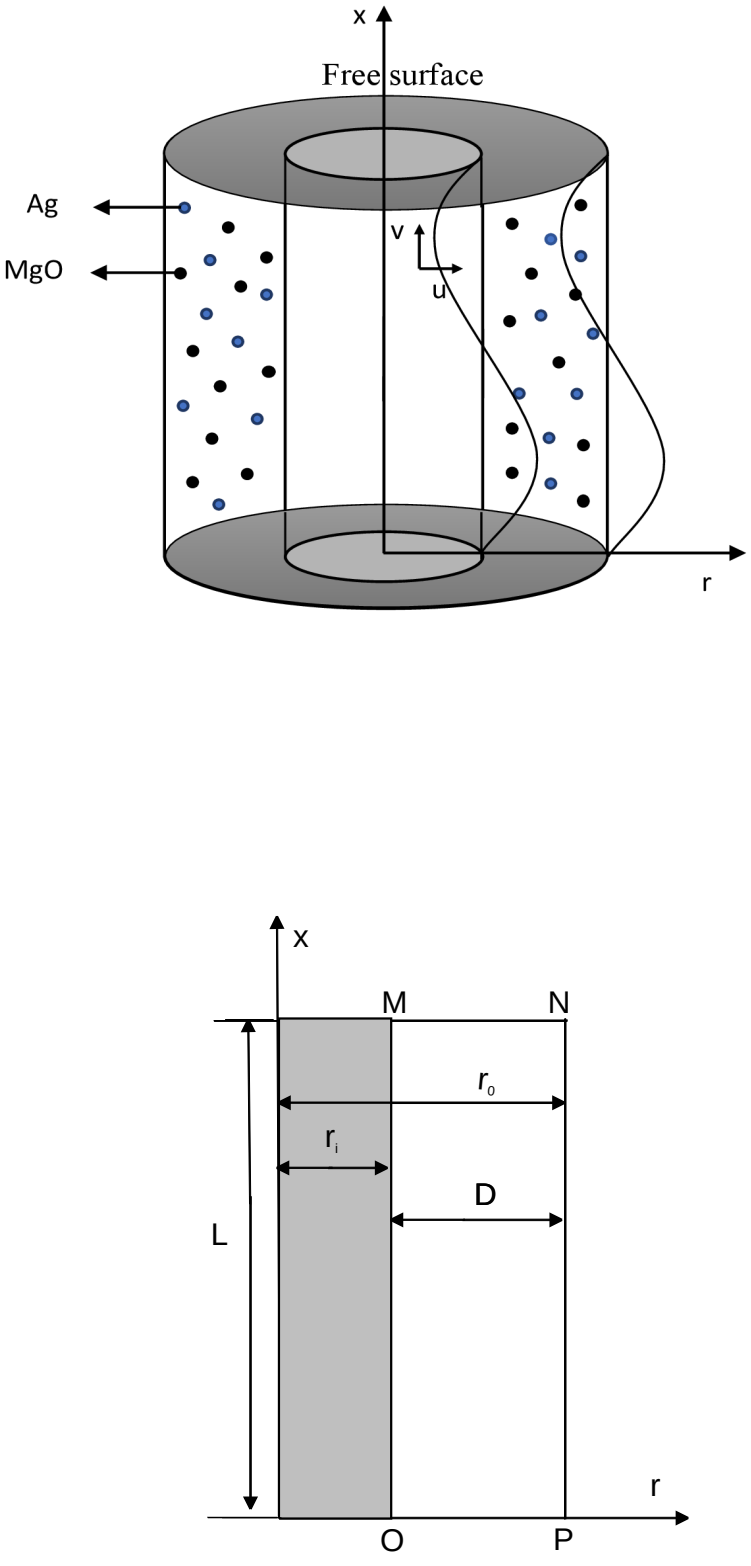
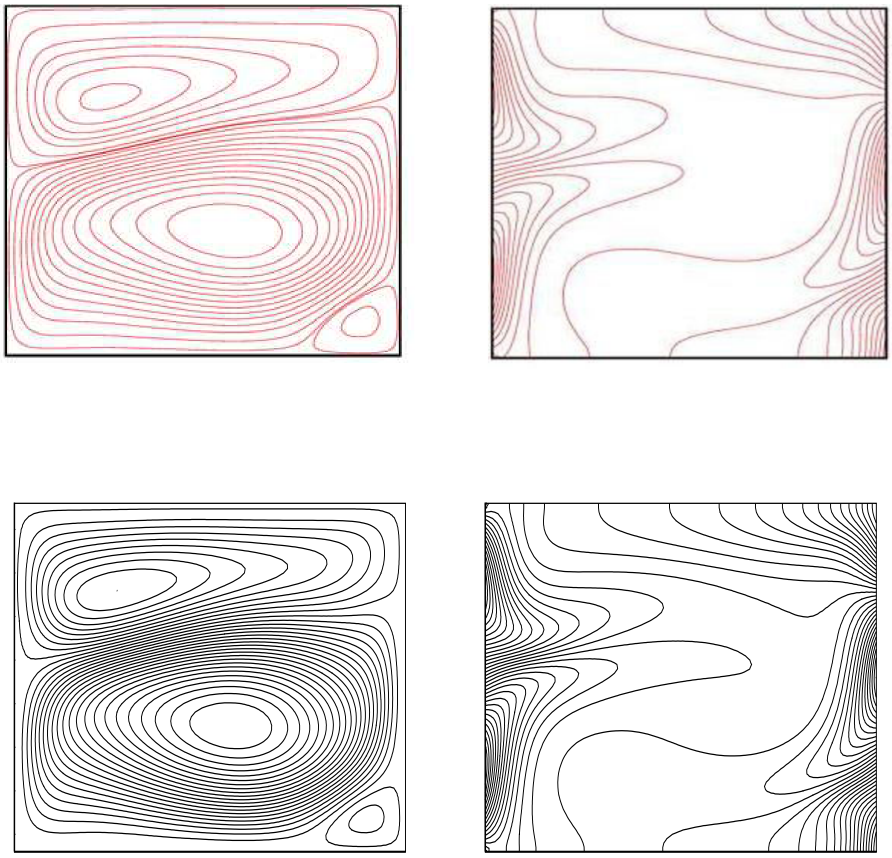


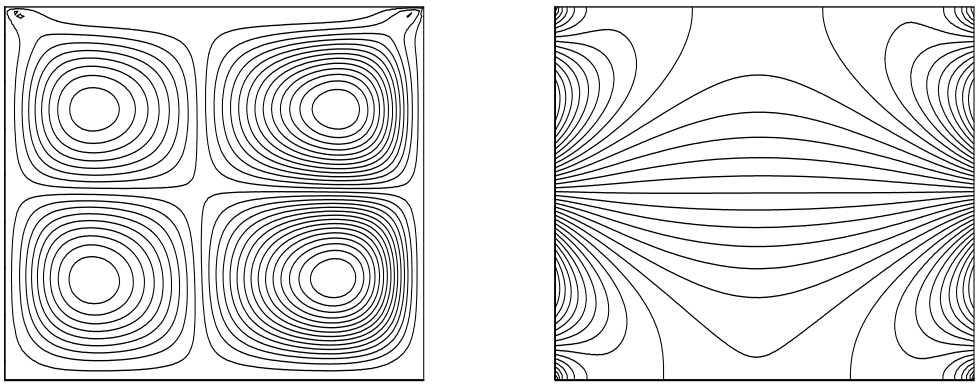
Fig. 1. Flow Configuration and Coordinate System



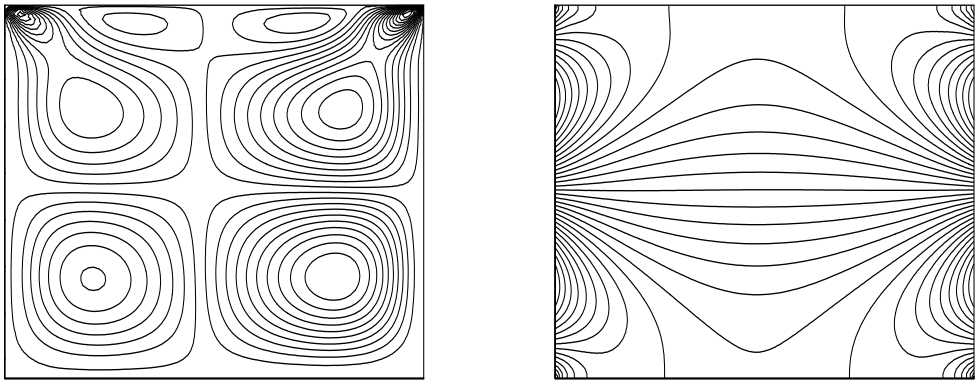
(*a*) (*b*)

Fig. 2. Comparison of flow field(*a*) and thermal contours(*b*) with Deng and Chang(2008)

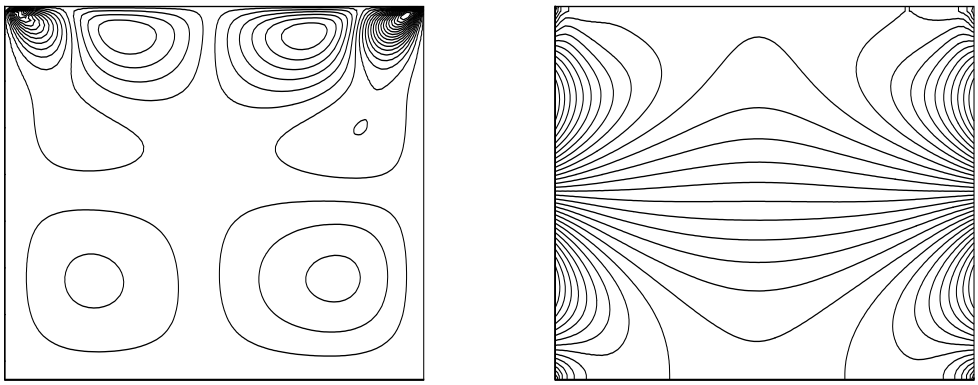
.



$Ma = 10^2$

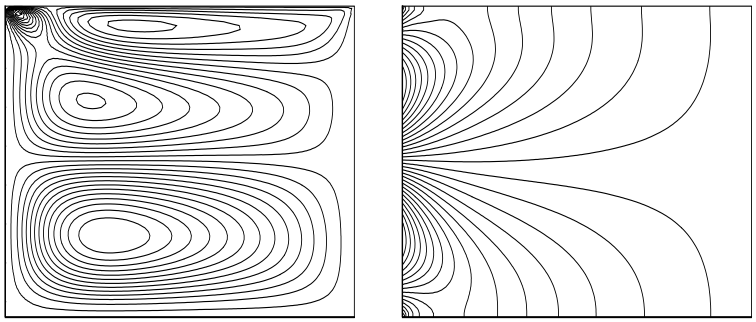


$Ma = 10^3$

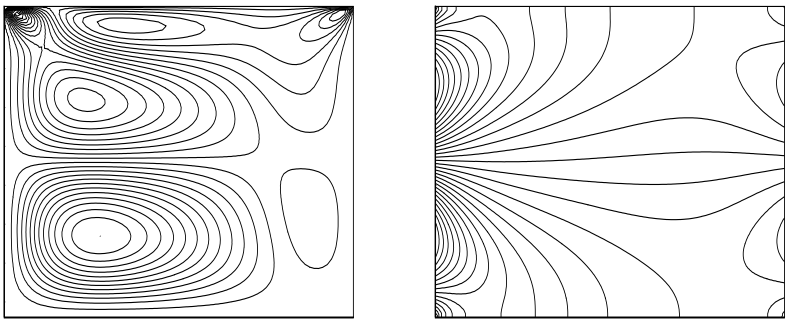


$Ma = 10^4$

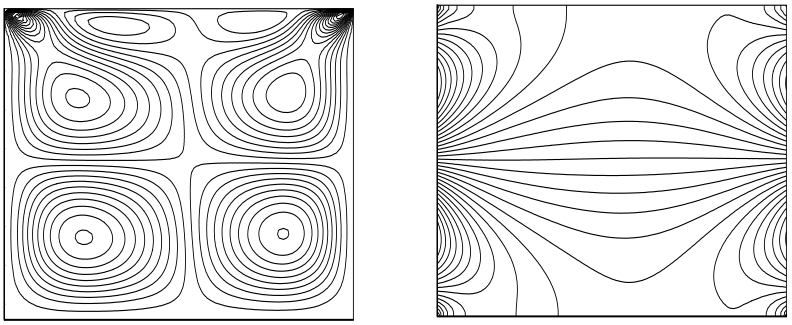
Fig. 3. Effect of Marangoni number on streamlines and isotherms for $Ra = 10^4$, $\epsilon = 1$, $\gamma = 0$, $Ha = 10$, $\phi = 0.02$, $\lambda = 2$, $A = 1$



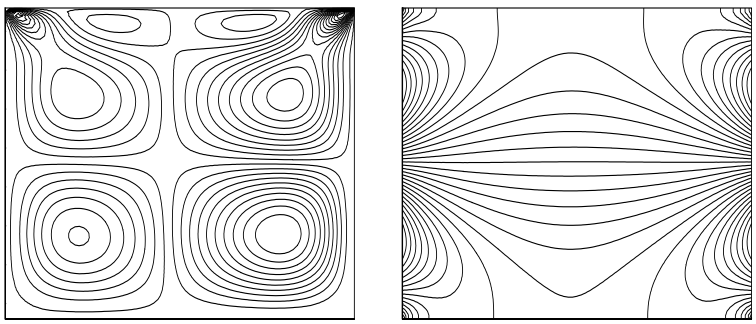
$\epsilon = 0$



$\epsilon = 0.25$

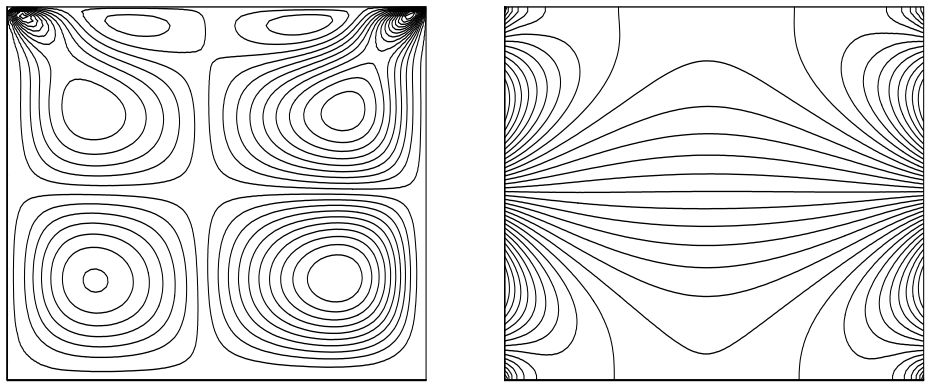


$\epsilon = 0.75$

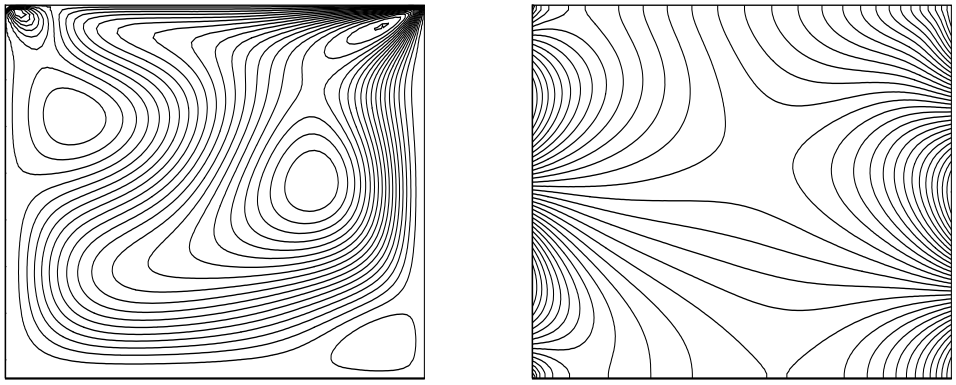


$\epsilon = 1$

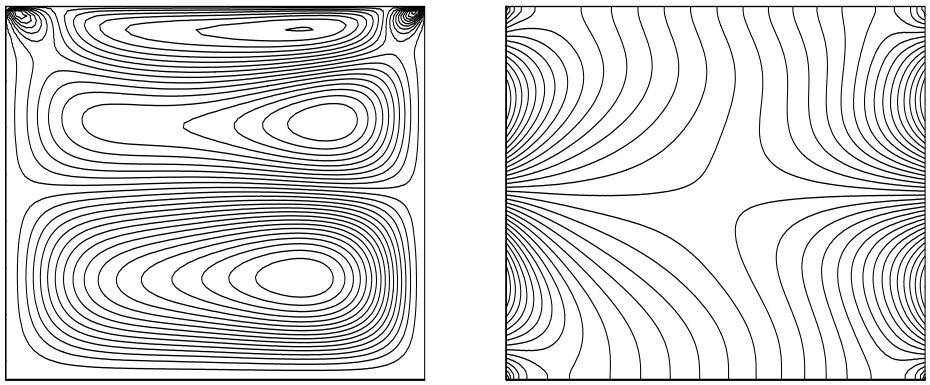
Fig. 4. Effect of amplitude ratio on streamlines and isotherms for $Ra = 10^4$, $Ma = 10^3$, $\gamma = 0$, $Ha = 10$, $\phi = 0.02$, $\lambda = 2$, $A = 1$



$\gamma = 0$

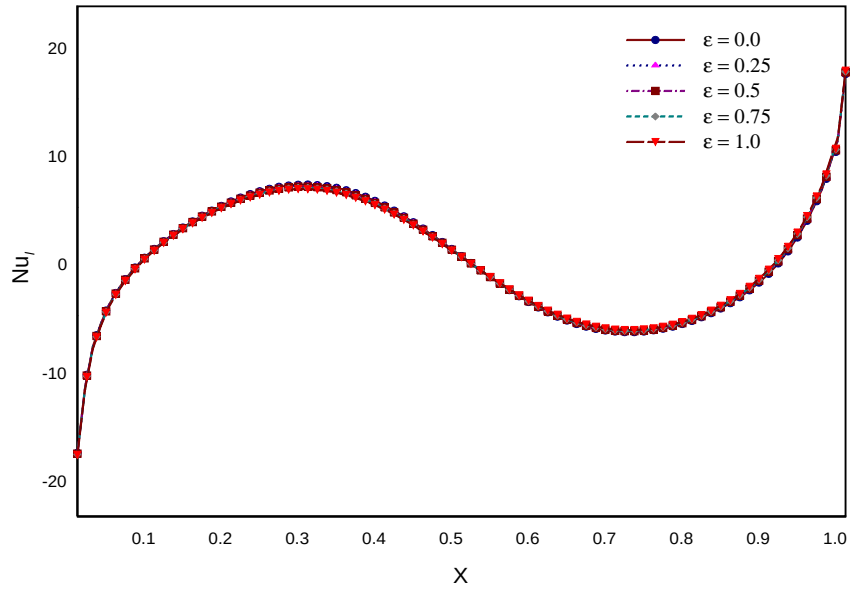


$\gamma = \pi/2$

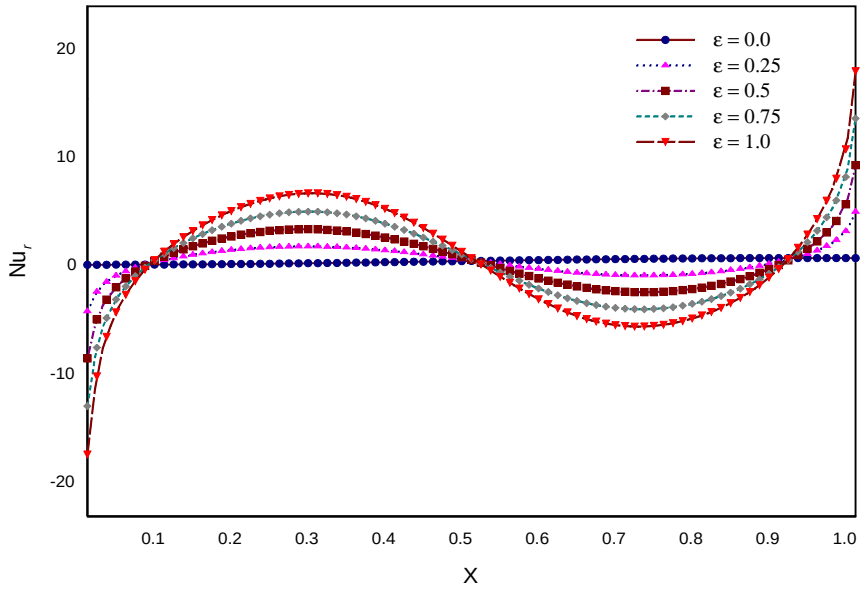


$\gamma = \pi$

Fig. 5. Effect phase deviation on streamlines and isotherms for $Ra = 10^4$, $Ma = 10^3$, $\epsilon = 1$, $Ha = 10$, $\phi = 0.02$, $\lambda = 2$, $A = 1$



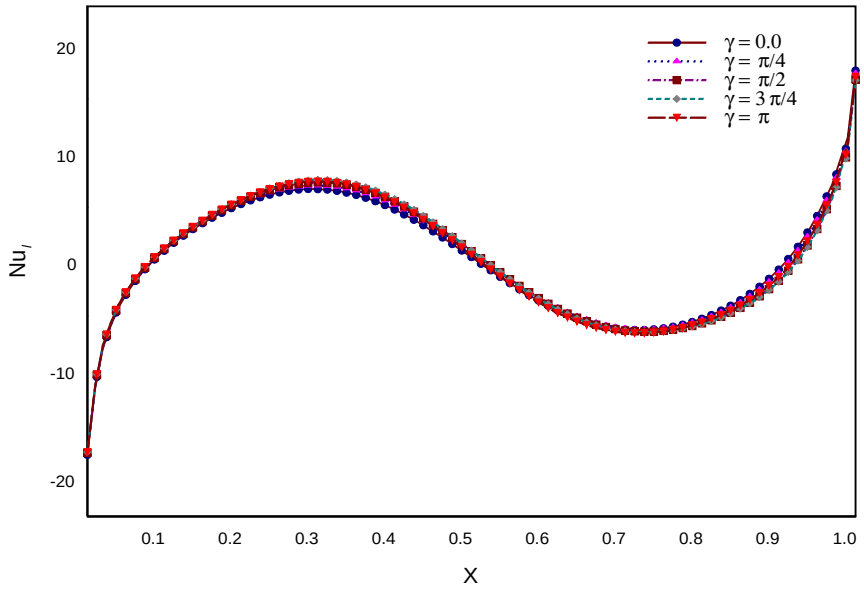
(a)



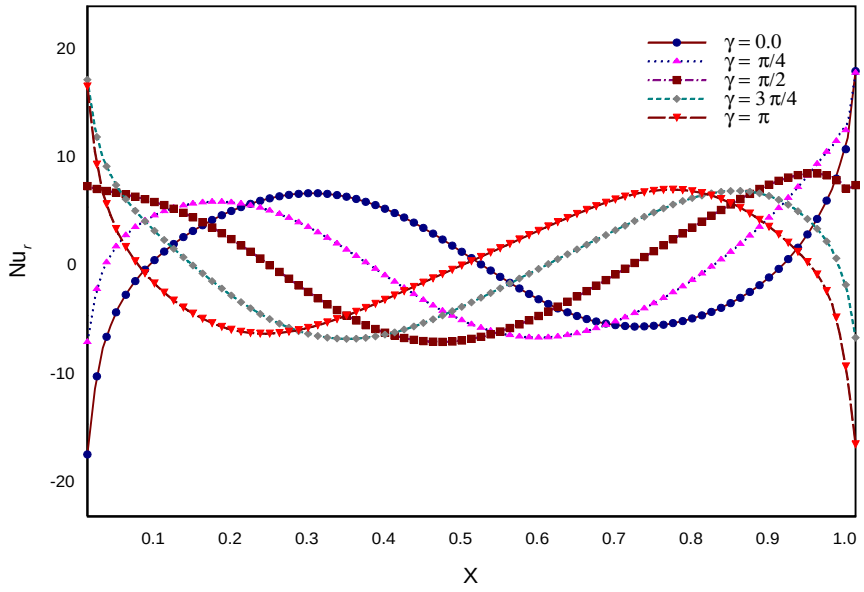
(b)

Fig. 6. Variation of Local nusselt number along the left and right walls of the enclosure for various amplitude ratios for $Ra = 10^4$, $Ma = 10^3$, $\gamma = 0$, $Ha = 10$, $\phi = 0.02$, $\lambda = 2$, $A = 1$

.



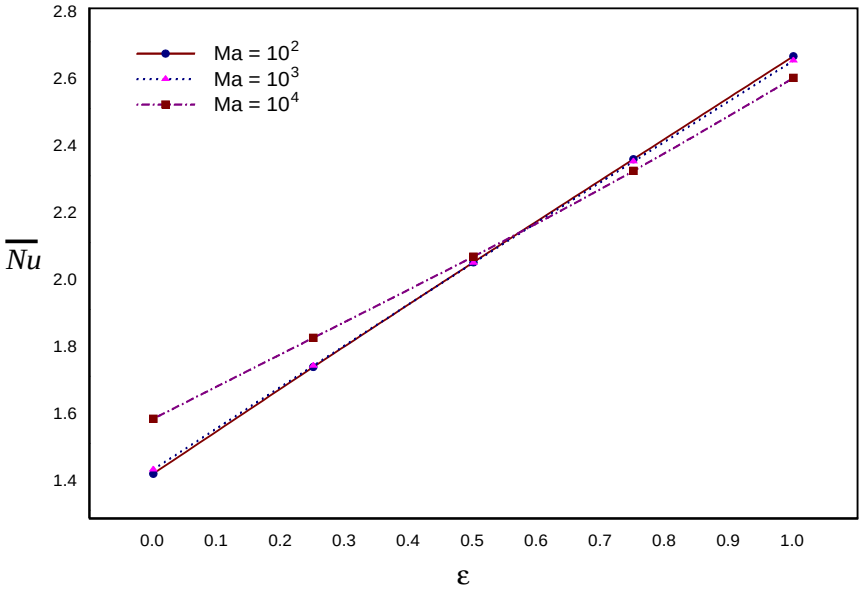
(a)



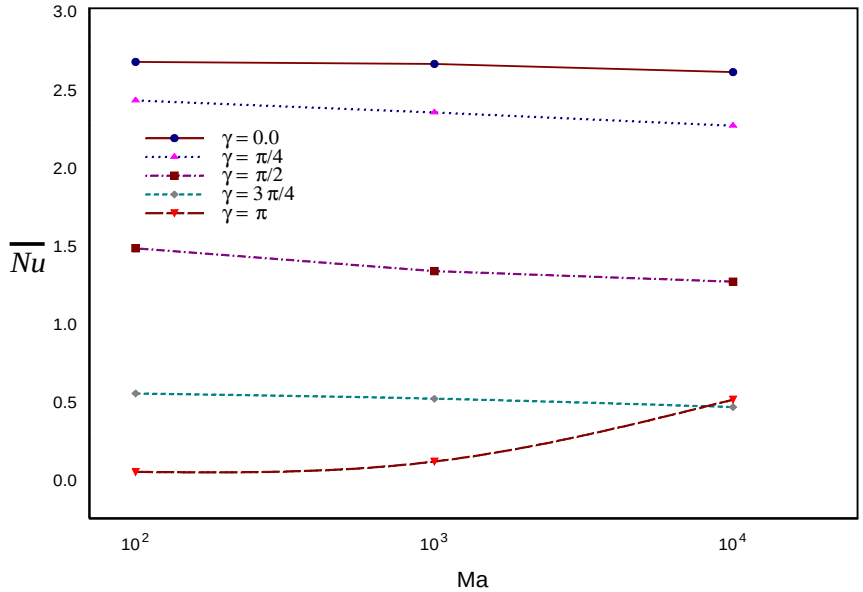
(b)

Fig. 7. Variation of Local nusselt number along the left and right walls of the enclosure for various phase deviations for $Ra = 10^4$, $Ma = 10^3$, $\epsilon = 1$, $Ha = 10$, $\phi = 0.02$, $\lambda = 2$, $A = 1$

.



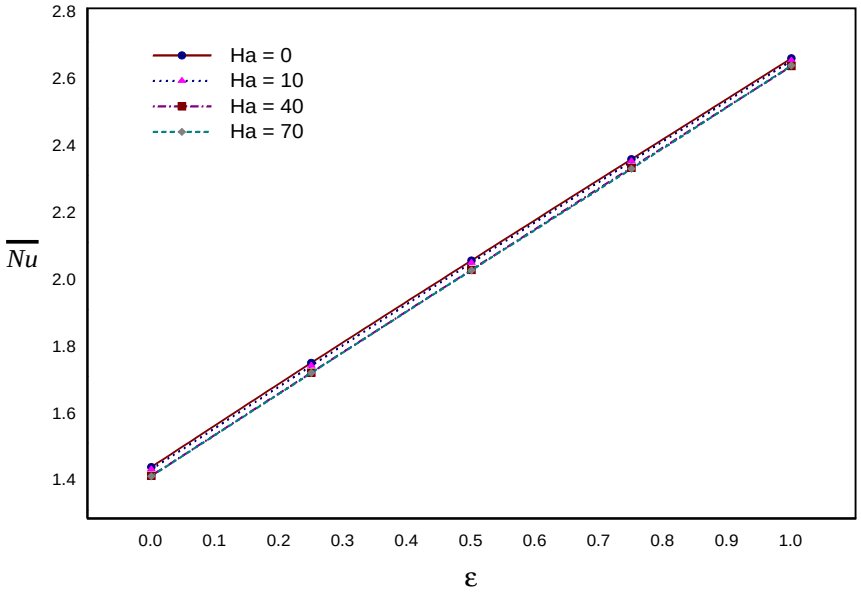
(a)



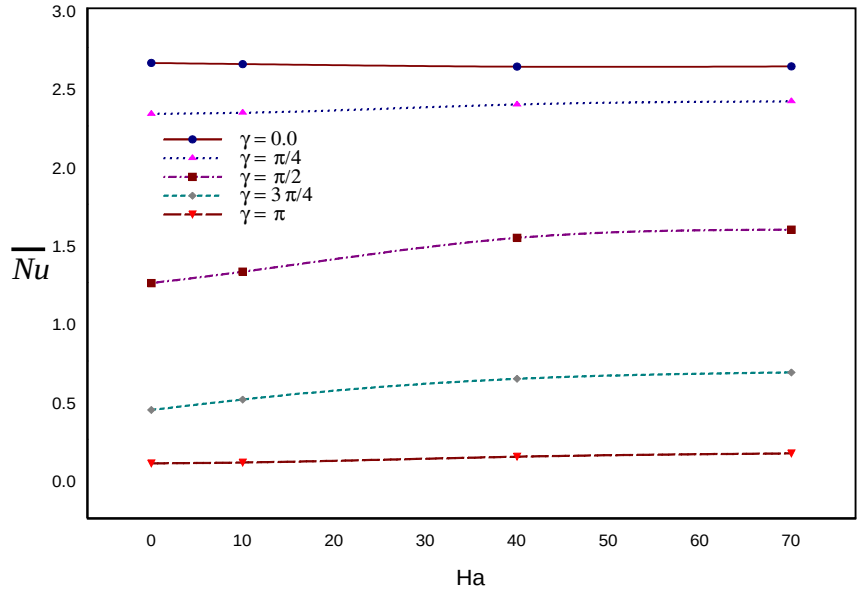
(b)

Fig. 8. Effect of the Marangoni number on the (a) amplitude ratio(ϵ) and (b) phase deviation(γ) for $Ra = 10^4$, $Ha = 10$, $\phi = 0.02$, $\lambda = 2$, $A = 1$

.



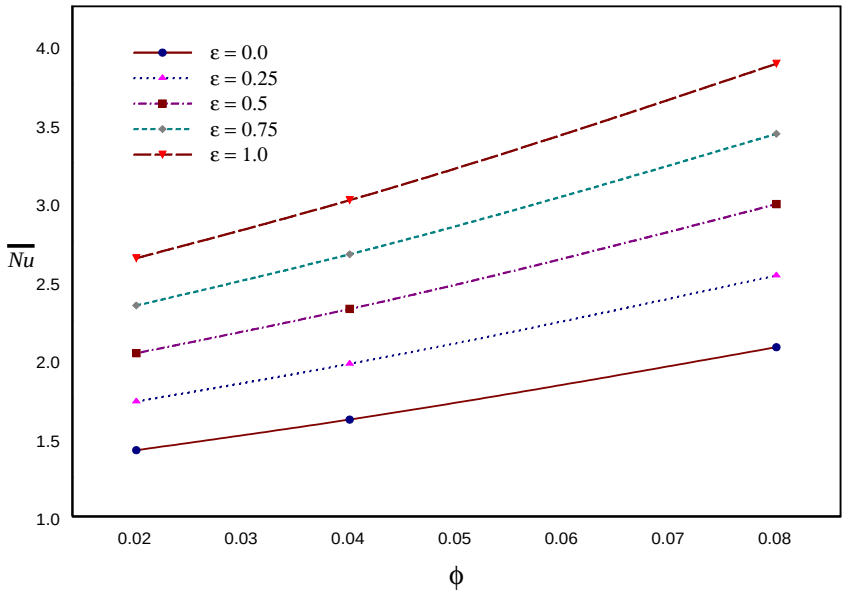
(a)



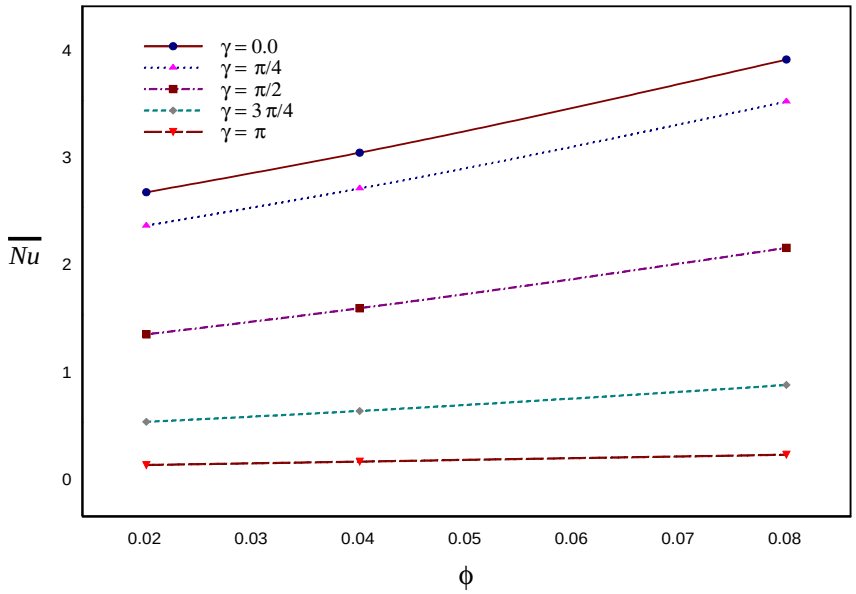
(b)

Fig. 9. Effect of the Hartmann number on the (a) amplitude ratio(ϵ) and (b) phase deviation(γ) for $Ra = 10^4$, $Ma = 10^3$, $\phi = 0.02$, $\lambda = 2$, $A = 1$

.



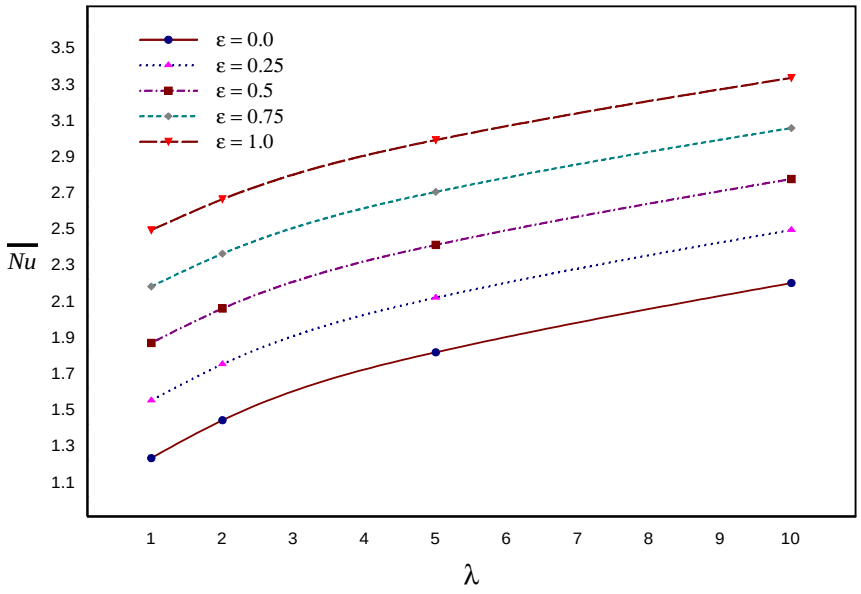
(a)



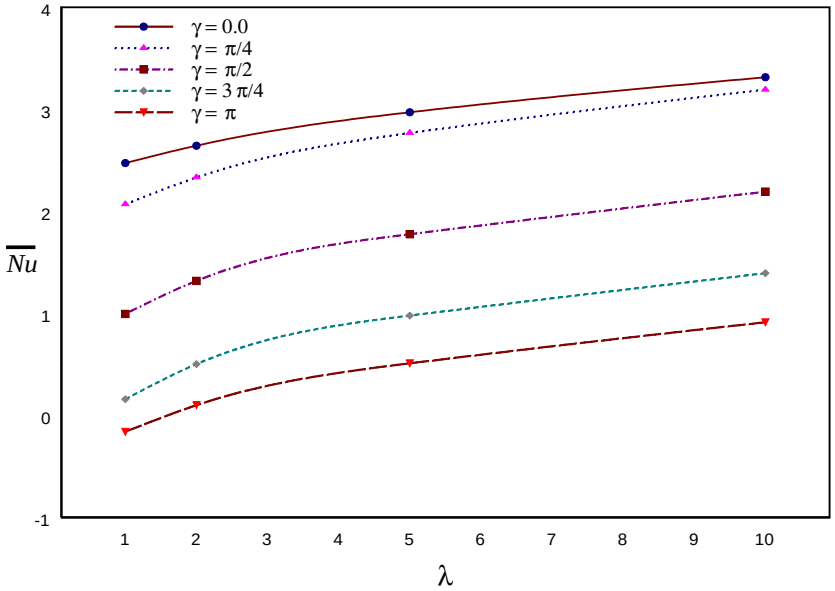
(b)

Fig. 10. Effect of the nanoparticle volume fraction on the (a) amplitude ratio(ϵ) and (b) phase deviation(γ) for $Ra = 10^4$, $Ma = 10^3$, $Ha = 10$, $\lambda = 2$, $A = 1$

.



(a)



(b)

Fig. 11. Effect of the radii ratio on the (a) amplitude ratio(ϵ) and (b) phase deviation(γ) for $Ra = 10^4$, $Ma = 10^3$, $Ha = 10$, $\phi = 0.02$, $A = 1$

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