INTERNATIONAL QUALIFICATIONS

AND ASSESSMENT CENTRE (IQAC)

«Approved»

2025 y. «____» _____

Programme	**LEVEL 5 EXTENDED DIPLOMA IN ARTIFICIAL INTELLIGENCE**		
Unit Number/ Unit Title	UNIT 11 PROBABILISTIC MODELLING AND REASONING		
Cohort Code:	L05PMR-U11		
Unit Level	5		
Total GLH	Total qualification time 200/ Total Guided learning hours 90/ Self-guided learning hours 110		
Credits	20 CATS/ 10 ECTS		
Lecturer			
Start Date		**End Date**	

Unit Aims	To introduce students to probabilistic models and reasoning techniques, providing them with the skills to handle uncertainty in AI systems. Students will explore fundamental concepts in probabilistic models, including Bayesian networks and Markov decision processes. The unit will cover techniques for reasoning under uncertainty, enabling students to apply probabilistic approaches to AI challenges such as decision-making and inference. By the end of the course, students will be equipped to design and implement AI systems that effectively manage uncertainty in real-world applications.
Differentiation Strategies *(e.g. planned activities or support for individual learners according to their needs)*	The total number of students to be in the lesson is approximately 20. This is a multicultural group of students predominantly between the ages of 24 – 45, with numerous ethnic, gender, and creed background. These are UK academic level 5 students; hence it is assumed that they have practical, theoretical, or technological knowledge and understanding of a subject or field of work to find ways forward in broadly defined, complex contexts. These students must be able to generate information, evaluate, synthesise the use information from a variety of sources. Various approaches to addressing the various identified students needs will be adopted throughout the lesson. Such will include:- 1. Progressive tasks 2. Digital resources

	3. Verbal support 4. Variable outcomes 5. Collaborative learning 6. Ongoing assessment 7. Flexible-pace learning
Equality & Diversity	Variety of teaching techniques will be employed to ensure that the needs of each individual learner are met.
Safeguarding & Prevent	Safeguarding policies and the Prevent duty are strictly observed to ensure the safety, well-being, and inclusivity of all students and staff.
Health & Safety	SIRM H&S policies will be maintained.
Learning Resources	**Teaching and Learning Materials** • "Pattern Recognition and Machine Learning" by Christopher Bishop • "Bayesian Reasoning and Machine Learning" by David Barber • "Probabilistic Graphical Models: Principles and Techniques" by Daphne Koller and Nir Friedman • "Bayesian Networks and Decision Graphs" by Finn V. Jensen and Thomas D. Nielsen • "Introduction to Probability" by Dimitri P. Bertsekas and John N. Tsitsiklis.

Learning Outcome	Assessment Criteria
LO1. 1. Understand the fundamentals of probabilistic modeling.	1.1 : Explain the concepts of probability theory and random variables. 1.2 : Describe common probabilistic models such as Bayesian networks and Markov chains. 1.3 : Discuss the applications of probabilistic models in AI.
LO2. 2. Develop and apply probabilistic models.	2.1 : Construct Bayesian networks for reasoning under uncertainty. 2.2 : Implement hidden Markov models for sequence analysis. 2.3 : Apply probabilistic graphical models to real-world problems.
LO3. 3. Utilize probabilistic reasoning techniques.	3.1 : Perform inference using exact and approximate methods. 3.2 : Apply Monte Carlo methods for probabilistic reasoning. 3.3 : Use variational inference for large-scale probabilistic models.
LO4. 4. Evaluate probabilistic models.	4.1 : Assess model performance using appropriate metrics. 4.2 : Conduct sensitivity analysis to understand model behavior. 4.3 : Optimize probabilistic models for accuracy and efficiency.
LO5. 5. Understand the ethical considerations in probabilistic modeling.	5.1 : Discuss the ethical implications of using probabilistic models in decision-making. 5.2 : Evaluate the impact of biased data on probabilistic model predictions. 5.3 : Develop strategies to ensure the responsible use of probabilistic models.

No	Learning Outcome / Topic	Learning and Teaching Activities	Which assessment criteria does the session relate to?	Day/month/year/ signature
1.	**Probability Theory Review**	**Probability Theory Review** Random variables, PDFs/PMFs, Bayes' theorem	LO1: Fundamentals of Probabilistic Modeling	
2.	**Common Distributions**	**Common Distributions** Gaussian, Poisson, Bernoulli, and their AI applications	LO1: Fundamentals of Probabilistic Modeling	
3.	**Bayesian Networks**	**Bayesian Networks** Structure, d-separation, conditional independence	LO1: Fundamentals of Probabilistic Modeling	
4.	**Markov Chains & Processes** T	**Markov Chains & Processes** Transition matrices, stationary distributions	LO1: Fundamentals of Probabilistic Modeling	
5.	**Applications in AI**	**Applications in AI** Case studies: Spam filters, medical diagnosis	LO1: Fundamentals of Probabilistic Modeling	
6.	**Building Bayesian Networks**	**Building Bayesian Networks** Tools: pgmpy, Stan (hands-on with simple networks)	LO2: Model Development & Application	
7.	**Inference in Bayesian Networks**	**Inference in Bayesian Networks** Variable elimination, message passing	LO2: Model Development & Application	
8.	Half-Term Exam	- Review of LO1 topics - Practice questions and mock assessment - **Half-term assessment** based on LO1 (theory)	LO1 LO2	
9.	**Hidden Markov Models (HMMs)**	**Hidden Markov Models (HMMs)** Viterbi algorithm, forward-backward procedure	LO2: Model Development & Application	
10.	**HMM Applications**	**HMM Applications** Speech recognition, gene sequencing	LO2: Model Development & Application	
11.	**Probabilistic Graphical Models (PGMs)**	**Probabilistic Graphical Models (PGMs)** Factor graphs, Markov random fields	LO2: Model Development & Application	

12.	**Exact Inference Methods**	**Exact Inference Methods** Junction tree algorithm, sum-product	LO3: Probabilistic Reasoning Techniques	
13.	**Approximate Inference**	**Approximate Inference** Loopy belief propagation	LO3: Probabilistic Reasoning Techniques	
14.	Final Exam Preparation & Review	- Comprehensive review of all learning outcomes - Practice questions and revision of key topics		
15.	Final Exam	- **Final-term assessment** covering all learning outcomes (theory and practical elements)		
16.	Feedback & Reflection	- Review of final exam - Individual feedback on performance - Reflective discussion on key learning points		
17.	**Monte Carlo Methods**	**Monte Carlo Methods** Rejection sampling, importance sampling	LO3: Probabilistic Reasoning Techniques	
18.	**Markov Chain Monte Carlo (MCMC)**	**Markov Chain Monte Carlo (MCMC)** Metropolis-Hastings, Gibbs sampling	LO3: Probabilistic Reasoning Techniques	
19.	**Variational Inference**	**Variational Inference** Mean-field approximation, ELBO	LO3: Probabilistic Reasoning Techniques	
20.	**Performance Metrics**	**Performance Metrics** Log-likelihood, BIC, WAIC	LO4: Model Evaluation & Optimization	
21.	**Sensitivity Analysis**	**Sensitivity Analysis** Perturbation analysis for Bayesian networks	LO4: Model Evaluation & Optimization	
22.	**Model Optimization**	**Model Optimization** Stochastic variational inference, mini-batch methods	LO4: Model Evaluation & Optimization	
23.	Half-Term Exam	**Project** Build a PGM for a real-world problem (e.g., fraud detection)		

		Debate: "Algorithmic Transparency in Probabilistic AI"		
24.	**Scalability Techniques**	**Scalability Techniques** Distributed inference with Pyro/TensorFlow Probability	LO4: Model Evaluation & Optimization	
25.	**Ethical Implications**	**Ethical Implications** Probabilistic models in criminal justice, hiring	LO5: Ethics & Responsible AI	
26.	**Bias in Probabilistic Models**	**Bias in Probabilistic Models** Dataset bias, algorithmic fairness metrics	LO5: Ethics & Responsible AI	
27.	**Mitigation Strategies**	**Mitigation Strategies** Fairness constraints, adversarial debiasing	LO5: Ethics & Responsible AI	
28.	**Case Study: COVID-19 Spread Modeling**	**Case Study: COVID-19 Spread Modeling** SEIR model with MCMC parameter estimation	LO5: Ethics & Responsible AI	
29.	Final Exam Preparation & Review	LO1, LO2, LO3, LO4	LO1, LO2, LO3, LO4	
30.	Final Exam		LO1, LO2, LO3, LO4	