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Nanofluids for Heat Transfer: An Analysis of Thermophysical Properties

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Abstract: *Nanofluids have emerged as a new class of fluids with special characteristics of enhanced heat transfer characteristics. It is designed by suspending nanoparticles of dimension ranging from 1nm-100nm into a base fluid like water ,ethylene glycol or oil. The volume fraction of particles under study ranges from 2% to 8%. A higher volume fraction results in the particles agglomerating as well as causing abrations in the walls through which it flows. Nanofluids for heat transfer has managed to overcome both these problems. The suspensions are more stable and cause lesser damage to the walls along with better heat transfer characteristics than the base fluids. It is therefore possible to design lighter and more compact heat exchangers as the quantity of the fluid required is much smaller than the base fluid. The suspension of metal and metal oxides in base fluids which are the conventional heat removing fluids, are the nanofluids under study in this paper. Investigating the thermophysical properties of these nanofluids therefore becomes important for designing efficient nanofluids. We compare the thermal conductivity, density, specific heat capacity and viscosity of nanofluids with special focus on suspensions of Al_2O_3,Cu, TiO_2 and Au in water. A detailed study is carried out for the dependence of these properties on the volume fraction of the nanoparticles and on the temperature.*
Keywords: *heat transfer, nanofluid,thermophysical properties, volume fraction.*

I. Introduction

In 1995, Choi [1] designed a new fluid called the nanofluid which was synthesized by suspending nanoparticles of metals and metal oxides in base fluids. Maxwell's studies on thermal conductivity of suspensions showed an increase in thermal conductivity in comparison to the base fluid. However the earlier studies had large and micro particles suspended in the base fluid. While there was an enhancement in heat transfer, the bigger size resulted in sedimentation of the particles and also heavier particles corroded the channels through which they passed resulting in the general wear and tear of the channels and pipes. Nanofluids for heat transfer has managed to overcome both these problems. The suspensions are more stable and cause lesser abrations along with better heat transfer characteristics than the base fluids [2],[3],[4]. It is therefore possible to design lighter and more compact heat exchangers as the quantity of the fluid required is much smaller than the base fluid. Nanofluids can be used as coolants in micro-electronic devices where the sizes have been diminishing resulting in high heat generation which need to be removed efficiently for the optimal functioning of these devices[5],[6]. In the automobile industries nanofluids can play a very important role in removal of excess energy that is generated due to the combustion of the fuel. When flowing through the tubes of the radiator nanofluids can lose its heat to the surrounding air through its walls . In all manufacturing processes which require heat transfers, the conventional fluids can be replaced by nanofluids. Understanding the underlying mechanisms which cause the enhancements, it is important to investigate the properties and flow characteristics of nanofluids.

II. Description Of The Problem

We have used Cu,Al_2O_3,TiO_2 and Au in water as nanofluids for our study. The idea was also to explore if materials with higher thermal conductivities mixed with base fluids always resulted in better heat transfers. The hypothesis is, that since the solid nanoparticles have a higher thermal conductivity than the base fluid therefore when suspended in base fluid the heat transfer characteristics will be enhanced. It is also important to understand that the flow characteristics depend on the thermal characteristics of the nanofluids. Our assumption is that density, specific heat, thermal conductivity and viscosity are nonlinear functions of temperature.The volume fraction ranges from 2% to 8%. Higher volume fractions have experimentally been proved to cause agglomerations and sedimentations.

III. Equations For The Thermophysical Properties

Empirical correlations from literature have been used for calculating the density, viscosity, specific heat and thermal conductivity for the nanofluids as a function of volume fraction[7].

$$\mu_{nf} = \mu_f(1 + 2.5\varphi) \qquad (1)$$

$$\rho_{nf} = (1-\varphi)\rho_f + \varphi\rho_s \quad (2)$$
$$\beta_{nf} = ((1-\varphi)\rho_f\beta_f + \varphi\rho_s\beta_s)/\rho_{nf} \quad (3)$$
$$c_{nf} = ((1-\varphi)\rho_f c_f + \varphi\rho_s c_s)/\rho_{nf} \quad (4)$$
$$k_{nf} = k_f(k_s + 2k_f - 2\varphi(k_f - k_s)/(k_s + 2k_f + \varphi(k_f - k_s)) \quad (5)$$

where the symbols have the following meaning.
ρ_{nf} represents the density of the nanofluid.
φ is the volume fraction of the nanoparticles suspended in base fluid
ρ_f is the density of the base fluid
ρ_s is the density of the nanoparticle.
μ_{nf} is the viscosity of the nanofluid
μ_f is the viscosity of the base fluid.
β_{nf} is the coefficient of volume expansion of the nanofluid
β_f is the coefficient of volume expansion of the base fluid
β_s is the coefficient of volume expansion of the nanoparticle
c_{nf} is the specific heat capacity of nanofluid at constant pressure
c_f is the specific heat capacity of base fluid at constant pressure
c_s is the specific heat capacity of nanoparticle at constant pressure
k_{nf} is the thermal conductivity of the nanofluid
k_f is the thermal conductivity of the base fluid
k_s is the thermal conductivity of the nanoparticle
The values of the properties have been adopted from literature [8] ,[9]

Table 1

Nanoparticle	k_s(W/mK)	ρ_s(kg/m^3)	c_s(J/kgK)	β_s(10^5)/K
Cu	401	8933	385	1.16
Al_2O_3	40	3970	765	0.9
TiO_2	8.95	4250	686.2	0.9
Au	314.4	19320	128.8	1.4

Table 2

Base fluid	k_f(W/mK)	ρ_f(kg/m^3)	c_f(J/kgK)	β_f(10^5)/K	μ_f(Pa s)
Water	0.613	997.2	4179	21	.0011

IV. Results

From Table 1 and Table 2 above for the thermophysical properties of nanoparticles and base fluid, respectively we evaluate the thermophysical properties of the nanofluids using (1)-(5). The variation of the thermophysical properties with volume fraction is compared for the given nanofluids graphically.

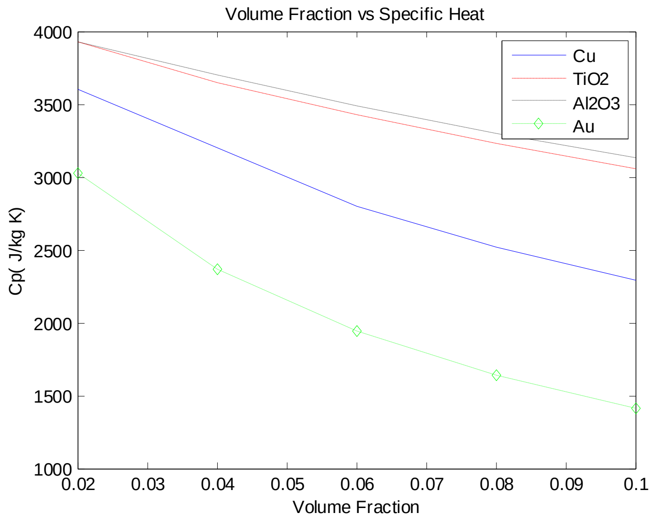

Fig 1 Specific Heat as a function of vol. fr.

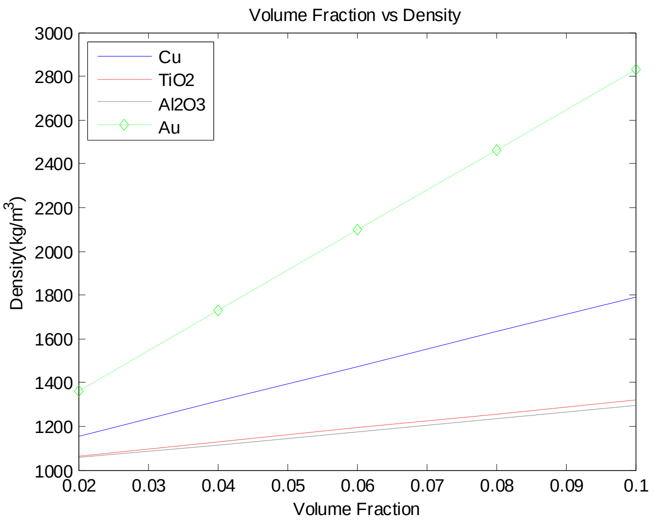

Fig 2 Density as a function of vol. fr.

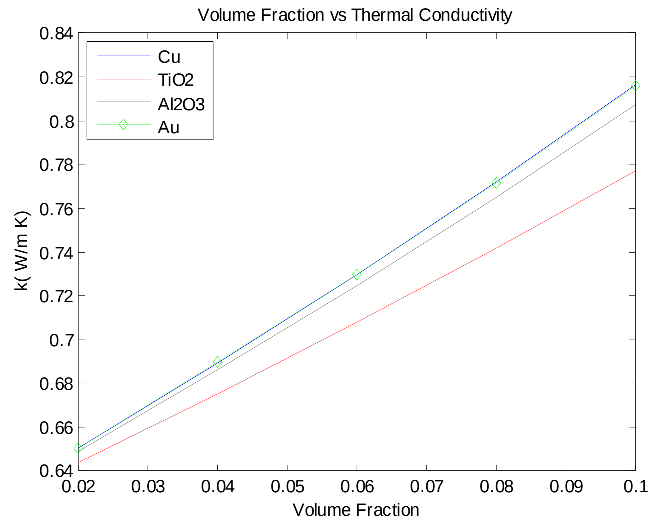

Fig 3 Thermal conductivity as a function of vol. fr.

The graphical representations are the variations of the thermophysical properties with the volume fractions for nanofluids synthesized from Cu,TiO_2, Al_2O_3 and Au nanoparticles in water.

Since our focus in on the efficient removal of heat by nanofluids, we have also studied the variation of the thermophysical properties with temperature. This will be extremely important in designing nanfluids for using it in heat exchangers and as coolants. For example if a nanofluid is used in heat exchanger, removing of heat will result in an increase in temperature of the nanofluid which will alter its thermophysical properties[10]. In the following figures , we represent the variation of density with temperature for a copper nanofluid for volume fractions ranging from 0.02 to 0.06 Fig4(a-c).

In Fig 5 (a-c) we study the variation of viscosity with temperature for different volume fractions for copper nanofluid. The range of temperatures considered is from 298K-323K. Generally the nanofluid at the inlet is likely to be at the room temperature(25℃). When it is circulated for heat removal purposes its surroundings could be at much higher temperatures. In our present analysis we therefore consider the variation of thermophysical properties in the range of 25℃ -50℃ . We assume that the values of thermal conductivity, viscosity and density remains constant for the solids in this range[11].

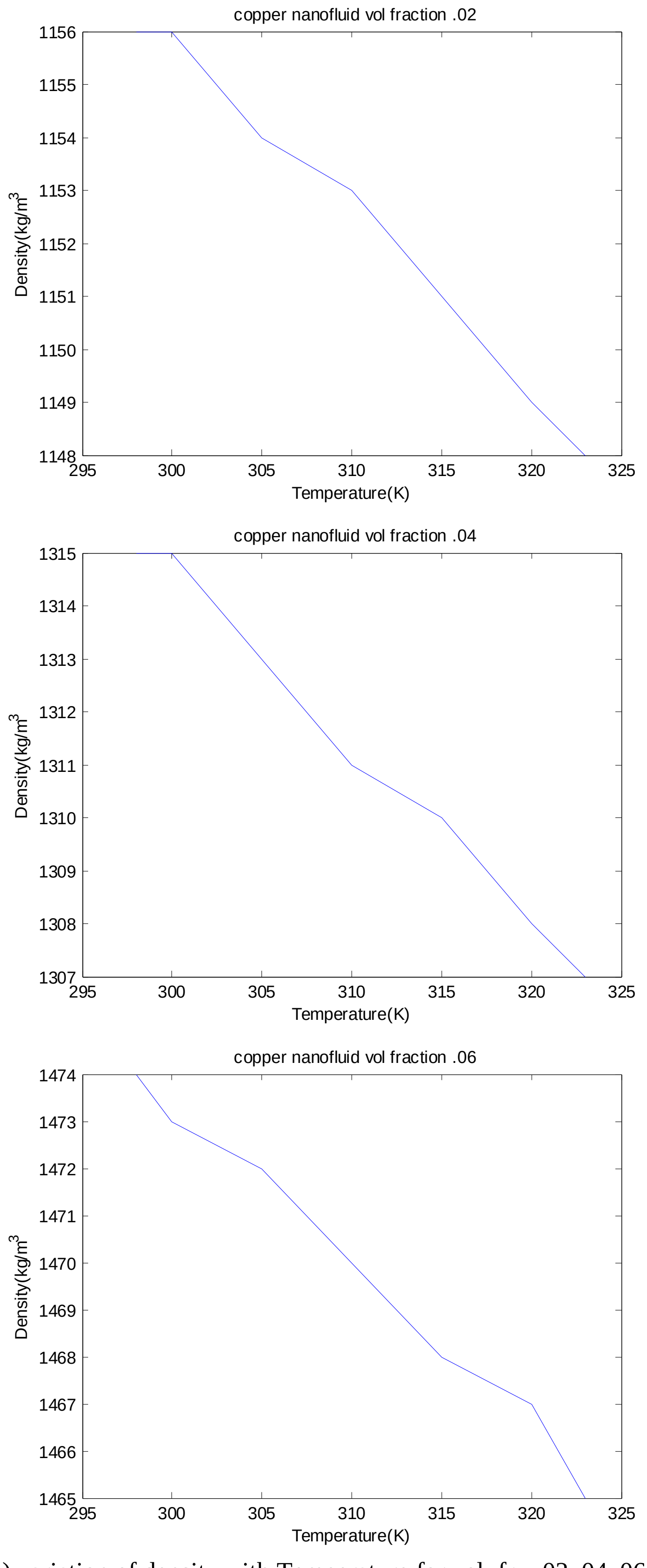

Fig 4(a-c) variation of density with Temperature for vol. fr =.02,.04,.06 respectively

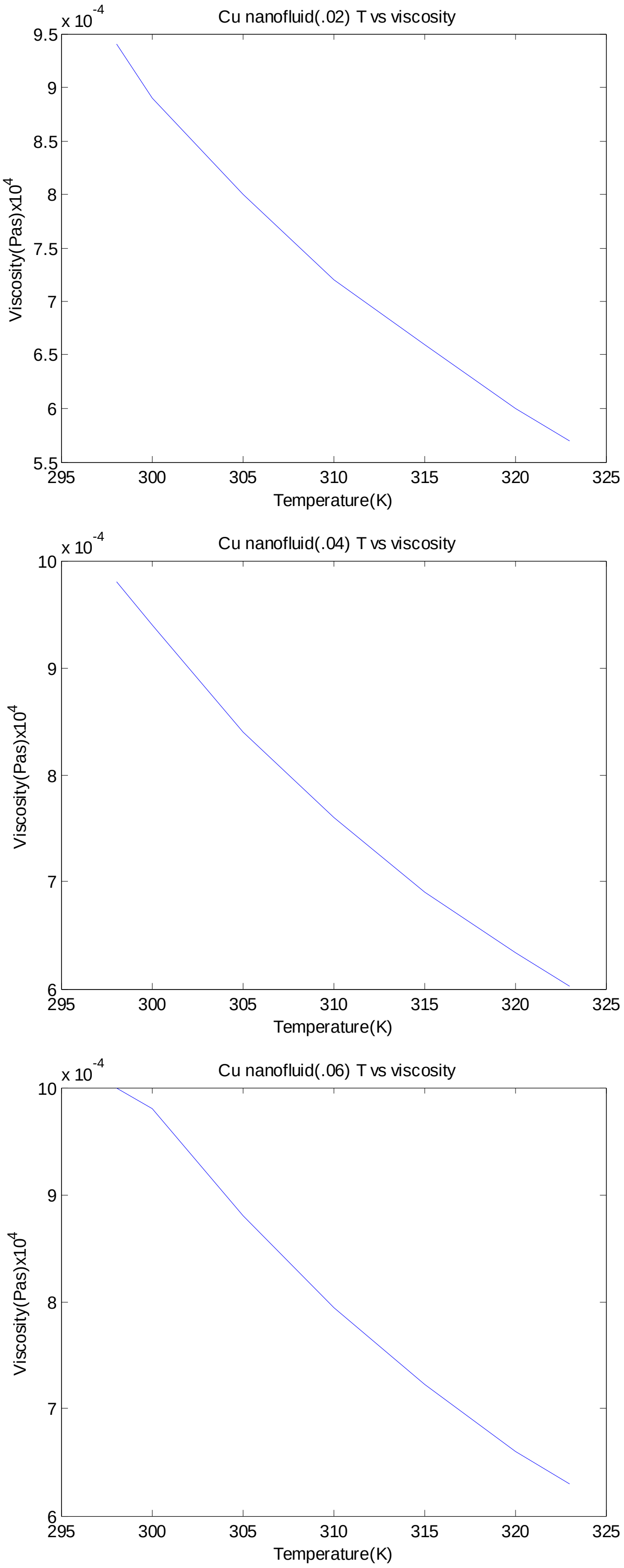

Fig 5(a-c) variation of viscosity with Temperature for vol. fr.= 0.02,.04,.06 respectively

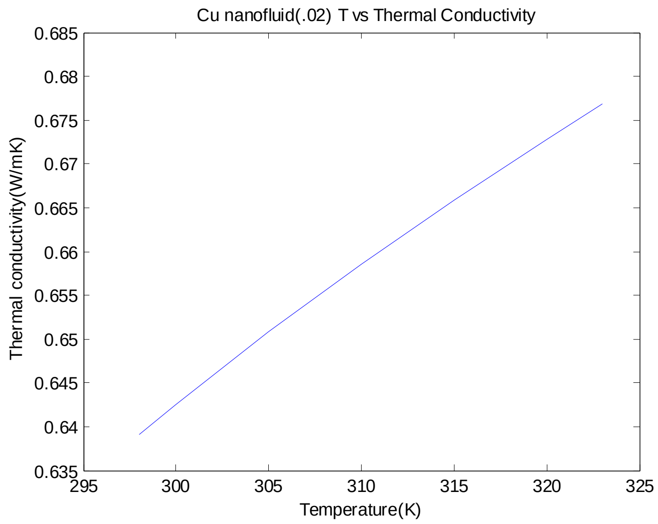

Fig 6(a) Variation of Thermal conductivity with T for vol. fr.=.02

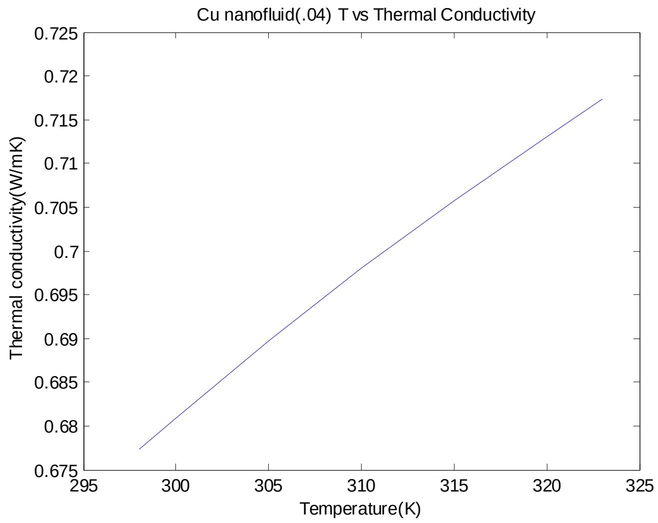

Fig (6b) Variation of thermal conductivity with T for vol. fr.=.04

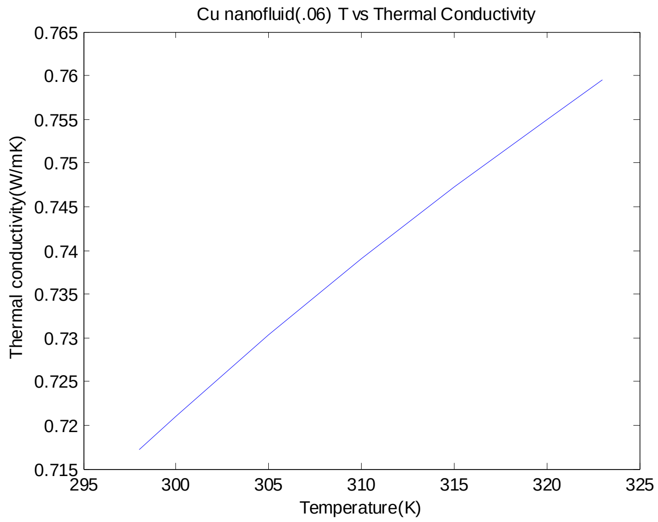

Fig 6(c) Thermal conductivity as a function of T for vol. fr. =.06

V. Conclusions

In the present work we have studied the thermophysical properties of the nanofluids with Cu, TiO_2, $Al_2O_3$and Au nanoparticles in water. We have further investigated the dependence of thermophysical properties with temperature. The range of temperature considered is relevant for the practical applications of nanofluids as heat transfer fluids. While density ,viscosity and thermal conductivity increases with increase in volume fraction , specific heat decreases with the increase in the particle concentration. We find that though there is a difference in the thermal conductivity of copper and gold nanoparticles but the variation of the thermal conductivity with volume fraction is exactly the same for the corresponding nanofluids. The dependence on temperature of the properties is approximately the same for the different volume fractions of the nanofluid. We have not compared the variation of viscosity with volume fraction for the given nanofluids as the viscosity is dependent only on the viscosity of the base fluid and the volume fraction. The viscosity is found to increase with volume fraction. This has the negative effect as more pumping power will be required for maintaining the flow of the nanofluid. Engineering nanofluids for heat transfer ,therefore involves coupling of the flow dynamics with the heat transfer. This will enable the investigation of the velocity profile and the temperature distribution of the nanofluid .The present study therefore is of paramount importance in studying the dynamics of the nanofluids, flow characteristics subjected to temperature changes. In most of the past theoretical investigations, the thermal conductivity and viscosity have been considered as constants and only the variation of density with temperature is considered. For the temperature ranges that should be considered for nanofluids for heat transfer , there seems to be a significant dependence of these properties on temperature. Thus for a more accurate flow and heat transfer characteristics , future simulations must incorporate these important results . This would also be significant in undertanding the underlying mechanisms for the anomalous heat transfer capabilities of nanofluids which in turn would aid in designing efficient nanofluids for optimum utilization as heat transfer fluids.

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References

[1]. S.U.S. Choi , Enhancing thermal conductivity of fluids with nanofluids, Developments and Applications of Non-Newtonianflows,99, ASME, 1995

[2]. P.Keblinski ,S.R.Phillipot, S.U.S.Choi, J.A.Eastman, Mechanisms of heat flow in suspensions of nanosized particles(nanofluids), International J. Heat and Mass Transfer,45, 2002,855-863

[3]. Y.Xuan, Q.Li, Heat Transfer Enhancement of Nanofluids, Int.J.Heat&Fluid Flow,21,2000,158-164

[4]. Semiha Öztuna, Kamil Kahveci , Baha Tulu Tanju , Natural Convection of Water-Based CuO Nano fluid Between Concentric Cylinders, Recent Advances in Fluid Mechanics and Heat & Mass Transfer, 164-169.

[5]. Vatsal. S. Patel, Ragesh. G. Kapadia , Dipak A. Deore , An Experimental Study of Counter flow Concentric Tube Heat Exchanger using CuO / Water Nanofluid , International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 6, 2006, 914-920

[6]. Sarit Kumar Das, Stephen U. S. Choi, Heat transfer in Nanofluids— A review, Heat transfer engineering, 27(10), 2006, 3–19

[7]. Bilal Elhajjar , Glades Bachir , Abdelkader Mojtabi , Chakib Fakih, Marie Catherine Charrier-Mojtabi , Modeling of Rayleigh–Bénard natural convection heat transfer in nanofluids , Comptes Rendus Mecanique 338 , 2010 , 350-354

[8]. J. M. Jawdat, I. Hashim , S. Momani , Dynamical System Analysis of Thermal Convection in a Horizontal Layer of Nanofluids Heated from Below , Mathematical Problems in Engineering , 2012, 1-13

[9]. X.Q. Wang, A.S. Mujumdar, Heat transfer characteristics of Nanofluids: a review , Int. J. Therm. Sci. 46 , 2007, 1–19

[10]. N. Putra, W. Roetzel, S.K. Das , Natural convection of Nanofluids , Heat Mass Transfer ,39 , 2003, 775–784 Book

[11]. John H Lienard IV, John H Lienard V , Heat Transfer text book ,Phlogiston Press, March 2015.