Department of Earth Sciences
Indian Institute of Technology Kanpur

Proposal for a new course

1. **Course No:** ES6XX
2. **Course title:** Quantitative Seismic Hazard and Risk Analysis
3. **Department**: Earth Sciences
4. **Proposing Instructor**: Shyam Nandan
5. **Units:** 2-0-3-0-9 (2 Lectures + 0 Tutorials + 3 Lab Hours + 0 Project Hours = 9 Credits)
6. **Course Type**: Departmental Elective (PG), Open to senior UGs
7. **Prerequisite**: Basic Probability and Statistics; Basic MATLAB
8. **Other Potential Interested Faculties**: Javed N. Malik

Course Description & Objectives:

Objectives

This course provides a rigorous, computational framework for quantifying the potential for future shaking (Hazard) and the consequent financial or safety losses (Risk). This course bridges the gap between Earth Science (source characterization) and Engineering (performance assessment).

In this course, students will use MATLAB to code the fundamental PSHA integrals and Risk convolutions themselves, rather than relying on pre-packaged software.

The specific learning outcomes are:

1. Source & Ground Motion Characterization: Master the statistical fitting of earthquake recurrence laws (Gutenberg-Richter) and the implementation of empirical Ground Motion Models (GMMs) to predict intensity measures like PGA and Spectral Acceleration.
2. Computational DSHA and PSHA: Understand the difference between Deterministic (Scenario-based) and Probabilistic (Rate-based) approaches, and learn when to apply each (e.g., deterministic caps in design codes vs. risk-targeted design). Develop a custom MATLAB solver to perform the PSHA integration, handling Aleatory Variability (randomness in ground motion) and Epistemic Uncertainty (model uncertainty) via Logic Trees.
3. Hazard De-aggregation & Selection: Identify "controlling earthquakes" through de-aggregation and implement advanced ground motion selection algorithms (e.g., Conditional Mean Spectrum) for engineering design.

4. Quantitative Risk Assessment: Move beyond hazard to Risk by deriving Fragility Functions and convolving them with hazard curves to compute actionable metrics like Average Annual Loss (AAL) and Loss Exceedance Curves.

Course Contents/Topics	**Suggested number of lectures**
Hazard Inputs: Sources & Ground Motion Seismic Source Modeling: Defining fault geometries and area sources; Statistical fitting of Bounded Gutenberg-Richter and Characteristic recurrence laws to regional seismicity catalogs; Handling time-dependent rupture rates. Ground Motion Models (GMMs): Mathematical formulation of GMMs; Modeling Aleatory Variability (inter-event vs. intra-event sigma); Implementation of modern NGA-West/East equations in MATLAB. Epistemic Uncertainty: Constructing Logic Trees to weight alternative scientific hypotheses (e.g., different max magnitude or attenuation relations).	6 Lectures 9 Lab Hours
Probabilistic Seismic Hazard Analysis (PSHA) Deterministic Analysis (DSHA): Scenario-based assessment; Defining the Maximum Credible Earthquake (MCE); Deterministic caps in building codes; Limitations of the "worst-case" approach. The PSHA Integral: Numerical integration of hazard curves over Magnitude, Distance, and Epsilon; Calculating the Uniform Hazard Spectrum (UHS) for design. Advanced Hazard Products: Disaggregation techniques to identify the modal earthquake (M,R) controlling the hazard; Vector PSHA for correlating multiple intensity measures. MATLAB Implementation: Writing a vectorized PSHA code to compute annual rates of exceedance for a site-specific scenario.	10 Lectures 15 Lab Hours
Seismic Risk & Ground Motion Selection Risk Framework: The PEER Probabilistic Framework (Hazard → Demand → Damage → Loss); Distinguishing between direct physical damage and financial loss. Fragility & Vulnerability: Deriving Fragility Functions (lognormal CDFs) from structural capacity data; Calibrating Vulnerability functions for building portfolios. Risk Metrics: Computing Average Annual Loss (AAL) and Probability of Failure; Generating Loss Exceedance Curves for insurance applications. Record Selection: constructing the Conditional Mean Spectrum (CMS) and selecting time-histories from the NGA database that match the target hazard.	10 Lectures 15 Lab Hours
Total number of lectures	26 Lectures

	39 Lab Hours

<u>Recommended Books/resources:</u>

- Baker, J. W., Bradley, B. A., & Stafford, P. J. (2021). *Seismic Hazard and Risk Analysis*. Cambridge University Press.
- McGuire, R. K. (2004). *Seismic Hazard and Risk Analysis*. EERI MNO-10.
- MathWorks Documentation: *Statistics and Machine Learning Toolbox User Guide*.

Dated: 03/02/2026 Proposer:

Dated: DUGC/DPGC Convener, ES

The course is approved/ not approved

Chairman, SUGC/SPGC
Dated:___________