UNIVERSITY COLLEGE LONDON

EXAMINATION FOR INTERNAL STUDENTS

MODULE CODE	:	**GEOLGH07**
ASSESSMENT PATTERN	:	**GEOLGH07A**
MODULE NAME	:	**Earthquake Seismology and Earthquake Hazard**
DATE	:	**06 May 2016**
TIME	:	**10:00 am**
TIME ALLOWED	:	**2 hours 30 mins**

This paper is suitable for candidates who attended classes for this module in the following academic year(s):

2014/15 and 2015/16

2015/16-GEOLGH07A-001-EXAM-19

TURN OVER

GEOLGH7 GG09 M002 – EARTHQUAKE SEISMOLOGY & EARTHQUAKE HAZARD

EARTH SCIENCES GEOLGH7 (MSc Geophysical Hazards)
GEOLGG09 (MSc Geoscience & MSc Earthquake Engineering with Disaster Management)
GEOLM002 (MSci)

*Answer **THREE** questions. All questions carry equal marks. Where questions comprise more than one part, percentage weightings of marks are given in brackets. You may use a standard electronic calculator.*

Question one Observational seismology

You are provided (Fig. 1.1) with three broadband seismograms (vertical component, N-S component and E-W component) from an earthquake (M_w = 7.8) that occurred on April 25th 2015, recorded at Morro de la Arena, Canary Islands (Latitude: 28.25° N; Longitude: -16.508° E). The origin time of the traces is 06:23:05 UTC on April 25th 2015 (Julian day 115). You are also provided with a Jeffreys-Bullen travel time diagram (Fig. 1.2).

(a) Identify the P and S waves, and the surface wave trains, wherever they occur on each of the three seismogram traces. Annotate the traces in Fig. 1.1, and explain your reasons for your identifications.

[30%]

(b) Show how the particle motions of the P-waves confirm the general easterly direction from which the signal came, explaining your reasoning.

[15%]

(c) Use the Jeffreys-Bullen travel-time diagram to calculate the epicentral distance (in degrees) of the earthquake, making use of the time-difference between the arrival of different phases and explaining your reasoning. Hence find the origin time of the earthquake. The origin time of the trace is 06:23:05 UTC on April 25th 2015 (Julian day 115).

[20%]

(d) Use the Jeffreys-Bullen diagram to either identify the PcP and SS phases on the seismogram or explain why they are not identifiable, commenting on your identifications and discussing potential ambiguities in phase identifications.

[15%]

(e) The near-sinusoidal waves appearing from about 23 minutes after the start of the trace, on the right hand side of the traces, are most likely surface waves. If so they are earlier than expected from the Jeffreys-Bullen diagram. Estimate their dominant wave period and the differences between their actual arrival time and the predicted arrival times of Rayleigh and Love waves that is indicated by your answer to (c) above. Comment on the physical relationship between their long dominant wave period, their early arrival time, and their arrival from the east of the Canary Islands.

[20%]

Turn over

Question two **Seismotectonics**

A significant earthquake in Bhutan in 2009 had the following fault plane solutions according to the USGS moment tensor solution, with moment magnitude, M_w, strike, ϕ, and dip, δ, for each nodal plane:

Date	Region	M_W	ϕ 1	δ 1	ϕ 2	δ 2
2009/09/21	27.33° N 91.44° E	6.1	285	6	96	84

The earthquake focal depth was 14 km

You are provided with a Schmidt net (Fig. 2.1) and tracing paper. You are also provided with a seismicity map of earthquakes in the central Himalayas (80° E to 95° E) between January 1973 and January 2016 (Fig 2.2) and a seismic hazard map (Fig. 2.3).

(a) Sketch and label the focal mechanism of this earthquake, showing the orientation of the two possible fault planes. Identify the dominant type of faulting for the event. Measure the rake angles for each of the nodal planes using your Schmidt net. Label the pressure and tension axes (i.e., the P and T axes).

[40%]

(b) With the aid of the seismicity map of the central Himalayas (Fig. 2.2), interpret the focal mechanism and the regional tectonics. Discuss this earthquake, with the aid of a sketch, in terms of its magnitude and type of faulting in relation to its regional tectonic setting.

[40%]

(c) With the aid of the seismic hazard map (Fig. 2.3), discuss the zoning of the Central Himalayan region for earthquake hazard (focus on the region covered by Fig. 2.2 but use information for adjacent areas that you consider to be relevant).

[20%]

Question three **Earthquake mechanics**

(a) With the aid of labelled Mohr diagrams, explain both Amonton's frictional failure criterion and Coulomb's shear failure criterion, and the effect of pore fluid pressure on the predictions of these failure criteria. Discuss in terms of these failure criteria how failure of faults which are not optimally oriented with respect to the principal stresses takes place, with particular reference to the case of low-angle thrust faults.

[50%]

(b) You are provided with a finite-fault model map (Fig. 3.1) of the slip extent of the M_w = 7.8 April 25^{th}, 2015 earthquake in Nepal and a map (Fig. 3.2) showing the locations of earthquakes during the following 6 months in the region, including a large (M_w = 7.3) earthquake on May 12^{th}, 2015. Focal mechanisms of these two earthquakes are provided in Fig. 3.1. Discuss the slip that occurred in the April 25^{th} earthquake and, with the aid of a sketch, the implications for Coulomb stress changes, and thus predicted levels of post- April 25^{th} activity, on nearby faults including that on which the May 12^{th} earthquake was located.

[30%]

(c) Discuss the use and limitations of Coulomb stress models in earthquake prediction, in the light of the contrast in earthquake activity east and west of the April 25^{th} earthquake rupture during the following 6 months. What additional information about previous seismic activity in the region might be useful in applying Coulomb stress models to the major faults in this region?

[20%]

Continued

Question four **Earthquake magnitude and earthquake engineering**

Discuss, with the aid of examples and diagrams, (i) whether earthquake epicentral locations, depths and moment magnitudes alone are an adequate description of earthquake sources for the purposes of earthquake engineering, especially in the context of large earthquakes ($M_w > \sim 7$); (ii) the implications of this question for probabilistic hazard assessment in earthquake engineering, especially in relation to large buildings and sites on thick sequences of low-velocity sediments.

[100%]

Question five **Earthquake hazard assessment**

(a) Compare and contrast the problems of assembling the evidence bases needed for the source recurrence frequency – magnitude distribution component of earthquake hazard assessment in regions near subduction zone plate boundaries and in regions of diffuse deformation in continental interiors. Illustrate your answer with examples and diagrams.

[60%]

(b) Are the assumptions of Poisson statistics as applied to earthquake recurrence patterns consistent with the assumptions of Coulomb stress transfer models? What are the merits and disadvantages of these approaches in different tectonic settings?

[40%]

END OF PAPER