Message from the Vice Rector for Graduate Studies and Research

It is my pleasure to present to you the first issue of the Deanship of Graduate Studies and Research Newsletter. It highlights research initiatives and projects of our researchers at PMU. This is in line with PMU's strategic vision for research. I want to thank every faculty and researcher at PMU who work hard to improve their research productivity that will have a great impact on PMU's scientific and research reputation. Special thanks are also due to the Dean of Graduate Studies and Research, Dr. Ali Chamkha who is leading this effort.

Research Newsletter

15th March 2019

Feature article: Energy Enhancement Using Nanofluids – A Trending Research at Prince Mohammad Bin Fahd

IMPACTFUL AND INSPIRING

Message from the Dean of Graduate Studies and Research

Let me take this opportunity to welcome all of you to PMU research community. This is our first issue of the Research Newsletter to serve as a platform to voice opinion, inform, and promote excellence in scholarship and research at PMU. It will be a regular publication to show case PMU research and activities.

As Dean of Graduate Studies and Research, it gives me great pleasure and honor to provide you with the necessary resources, tools, comfortable and a conducive environment to conduct cutting-edge research.

At PMU, we are very proud of our distinguished faculty members and their high level of commitment towards research, innovation and entrepreneurism. PMU will reward, appreciate, and promote scholarly initiatives by our faculty members. The PMU Rector Dr. Issa H. Al-Ansari and the Vice Rector for Graduate Studies and Research Dr. Muhammed Al-Mulhem are very committed and have taken serious steps to support and provide incentives for research activities at PMU. The PMU Rector recently announced that all faculty members are invited to initiate collaborative research with reputable organizations and institutions. It is a giant step forward and is already producing excellent results. Keep at it!

Feel free to contribute to the PMU Research Newsletter to show-case your work. The electronic version of the newsletter will have a very high circulation all over the world.

Inside this Issue page

PMU Research Center

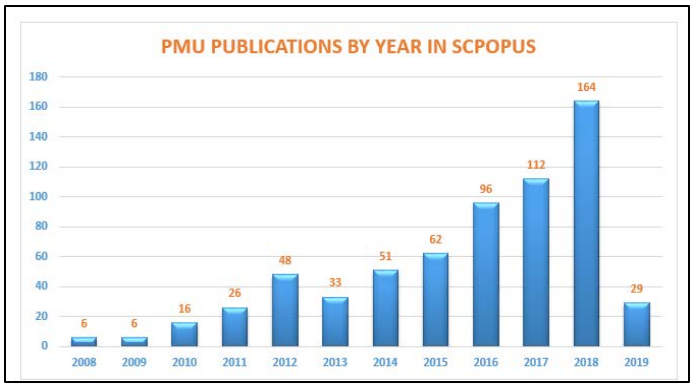
Since inception, PMU has had a strong focus and effectiveness on teaching. Starting in 2015, PMU intends to build on its potential, entrepreneurial spirit to raise its research productivity in selected strategic fields of research pertaining to the trends of the KSA society and economy aiming to lead the University with a clear vision to be among the top comprehensive universities in the Kingdom of Saudi Arabia (KSA).

The PMU research center aim to concentrate and consolidate PMU research activity, including postgraduate's studies in fields of verifiable strength and national significance in order to achieve the mission of PMU. And to Increasing research productivity and academic publications for PMU Faculty.

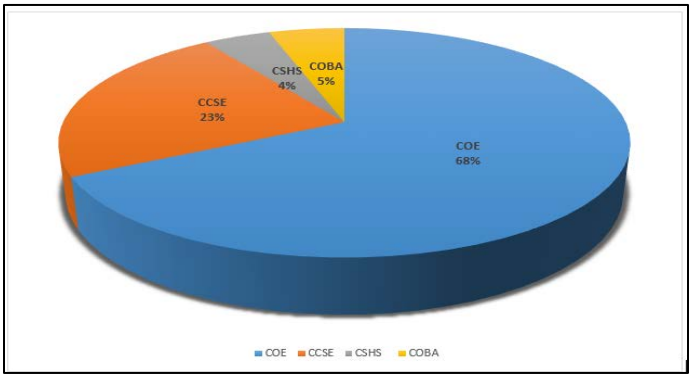
To achieve these goals, the PMU Research Center has developed strategic programs and action plan, and has advertised various jobs for full-time and visiting research professors, post-doctoral associates, and research assistants in various disciplines with the aim to create strong research groups of full-time researchers to conduct scientific research that achieves the objectives of the PMU Research Center.

PMU Research Productivity

The critical importance of scientific research in universities and the fact that it is the backbone of academic activity has evolved



the research productivity of the PMU across several stages. The research productivity of PMU in Scopus database only (6) publication in 2008, now the number of publications with PMU affiliation is (649) publications in



different areas of knowledge. The below table shows the significant increase of PMU publications from 2008 to 2019.

From the table above, it is evident that there is a clear increase in the number of publications in accredited scientific journals that support the PMU rankings globally.

As research productivity has become a top priority at PMU in light of its paramount importance in the visibility, reputation and ranking of PMU, the top management has allocated a sufficient budget for internally-funded research projects among which are applied research centers and centers of excellence. In the first call for research proposals in (Phase I /2015) and in the second stage of proposals in (Phase II /2016), two applications (one for applied research center and one for a center of excellence) were submitted by PMU faculty members. A new call for proposals (Phase III) will be launched soon.

The substantive coverage of the Scopus publications was distributed to the PMU colleges, where the College of Engineering received the largest percentage of 68% followed by the College of Computer Engineering and Science by 23% then the College of Business Administration by 5% and the College of Sciences and Human Studies by 4% as the below table shows:

As part of PMU's commitment to support faculty and researchers in disseminating the results of their research through good quality open access (ISI) journals and to motivate them to increase their research productivity, PMU has established a policy to cover publication fees or Article Processing Charges for open access ISI journals.

International Collaboration

International collaboration is being heralded as the hallmark of contemporary scientific production, the benefits and merits of research collaboration

Include: sharing and transferring knowledge and research equipment, connecting scholars to a large scientific network, expediting the research process, and increasing the visibility of articles, PMU is very interested in international cooperation and exchange, and it supports not only its faculty and researchers but also its student's projects, when they engage in research cooperation with international partners. All can also benefit from this as a cooperation partner and move forward in this strategically critical area of PMU research.

Prince Mohammad Bin Fahd University (PMU) launched an initiative under the name "The Knowledge Project" to monitor and track the progress and development of knowledge in the various fields and publish it using

the different international languages so that it becomes accessible to all human communities worldwide.

The Objectives of the Project are:

- Participation in the dissemination of knowledge.
- Increasing the scope of making useful usage of the development of knowledge worldwide by maintaining and publishing it using the different international languages.
- Support scientists contributing to the advancement of knowledge by translating their publications to the different international languages.
- Contribute to the provision of international references in the various fields of knowledge using the different international languages.

PMU developed procedures for establishing and operating an Academic Collaboration Program with an external university and academic institutions, a committee for this purpose was named "Academic Collaboration Programs Committee",

PMU is establishing contact points in key industries across the region to disseminate information on funding opportunities, DGRS is keen to support international collaboration, with a focus on locating projects within national organizations and linking with advanced Saudi economies.

PMU developed an International Academic Collaborative Programs Policy that explains the procedures for establishing and operating an Academic Collaboration Program with an external university and institutions.

PMU currently has collaboration agreements with many international universities among them the University of Central Florida, University of Pepperdine, and the University of California at Santa Barbara. These international collaboration agreements involve faculty collaborative research, student workshops and symposia, students and faculty visits, establishment of joint graduate programs, organizing joint international conferences, and establishing centers of excellence.

PMU D-Space Repository Project

In the Fall Semester 2018, the Deanship of Graduate Studies and Research was proud to unveil the D-Space Repository Project. D-Space is an open-source digital archiving project, which lets scholars capture, store, index, and distribute all kinds of digital material, including text, video, audio and data.

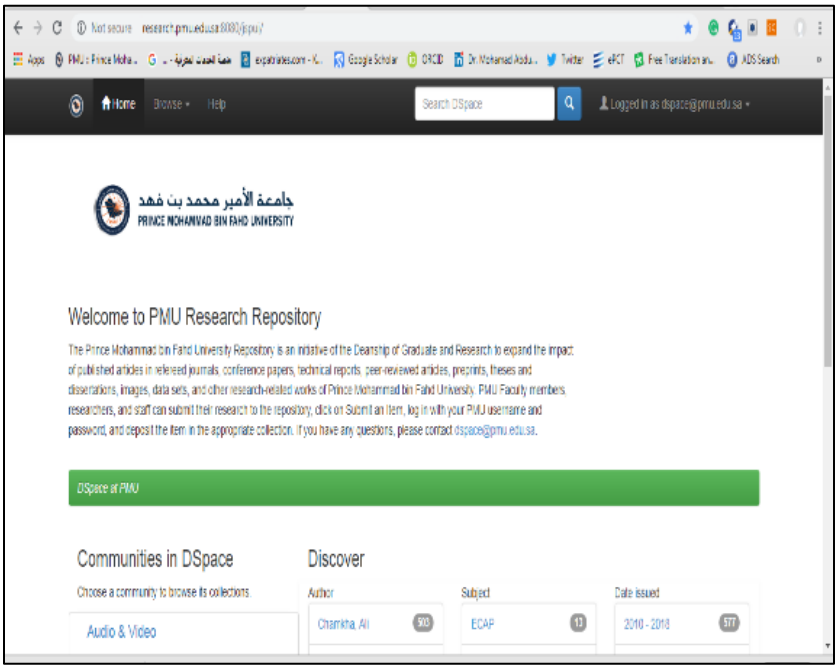
PMU faculty and staff can now use D-Space for full-text storage, access, and distribution of their academic and scientific output.

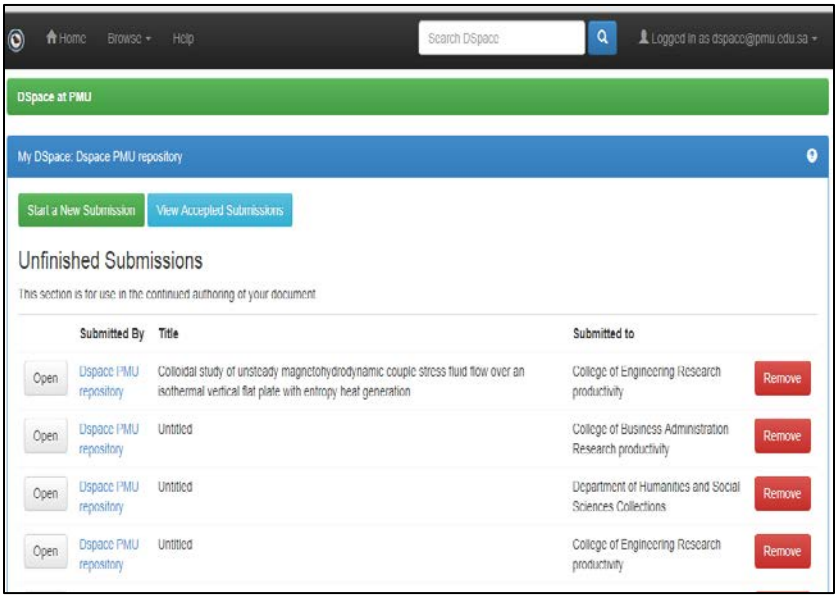
The D-Space Project at PMU was accomplished by several collaborators, including Dr. Mohamed Abdulla of the DGSR (D-Space Manager); Mr. Furkan Yousaf, Assistant Librarian (Assistant D-Space Manager); and the Merite Team Mr. Mohsin; under the supervision of Dr. Ali Chamkha, Dean of Graduate Studies and Research. Dr. Mohamed held several training sessions for the admin assistants of all PMU colleges to introduce them to D-Space and inform them on how to use it to upload all research publications and other files for the faculty and staff in their colleges.

All faculty are encouraged to upload their papers to PMU's D-Space repository. Directions are as follows:

1. Access D-Space at the login page: http://research.pmu.edu.sa:8080/jspui/password-login

2. Create an account, if necessary, and log in.





3. Choose the Collection you want to submit to.

4. Enter the requested descriptive and metadata information for your submission.

5. Upload your document.

6. Complete the requested formalities, and you're done!

You can learn more about D-Space at: https://wiki.duraspace.org/pages/viewpage.action?pageId=25467341

For questions or guidance in using D-Space, please contact:

dspace@pmu.edu.sa

Image Processing: Towards Autonomous Medical Diagnosis

Nowadays, Image processing algorithms are heavily researched for the purpose of Automatic Medical Diagnosis. The automation in the diagnosis process has many benefits but the two most important are that human error is removed from the diagnosis process and second reduction in medical cost. The Image processing techniques fall in one of two categories; supervised and unsupervised learning techniques. The method rely heavily on the acquired images, the noise is first removed from the images through various preprocessing techniques. The second step is what is called feature extraction which relies heavily on the designer of the algorithm and engineers. The third phase is classification of images based on the features extracted and predefined labels and finally the last phase called the recognition phase is the phase in which the decision is made in diagnosis process. An addition phase sometimes is needed called the segmentation phase in which a particular portion of the image is segmented from the complete image and this segmented portion contains the disease being diagnosed. Recently, with the advances in computer technology hardware, researchers have been able to revive deep learning; an algorithm that removes the need for engineers and designers to identify features. Features will be extracted automatically in deep learning from hundreds of thousands or even millions of images and the algorithm is able to achieve high accuracy in recognition and thus diagnosis.

At Prince Mohammad Bin Fahd University, excellent work is being done in the field of image processing for medical purposes. Mr. Ghazanfar Latif has targeted the recognition of Glioma Brain Cancer for his Ph.D. dissertation prepared and submitted in fulfillment of his degree. In his work, he has specifically used the latest state of the art deep learning algorithms as well as various algorithms for the classification and recognition of Glioma Brain cancer. Also a group consisting of Dr. Jaafar Alghazo, Mr. Ghazanfar Latif, Dr. Nazeerudin Mohammad, Mr. Adil Khan and Mr. Muhsin Butt have published various articles in reputable Journals and Conference in the field of recognition of Brain cancer using various supervised and unsupervised techniques. New areas in medical diagnosis are now targeted for skin cancer detection which is part of Mr. Adil khan's dissertation for his Ph.D. and Retinopathy Detection, classification and recognition part of Mr. Muhsin Butt Dissertation for his Ph.D.

PMU Paving the Way for Arabic Numeral and Text Automatic Recognition

The way technology is advancing nowadays and the need to automate many processes that are usually done by Humans, the field of Image Recognition is taking center stage in the research arena in all walks of life. One the most important application targeted is the handwritten text and numeral recognition which can be used for many critical sectors such as the banking and finance sector to recognize the authenticity of written checks. There are many applications that require handwritten numeral and text recognition. In Image processing, the recognition process is put in four phases. Phase 1; preprocessing consists of isolating the letters in text and individual numeral and removing noise as well as other processing techniques to get the image ready. The second phase called the feature extraction phase based on certain features set by the algorithm designer. The third phase is the classification phase to classify the images based on predefined labels and final the phase of recognition. Recently, Deep learning algorithms have also been explored to remove the need for engineers and scientists to interfere in the feature extraction. The features are

extracted automatically in deep learning and usually achieve a much better accuracy than other recognition techniques.

At Prince Mohammad Bin Fahd University, Ground breaking research is being done on the Arabic Text and Numeral Recognition. The research was funded by PMU for the group consisting of Dr. Jaafar Alghazo, Mr. Ghazanfar Latif, Dr. Loay Alzubaidi, Dr. Ammar Elhassan, Dr. Rami Alhmouz and Dr. Ahmad Alhmouz. The group has published in various reputable conferences and journals.

Electronic Waste:

An Untapped Economical source in Saudi Arabia

Electronic Waste (E-Waste) consisting of all electrical and electronic equipment that has been dubbed as obsolete, broken, not functional or discarded by the owner with no intention to reuse. In Saudi Arabia, minimal attention is paid to the E-waste produced by the population even though a huge economic benefit is untapped in this area and at the same time there is extreme environmental and health hazards existing in these devices if not handled or recycled properly. Therefore, the proper handling of E-waste in Saudi Arabia and the GCC countries is of the utmost importance because current practice handles the E-waste like any normal waste and is disposed of in landfills. This improper handling can cause health hazards in the surrounding urban areas near the landfills. The E-waste has an economic value because it contains valuable and rare materials that can be extracted and re-used for new electronic equipment. For example, studies have suggested that one ton of cell phone contains 3.5 kg of silver, 340 g of gold, 140 g of palladium, and 130 kg of copper with a total estimate market value of 15,000 USD. Imagine the economic potential for all E-waste material not only in Saudi Arabia but all the GCC countries.

At Prince Mohammad Bin Fahd University, a group of researchers have found that the area of research into E-waste is lacking in Saudi Arabia in particular and the GCC countries in general and have thus published various articles in renowned conference and reputable journals tackling the problems of E-waste and E-waste handling/recycling in the GCC countries. In the research, the huge economic benefit of E-waste recycling in GCC countries is estimated and the call for a recycling free zone between GCC countries is proposed.

The Linear relationship between Research and Ranking-Ranking Ambitions

Recently, the impact of ranking agencies among university in the GCC countries have gained momentum. Many universities in the GCC aspire to be ranked among the top universities globally, regionally, and nationally. Ranking Agencies such as QS, Time Higher Education (THE), US News, and Shanghai have put a large portion and weight in the ranking criteria on research. Particularly research published in Scopus-indexed and ISI (Clarivate Analytics) Indexed Journals and Conferences. In addition, some of the ranking agencies put weight on the citation of the published work, stressing the importance of research with impact.

At Prince Mohammad Bin Fahd University, several measures have been taken to increase research productivity to meet the standards set by the International ranking bodies. Prof. Ali Chamkha, Dean of Graduate Studies and Research at PMU has met with all colleges and delivered workshops to stress on the need for increasing research productivity and also to highlight strategies for citation and being cited by peers. Below are some of

the measures taken by Prince Mohammad Bin Fahd University:

1- Requiring research as part of the faculty contractual agreement (Scopus Indexed).
2- Offering Incentives for individuals who produce high quality research.
3- Offering incentives for individuals who publish a large number of Scopus Indexed papers annually.
4- Offering Summer Research Contracts.
5- Offering Reduced load incentives for researchers.
6- Funding internal research projects for faculty and students.
7- Hiring research professors in various fields related to PMU Colleges.
8- Hiring highly cited professors.
9- Setting Research Awards for best researcher award at all professorial ranks and even for Lecturers.

With all the various programs rolled out by the Deanship of Research, PMU aspires to be one of top ranked universities nationally, regionally and internationally within the next decade. Steps and Measures are being taken carefully planned and executed to ensure that PMU achieve its aspirations.

Energy Enhancement Using Nanofluids – A Trending Research at Prince Mohammad Bin Fahd University

Energy enhancement in phase-change materials and solar devices is one of the key issues of energy saving and compact designs. Pioneering heat transfer research has been carried out leading to the development of new innovative energy enhancement technique through the addition of nanoparticles (usually less than 100nm) to low thermal conductivity conventional fluids. The fluids with suspended nanoparticles suspended are called "nanofluids". The suspended metallic or non-metallic nanoparticles change the transport properties and heat transfer characteristics of the base fluid tremendously. Metallic nanofluids often refer to those containing metallic nanoparticles such as (Cu, Al, Zn, Ni, Si, Fe, Ti, Au and Ag), while nanofluids containing non-metallic nanoparticles such as aluminium oxide (Al_2O_3), copper oxide (CuO) and silicon carbide (SiC, ZnO, TiO_2) are often considered as non-metallic nanofluids. Nanofluids exhibit superior heat transfer properties compared to conventional heat transfer fluids. Very recently, the idea of using hybrid nanofluids by suspending dissimilar nanoparticles has been investigated for further improvement of heat transfer and pressure drop characteristics by trade-off between advantages and disadvantages of individual suspension, attributed to good aspect ratio, better thermal network and synergistic effect of nanomaterials. Recently, phase-change materials and solar thermal systems combined with the cutting edge technology of nanofluids and various types of nanometer-sized materials (nanoparticles, nanofibers, nanotubes, nanowires and nanorods) suspensions have been considered as an innovative approach of nanoparticles-enhanced phase-change materials and solar collectors.

The conventional direct absorption solar collector system is a well-established technology that has been employed in a variety of applications. However, the efficiency of this type of collectors is limited by the absorption properties of the working fluid. The solar collector technology in combination with the emerging nanofluids technology prepared by conventional heat transfer fluid with suspended nanoparticles has been considered as a promising combined technology. Reviews on the topic give a paramount awareness about the potential enhancements in the efficiency and the performance of the solar thermal system, solar water heater, thermal energy storage,

solar cells and solar stills. In spite of the highlighted importance, a very limited number of research papers in the area of solar collectors augmented with nanofluids has been published in the literature.

Solar energy has the greatest potential of all the sources of renewable energy especially when other sources in the country have depleted. Solar energy is one of the best sources of renewable energy with minimal environmental impact. There are so many methods introduced to increase the efficiency of the solar water heater. But the novel approach is to introduce nanofluids in solar water heater instead of conventional heat transfer fluids. The poor heat transfer properties of these conventional fluids compared to most solids are the primary obstacle to the high compactness and effectiveness of the solar system. The essential initiative is to seek solid particles having a thermal conductivity of several hundred times higher than those of the conventional fluids. An innovative idea is to suspend ultra-fine solid particles in the base fluid for improving the thermal conductivity of the nanofluid. Experiments show that the thermal conductivity enhancement depends on the volume fraction of the suspended nanoparticles and the thermal conductivities of the nano-sized particles and the base fluids, and the experiments prove that a nanofluid composed of a base or conventional fluid with suspended nanoparticles is more thermally effective than the conventional base fluids. If these nanofluids are used as a heat transport medium, they will increase the efficiency of the traditional solar water heater appreciably. Moreover, the presence of nanoparticles in the nanofluid enhances the absorption capability of the fluid, and hence, the nanofluids are engineered fluids with promising potentials and appropriate candidates for direct absorption solar collectors (DAC); as the nanofluid, which is a mixture of a conventional heat transfer media and nanoparticles, can be used as the absorbing medium. Fig. 1 illustrates a receiver of a solar collector filled with a nanofluid. As seen, the incoming solar radiant crosses the glass cover of the receiver and reaches to the nanofluid. The nanoparticles can absorb and scatter the crossing solar radiant and enhances the energy absorption in the collector.

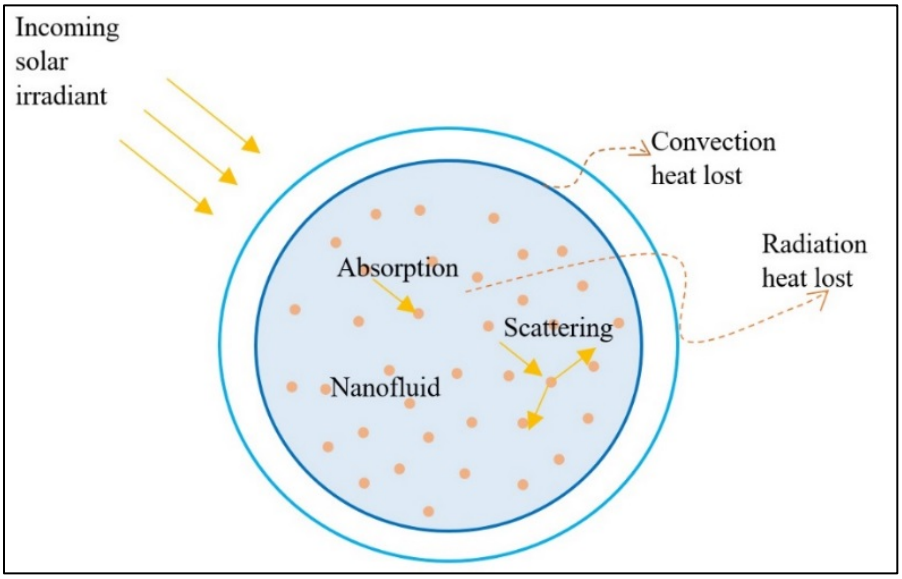


Fig. 1: Schematic view of the receiver of a solar collector

On the other hand, the migration of nanoparticles in a nanofluid results in new heat transfer mechanisms and capabilities sufficient for renewable energy applications as the nanofluid can act as a smart heat transfer material. However, as nanofluids are new fluids with new behaviours, there are very few studies on modelling of nanofluids in applications for renewable energy systems. This is while the modelling and simulation of nanofluids is a key for proper application and design of new devices in renewable energy systems. In the last decade, we have put efforts to model and examine the nanofluids potentials in different situations and applications including renewable energy systems. Due to its renewable and non-polluting nature, solar energy is often used in applications such as electricity generation, thermal heating, and chemical processing. The most cost-effective solar

heaters are of the "flat-plate" type, but these suffer from relatively low efficiency and outlet temperatures. It is clear that any enhancement in the absorption coefficient of conventional heat transfer fluids or enhancement of the thermo-physical properties of conventional fluids could result in enhancement of the renewable energy systems and push the heat transfer technology of the available devices beyond the current edge.

The thermophoresis and Brownian motion effects are two important nano-scale mechanisms, which affect the migration of nanoparticles in the nanofluid. The Brownian motion effect tends to uniform the nanoparticles in the fluid, but the thermophoresis tends to move nanoparticles from the hot regions to the cold regions. Thus, the combination of the Brownian motion and the thermophoresis effects results in a fluid in which its concentration can be changed when it is subject to temperature gradients. Moreover, the migration of heavy nanoparticles from the plate into the inner regions of the solar collector induces a secondary buoyancy force in the vicinity of the solar collector plate. The migration of nanoparticles would also change the local thermo-physical properties of the nanofluid in a solar device or collector.

Many of the solar collectors can be modelled as flat plates subject to heat flux. In this regard, we have modelled the convective heat transfer of flat plates subject to different aspects of nanofluids and heat transfer scenarios using the boundary-layer theory. In our studies, the direct solar absorption is modelled as a variable internal heat generation term. In many cases, the solar collector is supported with heat sinks to enhance the heat transfer.

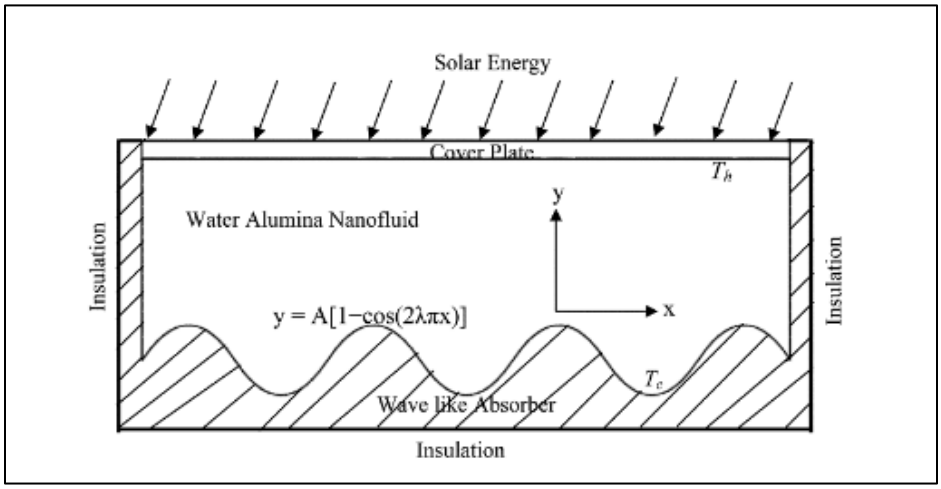


Fig. 2: Schematic view of a solar collector

We have performed a series of researches to understand the behaviour and effect of nanofluids on the thermal performance of solar collectors and thermal boundary layer inside these collectors. In one of our research papers [1], we have performed numerical studies to investigate the effect of natural convection inside a solar collector having a flat-plate cover and a sine-wave absorber. The water-alumina nanofluid is used as the working fluid inside the solar collector. A schematic view of the physical model of the collector is depicted in Fig. 2. The fluid in the collector is a water-based nanofluid containing Al_2O_3 nanoparticles. The nanofluid is assumed incompressible and the flow is considered to be laminar. It is taken that the water and nanoparticles are in local thermal equilibrium and no slip occurs between them. The solar collector is a metal box with a cover on top and a dark-colored wave-like absorber plate on the bottom. The analysis also defines the operating range where a water-Al_2O_3 nanofluid can be considered effective in determining the level of heat transfer augmentation.

The governing differential equations with the physical boundary conditions are solved by the finite element method using the Galerkin's weighted residual scheme. The effects of the physical parameters on the natural convection heat transfer are simulated. These parameters include the number of waves λ and the non-dimensional amplitude *A* of the sinusoidal corrugated absorber. The effects of the nanofluid and other mentioned

parameters on the efficiency of the solar collector are addressed. The analysis shows the operating range where a water-Al_2O_3 nanofluid can be considered effective in determining the level of heat transfer augmentation.

In our study [1], we have assumed a uniform concentration for nanoparticles. Later, we have performed other studies [2, 3] and we have extended our model of nanofluids to a model in which nanoparticles can migrate in the nanofluid due to nano-scale effects [2, 3]. The effects of heat sinks (porous media) at the collector side as well as diameters of nanoparticles are also taken into account [3]. In order to increase the accuracy of the model, the thermal conductivity and the viscosity of the nanofluid are assumed as simultaneous functions of temperature and local volume fraction of nanoparticles using experimental correlations. We have also included the effect of size, shape and type of nanoparticles, type of base fluid and working temperatures on the efficiency of using nanofluids by analysing nine series of nanofluids' samples.

The results show that the material types of nanoparticles is crucial as some nanoparticles can result in significant enhancement of the heat transfer rate, but some other nanoparticles can significantly deteriorate the heat transfer from the surface. For example, the dispersion of 40 nm spherical zinc-oxide nanoparticles in water enhances the heat transfer while dispersion of 43 nm spherical alumina nanoparticles in water deteriorates the heat transfer. In addition, the type of the base fluid is very important. For example, dispersing 40 nm spherical alumina nanoparticles in kerosene enhances the natural convection heat transfer while dispersing the same nanoparticles in water deteriorates the natural convection heat transfer. The analysis of the influence of the type of nanoparticles on natural convection of nanofluids indicates that the type of nanoparticles also could deteriorate or enhance the natural convection heat transfer. Hence, the type of nanoparticles and the type of the base fluid are two important issues, which should be considered simultaneously. The increase of the working temperature of a nanofluid reduces the heat transfer enhancement. Indeed, by increasing the working temperature of the nanofluid, the dynamic viscosity increases while the thermal conductivity of the nanofluid decreases. The decrease in the efficiency of nanofluids as the result of increasing the working temperature is a very important issue in applications of nanofluids. It means that when a system gets hot and goes into a critical situation, the efficiency of the heat removal of the nanofluids reduces. Hence, this effect needs a sufficient caution in design procedures, and it can limit the potential of nanofluids in reducing the size of solar collectors.

In our paper [4], we have modelled forced convective heat transfer of nanofluids in a two-dimensional flat channel with a step which represents a collector in which the receiver is placed at the bottom. The non-uniform heat flux at the bottom simulates the solar irradiates. The inside of the collector is supported with conductive fins to enhance the heat removal from the receiver. The fins inside the collector are modelled as a porous media space. The flow rate inside the collector is considered to be high, and hence, the non-Darcy effects become important and are taken into account. The simulations are carried out in a non-dimensional form to generalize the study for different nanofluids, flow rates and conditions. The results are also reported for TiO_2 nanoparticles well dispersed in water (water-TiO_2 nanofluid) as a case study. The results show significant enhancement of heat transfer by using nanofluids. As the volume fraction of nanoparticles increases, the heat removal capacity of the solar collector increases.

Another aspect of nanofluids in the technology of solar collectors is the entropy generation. All thermo-fluidic processes involve irreversibilities and therefore incur an efficiency loss. In practice, the extent of these irreversibilities can be measured by the entropy generation rate. In designing practical systems, it is desirable to minimize the rate of entropy generation so as to maximize the

available energy. Indeed, the net entropy generation is directly related to the amount of lost work in a system. In our paper [5], we have studied the effect of the presence of nanoparticles on the entropy generation of nanofluids. We have studied different aspects of entropy generation in an odd-shaped cavity (as representing the solar collector). We have found that increasing the Rayleigh number causes an increase of the average Nusselt number as well as the heat transfer term of entropy generation and a decrease of the viscous term. The proper choice of the Rayleigh number could be able to maximize the heat transfer rate and simultaneously minimizing the entropy generation.

In our paper [6], we have presented a review of solar energy collectors and presented their corresponding models and potential applications. In our paper [7] we have numerically simulated the thermal performance of a photovoltaic thermal solar collector which uses a SiO_2-water nanofluid instead of regular water. The effects of various particle shapes, solid volume fractions, water inlet temperature, solar irradiation and wind speed on the thermal and PV efficiency of the unit were analyzed. We have obtained correlation for the efficiencies using the radial basis function neural networks. Cylindrical shape particles were found to give best performance in terms of efficiency enhancements. We have found that the total efficiency enhanced by about 7.39% at the highest volume fraction with cylindrical shape particles. We have also found that the use of cylindrical shape particles gave 3.95% more enhancement as compared to spherical ones for the highest value of solid particle volume fraction. The thermal and total efficiency enhanced for higher values of solid particle volume fractions and solar irradiation and lower values of convective heat transfer coefficient and inlet temperatures. The performance characteristics of solar PV-thermal unit with radial basis function artificial neural network are found to be in excellent agreement with the results obtained from computational fluid dynamics modeling. In summary, we have shown that significant improvements in the total collector efficiency due to enhancements in heat transfer as a result of using a SiO_2-water nanofluid.

In a recent paper [8], we have investigated the effects of different morphology of supported nanoparticles, including copper, silver, aluminum dioxide, boehmite alumina, molybdenum disulfide and silicon dioxide, on heat transfer and entropy generation in comparison with each other in the case of a water-based heat sink solar collector. Based on the results of the study the maximum value of average Nusselt number is achieved for MoS_2 nanoparticles with sphere shape in ϕ=4%, and it is followed by Ag with sphere shape in ϕ=0.15%, Cu with sphere shape in ϕ=0.20%, γ-AlOOH with sphere shape in ϕ=4%, Al_2O_3 with sphere shape in ϕ=4% and SiO_2 with sphere shape in ϕ=4%. The maximum value of outlet temperature is achieved for Ag nanoparticles with sphere shape in ϕ=0.15%, and it is followed by Cu with sphere shape in ϕ=0.20%, MoS_2 with sphere shape in ϕ=4%, Al_2O_3 with sphere shape in ϕ=4%, SiO_2 with sphere shape in ϕ=4% and γ-AlOOH with sphere shape in ϕ=4%. The minimum value of entropy generation is achieved for γ-AlOOH nanoparticles with bricks shape in ϕ=2%, and it is followed by SiO_2 with bricks shape in ϕ=1%, MoS_2 with bricks shape in ϕ=1%, Ag with sphere shape in ϕ=0.05%, Cu with sphere shape in ϕ=0.05% and Al_2O_3 with bricks shape in ϕ=1%. In the case of heat transfer for all studied nanoparticles (metal and non-metal nanoparticles), the sphere shape is the best morphology for each nanoparticle material. For metal nanoparticles the minimum value of entropy generation is achieved by the sphere shape. But for non-metal nanoparticles the minimum value of entropy generation is reached by bricks shape morphology. It is found that in order to fulfill a heat exchanger with more energy efficiency, usage of spherical nanoparticles with an optimum size and appropriate volume fraction is recommended. In order to achieve a heat exchanger with less entropy generation (2nd law view point), usage of bricks shape non-metal nanoparticles with

optimum size and volume fraction and sphere shape metal nanoparticles with optimum size and volume fraction is recommended.

References

1. R. Nasrin, M.A. Alim, A.J. Chamkha, Effects of physical parameters on natural convection in a solar collector filled with nanofluid, *Heat Transfer—Asian Research*, 42 (1) (2013) 73-88.
2. M. Ghalambaz, A. Behseresht, J. Behseresht, A. Chamkha, Effects of nanoparticles diameter and concentration on natural convection of the Al_2O_3–water nanofluids considering variable thermal conductivity around a vertical cone in porous media, *Advanced Powder Technology*, 26 (2015) 224–235.
3. A. Zaraki, M. Ghalambaz, A. J. Chamkha, M. Ghalambaz, D. De Rossi, Theoretical analysis of natural convection boundary layer heat and mass transfer of nanofluids: Effects of size, shape and type of nanoparticles, type of base fluid and working temperature, *Advanced Powder Technology*, 26 (2015) 935–946.
4. R. Nasrin, M.A. Alim, A.J. Chamkha, Numerical simulation of non-Darcy forced convection through a channel with nonuniform heat flux in an open cavity using nanofluid, *Numerical Heat Transfer, Part A*, 64 (2013) 820–840.
5. S. Parvin, A.J. Chamkha, An analysis on free convection flow, heat transfer and entropy generation in an odd-shaped cavity filled with nanofluid, *International Communications in Heat and Mass Transfer*, 54 (2014) 8–17.
6. Y. Menni, A. Azzi, A.J. Chamkha, A review of solar energy collectors: Models and applications, *Journal of Applied and Computational Mechanics*, 4 (2018) 375–401.
7. A.J. Chamkha, and F. Selimefendigil, Numerical analysis for thermal performance of a photovoltaic thermal solar collector with SiO2-water nanofluid." *Applied Sciences*, 8 (2018), Article 2223; doi: 10.3390/app8112223.
8. S. Sadripour and A.J. Chamkha, "The effect of nanoparticle morphology on heat transfer and entropy generation of supported nanofluids in a heat sink solar collector." *ASME Journal of Thermal Science and Engineering Applications*, 9 (2019), 266–280.

Contact Us:

Deanship of Graduate Studies and Research

Prince Mohammad Bin Fahd University

Al-Khobar 31952, Saudi Arabia

Phone: +966 13 849 8800

Fax: +966 13 896 4566

E-mail: deanshipofresearch@pmu.edu.sa