Introduction to Earthquake Seismology
Assignment 10

Department of Earth and Atmospheric Sciences **EASA-462**
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Simple Crustal Model

Goals:

- Compute and plot the P-wave travel times for a simple crustal model
- Plot the direct and refracted arrivals using a reduced travel time plot

Background:

Travel time computation for a simple layer over a halfspace is simple if the source and receiver are at the surface. Assuming a layer with thickness H and velocity V_1 overlying a halfspace with velocity V_2, the equations of the arrivals of interest are as follow:

Direct:

$$t_{direct} = \frac{x}{V_1}$$

First refection

$$t_{refl} = \frac{\sqrt{x^2 + 4H^2}}{V_1}$$

Refraction

$$t_{refr} = \frac{2H \cos i_{c_{12}}}{V_1} + \frac{x}{V_2}$$

where the critical angle is defined by the relation based on Snell's law:

$$\sin i_{c_{12}} = \frac{V_1}{V_2}$$

If you compute values of these times and plot them, it is difficult to see much detail because of the plot scale. In refraction studies one often uses the reduced travel time plot, which entails plotting $t - \frac{x}{V_{red}}$ *vs* x instead of the normal t *vs* x. This is illustrated in Figure 1. Figure 1a shows the travel time plot. Note that most of the figure is white-space which means you may not be able to see individual data points because of the scale. The idea of the reduced-travel time plot is to focus on the travel times in the shaded region. This shaded region has a slope of $\frac{1}{V_{red}}$ and maps into the larger region to the right. The advantage is that small variations in observed data can now be seen on this expanded plot. The straight lines of the direct and refracted arrivals are still lines, but with exaggerated slopes - making it easier to see the crossover distance.

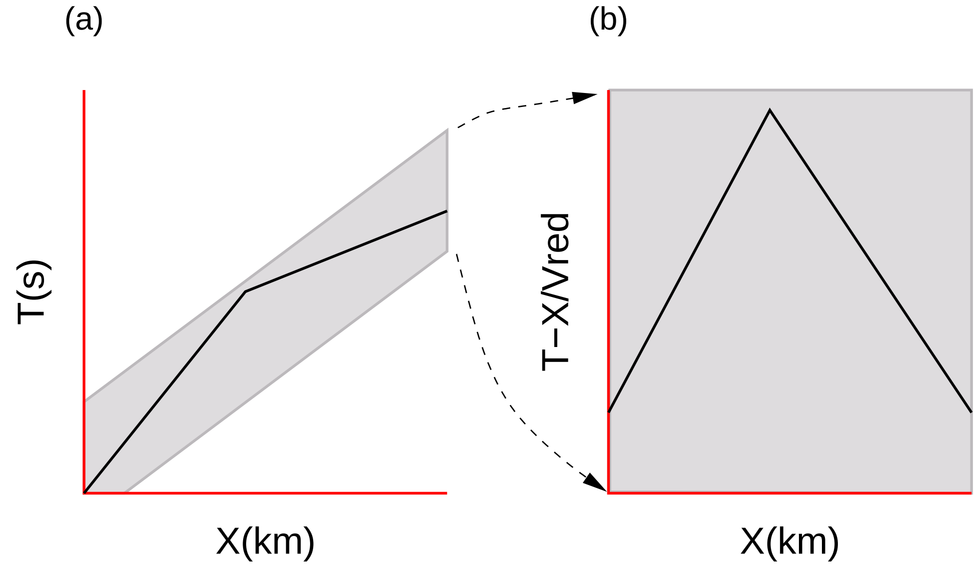

Fig. 1. Comparison of travel-time (a) and reduced travel-time (b) plots.

Crossover distance

The distance at which the first arrival changes from the direct to the refracted arrival is called the crossover distance, x_c, which is define by solving the equality

$$t_{direct}(x_c) = t_{refr}(x_c)$$

$$\frac{x_c}{V_1} = \frac{2H\sqrt{1-(\frac{V_1}{V_2})^2}}{V_1} + \frac{x}{V_2}$$

With little effort you can show that this is

$$x_c = 2H\sqrt{\frac{V_2+V_1}{V_2-V_1}}$$

The value of this equation is that if you know the crossover distance and the velocities, you can compute the layer thickness H.

What you must do:

For the following model:

Simple crustal model (SCM)

H (km)	V_P (km/s)
40	6.0
-	8.0

a) Compute the direct arrival
b) Compute the reflected arrival
c) Compute the refracted arrival

What you must submit:

a) Plot all three on the same figure for the distance range of 0 - 300 km
b) Plot the directed arrival and refracted arrival on a "reduced travel time" using a reduct on velocity of 7.0 km/s
c) Give the equations of the arrivals:

$$Direct:\ t_{direct} = \_\_\_\_\_\_\_\_\_\_ + x/\_\_\_\_\_\_\_\_\_\_$$

$$Reflection:\ t_{refl} = \sqrt{x^2 + (2\_\_\_\_\_\_\_\_\_\_)^2}$$

$$Refraction:\ t_{refr} = \_\_\_\_\_\_\_\_\_\_ + x/\_\_\_\_\_\_\_\_\_\_$$

d) Give the computed crossover distance between the direct and refracted arrivals.

$$x_c = \_\_\_\_\_\_\_\_\_\_\ km$$