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# Active cooling of hot integrated circuits using a rotating cylinder and NEPCM-water mixture: Numerical analysis of the impact of phase change and Magnetohydrodynamics on double-diffusive mixed convection

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## Abstract

Efficient cooling of integrated circuits is crucial for maintaining optimal performance and longevity of electronic devices. This study addresses this challenge by investigating the double-diffusive mixed convection around a hot integrated circuit (using) a nano-encapsulated phase change material-water mixture for enhanced heat absorption. The cooling process is carried out by a cylinder rotating at a constant speed inside a square cavity surrounded by the NEPCM-water mixture. Using the Galerkin finite element method, we numerically analyzed the influence of various parameters, including the Reynolds number ( $10 \leq Re \leq 100$ ), Richardson number ( $0.1 \leq Ri \leq 10$ ), Hartmann number ( $0 \leq Ha \leq 80$ ), NEPCM volume fraction ( $0.01 \leq \phi \leq 0.035$ ), Lewis number ( $0.1 \leq Le \leq 10$ ), buoyancy ratio ( $1 \leq Nz \leq 5$ ), fusion temperature ( $0.1 \leq \theta_f \leq 0.9$ ), and Stefan number ( $0.1 \leq Ste \leq 0.8$ ), on the average Nusselt number ( $Nu_{av}$ ), average Sherwood number ( $Sh_{av}$ ), total entropy generation ( $S_{total}$ ), and Bejan number ( $Be$ ). The results demonstrate that increasing  $Re$  and  $Ri$  enhances  $Nu_{av}$  and  $Sh_{av}$  by up to 175% and 162%, respectively, while applying a magnetic field (increasing  $Ha$ ) suppresses heat and mass transfer rates by up to 58% and 50%, respectively. Increasing  $\phi$  improves  $Nu_{av}$  by up to 34% with minimal impact on  $Sh_{av}$ . The  $Le$  and  $Nz$  govern the coupling between heat and mass transfer processes, with  $Le$  substantially influencing  $Sh_{av}$  and  $Nz$  affecting both  $Nu_{av}$  and  $Sh_{av}$ . The  $\theta_f$  exhibits a non-monotonic effect on  $Nu_{av}$ , suggesting an optimal fusion temperature, while  $Ste$  shows an inverse relationship with  $Nu_{av}$ . The  $S_{total}$  is significantly influenced by  $Re$ ,  $Ri$ ,  $Ha$ , and  $\phi$ , while  $Be$  is affected by  $Re$ ,  $Ri$ ,  $Ha$ , and  $\phi$  to a lesser extent. These findings provide valuable insights into the complex interplay of forced and natural convection, magnetohydrodynamics, and NEPCMs in the active cooling of hot electrical elements. The results can be applied to optimize cooling system designs, potentially leading to more efficient and effective thermal management in electronic devices.