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# Mathematical model for velocity and temperature of gravity-driven convective optically thick nanofluid flow past an oscillating vertical plate in presence of magnetic field and radiation

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**Abstract**

Analytic expression for unsteady hydromagnetic boundary layer flow past an oscillating vertical plate in optically thick nanofluid in presence of thermal radiation and uniform transverse magnetic field is obtained. The Rosseland diffusion flux model is adopted to simulate thermal radiation effects. The momentum and energy conservation equations are made dimensionless and analytic solution is obtained using the Laplace transform. The results for velocity and temperature are obtained and plotted graphically. It is found that the velocity of the nanofluid increases with radiation parameter Nr, Grashof number Gr and time while decreases with increase in magnetic field and Prandtl number Pr. Temperature of nano-fluids increases with time while decrease with increase in Nr and Pr.


*Keywords:* Analytic solution; Laplace transform; Radiation; Magnetic field; Nanofluid

## 1. Introduction

Working fluids have great demands placed upon them in terms of increasing or decreasing energy release to systems, and their influences depend on thermal conductivity, heat capacity and other physical properties in modern thermal and manufacturing processes. Potential for heat transfer in the high-tech applications such as microelectronics, data centres and micro-channels have attracted the most attentions. Conventional heat transfer fluids such as ethylene glycol, water, pumping oil, etc., do not possess sufficient capability for cooling applications due to their poor thermal performance. A low thermal conductivity is one of the most remarkable parameters that can limit the heat transfer performance. Adding solid particles to these fluids could enhance their thermal performance.

This is one of the most modern and appropriate methods for increasing the coefficient of heat transfer. However, still these suspensions with micrometre or larger size particles are not efficient choice for such applications. Therefore,

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**Nomenclature**

| | |
|---|---|
| $T$ | Temperature |
| $T_w$ | Constant temperature |
| $u$ | Velocity |
| $u_0$ | Amplitude of the plate oscillations |
| $B$ | External uniform magnetic field |
| $B_0$ | Constant magnetic flux density |
| $C_p$ | Specific heat at constant pressure |
| $t$ | Time |
| g | Acceleration due to gravity |
| k | Thermal conductivity |
| $q_r$ | Radiation heat flux |
| $k^*$ | Rosseland mean absorption coefficient |
| $M$ | Magnetic parameter (Ratio of Lorentz force to viscous force) |
| Nr | Radiation parameter (larger the value more is the radiation) |
| Pr | Prandtl number (ratio of momentum diffusivity to thermal diffusivity) |
| Gr | Grashof number (ratio of buoyancy force to viscous force) |

*Greek symbols*

| | |
|---|---|
| $\beta$ | Thermal expansion |
| $\rho$ | Density |
| $\sigma^*$ | Stefan Boltzman constant |
| $\sigma$ | Electrical conductivity (S/m) |
| Ø | Nanoparticle volume fraction |
| $\theta$ | Dimensionless temperature ($\theta = \frac{T-T_0}{T_w-T_0}$) |
| $\omega$ | Frequency of oscillation of the plate |
| $\mu$ | The viscosity |

*Subscripts*

| | |
|---|---|
| $f$ | Fluid phase |
| $nf$ | Nano-fluid |
| $s$ | Solid phase |
| 0 | Ambient condition |

development of highly efficient heat transfer fluids for solving the drawback of conventional fluids has become one of the most important priorities in the cooling industries.

Choi and Eastman [1] were probably the first to employ a mixture of nanoparticles and base fluid that such fluids were designated as "nano-fluids".

In nano particles due to the increase of surface area to the volume, some physical properties such as thermal, electrical, mechanical, optical and magnetic property of the materials can be changed significantly. The most important point is that nano structured materials exhibit different and unique properties as compared to the bulk materials with the same compositions. Experimental studies have displayed that with 1%–5% volume of solid metallic or metallic oxide particles, the effective thermal conductivity of the resulting mixture can be increased by 20% compared to that of the base fluid [2]. A variety of research papers on nano-fluids and their different applications can be found in [3].

The study of magneto hydrodynamic flow and heat transfer has received considerable attention in recent years due to its essential applications in engineering and technology such as MHD generators, pumps, plasma studies, bearings, nuclear reactors and geothermal energy extractions. Interaction between the electrically conducting fluid and a magnetic field is used as a control mechanism in material manufacturing industry, as the convection currents are