SYNOPSIS

The investigation of problems of hydromagnetic flow of a viscous, incompressible and electrically conducting fluid in rotating and non-rotating media is of much significance because there are several natural phenomena and engineering problems susceptible to magnetohydrodynamic analysis. Geophysicists encounter hydromagnetic phenomena in the interactions of electrically conducting fluids and magnetic fields that are present in and around heavenly bodies. It is useful in astrophysics because much of the universe is filled with widely spaced charged particles and permeated by magnetic fields. Engineers use hydromagnetic principles to design heat exchangers, pumps, accelerators and flow-meters, in solving space vehicle propulsion, control and re-entry problems, in creating novel electric current generating systems and in developing confinement schemes for controlled nuclear fusion. Keeping in view the importance of such study, problems of magnetohydrodynamic flow of a viscous, incompressible and electrically conducting fluid in rotating and non-rotating media are investigated in the present thesis considering different aspects of the problems.

Present thesis contains nine chapters. Chapter 1 is introductory. Chapters 2 to 4 are devoted to the study of steady/unsteady hydromagnetic flow in a rotating channel. Chapter 5 deals with the study of effects of Hall current on unsteady hydromagnetic Couette flow within a porous channel when magnetic field is fixed relative to the moving plate of the channel. Chapters 6 to 8 are concerned with the study of the effects of Hall current on unsteady hydromagnetic natural convection flow through a porous medium past an impulsively moving vertical plate in non-rotating or rotating system considering different aspects of the problem. Finally in Chapter 9, summary and conclusions of the research studies made in the present thesis are presented.

Chapter 1 includes a brief discussion on some topics related to magnetohydrodynamic phenomena, namely, concept of Mangetohydrodynamics and its applications, dynamics of
rotating fluids and its applications, Hall current, convective heat transfer, basic equations of Magnetohydrodynamics, boundary conditions, boundary layers and a literature survey of related research studies made in the past is presented.

Chapter 2 is devoted to the study of steady MHD Couette flow of class-II of a viscous, incompressible and electrically conducting fluid in a rotating system in the presence of a uniform transverse magnetic field applied parallel to the axis of rotation taking Hall current into account. Exact solution of the governing equations is obtained in closed form. Expressions for the shear stress at stationary and moving plates due to primary and secondary flows and mass flow rates in the primary and secondary flow directions are derived. Heat transfer characteristics of the flow are considered taking viscous and Joule dissipations into account. The numerical solution of energy equation and numerical values of rate of heat transfer at both the stationary and moving plates are obtained with the help of MATLAB software. Asymptotic behavior of the solution for fluid velocity and induced magnetic field is analyzed for large values of rotation parameter $K^2$ (reciprocal of Ekman number) and magnetic parameter $M^2$ (square of Hartmann number) to gain some physical insight into flow pattern. It is noticed that, when rotation parameter is large and magnetic parameter is of small order of magnitude, there arises a thin boundary layer of thickness $O(\alpha_i^{-1})$ near stationary plate of the channel. This boundary layer may be recognized as modified Ekman boundary layer and may be viewed as classical Ekman boundary layer modified by Hall current and magnetic field. The thickness of this boundary layer decreases on increasing either $M^2$ or $K^2$ or both and increases on increasing $m$. Similar type of boundary layer also appears near moving plate of the channel. Outside the boundary layer region fluid flows in primary flow direction only. This is due to the reason that fluid flow within the channel is induced due to movement of upper plate of the channel. Both primary and secondary induced magnetic fields persist. These magnetic fields have considerable effects of Hall current and rotation and are unaffected by applied magnetic field. It is also observed that when magnetic parameter is large and rotation parameter is of small order of magnitude, there also appears a thin boundary layer of thickness $O(\alpha_i^{-1})$ near stationary
plate of the channel. This boundary layer may be identified as modified Hartmann boundary layer and may be viewed as classical Hartmann boundary layer modified by Hall current and rotation. The thickness of this boundary layer decreases on increasing either $M^2$ or $K^2$ or both and increases on increasing $m$. In the absence of Hall current there arises classical Hartmann boundary layer near stationary plate. Similar type of boundary layer also appears near moving plate. Outside the boundary layer region, fluid flows in primary flow direction only while both the primary and secondary induced magnetic fields persist. These induced magnetic fields have considerable effects of Hall current and magnetic field and are unaffected by rotation.

The numerical values of fluid velocity and induced magnetic field are displayed graphically versus channel width variable $\eta$ for various values of $m$ and $K^2$ whereas those of fluid temperature are depicted graphically versus channel width variable $\eta$ for different values of $m, K^2, P$, and $E_r$. The numerical values of shear stress at the stationary and moving plates due to primary and secondary flows and mass flow rates in the primary and secondary flow directions are presented in tabular form for various values of $m$ and $K^2$ whereas those of rate of heat transfer at the stationary and moving plates are given in tables for different values of $m, K^2, P$, and $E_r$. It is observed that Hall current tends to retard fluid flow in primary flow direction whereas it has reverse effect on the fluid flow in secondary flow direction. Rotation has tendency to accelerate fluid flow in primary flow direction throughout the channel whereas it tends to accelerate fluid flow in secondary flow direction in lower half of the channel. Hall current tends to reduce primary induced magnetic field whereas it has reverse effect on the secondary induced magnetic field. Rotation tends to enhance both the primary and secondary induced magnetic fields. Hall current tends to reduce fluid temperature whereas rotation has reverse effect on it. Viscous dissipation tends to enhance fluid temperature whereas thermal diffusion has reverse effect on it. Hall current tends to reduce primary shear stress at the stationary plate whereas it has reverse effect on secondary shear stress at the stationary plate. Rotation tends to enhance both primary and secondary shear stress at the stationary plate. Hall current tends to
enhance secondary shear stress at the moving plate and it tends to enhance primary shear stress at the moving plate when $K^2 \geq 5$. Rotation tends to enhance primary shear stress at the moving plate whereas it has reverse effect on secondary shear stress at the moving plate. There exists flow separation at the moving plate in the primary flow direction on increasing $K^2$. Hall current tends to enhance secondary mass flow rate whereas it has reverse effect on primary mass flow rate when $K^2 \leq 5$. Rotation tends to enhance primary mass flow rate. Hall current tends to reduce rate of heat transfer at the stationary plate whereas rotation has reverse effect on it. Rate of heat transfer at the moving plate is unaffected by Hall current and rotation. Viscous dissipation tends to enhance rate of heat transfer at the stationary plate whereas thermal diffusion has reverse effect on it. Viscous dissipation tends to reduce rate of heat transfer at the moving plate and thermal diffusion has reverse effect on it when $P_r \leq 1$ and viscous dissipation tends to enhance rate of heat transfer at the moving plate whereas thermal diffusion has reverse effect on it when $P_r > 1$.

There exists flow reversal of heat near the moving plate due to thermal diffusion. Also there is no flow of heat either from moving plate to the fluid or from fluid to the moving plate when $E_r = 2$ and $P_r = 1$. This situation arises when the thicknesses of viscous and thermal boundary layers are of same order of magnitude. $E_r = 2$ for $P_r = 1$ is called critical Eckert number corresponding to the moving plate.

Chapter 3 deals with the study of combined free and forced convection Couette-Hartmann flow of a viscous, incompressible and electrically conducting fluid in a rotating system with Hall effects in the presence of a uniform transverse magnetic field. Exact solution of the governing equations is obtained in closed form. Expressions for the shear stress at both stationary and moving plates of the channel due to primary and secondary flows and mass flow rates in the primary and secondary flow directions are also derived. Heat transfer characteristics of the fluid flow are considered taking viscous and Joule dissipations into account. Numerical solution of the energy equation and numerical values of rate of heat transfer at both stationary and moving plates of the channel are computed with the help of MATLAB software. Asymptotic behavior of the solution for fluid velocity
and induced magnetic field is analyzed for large values of rotation parameter $K^2$ and magnetic parameter $M^2$ to gain some physical insight into the flow pattern. It is demonstrated that, when rotation parameter is large and magnetic parameter is of small order of magnitude, there arises a thin boundary layer of thickness $O(\alpha_1^{-1})$ near moving plate of the channel. This boundary layer may be recognized as modified Ekman boundary layer and can be viewed as classical Ekman boundary layer modified by Hall current and magnetic field. The thickness of this boundary layer increases on increasing Hall current parameter whereas it decreases on increasing either rotation parameter or magnetic parameter or both. Similar type of boundary layer appears near stationary plate of the channel. Outside the boundary layer region, velocity in the primary flow direction vanishes while it persists in the secondary flow direction. In this region, fluid velocity is unaffected by Hall current and magnetic field and varies linearly with $\eta$. In the central core region, induced magnetic field persists in both the primary and secondary flow directions due to Hall current, rotation and thermal buoyancy force. It is unaffected by magnetic field and variation in it is non-linear with $\eta$ due to presence of thermal buoyancy force. It is also noticed that, when magnetic parameter is large and rotation parameter is of small order of magnitude, there also appears a thin boundary layer of thickness $O(\alpha_2^{-1})$ near moving plate of the channel. This boundary layer may be identified as modified Hartmann boundary layer and can be viewed as classical Hartmann boundary layer modified by Hall current and rotation. The thickness of this boundary layer decreases on increasing either rotation parameter or magnetic parameter or both whereas it increases on increasing Hall current parameter. In the absence of Hall current it reduces to classical Hartmann boundary layer of thickness $O(M^{-1})$. Similar type of boundary layer arises adjacent to the stationary plate of the channel. Outside the boundary layer region, fluid flows in both the primary and secondary flow directions. Fluid flow in both the primary and secondary flow directions are affected by thermal buoyancy force and magnetic field and varies linearly with $\eta$. In the absence of Hall current fluid flow persists in the primary flow direction only. Induced magnetic field persists in both the primary and secondary flow directions. Primary induced
magnetic field is affected by Hall current, rotation, thermal buoyancy force, pressure gradient and magnetic field and variation in it is non-linear with $\eta$ due to presence of thermal buoyancy force. Secondary induced magnetic field is unaffected by thermal buoyancy force and pressure gradient and it varies linearly with $\eta$.

The profiles of fluid velocity, induced magnetic field and fluid temperature are depicted graphically versus channel width variable $\eta$ for various values of pertinent flow parameters while numerical values of shear stress at both the stationary and moving plates of the channel due to primary and secondary flows, mass flow rates in the primary and secondary flow directions and rate of heat transfer at both the stationary and moving plates of the channel are presented in tabular form for various values of pertinent flow parameters. It is found that Hall current tends to retard fluid flow in the primary flow direction in the region $0 \leq \eta \leq 0.7$ and it tends to retard fluid flow in the secondary flow direction in the region $0 \leq \eta \leq 0.55$. It has reverse effect on the fluid flow in the primary flow direction in the region $0.7 < \eta \leq 1$ and on the fluid flow in the secondary flow direction in the region $0.55 < \eta \leq 1$. Magnetic field tends to retard fluid flow in the secondary flow direction throughout the channel whereas it tends to accelerate fluid flow in the primary flow direction in the region $0 \leq \eta \leq 0.69$. Magnetic field has reverse effect on the fluid flow in the primary flow direction in the region $0.69 < \eta \leq 1$. Rotation tends to accelerate fluid flow in the secondary flow direction whereas it has reverse effect on the fluid flow in the primary flow direction. Thermal buoyancy force tends to retard fluid flow in both the directions when walls of the channel are heated whereas it has reverse effect on fluid flow in both the directions when walls of the channel are cooled. Hall current tends to reduce primary induced magnetic field whereas it has reverse effect on the secondary induced magnetic field. Magnetic field tends to reduce both the primary and secondary induced magnetic fields. Rotation tends to reduce both the primary and secondary induced magnetic fields in lower half of the channel whereas it has reverse effect on both the primary and secondary induced magnetic fields in the region near to moving plate. Thermal buoyancy force tends to reduce primary induced magnetic field in the region $0 \leq \eta \leq 0.65$ when walls
of the channel are heated whereas it tends to enhance primary induced magnetic field in the region $0 \leq \eta \leq 0.65$ when walls of the channel are cooled. Thermal buoyancy force has reverse effect on the primary induced magnetic field near moving plate. Thermal buoyancy force has same effect on the secondary induced magnetic field in the region $0.3 \leq \eta \leq 1$ as it has on primary induced magnetic field in the region $0 \leq \eta \leq 0.65$ and it has reverse effect on the secondary induced magnetic field near stationary plate. Hall current and rotation tend to enhance fluid temperature. Magnetic field tends to reduce fluid temperature. Thermal buoyancy force tends to reduce fluid temperature when walls of the channel are heated and it has reverse effect on fluid temperature when walls of the channel are cooled. Thermal diffusion tends to reduce fluid temperature whereas viscous dissipation has reverse effect on it. Magnetic field tends to enhance primary shear stress at the stationary plate and it tends to enhance secondary shear stress at the stationary plate when $K^2 \geq 5$. Rotation tends to reduce primary shear stress at the stationary plate whereas it has reverse effect on the secondary shear stress at the stationary plate. Magnetic field and rotation tend to enhance both the primary and secondary shear stress at the moving plate. Hall current tends to reduce primary shear stress at the stationary plate. Thermal buoyancy force tends to reduce primary shear stress at the stationary plate when walls of the channel are heated and it has reverse effect on the primary shear stress at the stationary plate when walls of the channel are cooled. Hall current tends to reduce secondary shear stress at the stationary plate when walls of the channel are cooled. Thermal buoyancy force tends to enhance secondary shear stress at the stationary plate when walls of the channel are cooled and it has same effect on the secondary shear stress at the stationary plate when the channel walls are heated and $m \geq 1$. Also there exists flow separation at the stationary plate in the secondary flow direction on increasing Hall current parameter $m$ when walls of the channel are heated. Hall current tends to reduce primary shear stress at the moving plate. Thermal buoyancy force tends to enhance primary shear stress at the moving plate when walls of the channel are heated and it has reverse effect on primary shear stress at the moving plate when walls of the channel are cooled. Hall current tends to enhance secondary shear stress at the moving plate. Thermal buoyancy force tends to reduce
secondary shear stress at the moving plate when walls of the channel are heated and it has reverse effect on secondary shear stress at the moving plate when walls of the channel are cooled. Magnetic field tends to enhance mass flow rate in the primary flow direction and it has reverse effect on the mass flow rate in the secondary flow direction when \( K^2 \leq 5 \).

Rotation tends to reduce mass flow rate in the primary flow direction and it has reverse effect on the mass flow rate in the secondary flow direction. There is no variation in the secondary mass flow rate on increasing \( M^2 \) when \( K^2 = 7 \) and \( M^2 \geq 36 \). Hall current tends to reduce mass flow rate in the primary flow direction. It tends to reduce mass flow rate in the secondary flow direction when walls of the channel are heated whereas it has reverse effect on the mass flow rate in the secondary flow direction when walls of the channel are cooled and \( G \leq -2 \). Thermal buoyancy force tends to reduce mass flow rates in both the directions when walls of the channel are heated whereas it has reverse effect on mass flow rates in both the directions when walls of the channel are cooled. Magnetic field and rotation have tendency to enhance rate of heat transfer at both the stationary and moving plates. Hall current tends to reduce rate of heat transfer at the stationary plate. Thermal buoyancy force tends to reduce rate of heat transfer at the stationary plate when walls of the channel are heated and it has reverse effect on the rate of heat transfer at the stationary plate when walls of the channel are cooled. Hall current tends to reduce rate of heat transfer at the moving plate when \( G \geq 2 \) and it has reverse effect on the rate of heat transfer at the moving plate when \( G = -3 \). Thermal buoyancy force tends to enhance rate of heat transfer at the moving plate when walls of the channel are either heated or cooled. Thermal diffusion tends to reduce rate of heat transfer at the stationary plate. Viscous dissipation tends to enhance rate of heat transfer at the stationary plate, it tends to reduce rate of heat transfer at the moving plate when \( P_r \leq 0.3 \) and it has reverse effect on rate of heat transfer at the moving plate when \( P_r \geq 3 \).

In Chapter 4, an investigation of unsteady hydromagnetic Couette flow of a viscous, incompressible and electrically conducting fluid in a rotating channel with non-conducting walls in the presence of uniform transverse magnetic field taking induced magnetic field into account is made. Fluid flow within the channel is induced due to non-torsional
oscillations of upper plate of the channel in its own plane. Exact solution of governing equations is obtained in closed form. Expressions for shear stress at both the plates due to primary and secondary flows and mass flow rates in the primary and secondary flow directions are also derived. The mathematical formulation of the problem contains four pertinent flow parameters, namely, magnetic interaction parameter $\alpha_m$, Ekman number $E$, magnetic Prandtl number $P_m$ and frequency parameter $\omega$. Solution valid in the limit of vanishing magnetic Prandtl number $P_m$ is also obtained and asymptotic behavior of the solution for large values of frequency parameter $\omega$ is analyzed to gain some physical insight into the flow pattern. There exist two modes of oscillations in the flow-field. These two modes correspond to modified hydromagnetic Stokes flow and are confined to thin boundary layers of thicknesses $O(\alpha^{-1}_m)$ and $O(\alpha^{-1}_e)$. These boundary layers may be identified as hydromagnetic Stokes-Ekman boundary layers. The thickness of these boundary layers decreases on increasing magnetic interaction parameter whereas it increases on increasing Ekman number. In the absence of magnetic field these two boundary layers may be recognized as Stokes-Ekman boundary layers. It is also noticed that there is no flow of fluid outside hydromagnetic Stokes-Ekman boundary layer region. For large $\omega$ thickness of $m_1$ and $m_2$ layers, which can be identified as magnetic diffusion layers, tends to infinity implying thereby that the magnetic diffusion region extends up to the central line of the channel just as it happens in the limit $\omega \to 0$ and $P_m \neq 0$.

The numerical values of primary and secondary fluid velocities and primary and secondary induced magnetic fields are displayed graphically versus channel width variable $\eta$ for various values of $\alpha_m$, $E$ and $\omega$ whereas those of shear stress due to primary flow, shear stress due to secondary flow, mass flow rate in the primary flow direction and mass flow rate in the secondary flow direction are presented in tabular form for different values of $\alpha_m$, $E$ and $\omega$. It is found that magnetic field tends to retard fluid flow in both the primary and secondary flow directions whereas rotation and oscillations have reverse effect on it. Magnetic field tends to reduce both the primary and secondary induced magnetic fields whereas rotation and oscillations have reverse effect on it. Secondary induced
magnetic field moves in different directions in upper and lower half of the channel. Magnetic field tends to reduce primary shear stress at the oscillating plate whereas it has reverse effect on secondary shear stress at oscillating plate. Rotation tends to enhance secondary shear stress at the oscillating plate. Magnetic field and rotation tend to enhance primary and secondary shear stress at the stationary plate. Oscillations tend to enhance primary shear stress at the oscillating and stationary plates whereas these have reverse effect on secondary shear stress at the oscillating and stationary plates. Magnetic field tends to reduce primary and secondary mass flow rates whereas rotation and oscillations have reverse effects on it. 

Chapter 5 deals with the study of effects of Hall current on unsteady hydromagnetic Couette flow of a viscous, incompressible and electrically conducting fluid within an infinitely long parallel plate porous channel in the presence of a uniform transverse magnetic field. Fluid flow within the channel is induced due to impulsive movement of lower plate of the channel and magnetic lines of force are fixed relative to moving plate of the channel. Solution of the governing equations is obtained by Laplace transform technique. Expression for shear stress at the moving plate due to primary and secondary flows is also derived. Asymptotic behavior of the solution valid for small and large values of time is analyzed to gain some physical insight into the flow pattern. It is noticed that, for small values of time $t$, there arises a Rayleigh boundary layer of thickness $O(\sqrt{t})$ near the moving plate due to initial impulsive movement of the plate. Both the primary and secondary fluid velocities are affected by the Hall current, magnetic field and suction/injection. In the absence of Hall current secondary velocity vanishes. This is due to fact that Hall current induces secondary flow in the flow-field. Up to this stage there are no inertial oscillations in the flow-field. For large values of time $t$, fluid flow is in quasi-steady state. The steady state flow is confined within a thin boundary layer of thickness $O\left((\alpha + S/2)^{-1}\right)$. This boundary layer may be recognized as modified Hartmann boundary layer and may be viewed as classical Hartmann boundary layer modified by Hall current and suction/injection. Thickness of this boundary layer decreases on increasing either magnetic parameter $M^2$ or suction/injection parameter $S$ or both whereas it increases on
increasing Hall current parameter $m$. Steady state flow represents spatial oscillations in the flow-field excited by Hall current, magnetic field and suction/injection. Unsteady part of the flow, represented by $u_\mu$ and $v_\mu$, exhibits inertial oscillations in the flow-field excited by Hall current. Suction/injection reduces the time of decay of inertial oscillations in the major part of unsteady state flow whereas Hall current increases the time of decay of inertial oscillations in both the parts of unsteady state flow. In the absence of Hall current, there are no inertial oscillations in the flow-field.

The numerical values of primary and secondary fluid velocities are displayed graphically versus channel width variable $\eta$ for various values of Hall current parameter $m$, magnetic parameter $M^2$, suction/injection parameter $S$ and time $t$ whereas those of shear stress at the moving plate due to primary and secondary flows are presented in tabular form for different values of $m, M^2, S$ and $t$. It is observed that, Hall current tends to retard fluid flow in the primary flow direction throughout the channel and fluid flow in the secondary flow direction in upper half of the channel. It has reverse effect on the fluid flow in the secondary flow direction in lower half of the channel. Magnetic field tends to accelerate fluid flow in both the primary and secondary flow directions. This tendency of magnetic field may be attributed to the movement of magnetic field along with the moving plate of the channel. Suction tends to retard fluid flow in the primary flow direction in major part of the channel whereas injection has reverse effect on it. Suction tends to retard fluid flow in the secondary flow direction in the region $0 \leq \eta < 0.6$ whereas injection tends to accelerate fluid flow in the secondary flow direction throughout the channel. Fluid flow in both the primary and secondary flow directions is accelerated with passage of time. Hall current tends to enhance primary shear stress at the moving plate. Magnetic field tends to reduce primary shear stress at the moving plate whereas it has reverse effect on secondary shear stress at the moving plate. Suction tends to enhance primary shear stress at the moving plate whereas injection has reverse effect on it. Primary shear stress at the moving plate is reduced with passage of time. Injection tends to reduce secondary shear stress at the moving plate at each time level whereas suction tends to reduce it when $t \leq 0.05$. 
Secondary shear stress at the moving plate is enhanced with passage of time in case of suction.

Chapter 6 is devoted to study the effects of Hall current on unsteady hydromagnetic natural convection transient flow of a viscous, incompressible, electrically conducting and heat absorbing fluid past an impulsively moving vertical plate embedded in a fluid saturated porous medium, under Boussinesq approximation, taking into account the effects of thermal diffusion when temperature of the plate has a temporarily ramped profile. Natural convection flow resulting from such a plate temperature profile may have bearing on several engineering problems especially where the initial temperature profiles are of much significance in the designing of electromagnetic devices and several natural phenomena which occur due to natural convection and heat generation/absorption. Exact solution of momentum and energy equations, under Boussinesq approximation, is obtained in closed form by Laplace transform technique for both ramped temperature and isothermal plates. Solution is also obtained in the case of unit Prandtl number for ramped temperature plate. Expressions for skin friction due to primary and secondary flows and Nusselt number for both ramped temperature and isothermal plates are also derived. Mathematical formulation of the problem, in non-dimensional form, contains six pertinent flow parameters viz. $M^2$ (magnetic parameter), $m$ (Hall current parameter), $G_r$ (Grashof number), $K_1$ (permeability parameter), $P_r$ (Prandtl number) and $\phi$ (heat absorption coefficient).

The numerical values of primary and secondary fluid velocities are displayed graphically versus boundary layer coordinate $y$ for various values of $m$, $G_r$, $K_1$, $\phi$ and time $t$ while those of fluid temperature are presented in graphical form versus $y$ for different values of $P_r$, $\phi$ and $t$ for both ramped temperature and isothermal plates. For both ramped temperature and isothermal plates, the numerical values of skin friction due to primary and secondary flows are presented in tabular form for various values of $m$, $G_r$, $K_1$, $\phi$ and $t$ whereas those of Nusselt number are given in tables for different values of $P_r$, $\phi$ and $t$. It is seen that Hall current, thermal buoyancy force and permeability
of medium tend to accelerate fluid flow in the primary and secondary flow directions for both ramped temperature and isothermal plates. As time progresses, for both ramped temperature and isothermal plates, primary and secondary fluid velocities are getting accelerated. Heat absorption tends to retard fluid flow in the primary and secondary flow directions for both ramped temperature and isothermal plates. For both ramped temperature and isothermal plates, primary and secondary velocities attain a distinctive maximum value near surface of the plate and then decrease properly on increasing boundary layer coordinate \( y \) to approach free stream value. Also the primary and secondary fluid velocities are faster in case of isothermal plate than that of ramped temperature plate. Thermal diffusion tends to enhance fluid temperature whereas heat absorption tends to reduce it for both ramped temperature and isothermal plates. As time progresses, there is an enhancement in fluid temperature for both ramped temperature and isothermal plates. Fluid temperature is maximum at the surface of the plate for both ramped temperature and isothermal plates and it decreases on increasing boundary layer coordinate \( y \) to approach free stream value. Also fluid temperature is lower for ramped temperature plate than that of isothermal plate. Hall current, thermal buoyancy force and permeability of medium tend to reduce primary skin friction whereas these have reverse effect on secondary skin friction for both ramped temperature and isothermal plates. Heat absorption tends to enhance primary skin friction whereas it has reverse effect on secondary skin friction for both ramped temperature and isothermal plates. As time progresses, for both ramped temperature and isothermal plates, there is a reduction in primary skin friction and enhancement in secondary skin friction. For both the ramped temperature and isothermal plates, heat absorption tends to enhance rate of heat transfer at the plate whereas thermal diffusion tends to reduce it. As time progresses, there is an enhancement in rate of heat transfer at the ramped temperature plate whereas there is reduction in rate of heat transfer at the isothermal plate.

In Chapter 7, the effects of Hall current on unsteady hydromagnetic natural convection transient flow of a viscous, incompressible and electrically conducting fluid with radiative heat transfer past an impulsively moving vertical plate embedded in a fluid saturated
porous medium taking into account the effects of thermal diffusion is discussed when the
temperature of the plate has a temporarily ramped profile. Hydromagnetic natural
convection flow with radiative heat transfer resulting from such a plate temperature profile
may have bearing on several engineering problems especially where initial temperature
profiles assume much significance in designing of electromagnetic devices and several
natural convection phenomena which occur due to such initial temperature profiles. Exact
solution of momentum and energy equations, under Boussinesq and Rosseland
approximations, is obtained in closed form by Laplace transform technique for both ramped
temperature and isothermal plates. Expressions for skin friction and Nusselt number for
both ramped temperature and isothermal plates are also derived.

The numerical values of fluid velocity and fluid temperature are displayed graphically
versus boundary layer coordinate $y$ for various values of pertinent flow parameters for both
ramped temperature and isothermal plates. The numerical values of skin friction due to
primary flow, skin friction due to secondary flow and Nusselt number are presented in
tabular form for various values of pertinent flow parameters. It is found that Hall current,
thermal buoyancy force, permeability of medium and radiation tend to accelerate fluid flow
in the primary and secondary flow directions in the boundary layer region for both ramped
temperature and isothermal plates. As time progresses, primary and secondary fluid
velocities are getting accelerated in the boundary layer region for both ramped temperature
and isothermal plates. Primary and secondary fluid velocities are faster in case of
isothermal plate than that of ramped temperature plate. Radiation and thermal diffusion
tend to enhance fluid temperature in the boundary layer region for both ramped temperature
and isothermal plates. As time progresses, there is an enhancement in fluid temperature in
the boundary layer region for both ramped temperature and isothermal plates. Fluid
temperature is lower for ramped temperature plate than that of isothermal plate. Hall
current, thermal buoyancy force, permeability of medium and radiation tend to reduce
primary skin friction whereas these physical quantities have reverse effect on secondary
skin friction for both ramped temperature and isothermal plates. As time progresses, there
is reduction in primary skin friction whereas there is an enhancement in secondary skin
friction for both ramped temperature and isothermal plates. Radiation and thermal diffusion
tend to reduce rate of heat transfer at both ramped temperature and isothermal plates. As time progresses, rate of heat transfer at ramped temperature plate is enhanced whereas it is reduced at isothermal plate.

Chapter 8 deals with the study of the effects of Hall current and rotation on unsteady hydromagnetic natural convection flow of a viscous, incompressible, electrically conducting and heat absorbing fluid past an impulsively moving vertical plate embedded in a fluid saturated porous medium taking into account the effects of thermal diffusion when temperature of the plate has a temporarily ramped profile. Exact solution of momentum equation, under Boussinesq approximation, is obtained in closed form by Laplace transform technique for both ramped temperature and isothermal plates. Solution is also obtained in the case of unit Prandtl number for ramped temperature plate. Expressions for skin friction are also derived for both ramped temperature and isothermal plates.

The numerical values of fluid velocity are depicted graphically whereas those of skin friction are presented in tabular form for various values of pertinent flow parameters for both ramped temperature and isothermal plates. For both ramped temperature and isothermal plates: Hall current tends to accelerate primary and secondary fluid velocities in the boundary layer region. Rotation tends to retard primary velocity whereas it has reverse effect on secondary velocity in the boundary layer region. Thermal buoyancy force and permeability of medium tend to accelerate primary and secondary fluid velocities in the boundary layer region. Heat absorption tends to retard primary and secondary fluid velocities in the boundary layer region. There is an enhancement in primary and secondary fluid velocities as time progresses in the boundary layer region. Fluid velocities are faster in case of isothermal plate than that of ramped temperature plate. For both ramped temperature and isothermal plates: Hall current tends to reduce primary skin friction whereas it has reverse effect on secondary skin friction. Rotation has tendency to enhance both the primary and secondary skin friction. Thermal buoyancy force and permeability of the medium tend to reduce primary skin friction whereas these have reverse effect on secondary skin friction. Heat absorption tends to enhance primary skin friction whereas it has reverse effect on secondary skin friction. As time progresses, there is reduction in
primary skin friction for ramped temperature plate whereas there is enhancement in secondary skin friction for both ramped temperature and isothermal plates.

In Chapter 9, Summary and significant outcomes from the problems discussed in chapters 2 to 8 are presented.