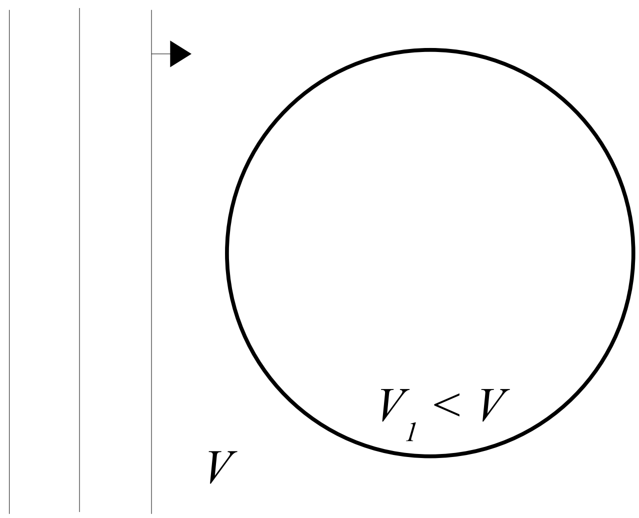
1) A spherical low-velocity body is embedded in a constant-velocity medium.

   a) Sketch the wavefronts of a plane seismic wave incident from the left, as they propagate through the body.

   b) Explain the use of Huygens' principle in building the wavefronts.

   c) How do the wavefronts change as they move to the far right after leaving the body?



Solution hints:

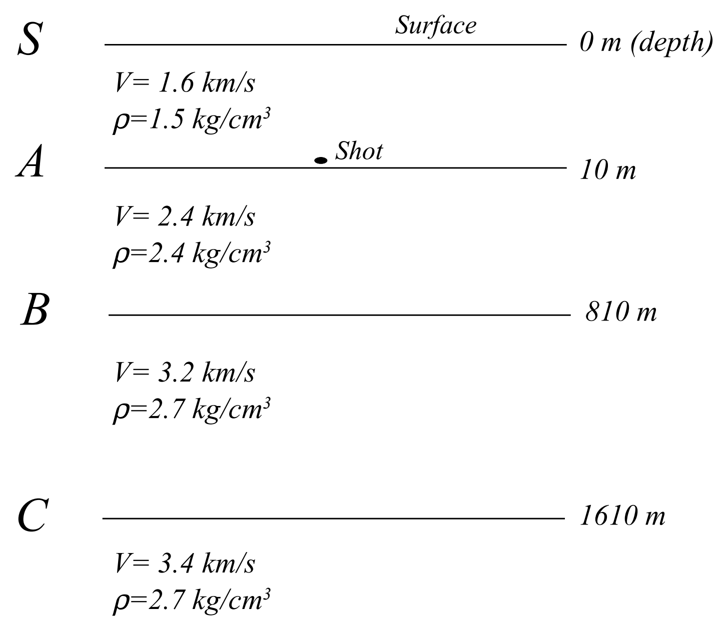
- The time intervals between the wavefromts are constant (e.g., equal to the wave periods), and therefore the wavefronts will be spaced closer within the low-velocity body.
- At the far right, the depression in the wavefronts will gradually "heal" and the wavefronts will resume their flat shapes. This closure of the zone of delayed wavefronts can be illustrated by applying the Huygens principle.
- Can you estimate the distance at which the depression in the wavefronts (in terms of propagation time) will become less than 1% of R/V (R is the radius of the body)? Note that the value of V_1 is insignificant for this answer, and you can even a assume a cavity (V_1=0).

2) Assume horizontal layering as shown below, with a shot at surface A generating a wave of amplitude 1 when it reaches interface B.

a) Calculate the amplitude of refection observed at the surface from interface B.

b) same for interface C.

Disregard the dependence of geometrical spreading on the layering (that is, assume that geometrical spreading is controlled by the total ray path only).



Solution guidelines:

1. Denote the source amplitude A_S. .
2. Upon propagation from the source to the various interfaces, the wave amplitudes will be $A(R)=\frac{A_S}{R}$ (geometrical spreading). Here, R is the distance from the source to the corresponding interface (800 m for B or 1600 m for C).
3. The amplitude at interface B is given: $A(B)=\frac{A_S}{800}=1$, therefore $A_S = 800$.
4. Upon reflection, the amplitudes will be multiplied by reflection coefficients: $R_{PP}=\frac{A_{reflected}}{A_{incident}}=\frac{Z_2-Z_1}{Z_2+Z_1}$, where the impedances $Z=\rho V$ can be calculated from the data

provided for the layers. The reflection coefficient for boundary B is thus 0.23, for boundary C - 0.03. For boundary A, the reflection coefficient is 0.4 (it will be needed in step 7 below).

5. Upon travelling upward, geometrical spreading will continue to reduce the amplitudes. The resulting spreading effect will be $A(R)=\frac{A_S}{R}$, where R is now the total path (800+810 m for reflection from interface B and 1600+1610 m from C).

6. In addition to the geometric loss, the upward propagating waves will experience transmission losses through boundary A. The transmission coefficient is: $T=\sqrt{1-R^2}=\sqrt{1-0.4^2}\approx 0.91$ for interface A.

7. Therefore, amplitude of reflection from B will be:
$$A_{reflB}=0.23\times 0.91\times\frac{A_S}{R}=0.23\times 0.91\times\frac{800}{1610}\approx 0.104 \quad .$$

8. For a reflection from C, an additional transmission through interface B will occur, with transmission coefficient 0.97 (see step 6). The resulting amplitude is:
$$A_{reflC}=0.03\times 0.97\times 0.91\times\frac{A_S}{R}=0.03\times 0.97 \mathrm{times}\, 0.91\times\frac{800}{3210}\approx 0.007$$

3) A linear Common Mid-Point (CMP) reflection survey is conducted using a cable with N geophone groups. Shots are carried out at every k-th geophone location, and the cable is rolling with every shot.

a) Derive the expression for the nominal CMP fold in terms of N and k.

b) Describe the three key processing steps applied to the data to produce a zero-offset time section (*Hint:* This does not include filtering, deconvolution, migration, etc.; we are only interested in the steps needed to transform the records to as if they were recorded by co-located shots and geophones).

4) A compressional (P-) plane wave strikes at a planar velocity contrast at an incidence angle i.

a) (10%) Sketch a ray diagram showing all refracted, refracted, and converted waves;

b) (5%) Indicate the directions of particle motion in each of these waves;

c) (5%) On ray diagram, sketch the waveforms of refracted and reflected P-waves.

5) Describe at least two situations in which a layer with velocity different from those of surrounding layers may *not* be detectable in first-arrival refraction imaging.

6) Give an expression for the Snell's law of refraction.

7) Explain the relation/differences between the apparent and true velocities.

8) Give definitions for the intercept time, delay time, reciprocal time, and ray parameter.

9) A seismic recorder has recorded a direct wave and a reflection. The direct wave resulted in a voltage pulse of 5 mV, and the reflection was 60 dB lower.

- a) What was the electrical output (voltage) for the reflection? Explain.
- b) Can both of these signals be recorded correctly using a 16-bit recorder? Explain.