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How OHM and Viscous Dissipation Interact with MHD Jeffery Nanofluid Flow The Effect of Magnetic Dipoles

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ABSTRACT
A numerical investigation of a nanofluid called Jeffrey is carried out across a stretched sheet in the presence of a magnetic dipole effect, as well as the combined effects of viscous dissipation and ohmic heating. The original set of governing equations is simplified to a system of linked non-linear ordinary differential equations with appropriate boundary conditions by using the similarity transformation. By using the shooting and MATLAB bvp4c methods, the resultant equations are numerically solved. Previous research has explored the influence of several dimensionless factors on fluid velocity, temperature, and concentration, and these effects have been confirmed with a few limiting examples. For a variety of parameter values, we tabulate and analyze the skin friction coefficient and the local nusselts number numerically. The following terms are essential: Ohmic Heating, Jeffrey Nano Fluid, Viscous Dissipation, and Stretching Sheet.

INTRODUCTION
Due to its many uses in industrial and technical processes pertaining to electronic device cooling, the Jeffrey fluid model has recently attracted a lot of attention from researchers as a subclass of fluids. Recent decades have seen a rise in the number of applications using flows over stretched surfaces, such as cooling transformers, cooling silicon mirrors, cooling vehicles, regulating fussion, magnetic cell separation, and many more. The extrusion of metals and polymers, the drawing of plastic sheets, the coating of cables, the textile and paper industries, and many more produce these flows. The first investigation into flow caused by a moving surface was carried out by Sakiadis [1]. Crane investigates the flow produced by a stretched linear sheet [2].

In subsequent years, several researchers have examined stretched sheet flow in relation to other non-Newtonian fluids, as well as rotation, velocity, thermal slip conditions, heat and mass transfer, chemical reactions, MHD, suction/injection, and other non-Newtonian fluids. the numbers3,4,5,6,7,8,9,10, and 11 Nanoparticles, which are particles smaller than a nanometer, are contained in a fluid known as a nanofluid. These substances are synthetic nanoparticle suspensions in a base fluid.[12]Heat exchangers, electronic cooling systems (such flat plates), and radiators are some of the most common places you could see nanofluids employed as coolants due to their improved thermal characteristics [13].Nanofluids have unique characteristics that might find several uses in heat transfer [14],[15] An crucial process in high-speed fluid flow, viscous dissipation converts the work a fluid does on a neighboring layer as a result of shear forces into heat. This has a substantial impact on the fluid's internal temperature. Most researchers, like Hayat, have done some work on the heating impact of viscous dissipation and Ohmic heating, which is the process by

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which electrical energy is converted into heat when an electric current flows through a conductor. This phenomenon is particularly relevant when dealing with electrically conducting fluids, such as Jeffrey fluids. [16] Spherical porous rotating disks have been used to assess the sequential effects of viscous dissipation and Joule flow insulation. Radiative flow saturation of porous space is taken into account. Borisevich [17] investigated the flow of a time-dependent heat transfer disk in a uniformly strong electric field of velocities. The rate of heat transfer at the surface of the discs is tracked as a function of both the amplitude of the magnetic field and the speed at which the disks rotate, taking into account viscous dissipation and joule heating (ohmic heating). In osalusi, the effects of steady MHD in conjunction with viscous dissipation and joule heating (ohmic heating) are investigated [18].

MATHEMATICAL FORMULATION

The essential equations for Jeffrey fluid can be written as

$$\tau = -pl + \mathrm{E} \quad (1)$$

$$\mathrm{E} = {}^{\mu} R$$

Where E is the extra stress tensor, τ is the Cauchy stress tensor, $\lambda_1$and $\lambda_2$are thematerial parameters of Jeffrey fluid and R_1 is the Rilin -Ericksen tensor defined by

$$R_1 = (\nabla V) + (\nabla V)'$$

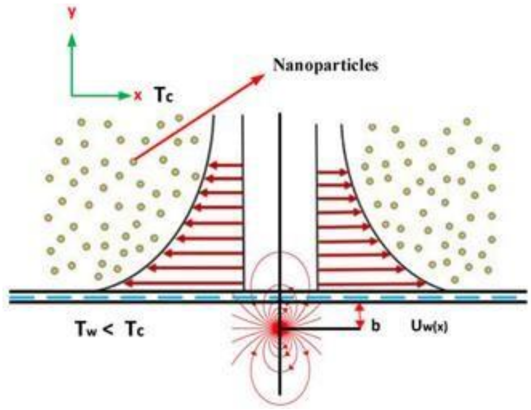

Fig 1 The physical model of the flow problem and coordinate system

Combined Effect of Viscous Dissipation and Ohmic Heating on Mhd Jeffrey Nanofluid Flow with Magnetic Dipole Effect

A steady two-dimensional incompressible, electrically conducting Jeffrey fluid over a linear stretching sheet in the presence of chemical reaction, thermal radiation and heat source flow is generated, due to linear stretching of the sheet, caused by simultaneous application of two equal and opposite forces along the *x*-axis and *y*-axis is taken normal to it. Theorigin is fixed as shown in Fig. 1.

The temperature and the species concentration have power index *m* variations with the distance from the origin. At $t = 0$, the sheet is impetuously stretched with the variable velocity $U_w(x)$.

Under these assumptions the governing equation of continuity and momentum take the

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following form

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \quad (3)$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\frac{u}{1+\lambda_1}\left[\frac{\partial^2 u}{\partial y^2}+\lambda_2\left(u\frac{\partial^3 u}{\partial x\partial y^2}+v\frac{\partial^3 u}{\partial y^3}-\frac{\partial u}{\partial x}\frac{\partial^2 u}{\partial y^2}+\frac{\partial u}{\partial y}\frac{\partial^2 u}{\partial x\partial y}\right)\right]+\frac{\mu_0}{\rho}M\frac{\partial H}{\partial x} \quad (4)$$

Where u, v are the velocity components in the x and y direction, respectively, u is the kinematic viscosity, λ_1 is the ratio of relaxation and retardation time, λ_2 is the relaxation time.the magnetic liquid flow under the influence of dipole field whose permanent magnetic scalar potential is taken as

$$\gamma = \frac{x}{2\pi\,(x^2+(y+a)^2)}$$

The resultant magnitude of H of the magnetic field intensity is given by

$$H=\sqrt{\left[\left(\frac{\partial}{\partial x}\right)^2+\left(\frac{\partial}{\partial y}\right)^2\right]}$$

$$\frac{\partial H}{\partial x}=-\frac{\gamma}{2\pi}\left(\frac{2x}{(y+a)^4}\right)$$

$$\frac{\partial H}{\partial y}=-\frac{\gamma}{2\pi}\left(\frac{-2}{(y+a)^3}+\overline{(y+a)}\right)$$

$$f'''+(1+\lambda_1)(ff''-f'^2)+\beta(f''^2-ff^{iv})-(1+\lambda_2)\frac{2\beta_1}{(y+\alpha_1)^4}=0 \quad (14)$$

The variation of magnetization M can be considered as a linear function of temperature [26],$M=K^*(T_c-T)$, where K^* is a pyromagnetic coefficient and T_c is the Curie temperature, however, the following point is essential for the occurance of ferrohydrodynamic interaction.
By using Rosseland diffusion approximation the radiative heat flux q_r is given by
T^4can be expressed as linear function of temperature.

$$T^4 \approx 4T_\infty^{3}T-3T_\infty^{4} \quad (7)$$

On solving (6) (7) and (5) we get

$$\frac{\partial q_r}{\partial y}=-\frac{16\sigma^*T_\infty^{3}}{3K_s}\frac{\partial^2 T}{\partial y^2} \quad (8)$$

We introduce a dimensionless temperature variable $\theta(\xi)$ of the form $\theta(\xi)=\frac{T-T_\infty}{T_w-T_\infty}$

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(9)

The first order chemical reaction with concentration diffusion of the laminar boundary layer flow is given as

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D\frac{\partial^2 C}{\partial y^2} - Kr^*(C - C_\infty) \quad (10)$$

Where D is the diffusion coefficient $Kr^*$is the chemical reaction parameter

We introduce a dimensionless temperature variable $\emptyset(\xi)$ of the form

$$\emptyset(\xi) = \frac{C - C_\infty}{C_w - C_\infty} \quad (11)$$

Boundary Conditions:

The following boundary conditions on velocity, temperature and concentration are appropriate in order to employ the effect of stretching of the boundary surface causing flow in x-direction as

$$u = U_w(x) = cx, v = 0 \; at \; y = 0$$

$$u \to 0, u' \to 0 \; as \; y \to \infty$$

$$T = T_w = T_\infty + A_1 \left(\frac{x}{l}\right)^m \quad \text{at y=0}$$

$$T \to T_\infty \text{as } y \to \infty$$

$$C = C_w = C_\infty + A_2 \left(\frac{x}{l}\right)^m \quad \text{at y=0}$$

$C \to C_\infty$ as $y \to \infty$ (12)

Where A_1, A_2 are constants, l is the characteristic length, m is the surface temperature parameter, T_w is the stretching sheet temperature, C_w *and* C_∞ are the concentration at the wall and far away from the wall, resp.

The following similarity transformations are introduced to solve equation (4) (5) and (10)

$$u = cxf'(\xi), v = -\sqrt{cu}f(\xi) \ \ where \ \xi = \sqrt{^{c}}\ y \quad (13)$$

u

Where ξ is the similarity variable and $f(\xi)$ is the dimensionless stream function

Substituting eq (13) in eq (4) (5) and (10) we obtain second and fourth order ordinary differential equations as follows Combined Effect of Viscous Dissipation and Ohmic Heating on Mhd Jeffrey Nanofluid Flow withMagnetic Dipole Effect

$$(1 + \frac{4R}{3})\,\theta'' + \Pr(f\theta' - Nb'\theta' + Nt\theta'^2 + Ec(f''^2 + Mf'^2)) = 0 \quad (15)$$

$$\phi'' + Sc(f\phi' - mf'\phi - Kr\phi) = 0 \quad (16)$$

With boundary conditions (12) takes the form:

$$f(\xi) = s, f'(\xi) = 1 \ at\ \xi = 0; f'(\xi) = 0, f''(\xi) = 0 \ as\ \xi \to \infty$$

$$\theta(\xi) = 1 \ at\ \xi = 0 \ ; \ \theta(\xi) = 0 \ as\ \xi \to \infty$$

$$\phi(\xi) = 1 \ at\ \xi = 0 \ ; \ \phi(\xi) = 0 \ as\ \xi \to \infty \quad (17)$$

Where $\beta = \lambda_2 c$ is the Deborah number ,$R = \frac{4\sigma^* T_\infty{}^3}{K_s}$ the radiation parameter,

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$Pr = \frac{\rho c_p}{k}$ the Prandtl number , $\gamma = \frac{Qu}{\rho c_p}$ is a heat source parameter, $Sc = \frac{u}{D}$ is the Schmidt number and $Kr = \frac{Kr^{*}\delta^2}{u}$ is the chemical reaction parameter, $s = \frac{-v_w}{\sqrt{cu}}$ is the parameter with s>0.

The system of non -linear ordinary differential equations (14) (15) (16) with the boundary conditions (17) are converted to ordinary differential equations using shooting method and using MATLAB bvp4c the numerical solution is obtained, thus the fourth order and second order equations are reduced to system of simultaneous equations of order one.

$$f = y(1), f' = y(2), f'' = y(3), f''' = y(4)$$

$$\theta = y(5), \theta' = y(6)$$

$$\phi = y(7), \phi' = y(8) \quad (18)$$

Substituting these in (14)(15)(16) and (17) we have

$$y(4) + (1+\lambda)(y(1)y(3) - y(2)^2) + \beta(y(3)^2 - y(1)f^{iv}) = 0 \quad (19)$$

$$\theta''\left(1 + \frac{4}{3R}\right) - Pr(y(1)y(6) - my(2)y(5) + \gamma y(5)) = 0 \quad (20)$$

$$\phi'' - Sc(my(2)y(7) + Kry(7) - y(1)y(8)) = 0 \quad (21)$$

With boundary conditions

$$y_0(1) = 1, y_0(2) = 1;\ y_\infty(2) = 0, y_\infty(3) = 0; y_0(5) = 1, y_\infty(5) = 0; y_0(7) = 1, y_\infty(7) = 0;$$

Equations (19)(20)(21) are reduced to eight simultaneous equations of first order as follows

$$y'(1) = y(2)$$

$$y'(2) = y(3)$$

$$y'(3) = y(4)$$

$$y'(4) = (y(4) - (1+\lambda_1)(y(2)^2 - y(1)y(3)) + \beta y(3)^2 + (1+\lambda_1)((2\gamma_1 P_1)/(\eta + \alpha_1)^4)/(\beta y(1)) \quad (22)$$

$$y'(5) = y(6)$$

$$y'(6) = -(3Pr/(3 + 4R))(Nby(8)y(6) - Nty(6)^2 + y(1)y(6) + Ec(y(3)^2 + My(2)^2)) \quad (23)$$

$$y'(7) = y(8)$$

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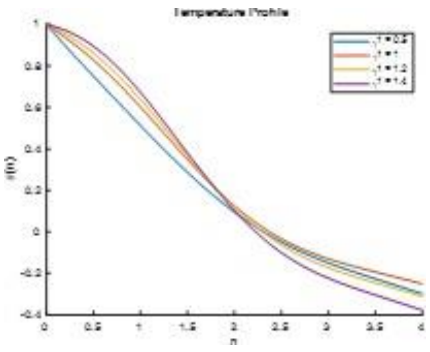
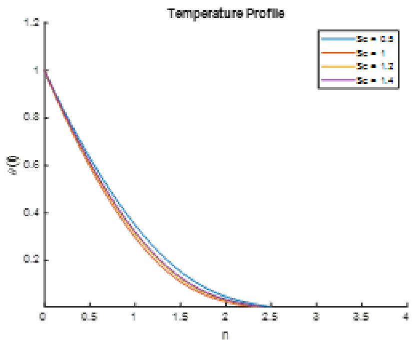
$$y'(8) = Sc(my2y7 + Kry7 - y1y8) \quad (24)$$

The governed equations are solved numerically using MATLAB using bvp4c





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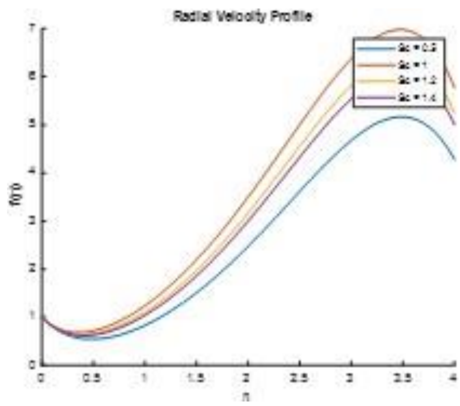

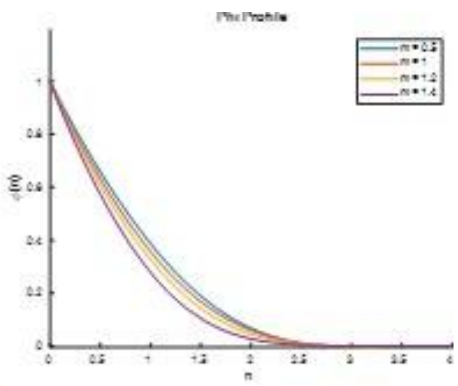

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