slip MHD stream of a Casson liquid over a dramatically slanted penetrable extending surface having warm radiation, while study on substance response was being talked about by Bala Ankireddy" [5] respectively. "Vishnu Ganesh et al." [6] undertook work on estimating working of "Darcy for chheimer stream of hydro attractive Nano liquid over an extending/contracting sheet in a thermally separated permeable medium with second-order slip, thereby showing impact pertaining to viscous and ohmic disseminations", primarily. Besides this, works on MHD visco-elastic limit layer stream alongside dissemination of heat past a convectively warmed emanating extending/contracting plate having temperature subordinate warmth source/sink installed in soaked permeable media, were subsequently being examined by "Subhas Abel et al." [7].

In addition to this, "Krishnendu Bhatacharyya et al." [8] Considered double arrangement in limit stream of Maxwell liquid over a permeable evading plate, while mathematical answer for MHD stagnating point stream towards an extending/contracting surface in an immersed permeable medium is considerably studied by "Susheela Chaudhary et al." [9]. Moreover, "Alam et al." [10] broke down impacts of variable liquid properties as well as thermophoresis, a precarious constrained convective limit layer stream alongside a penetrable extending/contracting wedge with variable "Prandtl as well as Schimidt numbers". Similarly, "Santosh Chaudhary et al." [11] Examined about dissemination of heat & mass, through means of MHD stream close by a stagnation point over an extending/contracting sheet in a permeable medium. "Azhar Ali et al." [12] Thereby performed a detailed work on formulating scientific answer for liquid stream over a dramatically extending permeable sheet having surface warmth motion in permeable medium through means of homotopic investigation techniques, while arrangements of non-Newtonian limit layer stream in permeable medium was accounted for by "Nabeela kausar et al.", respectively [13]. Furthermore, study of limit layer stagnation point on slip stream alongside dissemination of heat towards an extending/contracting chamber over a penetrable surface was thereto examined by "Azaiah Aihi Mat" [14]. As a result, several insightful answer for "MHD limit layer stream of Casson liquid through means of an extending/contracting sheet having proper mass dissemination was being acquired by Krishnendu Bhattacharya et al. [15], while study in relation to MHD stream of Newtonian liquid, is explored by Chakrabarti and Gupta" [16], subsequently.

2. FORMULATING OF PROBLEM

For the purpose of formulating problem for our study, we have thereby considered utilizing of stable hardened "Casson liquid flow through means of stretched upon plates having a permeable medium", respectively, wherein the plate is being placed at (y = 0), such that its concerned stream is determined as (y > 0). Besides this, a stable field having magnetic strength (Be), is thereto made applicable onto a stretched plate, in a manner that, concerning magnetic field is determined as to be somewhat neglecting. As a result, the "rheological equation of state for an isotropic and incompressible flow of a Casson fluid is thereby presented by Eldabe and Salwa" [17] considerably.

$$\tau_{i\,j} = \begin{cases} \left(\mu_B + p_y/\sqrt{2\pi}\right)2e_{i\,j}\,, & \pi > \pi_{c,} \\ \left(\mu_B + p_y/\sqrt{2\pi}\right)2e_{i\,j}\,, & \pi < \pi_{c,} \end{cases} \quad \ldots (1)$$

Wherein, μ_B denotes "plastic dynamic viscosity of the non-Newtonian fluid", while p_y represents respective yielding pressure of liquids, π denotes the "product representing component of deformation rate with itself", including $\pi = e_{ij}\, e_{ij}$, e_{ij} such that it highlights the (i, j)th element pertaining to rate of deformation, while other relevant parameters in relation to "Non-Newtonian model", are also considered.

Further, in case of normal limiting conditions, the diverse expression which shall be used for highlighting subsequent flows, are represented as under-

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

$$u\frac{\partial u}{\partial x} + v\frac{\partial v}{\partial y} = \nu\left(1 + {}^{1}\!/_{\beta}\right)\frac{\partial^2 u}{\partial y^2} - \frac{\sigma B_0^2}{\rho}u - \frac{\nu}{k}u \quad \ldots (3)$$

Wherein, u alongside v represents different velocity elements based upon "x & y axis" respectively, whereas, x denotes the concerned distance in relation to the plate, y highlights respective distance in relation to those plates, while ν tends to highlight the "kinematic fluid viscosity, and represents the concerned density of liquid, such that- $\mu_B\sqrt{2\pi_c}/p_y$ highlights "non-Newtonian (Casson) parameter. w is the electrical conductivity of the fluid, ν kinematic viscosity, k denotes permeability, and B_o is the strength of magnetic field pertaining to y-axis", respectively.

As a result, different limiting conditions are stated as under-

$$u = U_w\,, v = -v_w \quad at \quad y = 0\,; \;\; u \to 0 \;\; as \;\; y \to \infty \quad \ldots (4)$$

Based on above expression, stretching alongside contraction in relation to velocity attributes of various plates having condition- U_W is being provided, while condition- $U_W = cx$ highlights variables in relation to shrinking plates having c (>0) such that the factors denoting extension as well as contraction is determined to be constant. Furthermore, it is observed that, ν_W significantly highlights the respective "mass dissemination velocity having $\upsilon_W > 0$ for mass suction, while on the contrary, $\upsilon_W < 0$ pertaining to mass injection", subsequently.

As a result, the elements “u and v” of velocity can thereby be denoted as under-

$$u = \frac{\partial \psi}{\partial y} \text{ and } \quad v = -\frac{\partial \psi}{\partial x} \qquad \dots (5)$$

Moreover, when thought of expression-(5), resulting conservation of mass in case of expression-(2) gradually gets approved, such that momentum expression-(3) gets thereby transformed into-

$$\frac{\partial \psi}{\partial y}\frac{\partial^2 \psi}{\partial x \partial y} - \frac{\partial \psi}{\partial x}\frac{\partial^2 \psi}{\partial y^2} = \nu\left(1 + \frac{1}{\beta}\right)\frac{\partial^3 \psi}{\partial y^3} - \frac{\sigma B_0^2}{\rho}\frac{\partial \psi}{\partial y} - \frac{\nu}{k}\frac{\partial \psi}{\partial y} \qquad \dots (6)$$

Thus, it is been identified that, limiting condition in relation to expression-(4) gets subsequently reduced to expression-(7).

$$\frac{\partial \psi}{\partial y} = U_w \text{ }, -\frac{\partial \psi}{\partial x} = v_w \text{ } at \text{ } y = 0 \quad \frac{\partial \psi}{\partial y} \to 0 \text{ } as \text{ } y \to \infty \qquad \dots (7)$$

Hence, by undertaking use of expression (8), expression (6) thereby gets transformed

$$\psi = \sqrt{c\nu}x \text{ } f(\eta) \quad \text{and } \eta = y\sqrt{\frac{c}{\nu}} \qquad \dots (8)$$

into expression,

$$\left(1 + \frac{1}{\beta}\right)f''' + ff'' - f'^2 - (M + \lambda_1)f' = 0 \qquad \dots (9)$$

Wherein, $M = \frac{\sigma B_0^2}{PC}$ is highlights the “magnetic parameter $\lambda_1 = \frac{\nu}{Ck}$ = permeability (or) porous parameter”, and concerned limiting conditions are thereby expressed as-

$$f(\eta) = S\text{ }, \text{ } f'(\eta) = 1 \text{ } at \text{ } \eta = 0\text{ }; \text{ } f'(\eta) \to 0 \text{ } as \text{ } \eta \to \infty \qquad \dots (10)$$

$$f(\eta) = S\text{ }, \text{ } f'(\eta) = -1 \text{ } at \text{ } \eta = 0\text{ }; \text{ } f'(\eta) \to 0 \text{ } as \text{ } \eta \to \infty \qquad \dots (11)$$

Such that, $S = v_w/(c\nu)^{1/2}$ showcase mass dissemination elements having S > 0 (i.e., $v_w > 0$) in relation to different mass suction plates concerning towards S > 0 (i.e., $v_w < 0$) highlighting injecting of mass plates.

3. SOLUTION WITH RESPECT TO FORMULATED PROBEM

a. Stretching plate situation

For ascertaining solution to this particular case, following expression may be considered-

$$f(\eta) = a + be^{-\lambda\eta} \qquad \dots (12)$$

Such that, a, b as well as λ denotes constant variables having λ > 0. Furthermore, on interchanging relation-12 into expression- 9 as well as expression-10, we thereby derive-

$$b = -\frac{1}{\lambda} \quad , \quad a = s + \frac{1}{\lambda} \quad \text{and } \lambda = \frac{s + \sqrt{s^2 + 4\left(1 + \frac{1}{\beta}\right)(1 + (M + \lambda_1))}}{2\left(1 + \frac{1}{\beta}\right)} \qquad \dots (13)$$

As a result, the considered analytical outcome gets reduced to-

$$f(\eta) = s + \frac{1}{\lambda} - \frac{1}{\lambda}e^{-\frac{s + \sqrt{s^2 + 4\left(1 + \frac{1}{\beta}\right)(1 + (M + \lambda_1))}}{2\left(1 + \frac{1}{\beta}\right)}\eta} \qquad \dots (14)$$

$$f'(\eta) = be^{-\lambda\eta}(-\lambda) = e^{-\lambda\eta}$$

$$f''(\eta) = e^{-\lambda\eta}(-\lambda) = -\lambda e^{-\lambda\eta} \qquad \dots (15)$$

$$f''(0) = -\lambda = -\sqrt{\frac{S + \sqrt{S^2 + 4\left(1+\frac{1}{\beta}\right)(1 + (M+\lambda_1))}}{2\left(1+\frac{1}{\beta}\right)}} \qquad \ldots (16)$$

b. Shrinking plate situation

An important thing to note is that, this particular case is considered to be much more appropriate than that of previous discussed case. Thus, on interchanging expression-(12) into expression-(9) as well as expression-(11), we derive-

$$b = \frac{1}{\lambda}\ , \quad a = s - \frac{1}{\lambda} \quad \text{and } \lambda = \frac{s \pm \sqrt{s^2 - 4\left(1+\frac{1}{\beta}\right)(1-(M+\lambda_1))}}{2\left(1+\frac{1}{\beta}\right)} \qquad \ldots (17)$$

As a result, the considered analytical outcome gets reduced to-

$$f(\eta) = a + be^{-\lambda\eta}$$

$$f(\eta) = s - \frac{1}{\lambda} + \frac{1}{\lambda} e^{-\frac{s \mp \sqrt{s^2 - 4\left(1+\frac{1}{\beta}\right)(1-(M+\lambda_1))}}{2\left(1+\frac{1}{\beta}\right)}\eta} \qquad \ldots (18)$$

hence

$$f'(\eta) = be^{-\lambda\eta}(-\lambda) = -e^{-\lambda\eta} = -e^{-\left(\frac{s \pm \sqrt{s^2 - 4\left(1+\frac{1}{\beta}\right)(1-(M+\lambda_1))}}{2\left(1+\frac{1}{\beta}\right)}\right)\eta}$$

$$f''(\eta) = be^{-\lambda\eta}(\lambda)$$

$$f''(0) = -\lambda = \sqrt{\frac{S \mp \sqrt{S^2 - 4\left(1+\frac{1}{\beta}\right)(1 - (M+\lambda_1))}}{2\left(1+\frac{1}{\beta}\right)}}$$

Based upon the "MHD flow of Cassonian fluid", the existence alongside appropriateness of resulting similarity outcomes, gets highly dependent upon "magnetic element M. As a result, three distinctive situations arise, which needs to be considered individually, that are mentioned as under-

$M + \lambda_1 < 1, M{+}{=}{<}\ 1, M + \lambda_1 > 1$

Case 1: M+λ_1 < 1

It is considered that stable flow is basically achievable, when below mentioned situation is being approved-

$$s^2 \geq 4\left(1+\frac{1}{\beta}\right)(1-(M+\lambda_1)) \qquad \ldots (19)$$

Additionally, similarity outcomes are assumed to be different, in case - $S^2 = 4\left(1+\frac{1}{\beta}\right)(1-(M+\lambda_1))$ and is regarded of having dual existence, in case $S^2 < 4\left(1+\frac{1}{\beta}\right)(1-(M+\lambda_1))$ respectively.

Case 2: M+λ_1 < 1

This very situation deals with stable stream of Cassonian fluid, utilized so as for ensuring suction activities only, such that (s > o), due to which resulting outcomes are said to be mostly unique.

Case 3: M+λ_1 < 1

Based on this particular case, there exists no kind of limitation in terms of making use of stable streaming "Casson fluid over a shrinking sheet, such that its similarity outcomes exist for any values of the mass transfer parameter, Casson parameter, porous parameter alongside its subsequent outcomes appear to be unique".

4. Home-based “Skin friction coefficient”

Various kinds of researchers have done work, which determines interest on physical quantity of “Skin friction co-efficient C_f, which are thereto mentioned through means of below expression-

$$c_f = \frac{\mu\left(1+\frac{1}{\beta}\right)}{\frac{1}{2}\rho u^2}\left(\frac{\partial U}{\partial y}\right)_{y=0} \qquad \dots (20)$$

Such that, it can be denoted for our work, through below highlighted form-

$$c_f = -(1+\frac{1}{\beta})f''(0) \qquad \dots (21)$$

5. RESULT AND DISCUSSIONS

By means of this paper, efforts have been made in undertaking work relating to- “Boundary layered MHD flow through Cassonian liquid dependent on a penetrable extending/contracting plate in relation permeable medium”, based on which various technical outcomes are being ascertained, through means of diverse expressions provided thereto, including- “Casson parameter β, magnetic parameter M, porous parameter λ_1, as well as suction/injection parameter s, respectively”. Further, for better clarity, certain diagrams are also provided which will help in estimating the outcomes.

6. STRETCHING PLATE SITUATION

For this case, it was observed that, changes in terms of velocity $f'(\eta)$ for diverse parameter of Cassonian values β is being highlighted through means of image-1, based on which its identified that magnitude of velocity tends to get reduce, through a subsequent enhancement in Cassonian parameter β resulting in decreasing the considered width of boundary layers, respectively.

Changes in terms of velocity $f'(\eta)$ for diverse variables of Cassonian values M having element of “mass injection S”, is being significantly highlighted in image-2, based on which its identified that magnitude of velocity tends to get reduce, through a subsequent enhancement in β resulting in decreasing the considered width of boundary layers, respectively.

Changes in terms of magnitude of velocity $f'(\eta)$ for diverse parameter of “magnetic attributes M with mass suction/injection”, are particularly highlighted through means of image-3 & 4, considerably, based on which its identified that magnitude of velocity tends to get reduce, as because of the presence of Lorentz force, being regarded as a mechanical force initiating as because of the interaction taking place amongst magnetic and electric fields for the motion of an electrically conduction fluid. As a result, its being considered that, such force tends to get enhanced at times wherein M enhances, thereby resulting in decreasing width of boundary layers gradually.

Changes in terms of magnitude of velocity $f'(\eta)$ in relation to diverse attributes of “porous parameter” λ_1 having “mass suction/injection S”, are thereby been highlighted based upon image-5 & 6, respectively. As a result, it is observed that- magnitude of velocity tends to get reduce, through a subsequent enhancement in λ_1, resulting in decreasing the considered width of boundary layers, respectively.

Further, it is observed that outcomes relating to home-based “skin friction coefficient” $f''(0)$ in comparison to “mass suction" for diverse variables of Cassonian values β is being highlighted through means of imge-7, from where it’s observed that resulting “skin friction coefficient tends to get diminished with a subsequent enhancement in $f''(0)$ respectively”.

Outcomes relating to home-based “skin friction coefficient” $f''(0)$ in comparison to “mass suction" for diverse variables of “Magnetic parameter M”, is being highlighted through means of imge-8, from where it’s observed that resulting “skin friction coefficient tends to get diminished with a subsequent enhancement in M, respectively”.

On a similar term, outcomes relating to home-based “skin friction coefficient” $f''(0)$in comparison to “mass suction" for diverse variables of “porous parameter λ_1”, is being highlighted through means of imge-9, based on which its ascertained that resulting “skin friction coefficient tends to get diminished with a subsequent enhancement in those permeable mediums, respectively”.

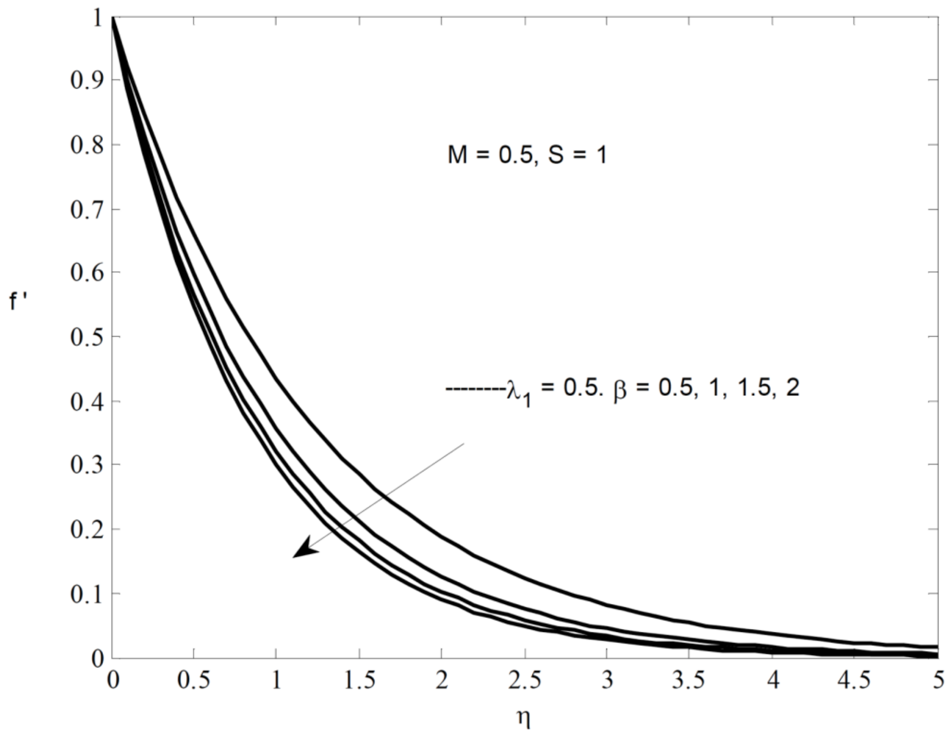

Image 1. Velocity attributes pertaining to diverse factors of β having mass suction

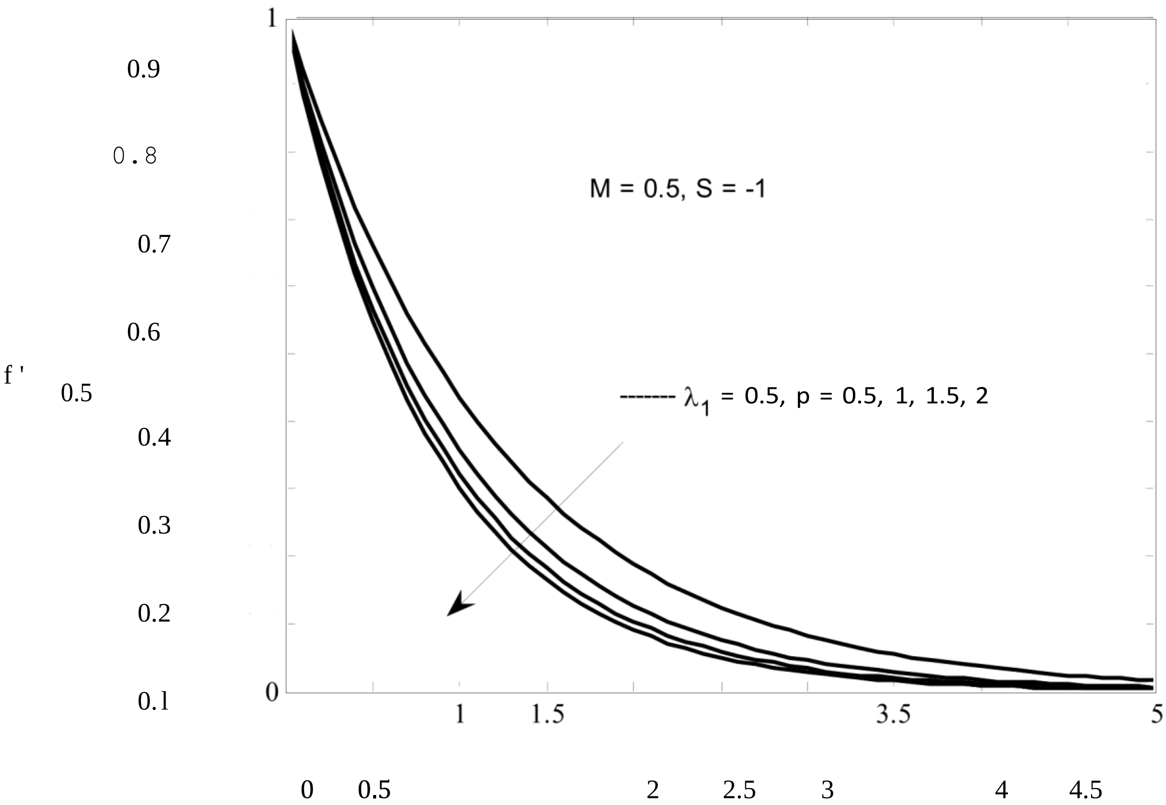

Image 2. Velocity attributes pertaining to diverse factors of β having mass injection

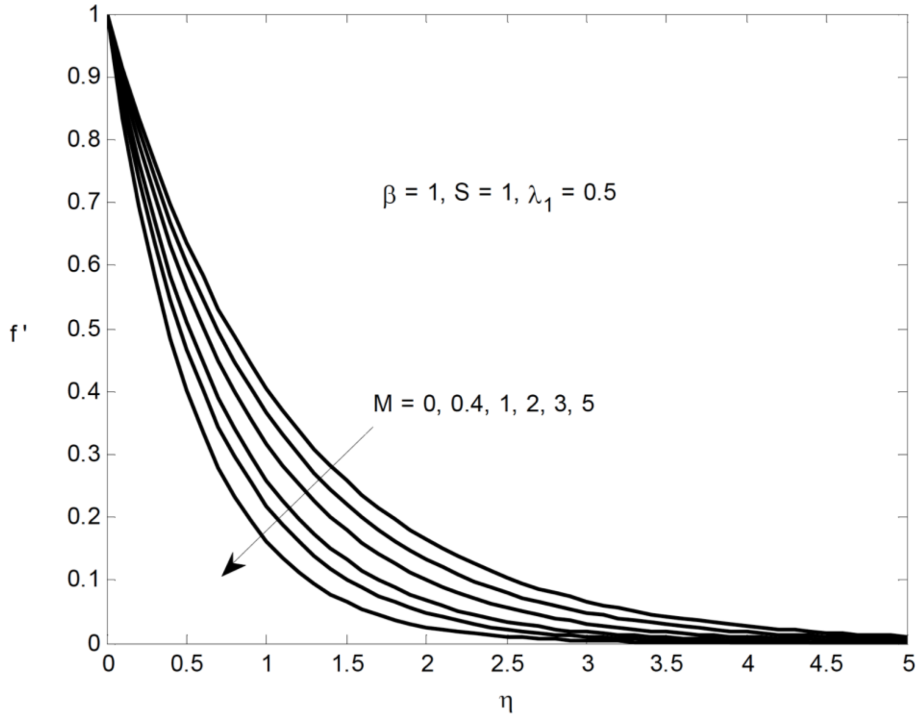

Image 3. Velocity attributes pertaining to diverse factors of M having mass suction

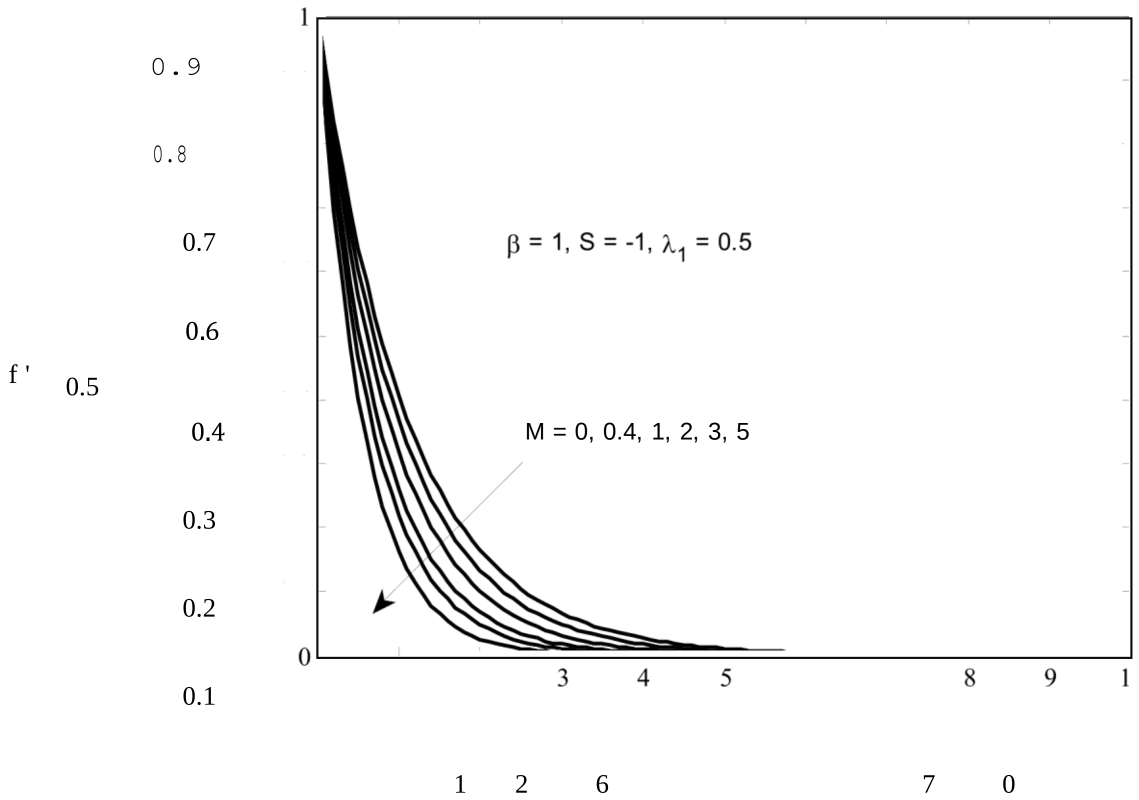

Image 4. Velocity attributes pertaining to diverse factors of *M* having mass injection

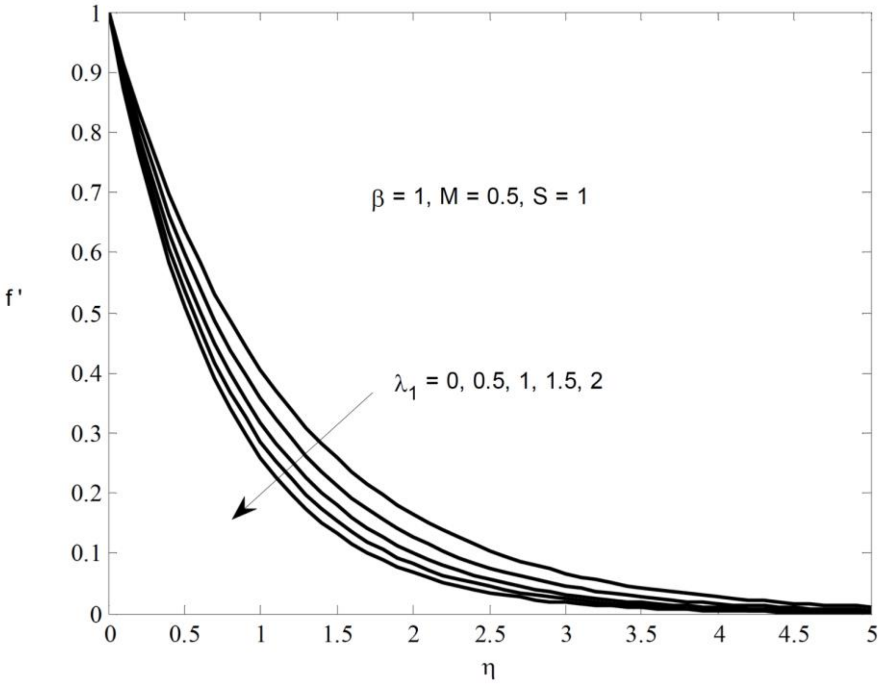

Image 5. Velocity attributes pertaining to diverse factors of λ_1 having mass suction

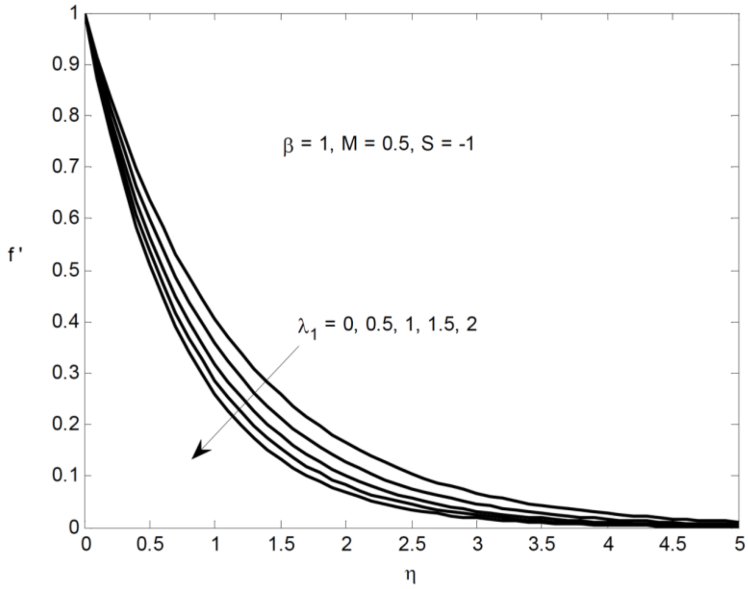

Image 6. Velocity attributes pertaining to diverse factors of λ_1 having mass injection

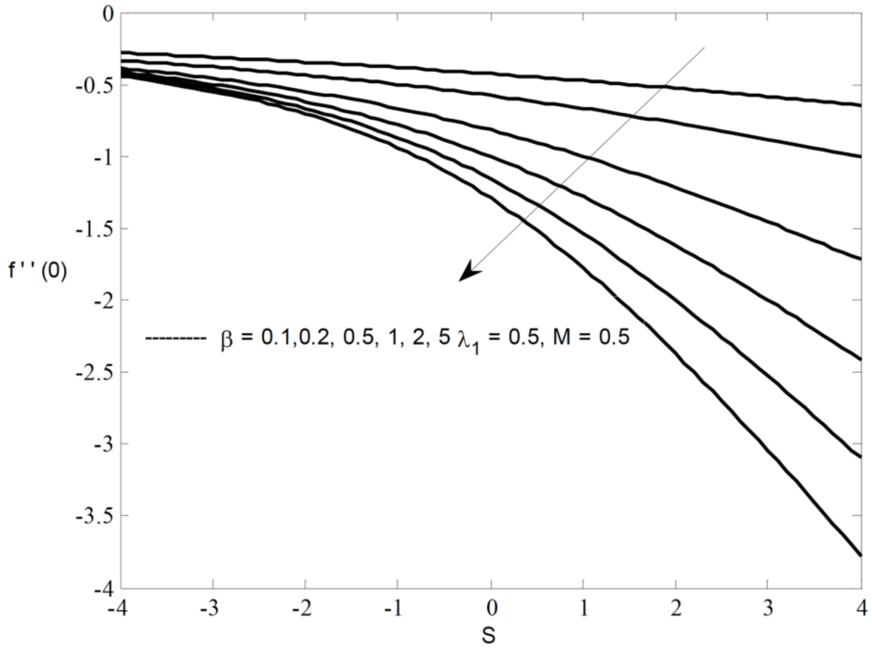

Image 7. Skin friction coefficient in comparison to S for varied factors of β

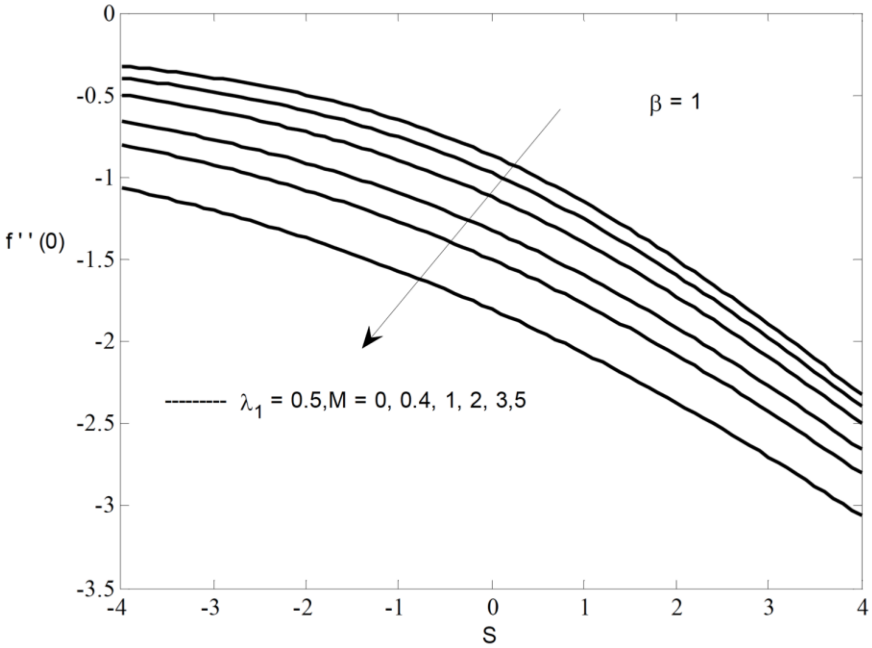

Image 8. Skin friction coefficient in comparison to S for varied factors of M

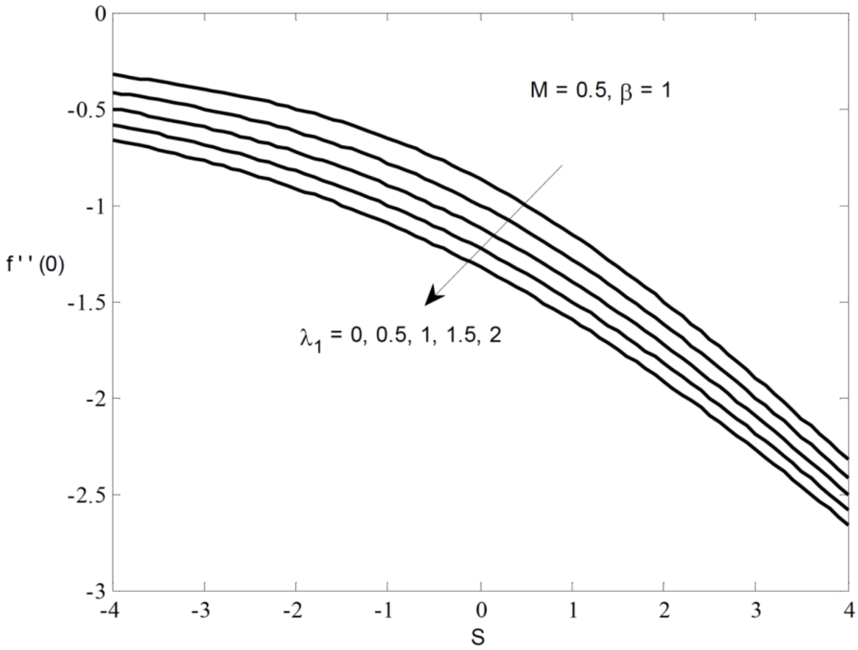

Image 9. Skin friction coefficient in comparison to S for varied factors of λ_1

7. Shrinking Plate situation-

Changes in terms of "velocity parameter $f'(\eta)$ for diverse variables of magnetic parameter M", is being significantly highlighted in image-10, based on which its identified that magnitude of velocity tends to get enhanced, through a subsequent uplift in values of "magnetic parameter M".

Changes in terms of "velocity parameter $f'(\eta)$ for diverse variables of Cassonian parameter β", is being significantly highlighted in image-11, based on which its identified that magnitude of velocity tends to get enhanced, through a subsequent enhancement in "Cassonian parameter". Further, changes in dual-velocity $f'(\eta)$attributes are thereby expressed in relation to varied factors of "Magnetic parameter M", respectively.

As a result, opposing outcomes pertaining to velocity attributes are thereby being highlighted through means of image-12.

Further, it is observed that changes relating to home-based "skin friction coefficient" $f''(0)$ in comparison to diverse variables of Cassonian values β is being highlighted through means of image-13, from where it's observed that resulting "skin friction coefficient tends to get enhanced with a subsequent enhancement in $f''(0)$ respectively".

Changes pertaining to home-based "skin friction coefficient" $f''(0)$ in comparison to λ_1, showing diverse variables of "porous parameter" is being highlighted through means of image-14, from where it's observed that resulting "skin friction coefficient" tends to get enhanced with a subsequent enhancement in permeable platform, respectively".

On a likewise manner, changes pertaining to home-based "skin friction coefficient" $f''(0)$in comparison to s, showing diverse variables of "Magnetic parameter M" is being highlighted through means of image-15, from where it's observed that resulting "skin friction coefficient" tends to get enhanced with a subsequent enhancement in M.

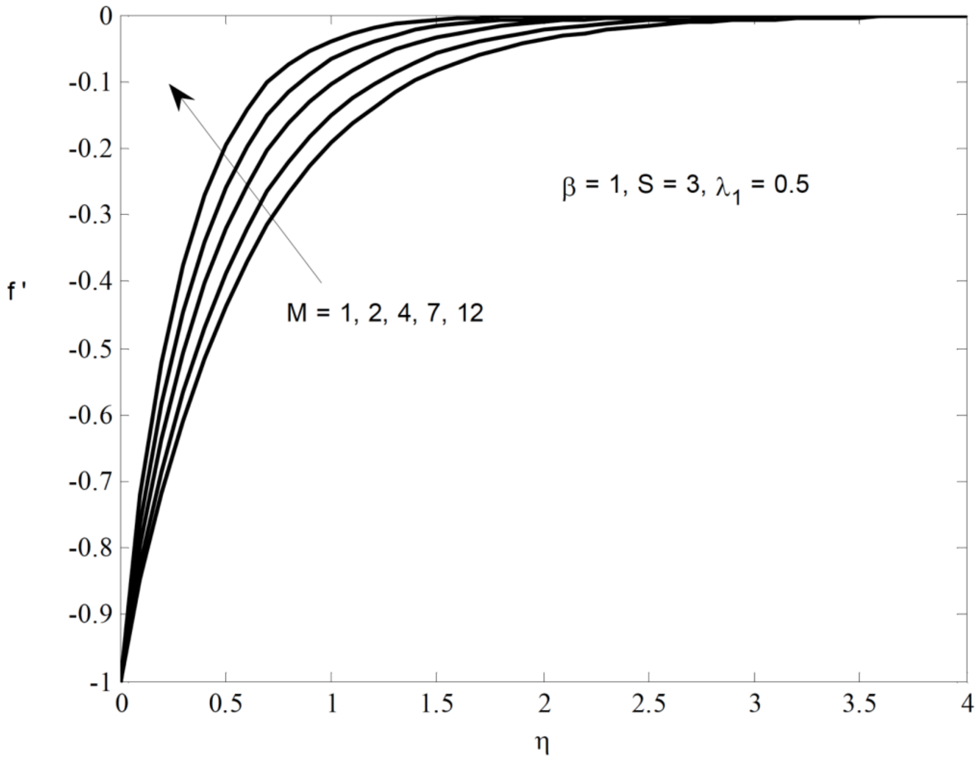

Image 10. Velocity attributes pertaining to diverse factors of M.

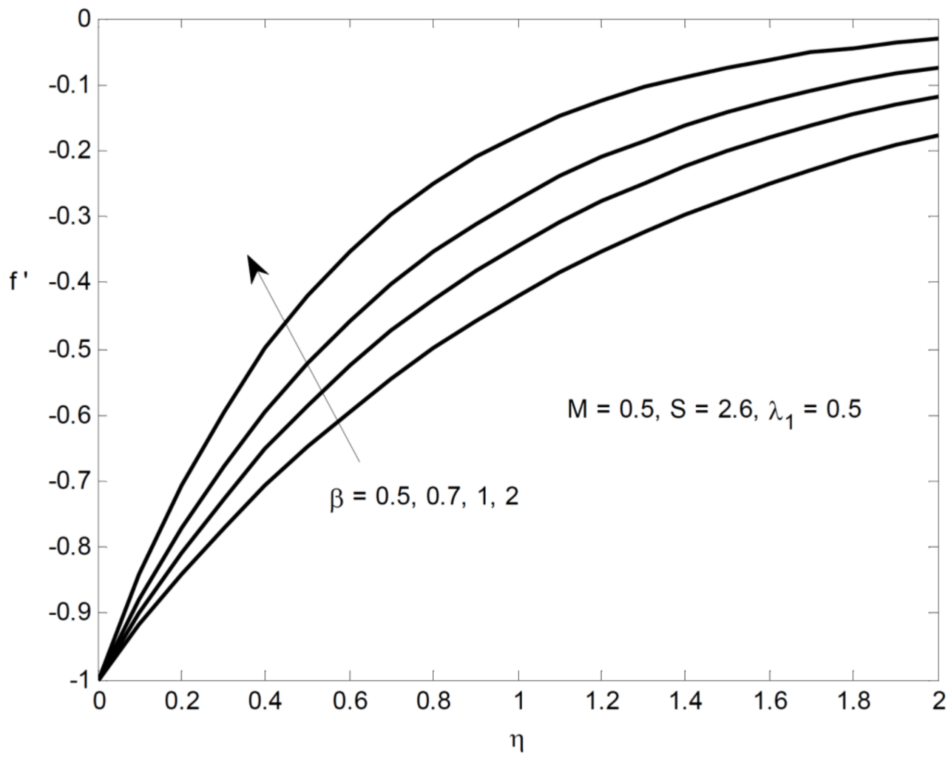

Image 11. Velocity attributes for varied factors of beta.

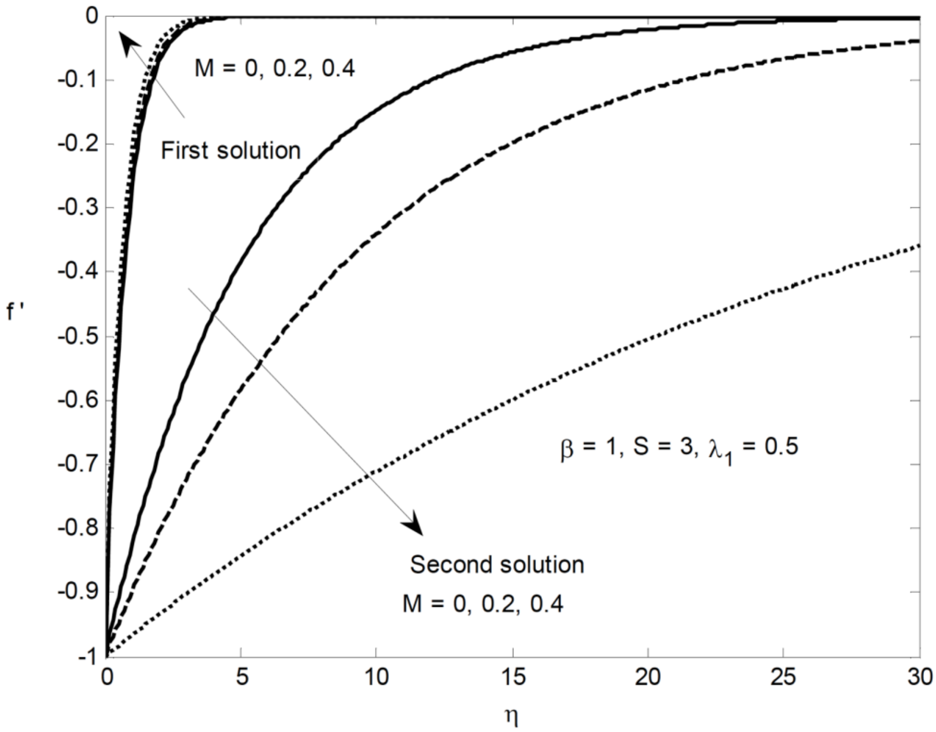

Image 12. Dual Velocity profile for varied factors of M.

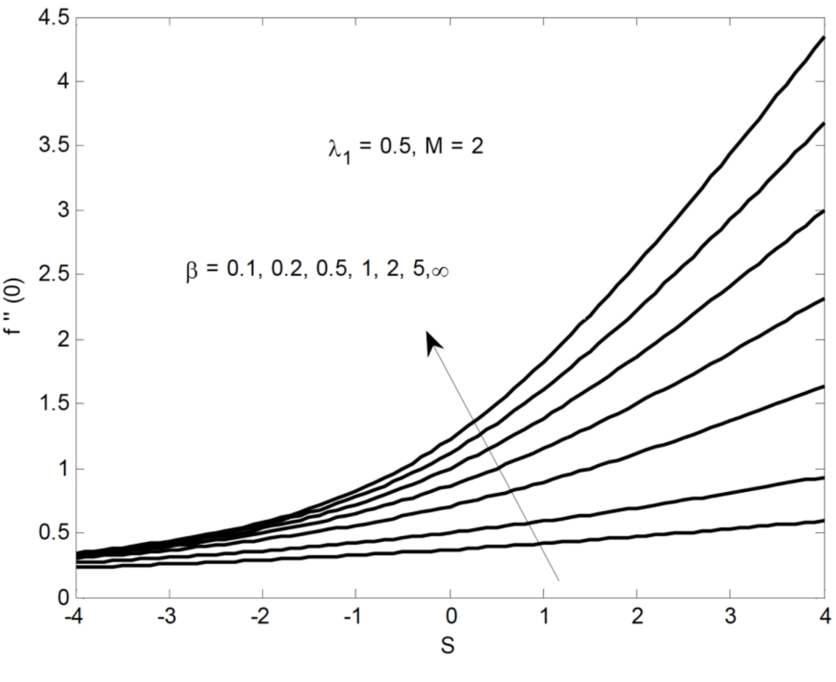

Image 13. Skin friction coefficient in comparison to S for varied factors of beta

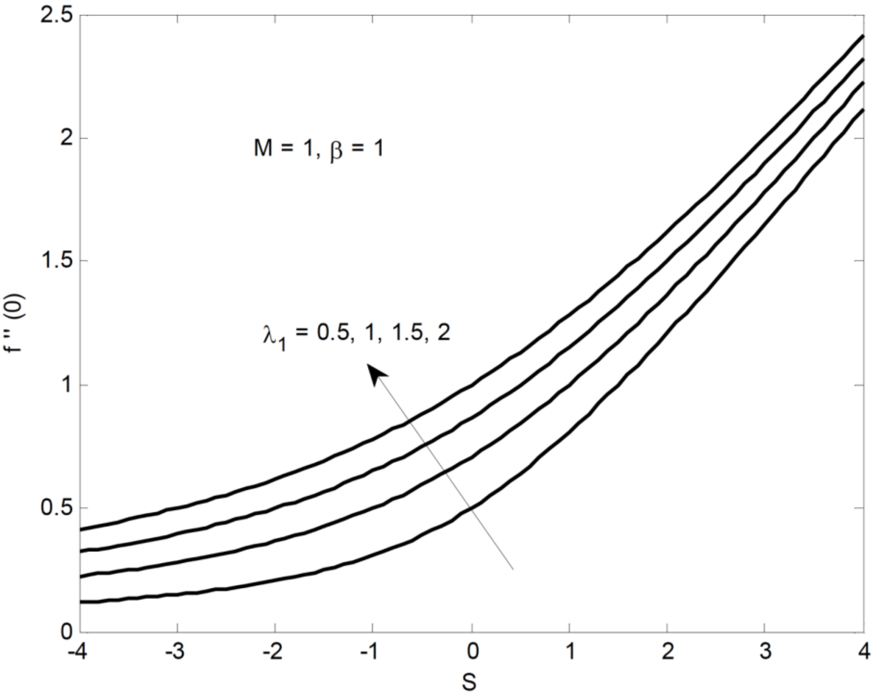

Image 14. Skin friction coefficient in comparison to S for varied factors of lambda

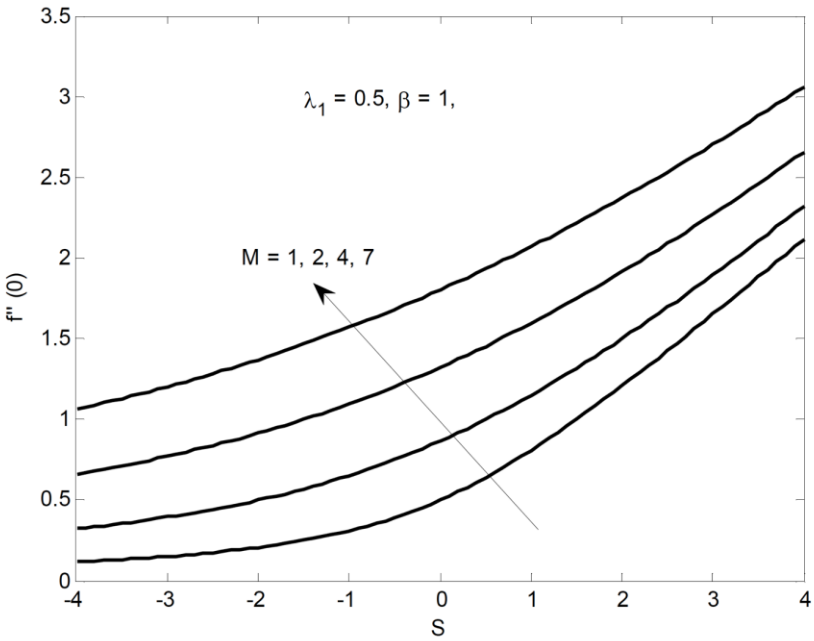

Image 15. Skin friction coefficient in comparison to S for varied factors of M

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