地震勘探原理 双语教学材料

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作业 1 利用费马原理证明反射定律和透射定律

Objective

To understand the importance of Fermat's principle in deriving Snell's law in the reflection and refraction cases.

Introduction

Fermat's principle states that a wave will take that path which will make the traveltime stationary (i. e., maximum or minimum). Mathematically:

$$dT / dX = 0,$$

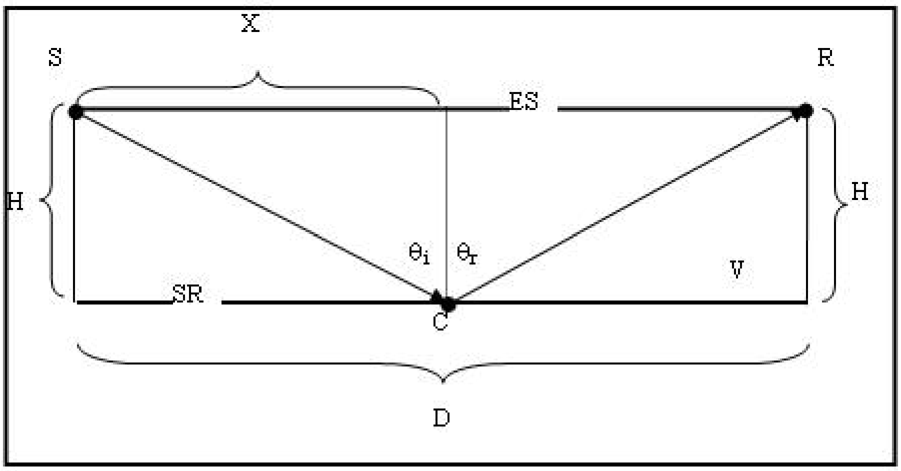
where T is the total traveltime along the wave path and X is the distance from the source to the point where the wave changes its direction (e.g., point of reflection or refraction). In most situations in the earth, the stationary path is the minimum-time path. In this exercise, we will use Fermat's principle to derive Snell's law in the following cases:

1. Reflection.
2. Refraction.(在此处，我们指透射)

Exercises

1. Given Figure 1:
    a. Use Fermat's principle to derive Snell's law in terms of the angles of incidence and reflection.
    b. Find at what value of X (as a function of D) does Fermat's principle hold?
    c. Verify that this value of X refers to a minimum-time path.
    d. Verify that the ray will always take a minimum-time path.
2. Given Figure 2:
    a. Use Fermat's principle to derive Snell's law in terms of the angles of incidence and refraction.
    b. Verify that the ray will always refer to a minimum-time path.

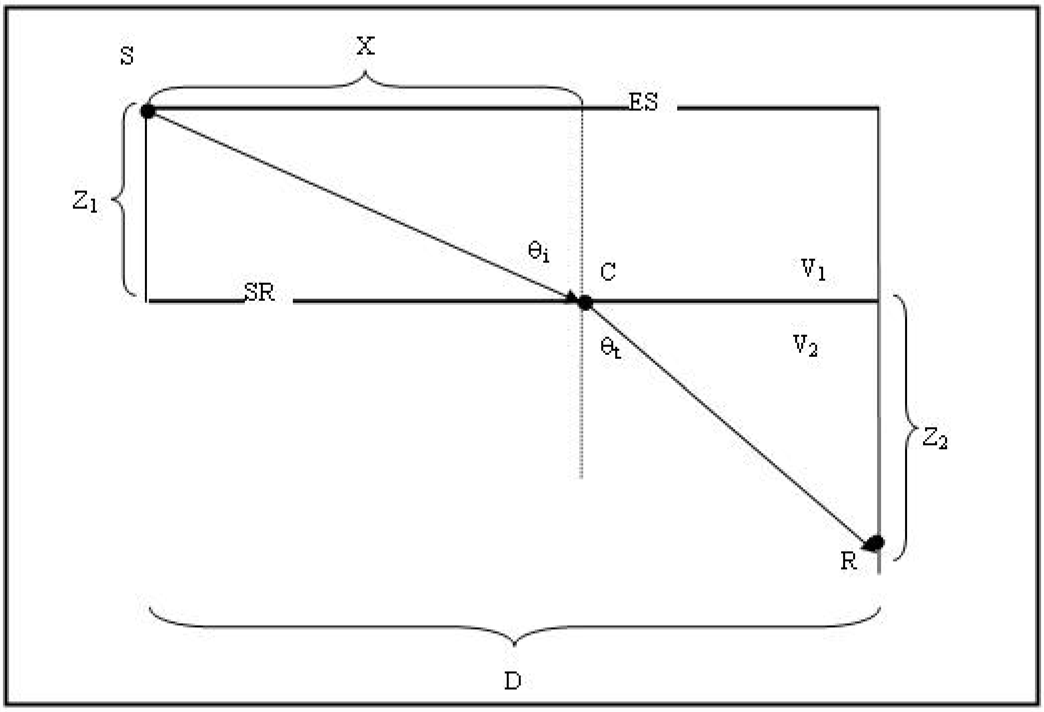
Exercise 1



S: Source
R: Receiver
C: Reflection point

ES: Earth's surface
SR: Subsurface reflector
H: Layer thickness
V: Layer velocity
D: Source-receiver offset
X: Distance to reflection point
Θ_i: Incidence angle
Θ: Reflection angle

Exercise 2



S: Source
R: Receiver
C: Refraction point
ES: Earth's surface
SR: Subsurface reflector
Z_1: Depth from source to reflector
Z_2: Depth from receiver to reflector
V_1: Velocity in Layer 1
V_2: Velocity in Layer 2
D: Source-receiver offset
X: Distance to refraction point
Q_i: Incidence angleΘ_t: Refraction angle

作业 2 计算反射系数

Objective

To calculate the reflection coefficients between different lithologies and determine the effect of ignoring the density in calculating the reflection coefficient.

Introduction

The reflection and transmission coefficients (R, T) are defined as:

$$R = (Z_2 - Z_1) / (Z_2 + Z_1)$$

$$T = 1 - |R| = 2Z_1 / (Z_2 + Z_1);$$

where $Z = \rho V$ is the acoustic impedance, r and V are the density and velocity, respectively.

Exercises

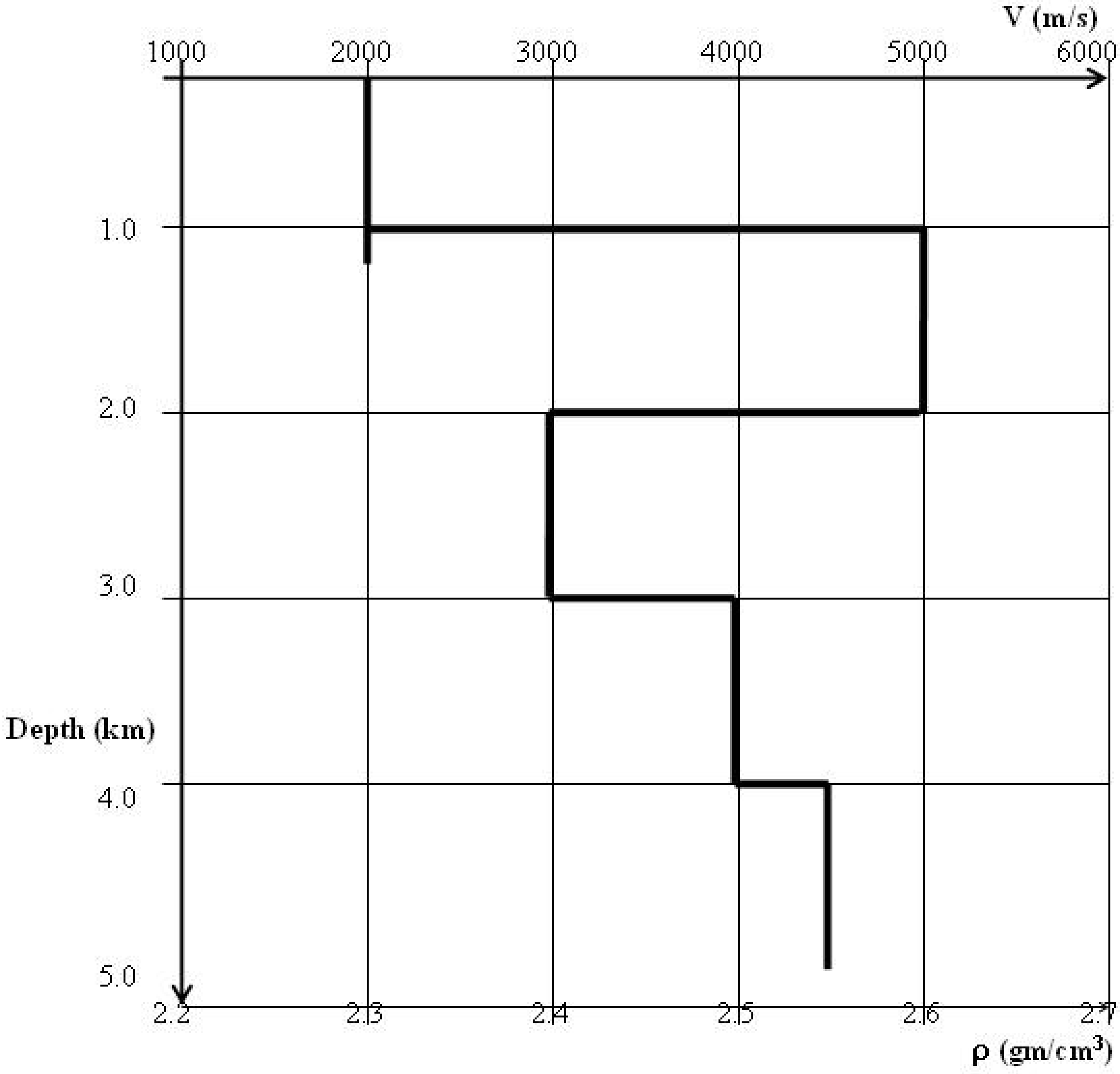
Given the attached velocity-density model, use an Fig 1 :

1. Calculate $R = R(V, \rho)$ at each interface.
2. Calculate $T = T(V, \rho)$ at each interface.
3. Calculate R = R(V) at each interface using only velocities (i.e., drop r from the formula).
4. Calculate the absolute error between R found in steps 1 & 3. The absolute error is defined as:

$$E(\%) = \left| \frac{R(V,\rho) - R(V)}{R(V,\rho)} \right| \times 100$$

5. Plot E(%) versus:
   a. |R|
   b. V2/V1
   c. $\rho 2/\rho 1$
6. How does E(%) changes with:
   a. |R|
   b. V2/V1
   c. $\rho 2/\rho 1$
7. What would you do if you were given only V and have been asked to calculate R?

Fig1



作业三 计算和识别反射波同相轴

Homework assignment

Definition of Seismic Events

Objective

To be able to calculate layer parameters for T-X curves of various seismic events.

Introduction

The T-X equation for a reflection from a horizontal interface between two layers of velocities V_1 and V_2 above and below the interface, respectively is:

$$T^2 = T_0^2 + X^2/V_1^2,$$

where $T_0 = 2H/V_1$, V_1 and H are the upper-layer's velocity and thickness, respectively. The T-X equation of a direct wave is:

$$T = X/V_1.$$

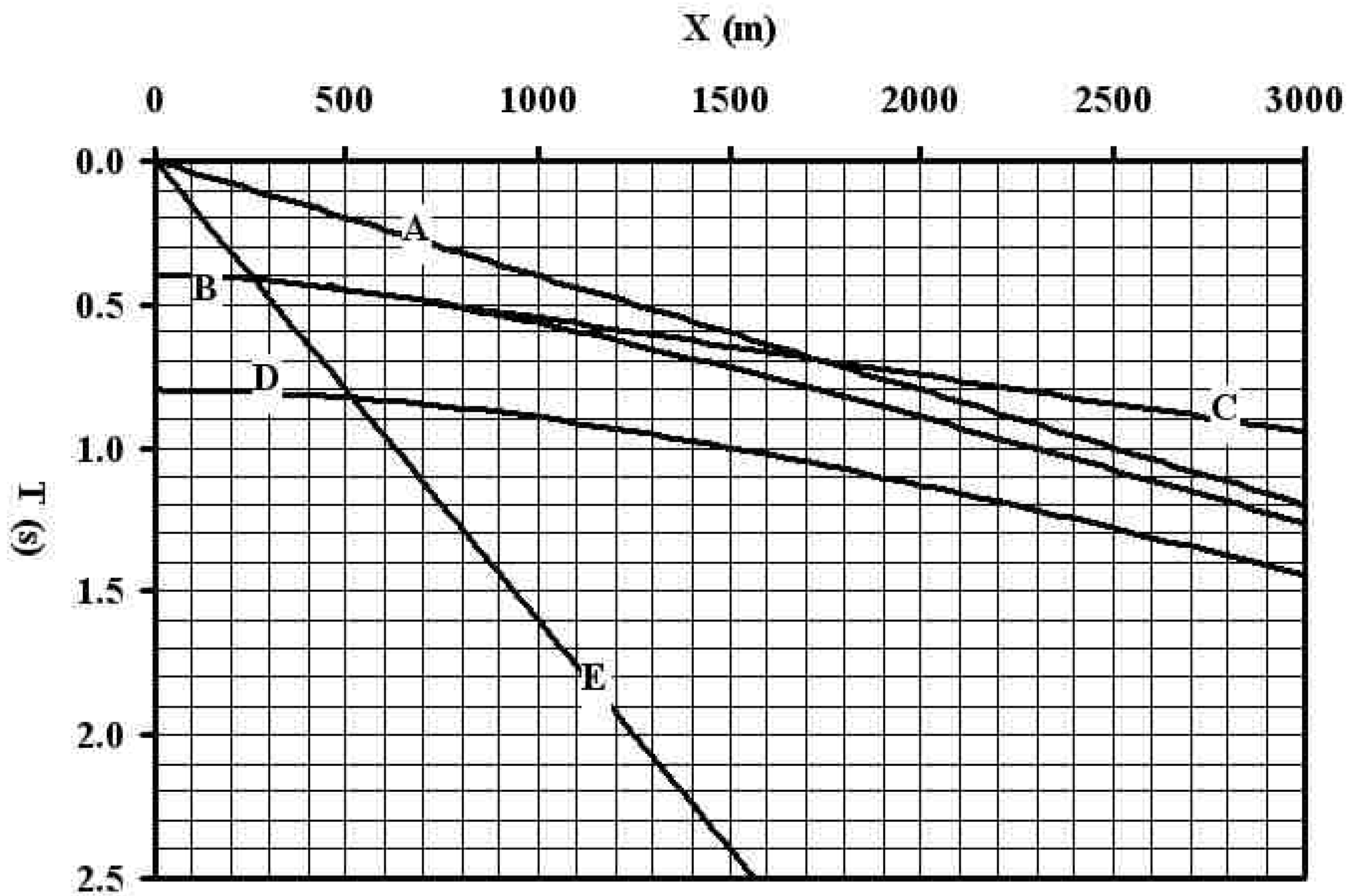
The T-X equation for a head-wave from the interface is:

$$T = T_0 \cos q_c + X/V_2,$$

The critical angle q_c is given by:

$$q_c = \sin^{-1}(V_1/V_2),$$

where $V_1 < V_2$. The critical distance at which the head-wave begins is:



$$X_c = 2H \tan q_c.$$

The crossover distance at which the head-wave traveltime equals the direct traveltime is:

$$X_o = T_0 \cos q_c/(1/V_1 - 1/V_2).$$

Exercises

The attached figure consists of several events:

(a) Define event A and find its velocity.

(b) Define event B and find its velocity.

(c) Define event C and find its velocity.

(d) Define event D and find its velocity.

(e) Define event E and find its velocity.

(f) Compute the thickness of the first layer.

(g)

  (i) Compute q_c, X_c, and X_o using the information from previous parts.

  (ii) Determine q_c, X_c, and X_o from the figure.

  (iii) Calculate the error E(%) in q_c, X_c, and X_o between the value calculated from parts (i) and (ii).

作业四

Exercise 1:

- 20 Hz seismic wave
- Travels with 5 km/s
- Propagates for 1000 m. through

Medium: absorption coefficient 0.25 dB/ λ

- What is the wave attenuation in dB due solely to absorption?

Exercise 2
Sampling at 4ms intervals
• What is the Nyquist frequency
• In absence of anti-alias filtering, at what frequency would noise at 200 Hz be aliased back into the Nyquist interval?

作业五

Circle the most correct answer in each of the following questions:

(1) The S-wave velocity in water is closest to:
(i) 0 m/s (ii) 340 m/s (iii) 1000 m/s
(iv) 1200 m/s (v) 1500 m/s

(2) In seismology, we know that the first energy to arrive at a geophone from a source
travels by the fastest time path. This principle is attributed to:
(i) Huygen (ii) Fermat (iii) Snell
(iv) Trudeau (v) Newton

(3) The shape of a reflection, from a flat reflector, on a traveltime vs distance plot is:
(i) straight line (ii) parabolic (iii) circular
(iv) hyperbolic (v) elliptical

(4) In a reflection seismic survey, you observe a zero-offset reflection time of 100ms. If
the velocity down to the boundary that generated the reflection is 3000m/s, the depth
to the reflector is:
(i) 30 m (ii) 150 m (iii) 300 m
(iv) 330 m (v) none of (i) through (iv)

(5) If a seismic wave has a wavelength of 100 m and a velocity of 4000 m/s, its frequency
is:
(i) 25 Hz (ii) 40 Hz (iii) 400 Hz
(iv) 2.5 Hz (v) none of (i) through (iv)

(6) A rock with a P-wave velocity of 6000 m/s is most likely to be:
(i) shale (ii) sandstone (iii) limestone
(iv) glacial till (v) volcanic ash

(7) Fermat's Principle states that the first energy to arrive at a geophone from a shot travels by:
(i) a straight line (ii) fastest time path (iii) a circle
(iv) shortest geometric path (v) secondary wavelets

(8) If a seismic wavelet has a period of 0.025 seconds, its frequency is:
(i) 25 Hz (ii) 50 Hz (iii) 250 Hz
(iv) 40 Hz (v) none of the above

(9) If seismic data has a maximum frequency of 250 Hz, then the sample interval for digital sampling without aliasing must be no greater than:
(i) 1 ms (ii) 2 ms (iii) 2.5 ms
(iv) 5 ms (v) 250 ms

(10) Layer 1 has a velocity of 3000 m/s and a density of 2000 kg/m3; layer 2 has a velocity of 2000 m/s and a density of 1800 kg/m3. The reflection coefficient for a seismic wave incident on layer 2 from layer 1 is:
(i) 0.1 (ii) -0.1 (iii) 0.25
(iv) -0.25 (v) 0.5

(11) If we sample a seismic trace every 1 ms, the Nyquist frequency is:
(i) 1000 Hz (ii) 100 Hz (iii) 500 Hz
(iv) 1 Hz (v) 2000 Hz

(12) If a seismic wave has a wavelength of 100 m and a frequency of 50 Hz, its velocity is:
(i) 50 m/s (ii) 1000 m/s (iii) 2500 m/s
(iv) 5000 m/s (v) none of the above

(13) Young's modulus in a uniaxial stress experiment is:
(i) stress/strain (ii) strain/stress (iii) Vp/Vs

(iv) 0.5 (v) ratio of axial contraction to lateral expansion.

What is critical refraction ? If V1 = 1500 m/s and V2 = 2500 m/s,

calculate the

critical angle, ic.