Questions: Seismic Refraction and Reflection

1. Before stacking reflection seismic data, a normal move-out correction is applied. This correction is applied to data that is sorted in
   a. common shot gathers
   b. common receiver gathers
   c. common midpoint gathers
   d. common offset gathers

2. A synthetic seismogram is generated by from an acoustic impedance log by
   a. convolving it with an input pulse
   b. determining the density of each layer
   c. determining the seismic velocities of each layer
   d. generating a reflection coefficient log and convolving it with an input pulse

3. A synthetic seismogram is important for interpreting reflection seismic data because it provides a relationship between
   a. travel times and depth to interfaces
   b. density and seismic velocity
   c. layer thicknesses and travel times
   d. density and depth to interfaces

4. Within a given sedimentary layer, a change in the p-wave acoustic impedance could indicate a change in
   a. Porosity
   b. Pore fluid content
   c. Lithification
   d. All of the above

5. In marine seismic exploration, a seismic source such as an air gun or water gun is used to generate seismic energy. All seismic sources deployed in the water have what feature in common?
   a. They generate P-waves only
   b. They generate S-waves only
   c. They generate both P and S waves
   d. They generate both P and SV waves

6. In order to determine the velocity of a layer using refraction seismic, we need at least two geophones with first arrivals from that interface to _____________ for that event on the T-X plot.
   a. Account for noise
   b. Compute the slope
   c. Determine the offset distance
   d. Compute the critical angle
7. Typically, seismic velocity increases with depth. The main reason for this is that, in general, ______________ with depth
   a. Density increases
   b. Bulk and shear modulus increase
   c. Bulk and shear modulus increase more rapidly than density
   d. Density increases more rapidly than bulk and shear modulus

8. For a reflection seismic survey, where the subsurface has an average P-wave velocity of 1000m/s and we use a 10ms seismic wavelet, the best resolution we could obtain is?
   a. 1 m
   b. 2.5 m
   c. 5 m
   d. 10 m

9. Seismic migration can be best described as
   a. Converting the seismic section from time to depth
   b. Adjusting the reflection time based on the hyperbolic travel time
   c. Stacking the traces
   d. Putting seismic reflectors in their correct location

10. A refraction seismic survey is conducted in a region with a planar, dipping layer beneath a flat overburden layer. The surface is flat. The velocity of each layer is constant, and \( v_1 < v_2 < v_3 \). Do you expect the reciprocal times from the dipping interface to match?
    a. No, because the forward and reverse shots travel along different ray paths
    b. Only if there is no noise in the data
    c. Yes, because the forward and reverse shots travel along the same ray path
    d. No, because the velocity in the up-dip direction is greater than in the down-dip direction

11. A refraction seismic survey is conducted in a region with a planar, dipping layer, with \( \gamma = 1^\circ \). The velocity in layer 1 is 400 m/s, and the velocity of the second layer is 2000 m/s. Which of the following pairs of up and down dip velocities could be observed
    a. \( v_u = 2105 \text{ m/s} , v_d = 1910 \text{ m/s} \)
    b. \( v_u = 1910 \text{ m/s} , v_d = 2105 \text{ m/s} \)
    c. \( v_u = 2000 \text{ m/s} , v_d = 1900 \text{ m/s} \)
    d. \( v_u = 1900 \text{ m/s} , v_d = 2000 \text{ m/s} \)

12. In a seismic survey, an air wave can be best described as
    a. A wave that travels through the air
    b. A compression wave that travels through the air in the pore spaces in the rock
c. A direct, compression wave that travels from the source to the geophones through the air
d. All of the above

13. A seismic survey is conducted in a region with two layers. The top layer is shale, with density 2500 kg/m³, and seismic velocity of 2900 m/s, and the bottom layer is sandstone, with a density of 2100 kg/m³, and a seismic velocity of 3000 m/s. The reflection coefficient will be
   a. Positive
   b. Negative
   c. Zero
   d. Not enough information

14. A seismic survey is set-up with a source in a borehole, 100m below the surface, and an array of geophones on the surface. There is an interface at 200m. The top layer has velocity 1000 m/s and the lower layer has velocity 2000 m/s. Which of the following characteristics on a T-X plot will remain the same if the source was now moved to the surface?
   a. Slope of the refracted arrivals
   b. Intercept times of the refracted arrivals
   c. Arrival times of the direct ray
   d. Arrival times of the reflections

15. When looking at first arrival times in a seismic refraction survey, what relationship between the layer velocities allow us to determine the velocity of layer 3 and know that it is in fact the velocity for layer 3?
   a. V₁ < V₂ < V₃
   b. V₂ < V₁ < V₃
   c. as long as V₂ > V₃
   d. V₁ > V₂ < V₃

16. When considering the critical angle for V₁ > V₂, what of the following is true?
   a. We can calculate the critical angle using Snell’s law
   b. The critical angle in this case is calculated by another method
   c. We need some more information to compute critical angle
   d. There is no critical refraction

17. Which of the following statements about Snell’s law in the context of a seismic survey is incorrect?

Snell’s law: \[ \frac{\sin \theta_1}{\sin \theta_2} = \frac{v_1}{v_2} \]
Here, \( \theta_1 \) is the incidence angle and \( \theta_2 \) is the transmission angle.
   a. Snell’s law shows the angular relationship between the incident and transmitted waves at the interface in terms of velocities
   b. The angle of reflection can be different from the angle of incidence
c. When a seismic wave travels from a region of low velocity to high velocity, the wave is refracted away from the normal vector of the interface

d. When $\theta_2=90$ degree, a head wave develops due to critical refraction

18. Which of these elastic moduli describes the ratio between volumetric stress and volumetric strain?
   a. Young’s Modulus
   b. Shear Modulus
   c. Bulk Modulus
   d. Poisson’s Ratio

19. A compressional wave…
   a. Is also called an S-wave.
   b. Can travel only through solids.
   c. Depends on density, shear modulus, and bulk modulus.
   d. All of the above

20. In which of the following geoscience problems is a seismic refraction survey most likely to provide valuable information?
   a. geological mapping of British Columbia
   b. oil and gas exploration in the Gulf of Mexico
   c. locate a near surface pipeline outside EOS East Building
   d. geotechnical study for the site of the new earth system science building of UBC

21. Which geological model would lead to a failure of refraction survey?
   a. more than two layers overlying the basement
   b. dipping or irregular interface
   c. seismic wave travels faster in the surface layer than in any other layer
   d. all of above

22. Reciprocal times are total travel times from the
   a. first geophone to the last geophone of a spread
   b. first geophone to the last geophone of a reverse spread
   c. shot of forward spread to the shot location of reverse spread
   d. shot to the last geophone of a spread
23. If the incident angle is 45 degrees and the seismic velocity in the first medium is a reasonable value for sediments, and the seismic velocity in the second medium is 4 times slower than in the first medium, then the refracted angle
  a. Is less than 45 degrees.
  b. Is more than 45 degrees.
  c. Is 45 degrees.
  d. Cannot be determined given this information.

24. Suppose a seismic refraction survey was conducted over an area with 3 horizontal layers (ie 2 interfaces). Which of the following scenarios would produce first arrivals at surface geophones from all three layers? (Top layer: seismic velocity v1, middle layer: seismic velocity v2, lower layer: seismic velocity v3)
   a. V1 = 400 m/s, v2 = 2000 m/s, v3 = 1500 m/s
   b. V1 = 1500 m/s, v2 = 2000 m/s, v3 = 400 m/s
   c. V1 = 2000 m/s, v2 = 1500 m/s, v3 = 400 m/s
   d. V1 = 400 m/s, v2 = 1500 m/s, v3 = 2000 m/s

25. Suppose the correct scenario was found for the above question, for a refracted ray path traveling along the second interface (between the middle and lower layer), what is its incident angle at the first interface (between the top and middle layer)?
   a. Sin⁻¹(v2/v3)
   b. Sin⁻¹(v1/v3)
   c. Sin⁻¹(v1/v2)
   d. Sin⁻¹(v2/v1)

26. Assume that the earth is represented by a horizontal layer overlying a half-space. A simplest refraction survey with minimum instrument requires
   a. one shot and one geophone
   b. one shot and two geophones
   c. one shot and three geophones
   d. two shots with two geophones

27. Dave carried out a single-shot seismic refraction survey to find the depth to the basement and the velocity structure. Exact knowledge about the material above the basement and the shape of the basement interface was not known. After carrying out the survey he picked out the first arrivals and plotted the T-X graph
as below. What conclusion can Dave make?

\[ T \]

\[ X \]

a. he can only see one refraction so there is only one layer overlaying the basement
b. he can determine the velocity of the basement by measuring the slope of the dashed line
c. he can estimate the critical angle using the intercept time of the refraction arrival
d. none of the above

28. In a seismic reflection survey each trace in the processed section
   a. Is the signal that would be received if the source and receiver were coincident
   b. Is the measured signal from the geophone that is closest to the receiver
   c. Is the signal from the common offset array
   d. Is the signal from a common midpoint array

29. The acoustic impedance of a medium
   a. is equal to the value of the seismic velocity
   b. depends upon the product of density and velocity
   c. depends upon the ratio of density and velocity
   d. depends upon velocity and bulk modulus

30. “Seismic reflections can occur when only when there is a change in seismic velocity”. (This is a Right – Wrong question for a final mark. Correct gets one mark; wrong loses a mark)
   a. TRUE
   b. FALSE
31. How does the seismic method differ from the magnetic method?
   a. Seismic is sensitive to density changes while magnetics is sensitive to magnetic susceptibility
   b. The magnetic method is a natural source field while seismic method can use either an artificial or a natural source
   c. Collecting seismic measurement requires contact with the ground while collecting magnetic data can be done at the surface or airborne.
   d. All of the above

32. Acoustic impedance is used to describe the efficiency of seismic reflection and transmission. Its value depends upon
   a. critical angle and velocity
   b. velocity and density
   c. reflection and transmission coefficients
   d. layer thickness and velocity

33. Which of the following is the most important first step in the sequence of processing seismic refraction data?
   a. Choosing whether arrivals are direct or refracted.
   b. Picking first breaks from raw seismic traces.
   c. Guessing seismic velocities of expected materials.
   d. Transferring arrival times to a TX graph.

34. A ray path is passing through the interface between Layer 1 and Layer 2 with incident angle 45 degree. Suppose the velocity of Layer 1 is 500m/s, what is the velocity of Layer 2 if we expect a critical refraction on the interface?
   a. 850m/s
   b. 250m/s
   c. 707m/s
   d. 354m/s

35. Please order the common materials below according to their seismic velocity
   a. air > sediments > sandstone> granite
   b. granite > sandstone > sediments > air
   c. granite > sediments > sandstone > air
   d. air > sediments > granite > sandstone

36. What is a possible physical reason for the increase in slope of this TX graph?
a. There may be a low velocity layer that is detectible with refraction data.
b. The dip of a refracting horizon steepens half way along the portion observed by the survey
c. The first two segments of the graph are both direct arrivals.
d. The thickness of the overlying layer decreases with distance.

37. Why is a NMO (normal moveout) correction applied to reflections in a CMP gather?
   a. To correct for the dip of the interface from where the reflection occurred
   b. To align reflection events so they can be stacked
   c. To account for the different source-geophone separations
   d. To convert the data to a common shot gather

38. The final seismic trace after processing is best thought of as
   a. reflections from layers directly below a coincident source and receiver at the surface
   b. reflections from seismic waves that travel various paths in the earth
   c. refracted arrivals due to layer interfaces
   d. a direct representation of the local geology

39. Seismic velocity of materials depends upon the elastic moduli of the material. An elastic modulus is the
   a. amount of deformation before material breaks.
   b. force needed to initiate S-wave or P-wave travel.
   c. ratio of a particular stress to a resulting strain.
   d. ratio of velocities of different types of waves.

40. The data recorded by a seismometer consists of
   a. First break picks, which are time versus geophone position.
   b. Records of ground motion for 10's to 100's of milliseconds following the initial source energy.
   c. Depths to refraction interfaces as a function of distance along a line.
   d. Distance from shot to detector.

41. Acoustic impedance, involving _______, is a compound parameter that can be used to describe the efficiency of seismic reflection and transmission.
   a. velocity and density
   b. critical angle and velocity
42. What is the minimum data set that can be interpreted to yield two depths for a 1-interface model?
   a. One shot into one end of a line of geophones.
   b. Two shots; one at each end of the line.
   c. One shot at each end of the line and one at its centre.
   d. As many shots as it takes to get a refraction arrival at every geophone from both directions.

43. If the layer is dipping instead of flat, the ITM (Intercept Time Method) approach to interpretation is made a little more complicated because ...
   a. The critical angle changes if the interface is dipping.
   b. Dipping layers are “hidden” from refraction measurements.
   c. Depths under each geophone are required in this case.
   d. The second layer’s velocity is not obtainable directly from the slope of refraction arrivals from one shot.

44. In a travel-time versus distance plot in seismic refraction, the slopes of the segments depend on the _______.
   a. change in seismic velocity at the boundary
   b. seismic velocity in each layer
   c. seismic velocity and dip in each layer
   d. thickness of each layer

45. Two seismic refraction surveys have been done at two different sites, where the basic geological models are all believed to be single horizontal layer plus basement. The two time-offset plots have the same slope for direct arrival and refracted arrival, but differ in the intercept time. The intercept time at Site A is 20ms while at Site B is 35ms, so what can be concluded?
   a. Site A and Site B have exactly the same velocity model
   b. the surface layer in Site B is thicker than that in Site A
   c. the surface layer in Site A is thicker than that in Site B
   d. not enough information to give any conclusion

46. A common midpoint gather refers to
   a. seismic traces acquired from a single shot
   b. seismic traces that are acquired with a constant source receiver separation
   c. seismic traces that have been moveout corrected with respect to a central geometrical location.
   d. seismic traces that have a source and receiver symmetrically placed about a single location.
47. Prior to “stacking” the data must be
   a. corrected for the normal moveout of the reflections
   b. filtered to remove noise
   c. converted to common shot gathers
   d. all of these

48. Consider an earth composed of three layers and a basement and let \( r_i \) denote the reflection coefficient at the bottom of the \( i \)'th layer and let \( t_i \) denote the transmission coefficient at the bottom of the \( i \)'th layer. If the initial amplitude of the seismic wave is unity, what is the amplitude of the wave that arrives at the surface? :
   a. \( r_2(1 - r_1^2) \)
   b. \( r_2 \)
   c. \( r_1 r_2 \)
   d. \( r_2 t_1 \)

49. A rural town needs a new source of water, and you are asked to map the water table. Your goal is to detect the interface between a dry and saturated sand. What would be the optimal seismic refraction experiment?
   a. Dynamite source to generate strong ground roll
   b. An air-gun to generate P-waves
   c. Sledge hammer striking a plate vertically to generate P-waves
   d. Sledge hammer striking a plate horizontally to generate S-waves

50. Assuming a positive impulse source, which of the following configurations will likely give rise to the strongest negative (-) reflection? (Assume layer 2 below layer 1)
   a. \( v_1 > v_2 \) & \( \rho_1 < \rho_2 \)
   b. \( v_1 < v_2 \) & \( \rho_1 < \rho_2 \)
   c. \( v_1 < v_2 \) & \( \rho_1 > \rho_2 \)
   d. \( v_1 > v_2 \) & \( \rho_1 > \rho_2 \)

51. Assume a layered Earth with increasing impedance as a function of depth \((Z_1 < Z_2 < Z_3 < Z_4)\), layer 4 is assumed to be infinite in depth (halfspace). If you were to increase the impedance of layer 4 \((Z_4)\), which of the following statements is true:
   a. The reflectivity of the first and second interface would not change.
   b. Only the reflectivity of the first interface would not change.
   c. The transmission coefficient at the base of the third layer would not change since \( Z_4 \) is a halfspace.
   d. The change will give rise to a negative reflection measurable at surface
Short Answer Questions

For the next question you will need to use the seismic section shown below. Note the units for the x-axis is meters and for y-axis is milliseconds.

Assume that the geology is adequately represented as uniform layer of contant thickness overlying a halfspace.

a. What is the velocity of the upper layer?

b. What is the velocity of the layer below (that is, the halfspace)?

c. What is the thickness of the top layer?

d. What are the linear features arriving at (x=25m, t=200ms) and (x=5-10m, t=200ms)?
52. (8 pts) Consider the two plots below

![P-wave](image1.png) ![SH-wave](image2.png)

(i) P-wave  (ii) SH-wave

a. (2 pts) What source is used for generating a P-wave refraction experiment? What source is used for generating an SH refraction?

b. (2 pts) In plot (i) what is meant by the air wave? Why is it not seen in plot (ii)?

c. (3 pts) What is the thickness of the top layer that can be obtained directly for the SH reflection seen in (ii). Show your work.

d. (1 pt) How would you determine if the refracted P and S waves were, or were not, coming from the same interface.

53. (12 pts) Consider the three layer earth described below. All layers have the same density.

![Layered Earth](image3.png)
a. (2 pts.) We’re interested in the seismogram that would be obtained at zero offset. Consider the reflection from the top of layer 2: What is the travel time for that reflection event and what is the value of the reflection coefficient?

b. (2 pts) Consider the reflection from the top of layer 3. What is the travel time for that reflection event and what is the value of the reflection coefficient?

c. (2 pts) Compute the transmission coefficients associated with waves that travel through the first interface; that is, the transmission coefficients for the downward and upward travelling waves.

d. (1 pt) Plot the final reflectivity log as a function of time. Make sure you provide the amplitude of each event.

e. (2 pts) Now consider the refracted wave along the first interface: What is the shortest offset you could measure the refracted wave?

f. (1 pt) Why would you not expect refraction before this offset?

g. (2 pts) Where would the refracted wave overtake the direct arrival?

54. (5 pts) A seismic refraction survey was carried out to find the depth and dip of a bedrock interface. Forward and reverse shots were used and the travel time plots are provided below:

![Travel Time Plot]

a. (3 pts) Using the plot above, estimate the velocity of the upper layer as well as the up and down dip velocities of the second layer.

b. (2 pts) Which way is the layer dipping? Show how you arrived at your answer.
55. (3 pts) Sketch the motion of a particle due to three different wave types: P, SH and SV waves (3 drawings)

56. (4 pts) Your team completed their first day of seismic refraction survey over a flat-layered Earth. You constantly start measuring the refracted wave as first arrival for receiver offsets > 25 m. You would like optimize your next day of survey by increasing the offset between the source and the first receiver. Assuming that the geophone spacing is fixed a 5 m, and the closest distance from the source you can measure is also 5 m:

   a. What would be largest distance between the source and your first geophone in order to measure velocity of the first layer?

   b. Why would want to increase the source-receiver array separation?

57. The plot below shows ray paths and arrival times for P-wave seismic signals recorded at a geophone located 60m from a source.

   a. Using the plots below, what can you deduce about the relationship between the velocities of each of the layers?
b. Imagine you can extend the spread of geophone to some large offset. From your answer above, would you expect to see the refracted wave along layers as first arrival?

58. The normal incidence trace below (right) was generated from the noisy data on the right.
   a. What is a CMP gather? Using a geologic model consisting of a single layer over a half-space, sketch 3 ray-paths to support your explanation.
   b. There are two main processing steps used to obtain a single seismic trace from the noisy CMP gather. Name and describe these two steps.

59. You have a geologic model consisting of 3 layers with seismic velocities \( v_1, v_2, v_3 \), and thicknesses \( h_1, h_2, \) and \( h_3 \), where \( h_3 \to \infty \)
   a. Describe a scenario where second layer may not be detected using refraction seismic.
   b. Describe a scenario where second layer may not be detected using reflection seismic.
60. To aid in performing an NMO correction to the noisy seismic data on the left, the semblance plot on the right was generated.

a. Describe what a semblance analysis does (you may want to use a sketch on the CMP gather to explain)?

b. Using these plots, approximately what intercept time and stacking velocity would you use to perform the NMO correction?