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Effects of Activation Energy on Reactive MHD Flows with Joule Heating

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***Abstract*-This paper explores the effects of Arrhenius activation energy on a chemically reactive MHD flow through a porous surface while considering the joule heating effect of the two-dimensional free convective flow. The study incorporates the impact of the activation energy on the flow, the effect of the chemical reaction rate parameter on the velocity and temperature profiles as well as the joule heating parameter on the flow. The concentration of the species in the fluid will be investigated and the results discussed. The resulting non-linear partial differential equations are solved using the finite difference methods and results displayed graphically to show the effects of the resulting dimensionless parameters. It is found that the presence of the chemical reaction rate parameter on the flow decreases the concentration of the fluid while the activation energy shows the converse results.**

Index terms- **Arrhenius Activation energy, free convective flow, Joule heating, reactive MHD flow, reaction rate parameter, Soret effect.**

I. INTRODUCTION

The study of the Arrhenius activation energy, named after the Swedish scientist, Svante Arrhenius, has created numerous pathways in both engineering and industrial fields. Scientists and engineers continue to research on the effects of the activation energy in magnetohydrodynamic flows with the aim of to improve on efficiency of the already existing applications like streamlined expulsion of plastic sheets, condensation process of metallic plates in the cooling baths etc and other greater innovations that will meet the emerging scientific demands.

Magnetohydrodynamic (MHD) flows are the flows of electrically conducting fluids in the presence of magnetic fields. Reactive MHD flows are the flows consisting of chemical species that cause chemical reactions within the layers of the fluid. Heat is dissipated in the process as a result of these reactions. The chemical reactions may be exothermic or endothermic.

Arrhenius activation energy is the minimum amount of energy required for a chemical reaction to occur within the reactive fluid. The study of reactive MHD fluid flows has intriguing significance in science and innovation where many scientists and researchers have studied among other applications, the effects of heat and mass transfers in polymer procedures, food processing among others.

Reference [1] studied the effects of free convection and chemical reactions in fluids with heat and mass transfer transition conditions. The results revealed that the heat transfer, represented by the Nusselt number, Nu, increases with an increase in the viscous dissipation, which was represented by the Eckert number, Ec.

Joule heating is the process of heat production by passing an electric current through a conductor. It is also called resistance, Ohmic heating or resistive heating. There are numerous applications of joule heating, mostly in electronic processes, like food heating and food processing equipment. The component that transforms electricity into heat is called the heating element. The combined effects of joule heating, viscous dissipation, thermal radiation, and heat generation on a magnetohydrodynamic flow were analyzed by [2]. The results revealed that for larger values of the joule heating parameter, the velocity profiles diminished. According to [3], the amount of activation energy required for a chemical reaction varies from one fluid to another.

The activation energy with both endothermic and exothermic reactions exists in heat and mass transfer where they have numerous applications including geothermal heating. In the electronic components, joule heating is significantly useful in lowering the damages by reducing the strength of electrical transportation with the reduction of current flow. Other applications of activation energy are found in chemical engineering, geothermal reservoirs, emulsions of various suspensions, food processing among others.

The study of activation energy for reactive flows was first conducted by [4]. The study showed an increase in velocity with more free convection which was represented by the increase in the Grashof number. Reference [5] studied the activation energy with binary chemical reactions and the accompanying entropy generation in a Casson nanofluid enhancing the consumption of reactive species with the chemical parameter. From this research, it was discovered that the influence of Hartmann number, M on velocity field decreases due to the Lorentz force which rises as the value of M increases.

Many researchers have undertaken studies on the Arrhenius activation energy on fluid flows to date. The area is drawing more attention due to the numerous industrial applications. Reference [6] studied the Arrhenius activation energy in mixed convection nonlinear unsteady Carreau tiny particles on a two-dimensional stretching sheet where the results revealed an enhancement of the activation energy and thermophoresis.

In-spite of all these studies, the effects of Arrhenius activation energy on reactive MHD flows with joule heating is still an area worth exploring due to the immense industrial and

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technological applications hence the present research. The main objective of this study is to explore the effects of the Arrhenius activation energy in a reactive MHD fluid flow with joule heating. The effects of the resulting parameters will be analyzed and discussed, and the equations displayed graphically.

II. MATHEMATICAL PROBLEM FORMULATION

In this study, an incompressible 2-dimensional reactive MHD flow is considered. The fluid flow is taken in the *x*-direction along the plate and the *y*-axis is orthogonal to the plate. In this study, we assume the velocity of the plate is $U_x(x)$ in the positive *x*-axis. The flow occupies the plane represented by $y \geq 0$ and that the temperature at the wall is T_w which is more than the ambient temperature T_∞ of the fluid. A transverse uniform magnetic field is applied to the flow which is viscous and electrically conducting through the permeable plate as shown. Along the fluid lines, the chemical reaction rate parameter, Arrhenius activation energy parameter and joule heating parameter are incorporated and their overall effects on the flow investigated. By assuming low Reynold's number, the induced magnetic fields due to the application of the magnetic field on the elongated plate are ignored. The equations governing the flow are formulated including the Maxwell and Ohm's law equations.

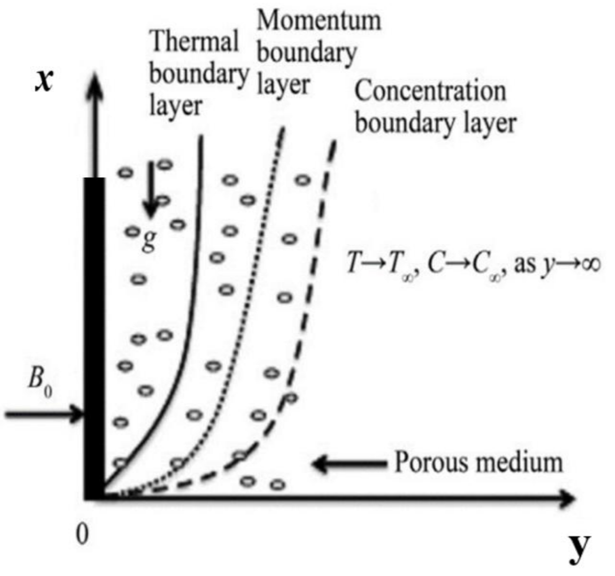

Figure 1: Flow configuration

In the study, the density variations due to the buoyancy forces in the momentum equation are ignored. However, the joule heating, viscous dissipation, chemical reactions and the Soret effect are considered for the flow described.

A. Governing Equations

The main equations governing the flow are continuity, momentum, energy, and concentration equations. Considering the above assumptions and the Boussinesq's approximations, the governing equations for the flow are given as shown below.

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\frac{\partial u}{\partial t} + \left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right) = -\frac{\mu u}{\rho k} + \frac{\mu}{\rho}\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) - \frac{\sigma}{\rho}{B_0}^2 u + g_x[\beta_T(T - T_\infty) + \beta_c(C - C_\infty)] \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\frac{\partial v}{\partial t} + \left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) = \frac{k}{\rho C_p}\left[\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right] + \frac{\mu}{\rho C}\left(2\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial u}{\partial y}\right)^2\right] + \left(\frac{\partial u}{\partial x} + \frac{\partial u}{\partial y}\right)^2 + \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)^2\right) + \frac{1}{\rho C_p}\sigma {B_y}^2 u^2 + \frac{1}{\rho C_p}\alpha_v\left(\frac{\partial T}{\partial x} + \frac{\partial T}{\partial y}\right) \qquad \ldots\ldots\ldots\ldots\ldots (3)$$

$$\frac{\partial v}{\partial t} + \left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) = \frac{k}{\rho C_p}\left[\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right] + \frac{\mu}{\rho C}\phi + \frac{1}{\rho C_p}\sigma {B_y}^2 u^2 + \frac{1}{\rho C_p}\alpha_v\left(\frac{\partial T}{\partial x} + \frac{\partial T}{\partial y}\right) \qquad \ldots\ldots\ldots\ldots\ldots (4)$$

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D_{ij}\left(\frac{\partial^2 C}{\partial x^2} + \frac{\partial^2 C}{\partial y^2}\right) + D_T\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) - k_r^2(C - C_\infty)\left(\frac{T}{T_\infty}\right)^m e^{-E_a/RT} \qquad \ldots\ldots\ldots\ldots\ldots (5)$$

Subject to the initial boundary conditions,

$u = u_0(x)$, $\quad v = 0 \quad\quad u \to 0$
$C^* = C_\infty \quad\quad C^* \to C_\infty$
$T^* = T_\infty \quad\quad T^* \to T_\infty \quad$ as $\; y \to \infty$

According to [7], the following dimensionless parameters and variables were used to non-dimensionalize the equations:

$$\theta = \frac{T^* - T_\infty}{T_W - T_\infty}, \quad \omega = \frac{k_r^2}{a}, \quad \delta = \frac{(T_W - T_\infty)}{T_\infty}, \quad a = \frac{U}{L},$$

$$S_r = \frac{D_t(T_W - T_\infty)}{uL(C_W - C_\infty)}, \; M = \frac{\sigma B_0^2 L}{\rho u}, \; C = \frac{C^* - C_\infty}{C_W - C_\infty}, \; Sc = \frac{v}{D},$$

$$Gr = \frac{g\beta(T^* - T_\infty^*)v}{U^3}, \; G_C = \frac{g\beta(C - C_\infty^*)v}{U^3},$$

Where θ is the dimensionless temperature, M is the Magnetic parameter, S_r is the Soret number, Gr is the Grashof number while Gc is the modified Grashof number, k_r^2 is the reaction rate, ω is the reaction rate parameter, δ is the temperature difference parameter, $k_r^2\left(\frac{T}{T_\infty}\right)^m e^{-E_a/RT}$ is the modified Arrhenius equation, E_a is the activation energy and m is the fitted rate constant which lies between -1 and 1 for the fluid flow, Sc is the Schmidt number.

Reference [8] considered the joule heating effects on MHD natural convective flows in the presence of pressure stress work from a circular cylinder and defined the Grashof number, $Gr = \frac{g\beta a^3(T_W - T_\infty)}{v^2}$ and considered it to be large, hence defined the following resulting dimensionless parameters which were used to non-dimensionalize the energy equation.

$$x^* = \frac{x}{a}, \quad y^* = \frac{y}{a}Gr^{\frac{1}{2}}, \quad u^* = \frac{ua}{v}Gr^{-\frac{1}{2}}, \quad v^* = \frac{va}{v}Gr^{-\frac{1}{4}},$$

where a is the distance. For this study, the distance will be represented by l, hence the joule heating parameter, J in the energy equation will be given as,

$J = \frac{\sigma v \beta_0^2 Gr^{\frac{1}{2}}}{\rho C_p(T_W - T_\infty)}$. Thus, the Joule heating term in the energy equation becomes, Ju^*.

The nondimensionalized equations are as follows:

$$\frac{\partial u^*}{\partial t^*}+\left(u^*\frac{\partial u^*}{\partial x^*}+v^*\frac{\partial u^*}{\partial y^*}\right)=-NuPru^*+\frac{1}{Re}\left(\frac{\partial^2 u^*}{\partial x^{*2}}+\frac{\partial^2 u^*}{\partial y^{*2}}\right)-Mu^*+Gr\theta+GcC \qquad \text{.......... (6)}$$

$$\frac{\partial u^*}{\partial t^*}+\left(u^*\frac{\partial u^*}{\partial x^*}+v^*\frac{\partial u^*}{\partial y^*}\right)=-NuPru^*+\frac{1}{Re}\nabla^2u^*-Mu^*+Gr\theta+GcC \qquad \text{.......... (7)}$$

$$\frac{\partial \theta^*}{\partial t^*}+\left(u^*\frac{\partial \theta^*}{\partial x^*}+v^*\frac{\partial \theta^*}{\partial y^*}\right)=\frac{1}{PrRe}\left(\frac{\partial^2 \theta^*}{\partial x^{*2}}+\frac{\partial^2 \theta^*}{\partial y^{*2}}\right)+\frac{Ec}{Re}\phi+Ju^*-St\left(\frac{\partial^2 \theta^*}{\partial x^{*2}}+\frac{\partial^2 \theta^*}{\partial y^{*2}}\right) \qquad \text{........... (8)}$$

$$\frac{\partial C^*}{\partial t^*}+u^*\frac{\partial C^*}{\partial x^*}+v^*\frac{\partial C^*}{\partial y^*}=\frac{1}{ScRe}\left(\frac{\partial^2 C^*}{\partial x^{*2}}+\frac{\partial^2 C^*}{\partial y^{*2}}\right)+Sr\left(\frac{\partial^2 \theta^*}{\partial x^{*2}}+\frac{\partial^2 \theta^*}{\partial y^{*2}}\right)-\omega C((1+\delta\theta))^m e^{-E} \qquad \text{.......... (9)}$$

III. METHOD OF SOLUTION

The solutions to the resulting partial differential equations are solved using the finite difference method. This method is used to solve the resulting equations because of the non-linearity of the equations defining the fluid flow. The method is also used due to its stability and accuracy in solving the nonlinear partial differential equations. It is thus convenient to use this method since analytic methods may not be easily used. The resulting set of the governing equations are presented as shown and later solved using appropriate computer-generated programs on MATLAB. The finite difference technique of approximating solutions to partial derivatives are conveniently obtained by performing a Taylor series expansion of the dependent variable followed by a substitution of the truncated expressions into the differential equation. We will further approximate the differentials by using the differences in the solution at various points.

The final set of equations solved using the finite difference method are given below:

$$v_{(i,j)}^{n+1}=\Delta t\left\{-v_{(i,j)}^n\left[\frac{v_{(i+1,j)}^n-v_{(i-1,j)}^n}{2\Delta x}\right]-v_{(i,j)}^n\left[\frac{v_{(i,j+1)}^n-v_{(i,j-1)}^n}{2\Delta y}\right]-NuPr\,u_{(i,j)}^n+\frac{1}{Re}\left[\frac{v_{(i+1,j)}^n-2v_{(i,j)}^n+v_{(i-1,j)}^n}{(\Delta x)^2}+\frac{v_{(i,j+1)}^n-2v_{(i,j)}^n+v_{(i,j-1)}^n}{(\Delta y)^2}\right]-M\,u_{(i,j)}^n+Gr\theta_{(i,j)}^n+GcC_{(i,j)}^n\right\}+v_{(i,j)}^n \qquad \text{........... (10)}$$

$$\theta_{(i,j)}^{n+1}=\Delta t\left\{-u_{(i,j)}^n\left[\frac{\theta_{(i+1,j)}^n-\theta_{(i-1,j)}^n}{2\Delta x}\right]-v_{(i,j)}^n\left[\frac{\theta_{(i,j+1)}^n-\theta_{(i,j-1)}^n}{2\Delta y}\right]+\frac{1}{PrRe}\left[\frac{\theta_{(i+1,j)}^n-2\theta_{(i,j)}^n+\theta_{(i-1,j)}^n}{(\Delta x)^2}+\frac{\theta_{(i,j+1)}^n-2\theta_{(i,j)}^n+\theta_{(i,j-1)}^n}{(\Delta y)^2}\right]+\frac{Ec}{Re}\phi+Ju_{(i,j)}^n-St\left[\frac{\theta_{(i+1,j)}^n-\theta_{(i-1,j)}^n}{2\Delta x}+\frac{\theta_{(i,j+1)}^n-\theta_{(i,j-1)}^n}{2\Delta y}\right]\right\}+\theta_{(i,j)}^n \qquad \text{.......... (11)}$$

$$C_{(i,j)}^{n+1}=\Delta t\left\{-u_{(i,j)}^n\left[\frac{C_{(i+1,j)}^n-C_{(i-1,j)}^n}{2\Delta x}\right]-v_{(i,j)}^n\left[\frac{C_{(i,j+1)}^n-C_{(i,j-1)}^n}{2\Delta y}\right]+\frac{1}{ScRe}\left[\frac{C_{(i+1,j)}^n-2C_{(i,j)}^n+C_{(i-1,j)}^n}{(\Delta x)^2}+\frac{C_{(i,j+1)}^n-2C_{(i,j)}^n+C_{(i,j-1)}^n}{(\Delta y)^2}\right]+Sr\left[\frac{\theta_{(i+1,j)}^n-2\theta_{(i,j)}^n+\theta_{(i-1,j)}^n}{(\Delta x)^2}+\frac{\theta_{(i,j+1)}^n-2\theta_{(i,j)}^n+\theta_{(i,j-1)}^n}{(\Delta y)^2}\right]-\omega C(1+\delta\theta)^m e^{-E}\right\}+C_{(i,j)}^n \qquad \text{.......... (12)}$$

These equations are solved subject to the initial conditions shown:

$u=u_0(x)$, $\quad v=0 \quad u\to 0$
$C^*=C_\infty \quad C^*\to C_\infty$
$T^*=T_\infty \quad T^*\to T_\infty$ as $y\to\infty$

IV. RESULTS AND DISCUSSIONS

In this study, there are several dimensionless parameters affecting the flow. This is evident from the resulting equations which were solved using MATLAB. The dimensionless parameters entering the fluid flow under study include the Grashof number, Gr, Prandtl number Pr, Eckert number, Ec, the Magnetic number, M, the Schmidt number, Sc, the reaction rate parameter, ω, the dimensionless activation energy, E and the Soret number, Sr. It is crucial that the effect of each of the parameters are investigated while keeping the others constant. The results are then discussed and displayed in the form of velocity, temperature, and concentration profiles for the different dimensionless parameters.

B. Fluid profiles for the flow

The resulting graphs for the dimensionless parameters affecting the fluid flow are displayed as shown below.

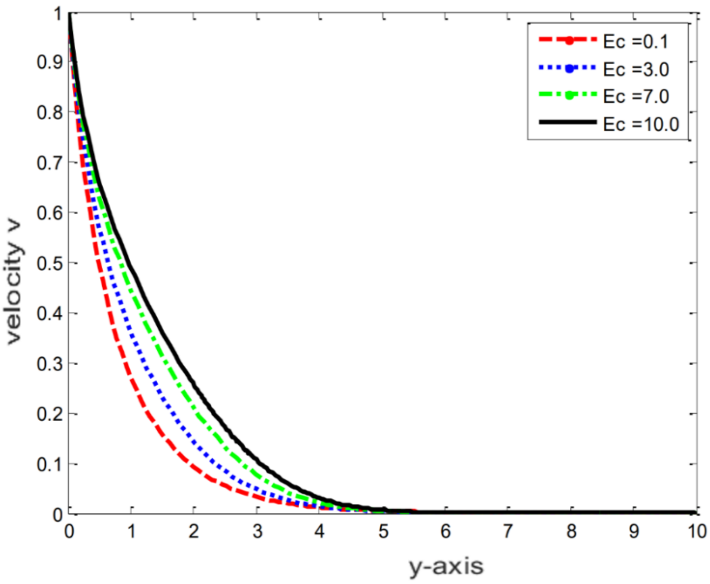

Figure 2: Effect of Eckert number, Ec on velocity profiles

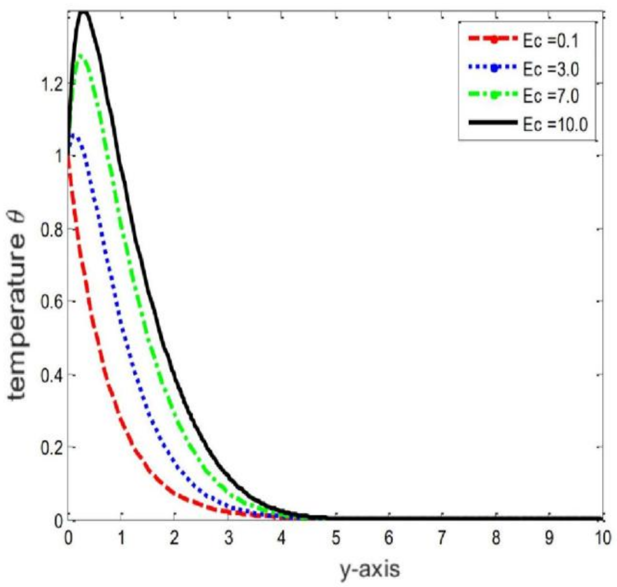

Figure 3: Effect of Eckert number, Ec on temperature profiles

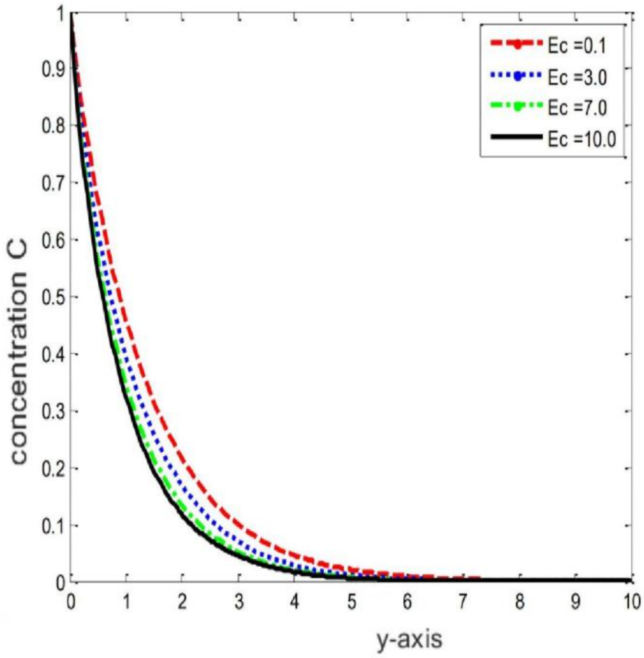

Figure 4: Effect of Eckert number, Ec on concentration profiles

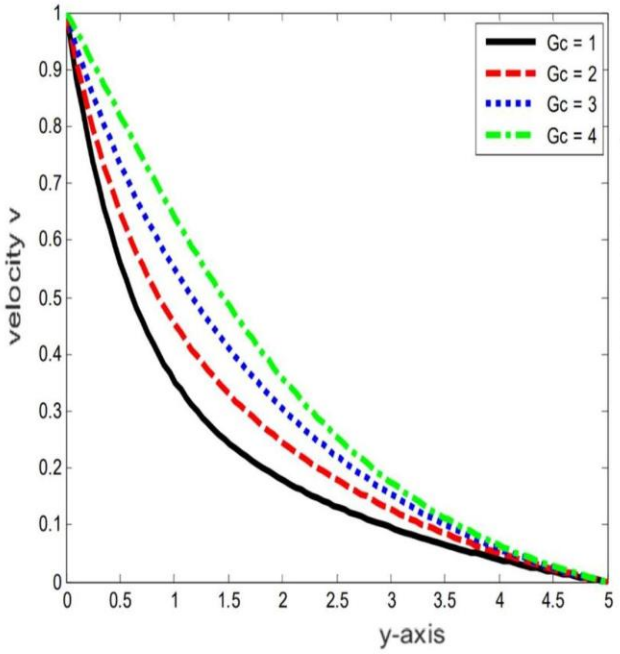

Figure 5: Effect of Grashof number, Gc on the velocity profiles

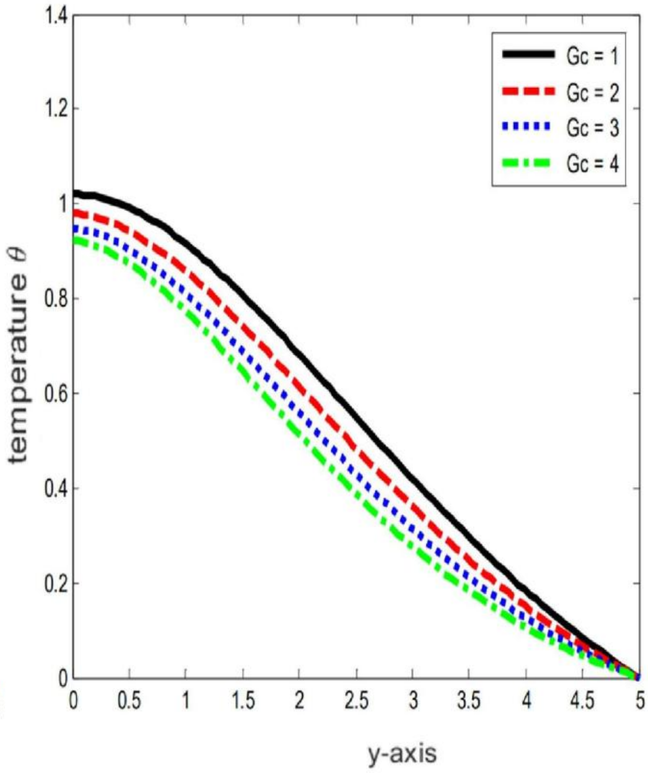

Figure 6: Effect of Grashof number, Gc on temperature profiles

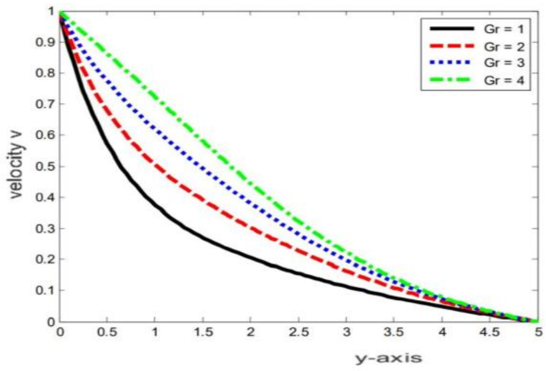

Figure 7: Effect of modified Grashof number, Gr on velocity profiles

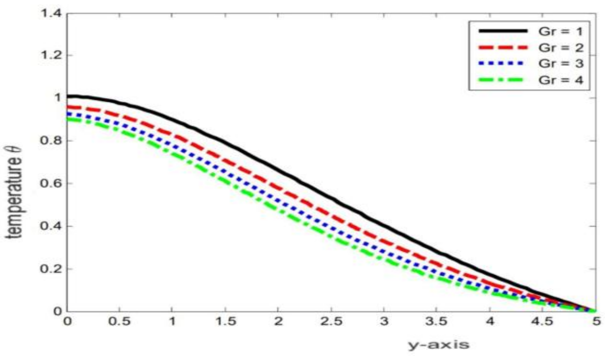

Figure 8: Effect of modified Grashof number, Gr on temperature profiles

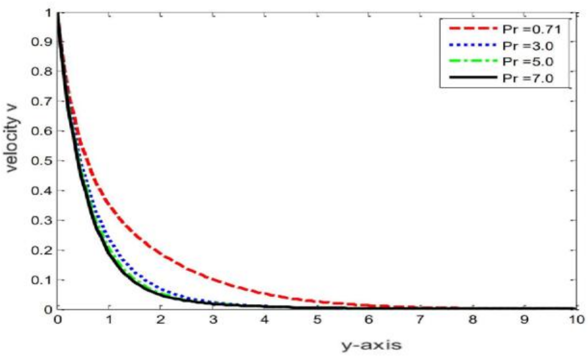

Figure 9: Effect of Prandtl number, Pr on velocity profiles

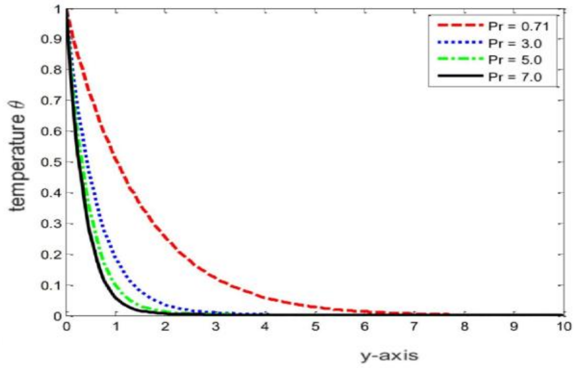

Figure 10: Effect of Prandtl number, Pr on temperature profiles

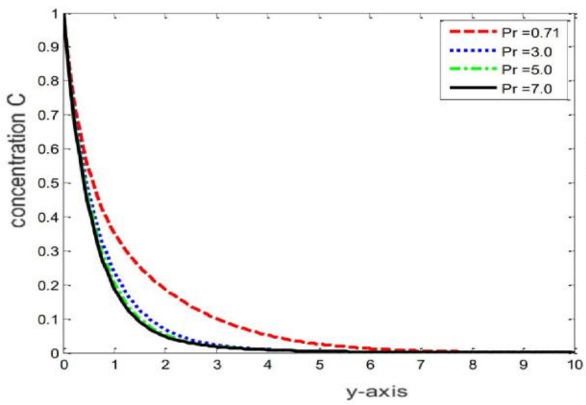

Figure 11: Effect of Prandtl number, Pr on concentration profiles

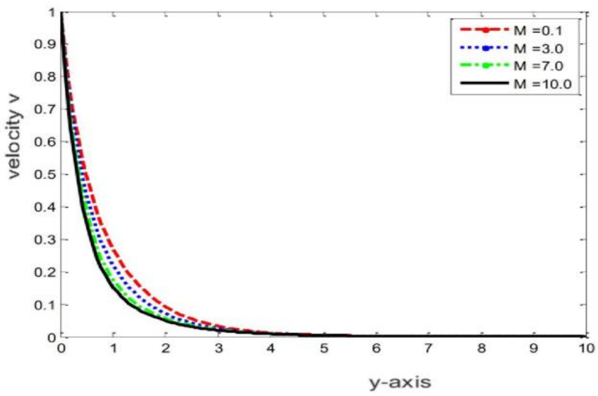

Figure 12: Effect of Magnetic number, M on velocity profiles

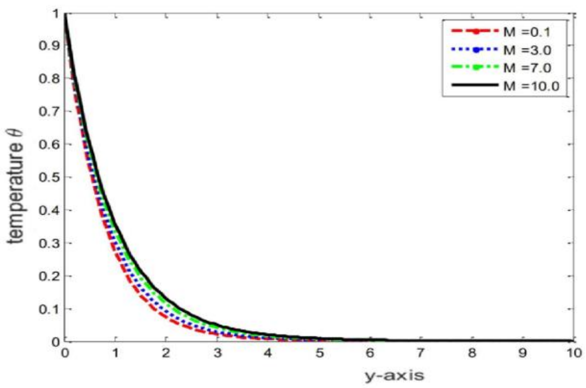

Figure 13: Effect of Magnetic number, M on temperature profiles

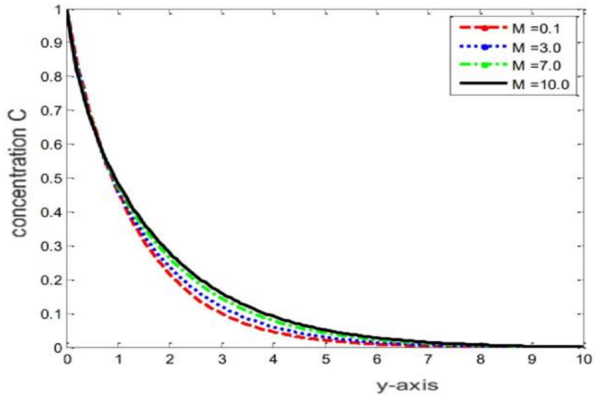

Figure 14: Effect of Magnetic number, M on concentration profiles

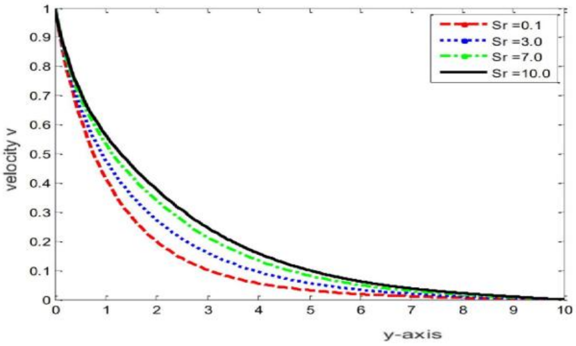

Figure 15: Effect of Soret number, Sr on velocity profiles

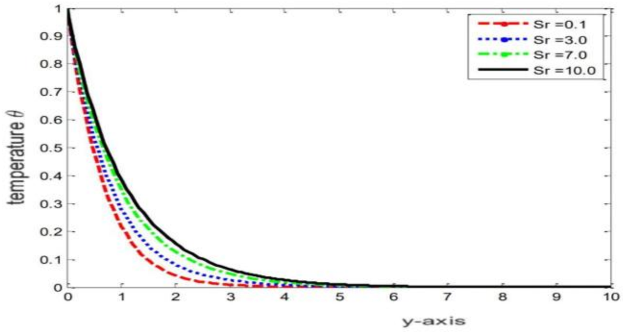

Figure 16: Effect of Soret number, Sr on temperature profiles

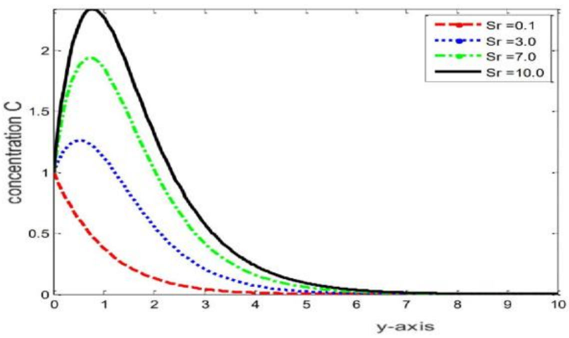

Figure 17: Effect of Soret number, Sr on concentration profiles

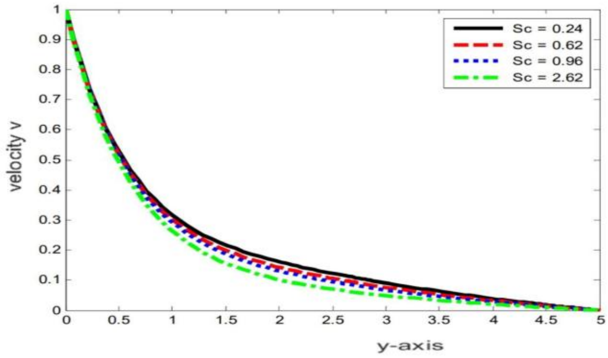

Figure 18: Effect of Schmidt number, Sc on velocity profiles

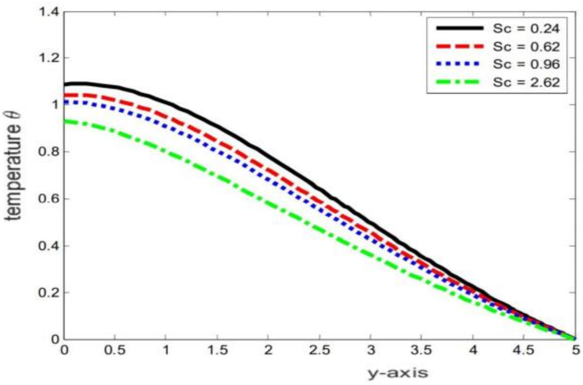

Figure 19: Effect of Schmidt number, Sc on temperature profiles

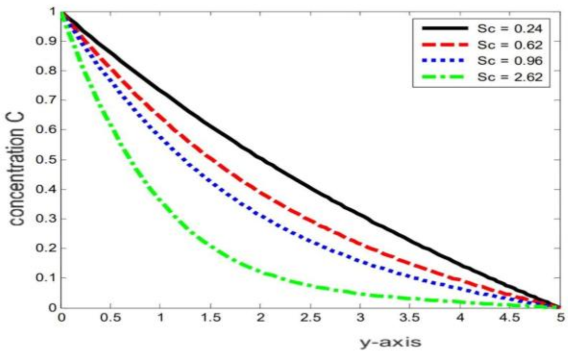

Figure 20: Effect of Schmidt number, Sc on concentration profiles

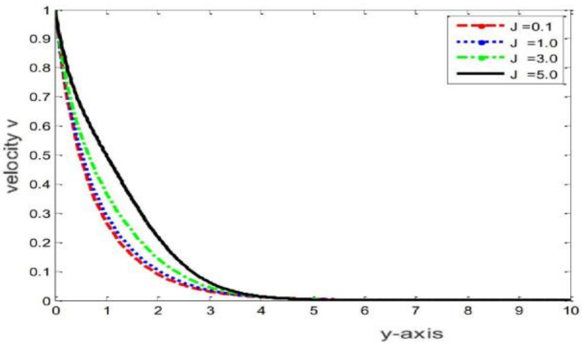

Figure 21: Effect of joule heating parameter, J on velocity profiles

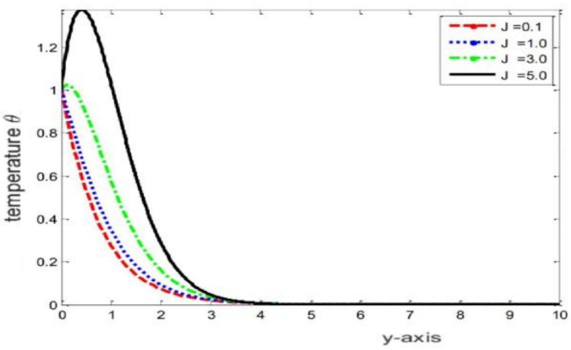

Figure 22: Effect of Joule heating parameter, J on temperature profiles

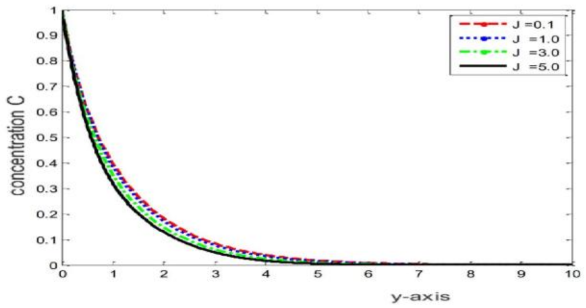

Figure 23: Effect of Joule heating parameter, J on concentration profiles

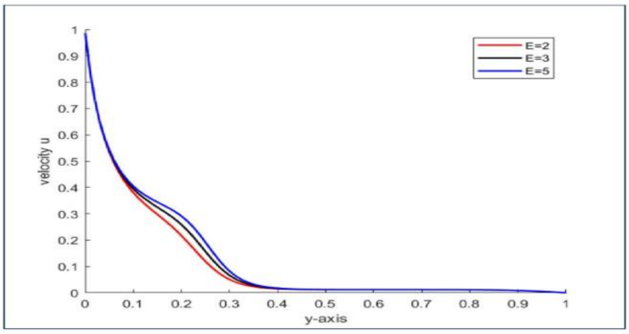

Figure 24: Effect of Activation energy, E on velocity profiles

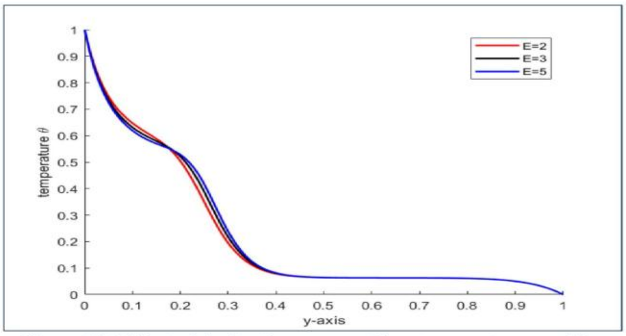

Figure 25: Effect of Activation energy, E on temperature profiles

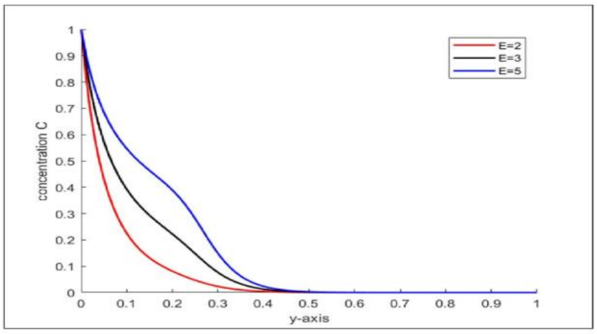

Figure 26: Effect of Activation energy, E on concentration profiles

The results, from figure 2 show that the Eckert number influences the fluid's velocity. The effect of the Eckert number on the velocity profiles, temperature profiles and concentration profiles are displayed from figure 2-4. It can be noted that an increase in the Eckert number leads to an increase in the velocity profiles. This is because the consideration of the viscous dissipation effects for the fluid flow causes the mechanical energy of the fluid to be converted to thermal energy which results in the increase in the temperature of the fluid as well. Consequently, the fluid gets thinner leading to an increase in the velocity of the fluid. The mass concentration of the fluid however reduces as a result since the chemical species are used up. The Eckert number represents the ratio of advective transport to the heat dissipation potential in the fluid. Hence, an increase in the Eckert number causes a definitive increase in the temperature of the fluid.

The effect of Grashof number on the fluid flow can be seen from figure 5-8. It is evident that increasing the Grashof number, Gc and the modified Grashof number, Gr for the heat transfer leads to an increase in the velocity profiles in the mainstream. The same observation is made when the Grashof number for mass transfer, Gm is increased leading to an increase in the momentum of the fluid. This is because increasing the Grashof number leads to a decrease in the viscosity hence the motion of the fluid increases. This leads to an increase in the convective heat transfer and hence the temperature increases in the mainstream. Clearly, increasing the Gr results to higher speeds of the fluid which is also observed when the values of the Gm are also increased which leads to an increase in the momentum of the fluid. This happens because increasing Gr and Gm values makes the fluid lighter by impacting the viscosity and hence increase the velocity of the fluid flow. It is however noted that near the plate, higher values of the Grashof number represents convective cooling at the chemical walls which leads to a decrease in temperature. It is further noted that an increase in the Grashof number gave rise to an increased mass transfer gradient.

The effect of the Prandtl number on the fluid flow is represented from figure 9-11. Increasing the values of the Prandtl number leads to a decrease in the temperature of the fluid. This leads to a decrease in the velocity profiles as seen on figure 9. The decrease in temperature is attributed to the decrease in the thermal layer thickness for higher values of the Pr. The Prandtl number denotes the ratio of energy diffusivity. Hence, as the thermal diffusivity decreases with an expansion of the Pr, the temperature change is initiated throughout the fluid from the plate. As the Pr increases, the viscosity of the fluid strengthens which results to a weaker thermal conductance which leads to decrease in the fluid's velocity as well as the temperature of the fluid. As seen on figure 11, the concentration of the fluid also reduces as the Pr increases.

The effect of the Magnetic number, M on the flow is represented graphically from figure 12-14 where the velocity, temperature and concentration profiles are clearly shown. It is evident that as the Magnetic number increases, the velocity of the fluid reduces. It can also be seen that the temperature of the fluid increases with an increase in the Magnetic number. The concentration also increases with an increase in the Magnetic parameter. The increase in Magnetic number liberates high magnetic forces, also called Lorentz forces that opposes the flow of the fluid. These forces resist the fluid flow, hence leads to a reduction or decrease in the velocity of the fluid. As the magnetic field interacts with the flowing fluid, a current is generated in the fluid domain that creates resistance which leads to increase in the temperature of the fluid and a decline in the fluid velocity, due to the Lorentz forces. Thus, the resistance to the fluid flow liberates the heat which leads to the enhancement of the temperature profiles of the fluid as shown in figure 13. The heat liberated leads to dissociation of the chemical species in the fluid leading to an increase in the concentration of the fluid as the Magnetic parameter increases as depicted on figure 14.

The Soret number, Sr represents the ratio of the difference in temperature to the fluid concentration. The results show that increasing the Soret number, Sr leads to an increase in the velocity, temperature, and concentration profiles for the fluid under consideration as depicted from figure 15-17. This happens because of the reduction in the viscous forces are minimized and the reference temperature enhanced as the concentration gradient is increased. Consequently, the velocity, temperature and concentration profiles are intensified in the fluid.

The Schmidt number, Sc denotes the dimensionless parameter that represents the ratio of the kinematic viscosity of a fluid to the mass diffusivity of the fluid. The Schmidt number compares the relative sizes of the hydrodynamic boundary layer and the concentration boundary layer. The effect of the Schmidt number, Sc on the fluid velocity, temperature and concentration profiles are investigated and displayed graphically from figure 18-20. It is evident that decreasing the Schmidt number, Sc increases the velocity, temperature and concentration of the fluid. This is because decreasing the Sc decreases the viscosity of the fluid hence increases the velocity and temperature of the fluid. As the velocity increases. Reduction in the Schmidt number increases the rate at which the chemical species react and thus increase the reaction as the fluid's mass diffusivity increases, thus enhancing the concentration profiles as shown.

The effect of the Joule heating parameter on the fluid is investigated and displayed from figure 21-23. It is evident from the results that an increase in the Joule heating parameter leads to an increase in both the velocity and temperature of the fluid flow as seen on figure 21 and 22. The concentration of the fluid however decreases as the Joule heating parameter increases. This happens because as the Joule heating parameter increases, the fluid's electrical conductivity and magnetic field strength interact resulting to an increase in the current generation in the fluid that leads to an increase in the fluid temperature. This therefore leads to an increase in the velocity of the fluid and hence velocity profiles. The concentration profiles however decline as seen on figure 23 since the liberated chemical species are used up in the chemical reactions in the reactive fluid.

The effect of the activation energy on the velocity, temperature and concentration profiles are also displayed from figure 24-26. It is evident from the graphs that the activation energy E, leads to an increase in fluid velocity and temperature. This is because the increased fluid temperature with increase in activation energy parameter causes a reduction in fluid's viscosity and hence leads to increased fluid velocity. When the fluid's viscosity reduces, the momentum diffusion increases and hence the velocity enhances. Increasing the activation energy leads to an increase in the reacting species which eventually leads to an increase in the concentration of the fluid. As the activation energy increases, the species concentration increases and their equivalent solute boundary layer increases.

It can be further noted that as the reaction rate parameter increases, the concentration of the fluid decreases. This is because with an increase in the reaction rate parameter, the rate of chemical reactions in the region of the boundary layer increase which eventually slows down the fluid flow. This means that the consumption of the chemical species leads to a reduction in the concentration field which eventually leads to a decrease in the velocity of the fluid. It is evident that as the reaction rate parameter increases, there is a higher number of chemical reactions taking place in the fluid which decreases the concentration. However, when the value of E is increased, the concentration increases. It is further noted that increasing the fitted rate parameter reduces the fluid concentration.

C. Conclusion

The study has analyzed the effect of the activation energy E, for the reactive MHD flow with Joule heating. A 2-dimensional reactive fluid flow was considered in the presence of the magnetic field shown and the finite difference technique was used to solve the resulting governing equations.

It was discovered that the flow is affected by several dimensionless parameter whose effects were investigated and analyzed in detail. Some of the key findings from the study are given below:

- The concentration of the fluid increases with an increase in the activation energy, E. However, the increase in the reaction rate parameter decreases the concentration of the reactive fluid.
- An increase in the Joule heating parameter, J leads to an increase in the velocity and temperature profiles of the fluid. However, the concentration of the fluid decreased with an increase in the Joule heating parameter.
- An increase in the Soret number, Sr leads to an increase in the velocity, temperature, and concentration profiles of the fluid.
- Decreasing the Schmidt number, Sc increases the velocity, temperature, and concentration of the fluid.

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