12.510 Introduction to Seismology
Spring 2008

Problem Set 3 (Due on Wednesday, Apr. 23, 2008)

Figures 4.16, 4.18-4.23 are taken from *Introduction to Seismology* [Peter M. Shearer, 1999].

1. For spherically symmetric Earth models, P-S_V wave motion separates completely form S_H motion. Despite this, P-wave are often observed (weakly) on traverse component (e.g., Figures 4.16 and 4.22). Give several reasons why this might occur. (10 points)

2. The stacked images in Figures 4.20-4.22 appear 'grainier' at source-receiver distances near 0^0 and 180^0 than at 90^0, owing to a smaller number of seismograms available at these distances. Why might one expect the number of seismograms to diminish at small and long ranges? (10 points)

3. Some of the seismic phases in Figures 4.18-4.23 are plotted with negative slopes, that is, they arrive sooner at long distances. How can this be? (10 points)

4. You will need to run a Matlab script called runrays.m for this problem. Runrays uses the eikonal equation to calculate traveltimes in a layered earth model that you define. The default model provided in runrays.m has 2 discontinuities. The first is at 10 km depth and the second is at 30 km depth.

    (a) The discontinuities give rise to two major triplications at which distances? (5 points)

    (b) On the blowup of traveltimes that is plotted (figure 3 that is output by the code) connect the appropriate dots to outline the two triplications. (10 points)

    (c) Label the traveltime branch that represents the rays that turn above, below and at the first discontinuity. Do the same for the rays that correspond to the second discontinuity. (5 points)

    (d) Create a velocity model with a low-velocity zone. Set the velocity nodes at

[0 5 10 15 20 25 30 35 40]

and set the velocities to be

[5 8 11 8 11 15 20 25 30]

the low-velocity zone gives rise to a shadow zone starting at which distance? Make a comparison between an estimate from figures generated by the code and your calculation. (10 points)

5. Assume that a half-space medium has a linear P wave velocity gradient of the form $v_p(z) = az + b$ ($z>=0$), where a and b are constants.

   (a) Show that rays propagating in this kind of medium have ray paths that are circular. Derive an expression for the radius of the circle in terms of a and the ray parameter p. (10 points)

   (b) For a source on the surface, derive the travel time T of P wave in terms of a, b, and the epicentral distance X. (15 points)

   (c) Assume that a=0.001 s^{-1} and b=3 kms^{-1}. Plot the travel time curve and explain it. (5 points)

   (d) Give graphical as well as analytical arguments that show the PP midpoint must be a maximum time point. (10 points)

   (e) (BONUS) For a source at the depth of c, derive the travel time of P and pP in terms of a, b, c and the epicentral distance X. (30 points)