Mathematical Analysis of Radiating Viscoelastic Unsteady MHD Fluid Flow through an Absorbent Media between Upstanding Equidistant plates with Joule Heating Impact

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Abstract. Focus of the present study is to explore Joule heating effect on incompressible, radiating, electrically conducting viscoelastic unsteady magnetohydrodynamic fluid and heat transfer through an absorbent media between upstanding equidistant plates with constant suction and slip condition. Lorentz force and Joule heating is discussed by momentum and energy equation respectively. Electric conductivity and the electromagnetic force both are in very small case in fluid flow. A consistent magnetic field is taking to perpendicular to the plane of the plates. The oscillatory time-dependent coupled equations (non-linear) are simplified to provide result for the fluid velocity and heat transfer by using structured perturbation execution. It has been noticed that velocity and heat transfer rise due to rise in Grashof number, Eckert number, heat source parameter or slip parameter while decrease as permeability parameter, radiation parameter or wavelength rises. As Hartmann number rises the fluid velocity diminishes, while opposite behaviour is noted in case of heat transfer effect. The velocity and heat transfer impact of the fluid rise with cross flow Reynolds parameter or frequency of the oscillation. Numerical outcomes for the motion and heat transpose effect profiles for multiples physical numbers also the local skin friction coefficient and spot Nusselt number are argued numerically, presented graphically along with.

1. Introduction
Magnetohydrodynamic flow and temperature distribution between equidistant plates has extensive implementation in synthetic engineering, metallurgical engineering, and various industries. Because of its significance in industry, flow problem and heat transfer distribution in absorbent media in the existence of magnetic field has been the subject of many investigational and analytical studies. Scientists have considerable attention in the learning of flow circumstance between two equidistant plates, due to its development in rheumatic applications to calculate the fundamental effects of the fluid, in lubricator engineering, and in transport engineering, etc. It is of great practical importance in opinion of numerous physical snags such as underground liquid resources, seepage of water in riverbeds, absorbent heat exchangers, cooling of nuclear reactors, filtration and purification processes.
Magnetohydrodynamic has important application in research and technology. It has many submissions in magnetohydrodynamic power cohort, cosmological and weather-related studies, plasma flow through magnetohydrodynamic power generators.

Flow of a viscous fluid which is not compressible through equidistant plates in which one is on resettlement and another is at rest, Verma and Bansal [1]. Derivative approximation for radiative transverse near equipoise in a non-Gray gas, Cogley, Vincenti and Gill [2]. Magneto fluid dynamics of Viscous Fluids discussed Bansal [3]. Magnetohydrodynamic flow with heat transfer distribution through channel problem, Attia and Kotb studied [4]. Magnetic field outcomes on the free convection and mass transfer flow concluded absorbent media with sustained suction and incessant heat flux Acharya, Dash and Singh investigated [5]. Computational Fluid Dynamics by Chung [6]. Unsteady flow and heat transfer distribution of an electrically conducting adhesive incompressible fluid b/w two non-conducting equidistant absorbent plates under consistent transversal magnetic field Sharma and Chaturvedi [7]. Heat transfer to magnetohydrodynamic fluctuating flow through in-between plates in the existence of absorbent media Makinde and Mhone [8]. Steady laminar movement and warmness transference distribution of a non-Newtonian fluid through a lineal horizontal absorbent network in the company of heat source, Sharma, Gaur and Sharma [9]. magnetohydrodynamic unsteady slip flow and heat transfer distribution through equidistant plates with slip at the permeable partitions Sharma and Mehta [10]. Unsteady magnetohydrodynamic convection flow within an equidistant dish circling channel with thermal source/sink in a permeable media under slip-up border conditions, Seth, Nandkeolyar and Ansari [11]. Unsteady magnetohydrodynamic convective flow and heat transfer between heated disposed plates with alluring field and radiation effects Sharma, Kumar, and Sharma analysed [12]. Instable heat transfer to magnetohydrodynamic oscillatory current through an absorbent media under slip ailment Hamza, Isah and Usman [13]. Unsteady hydro-magnetic shuddering flow past an absorbent media with suction/injection and with slip effects Pal and Talukdar [14]. Unsteady MHD transmission heat and mass transfer departed an endless upstanding panel in an absorbent media with thermal radiation also with heat generation/absorption and chemical reaction Shateyi and Motsa [15]. Singh obtained solution of magnetohydrodynamic oscillatory convection flow through absorbent media in an upstanding absorbent equidistant plate in slip flow regime [16]. Mao, Aleksandrova, and Molokov analyzed Joule heating system in magnetohydrodynamic movements in canals with narrow conducting walls [17]. Sharma and Dadheech explained result of major heat generation/absorption on convective heat and mass transfer in absorbent media in amid two upstanding plates [18]. Magnetohydrodynamic oscillatory flow of a viscoelastic fluid in an absorbent equidistant passage with chemical reaction Devika, Satya Narayana and Venkataramana [19]. Things of radiation and able convection currents on Couette flow which is not steady b/w two upstanding equidistant plates with fixed heat flux and heat source through absorbent media Kesavaiah, Satyanarayana and Sudhakaraiah [20]. Magnetohydrodynamic flow which is not steady of a Casson fluid in an equidistant passage with heat transfer and mass transfer Kirubhashankar and Ganesh [21]. Sheikholeslami et al. [22] investigated effect of thermal radiation on magnetohydrodynamics nanofluid flow and heat transfer by means of two-phase model. Zin et al. [23] described Influence of thermal radiation on unsteady MHD free convection flow of Jeffrey fluid over a vertical plate with ramped wall temperature. Boundary layer flow of MHD generalized Maxwell fluid over an exponentially accelerated infinite vertical surface with slip and Newtonian heating at the boundary explained by Imran et al. [24]. Significance of temperature dependent viscosity, nonlinear thermal radiation, and viscous dissipation on the dynamics of water conveying cylindrical and brick shaped molybdenum desulphated nanoparticles elaborated by Gireesha et al. [25]. Jha and Samaila [26] explained Thermal radiation effect on boundary layer over a flat plate having convective surface boundary condition. Haq et al. [27] investigated Heat and mass transfer of fractional second grade fluid with slippage and ramped wall temperature using Caputo-Fabrizio fractional derivative approach.

Goal of the present analysis is to inspect Joule heating conclusion on incompressible, electrically conducting, radiating viscoelastic unsteady magnetohydrodynamic fluid movement and heat transfer through an absorbent media between upstanding equidistant plates with constant suction and slip.
condition. Equations of momentum (law of conservation of momentum) and energy, which administrate the fluid flow and heat transfer are answered by structured perturbation execution. The effects of several physical non-dimensional numbers on fluid velocity, heat transfer, skin friction coefficient and Nusselt number at the plates are derived, discoursed mathematically, and shown graphically.

2. Mathematical Analysis

In this paper considerations are

(i) The instable magnetohydrodynamic oscillatory, viscoelastic, incompressible and electrically conducting fluid flow through an absorbent media embedded by upstanding equidistant plates at a distance \(d\) apart in the existence of continual suction and heat transfer gradient dependent heat source.

(ii) Along the plate (when upstanding axis \(y^* = 0\)) horizontal axis \(x^*\) is taken and the normal to the dish vertical axis \(y^*\) is taken

(iii) Since the plates occupying the planes \(y^* = 0\) and \(y^* = d\) are of endless extent, all the physical quantities depend on \(y^*\) and \(t^*\) only.

(iv) In the normal direction of the plate a diagonal magnetic field of consistent strength \(B_0\) is applied.

(v) The induced magnetic field is neglected by the assumption that the magnetic Reynolds number is small.

Figure 1. Physical Model

Under the above expectations, Boussinesq guesstimate & Joule effect, the governing equations of motion and energy are as ensues.

\[
\frac{\partial v^*}{\partial y^*} = 0, \quad (1)
\]

\[
\frac{\partial u^*}{\partial t^*} + v^* \frac{\partial u^*}{\partial y^*} = -\frac{1}{\rho} \frac{\partial P^*}{\partial x^*} + \nu \frac{\partial^2 u^*}{\partial y^*^2} + \frac{K_0}{\rho} \frac{\partial^3 u^*}{\partial y^*^3} + g \beta_T (T^* - T_0)
\]
\[-\frac{\sigma_e B_0^2}{\rho} u^* \frac{\partial u^*}{\partial t} - \frac{\nu}{K^*} u^*, \quad (2)\]

\[\frac{\partial T^*}{\partial t} + \nu \frac{\partial T^*}{\partial y^*} = \frac{\kappa}{\rho C_p} \frac{\partial^2 T^*}{\partial y^*^2} - \frac{1}{\rho C_p} \frac{\partial q_r}{\partial y^*} + \frac{Q_0}{\rho C_p} \frac{\partial T^*}{\partial y^*} + \frac{\sigma_e B_0^2}{\rho C_p} u^* \frac{\partial u^*}{\partial y^*} , \quad (3)\]

where \(u^*\) and \(v^*\) velocity elements of fluid in horizontal and vertical commands, \(t^*\) time, \(T^*\) fluid heat transfer, \(P^*\) fluid pressure, \(\beta_r\) coefficient of the thermal extension, \(\nu\) kinematic viscosity, \(B_0\) asset of the magnetic field, \(\sigma_e\) electric conductivity, \(K_0\) viscoelastic parameter, \(\rho\) fluid density, \(K^*\) permeability of absorbent media, \(\kappa\) thermal conductivity, \(C_p\) specific heat when pressure is constant, \(q_r\) radiative heat flux along with \(y^*-\)direction, \(Q_0\) heat generation/absorption constant.

The settings at boundaries are arranged by

\[y^* = 0: u^* = U^* \frac{\partial u^*}{\partial y^*}, \quad T^* = T_0; \]

\[y^* = d: u^* = 0, \quad T^* = T_w + \varepsilon(T_w - T_0) \cos \omega t^*. \quad (4)\]

From the equation (1), here suction velocity is constant or function of time only. Here, the suction velocity perpendicular to the plate is putative as \(v^* = V_0\).

It is also putative that the fluid is optically dilute with a relative short density and radiative heat flux is according to Cogley et al. (1968) and given by

\[\frac{\partial q_r}{\partial y^*} = 4\alpha^2(T^* - T_0). \quad (6)\]

Familiarizing the next dimensionless quantities

\[u = \frac{u^*}{U_0}, \quad x = \frac{x^*}{d}, \quad y = \frac{y^*}{d}, \quad t = \frac{t^* \nu}{d^2}, \quad \omega = \frac{\omega^* \nu}{d}, \quad P = \frac{d}{\nu \rho U_0} \frac{p^*}{P^*}, \quad \theta = \frac{T^* - T_0}{T_w - T_0}, \quad \text{Re} = \frac{V_0 d}{\nu}, \]

\[\gamma = \frac{K_0}{\rho d^2}, \quad Gr = \frac{g \beta_r d^2 (T_w - T_0)}{\nu U_0}, \quad Ha = \frac{\sigma_e B_0^2 d^2}{\kappa}, \quad K^* = \frac{d^2}{K^*}, \quad Pr = \frac{\nu C_p}{\kappa}, \quad R^2 = \frac{4\alpha^2 d^2}{\nu C_p}, \]

\[S = \frac{Q_0 d^2}{\nu C_p}, \quad Ec = \frac{U_0^2}{C_p (T^*_w - T_0)}, \quad L = \frac{U_0}{d} L^*. \quad (7)\]

into the equations (2) to (3), we become

\[\frac{\partial \theta}{\partial t} + \text{Re} \frac{\partial \theta}{\partial y} = -\frac{\partial P}{\partial x} + \frac{\partial^2 \theta}{\partial x^2} + \frac{\gamma}{\text{Re}} \frac{\partial^2 \theta}{\partial y^2} + Gr \theta - (Ha^2 + K^2) \theta, \quad (8)\]

\[\frac{\partial \theta}{\partial t} + \text{Re} \frac{\partial \theta}{\partial y} = \frac{1}{\text{Pr}} \frac{\partial^2 \theta}{\partial y^2} - R^2 \theta + S \frac{\partial \theta}{\partial y} + Ha^2 Ec u^2, \quad (9)\]

Where, \(u\) is dimensionless velocity along \(x\)-axis, \(t\) the dimensionless time, \(y\) nondimensional coordinate rachis to the plates, \(\theta\) dimensionless heat transfer, \(P\) dimensionless fluid pressure, \(Gr\) Grashof number, \(\text{Re}\) cross flow Reynolds number, \(Ha\) Hartmann number, \(K\) permeability parameter, \(\gamma\) Visco-elastic parameter, \(\text{Pr}\) Prandtl number, \(R\) Radiation parameter, \(S\) heat source parameter and \(Ec\) Eckert number.

The non-dimensional boundary cases are given by
\[ y = 0 : u = \frac{\partial u}{\partial y}, \theta = 0; \]
\[ y = 1 : u = 0, \theta = 1 + \varepsilon \cos \omega \xi. \]  
where \( h \) is the slip parameter.

3. System of Solution

In order to crack equations (8) and (9) under the borderline conditions (10), assuming.
\[ \frac{\partial P}{\partial x} = \lambda e^{i\omega \xi}, \]
\[ u(y,t) = u_0(y) + \varepsilon e^{i\omega \xi} u_1(y) + \text{higher order terms}, \]
\[ \theta(y,t) = \theta_0(y) + \varepsilon e^{i\omega \xi} \theta_1(y) + \text{higher order terms}. \]

Using (11) into the equations (8) and (9), equating the multiplier of the harmonically and non-harmonically equal terms and abstain from the multiplier of \( \varepsilon^2 \), we obtain
\[ \frac{d^2 u_0}{dy^2} - Re \frac{du_0}{dy} - a_4 u_0 = -Gr \theta_0, \]  
(12)
\[ \frac{d^2 u_1}{dy^2} - a_8 \frac{du_1}{dy} - a_9 u_1 = a_{10} + a_{11} \theta_1, \]  
(13)
\[ \frac{d^2 \theta_0}{dy^2} + a_4 \frac{d\theta_0}{dy} - a_5 \theta_0 = -Pr Ha^2 Ecu_0^2, \]  
(14)
\[ \frac{d^2 \theta_1}{dy^2} + a_4 \frac{d\theta_1}{dy} - a_6 \theta_1 = -2Pr Ha^2 Ecu_0 u_1, \]  
(15)

where \( a_4 = Pr(S - Re), \ a_5 = Pr R^2, \ a_6 = Pr(R^2 + i\omega), \ a_7 = (Ha^2 + K^2), \ a_8 = \frac{Re}{(1 + i\gamma \omega)}, \ a_9 = \frac{(Ha^2 + K^2 + i\omega)}{(1 + i\gamma \omega)}, \ a_{10} = \frac{\lambda}{(1 + i\gamma \omega)}, \ a_{11} = -\frac{Gr}{(1 + i\gamma \omega)}. \)

Now, the equivalent boundary cases are reduced to
\[ y = 0 : u_0 = h \frac{du_0}{dy}, u_1 = h \frac{du_1}{dy}, \theta_0 = 0, \theta_1 = 0; \]
\[ y = 1 : u_0 = 0, u_1 = 0, \theta_0 = 1, \theta_1 = 1. \]  
(16)

The equations (12) to (15) are still coupled ordinary second order differential equations. Since the \( Ec \) is very small for incompressible fluid flows, therefore \( u_0, \ u_1, \ \theta_0, \) and \( \theta_1 \) can be extended in the powers of \( Ec \) as given below
\[ F = F_0 + Ec F_1 + O(Ec^2), \]  
(17)
where \( F \) stands for \( u_0, u_1, \theta_0 \) and \( \theta_1 \).

Substituting (17) into the equations (12) to (15), equating the coefficients of alike powers of \( Ec \) and ignoring terms of \( O(Ec^2) \), we get
Zeroth order equations
\[ \frac{d^2 u_{00}}{dy^2} - \text{Re} \frac{du_{00}}{dy} - a_7 u_{00} = -Gr \theta_{00}, \]  
(18)

\[ \frac{d^2 u_{10}}{dy^2} - a_8 \frac{du_{10}}{dy} - a_9 u_{10} = a_{10} + a_{11} \theta_{10}, \]  
(19)

\[ \frac{d^2 \theta_{00}}{dy^2} + a_4 \frac{d\theta_{00}}{dy} - a_5 \theta_{00} = 0, \]  
(20)

\[ \frac{d^2 \theta_{10}}{dy^2} + a_4 \frac{d\theta_{10}}{dy} - a_6 \theta_{10} = 0, \]  
(21)

First order equations

\[ \frac{d^2 u_{01}}{dy^2} - Re \frac{du_{01}}{dy} - a_7 u_{01} = -Gr \theta_{01}, \]  
(22)

\[ \frac{d^2 u_{11}}{dy^2} - a_8 \frac{du_{11}}{dy} - a_9 u_{11} = a_{10} + a_{11} \theta_{11}, \]  
(23)

\[ \frac{d^2 \theta_{01}}{dy^2} + a_4 \frac{d\theta_{01}}{dy} - a_5 \theta_{01} = -Pr Ha^2 u_{00}^2, \]  
(24)

\[ \frac{d^2 \theta_{11}}{dy^2} + a_4 \frac{d\theta_{11}}{dy} - a_6 \theta_{11} = -2Pr Ha^2 u_{00} u_{10}, \]  
(25)

Now, the relating boundary conditions are converted to

\[ y = 0: u_{00} = h \frac{du_{00}}{dy}, u_{10} = h \frac{du_{10}}{dy}, \theta_{00} = 0, \theta_{10} = 0, \]  
\[ u_{01} = h \frac{du_{01}}{dy}, u_{11} = h \frac{du_{11}}{dy}, \theta_{01} = 0, \theta_{11} = 0, \]  
\[ y = 1: u_{00} = 0, u_{10} = 0, \theta_{00} = 1, \theta_{10} = 1, \]  
\[ u_{01} = 0, u_{11} = 0, \theta_{01} = 0, \theta_{11} = 0. \]  
(26)

Equations (18) to (25) are ordinary II order de’s and answered under the Boundary conditions (26).

Through outright fore working \( u_{00}(y), u_{01}(y), u_{10}(y), u_{11}(y), \theta_{00}(y), \theta_{01}(y), \theta_{10}(y), \) and \( \theta_{11}(y) \) are known and given by

\[ u_{00}(y) = A_{13}e^{m_0y} + A_{14}e^{m_0y} + A_{15}e^{m_0y} + A_{16}e^{m_0y} + A_{17}e^{m_0y} + A_{18}e^{m_0y}, \]  
(27)

\[ u_{01}(y) = A_{46}e^{m_0y} + A_{47}e^{m_0y} + A_{48}e^{m_0y} + A_{49}e^{m_0y} + A_{50}e^{2m_0y} + A_{51}e^{2m_0y} + A_{52}e^{2m_0y} + A_{53}e^{2m_0y} \]  
\[ + A_{54}e^{2m_0y} + A_{55}e^{2m_0y} + A_{56}e^{(m_0+m_1)y} + A_{57}e^{(m_0+m_1)y} + A_{58}e^{(m_0+m_1)y} + A_{59}e^{(m_0+m_1)y} \]  
\[ + A_{60}e^{(m_0+m_1)y} + A_{61}e^{(m_0+m_1)y} + A_{62}e^{(m_0+m_1)y} + A_{63}e^{(m_0+m_1)y} + A_{64}e^{(m_0+m_1)y} + A_{65}e^{(m_0+m_1)y} \]  
\[ + A_{66}e^{(m_0+m_1)y} + A_{67}e^{(m_0+m_1)y} + A_{68}e^{(m_0+m_1)y} + A_{69}e^{(m_0+m_1)y} + A_{70}e^{(m_0+m_1)y}, \]  
(28)

\[ u_{10}(y) = A_{71}e^{m_1y} + A_{72}e^{m_1y} + A_{73}e^{m_1y} + A_{74}e^{m_1y} + A_{75}e^{m_1y} + A_{76}e^{m_1y} + A_{77}e^{m_1y} + A_{78}e^{m_1y} + A_{79}e^{m_1y}, \]  
(29)

\[ u_{11}(y) = A_{128}e^{m_1y} + A_{129}e^{m_1y} + A_{130}e^{m_1y} + A_{131}e^{m_1y} + A_{132}e^{m_1y} + A_{133}e^{m_1y} + A_{134}e^{m_1y} \]
\[ + A_{135}e^{m_3y} + A_{136}e^{m_4y} + A_{137}e^{m_5y} + A_{138}e^{m_6y} + A_{139}e^{m_7y} + A_{140}e^{m_8y} + A_{141}e^{m_9y}, \]

\[ \theta_{00}(y) = A_2e^{m_1y} + A_{10}e^{m_2y}, \]

\[ \theta_{01}(y) = A_{21}e^{m_3y} + A_{22}e^{m_4y} + A_{23}e^{m_5y} + A_{24}e^{m_6y} + A_{25}e^{m_7y} + A_{26}e^{m_8y} + A_{27}e^{m_9y} + A_{28}e^{m_10y} + A_{29}e^{m_11y} + A_{30}e^{m_12y} + A_{31}e^{m_13y} + A_{32}e^{m_14y} + A_{33}e^{m_15y} + A_{34}e^{m_16y} + A_{35}e^{m_17y} + A_{36}e^{m_18y} + A_{37}e^{m_19y} + A_{38}e^{m_20y} + A_{39}e^{m_21y} + A_{40}e^{m_22y} + A_{41}e^{m_23y} + A_{42}e^{m_24y} + A_{43}e^{m_25y}, \]

where \( A_1 \) to \( A_{13} \) are constants, whose terms are not given here due to sake of briefness.

Thus, the expressions for \( u(y,t) \), \( \theta(y,t) \) and \( C(y,t) \) are identified and given by

\[ u(y,t) = u_{00} + Ec u_{01} + e^{e\tau} (u_{10} + Ec u_{11}), \]

\[ \theta(y,t) = \theta_{00} + Ec \theta_{01} + e^{e\tau} (\theta_{10} + Ec \theta_{11}), \]

4. Skin-friction Coefficient

The non-dimensional stress tensor in relations of skin-friction coefficient at both the plates are given

\[ C_f = \frac{du}{dy} + \frac{du_{00}}{dy} + \frac{du_{01}}{dy} + e^{e\tau} \left( \frac{du_{10}}{dy} + Ec \frac{du_{11}}{dy} \right) \text{ at } y = 0 \text{ and } y = 1. \]

Hence, skin-friction coefficient at the plate (when \( y = 0 \)) is

\[ (C_f)_{0} = A_{1}m_{1} + A_{1+4}m_{10} + A_{1+5}m_{1} + A_{1+6}m_{2} + A_{1+7}m_{3} + A_{1+8}m_{4} + Ec (A_{20}m_{9} + A_{30}m_{10} + A_{11}m_{5}) + A_{21}m_{6} + 2A_{22}m_{1} + 2A_{23}m_{2} + 2A_{24}m_{3} + 2A_{25}m_{4} + 2A_{26}m_{5} + 2A_{33}m_{10} + A_{36}m_{6} + m_{1} + m_{2} \]
\[ + A_{57}(m_1 + m_3) + A_{58}(m_1 + m_6) + A_{59}(m_1 + m_9) + A_{60}(m_1 + m_{10}) + A_{61}(m_2 + m_3) \\
+ A_{62}(m_2 + m_4) + A_{63}(m_2 + m_5) + A_{64}(m_2 + m_{10}) + A_{65}(m_2 + m_6) + A_{66}(m_5 + m_4) \\
+ A_{67}(m_5 + m_6) + A_{68}(m_6 + m_9) + A_{69}(m_6 + m_{10}) + A_{70}(m_9 + m_{10}) + \varepsilon e^{i\alpha}[A_{73}m_{11} \\
+ A_{74}m_{12} + A_{76}m_3 + A_{77}m_4 + A_{78}m_7 + A_{79}m_8 + Ec[A_{128}m_1 + A_{129}m_{12} + A_{130}m_1 \\
+ A_{131}m_2 + A_{132}m_5 + A_{133}m_6 + A_{134}m_8 + A_{135}m_9 + A_{136}m_{10} + A_{137}m_1 + m_3) \\
+ A_{138}(m_1 + m_4) + A_{140}(m_1 + m_7) + A_{141}(m_1 + m_8) + A_{142}(m_1 + m_{11}) + A_{143}(m_1 + m_{12}) \\
+ A_{144}(m_2 + m_3) + A_{145}(m_2 + m_4) + A_{146}(m_2 + m_7) + A_{147}(m_2 + m_8) + A_{148}(m_2 + m_{11}) \\
+ A_{149}(m_2 + m_{12}) + A_{150}(m_5 + m_3) + A_{151}(m_5 + m_4) + A_{152}(m_5 + m_6) + A_{153}(m_5 + m_{12}) \\
+ A_{154}(m_5 + m_1) + A_{155}(m_6 + m_{12}) + A_{156}(m_6 + m_3) + A_{157}(m_6 + m_4) + A_{158}(m_6 + m_7) \\
+ A_{159}(m_6 + m_8) + A_{160}(m_6 + m_{11}) + A_{161}(m_6 + m_{12}) + A_{162}(m_9 + m_3) + A_{163}(m_9 + m_4) \\
+ A_{164}(m_9 + m_7) + A_{165}(m_9 + m_8) + A_{166}(m_9 + m_{11}) + A_{167}(m_9 + m_{12}) + A_{168}(m_{10} + m_3) \\
+ A_{169}(m_{10} + m_4) + A_{170}(m_{10} + m_7) + A_{171}(m_{10} + m_8) + A_{172}(m_{10} + m_{11}) + A_{173}(m_{10} + m_{12}) \] \\
\] (38) \]

The skin-friction coefficient at the plate (when \( y = 1 \))

\[ C_f = A_{13}m_3e^{m_5} + A_{14}m_3e^{m_6} + A_{15}m_3e^{m_9} + A_{16}m_3e^{m_{10}} + A_{17}m_6e^{m_6} + A_{18}m_6e^{m_{10}} + Ec[A_{129}m_3e^{m_5} \\
+ A_{132}m_3e^{m_6} + A_{133}m_3e^{m_9} + A_{134}m_3e^{m_{10}} + A_{135}m_3e^{m_6} + A_{136}m_3e^{m_{10}} + A_{137}m_6e^{m_5} \\
+ A_{138}(m_1 + m_3)e^{(m_i + m_i)} + A_{139}(m_1 + m_4)e^{(m_i + m_i)} + A_{140}(m_1 + m_7)e^{(m_i + m_i)} \\
+ A_{141}(m_1 + m_8)e^{(m_i + m_i)} + A_{142}(m_1 + m_{11})e^{(m_i + m_i)} + A_{143}(m_1 + m_{12})e^{(m_i + m_i)} \\
+ A_{144}(m_2 + m_3)e^{(m_i + m_i)} + A_{145}(m_2 + m_4)e^{(m_i + m_i)} + A_{146}(m_2 + m_7)e^{(m_i + m_i)} \\
+ A_{147}(m_2 + m_8)e^{(m_i + m_i)} + A_{148}(m_2 + m_{11})e^{(m_i + m_i)} + A_{149}(m_2 + m_{12})e^{(m_i + m_i)} \\
+ A_{150}(m_5 + m_3)e^{(m_i + m_i)} + A_{151}(m_5 + m_4)e^{(m_i + m_i)} + A_{152}(m_5 + m_6)e^{(m_i + m_i)} \\
+ A_{153}(m_5 + m_8)e^{(m_i + m_i)} + A_{154}(m_5 + m_{11})e^{(m_i + m_i)} + A_{155}(m_5 + m_{12})e^{(m_i + m_i)} \\
+ A_{156}(m_6 + m_3)e^{(m_i + m_i)} + A_{157}(m_6 + m_4)e^{(m_i + m_i)} + A_{158}(m_6 + m_7)e^{(m_i + m_i)} \\
+ A_{159}(m_6 + m_8)e^{(m_i + m_i)} + A_{160}(m_6 + m_{11})e^{(m_i + m_i)} + A_{161}(m_6 + m_{12})e^{(m_i + m_i)} \\
+ A_{162}(m_9 + m_3)e^{(m_i + m_i)} + A_{163}(m_9 + m_4)e^{(m_i + m_i)} + A_{164}(m_9 + m_7)e^{(m_i + m_i)} \\
+ A_{165}(m_9 + m_8)e^{(m_i + m_i)} + A_{166}(m_9 + m_{11})e^{(m_i + m_i)} + A_{167}(m_9 + m_{12})e^{(m_i + m_i)} \\
+ A_{168}(m_{10} + m_3)e^{(m_i + m_i)} + A_{169}(m_{10} + m_4)e^{(m_i + m_i)} + A_{170}(m_{10} + m_7)e^{(m_i + m_i)} \\
+ A_{171}(m_{10} + m_8)e^{(m_i + m_i)} + A_{172}(m_{10} + m_{11})e^{(m_i + m_i)} + A_{173}(m_{10} + m_{12})e^{(m_i + m_i)} \] \\
\]
The Nusselt number at the plate (when \( y = 0 \))

\[
\left( Nu \right)_0 = \left[ \frac{\partial \theta}{\partial y} \right] = \left( \frac{d\theta_0}{dy} + Ec \frac{d\theta_{01}}{dy} + \varepsilon e^{i\alpha} \left( \frac{d\theta_1}{dy} + Ec \frac{d\theta_{11}}{dy} \right) \right) \text{ at } y = 0 \text{ and } y = 1,
\]

(40)

Hence, Nusselt number at the plate (when \( y = 0 \))

\[
\left( Nu \right)_0 = \left[ A_1 m_5 + A_2 m_6 + Ec(A_3 m_5 + A_4 m_6 + 2A_5 m_4 + 2A_6 m_5 + 2A_7 m_6 + 2A_8 m_7 + 2A_9 m_8 + A_{10} m_9 + A_{11} m_10 + A_{12} m_11 + A_{13} m_12 \right] \text{ (41)}
\]

The Nusselt number at the plate (when \( y = 1 \))

\[
\left( Nu \right)_1 = \left[ A_1 m_5 e^{m_5} + A_2 m_6 e^{m_6} + Ec \left( A_3 m_5 e^{m_5} + A_4 m_6 e^{m_6} + 2A_5 m_4 e^{m_4} + 2A_6 m_5 e^{m_5} + 2A_7 m_6 e^{m_6} + 2A_8 m_7 e^{m_7} + 2A_9 m_8 e^{m_8} + A_{10} m_9 e^{m_9} + A_{11} m_10 e^{m_{10}} + A_{12} m_11 e^{m_{11}} + A_{13} m_12 e^{m_{12}} \right) \text{ (42)}
\]
6. Results and Discussion

The outcome of Joule heating on incompressible, electrically conducting, radiating viscoelastic unsteady magnetohydrodynamic fluid flow and heat transfer through an absorbent media between upstanding equidistant plates with constant suction and slip condition are investigated.

It is observed from Figure 2 to 4 that the speed of fluid boost with the increment of Grashof number, heat source parameter or slip parameter. The Grashof number hint at the comparative position of buoyancy force to the viscid hydrodynamic force. Growth of Grashof number shows small viscous impacts in the momentum term and subsequently, causes rise in the velocity profile. Similarly, an increment in heat source number heat is produced the buoyancy force grows which brings the rise in the velocity of fluid. It is noted from Figure 5 to 9 that the velocity of fluid reduces for Hartmann number, Prandtl number, cross flow Reynolds number, radiation parameter or permeability parameter. The existence of magnetic field in the fluid movement produces a stretch like force named Lorentz force which in turn slows the fluid motion. The increasing values of permeability parameter retort to the big opening of the permeable space, which reduces lassitude of the flow thereby producing the velocity. A growth in radiation number supervise to decreasing the fluid boundary film this is for great values of radiation parameter resemble to an increase governance of conduction over radiation parameter thereby declining the buoyancy width of the momentum boundary layer.

![Figure 2. Velocity diagram versus y for varying values of Gr when Ha=2, K=1, γ=0.5, Ec=0.001, Pr=0.71, R=2, S=4, h=0.2, Re=2, λ=0.1, ε=0.001, ω=1, t=0.5](image)
Figure 3. Velocity diagram versus $y$ for varying values of $S$ when $Gr=5$, $Ha=2$, $K=1$, $\gamma=0.5$, $Ec=0.001$, $Pr=0.71$, $R=2$, $h=0.2$, $Re=2$, $\lambda=0.1$, $\epsilon=0.001$, $\omega=1$, $t=0.5$

Figure 4. Velocity diagram versus $y$ for varying values of $h$ when $Gr=5$, $Ha=2$, $K=1$, $\gamma=0.5$, $Ec=0.001$, $Pr=0.71$, $R=2$, $S=4$, $Re=2$, $\lambda=0.1$, $\epsilon=0.001$, $\omega=1$, $t=0.5$

Figure 5. Velocity diagram versus $y$ for varying values of $Ha$ when $Gr=5$, $K=1$, $\gamma=0.5$, $Ec=0.001$, $Pr=0.71$, $R=2$, $S=4$, $h=0.2$, $Re=2$, $\lambda=0.1$, $\epsilon=0.001$, $\omega=1$, $t=0.5$
Figure 6. Velocity diagram versus $y$ for varying values of $Pr$ when $Gr=5$, $Ha=2$, $K=1$, $\gamma=0.5$, $Ec=0.001$, $R=2$, $S=4$, $h=0.2$, $Re=2$, $\lambda=0.1$, $\varepsilon=0.001$, $\omega=1$, $t=0.5$

Figure 7. Velocity diagram versus $y$ for varying values of $Re$ when $Gr=5$, $Ha=2$, $K=1$, $\gamma=0.5$, $Ec=0.001$, $Pr=0.71$, $R=2$, $S=4$, $h=0.2$, $\lambda=0.1$, $\varepsilon=0.001$, $\omega=1$, $t=0.5$

Figure 8. Velocity diagram versus $y$ for varying values of $R$ when $Gr=5$, $Ha=2$, $K=1$, $\gamma=0.5$, $Ec=0.001$, $Pr=0.71$, $S=4$, $h=0.2$, $Re=2$, $\lambda=0.1$, $\varepsilon=0.001$, $\omega=1$, $t=0.5$
Figure 9. Velocity diagram versus \( y \) for varying values of \( K \) when \( Gr=5, Ha=2, \gamma=0.5, Ec=0.001, Pr=0.71, R=2, S=4, h=0.2, Re=2, \lambda=0.1, e=0.001, \omega=1, t=0.5 \)

Figure 10 demonstrates that as the Prandtl number rises the heat transfer of fluid also rises nearly the plate at \( y=0 \) and it cuts near the plate at \( y=1 \). It is revealed from Figure 11 that the heat transfer of fluid rises due to rising in heat source parameter. Figure 12 and 13 shows that the heat transfer of fluid reduces due to rise in cross fluid flow Reynolds number or radiation parameter. Fluid temperature diminishes for an increasing value of radiation parameter with an increment in thermal boundary layer thickness. This outcome qualitatively approves with opportunities, since the impact of radiation is to decline the rate of energy passage to the fluid, thereby falling the temperature of the fluid.

Figure 10. Heat transfer diagram versus \( y \) for varying values of \( Pr \) when \( Gr=5, Ha=2, K=1, \gamma=0.5, Ec=0.001, R=2, S=4, h=0.2, Re=2, \lambda=0.1, e=0.001, \omega=1, t=0.5 \)
It is detected from Table 1 that the skin-friction coefficient at the dish when $y = 0$ rises as the prices of Grashof number, Prandtl number, Eckert number, viscoelastic number, or heat source number, while it reduces due to increase in the values of Hartmann number, cross flow Reynolds number, permeability parameter, radiation parameter, wave distance, frequency of the oscillation or slip.
parameter. The skin-friction coefficient at the plate when \( y = 1 \) rises due to increase of Hartmann number, Prandtl number, permeability parameter, radiation parameter, viscoelastic parameter, wavelength, or frequency of the oscillation, while it reduces due to growth of Grashof number, Eckert number, heat source parameter or slip parameter. The skin friction coefficient at the plate when \( y = 1 \) reduces on increasing the crossflow Reynolds number from 1 to 2 and rises when cross flow Reynolds number rises from 2 to 3. Refer table 1.

Table 1. Mathematical values of skin friction coefficient at the plates for various parameters

| Gr | Re | H\(a \) | Pr | Ec | K | R | S | \( \lambda \) | \( \gamma \) | h | \( \omega \) | \( C_{f0} \) | \( C_{f1} \) |
|----|----|--------|----|----|---|---|---|--------|--------|---|--------|--------|--------|
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.38896547 | -2.8620732 |
| 1  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.19045613 | -1.590308  |
| 2  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.24008173 | -1.9087114 |
| 5  | 1  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.56591677 | -2.8089852 |
| 5  | 3  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.2523022  | -2.8280141 |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.54232207 | -3.3701157 |
| 5  | 2  | 3      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.25554883 | -2.3658879 |
| 5  | 2  | 2      | 0.1  | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.38271699 | -2.8829479 |
| 5  | 2  | 2      | 7    | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.38988712 | -2.7315046 |
| 5  | 2  | 2      | 0.71 | 0.01  | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.38908799 | -2.8624317 |
| 5  | 2  | 2      | 0.71 | 0.1   | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.39031321 | -2.866017  |
| 5  | 2  | 2      | 0.71 | 0.001 | 2 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.29779851 | -2.5312197 |
| 5  | 2  | 2      | 0.71 | 0.001 | 3 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.2088395  | -2.1699589 |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 1 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.4579296  | -3.072224  |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 3 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.31666079 | -2.6255049 |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 1 | 0.1  | 0.5   | 0.2 | 1      | 0.27968789 | -2.5273709 |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 2 | 0.1  | 0.5   | 0.2 | 1      | 0.31284718 | -2.6411239 |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 1      | 0.38870938 | -2.8616621 |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 3    | 0.5   | 0.2 | 1      | 0.38840131 | -2.8607487 |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.1   | 0.2 | 1      | 0.38894606 | -2.8621983 |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.1   | 0.2 | 1      | 0.38899802 | -2.8614911 |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.3 | 1      | 0.34898333 | -2.893237  |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 2      | 0.38893623 | -2.8615145 |
| 5  | 2  | 2      | 0.71 | 0.001 | 1 | 2 | 4 | 0.1  | 0.5   | 0.2 | 3      | 0.3888665  | -2.8609707 |

It is noted from Table 2 that the Nusselt number at the plate when \( y = 0 \) rises due to rise in cross flow Reynolds number, permeability parameter, radiation parameter, wavelength or frequency of the oscillation, while it reduces with an growth in Grashof number, Hartmann number, Prandtl number, Eckert number, heat source parameter or slip parameter. The Nusselt number at the plate when \( y = 0 \) reduces as viscoelastic parameter rises from 0.1 to 0.5 and rises as viscoelastic parameter rises from
0.5 to 1. The Nusselt number at the plate when $y = 1$ rises as Grashof number, Hartmann number, Eckert number, heat source parameter, frequency of the oscillation or slip parameter, while it reduces due to rise in cross flow Reynolds number, permeability parameter, radiation parameter, wavelength, or viscoelastic parameter.

### Table 2. Mathematical values of Nusselt number at the plates for numerous parameters

| $Gr$ | $Re$ | $Ha$ | $Pr$ | $Ec$ | $K$ | $R$ | $S$ | $\lambda$ | $\gamma$ | $h$ | $\omega$ | $Nu_0$ | $Nu_f$ |
|------|------|------|------|------|-----|-----|-----|-----------|---------|-----|--------|--------|--------|
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.227751897 | -1.21646797 |
| 1    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.227689117 | -1.21651941 |
| 2    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.22770104  | -1.216509514 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.227706534 | -1.216507423 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.22771628  | -1.216499025 |
| 5    | 1    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.606812088 | -1.004649965 |
| 5    | 3    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -0.907515774 | -1.481960604 |
| 5    | 2    | 1    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.227702777 | -1.216511056 |
| 5    | 2    | 3    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.227766892 | -1.216447805 |
| 5    | 2    | 2    | 0.1  | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.034039971 | -1.033947319 |
| 5    | 2    | 2    | 0.1  | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | 2.978129193  | -1.776297362 |
| 5    | 2    | 2    | 0.71 | 0.01 | 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.228521193 | -1.215823816 |
| 5    | 2    | 2    | 0.71 | 0.1  | 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.236214156 | -1.209382273 |
| 5    | 2    | 2    | 0.71 | 0.001| 2   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.22772284  | -1.216489634 |
| 5    | 2    | 2    | 0.71 | 0.001| 3   | 2   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.227699355 | -1.216508189 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 1   | 4   | 0.1      | 0.5     | 0.2 | 1      | -1.675755909 | -0.665710928 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 3   | 4   | 0.1      | 0.5     | 0.2 | 1      | -0.778057558 | -1.944927981 |
| 5    | 2    | 2    | 0.71 | 0.001| 2   | 2   | 1   | 0.1      | 0.5     | 0.2 | 1      | -0.446184804 | -2.192573849 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 2   | 0.1      | 0.5     | 0.2 | 1      | -0.647774739 | -1.806644427 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 1        | 0.5     | 0.2 | 1      | -1.227751852 | -1.216467999 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 3        | 0.5     | 0.2 | 1      | -1.227751753 | -1.216468064 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 3        | 0.1     | 0.2 | 1      | -1.227751896 | -1.216467968 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 1       | 0.2 | 1      | -1.227751885 | -1.216467987 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.1 | 1      | -1.227741173 | -1.216472406 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.3 | 1      | -1.227761422 | -1.216464298 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 2      | -1.227470441 | -1.21586628 |
| 5    | 2    | 2    | 0.71 | 0.001| 1   | 2   | 4   | 0.1      | 0.5     | 0.2 | 3      | -1.227055364 | -1.215075528 |

### 7. Conclusions
The present study emphasis on exploring Joule heating effect on incompressible, electrically conducting, radiating viscoelastic unsteady magnetohydrodynamic fluid flow and heat transfer through an absorbent media between upstanding equidistant plates with constant suction and slip condition.
Solution of governing partial differential equation has been obtained by perturbation technique based on solutions, numerical computations for numerous values of physical parameters are carried out and following conclusions are set out from this study:
The velocity and heat transfer of the fluid rises due to rise in Grashof number, heat source parameter, Eckert number or slip parameter. The velocity and heat transfer of the fluid reduces as permeability parameter, radiation parameter or wavelength rises. The velocity and heat transfer of the fluid boost with cross flow Reynolds number, or frequency of the oscillation. As Hartmann number rises the fluid velocity diminishes, while fluid heat transfer rises. As Grashof number, Eckert number or heat source parameter rises the skin-friction coefficient rises at the plate when \( y = 0 \) and reduces at the plate when \( y = 1 \). The skin-friction coefficient at both the plates rises with Prandtl number or viscoelastic parameter, while reduces with slip parameter. As Hartmann number, permeability parameter, radiation parameter, wave length or frequency of the oscillation rises the skin-friction coefficient reduces at the plate when \( y = 0 \) and rises at the plate when \( y = 1 \). The Nusselt number at the plate when \( y = 0 \) rises due to increase in permeability parameter, radiation parameter or wave length and it reduces as Grashof number, Eckert number, Hartmann number, heat source parameter or slip parameter rises, while the opposite behaviour is observed at the plate when \( y = 1 \). Due to an increase in Prandtl number, the Nusselt number reduces at both the plates. The Nusselt number rises at both the plates as frequency of the oscillation.

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