Problem Set #1: Earthquakes   Due date: March 12, 2010

1- Using the ray theory approximation, draw the paths of all possible seismic P-waves that travel from the source (star) to the seismometer (inverted triangle) for (a) a uniform wavespeed model, (b) a model in which the wavespeed increases linearly with increasing depth, and (c) a model in which the wavespeed decreases linearly with increasing depth. Axis z is vertical pointing downward and axis x is horizontal. Both the source and the seismometer are located at the surface. (15 points)
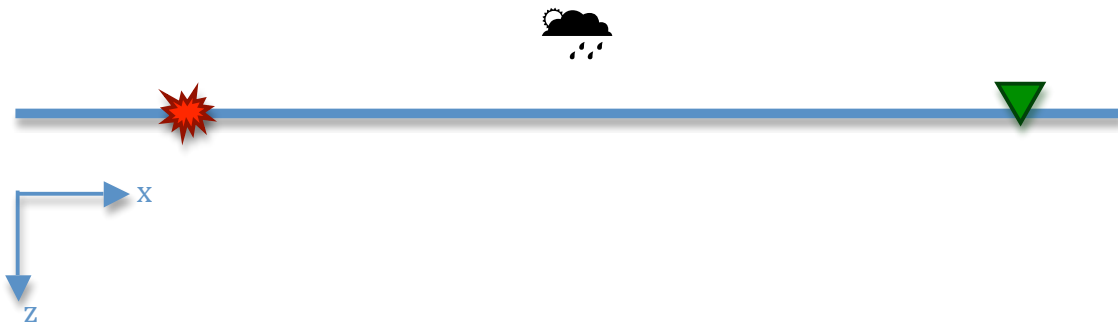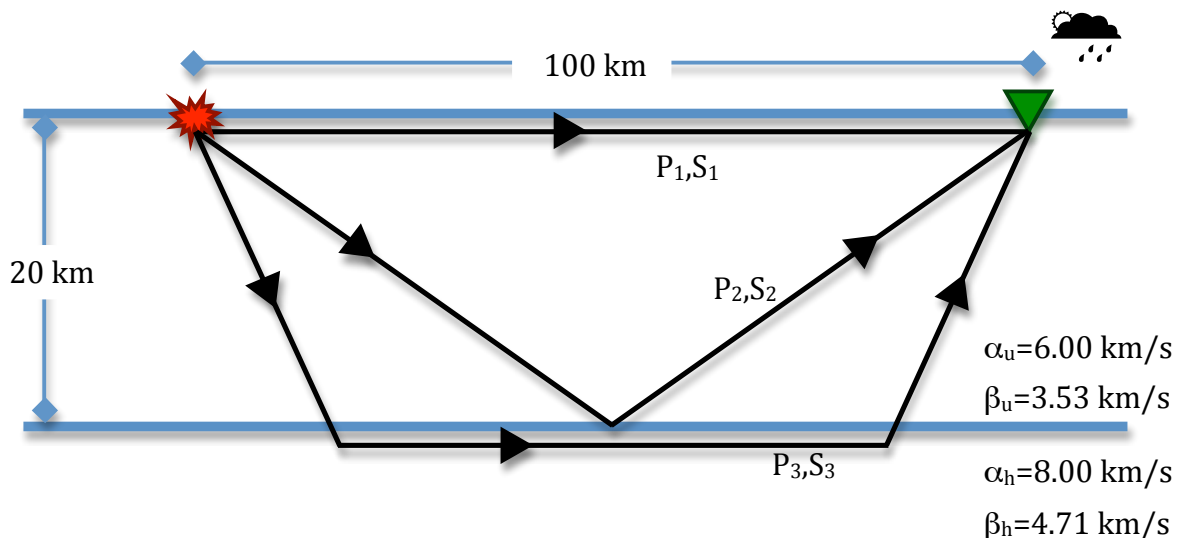
a)

X

Z

b)

X

Z

c)

X

Z
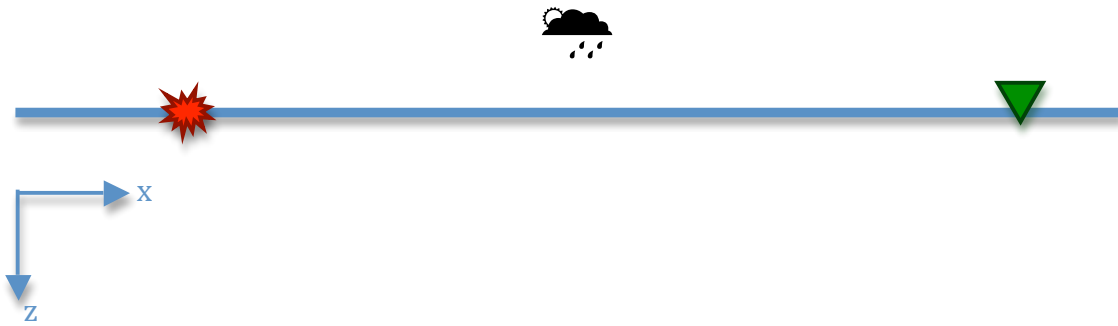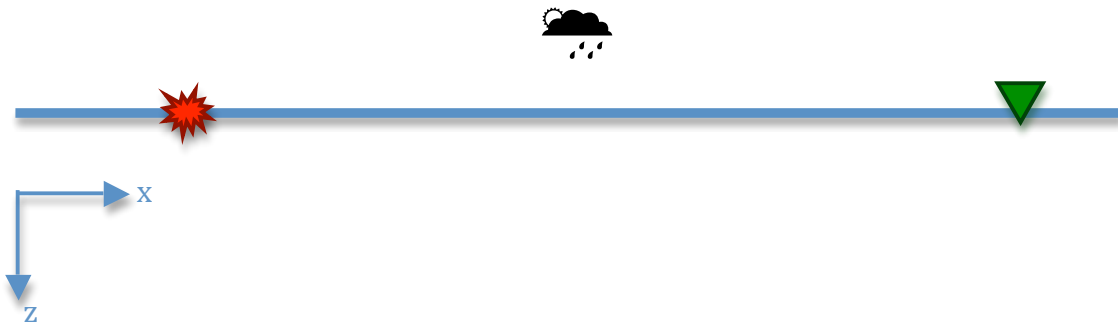
2- The schematic diagram below shows all the possible ray-paths for P- and S-waves traveling from a source (star) to a seismometer (inverted triangle) in a medium consisting of an upper layer overlying a half-space. Subscripts 1, 2 and 3 denote the direct, reflected, and critically refracted waves, respectively. The upper layer (subscript u) and half-space (subscript h) have uniform seismic wavespeeds, which are indicated to the right of the diagram. (a) Using Snell's law, determine the order in which the various waves arrive at the seismometer. To do this, you will have to calculate the actual travel time of each wave. (b) If the first arrival can be detected by the seismometer, what would be the minimum delay time – and therefore warning time - before the Love wave arrives at the location of the seismometer? (20 points)

100 km

P_1, S_1

20 km

P_2, S_2

$\alpha_u = 6.00$ km/s
$\beta_u = 3.53$ km/s

P_3, S_3

$\alpha_h = 8.00$ km/s
$\beta_h = 4.71$ km/s

3- Seismic wavespeeds in the Earth. (a) What causes seismic wavespeeds to generally increase with increasing depth in the Earth? (b) Why are there no S-waves in the outer core of the Earth? (c) Why does the P-wavespeed suddenly decrease when waves travel from the lower-mantle into the outer core? Use the expression of seismic wavespeeds to explain your answers. (15 points)

4- In your opinion (and based on the knowledge acquired in class), what is the safest location to erect a earthquake-proof building: Back Bay or Beacon Hill? Explain your reasoning. (10 points)

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5- Earthquake magnitude. (a) The San Andreas fault is 1300 km long, and is believed to be locked from the surface to approximately 10km depth. The typical slip associated with large earthquakes ranges between 2-8 m. With these values, and considering an average rigidity $\mu=4\times10^{11}$ dyn/cm^2, what is the largest magnitude earthquake that could be generated along the San Andreas fault? (b) Keeping the same parameter values as above (except for the fault length), how long would the San Andreas fault have to be for a 10.5 magnitude earthquake to occur – as suggested in the TV miniseries "10.5"? Is that a realistic value of magnitude? (20 points)

6- The San Andreas fault passes approximately 5km offshore (to the west) of the Golden Gate – the strait connecting San Francisco Bay to the Pacific Ocean. If rupture occurs along this segment of the fault, does this movement have the potential to trigger a large Tsunami? Explain your answer. (10 points)

7- Which of the following two cities faces the highest risk of earthquake-induced Tsunami: Boston or Los Angeles? Explain why. (10 points)

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