Instructions: There are NINE pages of questions. Take a minute or so now to page through the entire exam and to get a feeling for the length. Answer the easier questions first. Do not waste time struggling through any one question. Move on to another question and come back to the ones with which you were having difficulty. READ THE QUESTIONS CAREFULLY. Think carefully about your wording, trying to avoid ambiguity and unclear answers.

**PART 1: True or False**

(10 points)

For each of the following statements, circle whether the statement is true or false. IF THE STATEMENT IS FALSE, explain why the statement is false.

1. Strike-slip faults commonly rupture through unconsolidated material, leaving a linear mound of disrupted soil called a moletrack. **TRUE / FALSE**

2. The world's deepest earthquake occurred at a depth of about 680km in the vicinity of a subduction zone. **TRUE / FALSE**

3. In elastic materials, stress is proportional to strain through a constant called the coefficient of friction. **TRUE / FALSE**

4. In a normal faulting environment, the vertical stress is the maximum compressive principal stress, $s_1$. **TRUE / FALSE**

5. A left step along a left-lateral strike-slip fault is an extensional step. **TRUE / FALSE**

6. A single fault segment is also always an "earthquake segment". **TRUE / FALSE**
PART 2: Multiple Choice  
(8 points)

Choose the correct answer from those provided for each question.

1. The maximum depth of earthquakes during an aftershock sequence generally traces out the location of the lower limit of the:
   
   (seismologic zone / seismogenic zone / Moho)

2. Which of the following is not an isotropic stress state?:
   
   (lithostatic stress / hydrostatic pressure / principal stresses where faults are active)

3. The magnitude of very large magnitude earthquakes must be measured using a/an:
   
   (seismogram / body wave / accelerometer)

4. The magnitude scale that incorporates fault area into the magnitude calculation is:
   
   \( M_w \ / \ M_b \ / \ M_s \ / \ M_L \)

5. Two segments of a mid-ocean spreading ridge will be offset to the left with respect to each other along a:
   
   (left-lateral transform fault / right-lateral transform fault / normal fault)

6. Trench-parallel strike-slip faults develop because of:
   
   (back-arc extension / continent-continent collision / oblique convergence)

7. The name of the segment of the San Andreas fault currently thought to have the largest probability of a major earthquake by the year 2018 is?
   
   (San Francisco Peninsula / Parkfield / Imperial Valley)

8. The only two historical giant earthquakes along the San Andreas fault were the 1906 Great San Francisco earthquake and an 1857 event called the _______ earthquake.
   
   (Coalinga / Carizzo Plain / Fort Tejon)
PART 3: Fill in the blanks (11 points)

1. The largest magnitude historical earthquake was a Mw 9.5 event that occurred in 1960 off the coast of __________________________. (1)

2. Slip along a fault decreases away from the fault center, becoming zero along the __________________________. (1)

3. Small earthquakes that precede a large earthquake are called ________________ whereas small earthquakes that follow the main one are called _________________. (2)

4. In a focal mechanism solution, the _____ axis always bisects the compressional quadrant and the _____ axis bisects the extensional quadrant. (1)

5. The scale used to measure the intensity of an earthquake is called the ____________________________. (1)

6. Compressional stepovers occur at a ___________ step along a right-lateral fault. (1)

7. Canada's largest historical earthquake was a Mw 8.1 event in 1949 along the ____________________________ fault off the coast of British Columbia. (1)

8. The San Andreas fault is about _______ million years old. (1)

9. The main fault along the east side of San Francisco Bay that runs underneath Oakland and Berkeley stadium is the ____________________________ fault. (1)

10. The phenomenon by which multiple fault segments collectively behave as if they are a single, continuous fault surface is called ____________________________. (1)
PART 4: Short Answer Topical Questions

1. PLATE TECTONICS AND EARTHQUAKE GEOGRAPHY (8 points)

The map above illustrates the epicenters of earthquakes at depths of less than 50 km and with magnitudes equal to or greater than 5.5 in the period 1963-1987. The boundaries of the tectonic plates show up very well in the earthquake distributions.

On the map, indicate examples of locations of the following features: (the examples should be labeled from 1 to 7 on the map)

1. The Juan de Fuca plate spreading center
2. A right-lateral, indent-related, strike-slip fault
3. An intracontinental rift zone
4. The 1811 and 1812 New Madrid earthquakes
5. The Andrew Bain ridge-ridge transform fault
6. A region of high plateau extension behind a collision zone
7. An on-land example of a mid-ocean spreading center
8. The location of the world's largest earthquake so far this semester
1. Accurately draw a typical Mohr-Coulomb failure diagram for the case of pre-existing faults having zero inherent shear stress (cohesion). Show at least one Mohr circle on your graph. Assume that the coefficient of friction, \( \mu = 0.6 \). Label each axis and show the scale of each axis up to a maximum of 100 MPa. (5)

2. On your diagram above, indicate the following features:
   a) Frictional failure line
   b) Angle of internal friction
   c) Locations of \( s_1 \) and \( s_3 \)
   d) The values of \( t \) and \( s_n \) at the point of failure (5)

3. Use your Mohr circle diagram to prove that for the case of normal faulting, the optimum dip of the fault will always be 60°. Be very explicit with your explanation. Hint: determine the value of 2\( \mu \) at the point of failure, and consider this in the context of the expected "Anderson" state of principal stresses for normal faulting. (5)
3. SEISMIC WAVES AND FOCAL MECHANISMS

i) What is the order of arrival of the four types of seismic waves?  (4)

ii) Draw an example of a seismogram at a recording station where the first P-wave arrival is dilatational. Show and label the evidence of three types of seismic waves on the seismogram.  (5)

iii) Focal mechanism diagrams are shown below for the two largest earthquakes so far this semester: a M\textsubscript{w} 7.0 in the Mariana Islands region, and a M\textsubscript{w} 7.4 in the Banda Sea near Indonesia.

![Mariana Islands Focal Mechanism](image1)
![Banda Sea Focal Mechanism](image2)

a) Draw in the fault plane curves on each diagram.  (1)

b) For each earthquake, determine the fault plane solutions below. Give strike and dip in degrees. Dip direction can be given as a compass direction (e.g. NNE). If strike-slip components of slip exist, state whether left-lateral (LL) or right-lateral (RL).  (15)

<table>
<thead>
<tr>
<th>Mariana Islands:</th>
<th>Banda Sea:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fault 1</td>
<td>Fault 2</td>
</tr>
<tr>
<td>strike</td>
<td></td>
</tr>
<tr>
<td>dip</td>
<td></td>
</tr>
<tr>
<td>dip direction</td>
<td></td>
</tr>
<tr>
<td>sense of slip</td>
<td></td>
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</tbody>
</table>
Answer **SIX** of the following short questions. **Only the first six questions attempted will be graded.**

i) A common practice for classifying whether or not a fault is active is by determining whether or not the fault has produced an earthquake within the past 10,000 years. Why is this not necessarily a good assumption? Provide examples to substantiate your answer. (4)

ii) List FOUR different types of seismic hazards and provide examples of earthquake instances or locations where these hazards became reality. (4)

iii) Draw a cross-section through a tectonic plate, labeling the major geophysical layers. Indicate the location of the Moho. Alongside your cross-section, include a strength versus depth profile, illustrating brittle-ductile rheological transition. (4)

iv) What is meant by the term "irrecoverable strain" in elastic materials and how can this term be applied to the concept of elastic rebound theory for earthquakes? (4)
v) What is the most accurate scale for measuring large magnitude earthquakes, and why? (4)

vi) Use Mohr-Coulomb failure theory to show why two conjugate planes at 90° to each other experience the maximum possible amount of shear stress in any stress state. Also, explain why despite this fact, conjugate planes are typically 60° apart in nature. (4)

vii) What is the difference between stick-slip and stable sliding? (4)

viii) Earthquake intensity is not always greatest at the earthquake epicenter. Explain what is meant by "earthquake intensity", and explain why the above statement is true, giving at least one earthquake example that demonstrates this fact. (4)
ix) Name an example of a region where indent-related tectonics is occurring. Describe the faulting and earthquake behavior in that region.  

x) Describe the Landers earthquake sequence of 1992, providing the location of the earthquake and the importance of fault segmentation during this earthquake event.  

xi) Why are normal fault earthquake magnitudes at mid-ocean spreading ridges generally low to moderate in size?  

xii) Explain why despite the fact that strike-slip and normal faults can both be segmented, normal fault segments tend to be curved whereas strike-slip segments are straight.