Engineering Tripos Part IIA, 3G2: Mathematical Physiology, 2020-21

Module Leader

Dr A J Kabla [1]

Lecturers

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Lab Leader

Dr A Kabla [1]

Timing and Structure

Lent term. 16 lectures.

Aims

The aims of the course are to:

- introduce students to the key physiological functions that are necessary for a living organism,
- develop a interdisciplinary analytical approach to quantitatively describe these functions,
- provide an overview of the modelling techniques that are commonly used to understand and predict physiological processes.

Objectives

As specific objectives, by the end of the course students should be able to:

- identify the key physiological processes at play at all relevant scales, from moelcules to organisms,
- apply physical, mechanical and chemical principles in the context of physiological processes,
- critically discuss the validity of underlying assumptions and check their validity,
- use mathematical and computational tools to determine and interpret model solutions.

Content

A wide variety of topics are touched upon, from biochemistry and cellular function to neural activity and respiration. In all cases, the emphasis is on finding the simplest mathematical model that describes the observations and allows us to identify the relevant physiological parameters. The models often take the form of a simple functional relationship between two variables, or a set of coupled differential equations. The course tries to show where the equations come from and lead to: what assumptions are needed and what simple and robust conclusions can be drawn.

Physical and chemical principles (4L A Kabla)

- Molecular transport, diffusion, osmotic pressure
- Chemical reactions, law of mass action, kinetics

- Enzyme catalysis, Michaelis-Menten model, cooperativity.
- Gases, partial pressures and solubility

Electrophysiology (5L M Lengyel)

- Biophysical bases of cellular electrogenesis and basic ingredients of the equivalent circuit model.
- Action potential generation in neurons: Hodgkin-Huxley model.
- Phase plane analysis;reduced models,extension to bursting and pacemaking activity
- Signal propagation along dendritic and axonal projections, and across chemical and electrical synapses. .

Blood Physiology (3L A Kabla)

- Blood physiology, composition
- Gas storage in red blood cells
- Blood rheology, Cason equation, flow in capilleries

Physiological transport systems (4L A Kabla)

- Circulatory system, heart, cardiac output, arterial pulse
- Vessel compliance, pulsatile flow profile
- Blood flow in caplliery beds, filtration
- Respiratory system, gas exchange in the lungs, ventilation-perfusion

Coursework

Physiology of speech production.

Learning objectives:

At the end of this activity, students will be able to:

- describe how phonation occurs in humans and how vocal folds exploit a steady flow of air from the lungs to generate steady oscillations;
- model the movement of the vocal folds, from stating hypotheses to calculating numerical solutions;
- use standard numerical packages to solve non-linear ordinary differential equations.
- critically discuss the different dynamic regimes observed in the model and their significance.

Practical information:

- Sessions will take place in the EIETL, around week 3.
- This activity involves preliminary work (about 1h).

Full Technical Report:

Students will have the option to produce a Full Technical Report (FTR).

Booklists

Please refer to the Booklist for Part IIA Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [2].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [3] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

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Links
[1] mailto:ajk61@cam.ac.uk
[2] https://teaching.eng.cam.ac.uk/content/form-conduct-examinations

[3] https://teaching.eng.cam.ac.uk/content/uk-spec