# ELEC215

## Biomedical Engineering Fundamentals

S2 Day 2017

*Dept of Engineering*

## Contents

**Disclaimer**

Macquarie University has taken all reasonable measures to ensure the information in this publication is accurate and up-to-date. However, the information may change or become out-dated as a result of change in University policies, procedures or rules. The University reserves the right to make changes to any information in this publication without notice. Users of this publication are advised to check the website version of this publication [or the relevant faculty or department] before acting on any information in this publication.

# General Information

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Credit points
3

Prerequisites
(MATH133 or MATH136) and (PHYS106 or PHYS140)

Corequisites
MATH235

Co-badged status

Unit description
The aim of this unit is to provide a basic understanding of human physiology with an emphasis on the human body that can be described as an ensemble of interacting systems. In a first module, an overview of physiological dynamics will be provided against a background of structural components from cells and tissues to organs. In a second module, major physiological systems will be explained: The cardiovascular (circulatory) system, the respiratory system, the nervous system, the endocrine, reproductive and lymphatic system, the gastrointestinal and urinary system, the sensory (auditory, visual, olfactory) and integumentary system, the skeletal and muscular system. The physiological systems will be discussed from an engineering point-of-view with an emphasis on numerical modeling. This involves quantitative mechanical analysis, flow dynamics, heat and mass transport and electrical analysis. The third module will focus on pharmacokinetic models, i.e. how the uptake, distribution and excretion of exogenous substances can be modeled using differential equations. Finally, it will be shown how a multiscale model can be used to model cancer progression. The theory of physiological systems will be tested in practice through practical sessions which involve measurements of physiological signals with an eHealth Arduino module and numerical modelling in Matlab.

## Important Academic Dates

Information about important academic dates including deadlines for withdrawing from units are available at https://www.mq.edu.au/study/calendar-of-dates

# Learning Outcomes

On successful completion of this unit, you will be able to:

Demonstrate a profound understanding of physiological systems on both the microscopic and macroscopic level: the nervous system, the cardiovascular system, the pulmonary system, the urinary system, the musculoskeletal and sensory systems (auditory, visual, olfactory);

Be able to perform physiological measurements, process the acquired physiological signals and images, critically evaluate the processed results and present in a clearly written laboratory report.

Be able to translate a physiological system into a mathematical concept: The steps involved in this process consist of (1) drawing a block schematic diagram (with feedback loops), (2) translating the block diagram into a differential equation and (3) being able to solve the differential equation (e.g. by using the Laplace transform and/or numerical computational methods). It is expected that students should also have a sense of orders of magnitude of the outcomes which will enable them to interpret the simulated results critically;

Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

# General Assessment Information

**Notifications**

Formal notification of assessment tasks, grading rubrics and due dates will be posted on iLearn. Although all reasonable measures to ensure the information is accurate, the University reserves the right to make changes without notice. Each student is responsible for checking iLearn for changes and updates.

**Weekly Plan**

A weekly plan of lectures, assignments, tests, laboratory and workshop sessions will be posted on iLearn. Students are expected to be aware of possible minor variations.

**Assignment Tasks**

Assignment questions will be posted on iLearn. Assignment solutions will be posted within one to five days after the submission date. Submissions will not be accepted once the solution is posted.

All assignments must be submitted electronically through iLearn (in pdf format). Submissions are expected to be typed in a logical layout and sequence. Markers WILL NOT grade poorly organized or illegible scans or drafts. Illegible scans or drafts are assignments that are handwritten or digital photographed with for example a smartphone. The expected workload includes preparation of final copies and clear diagrams. Resubmissions will be permitted up to due date.

All assignments should be prepared individually. It is expected that students consult tutors, lecturers or other students while learning the concepts, but copying assignments from others is not accepted. Students are expected to have read and understood the academic honesty policy.

**Absences**

Late notices or absences from tests, workshops and laboratories will be considered under extenuating circumstances upon lodgement and approval of a formal notice of disruption of studies.

**Grading**

To obtain a passing grade (P/CR/D/HD) a total mark of 50% or more is required AND a mark of 50% or more is required for the final examination. The final exam is a hurdle requirement because it is the only reliable assessment of individual performance for this unit. A passing grade of 50% or more in the final examination is a condition of passing this unit. Students who make a serious attempt but fail to meet the hurdle requirement will be given one further opportunity to pass. A serious attempt is defined as achievement of a mark of 40% or greater.

# Assessment Tasks

| Name | Weighting | Hurdle | Due |
|------|-----------|--------|-----|
| Laboratory | 15% | No | Weekly (starts in week 2) |
| Hodgkin-Huxley model | 10% | No | week 6 |
| Physiological modeling | 10% | No | week 8 |
| Physiological measurements | 10% | No | week 9 |
| Literature study | 6% | No | week 10 |
| Oral presentation | 4% | No | week 11-12 |
| Exam | 45% | Yes | week 14-16 |

# Laboratory

Due: **Weekly (starts in week 2)**
Weighting: **15%**

Practical sessions start in week 2 and are comprised of laboratory or problem-solving workshop sessions linked to the learning outcomes. Practical sessions are compulsory for all students. Students are expected to arrive on time and use the laboratory time efficiently. Students should enroll in one practical class at the beginning of the semester. Laboratory or workshop worksheets, required data and other necessary items will be posted on iLearn prior to the weekly sessions and it is compulsory for students to complete the preparatory work before coming to the session. It is strongly advisable to rehearse the lecture material before each practical session.

Practicals will be largely assessed in class but there may be some "take-home" assignments for the laboratory sections. More information will be available on iLearn.

In laboratory sessions, students learn how to design and perform basic mathematical simulations on the microscopic and macroscopic level, process biomedical data and perform physiological measurements in a test environment using sensors interfaced with microcontroller boards (Arduino + eHealth shield), an electroencephalogram (EEG) device and an Ultrasound scanner. Students will further develop programming skills in MATLAB and data visualisation. Students do not need to bring their personal laptop to the laboratory sessions. Computers with the required software (such as MATLAB and Arduino) will be provided.

On successful completion you will be able to:
- Demonstrate a profound understanding of physiological systems on both the microscopic and macroscopic level: the nervous system, the cardiovascular system, the pulmonary system, the urinary system, the musculoskeletal and sensory systems (auditory, visual, olfactory);
- Be able to perform physiological measurements, process the acquired physiological signals and images, critically evaluate the processed results and present in a clearly written laboratory report.
- Be able to translate a physiological system into a mathematical concept: The steps involved in this process consist of (1) drawing a block schematic diagram (with feedback loops), (2) translating the block diagram into a differential equation and (3) being able to solve the differential equation (e.g. by using the Laplace transform and/or numerical computational methods). It is expected that students should also have a sense of orders of magnitude of the outcomes which will enable them to interpret the simulated results critically;
- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare

stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

# Hodgkin-Huxley model

Due: **week 6**
Weighting: **10%**

Matlab numerical modelling of propagating action potentials in neurons (Hodgkin-Huxley model)

On successful completion you will be able to:

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- Be able to translate a physiological system into a mathematical concept: The steps involved in this process consist of (1) drawing a block schematic diagram (with feedback loops), (2) translating the block diagram into a differential equation and (3) being able to solve the differential equation (e.g. by using the Laplace transform and/or numerical computational methods). It is expected that students should also have a sense of orders of magnitude of the outcomes which will enable them to interpret the simulated results critically;

# Physiological modeling

Due: **week 8**
Weighting: **10%**

Matlab simulations of physiological systems (cardiovascular and respiratory)

On successful completion you will be able to:

- Demonstrate a profound understanding of physiological systems on both the microscopic and macroscopic level: the nervous system, the cardiovascular system, the pulmonary system, the urinary system, the musculoskeletal and sensory systems (auditory, visual, olfactory);
- Be able to translate a physiological system into a mathematical concept: The steps involved in this process consist of (1) drawing a block schematic diagram (with feedback loops), (2) translating the block diagram into a differential equation and (3) being able to solve the differential equation (e.g. by using the Laplace transform and/or numerical computational methods). It is expected that students should also have a sense of orders

of magnitude of the outcomes which will enable them to interpret the simulated results critically;

# Physiological measurements

Due: **week 9**
Weighting: **10%**

Physiological measurements:

1. Cardiovascular and respiratory physiological measurements will be performed using Arduino cards with eHealth shields.

2. EEG data will be recorded and processed.

3. Ultrasound scanning will be performed on a perfusion phantom and data will be recorded and processed.

On successful completion you will be able to:
- Be able to perform physiological measurements, process the acquired physiological signals and images, critically evaluate the processed results and present in a clearly written laboratory report.

# Literature study

Due: **week 10**
Weighting: **6%**

Literature study: Subject to be picked from a list of provided topics.

On successful completion you will be able to:
- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

# Oral presentation

Due: **week 11-12**
Weighting: **4%**

Oral presentation of literature study by use of a powerpoint slide presentation.

On successful completion you will be able to:
- Analyse a healthcare problem from both an engineering, physiological and ethical

perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

## Exam

Due: **week 14-16**
Weighting: **45%**
**This is a hurdle assessment task (see assessment policy for more information on hurdle assessment tasks)**

Invigilated test of the learning outcomes.

On successful completion you will be able to:

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- Be able to translate a physiological system into a mathematical concept: The steps involved in this process consist of (1) drawing a block schematic diagram (with feedback loops), (2) translating the block diagram into a differential equation and (3) being able to solve the differential equation (e.g. by using the Laplace transform and/or numerical computational methods). It is expected that students should also have a sense of orders of magnitude of the outcomes which will enable them to interpret the simulated results critically;

# Delivery and Resources

Delivery of this course is through a series of 13 theoretical lectures of 2 hours each and a series of practical sessions / tutorials.

The theoretical lecture series consist of 3 modules:

1. The Physiome: From cell to organism with a focus on biophysical concepts;
2. Physiological systems with a focus on modelling and measurement techniques;
3. Pharmacokinetic models where the uptake and excretion of exogenous substances will be discussed.

The practical sessions and tutorials involve hands-on experimentation using Arduino microcontrollers and sensors for physiological monitoring, an EEG system for measuring brain activity and an ultrasound scanner. Tutorial sessions will be provided to teach how to process signals and images in Matlab and to write Matlab scripts and functions. Matlab exercises on physiological monitoring will be conducted in the practical sessions.

## Technology used and required

- Word processing (MS Word, Latex, ...)
- Arduino software (freeware)
- Matlab (can be downloaded from the university depositories)
- Powerpoint (or alternative presentation software (e.g. SliTex))
- Library and Internet search engines

## Textbooks

The provided lecture material should be sufficient to obtain a profound understanding of the covered topics but some helpful textbooks for further reading will be recommended on iLearn and/or in the lecture notes.

# Unit Schedule

| Week | Lecture | Practical session / Tutorial | Assignments |
|------|---------|------------------------------|-------------|
| *The Physiome* | | | |
| 1 | Biochemistry | | |
| 2 | The Cell | Matlab Tutorial Session | |
| 3 | Cell Physiology | Matlab Exercices (DNA sequence analysis) | |
| 4 | Human tissues | Fluorescence microscopy + Matlab Exercises (Tumour Growth model) | |
| *Physiological Systems* | | | |
| 5 | Mathematical modelling physiological systems | Matlab: Electrophysiology | |
| 6 | The nervous system | Elecroencephalography (EEG) | Hodgkin Huxley model (Report + code) |
| 7 | The cardiovascular system | Arduino: Cardiac monitoring + Ultrasound | |
| 8 | The respiratory system | Matlab: Cardiovascular system + Experiment Windkessel function | Physiological modeling (Report + code) |
| 9 | The urinary system | Practical: Thermal imaging / Image processing in Matlab | Physiological measurements (Lab report) |
| 10 | The musculoskeletal system | Practical: Kidney dialysis filter experiment / Simulation (Matlab) | Literature study (report) |
| *Pharmacokinetic models* | | | |
| 11 | Drug delivery | Literature study presentations + Matlab: Simulation | Literature study (oral presentation) |
| 12 | Pharmacokinetic modeling | Literature study presentations + Matlab: Pharmacokinetic modeling | Literature study (oral presentation) |

| 13 | Cancer treatment | Round up, Research lab visit and Q&A | |
|----|------------------|--------------------------------------|---|

# Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central. Students should be aware of the following policies in particular with regard to Learning and Teaching:

Academic Honesty Policy http://mq.edu.au/policy/docs/academic_honesty/policy.html

Assessment Policy http://mq.edu.au/policy/docs/assessment/policy_2016.html

Grade Appeal Policy http://mq.edu.au/policy/docs/gradeappeal/policy.html

Complaint Management Procedure for Students and Members of the Public http://www.mq.edu.au/policy/docs/complaint_management/procedure.html

Disruption to Studies Policy (in effect until Dec 4th, 2017): http://www.mq.edu.au/policy/docs/disruption_studies/policy.html

Special Consideration Policy (in effect from Dec 4th, 2017): https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policies/special-consideration

In addition, a number of other policies can be found in the Learning and Teaching Category of Policy Central.

## Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: https://students.mq.edu.au/support/student_conduct/

## Results

Results shown in *iLearn*, or released directly by your Unit Convenor, are not confirmed as they are subject to final approval by the University. Once approved, final results will be sent to your student email address and will be made available in eStudent. For more information visit ask.mq.edu.au.

# Student Support

Macquarie University provides a range of support services for students. For details, visit http://students.mq.edu.au/support/

## Learning Skills

Learning Skills (mq.edu.au/learningskills) provides academic writing resources and study strategies to improve your marks and take control of your study.

- Workshops
- StudyWise
- Academic Integrity Module for Students
- Ask a Learning Adviser

## Student Services and Support

Students with a disability are encouraged to contact the Disability Service who can provide appropriate help with any issues that arise during their studies.

## Student Enquiries

For all student enquiries, visit Student Connect at ask.mq.edu.au

## IT Help

For help with University computer systems and technology, visit http://www.mq.edu.au/about_us/offices_and_units/information_technology/help/.

When using the University's IT, you must adhere to the Acceptable Use of IT Resources Policy. The policy applies to all who connect to the MQ network including students.

# Graduate Capabilities

## Creative and Innovative

Our graduates will also be capable of creative thinking and of creating knowledge. They will be imaginative and open to experience and capable of innovation at work and in the community. We want them to be engaged in applying their critical, creative thinking.

This graduate capability is supported by:

### Learning outcomes

- Be able to perform physiological measurements, process the acquired physiological signals and images, critically evaluate the processed results and present in a clearly written laboratory report.
- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

### Assessment tasks

- Laboratory
- Physiological measurements

## Capable of Professional and Personal Judgement and Initiative

We want our graduates to have emotional intelligence and sound interpersonal skills and to demonstrate discernment and common sense in their professional and personal judgement. They will exercise initiative as needed. They will be capable of risk assessment, and be able to handle ambiguity and complexity, enabling them to be adaptable in diverse and changing environments.

This graduate capability is supported by:

## Learning outcome

- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

## Assessment tasks

- Laboratory
- Literature study
- Oral presentation
- Exam

# Commitment to Continuous Learning

Our graduates will have enquiring minds and a literate curiosity which will lead them to pursue knowledge for its own sake. They will continue to pursue learning in their careers and as they participate in the world. They will be capable of reflecting on their experiences and relationships with others and the environment, learning from them, and growing - personally, professionally and socially.

This graduate capability is supported by:

## Learning outcome

- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

## Assessment tasks

- Literature study
- Oral presentation

# Discipline Specific Knowledge and Skills

Our graduates will take with them the intellectual development, depth and breadth of knowledge, scholarly understanding, and specific subject content in their chosen fields to make them competent and confident in their subject or profession. They will be able to demonstrate, where relevant, professional technical competence and meet professional standards. They will be able to articulate the structure of knowledge of their discipline, be able to adapt discipline-specific knowledge to novel situations, and be able to contribute from their discipline to inter-disciplinary solutions to problems.

This graduate capability is supported by:

## Learning outcomes

- Demonstrate a profound understanding of physiological systems on both the microscopic and macroscopic level: the nervous system, the cardiovascular system, the pulmonary system, the urinary system, the musculoskeletal and sensory systems (auditory, visual, olfactory);

- Be able to perform physiological measurements, process the acquired physiological signals and images, critically evaluate the processed results and present in a clearly written laboratory report.

- Be able to translate a physiological system into a mathematical concept: The steps involved in this process consist of (1) drawing a block schematic diagram (with feedback loops), (2) translating the block diagram into a differential equation and (3) being able to solve the differential equation (e.g. by using the Laplace transform and/or numerical computational methods). It is expected that students should also have a sense of orders of magnitude of the outcomes which will enable them to interpret the simulated results critically;

- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

## Assessment tasks

- Laboratory
- Hodgkin-Huxley model
- Physiological modeling
- Physiological measurements
- Literature study
- Exam

# Critical, Analytical and Integrative Thinking

We want our graduates to be capable of reasoning, questioning and analysing, and to integrate and synthesise learning and knowledge from a range of sources and environments; to be able to critique constraints, assumptions and limitations; to be able to think independently and systemically in relation to scholarly activity, in the workplace, and in the world. We want them to have a level of scientific and information technology literacy.

This graduate capability is supported by:

## Learning outcomes

- Demonstrate a profound understanding of physiological systems on both the microscopic and macroscopic level: the nervous system, the cardiovascular system, the pulmonary system, the urinary system, the musculoskeletal and sensory systems (auditory, visual, olfactory);

- Be able to translate a physiological system into a mathematical concept: The steps involved in this process consist of (1) drawing a block schematic diagram (with feedback loops), (2) translating the block diagram into a differential equation and (3) being able to solve the differential equation (e.g. by using the Laplace transform and/or numerical computational methods). It is expected that students should also have a sense of orders of magnitude of the outcomes which will enable them to interpret the simulated results critically;

- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

## Assessment tasks

- Laboratory
- Hodgkin-Huxley model
- Physiological modeling
- Physiological measurements
- Literature study
- Oral presentation
- Exam

# Problem Solving and Research Capability

Our graduates should be capable of researching; of analysing, and interpreting and assessing data and information in various forms; of drawing connections across fields of knowledge; and they should be able to relate their knowledge to complex situations at work or in the world, in order to diagnose and solve problems. We want them to have the confidence to take the initiative in doing so, within an awareness of their own limitations.

This graduate capability is supported by:

## Learning outcomes

- Be able to perform physiological measurements, process the acquired physiological signals and images, critically evaluate the processed results and present in a clearly

written laboratory report.

- Be able to translate a physiological system into a mathematical concept: The steps involved in this process consist of (1) drawing a block schematic diagram (with feedback loops), (2) translating the block diagram into a differential equation and (3) being able to solve the differential equation (e.g. by using the Laplace transform and/or numerical computational methods). It is expected that students should also have a sense of orders of magnitude of the outcomes which will enable them to interpret the simulated results critically;

- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

## Assessment tasks

- Laboratory
- Hodgkin-Huxley model
- Physiological modeling
- Physiological measurements
- Literature study

# Effective Communication

We want to develop in our students the ability to communicate and convey their views in forms effective with different audiences. We want our graduates to take with them the capability to read, listen, question, gather and evaluate information resources in a variety of formats, assess, write clearly, speak effectively, and to use visual communication and communication technologies as appropriate.

This graduate capability is supported by:

## Learning outcomes

- Be able to perform physiological measurements, process the acquired physiological signals and images, critically evaluate the processed results and present in a clearly written laboratory report.

- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

## Assessment tasks

- Laboratory
- Physiological measurements
- Literature study
- Oral presentation

# Engaged and Ethical Local and Global citizens

As local citizens our graduates will be aware of indigenous perspectives and of the nation's historical context. They will be engaged with the challenges of contemporary society and with knowledge and ideas. We want our graduates to have respect for diversity, to be open-minded, sensitive to others and inclusive, and to be open to other cultures and perspectives: they should have a level of cultural literacy. Our graduates should be aware of disadvantage and social justice, and be willing to participate to help create a wiser and better society.

This graduate capability is supported by:

## Learning outcome

- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

## Assessment tasks

- Laboratory
- Literature study
- Oral presentation
- Exam

# Socially and Environmentally Active and Responsible

We want our graduates to be aware of and have respect for self and others; to be able to work with others as a leader and a team player; to have a sense of connectedness with others and country; and to have a sense of mutual obligation. Our graduates should be informed and active participants in moving society towards sustainability.

This graduate capability is supported by:

## Learning outcome

- Analyse a healthcare problem from both an engineering, physiological and ethical perspective and be able to communicate and discuss possible solutions with healthcare stakeholders (patients and patient organisations, clinicians, government policy makers, healthcare industry).

## Assessment tasks

- Laboratory
- Literature study
- Oral presentation