BME-460/760 | COURSE OUTLINE

Neuro-Cardiology

Course code	BME-460/760 (undergraduate section BME-460; graduate section BME-760)
Credit hours	3 (2 + 1): two lecture hours and one three-hour laboratory per week
Levels	BS (final year) | MS | PhD — one course, three levels of assessment
Prerequisites	Introductory physiology or biology; calculus and differential equations; basic signals and systems; programming in MATLAB or Python.
Instructor	Dr. Asif Mehmood, Department of Biomedical Engineering and Computer Science
Contact	asifnazquaidian@gmail.com
Delivery	Lectures with clinical case discussions, weekly computational and signal-analysis laboratory, graduate research project
Textbook	Neuro-Cardiology: The heart–brain axis: cardiac physiology, autonomic control, brain–heart disease, neuromodulation and computational monitoring (course textbook, October 2026), with the reference books below.

1 Course description

Neuro-cardiology studies the two-way connection between the nervous system and the heart. The heart has its own pacemaker and an intrinsic nervous system, yet every beat is tuned by sympathetic and parasympathetic nerves controlled by the brainstem, hypothalamus and cortex; in turn, cardiac and vascular receptors inform the brain. This course builds the subject from physiology to computation and the clinic. It begins with cardiac muscle, excitation–contraction coupling, pacemaking and conduction, the electrocardiogram and arrhythmias, following Guyton and Hall. It then develops the autonomic nervous system, the neural control of rate, conduction and contractility, the cardiac neuronal hierarchy and the baroreflex. The clinical half covers heart-rate variability, brain–heart disease (stroke, epilepsy, Takotsubo syndrome, heart failure, stress) and neuromodulation therapies (vagus-nerve stimulation, baroreflex activation, renal and cardiac sympathetic denervation). The course closes with mathematical models of neural control, signal processing and machine learning for the neuro-cardiac axis, and wearable devices built on microcontrollers and Bluetooth. Undergraduates master physiology, signals and simulations; master's and doctoral students add models, the primary literature and a research project.

2 Course learning outcomes (CLOs)

Outcomes are written at the cognitive levels of Bloom's revised taxonomy and mapped to the programme learning outcomes (PLOs) of the host programme (for engineering degrees, the Washington Accord graduate

CLO	Students will be abl
CLO1	Explain cardiac excita conduction and the E using correct values.
CLO2	Describe the autonon heart and circulation, hierarchy and the bar
CLO3	Measure and interpre signals with appropri
CLO4	Analyse brain–heart therapies against the
CLO5	Build and evaluate co monitoring devices fo
CLO6	Design, carry out and neural control, cardia method.

attributes used by PEC; for computing degrees, the Seoul Accord attributes used by NCEAC).

3 Weekly schedule

Sixteen weeks: fourteen teaching weeks, a mid-term week and a final-examination week. Each teaching week has two lecture hours and one three-hour computational laboratory.

Week	Topic (textbook chapter)	Laboratory	Assessment / CLO
1	The Heart–Brain Axis: An Integrated View (Ch. 1)	Exploring heart rate and its autonomic modulation	Diagnostic quiz
2	Cardiac Muscle, the Action Potential and the Cardiac Cycle (Ch. 2)	The cardiac cycle with a time-varying elastance	Problem set 1 (CLO1)
3	Rhythmical Excitation: Pacemaking and Conduction (Ch. 3)	A pacemaker cell under autonomic modulation	Lab report 1 (CLO1)
4	The Electrocardiogram and Vectorial Analysis (Ch. 4)	Synthesising and measuring the ECG	Lab report 2 (CLO1, CLO3)
5	Arrhythmias and Their Mechanisms (Ch. 5)	Re-entry and spiral waves in an excitable medium	Case discussion 1 (CLO1)
6	The Autonomic Nervous System (Ch. 6)	Dose–response curves and competitive antagonism	Quiz 1 (CLO1, CLO2)
7	Neural Control of the Heart and the Intrinsic Cardiac Nervous System (Ch. 7)	Vagal and sympathetic heart-rate dynamics	Problem set 2 (CLO2); project proposal (graduate)
8	**Mid-term examination (Chapters 1–7)**	–	Mid-term (CLO1, CLO2)
9	The Baroreflex and Short-Term Control of Arterial Pressure (Ch. 8)	A closed-loop model of the baroreflex	Lab report 3 (CLO2)
10	Heart-Rate Variability: Measurement and Meaning (Ch. 9)	Heart-rate variability analysis	Lab report 4 (CLO3)
11	Brain–Heart Interactions in Disease (Ch. 10)	Detecting ictal tachycardia	Case discussion 2 (CLO4)

Week	Topic (textbook chapter)	Laboratory	Assessment / CLO
12	Neuromodulation Therapies for the Heart and Circulation (Ch. 11)	Why sham control matters: simulating regression to the mean	Trial critique (CLO4)
13	Mathematical Models of Neural Cardiovascular Control (Ch. 12)	IPFM heartbeats and a delayed baroreflex	Lab report 5 (CLO5)
14	Signal Processing and Machine Learning for the Neuro-Cardiac Axis (Ch. 13)	The Pan–Tompkins QRS detector	Quiz 2 (CLO3, CLO5)
15	Wearable Monitoring, Embedded Devices and Implantables (Ch. 14)	Fixed-point beat detection for a microcontroller	Project presentations (CLO6)
16	**Final examination (all chapters)**	–	Final (CLO1–CLO5); project report (CLO6)

4 Assessment

Undergraduate (BS) and graduate (MS/PhD) students attend the same lectures but are assessed differently: graduate students complete the advanced (MS) and research (PhD) exercises and a research project.

BS students

Problem sets and quizzes	15%
Laboratory reports (5)	20%
Case discussions and trial critique	10%
Mid-term examination	20%
Final examination	35%

MS and PhD students

Problem sets and quizzes	10%
Laboratory reports (5)	10%
Critical review of two research papers	10%
Mid-term examination	15%
Research project (proposal, presentation, report)	25%
Final examination	30%

Graduate research project

Graduate students choose a project in week 7 and present it in week 15. A project links autonomic control, cardiac signals and a computational method. Examples: heart-rate variability before and during sleep or exercise from a public database, analysed with time, frequency and nonlinear measures; a closed-loop baroreflex model fitted to a tilt-table recording; detection of atrial fibrillation from wearable photoplethysmography; simulation of the effect of vagal stimulation on heart rate with a pacemaker-cell model; a low-power ECG monitor on an 8051-class microcontroller with Bluetooth. Deliverables: a two-page proposal, a 15-minute presentation and a report in journal format (6–8 pages) with code. PhD reports must state a hypothesis and position the result against the clinical and physiological literature.

Grading rubric for laboratory reports and projects

Criterion	Excellent (4)	Satisfactory (2–3)	Needs work (0–1)
Model and method	Correct equations, algorithms and parameters, justified choices	Minor errors that do not change conclusions	Wrong model or unexplained method
Code and results	Runs, reproducible, figures labelled with units, baselines and error bars	Runs with small gaps	Does not run or results missing
Interpretation	Links results to theory, physiology or the literature	Describes results without depth	No interpretation
Communication	Clear structure, correct references	Understandable, some gaps	Unclear or unreferenced

5 Reading list

Course textbook

Neuro-Cardiology: The heart–brain axis: cardiac physiology, autonomic control, brain–heart disease, neuromodulation and computational monitoring. Dr. Asif Mehmood, October 2026.

Reference books and papers

1. A. C. Guyton and J. E. Hall, *Textbook of Medical Physiology*, 11th ed. Elsevier Saunders, 2006 (principal text: Chapters 9–13, 14, 18, 20–22, 45, 57–60).
2. D. P. Zipes, J. Jalife and W. G. Stevenson (eds.), *Cardiac Electrophysiology: From Cell to Bedside*, 7th ed. Elsevier, 2018.
3. J. Keener and J. Sneyd, *Mathematical Physiology*, 2nd ed. Springer, 2009 (chapters on the heart and the circulation).
4. Task Force of the ESC and NASPE, Heart rate variability: standards of measurement, physiological interpretation and clinical use, *Circulation* 93:1043–1065, 1996.
5. K. Shivkumar *et al.*, Clinical neurocardiology, *J. Physiol.* 594:3911–3954, 2016; J. L. Ardell *et al.*, Translational neurocardiology, *J. Physiol.* 594:3877–3909, 2016.
6. M. A. Mazidi and J. G. Mazidi, *The 8051 Microcontroller and Embedded Systems.* Prentice Hall, 2000 (Chapters 1, 9–12; device laboratory).
7. Primary papers named in each chapter, including Armour (2004), Samuels (2007), Thayer and Lane (2009), Templin *et al.* (2015), the INOVATE-HF, BeAT-HF, SYMPLICITY HTN-3 and SPYRAL trials, and Pan and Tompkins (1985).

6 Course policies

- Attendance of at least 80% of lectures and laboratories is required to sit the final examination.

- Laboratory reports are individual work; data and code may be discussed but must be written and understood by the student; all sources, including AI assistants, must be acknowledged.
- Clinical material is for education only and is not medical advice; patient data used in laboratories are de-identified public datasets.
- Late submissions lose 10% per day and are not accepted after five days without a documented reason.
- Plagiarism is handled according to the institution's academic-integrity policy and the HEC plagiarism policy.