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Research Article

Fe_3O_4, Au nanoparticles influence on bio-nanofluid thermal conductivity

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ABSTRACT

Hyperthermia therapy is one of the new technologies emerging from nanotechnology. This study examines the relationship between bio-nanofluid thermal conductivity and hematocrit differences. In the treatment of cancer, researchers have used several types of nanoparticles. The bio-nanofluid used in this study was created by adding two types of nanoparticles (Fe_3O_4 and Au) to blood for the first time. Based on the results, thermal conductivity was found to be significantly affected by the shape of nanoparticles, and the proposed thermal conductivity models agreed with the literature. According to the nanomaterial and the age and gender of the participants, as well as the nanoparticles' shape, analysis of the study results is presented. For each group of men, women, and children, the effective thermal conductivity values of Plasma-Au nanoparticles and plasma-Fe_3O_4 nanoparticle fluids changed with the thickness of the interlayer. In comparison to iron nanoparticles (magnetite oxide Fe_3O_4), gold nanoparticles improved the thermal conductivity more. Nano-layer thickness increases with radius at the same time as thermal conductivity increases. A bio-nanofluid composed of plasma, nano-Fe_3O_4, or nano-Au was calculated by Yang's model. In addition, the thermal conductivity of nano-biofluid, consisting of plasma nano-Fe_3O_4, nano-Au, and red blood cells, was calculated using the Maxwell model. As a result of varying hematocrit values, nano-biofluids improve at a different rate of thermal conductivity. Depending on the gender and age of the patient, the rate of improvement varies. Au nanoparticles (5 nm) increased the bio-nanofluid thermal conductivity for children by 0.623% and 0.306% more than that for men and women, respectively, at nano-layer thickness (t=1 nm). Using Fe_3O_4 NPs of 25 nm diameter, the children thermal conductivity of nano-biofluid increased by 0.58% and 0.268% higher than men and women, respectively, at nano-layer thickness (t= 5 nm).

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INTRODUCTION

Nanoparticles have become increasingly popular in a wide range of scientific and practical applications since the early twenty-first century. New possibilities have been opened up in areas such as medicine, electronics, materials science and more thanks to nanotechnology. Because nanoparticles are so small, they have unique properties that allow them to be used in a wide range of applications, such as enhancing material properties in manufacturing to delivering medications in medicine. Different regions and areas can, however, experience varying levels of influence and extent of this "scientific revolution" [1, 2].

As a result of their unique thermal properties and uniqueness as fluids, nanofluids, which contain molecules of nanometers (nanoparticles), have been investigated in various applications. Nanofluids are commonly used in the following applications:

Heat transfer efficiency can be improved by using fluids with high thermal conductivity in cooling systems. As a result, the coolant is able to conduct heat more efficiently in thermal exchanges. Medical applications use nanofluids to treat high temperatures, since they target tissues containing nanoparticles to heat [3]. By improving heat transfer and solar radiation absorption, nanoscopic fluids were also used in solar energy applications [4, 5]. During oil and gas drilling operations, nanoparticles were used in drilling fluids to improve lubrication and heat transfer [6]. The use of nanofuids in the automotives industry can enhance heat transfer and improve the efficiency of the cooling system, in addition to improving the properties of fuel combustion and emissions [7, 8]. During the machine operations, these fluids can be mixed with metal movement fluids to increase heat dissipation [9]. Medicines are currently transferred to the targeted areas of the body using nanoparticles [10]. Thermal administration is investigated and high temperatures are prohibited in nanotechnology in electronic devices [11]. However, the different practical applications of nanoparticles require additional research to improve their performance in specific situations, despite the fact that nanoparticles provide promising improvements in heat transmission in addition to many other properties. Working with nanoparticles also involves safety and environmental considerations.

The use of nano-materials in medical applications has been successful, and it has greatly attracted researchers' attention since it provides alternatives to traditional treatments for many diseases. In addition, it may be useful in overcoming new viruses in the future [12, 13]. In recent years, these materials have been used as medical treatments for many diseases, such as cancer, by systematically injecting them into specific parts of the human body as a treatment. As a result of electromagnetic wave incitation effect, these materials produce thermal plasmons that generate heat nano-sources [14].

The use of different types of nanoparticles has been attempted in nano-medicine [15], including gold particles, magnetic particles, carbon nanotubes, graphene, etc. The preparation of bio-nanofluids is based on a mixture of biofluid and nanofluid sciences. There is a general definition of nanofluids as fluids with nanoparticles (1-100 nm in size) mixed in them [16]. A nanofluid containing cylindrical nanoparticles such as CNTs has a higher thermal conductivity (TC) value than a nanofluid containing spherical nanoparticles [17]. In this study, blood is treated as the basic fluid in a bio-nanofluid and as a means of eliminating cancer cells by acting as a drug carrier. The vast majority of previous studies about enhancing the thermal conductivity of bio-nanofluids have not taken into consideration differences in blood formation between sexes or between age categories, in which hematocrit values vary greatly [18]. studied a nano-liquid circulating in a vessel with a porous wall. The researchers studied the effect of many factors on this nanofluid, such as the magnetic field and porosity. These factors affect the fluid's rotation speed, temperature, and concentration. According to the study, an increase in nanoparticle concentration in the blood, together with an increase in porosity and negative pressure, increased blood velocity, while a decrease in blood velocity was observed when the magnetic field intensity was increased [19]. Red blood cells are measured by hematocrit, which, in turn, represents the composition of red blood cells, platelets, white blood cells, and plasma. Due to the amount of nano-Politian materials added, some of these groups generate temperatures over the required limit, causing damage to healthy cells, especially those located near the injection site. Bio-nanofluids have a different thermal conductivity as a result. Many researchers have studied blood flow as a non-Newtonian fluid using power law equations [20-22]. Blood flow inside an axisymmetric tube exposed to irregular surface heat flow is also computationally represented using continuity and momentum equations [23]. Blood flow is controlled by many factors, including surface heat flow, thermal properties of the fluid, and non-Newtonian flow structure [24]. As the best description of the heat transfer phenomenon in the flow of non-Newtonian fluids through tube, switching from constant wall heat flow to irregular wall heat flow varies sinusoidally along the length of the tube provides the most accurate numerical solutions [25]. Around the world, cancer kills many people every year. It is estimated that cancer is the second most common cause of death in the United States, according to the American Cancer Society. The number of cancer cases and deaths worldwide in 2018 was nearly 18 million [26]. Cancer comes in many forms, but glioblastoma multiforme (GBM) is the most dangerous [27]. Cancer is a disease with a very large number of patients as well as a high number of deaths, making it necessary to find more effective treatment methods with a reduced risk of collateral damage [28]. Cancer is currently treated with radiation, chemotherapy, and surgery. Radiation therapy and chemotherapy are not only designed to shrink tumours and kill cancerous cells, but also to prevent cancer from spreading [29].

Increasingly, nanotechnology has been used to create nanoparticles in recent years (Fig. 1) [27, 28]. By using several types of nanoparticles, nanoparticle hyperthermia generates heat that only harms cancer cells [30-32]. The treatment of this type of disease may be more effective when carbon nanotubes are employed compared to nano-gold, according to [33, 34] studies. Using MWCNTs or SWCNTs, Ali et al. [35] improved thermal conductivity of bio-nanofluids. SWCTs (0.7 nm size) produced higher K (nano-biofluids) in men by 2.1% and 4.24%, respectively, than in women and children. Using MWCNTs (2 nm radius), men's K (nano-biofluids) values were higher by 1.49% and 3%, respectively. Cancer cells coagulate when exposed to temperatures lower than those affecting healthy cells. It is possible to target and destroy cancer cells without harming healthy cells by using heat detection. Whenever the method of hyperthermia therapy is applied, one must take into consideration that the heat must be focused only on the area of the body that is being treated. Any dispersion of heat can reduce the effectiveness of the treatment as well as cause harm to the healthy cells [36]. Several types of nanoparticles have been studied to determine whether they can increase TC values in nano-biofluids. TC levels in blood are associated with greater effectiveness in treating some types of human cancers than when they are low. The effect of two types of high-TC nano-particles, nano-Fe_3O_4 and nano-Au, added to blood cells was evaluated and compared in order to achieve the best results. According to researchers' literature review, this study is the first of its kind to use these two types of nanoparticles for cancer treatment, considering hematocrit. With nanotechnology, new treatments for cancer may be possible in the future. Both nanoparticles type were selected because they were not used before ever (to the best of the authors' knowledge). A nano-biofluid was generated using nano-Fe_3O_4 and nano-Au nanoparticles, and their effects on the resulting nano-biofluid were assessed and compared. Reviewing the literature, the researchers found that this is the first study of its kind to use these two types of nanomaterials for treating cancer. In the future, nanotechnology may be used to treat various cancers, based on the findings of this experiment.

HEMATOCRIT AND HYPERTHERMIA THERAPY

Blood is used as the base fluid in this study along with nano-additives (one of the two nanoparticles). Blood contains approximately 55% plasma and about 45% blood cells. The majority of blood cells are red blood cells (RBC), followed by white blood cells and platelets. An illustration of blood components with hematocrit can be found in Figure 2. A red blood cell serves multiple functions in the body, including nourishing cells, transporting oxygen, and discharging waste. Human red blood cells play a vital role in all of the body's vital functions. The human body uses arteries, veins, and capillaries to transport these cells. Male and female RBC levels vary according to age and gender

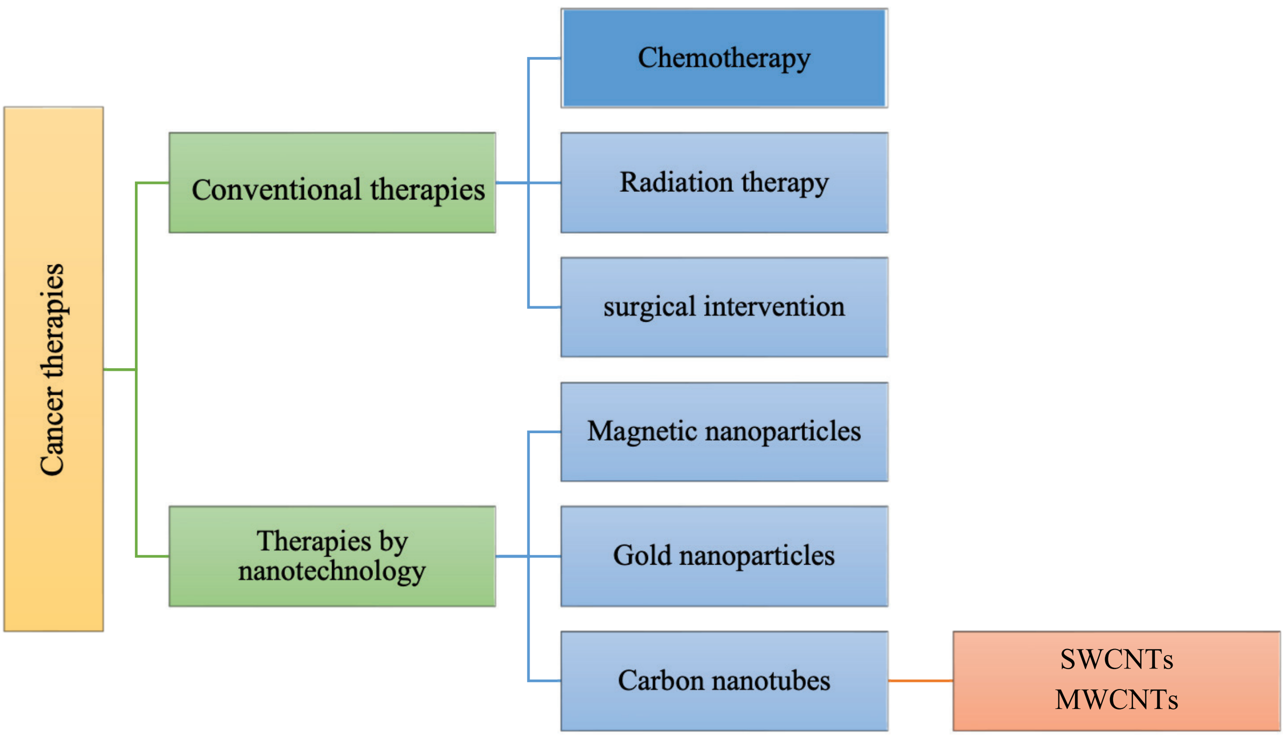

Figure 1. Cancer therapies types.

(child, young, old). Hematocrit is the term used to describe this variation. In the presence of nanoparticles, these differences cause changes in blood thermal conductivity (TC). It is believed that hyperthermia therapy for cancer works by differentiating the ratio of nano-additives in the base fluid (blood). Pregnancy in women or anaemia are two of the conditions that can decrease hematocrit levels in the body. A low hematocrit affects nano blood TC. Aside from red blood cells, white blood cells help protect humans from diseases by forming defensive lines against them [37].

Nanotechnology can be used to manufacture several anti-bacterial and anti-viral drugs that can be used to treat infectious diseases [38]. It means obtaining medicines that treat diseases and prevent epidemics, and bacteria and viruses cannot develop immunity to them. The new Covid-19 virus, according to Liu and Li [39], targets red blood cells to collect porphyrin, which contains iron specialized in oxygen transfer. Due to the linkage of nanoparticles to porphyrin, nanoparticles are able to directly target the virus, so the process of generating heat directly targets the virus. A new method for eliminating cancer that is very effective and has fewer side effects than conventional therapies, such as hair loss, where the patient does not experience any discomfort or other symptoms. Nanoscience has enabled the emergence of new methods for eliminating cancer very effectively and with fewer side effects. This innovative technology is called hyperthermia (HT). A high temperature is used here to end the growth of cancer cells by exposing them to high temperatures. For at least 20 minutes to 60 minutes, these temperatures range between 41°C and 46°C (varies in the literature) [40, 41]. It is difficult to prevent overheating in the deep region of a tumour due to the heterogeneous temperature distribution within the tumour mass. These nanoparticles are magnetic nanoparticles, golden nanoparticles, graphene/carbon nanotubes, which are used to solve this problem. They are used to achieve the target heating for GBM. High heat therapy involves injecting nanoparticles into a vein or cancer cell. An alternating magnetic field or laser beam is applied to the affected part of the patient during this process [14, 42]. Figure 3 shows the heat generated by nanoparticles interacting with these rays.

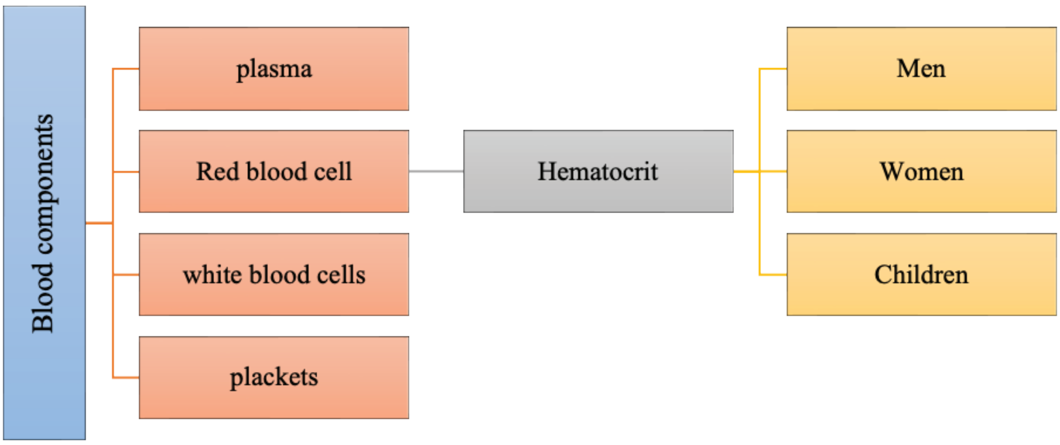

Figure 2. Blood components and hematocrit.

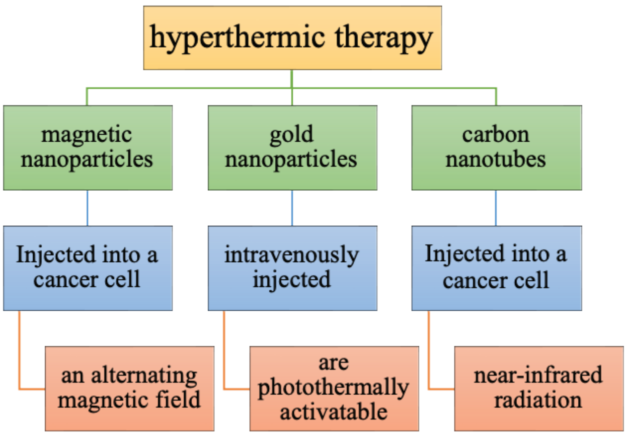

Figure 3. Hyperthermia using three types of nanoparticles.

Suggested Models for TC Calculation for Males, Females and Children

Blood components in males, females, and children are similar, but the proportions differ. In terms of the white blood cell percentage in the blood, it is neglected because it is so tiny, exceeding 1 percent. Red blood cells, on the other hand, are completely different, as human hematocrit ranges between 32 and 52 percent. There are several factors that affect TC for bio-Nanofluid, including age and gender. In men, RBC (hematocrit) percentages range from 42 to 52 % [43-45], in women, 36 to 48 % [44, 45,], and in children (aged one to six), 32 to 42 % [44]. In this case, it is possible to point out that the contrast in TC between the bio-Nanofluid and the plasma results from the different hemoglobin levels in the plasma [46].

The following section explains how TCs are calculated for RBCs according to their sex. Calculations were made based on the average hematocrit values for men, women, and children (in brief: 47%, 42%, and 37%). In order to calculate thermal resistance, parallel mixtures were used.

Calculations by parallel mixture rule and thermal resistance

There are two methods for calculating the TC of red blood cells, and each method produces different results, depending on the accuracy of the calculation. In Table 1, the formulas used for each method are shown.

Using the thermal resistance method, a rectangular parallel vessel full of blood with particles completely mixed has been assumed and the x-direction heat transfer has been taken into account. Based on both calculation methods, Table 2 lists the TC of BC (KBC). For steady flow conditions, the thermal resistance network calculates the heat transfer rate. By using ultrasonic mixing, it has become possible to mix blood molecules completely with nanoparticles uniformly, which was not possible when nanofluids were prepared. A major problem in nanofluids is the aggregation and subsequent deposition of nanoparticles. As a result, researchers apply ultrasonic re-mixing to such liquids after a period of time. Due to the instantaneous use of nanofluid in the current treatment, nanoparticles will not have enough time to settle. Calculating TC for nanofluids is based on some experimental correlations. A measurement by experiment is the best method, of course (Fig. 4).

TC of (plasma-NPs)

Different nanoparticles used as filler give different properties to nanofluids, with the nanoparticles differing

Table 1. Thermal resistance and parallel mixtures formulas

Parallel mixtures method	Thermal resistance method
$K_{Blood} = K_{plasma} * \varphi_{plasma} + K_{BC} * \varphi_{BC}$	$R_{Blood} = R_{plasma} + R_{BC}$ $\frac{1}{K_{Blood} * A} = \frac{\varphi_{plasma} * l}{K_{plasma} * A} + \frac{\varphi_{BC} * l}{K_{BC} * A}$
Where:	Where:
K_{Blood}: Blood TC (0.492 W/m. K) [32].	R_{Blood}: Thermal resistance of blood,
K_{plasma}: Plasma TC (0.57 W/m. K) [32].	R_{plasma}: Plasma thermal resistance,
K_{BC} : TC of RBCs (W/m. K).	R_{BC}: BC thermal resistance
φ_{plasma}: Blood plasma volume ratio	l: The length of the pot
φ_{BC}: RBCs volumetric fraction	A: The area of the cross section of the pot.

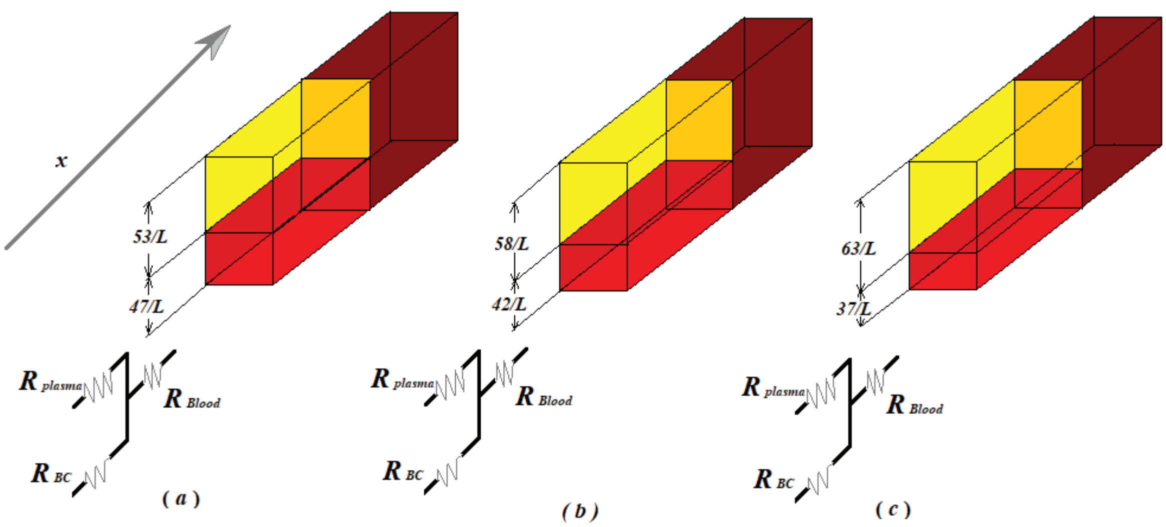

Figure 4. Thermal resistance method: (a) men, (b) women, (c) children.

Table 2. BC calculated TC based on parallel mixtures and thermal resistance

	Parallel mixtures method			Thermal resistance method		
	Men	**Women**	**Children**	**Men**	**Women**	**Children**
K_{Blood} (W/m. K)	0.492 [5]					
K_{plasma} (W/m. K)	0.57 [5]					
φ_{BC}	0.47	0.42	0.37	0.47	0.42	0.37
φ_{plasma}	0.53	0.58	0.63	0.53	0.58	0.63
K_{BC} (W/m. K)	0.404	0.384	0.359	0.426	0.414	0.399

in thermal conductivity, shape, and size. The objective of this section is to study the TC of blood plasma mixed with nanoparticles (gold, iron oxide) in this fluid. A different nanoparticle was chosen each time to be added to the plasma. Bio-liquids (nano-plasmas) produced in various cases are compared according to their TC values. Additionally, TC values of nano-plasmas that have been mixed with RBCs (of the studied categories) are compared.

TC of (plasma-Au NPs)

The thickness and shape of the interlayer nanoparticle (t) formed between the base fluid and the nanoparticles have been considered for the calculation of the bio-nanofluid TC consisting of plasma (as the base fluid) and nanogold particles. Based on the manufacturer's information, the gold nanoparticles used have a spherical shape and a radius of 5 nm. Au NPs have a K of 318 W/m. K [47]. A model developed by Yu and Choi was used [48]. Based on Maxwell's model, these two scientists developed a model that included the effect of nanolayers:

$$K_{plasma-Au} = \frac{K_{pe}+2*K_f+2*(K_{pe}-K_f)*(1+\delta)^3*\varphi}{K_{pe}+2*K_f-(K_{pe}-K_f)*(1+\delta)^3*\varphi} * K_f \quad (1)$$

$$K_{pe} = \frac{[2*(1-\gamma)+(1+\delta)^3*(1+2*\gamma)]*\gamma}{(\gamma-1)+(1+\delta)^3*(1+2*\gamma)} * K_p \quad (2)$$

$$\gamma = K_{layer}/K_p = 0.18 \quad (3)$$

$$\delta = t/R \quad (4)$$

Where the TC of the (plasma – Au NPs) fluid is expressed as $K_{plasma-Au}$, and the TC of the basic fluid, nanoparticles and equivalent particles as K_f, K_p, K_{pe} respectively. γ is the ratio of the nanolayer TC to the particle TC and δ is the ratio of the nanolayer thickness to the original particle radius. The following Table 3 illustrates the nano-Au-plasma TC values for different values of nano-layer thickness.

Table 3. Nano-Au-plasma TC values for different nano-layer thickness

	0.95 nm	1 nm	1.05 nm
δ	0.19	0.2	0.21
K_{pe}	152.91118	149.26812	145.83772
$K_{plasma-Au}$	0.65998	0.66237	0.66480

Calculation of the TC of (plasma-Fe_3O_4 NPs)-fluid

As with Au nanoparticles, iron oxide nanoparticles have a spherical shape. To find the TC of the (plasma-Fe_3O_4) fluid, the Yu and Choi [48] model was used, in which plasma forms the basic fluid while iron oxide nanoparticles make up the filler. As a result of its superior magnetic properties, iron oxide Fe_3O_4 is commonly used in medicinal applications. According to the manufacturer, the Fe_3O_4 nanoparticles used in this study have an oval shape and a radius of 25 nm and $K_{(Fe3O4\ NPs)}$ = 6 W/m. K [49]. It was assumed that $K_{layer} = 3 * K_{plasma}$. $\gamma = K_{layer}/K_p = 0.285$ It did not assume ($K_{layer} = 100 * K_{plasma}$) like the previous case because it gives a value (K_{layer}) greater than the value of the TC of the nanoparticle and this is illogical. Table 4 lists the nano-Fe_3O_4-plasma TC values for different nano-layer thickness.

Table 4. Nano-Fe_3O_4-plasma TC values for different nano-layer thickness

	4.75 nm	5 nm	5.25 nm
δ	0.19	0.2	0.21
K_{pe}	3.60980	3.54584	3.48508
$K_{plasma\text{-}Fe3O4}$	0.62717	0.62821	0.62926

Bio-nanofluid (Au NPs as fillers) TC calculation

Based on the formed nano-Au-Plasma TC, bio-nanofluids TC can be estimated using the Maxwell model.

$$K_{bio-nanofluid} = \frac{K_{BC}+2*K_{plasma-Au\,NPs}+2*\varphi_{BC}*(K_{BC}-K_{plasma-Au\,NPs})}{K_{BC}+2*K_{plasma-Au\,NPs}-\varphi_{BC}*(K_{BC}-K_{plasma-AuNPs})} * K_{plasma-Au\,NPs} \quad (17)$$

Table 5 lists the bio-nanofluids effective TC in the different studied cases for variable interfacial layer thicknesses as well as variable K_{BC} values.

Table 5. Bio-nanofluids' effective TC at variable nano-layer thickness (t) for nano-Au of R=5 nm

	K_{BC}	Nano-layer thickness		
		t = 0.95 nm	**t = 1 nm**	**t = 1.05 nm**
$K_{bio-nanofluid}$	0.404	0.53081	0.53194	0.53309
(men)	0.426	0.54266	0.54380	0.54495
$K_{bio-nanofluid}$	0.384	0.53387	0.53511	0.53637
(women)	0.414	0.54864	0.54990	0.55117
$K_{bio-nanofluid}$	0.359	0.53682	0.53817	0.53955
(children)	0.399	0.55467	0.55604	0.55743

Table 6. Effective TC of bio-nanofluids with Fe_3O_4 of R=25 nm and variable nano-layer thickness (t)

	K_{BC} (W/m. K)	Nano-layer thickness		
		t = 4.75 nm	**t = 5 nm**	**t = 5.25 nm**
$K_{bio-nanofluid}$	0.404	0.51524	0.51573	0.51624
(men)	0.426	0.52694	0.52744	0.52794
$K_{bio-nanofluid}$	0.384	0.51676	0.51730	0.51785
(women)	0.414	0.53134	0.53189	0.53244
$K_{bio-nanofluid}$	0.359	0.51815	0.51875	0.51935
(children)	0.399	0.53576	0.53636	0.53697

Figure 5 shows the bio- nanofluid $K_{bio\text{-}nanofluid}$ TC variation for the studied categories at variable thermal conductivities of RBC (K_{BC}) and R = 5 nm.

Plasma-Fe_3O_4 NPs, TC calculation

Based on the formed nano-Fe_3O_4-plasma TC values, bio-nanofluids (nano-Fe_3O_4-plasma and RCs) TC can be estimated using the Maxwell model.

$$K_{bio-nanofluid} = \frac{K_{BC}+2*K_{plasma-\mathrm{Fe3O4}\,NPs}+2*\varphi_{BC}*(K_{BC}-K_{plasma-\mathrm{Fe3O4}\,NPs})}{K_{BC}+2*K_{plasma-\mathrm{Fe3O4}\,NPs}-\varphi_{BC}*(K_{BC}-K_{plasma-\mathrm{Fe3O4}\,NPs})} * K_{plasma-\mathrm{Fe3O4}\,NPs} \quad (18)$$

Table 6 lists the bio-nanofluids' effective TC for the studied categories for variable interfacial layer thicknesses and K_{BC}.

Figure 6 shows the bio- nanofluid $K_{bio\text{-}nanofluid}$ for the examined genders TCs variations at variable R_{BC} K_{BC} and R = 25 nm

RESULTS AND DISCUSSION

Many physical factors enhance the thermal conductivity of nanofluids. Brownian motion of nanoparticles, layering at the liquid/particle interface, aggregation, dispersion, surface charges, and coupled transport, increases nanofluids' thermal conductivity. Stability of liquids, which depends on the nanoparticles suspended in the base fluid, also affects their thermal conductivity.

Figures 5 and 6 show the Plasma-Au nanoparticles and Plasma-Fe_3O_4 nanoparticles fluids effective TC values

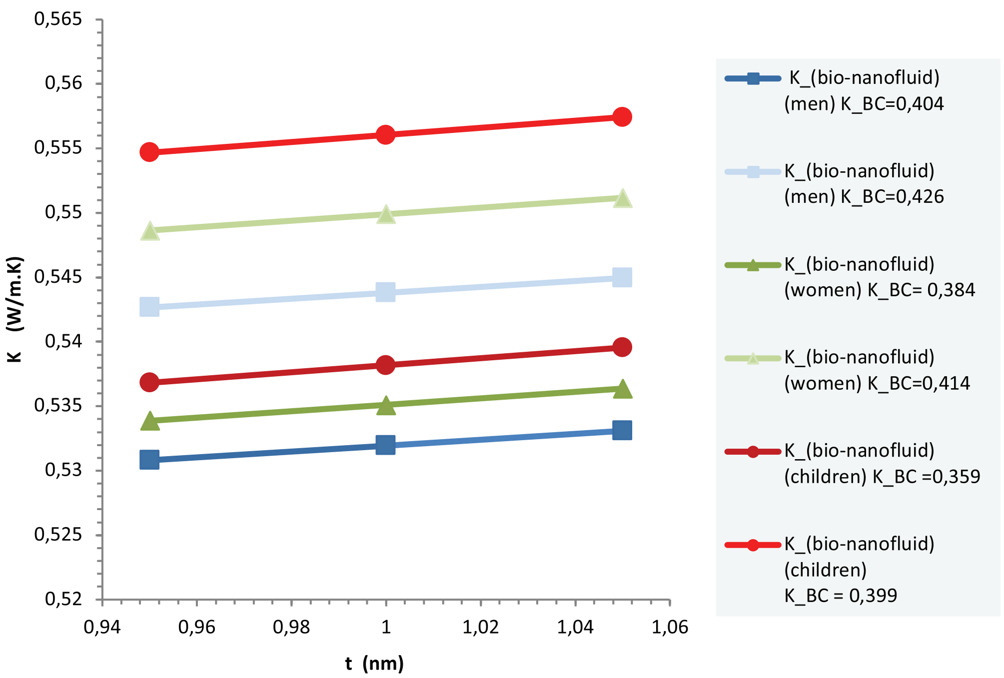

Figure 5. Two K_{BC} values (at R= 5nm Au NPs) for men, women, and children calculated by two methods parallel mixture and thermal resistance.

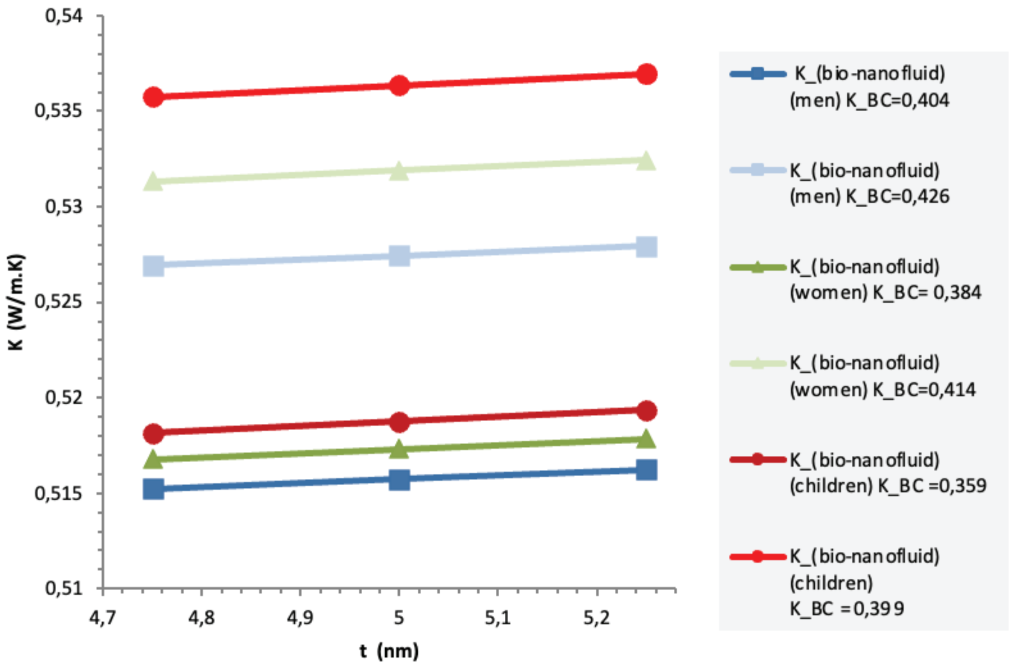

Figure 6. Bio-nanofluids thermal conductivity (at R= 25nm Fe3O4 NPs) for men, women, and children using two methods (parallel mixing and thermal resistance).

change with changes in the thickness of the interfacial layer for men, women, and children depending on the K_{BC} values (calculated by parallel mixture and thermal resistance). According to Tables 3, 4 and Figures 5 and 6, gold nanoparticles improve TC more than magnetite iron oxide nanoparticles (Fe_3O_4). TC values for gold nanoparticles are 318 W/m, which explains the large difference in TC between these types of nanoparticles. In the case of nano iron oxide (Fe_3O_4), it is equal to 6 W/m. K. In addition, the Au nanoparticles radius is 5 nm and the Fe_3O_4 nanoparticles radius is 25 nm. The larger the nanoparticles radius, the greater nano-layer thickness is employed. As an example, for nano Au biofluid, the nano-layers thickness used was 0.95, 1.0 and 1.05 nm while for nano-Fe_3O_4 biofluid, the nano-layers thickness used was 4.75, 5.0 and 5.25 nm.

The Yu and Choi model was used for calculating bio-nanofluids. As the nano-layer thickness increased at the same radius, the thermal conductivity was also increased. An increase in the surface area of a nanoparticle, due to its increased volume, results in an increase in its thermal conductivity, since more surface area is available for contact with the host medium particles. A decrease in the size of nanoparticles at the same mass concentration in the biological nanofluid also leads to an increase in their quantitative concentration, and as a result, the TC of the equivalent particle increases, which in turn increases the bio-nanofluid TC. In children, the TC values of bio-nanofluid are highest, while in women, they decrease, and in men, they drop to the lowest values. As a result, children have a lower volumetric fraction (hematocrit) of erythrocytes than women do. Furthermore, women have a lower percentage of R_{BCs} (hematocrit) than men do. This decrease in volumetric fraction of R_{BC} in the biotinylated nanofluid results from the lower TC of erythrocytes in comparison to the plasma nanofluid TC.

In Figure 5, the thermal conductivity coefficient (K) for bio-nanofluids is plotted using Au NPs with a radius of 5 nm. In a case of plasma NPs liquid mixed with red blood cells (with low TC values), the resultant nano-bio-liquid has a lower TC value than plasma biofluid. Children's nano-biofluid TC values are the highest, followed by those of women and men nano-biofluid TC values. Numerically, the increment rate of TC of children at nano-layer thickness (t=1), as an example, was 0.623% and 0.306% higher than that for men and women, respectively.

This was observed for the red blood cells TC values (K_{BC}), as the fraction of BC in children is lower than it is in women. The value is lower for women than for men. As a result, different concentrations of Au NPs need to be added to achieve the same temperature in these classes. A greater TC value is observed for fluids with a similar diameter when the interlayer thickness increases. In theory, increasing the thickness of the interfacial layer causes the liquid to swirl around the nanotube, causing heat to be distributed more evenly around the nanotube, resulting in a higher TC.

Based on Fe_3O_4 nanoparticles with a radius of 25 nm, Figure 6 shows the K values (bio-nanofluids). Children have the highest TC of nano-biofluid, followed by women and men. In this case, the difference is the same as what was discussed above when Au NPs were used. Numerically,

Table 7. A comparison between the results of the current study with the results of Ref. [35] for validation purpose

	K_{BC} (W/m. K)	Nano-layer thickness			
		t = 1 nm Au (5 nm) (Current study)	t = 5 nm Fe_3O_4 (25 nm) (Current study)	t = 0.294 nm SWCNT (0.7 nm) Ref, [35]	t =0.84 nm MWCNT (2 nm) Ref. [35]
$K_{bio\text{-}nanofluid}$ (men)	0.404	0.53194	0.51573	0.638050	0.593162
	0.426	0.54380	0.52744	0.650660	0.605494
$K_{bio\text{-}nanofluid}$ (women)	0.384	0.53511	0.51730	0.652186	0.602570
	0.414	0.54990	0.53189	0.667981	0.617993
$K_{bio\text{-}nanofluid}$ (children)	0.359	0.53817	0.51875	0.666432	0.611980
	0.399	0.55604	0.53636	0.685577	0.630654

when Fe_3O_4 NPs of 25 nm diameter was added, the children nano-biofluid TC was increased by 0.58% and 0.268% higher than men and women, respectively, at nano-layer thickness (t= 5 nm).

Validation

For verifying the numerical results, the current study results were compared to the results of one of the rare references that dealt with nanoparticles for cancer treatment and were based on gender and age group. Ref. [35] studied the effect of adding single wall carbon nanotubes (SWCNTs) and multi-walls carbon nanotubes (MWCNTs) to blood plasma and to blood (red blood cells and plasma) on thermal conductivity. When compared to the results of the current study, a similarity in the behavior of thermal conductivity can be demonstrated. For example, the smaller the diameter of the nanoparticle, it is possible to work with a nano-layer of thinner thickness. When working with SWCNT with a diameter of 0.7 nm, it was possible to study the behavior of the nanofluid at a nano-layer thickness of 0.294 nm. When MWCNT with a diameter of 2 nm was mixed, it was possible to study the behavior of the nanofluid at a nano-layer thickness of 0.84 nm. As for the solutions of the current study, the thickness of the nano-layer was 1 nm when working with nano- Au, and the thickness of the nano-layer was 5 nm when working with nano-Fe_3O_4 with a diameter of 25 nm. For both studies, the increase in thermal conductivity for children was higher than for women, and the latter was higher than for men. As a numerical example, the increase in thermal conductivity for children compared to men was 4.25%, 3.07%, 1.15% and 0.58% for SWCNT, MWCNT, Au and Fe_3O_4, respectively. The increments rate for children TC compared to women was 2.13%, 1.53%, 0.56% and 0.27% for SWCNT, MWCNT, Au and Fe3O4, respectively (Table 7).

CONCLUSION

As summarized in the study conclusion, there is a strong correlation between the development of nanotechnology and the development of medical methods for diagnosing and treating cancer. TC enhancement can be achieved by preparing bio-nanofluids based on this technology and using the right nanoparticles in these bio-nanofluids. In this paper, theoretical models are presented which estimate the effective TC of blood with two types of nanoparticles nanofluid in cancer treatment based on the shape of the nanoparticles. From these results, it can be concluded that it is very important to determine the age and gender of cancer patients when they are being treated with bio-nanofluid in hyperthermia. Also, it is important to determine the type of nanoparticles added to the bloodstream. Observations have shown that the thermal conductivity of gold nanoparticles in bio-nanofluids is higher than that of magnetite nanoparticles. It is urgent that more studies be conducted on the TC of different types of nanoparticles with blood. The results of this study can be used to conduct laboratory experiments, providing valuable and new information.

NOMENCLATURE

TC	Thermal conductivity.
RBC	Red blood cells.
k	Thermal conductivity coefficient, W / m. °c.
HT	Hyperthermia.
K_f	Thermal conductivity of basic fluid.
K_p	Thermal conductivity of nanoparticles.
K_{pe}	Thermal conductivity of equivalent particles.
γ	The ratio of the nano-layer TC to the particle TC.
δ	The ratio of the nano-layer thickness to the original particle radius
K_{layer}	Nano-layer thermal conductivity
Au NPs	Gold nanoparticles
Fe_3O_4 *NPs*	Magnetite oxide nanoparticles

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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