Earthquakes and Seismo-tectonics Chapter 5 HW answers

1. **A seismic recording station receives the first S arrival 8 minutes after the P one. What is the epicentral angle to the source.**

   Because P-waves and S-waves go a different wave speed, this fact can be exploited to measure the distance (not direction) to an earthquake via measurement of the time interval between the arrival times of the P- and S-wave. The accuracy of the distance to the earthquake is dependent upon the accuracy of the P- and S-wave speeds and the raypath taken by the earthquake waves. See Figure 5.4.

2. **The length of rupture on a fault plane associated with a large earthquake may be hundreds of kilometers long and tens of kilometers deep. How then can we refer to the hypocenter of the earthquake.**

   The hypocenter is where the point where the earthquake slip nucleated for a large earthquake.

3. **If the long-term average rate of displacement is roughly the same along the length of a long fault, how can some places experience large earthquakes yet other escape then.**

   While most faults only slip during an earthquake, a few faults (e.g., central San Andreas fault) actually mostly 'creep'. This does NOT mean that there are no earthquakes along the creeping sections of a fault; actually as there are many small ($M_b < 3$) earthquakes (see Fig. 5.20). But, given that the earthquake scale is logarithmic a large number of $M_b < 3$ earthquakes do NOT amount to any significant displacement on the fault compared to a $M_b > 5$ or 6 earthquake. So, why do only a few earthquake faults creep? Probably, something to do with the rock types on either side of the fault: e.g., serpentine is a very soft slippery rock that exists along the central San Andreas fault.

4. **A newspaper reported that an earthquake with an intensity of 7.3 on the Richter scale had caused thousands of deaths. What is their error.**

   The first obvious error in this questions statement is that the intensity of an earthquake is NOT measured via the Richter scale. An earthquake intensity is a measure of an earthquake's effect at a specific locality. Therefore, the intensity of an earthquake will change depending on distance from the earthquake. In addition, the intensity of an earthquake depends on the rigidity of the underlying rocks: e.g., soft sediments will amplify ground motion with respect to a hard-rock site. Whereas the Richter scale is a formal measurement of an earthquakes P-wave amplitude that is calibrated for distance effects (Fig. 5.23).

5. **Give at least two reasons why the P-waves recorded on a receiver due to an earthquake are not a single pulse.**

   First, an earthquake has a finite rupture time which for bigger earthquakes can be on the order of tens of seconds. During this rupture time interval, the rupture speed of the earthquake can both increase and decrease as high and low stress regions are encountered. This will cause the earthquake pulse to be much more complicated than a 'single pulse'. Second, as the wave propagates from the earthquake source to a receiver, seismic velocity heterogeneity (short-scale variations in seismic P- and S-wave speeds) is encountered which cause the wave energy to scatter (Fig. 5.22). This scattering of the earthquake waves cause a 'single pulse' to be redistributed into a series of pulses that are recorded.

6. **A first-arriving P-wave ray arrives at a seismic station 80° from near-surface hypocentre. What was its take-off angle.**

   To answer this question, one would need to estimate: (1) the 'near-surface' velocity which is typically about 6 km/s; (2) the ray parameter for an 80° distance event. Then, just plug these values into Snell's Law. Whether one use the Cartesian or spherical Snell's law will not matter as both the source and receiver are at the same radius from the center of the Earth.

7. **During an earthquake a building experiences horizontal shaking. It could have been due to which waves.**

   We have 4 types of waves and their vibration directions (particle direction or polarization) to consider: P-wave, S-wave, Love-wave and Rayleigh wave. Only two kinds of waves can potentially cause horizontal shaking: the Love-wave and an S-wave. In general, the S-wave is NOT always associated with horizontal shaking, albeit it can be. But, a Love-wave ALWAYS causes horizontal shaking. Also, a Love wave is generally has much larger amplitude than a S-wave and the shaking generally last much longer in time.

8. **A 3-component seismometer aligned N-S, E-W and vertically recorded the largest amplitude of Love waves in E-W direction. What is the approximate direction of the earthquake from the station.**

   This question requires an understanding of the vibration direction (particle direction) of the 4 different kinds of waves. A P-wave and S-wave are longitudinal and transverse waves respectively. A Rayleigh wave has circular motion (vertical ellipse of motion) and a Love wave has a horizontal (transverse) particle motion or direction. If a Love wave was recorded with the largest amplitudes on the E-W component of the seismometer, then the earthquake either came from the North or South direction because the particle motion of a Love wave is transverse with respect to its direction of propagation.

9. **Which of the following ways of measuring the size of an earthquake does not need an instrumental record.**

   All the answers require a seismic instrumental record to measure an earthquake size EXCEPT the intensity scale. The intensity scale is gauged by observed physical effects such as lamps swinging, chimneys cracking or falling, objects accelerated into air, etc.

10. **SKIP.**
11. **SKIP.**

12. **When a certain locality experienced an earthquake with a Richter magnitude of 7 there was little damage. A newspaper reported that as this was only a little less than the largest known in the area, magnitude 8, citizens could be confident that recent work to make buildings, bridges, and so on safe had been successful. Why should they not be confident.**

    The Richter magnitude scale is a base 10 logarithmic scale, therefore a magnitude 8 has ten times more energy released than a magnitude 7. So, just because a regions infrastructure survived the magnitude 7 would mean little with respect to a magnitude 8.

$$M_{richter} = \log_{10}(\max amp) \quad in \ \ units \ of \ \ 10^{-6} \quad m$$

Extra questions:

1. Define a force, force couple, and double couple.
2. Define the moment of a couple.
3. Define the seismic radiation pattern for a P-wave from a double-couple source.
4. Define elastic rebound.
5. Why are there two equally plausible fault planes for a seismic focal plane mechanism.