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M&M Post-Graduate Topics

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sonke siya phambili
saam vorentoe

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Contents

Dr Danie Els
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- **Research Field**
  Bio-veterinarian & Granular matter
- **General Description of Research Field**
  Research into the tranquiliser darting system of wild animals. This includes gas gun characterises, external ballistics and wound ballistics of darts. Wound ballistics is modelled with Discrete Element Method (DEM)

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Tranquiliser dart wound Ballistics Modelling of ballistic gel and skin membranes to simulate the wound ballistics of tranquiliser darts on wild animals. This is performed with Discrete Element Method (DEM) software and verified with experiments. **Requirements:** Dynamics		✓	✓	

Mrs Liora Ginsberg

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- **Research Field**
  Biomedical engineering - Microcirculation flow pattern in the lymph
- **General Description of Research Field**
  The lymphatic system is an important biological system, with main functions of immunity and transportation of excess fluid from amongst the capillaries in the loose connective tissue into the vascular system. Much research has been conducted on the flow patterns of the circulatory system, into which the lymphatic system flows, however little has been attempted on the lymphatic system.

  Parametric studies and numerical modelling of the micro-circulation of specific regions of the lymphatic system need to be conducted. The project takes place in the context on on-going final year projects and a PhD study.

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Studies of lymph micro-circulation Study of the micro flow of the lymph in the lymphatic network. Use of CFD to model the micro flow movement of the lymph within a lymphatic segment / duct. **Requirements:** CFD		✓		

Prof Josua Meyer
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- **Research Field**
  Heat transfer
- **General Description of Research Field**
  Heat transfer conveys energy from a high temperature to a lower temperature. The mechanisms of heat transfer are defined as conduction, radiation and convective. In convective heat transfer the heat transfer might be external forced convection, internal forced convection, or natural convection. Heat transfer has many applications and happens everywhere.

  The human body is constantly generating and/or rejecting heat by metabolic processes and exchanged with the environment and among internal organs by conduction, convection, evaporation, and radiation. Heat transfer is also one of the most important factors to consider when designing household appliances such as a heating and air-conditioning system, refrigerator, freezer, water heater, personal computer, mobile phone, TV, etc.

  Heat transfer also occurs in many other applications such as in car radiators, solar collectors, orbiting satellites, etc. However, one of the most important applications is in the generation of electricity which can happen in fossil fuel power plants, nuclear power plants or concentrating solar plants. The heat transfer during the generation of electricity happens in heat exchangers which normally has at least one passage through which a fluid flows. The passage geometry can be as simple such as a circular tube or it can have a very complex geometry with fins that not only enhances the heat transfer but induces flow rotation which reduces the size of the heat exchanger.

  For all these configurations empirical correlations are required for design and analyses purposes that can be used to estimate heat transfer rates. To develop thousands of empirical equations are not desirable as we first need to have a better understanding of the fundamentals and flow phenomena. Furthermore, different flow regimes (laminar, transitional or turbulent) normally each require its own empirical equations. Thus, to be able to understand complex heat transfer flow phenomena in complex geometries we must first understand what happens in simple geometries, such as in circular tubes.

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Developing flow in smooth circular horizontal tubes with a uniform wall temperature; forced and mixed convection. Relevant to concentrated solar power (CSP) generation and heat transfer in blood vessels through human organs. A lot of work has been conducted in the field of heat transfer in circular tubes. Most of this work was limited to forced convection flow through horizontal tubes, and with fully developed flow. Thus implying that the flow was both hydrodynamically and thermally fully developed. However, forced convection occurs very rarely in practical applications. It only occurs for heat transfer in small tube diameters, low heat fluxes and for flow in zero gravity conditions. Therefore, if the heat transfer condition does not satisfy forced convection conditions the heat transfer phenomena would definitely and most probably result in mixed convection. However, no work has been done for mixed convection with a uniform wall temperature during developing conditions. The purpose of this study would therefore be to numerically investigate and compare with CFD in a circular tube developing flow for forced and mixed convection with a uniform wall temperature. **Requirements:** CFD		✓	✓	✓
Local and average heat transfer coefficients for developing single-phase laminar flow in horizontal circular tubes with a constant heat flux boundary condition. Wide range of Prandtl numbers. Relevance: concentrated solar power (CSP) generation and heat transfer in blood vessels through human organs. Correlations to calculate the local and average heat transfer coefficients for single-phase laminar flow in horizontal circular tubes with a constant heat flux are usually restricted to fully developed flow, high Prandtl numbers or constant fluid properties. Recently work has been conducted with water (see URL: 10.1016/j.ijheatmasstransfer.2017.10.070). The purpose of this study is to conduct a similar study, however, using CFD, and as working fluids air and glycol. The reason for air and glycol is that its Prandtl numbers are about an order of magnitude lower and higher than that of water. The equations that were developed in the previous study for water can therefore not be used for a wide range of Prandtl number applications. **Requirements:** CFD		✓	✓	✓

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Local and average heat transfer coefficients for developing single-phase laminar gas and glycol flow in horizontal circular tubes with a uniform temperature boundary condition. Relevant to concentrated solar power (CSP) generation and heat transfer in blood vessels through human organs. Correlations to calculate the local and average heat transfer coefficients for single-phase laminar flow in horizontal circular tubes with a uniform heat flux are usually restricted to fully developed flow, high Prandtl numbers or constant fluid properties. Recently work has been conducted with water (see URL: 10.1016/j.ijheatmasstransfer.2017.10.070). The purpose of this study is to conduct a similar study, however, using CFD, with air and glycol as working fluid. The reason for air and glycol is that its Prandtl numbers are about an order of magnitude lower and higher than that of water. The equations that were developed in the previous study for water can therefore not be used for a wide range of Prandtl number applications and were also developed for a constant heat flux boundary condition – not a uniform wall temperature. In this study a uniform heat flux needs to be used. **Requirements:** CFD		✓	✓	✓
Local and average heat transfer coefficients for developing single-phase laminar gas and glycol flow in horizontal circular tubes with a uniform heat flux boundary condition. Relevant to concentrated solar power (CSP) generation and heat transfer in blood vessels through human organs. Correlations to calculate the local and average heat transfer coefficients for single-phase laminar flow in horizontal circular tubes with a constant heat flux are usually restricted to fully developed flow, high Prandtl numbers or constant fluid properties. Recently work has been conducted with water (see URL: 10.1016/j.ijheatmasstransfer.2017.10.070). The purpose of this study is to conduct a similar study, however, using CFD, with and air and glycol as working fluid. The reason for air and glycol is that its Prandtl numbers are about an order of magnitude lower and higher than that of water. The equations that were developed in the previous study for water can therefore not be used for a wide range of Prandtl number applications and were also developed for a constant heat flux boundary condition – not a uniform wall temperature. In this study a uniform heat flux needs to be used. **Requirements:** CFD		✓	✓	✓

Prof Willie Perold

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- **Research Field**
  Biosensors
- **General Description of Research Field**
  The Sensor Applications & Nano-Devices (SAND) research group focusses on the development of sensing devices applicable to human disease (cancer, HIV, TB, Covid, etc.), plant disease, animal disease and water and soil pollution. The sensors are fabricated in the nanotechnology-laboratory at Electrical & Electronic Engineering. The research is multidisciplinary by nature.

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Development and evaluation of a surface plasmon resonance device for biomarker detection Surface plasmon resonance (SPR) has been used extensively as a method of biosensor and biomarker evaluation. SPR is at the interface of optics and electromagnetics, where light is used to excite a metal layer at the interface of two dielectric materials. The result is a highly sensitive method of measuring small changes in dielectric constant at or near the dielectric-metal-dielectric interface. This project would require a student to first evaluate an existing SPR device, before continuing to develop their own as a biosensing platform. **Requirements:** Nano-fabrication Optics		✓		
Development of a membrane-based digital LAMP device Nucleic acid amplification techniques and assays based on them have revolutionised the fields of biotechnology, immunology, and pathology, to name but a few. The current standard, qPCR, is well-suited to lab-based implementations, but is difficult to perform otherwise due to the complexity of temperature control necessary for such a device. Isothermal amplification techniques, such as LAMP, are poised to change this, although several significant hurdles are still to be overcome before that can happen. One of these is the qualitative nature of LAMP, which can be overcome by converting the assay to a digital format. The membrane-based dLAMP assay has recently been proved to be a viable candidate for this role, whereby the LAMP reaction is performed in the micropores of commercial filter membranes instead of microfabricated reaction volumes. This project would require a student to design, build and test a device that integrates most of the processing steps necessary to perform and evaluate a digital LAMP assay. **Requirements:** Nano-fabrication Biochemistry/Microbiology		✓		

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Development of an automated immuno-PCR device The standard immunological test for biomarkers is the Enzyme-linked Immunosorbent Assay (ELISA), through which a colour change directly proportional to the concentration of a target analyte present in a sample is measured by a device to determine the concentration of that analyte. The development of the ELISA assay revolutionised the world of immunology, and made all of the analytical tests we know today possible. The next step in the evolution of the ELISA assay is to, instead of using a colour-changing enzyme to present a result, rather use fluorescent nucleotide tags that can be amplified through thermal cycling in the same manner as a PCR test, and have been shown to increase the sensitivity of such a test by up to 1000x. This project would require a student to develop a device with which to perform an automated immune-PCR assay and evaluate the feasibility of using such an assay as a point-of-care test. **Requirements:** Nano-fabrication Biochemistry/Microbiology		✓		

Dr Andie de Villiers

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- **Research Field**
  Computational Mechanics
- **General Description of Research Field**
  This field involves the modelling and simulation of mechanical problems. The field comprises of three parts: modelling, numerical implementation and computational implementation. The appropriate equations and boundary conditions need to be identified/developed to capture the physics of a system. It is often difficult to find analytical solutions for these problems, and numerical methods such as the finite element method is used to solve the equations. These problems can not be solved by hand and should be solved computationally. Depending on the problem at hand commercial software may or may not be useful.

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
A peridynamic model of skin Skin is a living material. Not only is the material properties anisotropic and incompressible but it is also influenced by the environment and changes over time. Mechanobiology is a multidisciplinary field that study the way that cells and their environment influence each other. Mechanical forces can regulate a wide range of biological activities including cell behaviour and growth. Peridynamics is a non-local continuum mechanics framework originally developed to overcome challenges that classical continuum mechanics encounter when modelling discontinuities, such as cracks, as well as long-range forces. The aim of this project is to develop a peridynamic model to skin and investigate how mechanobiology of the skin can be captured. **Requirements:** Students should have a background in solid mechanics and a love for mathematics and programming.		✓	✓	✓
Peridynamic model of tendons Tendons can be modelled by a visco-elastic material. Injuries to tendons are very common in runners. To capture damage and rupture in biological tissue can be a challenge. Peridynamics is a non-local continuum mechanics framework originally developed to overcome challenges that classical continuum mechanics encounter when modelling discontinuities, such as damage and fracture. The aim of this project is to develop a visco-elstic peridynamic model of a tendon and compare data captured when running (force-plate and motion data). The long-term vision of the bigger project is model tendon injuries. **Requirements:** Students should have some background in mechanics and an interest in mathematics and programming.	✓	✓	✓	

Dr Johan van der Merwe

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- **Research Field**
  Endoprosthesis design and biostatistical modelling
- **General Description of Research Field**
  In South Africa patients often present for medical care with severe musculoskeletal trauma and disease due to the high prevalence of personal violence, road traffic accidents, and insufficient early treatment. In such cases conventional orthopaedic treatment options may not be viable and instead the use of customized implants, instruments, surgical guides, navigation, or pre-operative planning tools may be required. However, developing patient-specific solutions is a multidisciplinary and iterative process that requires extensive and time-consuming effort on the part of various stakeholders. This leads to increased expense and delays in treatment within an already resource constrained healthcare system.

  Therefore, this research focuses on creating methods, techniques, and tools to automate and integrate the development of patient-specific implant solutions. The aim of this approach is to reduce the associated effort and cost by incorporating unique patient data into population-based models and from there to generate or adapt pre-programmed, customized solutions. In addition, special attention must be paid to the role and interaction of the various human stakeholders as truly robust and practical solutions must incorporate input and feedback from human specialists throughout the process.

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Mandible reconstruction using linear and non-linear machine learning methods The purpose of this project is to investigate linear and non-linear machine learning methods for reconstruction of simulated mandible defects according to the Jewer or Brown classification schemes. Linear principal component analysis may be compared to the use of techniques such as variational autoencoders and generative adversarial networks to reconstruct healthy patient geometry from sparse inputs. **Requirements:** Students must have a sound programming ability and sufficient mathematical background for further independent study in machine learning at a postgraduate level.		✓		
Development of a statistical shape model of the shoulder for patient-specific implant generation The purpose of this project is to first identify design parameters required for patient-specific shoulder implant design, and then to construct a statistical shape model with the required information embedded. When presented with a new patient case, the model must be able to provide an estimate of the patient's healthy situation given sparse data. The result will be used to create a patient-matched implant.		✓		

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Requirements: Students must have a sound understanding of engineering design, programming ability and sufficient mathematical background for further study in modelling, simulation, and optimization at a postgraduate level.				
Automated generation of patient-specific mandible reconstruction plates The purpose of this project is to develop a method for automatically generating a patient-specific mandible reconstruction plate for simulated defects according to the Jewer or Brown classification schemes. A statistical model of a population's mandible curve will be used to estimate an individual's pre-pathological state from minimal, clinically available inputs such as patient meta-data, cephalometric measurements, and / or sparse misaligned anatomic landmarks. The curve must be adapted to accommodate a specified number of fibular graft segments and will serve as input to a parametric CAD modeler to automatically generate the plate geometry along with other required features such as fixation holes. A systems engineering approach must be followed. **Requirements:** Students must have a sound understanding of engineering design, programming ability and sufficient mathematical background for further study in modelling, simulation, and optimization at a postgraduate level.		✓	✓	
Development of a temporomandibular joint replacement wear simulator standard The purpose of this project is to develop a temporomandibular wear simulator standard for pre-clinical assessment of implant wear. It will require identification of kinetic and kinematic motion profiles most representative of activities of daily living, as well as an assessment of primary implant characteristics and design requirements. General purpose finite element and wear simulation must be performed in LS Dyna, and a single-station concept demonstrator must be designed and built. **Requirements:** Students must be able to program, have a background in finite element analysis, and a sound understanding of statics and dynamics.		✓	✓	
Image-based patient-specific isogeometric analysis of a hip replacement Isogeometric analysis enables the integration of finite element analysis and CAD into one process. The purpose of this project is to implement a method for applying grid based finite element analysis directly on a CT image of a patient's hip containing an implant. The hip implant may be designed in CAD and manually placed on the image volume, or generated procedurally using constructive solid geometry and landmarks placed in the image. Results must be compared against standard mesh-based FEA. **Requirements:** The student must be able to program and have a background in FEA and CAD. This project will require independent self-study and custom implementation of isogeometric code.		✓	✓	

Topics	MEng Struct	MEng Resrch	PhD	Potential Funding
Design of a femoral hip stem for a local population This project involves studying the shape of the local population's hip through morphometric analyses and statistical shape modelling, to investigate how well commercially available hip implants fit the individuals in question. As a follow up, classification techniques will be used to determine the level of specificity required for implant design, which could range from a single mean shape representing the entire population to fully patient-specific models. A method for designing a hip stem based on the morphometric measurements and shape of the hip must be developed and applied to the representative shapes. **Requirements:** Students must have a sound understanding of engineering design, programming ability and sufficient mathematical background for further study in statistical learning and optimization at a postgraduate level.		✓	✓	