CNS-410/710 | COURSE OUTLINE

Computational Neuroscience

Course code	CNS-410/710 (undergraduate section CNS-410; graduate section CNS-710)
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	Calculus, ordinary differential equations and linear algebra; introductory probability; programming in MATLAB or Python. No biology background is assumed.
Instructor	Dr. Asif Mehmood, Department of Computer Science
Contact	asifnazquaidian@gmail.com
Delivery	Lectures with active learning, weekly computational laboratory, problem sets, graduate research project
Textbook	Computational Neuroscience: Neurons, circuits and computation: from membrane biophysics to networks, coding and inference (course textbook, October 2026), with the reference books below.

1 Course description

Computational neuroscience asks how the brain computes and answers with mathematics, simulation and data. This course follows the brain upward through its levels of organisation. It begins with the biophysics of the membrane, ion channels and the synapse, builds the Hodgkin–Huxley model, the cable theory of dendrites and the dynamical-systems theory of excitability, and derives the simplified spiking models used in large networks. It then asks what spikes mean: neural coding, spike-train statistics, information theory and the statistical fitting of encoding models. The second half studies circuits: synaptic plasticity and learning rules, rate and mean-field models, balanced excitation and inhibition, attractor networks for memory and decision making, brain-scale spiking simulation, and the population dynamics, Bayesian inference and decoding that underlie brain–computer interfaces. The level matches the computational-neuroscience courses of leading universities (for example MIT 9.40 and Harvard Neuro 140/231): undergraduates master concepts and simulations; master's and doctoral students add derivations, the primary literature and an independent 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 computing degrees, the Seoul Accord graduate at-

CLO	Students will be able to…	Bloom level	PLO
CLO1	Explain the electrical behaviour of membranes, neurons, dendrites and synapses from biophysical principles, with correct physiological values.	C2 Understand	PLO1
CLO2	Implement and simulate conductance-based, cable and simplified spiking models with appropriate numerical methods.	C3 Apply	PLO2, PLO5
CLO3	Analyse neuron and circuit models as dynamical systems (phase plane, stability, bifurcations, mean-field theory).	C4 Analyse	PLO2
CLO4	Quantify neural codes with spike statistics, information theory and fitted encoding and decoding models.	C4 Analyse	PLO2, PLO3
CLO5	Evaluate learning rules, attractor and population-dynamics models against experimental evidence.	C5 Evaluate	PLO3, PLO4
CLO6	Design, carry out and report an original computational study that links a model to neural data or to a computational function.	C6 Create	PLO4, PLO9

tributes 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 Brain, the Neuron and the Idea of Computation (Ch. 1)	Getting started: an artificial neuron and a spike train in MATLAB	Diagnostic quiz (CLO1)
2	Membranes, Ion Channels and the Action Potential (Ch. 2)	Nernst potentials and a passive membrane	Problem set 1 (CLO1)
3	Synapses, Synaptic Dynamics and Memory (Ch. 3)	Synaptic integration and STDP	Lab report 1 (CLO1, CLO2)
4	The Hodgkin–Huxley Model (Ch. 4)	Simulating the Hodgkin–Huxley model	Problem set 2 (CLO2)
5	Dendrites, Cable Theory and Compartmental Models (Ch. 5)	A passive dendrite: steady state and travelling EPSPs	Lab report 2 (CLO2)
6	Neurons as Dynamical Systems (Ch. 6)	Phase-plane analysis of the FitzHugh–Nagumo model	Problem set 3 (CLO3)
7	Simplified Spiking Neuron Models (Ch. 7)	Izhikevich and AdEx neurons	Quiz 1 (CLO2, CLO3); project proposal (graduate)
8	**Mid-term examination (Chapters 1–7)**	–	Mid-term (CLO1–CLO3)
9	Neural Coding: Spike Trains, Encoding Models and Information (Ch. 8)	Poisson spike trains, the STA and a GLM	Problem set 4 (CLO4)

Week	Topic (textbook chapter)	Laboratory	Assessment / CLO
10	Fitting, Evaluating and Comparing Neuron Models (Ch. 9)	Spike-train metrics and fitting by grid search	Lab report 3 (CLO4)
11	Synaptic Plasticity and Learning Rules (Ch. 10)	Oja's rule, BCM selectivity and reward-modulated learning	Problem set 5 (CLO5)
12	Rate Models, Mean-Field Theory and Balanced Networks (Ch. 11)	Wilson–Cowan oscillations and a balanced spiking network	Lab report 4 (CLO3)
13	Attractor Networks: Memory, Integration and Decisions (Ch. 12)	Hopfield memory and a ring attractor	Quiz 2 (CLO3, CLO5)
14	Spiking Networks and Brain-Scale Simulation (Ch. 13)	The 1,000-neuron network of Izhikevich (2003)	Lab report 5 (CLO2, CLO5)
15	Population Codes, the Bayesian Brain and Brain–Computer Interfaces (Ch. 14)	Population-vector and Bayesian decoding	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 (5)	15%
Quizzes (2)	10%
Laboratory reports (5)	15%
Mid-term examination	25%
Final examination	35%

MS and PhD students

Problem sets with MS/PhD problems	15%
Laboratory reports (5)	10%
Critical review of two research papers	10%
Mid-term examination	15%
Research project (proposal, presentation, report)	25%
Final examination	25%

Graduate research project

Graduate students choose a project in week 7 and present it in week 15. A project poses a question about how a neuron or circuit computes and answers it with a model and, where possible, data. Examples: fitting a generalised linear model to public spike trains (for example the Allen Brain Observatory or the International Brain Laboratory data) and comparing it with an adaptive-threshold model; testing whether a balanced network reproduces the irregular firing statistics of cortex; building a ring-attractor model of head direction and comparing it with the Drosophila data; decoding movement from population activity with a Kalman filter and with a recurrent network. Deliverables: a two-page proposal, a 15-minute presentation and a report in journal format (6–8 pages) with reproducible code. PhD reports must state a falsifiable hypothesis and compare the result with the 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

Computational Neuroscience: Neurons, circuits and computation: from membrane biophysics to networks, coding and inference. Dr. Asif Mehmood, October 2026.

Reference books and papers

1. P. Dayan and L. F. Abbott, *Theoretical Neuroscience.* Cambridge, MA: MIT Press, 2001 (principal graduate reference).
2. W. Gerstner, W. M. Kistler, R. Naud and L. Paninski, *Neuronal Dynamics.* Cambridge University Press, 2014 (free online).
3. E. M. Izhikevich, *Dynamical Systems in Neuroscience: The Geometry of Excitability and Bursting.* MIT Press, 2007.
4. A. C. Guyton and J. E. Hall, *Textbook of Medical Physiology*, 11th ed. Elsevier Saunders, 2006 (Chapters 4–5, 45–47, 57–58).
5. C. Koch, *Biophysics of Computation.* Oxford University Press, 1999; G. B. Ermentrout and D. H. Terman, *Mathematical Foundations of Neuroscience.* Springer, 2010.
6. F. Rieke *et al.*, *Spikes: Exploring the Neural Code.* MIT Press, 1997; T. M. Cover and J. A. Thomas, *Elements of Information Theory*, 2nd ed. Wiley, 2006.
7. P. Wallisch *et al.*, *MATLAB for Neuroscientists.* Academic Press, 2009 (laboratory reference).
8. Primary papers named in each chapter, including Hodgkin and Huxley (1952), Izhikevich (2003), Brunel (2000), Hopfield (1982), Potjans and Diesmann (2014) and the MICrONS (2025) and FlyWire (2024) connectome papers.

6 Course policies

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

- Problem sets and laboratory reports are individual work. Ideas may be discussed, but code and text must be written and understood by the student; all sources, including AI assistants, must be acknowledged.
- 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.
- Students with a disability or special need should contact the instructor in the first two weeks so that reasonable adjustments can be made.