1. The arrival time of the first earthquake $P$-wave at a seismograph station was 10:11:20 (hours:minutes:seconds). If the epicenter of the earthquake is 8000 km away, what was the approximate arrival time of the first $S$-wave from this earthquake?

A) 10:02:00  
B) 10:09:20  
C) **10:20:40**  
D) 10:32:00

2. Base your answer to the following question on the map below which shows part of the earthquake damage field that resulted from the earthquake that occurred in Northridge, in southern California, in January 1994. Several sites associated with the earthquake and earthquake damage are shown.

Which information would have been most useful for locating the earthquake epicenter?

A) **the difference between the arrival times of the $P$-wave and the $S$-wave**  
B) the arrival time of the $S$-wave  
C) the velocity of the $P$-wave  
D) the location of damage from the earthquake
3. What usually causes tsunamis?
   A) hurricanes
   B) high-pressure weather systems
   C) **undersea earthquakes**
   D) the collision of ocean currents

4. The cross section of Earth below shows a $P$-wave moving away from an earthquake epicenter to seismic station $A$.

   ![Diagram of Earth cross section with P-wave and seismic station A](image)

   No $S$-waves arrive directly at seismic station $A$ because

   A) **some parts of the core are liquid**
   B) $S$-waves travel too slowly
   C) the distance to seismic station $A$ is too great
   D) seismic station $A$ is located on glacial ice
Base your answers to questions 5 through 8 on the diagram and map below. The diagram shows three seismograms of the same earthquake recorded at three different seismic stations, X, Y, and Z. The distances from each seismic station to the earthquake epicenter have been drawn on the map. A coordinate system has been placed on the map to describe locations. The map scale has not been included.

5. On the map, which location is closest to the epicenter of the earthquake?
   A) E–5  B) G–1  C) H–3  D) H–8

6. Approximately how far away from station Y is the epicenter?
   A) 1,300 km  B) 2,600 km  C) 3,900 km  D) 5,200 km

7. The S-waves from this earthquake that travel toward Earth’s center will
   A) be deflected by Earth’s magnetic field
   B) be totally reflected off the crust-mantle interface
   C) be absorbed by the liquid outer core
   D) reach the other side of Earth faster than those that travel around Earth in the crust
8. Seismic station Z is 1,700 kilometers from the epicenter. Approximately how long did it take the P-wave to travel to station Z?

A) 1 min 50 sec  B) 2 min 50 sec  C) 3 min 30 sec  D) 6 min 30 sec

Base your answers to questions 9 through 11 on the map below, which shows seismograph recording stations at locations A, B, and C. Location D is an earthquake epicenter. The distances from locations A and B to this epicenter are given in kilometers.

9. Approximately how long did the S-wave take to travel from the epicenter to location A?

A) 11 min 15 sec  B) 9 min 35 sec  C) 5 min 20 sec  D) 4 min 20 sec

10. At which location is the arrival-time difference between the P-wave and the S-wave greatest?

A) A  B) B  C) C  D) D

11. If seismograph station B receives the first P-wave at 09:35:20, at what time did the earthquake occur?

A) 09:05:00  B) 09:06:15  C) 09:29:05  D) 09:33:25
Base your answers to questions 12 and 13 on the map below, which shows the depths of selected earthquakes along the crustal plate boundary near the west coast of South America. Letters $A$, $B$, $C$, and $D$ are epicenter locations along a west-to-east line at the surface. The relative depth of each earthquake is indicated.

12. The earthquake beneath epicenter $D$ occurred in which part of Earth’s interior?
   A) crust  B) rigid mantle  C) asthenosphere  D) stiffer mantle

13. Which graph best shows the depth of earthquakes beneath epicenters $A$, $B$, $C$, and $D$?
14. The cross-sectional diagram below of the Earth shows the paths of seismic waves from an earthquake. Letter \( X \) represents the location of a seismic station.

![Diagram of earthquake epicenter and seismic waves]

Which statement best explains why station \( X \) received only \( P \)-waves?

A) \( S \)-waves traveled too slowly for seismographs to detect them.

B) Station \( X \) is too far from the focus for \( S \)-waves to reach.

C) A liquid zone within the Earth stops \( S \)-waves.

D) \( P \)-waves and \( S \)-waves are refracted by the Earth's core.
Base your answers to questions 15 and 16 on the map and the modified Mercalli scale shown below. The map shows the intensities of the earthquake that occurred slightly southwest of New Madrid, Missouri, on December 16, 1811. The epicenter of this earthquake is represented by *. The Roman numerals on the map show zones of earthquake intensities determined by using the modified Mercalli scale.

15. The intensity numbers shown on the map were determined by
A) the arrival time of the first P-wave recorded at each city
B) the recorded time difference in the arrival of the first P-wave and S-wave at each city
C) observations made at different locations during and after the earthquake
D) observations made only at the earthquake epicenter

16. Which location would most probably have issued the report: "Many structures shifted off foundations"?
A) New Madrid  B) Syracuse  C) Pittsburgh  D) Nashville

17. A seismic station is recording the seismic waves produced by an earthquake that occurred 4200 kilometers away. Approximately how long after the arrival of the first P-wave will the first S-wave arrive?
A) 1 min 05 sec  B) 5 min 50 sec
C) 7 min 20 sec  D) 13 min 10 sec
Base your answers to questions 18 through 21 on the map and seismograms below. The map shows seismic stations in Chicago, Denver, Oklahoma City, and Tampa that recorded data from an earthquake. Seismograms A, B, C, and D show, in Greenwich time, the arrival times of the earthquake waves at the four stations.

18. What was the origin time of this earthquake?
   A) 2:33:00 a.m.       B) 2:34:40 a.m.       C) 2:35:40 a.m.       D) 2:37:00 a.m.

19. Which seismogram was recorded at Tampa?
   A) seismogram A       B) seismogram B       C) seismogram C       D) seismogram D

20. What is the minimum number of seismic stations needed to locate most earthquake epicenters?
21. The P-wave generated by this earthquake took 2 minutes and 40 seconds to reach one of the seismic stations. Approximately how long did the S-wave take to reach this same seismic station?

A) 1 minute 20 seconds  
B) 2 minutes 40 seconds  
C) 3 minutes 30 seconds  
D) 4 minutes 50 seconds

22. In 8 minutes, an earthquake P-wave travels a total distance of

A) 2,100 km  
B) 4,700 km  
C) 6,600 km  
D) 11,300 km

Base your answers to questions 23 and 24 on the map below which shows epicenters of some of the earthquakes that occurred in North America during a 2-week period. Five epicenters are labeled A through E. Denver and New York City are also indicated.

23. A seismograph station at Denver recorded the arrival of P-waves at 8:00 a.m. and the arrival of S-waves at 8:02 a.m. Which epicenter is located above the source of this earthquake?

A) A  
B) B  
C) C  
D) D

24. The distance from epicenter E to New York City is 3,000 kilometers. What was the approximate travel time for the P-waves from this epicenter to New York City?

A) 1 min 20 sec  
B) 5 min 40 sec  
C) 7 min 30 sec  
D) 10 min 00 sec
Base your answers to questions 25 through 27 on the data table below, which gives information collected at seismic stations A, B, C, and D for the same earthquake. Some of the data has been deliberately omitted.

<table>
<thead>
<tr>
<th>Seismic Station</th>
<th>P-Wave Arrival Time</th>
<th>S-Wave Arrival Time</th>
<th>Difference in Arrival Times</th>
<th>Distance to Epicenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>08:48:20</td>
<td>No S-waves arrived</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>08:42:00</td>
<td></td>
<td>00:04:40</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>08:39:20</td>
<td></td>
<td>00:02:40</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>08:45:40</td>
<td></td>
<td></td>
<td>6,200 km</td>
</tr>
</tbody>
</table>

25. How long did it take the P-wave to travel from the epicenter of the earthquake to seismic station D?
   A) 00:46:20   B) 00:39:20   C) 00:17:20   D) **00:09:40**

26. What is the most probable reason for the absence of S-waves at station A?
   A) **S-waves cannot travel through liquids.**
   B) S-waves were not generated at the epicenter.
   C) Station A was located on solid bedrock.
   D) Station A was located too close to the epicenter.

27. What is the approximate distance from station C to the earthquake epicenter?
   A) 3,200 km   B) 2,400 km   C) **1,600 km**   D) 1,000 km

28. Which of the following earthquake waves can travel through both solids and fluids?
   A) S-waves, only
   B) **P-waves, only**
   C) S-waves and P-waves
Base your answers to questions 29 and 30 on the diagrams below. Diagram 1 represents a cross section of Earth and its interior layers. The asterisk (*) shows the location of an earthquake epicenter. Letters A through D are seismic stations on Earth's surface. Diagram 2 shows four seismograms labeled I, II, III, and IV, which were recorded at seismic stations A, B, C, and D during the same time interval.
29. Which list correctly matches the seismograms with the seismic stations where they were recorded?

A) seismogram I - station A
   seismogram II - station B
   seismogram III - station C
   seismogram IV - station D

B) seismogram I - station B
   seismogram II - station D
   seismogram III - station A
   seismogram IV - station C

C) seismogram I - station C
   seismogram II - station B
   seismogram III - station D
   seismogram IV - station A

D) seismogram I - station A
   seismogram II - station D
   seismogram III - station B
   seismogram IV - station C

30. Station D is 8000 kilometers from the earthquake epicenter. How long did it take for the first P-wave to travel from the epicenter to station D?

A) 9 minutes 20 seconds  
B) 11 minutes 20 seconds
C) 20 minutes 40 seconds  
D) 4 minutes 20 seconds
Base your answers to questions 31 and 32 on the map below. The map shows point $X$, which is the location of an earthquake epicenter, and point $A$, which is the location of a seismic station.

31. Which statement best describes the arrival of the initial $S$-wave at the seismic station?

A) It arrived later than the $P$-wave because $S$-waves travel more slowly.

B) It arrived earlier than the $P$-wave because $S$-waves travel faster.

C) It arrived at the same time as the $P$-wave because $S$-waves and $P$-waves have the same velocity on Earth's surface.

D) It never reached location $A$ because $S$-waves can travel only through a liquid medium.

32. Approximately how long did the earthquake's $P$-wave take to arrive at the seismic station?

A) 3 min 40 sec

B) 5 min 10 sec

C) 6 min 20 sec

D) 11 min 5 sec

33. What is the approximate time difference between the first $P$-wave and the first $S$-wave recorded at a seismic station located 8000 kilometers from an earthquake’s epicenter?

A) 8 minutes 40 seconds

B) 9 minutes 20 seconds

C) 11 minutes 20 seconds

D) 20 minutes 40 seconds

34. A seismic station 4000 kilometers from the epicenter of an earthquake records the arrival time of the first $P$-wave at 10:00:00. At what time did the first $S$-wave arrive at this station?

A) 9:55:00

B) 10:05:40

C) 10:07:05

D) 10:12:40
Base your answers to questions 35 through 39 on
the map below, which shows seismic stations X, Y, and Z that have recorded seismic waves from the
same earthquake. The distances from seismic stations X and Y to the earthquake epicenter have been
drawn on the map. Locations A, B, C, and D represent possible earthquake epicenters. The distance
from seismic station Z to the earthquake epicenter has been deliberately omitted.

35. How far is station X from the earthquake epicenter?
   A) 5,200 km   B) 2,400 km   C) 3,000 km   D) 4,000 km

36. Station Z recorded a time difference of 6 minutes 40 seconds between the arrival of the P-waves and
the arrival of the S-waves. Determine the distance to the epicenter for station Z and draw in the third
circle.

   Distance: ___________ km

   The earthquake epicenter was located closest to location: A B C D (circle one)

   Draw the distance for station Z.
37. Compared to the speed of S-waves in a given Earth material, the speed of P-waves is
   A) always slower  B) always faster
   C) always identical  D) sometimes slower and sometimes faster

38. Station Z recorded a time difference of 6 minutes 40 seconds between the arrival of the P-waves and the arrival of the S-waves. The earthquake epicenter was located closest to location
   A) A  B) B  C) C  D) D

39. How long did the P-wave take to travel from the earthquake epicenter to station Y?
   A) 2 min 10 sec  B) 3 min 40 sec  C) 4 min 0 sec  D) 5 min 40 sec

Base your answers to questions 40 and 41 on the cross-sectional view of Earth below, which shows seismic waves traveling from the focus of an earthquake. Points A and B are locations on Earth’s surface.

40. A seismic station located at point A is 5400 kilometers away from the epicenter of the earthquake. If the arrival time for the P-wave at point A was 2:00 p.m., the arrival time for the S-wave at point A was approximately
   A) 1:53 p.m.  B) 2:07 p.m.  C) 2:09 p.m.  D) 2:16 p.m.

41. Which statement best explains why only one type of seismic wave was recorded at location B?
   A) S-waves cannot travel through the liquid outer core.
   B) S-waves cannot travel through the liquid inner core.
   C) P-waves cannot travel through the solid outer core.
   D) P-waves cannot travel through the solid inner core.
42. An earthquake’s magnitude can be determined by
   A) analyzing the seismic waves recorded by a seismograph
   B) calculating the depth of the earthquake faulting
   C) calculating the time the earthquake occurred
   D) comparing the speed of P-waves and S-waves

43. A huge undersea earthquake off the Alaskan coastline could produce a
   A) tsunami  B) cyclone
   C) hurricane  D) thunderstorm

44. Base your answer to the following question on the diagram below, which represents zones of Earth’s interior, identified by letters A through E. The scale shows depths below Earth’s surface, measured in kilometers.

   ![Zones of Earth's Interior Diagram]

   S-waves produced by an earthquake are transmitted through zones
   A) A and B, but not zones C, D, and E  B) A, B, and C, but not zones D and E
   C) C, D, and E, but not zones A and B  D) D and E, but not zones A, B, and C
45. Only P-waves were recorded at seismic station C because P-waves travel

A) only through Earth's interior, and S-waves travel only on Earth's surface
B) fast enough to penetrate the core, and S-waves travel too slowly
C) through iron and nickel, while S-waves cannot
D) through liquids, while S-waves cannot

46. Which process prevented P-waves from arriving at seismic station B?

A) refraction          B) reflection          C) convection          D) conduction

47. Seismic station A is 5000 kilometers from the epicenter. What is the difference between the arrival time of the first P-wave and the arrival time of the first S-wave recorded at this station?

A) 2 minutes 20 seconds          B) 6 minutes 40 seconds
C) 8 minutes 20 seconds          D) 15 minutes 00 second
Base your answers to questions 48 and 49 on the diagram below, which represents seismic stations A, B, and C. The distance from each station to an earthquake’s epicenter is plotted.

48. The epicenter is closest to point
   A) D    B) E    C) F    D) G

49. The P-wave of an earthquake originating 2,600 kilometers from seismic station A arrived at 5:24:45 a.m. What was the arrival time of the S-wave from the same earthquake?
   A) 1:24:45 a.m.    B) 5:21:05 a.m.    C) 5:28:45 a.m.    D) 9:24:05 a.m.

Base your answers to questions 50 and 51 on the diagram below, which shows models of two types of earthquake waves.

50. Model A best represents the motion of earthquake waves called
   A) P-waves (compressional waves) that travel faster than S-waves (shear waves) shown in model B
   B) P-waves (compressional waves) that travel slower than S-waves (shear waves) shown in model B
   C) S-waves (shear waves) that travel faster than P-waves (compressional waves) shown in model B
   D) S-waves (shear waves) that travel slower than P-waves (compressional waves) shown in model B
51. The difference in seismic station arrival times of the two waves represented by the models helps scientists determine the
   A) amount of damage caused by an earthquake
   B) intensity of an earthquake
   C) distance to the epicenter of an earthquake
   D) time of occurrence of the next earthquake

Base your answers to questions 52 and 53 on the map below. Seismic stations are located at the four cities shown on the map. Letter X represents the epicenter of an earthquake determined from seismic waves recorded at all four cities.

52. At which city is there a difference of approximately 3 minutes and 20 seconds between the arrival times of the $P$-waves and the $S$-waves?
   A) New Orleans   B) Louisville   C) Pittsburgh   D) New York City
53. Which map correctly shows how the location of the epicenter was determined?

A)  

B)  

C)  

D)  

54. What is the approximate difference in arrival times of the \( P \)-waves and the \( S \)-waves at a seismographic station that is 3,000 kilometers from an earthquake epicenter?

A) 2 min 15 sec  
B) 3 min 40 sec  
C) 4 min 30 sec  
D) 5 min 40 sec
55. Point A is located 7600 kilometers from the epicenter of this earthquake. How many minutes did it take the first S-wave to reach point A?

A) 9 min  B) 11 min  C) 16 min  D) 20 min

56. How many kilometers did the seismic waves travel from the earthquake directly to the outside of the outer core?

A) 800 km  B) 1400 km  C) 2900 km  D) 6400 km

57. A seismographic station determines that its distance from the epicenter of an earthquake is 4,000 kilometers. If the P-wave arrived at the station at 10:15 a.m., the time of the earthquake's origin was

A) 10:02 a.m.  B) 10:08 a.m.  C) 10:10 a.m.  D) 10:22 a.m.

58. What is the average velocity of an earthquake's S-wave in its first 4 minutes of travel?

A) 1 km/min  B) 250 km/min  C) 500 km/min  D) 4 km/min
59. A seismogram recorded at a seismic station is shown below.

Which information can be determined by using this seismogram?
A) depth of the earthquake's focus  
B) direction to the earthquake's focus  
C) location of the earthquake's epicenter  
D) distance to the earthquake's epicenter

60. A seismic station receives a P-wave at 12:07 a.m. and an S-wave at 12:12 a.m. The station's distance from the epicenter is approximately
A) 2,600 km  
B) 3,400 km  
C) 4,000 km  
D) 8,800 km

61. The map below shows the western part of the United States.

Which observation made at Salt Lake City would allow seismologists to determine that an earthquake had occurred somewhere along the circle shown on the map?
A) P-waves travel at a slower rate and take less time.  
B) P-waves travel at a faster rate and take less time.  
C) S-waves travel at a slower rate and take less time.  
D) S-waves travel at a faster rate and take less time.

62. Which statement best describes the relationship between the travel rates and travel times of earthquake P-waves and S-waves from the focus of an earthquake to a seismograph station?
A) P-waves travel at a slower rate and take less time.  
B) P-waves travel at a faster rate and take less time.  
C) S-waves travel at a slower rate and take less time.  
D) S-waves travel at a faster rate and take less time.
63. A seismograph station $3 \times 10^3$ kilometers from an epicenter received $P$-waves at 3:33:00 in the afternoon. What was the origin time of the earthquake?

A) 3:03:00 p.m.  
B) 3:27:20 p.m.  
C) 3:28:40 p.m.  
D) 3:38:40 p.m.

64. The epicenter of an earthquake is 6,000 kilometers from an observation point. What is the difference in travel time for the $P$-waves and $S$-waves?

A) 7 min 35 sec  
B) 9 min 20 sec  
C) 13 min 10 sec  
D) 17 min 00 sec

65. The diagrams below show demonstrations that represent the behavior of two seismic waves, $A$ and $B$.

Which statement concerning the demonstrated waves is correct?

A) Wave $A$ represents a compressional wave, and wave $B$ represents a shear wave.  
B) Wave $A$ represents a shear wave, and wave $B$ represents a compressional wave.  
C) Wave $A$ represents compressional waves in the crust, and wave $B$ represents compressional waves in the mantle.  
D) Wave $A$ represents shear waves in the crust, and wave $B$ represents shear waves in the mantle.

66. An earthquake occurs at 12:02 p.m. A seismic station records the first $S$-wave at 12:19 p.m. Which set of data shows the approximate arrival time of the first $P$-wave and the distance to the epicenter?

A) 12:11:25 p.m. and 4000 km  
B) 12:11:25 p.m. and 6000 km  
C) 12:19:40 p.m. and 4000 km  
D) 12:19:40 p.m. and 6000 km
Base your answers to questions 67 through 69 on the cross section of Earth below and on your knowledge of Earth science. The cross section represents the pattern of seismic wave movement away from an earthquake. Point W represents a location at the boundary between two layers of Earth's interior. Points X, Y, and Z represent seismic stations on Earth's surface.

67. Which statement best explains why no S-waves were received directly from this earthquake at some seismic stations?

A) An interior Earth layer absorbs S-waves.
B) Earth's mantle reflects S-waves.
C) S-waves travel slower than P-waves.
D) S-waves travel only on Earth's surface.
68. The diagram below represents the seismograms of this earthquake recorded at seismic stations X, Y, and Z.

Which table best matches each seismic station with its likely seismogram?

A)  | Seismic Station | Seismogram |
    |                |            |
    | X              | 1          |
    | Y              | 2          |
    | Z              | 3          |

B)  | Seismic Station | Seismogram |
    |                |            |
    | X              | 3          |
    | Y              | 2          |
    | Z              | 1          |

C)  | Seismic Station | Seismogram |
    |                |            |
    | X              | 2          |
    | Y              | 3          |
    | Z              | 1          |

D)  | Seismic Station | Seismogram |
    |                |            |
    | X              | 1          |
    | Y              | 3          |
    | Z              | 2          |

69. Which data best describe the depth below Earth's surface and the density of Earth's interior at location W?

A) Depth: 600 km  
   Density: changes from 3.4 g/cm³ to 5.6 g/cm³  

B) Depth: 1000 km  
   Density: averages 4.5 g/cm³  

C) Depth: 2900 km  
   Density: changes from 5.6 g/cm³ to 9.9 g/cm³  

D) Depth: 5100 km  
   Density: averages 11.1 g/cm³
70. Which city would have issued the report: "Heavy furniture moved, everyone felt the earthquake, and many people were frightened and ran outdoors"?

A) Cincinnati  B) Pittsburgh  C) Syracuse  D) Boston

71. What was the approximate travel time for the earthquake's P-wave from the epicenter to Syracuse, New York?

A) 1 min  B) 5 min  C) 3 min  D) 10 min
72. Which statement best describes the earthquake waves recorded at Louisville?

A) $S$-waves arrived ahead of $P$-waves.
B) $P$-waves arrived ahead of $S$-waves.
C) $S$-waves arrived but $P$-waves did not arrive.
D) Neither $S$-waves nor $P$-waves arrived.

73. What is the approximate location of the earthquake's epicenter?

A) 36º N, 90º W    B) 90º N, 36º W    C) 36º N, 90º E    D) 90º N, 36º E

74. For which city was the difference in arrival times between $P$-waves and $S$-waves greatest?

A) Nashville    B) Pittsburgh    C) Syracuse    D) Boston

75. The seismogram below shows the time that an earthquake $P$-wave arrived at a seismic station.

![Seismogram](image)

If the earthquake occurred at exactly 10:00 p.m., approximately how far from the earthquake epicenter from the seismic station?

A) 1,900 km    B) 3,200 km    C) 4,000 km    D) 5,200 km

76. An earthquake $P$-wave arrived at a seismograph station at 01 hour 21 minutes 40 seconds. The distance from the station to the epicenter is 3,000 kilometers. The earthquake's origin time was

A) 01 h 11 min 40 sec    B) 01 h 16 min 00 sec    C) 01 h 20 min 20 sec    D) 01 h 27 min 20 sec

77. An earthquake occurred in Massena, New York. For which two locations would the $P$-wave arrival times be approximately the same?

A) Rochester and New York City    B) Binghamton and Slide Mountain    C) Utica and Watertown    D) Watertown and Oswego

78. A characteristic of compressional waves and shear waves is that they both

A) travel at the same speed    B) travel faster through more dense solid materials    C) travel through liquid and solid materials    D) cause rock particles to vibrate in the same direction

79. The seismogram below shows the arrival times of $P$- and $S$-waves from a single earthquake. How far from the earthquake epicenter was the station that recorded this seismogram?

![Seismogram](image)

A) $1.5 \times 10^3$ km    B) $2.5 \times 10^3$ km    C) $3.0 \times 10^3$ km    D) $4.0 \times 10^3$ km

80. Which statement correctly compares seismic $P$-waves with seismic $S$-waves?

A) $P$-waves travel faster than $S$-waves and pass through Earth’s liquid zones.
B) $P$-waves travel faster than $S$-waves and do not pass through Earth’s liquid zones.
C) $P$-waves travel slower than $S$-waves and pass through Earth’s liquid zones.
D) $P$-waves travel slower than $S$-waves and do not pass through Earth’s liquid zones.
81. Base your answer to the following question on the diagram below which shows a method used to locate the epicenter of an earthquake.

If the distance from the epicenter to station 2 is 3,500 kilometers, what is the approximate difference in the arrival times of the P-waves and S-waves at station 2?

A) 1 minute 40 seconds
B) **5 minutes 10 seconds**
C) 6 minutes 20 seconds
D) 11 minutes 30 seconds
82. The map below shows changes in the position of the tsunami wave front produced by the 1964 Alaskan earthquake. The numbers indicate the time, in hours, for the wave front to reach the positions indicated by the isolines.

If the wave front reached the Hawaiian Islands at 10:30 p.m., at approximately what time did the earthquake occur?

A) 1:30 p.m.  B) 5:30 p.m.  C) 3:30 p.m.  D) 4:30 p.m.
Base your answers to questions 83 and 84 on the diagram of the Earth below showing the observed pattern of waves recorded after an earthquake.

83. The lack of S-waves in zone 3 can best be explained by the presence within the Earth of

A) density changes  
B) mantle convection cells  
C) a liquid outer core  
D) a solid inner core

84. The location of the epicenter of the earthquake that produced the observed wave pattern most likely is in the

A) crust in zone 1  
B) mantle in zone 2  
C) crust in zone 3  
D) core of the Earth

85. A seismogram recorded at a seismic station is shown below.

Which information can be determined by using this seismogram?

A) the depth of the earthquake's focus  
B) the direction to the earthquake's focus  
C) the location of the earthquake's epicenter  
D) the distance to the earthquake's epicenter
86. The diagram below is a seismogram of the famous San Francisco earthquake of 1906, recorded at a seismic station located 6,400 kilometers from San Francisco.

Which time scale best represents the arrival-time difference between $P$-waves and $S$-waves at this station?

A) $1.3 \times 10^3$ km  
B) $2.6 \times 10^3$ km  
C) $3.5 \times 10^3$ km  
D) $8.1 \times 10^3$ km

87. The difference in arrival times for $P$- and $S$-waves from an earthquake is 5.0 minutes. How far away is the epicenter of the earthquake?

A) $1.3 \times 10^3$ km  
B) $2.6 \times 10^3$ km  
C) $3.5 \times 10^3$ km  
D) $8.1 \times 10^3$ km

88. The cutaway diagram below shows the paths of earthquake waves generated at point $X$.

Only $P$-waves reach the side of Earth that is opposite the focus because $P$-waves

A) are stronger than $S$-waves  
B) travel faster than $S$-waves  
C) travel faster than $S$-waves  
D) can travel through liquids and $S$-waves cannot

89. What is the approximate $P$-wave travel time from an earthquake if the $P$-wave arrives at the seismic station 8 minutes before the $S$-wave?

A) 4 minutes 20 seconds  
B) 6 minutes 30 seconds  
C) 10 minutes 0 seconds  
D) 11 minutes 20 seconds

90. A seismic station recorded the $P$-waves, but no $S$-waves, from an earthquake because $S$-waves were

A) absorbed by Earth's outer core  
B) transmitted only through liquids  
C) weak and detected only at nearby locations  
D) not produced by this earthquake

91. A seismograph station recorded the arrival of the first $P$-wave at 7:32 p.m. from an earthquake that occurred 4000 kilometers away. What time was it at the station when the earthquake occurred?

A) 7:20 p.m.  
B) 7:25 p.m.  
C) 7:32 p.m.  
D) 7:39 p.m.
92. The diagram below represents three seismograms showing the same earthquake as it was recorded at three different seismic stations, A, B, and C.

Which statement correctly describes the distance between the earthquake epicenter and these seismic stations?

A) A is closest to the epicenter, and C is farthest from the epicenter.
B) B is closest to the epicenter, and C is farthest from the epicenter.
C) C is closest to the epicenter, and A is farthest from the epicenter.
D) A is the closest to the epicenter, and B is the farthest from the epicenter.

93. The arrival of P-waves and S-waves at a seismic station indicated that an earthquake occurred 4,000 kilometers from the station. The P-wave arrived at 3:32:30 p.m. When did the earthquake occur?

A) 3:25:30 p.m.  B) 3:32:23 p.m.
C) 3:27:00 p.m.  D) 3:39:30 p.m.

Base your answers to questions 94 and 95 on the earthquake seismogram below.

94. How many additional seismic stations must report seismogram information in order to locate this earthquake?

A) one  B) two  C) three  D) four
95. When did the first $P$-waves arrive at this seismic station?

A) 3 minutes after an earthquake occurred 2,600 km away  
B) 5 minutes after an earthquake occurred 2,600 km away  
C) 9 minutes after an earthquake occurred 3,500 km away  
D) 11 minutes after an earthquake occurred 3,500 km away

96. A seismograph station records a travel time difference of 5.5 minutes between the $P$-waves and $S$-waves of an earthquake. How far is the seismic station from the epicenter of this earthquake?

A) $1.5 \times 10^3$ km  
B) $2.0 \times 10^3$ km  
C) $3.0 \times 10^3$ km  
D) $4.0 \times 10^3$ km

97. The cross section below shows the distribution of earthquake waves as they travel through Earth's interior. The arrows within Earth's interior represent the pathways followed by some earthquake waves.

Which types of earthquake waves will most probably be detected in zones $A$ and $B$?

A) zone $A$: $P$-waves, only; zone $B$: $S$-waves, only  
B) zone $A$: $P$-waves, only; zone $B$: no $P$- or $S$-waves  
C) zone $A$: $S$-waves, only; zone $B$: $P$-waves, only  
D) zone $A$: $S$-waves, only; zone $B$: no $P$- or $S$-waves

98. Which conclusion based on the analysis of seismic data supports the inference that the Earth's outer core is liquid?

A) $S$-waves are not transmitted through the outer core.  
B) $S$-waves are transmitted through the outer core.  
C) $P$-waves are not transmitted through the outer core.  
D) $P$-waves are transmitted through the outer core.

99. How long would it take for the first $S$-wave to arrive at a seismic station 4,000 kilometers away from the epicenter of an earthquake?

A) 5 min 40 sec  
B) 7 min 0 sec  
C) 12 min 40 sec  
D) 13 min 20 sec
Base your answers to questions 100 and 101 on the information and the cross section below. The cross section represents a possible model of the Moon's interior.

Seismographs left on the Moon by astronauts have provided enough data to develop a model of the Moon's interior. Scientists believe that the Moon has a layered interior and that its crustal thickness varies greatly from one side of the Moon to the other.

100. According to the cross section, which characteristic of seismic waves has enabled scientists to determine that the Moon has a layered interior?

A) P-waves do not pass through liquid rock.
B) P-waves travel slower than S-waves.
C) Both P- and S-waves cannot be reflected.
D) Both P- and S-waves bend as they pass through different materials.

101. From a single seismograph recording of the P- and S-waves from a moonquake, scientists can determine the

A) distance to the Earth
B) location of the quake focus
C) distance to the quake epicenter
D) circumference of the Moon

102. An earthquake's first P-wave arrives at a seismic station at 12:00:00. This P-wave has traveled 6000 kilometers from the epicenter. At what time will the first S-wave from the same earthquake arrive at the seismic station?

A) 11:52:20  B) 12:07:40  C) 12:09:20  D) 12:17:00

103. Which generalization about earthquake S-waves and P-waves is correct?

A) When the P-waves and S-waves are near the epicenter, they both travel at the same speed.
B) The velocity of P-waves and S-waves is constant, regardless of the distance traveled.
C) P-waves always travel faster than S-waves, regardless of the distance traveled.
D) S-waves always travel about twice as fast as P-waves.

104. The epicenter of an earthquake is located 6,500 kilometers away from a seismic station. If the first S-wave arrived at this seismic station at 1:30 p.m., at what time did the first P-wave arrive?

A) 1:20 p.m.  B) 1:22 p.m.  C) 1:38 p.m.  D) 1:40 p.m.

105. The epicenter of an earthquake is located 2,800 kilometers from a seismic station. Approximately how long did the S-wave take to travel from the epicenter to the station?

A) 5:01:40 a.m.  B) 5:04:30 a.m.  C) 5:05:40 a.m.  D) 5:10:15 a.m.

106. An earthquake occurred at 5:00:00 a.m. At what time would the P-wave reach a seismic station 3,000 kilometers from the epicenter?

A) 5:01:40 a.m.  B) 5:04:30 a.m.  C) 5:05:40 a.m.  D) 5:10:15 a.m.

107. If a seismograph recording station located 5,700 kilometers from an epicenter receives a P-wave at 4:45 p.m., at which time did the earthquake actually occur at the epicenter?

A) 4:24 p.m.  B) 4:29 p.m.  C) 4:36 p.m.  D) 4:56 p.m.
108. The map below shows the locations of seismic stations A, B, and C. The data table shows the distance from each seismic station to the epicenter of an earthquake. The numbers on the map represent possible epicenter locations.

Which numbered location is closest to the epicenter of this earthquake?

A) 1  B) 2  C) 3  D) 4

109. A seismic station recorded an earthquake with an epicenter distance of 4,000 kilometers. If the origin time of the earthquake was 11:00 a.m., what time did the P-wave arrive at the seismic station?

A) 10:53 a.m.  B) 11:05 a.m.  C) 11:07 a.m.  D) 11:12 a.m.

110. The map below shows the location of an earthquake epicenter in New York State. Seismic stations A, B, and C received the data used to locate the earthquake epicenter.

The seismogram recorded at station A would show the

A) arrival of P-waves, only  
B) earliest arrival time of P-waves  
C) greatest difference in the arrival times of P-waves and S-waves  
D) arrival of S-waves before the arrival of P-waves

111. Following an earthquake, a seismograph station recorded the arrival of a P-wave at 3:09:30 a.m. and an S-wave at 3:14:00 a.m. What is the distance from the seismograph station to the epicenter of the earthquake?

A) 1,200 km  B) 3,000 km  
C) 6,100 km  D) 7,500 km

112. Which statement best describes the materials through which earthquake waves are transmitted?

A) P-waves are transmitted through solids, only.  
B) P-waves are transmitted through liquids, only.  
C) S-waves are transmitted through solids, only.  
D) S-waves are transmitted through solids and liquids.
113. Through which materials can *P*-waves travel?

A) solid rock, only  
B) magma and water, only  
C) magma, water, and natural gas, only  
D) **solid rock, magma, water, and natural gas**

114. The block diagram below shows a tectonic plate boundary. Points *A* and *B* represent locations on Earth's surface.

Which graph best shows the depths of most major earthquakes whose epicenters lie between *A* and *B*?

A) ![Graph A]  
B) ![Graph B]  
C) ![Graph C]  
D) ![Graph D]

115. A seismograph station records a difference in arrival time between the *S*- and *P*-wave of 4 minutes. About how far away is the earthquake epicenter?

A) 1,000 km  
B) 1,900 km  
C) **2,600 km**  
D) 5,200 km

116. Which evidence recorded at seismic stations following an earthquake supports the inference that Earth's interior changes from solid rock to molten iron and nickel at the mantle-core boundary?

A) *P*-waves arrive earlier than *S*-waves.  
B) *P*-waves and *S*-waves are both recorded at all stations.  
C) Only *S*-waves are recorded at all stations.  
D) **Only *P*-waves are recorded on the opposite side of Earth.**
117. Base your answer to the following question on the cross section below, which shows the paths of seismic waves traveling from an earthquake epicenter through the different layers of Earth's interior.

The distance from Albany, New York, to the epicenter of this earthquake is 5600 km. Approximately how much longer did it take for the S-wave to arrive at Albany than the P-wave?

A) 4 minutes and 20 seconds  
B) 7 minutes and 10 seconds  
C) 9 minutes and 0 seconds  
D) 16 minutes and 10 seconds

118. How far from an earthquake epicenter is a city where the difference between the P-wave and S-wave arrival times is 6 minutes and 20 seconds?

A) $1.7 \times 10^3$ km  
B) $9.9 \times 10^3$ km  
C) $3.5 \times 10^3$ km  
D) $4.7 \times 10^3$ km

119. How long after receiving the first P-wave from an earthquake centered 4000 kilometers away does a seismic station receive its first S-wave from the same earthquake?

A) 1 minute  
B) 5 minutes 35 seconds  
C) 7 minutes  
D) 12 minutes 40 seconds

120. Which statement best explains why the P-wave of an earthquake arrives at a seismic station before the S-wave?

A) The S-wave originates from the earthquake focus.  
B) The S-wave decreases in velocity as it passes through a liquid.  
C) The P-wave originates from the earthquake epicenter.  
D) The P-wave has a greater velocity than the S-wave.

121. The seismogram below shows P-wave and S-wave arrival times at a seismic station following an earthquake.

The distance from this seismic station to the epicenter of the earthquake is approximately

A) 1,600 km  
B) 3,200 km  
C) 4,400 km  
D) 5,600 km
Base your answers to questions 122 and 123 on the data table below, which gives information collected at seismic stations $W$, $X$, $Y$, and $Z$ for the same earthquake. Some of the data have been omitted.

<table>
<thead>
<tr>
<th>Seismic Station</th>
<th>P-Wave Arrival Time (h:min:s)</th>
<th>S-Wave Arrival Time (h:min:s)</th>
<th>Difference in Arrival Times (h:min:s)</th>
<th>Distance to Epicenter (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>10:50:00</td>
<td>no S-waves arrived</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>10:42:00</td>
<td>10:46:40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>10:39:20</td>
<td>10:46:40</td>
<td>00:02:40</td>
<td>6200</td>
</tr>
<tr>
<td>Z</td>
<td>10:45:40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

122. What is the most probable reason for the absence of $S$-waves at station $W$?

A) $S$-waves were not generated at the epicenter.
B) $S$-waves cannot travel through liquids.
C) Station $W$ was located on solid bedrock.
D) Station $W$ was located on an island.

123. At what time did the $S$-wave arrive at station $Y$?

A) 10:36:40        B) 10:39:20        C) 10:42:00        D) 10:45:20

124. Useful information regarding the composition of the interior of the Earth can be derived from earthquakes because earthquake waves

A) release materials from within the Earth
B) travel through the Earth at a constant velocity
C) travel at different rates through different materials
D) change radioactive decay rates of rocks

125. A seismic station recorded the arrival of a $P$-wave at 10:00:00 a.m. The $S$-wave arrival was recorded at 10:04:20 a.m. What is the approximate distance between the earthquake epicenter and the seismic station?

A) $1.1 \times 10^3$ km  B) $2.2 \times 10^3$ km  C) $2.9 \times 10^3$ km  D) $7.2 \times 10^3$ km

126. The first $S$-wave arrived at a seismograph station 11 minutes after an earthquake occurred. How long after the arrival of the first $P$-wave did this first $S$-wave arrive?

A) 3 min 15 s  B) 4 min 55 s  C) 6 min 05 s  D) 9 min 00 s

127. Which statement about earthquake waves best supports the inference that the Earth's outer core is liquid?

A) The velocity of earthquake waves increases as the distance from an epicenter increases.
B) The difference in arrival times for compressional and shear waves increases as the distance from an epicenter increases.
C) Compressional waves travel faster than shear waves.
D) Shear waves travel only through solids.

128. A $P$-wave reaches a seismograph station 2,600 kilometers from an earthquake epicenter at 12:10 p.m. At what time did the earthquake occur?

A) 12:01 p.m.  B) 12:05 p.m.  C) 12:15 p.m.  D) 12:19 p.m.
129. A seismic station received the $P$-waves generated by an earthquake but did not receive the $S$-waves. Which statement best explains the absence of the $S$-waves?

A) The earthquake was too weak to produce $S$-waves.

B) The earthquake's epicenter and focus were at the same location.

C) The $S$-waves were absorbed by a fluid layer as they traveled toward the seismic station.

D) The $S$-waves were reflected away from the seismic station when they reached the Moho interface.

130. The same earthquake was recorded by seismic stations in Eureka, California; Elko, Nevada; and Las Vegas, Nevada. The distance to the earthquake epicenter for each station is shown below.

<table>
<thead>
<tr>
<th>Seismic Station Location</th>
<th>Distance to Epicenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eureka, CA</td>
<td>485 km</td>
</tr>
<tr>
<td>Elko, NV</td>
<td>705 km</td>
</tr>
<tr>
<td>Las Vegas, NV</td>
<td>622 km</td>
</tr>
</tbody>
</table>

On which map do the circles correctly show the epicenter distance from each of the seismic stations?
131. The seismogram below shows the arrival times of an earthquake's P-wave and S-wave recorded at a seismic station in Portland, Oregon.

![Seismogram](image)

What was the distance from Portland to the earthquake's epicenter?

A) 1800 km  
B) 2500 km  
C) 3200 km  
D) 4100 km

132. The P-waves (compressional waves) from an earthquake travel through the Earth's

A) crust, only  
B) crust and mantle, only  
C) crust, mantle, and inner core, only  
D) crust, mantle, outer core, and inner core

133. The study of how seismic waves change as they travel through Earth has revealed that

A) P-waves travel more slowly than S-waves through Earth’s crust  
B) seismic waves travel more slowly through the mantle because it is very dense  
C) Earth’s outer core is solid because P-waves are not transmitted through this layer  
D) Earth’s outer core is liquid because S-waves are not transmitted through this layer

134. The cross section of Earth below represents a P-wave moving away from an earthquake epicenter. Seismic station A is shown on Earth's surface.

![Cross section of Earth](image)

At station A, the first P-wave arrives 11 minutes 40 seconds after the earthquake. How long after the first P-wave arrives will the first S-wave arrive?

A) 5 minutes 00 second  
B) 8 minutes 40 seconds  
C) 9 minutes 40 seconds  
D) 21 minutes 20 seconds

135. Which difference between gabbro bedrock and granite bedrock causes seismic waves to travel faster in gabbro than in granite?

A) Gabbro is more dense than granite.  
B) Gabbro has greater permeability than granite.  
C) Gabbro has a darker color than granite.  
D) Gabbro is made of smaller mineral grains than granite.

136. At a seismograph recording station, the difference between the arrival times of an earthquake's compression wave (P-wave) and its shear wave (S-wave) is 8 minutes 20 seconds. How far from the station is the epicenter?

A) 2,400 km  
B) 4,500 km  
C) 5,000 km  
D) 6,800 km
137. The circles on the map below show the distances from three seismic stations, X, Y, and Z, to the epicenter of an earthquake.

Which location is closest to the earthquake epicenter?
A) A  B) B  C) C  D) D

138. The map below shows the intensity values (Earth-shaking effects observed by people) during an earthquake that occurred in New York State. The numbered areas on the map were determined from the Modified Mercalli Scale shown at the right. The scale is used to group locations according to the observed effects of an earthquake.

At which location in New York State could everyone feel the vibrations caused by this earthquake?
A) 43°30' N, 75°30' W  
B) 43°00' N, 78°30' W  
C) 41°00' N, 74°00' W  
D) 42°45' N, 74°00' W
139. The diagram below represents the analysis of a seismogram used to calculate an earthquake's magnitude on the Richter Scale. This seismogram shows the difference in arrival times, in seconds, of the first P-wave and S-wave and the amplitude of the S-wave in millimeters.

The diagram below represents how the earthquake's magnitude is determined by drawing a line connecting the difference in arrival times of the P-wave and the S-wave, and the S-wave amplitude.
What is the magnitude of a recorded earthquake if the difference in arrival times of the first P-wave and S-wave is 2 seconds and the S-wave amplitude is 20 millimeters?

A) 3.8  
B) 2.0  
C) 3.0  
D) 4.8

140. Which seismic information is needed to find the distance from an observer to an earthquake epicenter?

A) origin time of the earthquake  
B) depth of the earthquake focus  
C) P-wave and S-wave refractions  
D) P-wave and S-wave arrival times

141. An earthquake's P-wave arrived at a seismograph station at 02 hours 40 minutes 00 seconds. The earthquake's S-wave arrived at the same station 2 minutes later. What is the approximate distance from the seismograph station to the epicenter of the earthquake?

A) 1,100 km  
B) 2,400 km  
C) 3,100 km  
D) 4,000 km

142. A P-wave takes 8 minutes and 20 seconds to travel from the epicenter of an earthquake to a seismic station. Approximately how long will an S-wave take to travel from the epicenter of the same earthquake to this seismic station?

A) 6 mm 40 sec  
B) 9 mm 40 sec  
C) 15 mm 00 sec  
D) 19 mm 00 sec

143. A P-wave takes 5 minutes to travel from the epicenter of an earthquake to a seismic station. Approximately how many minutes will it take an S-wave to travel that same distance?

A) 15 min  
B) 12 min  
C) 9 min  
D) 4 min

144. A seismic P-wave is recorded at 2:25 p.m. at a seismic station located 7600 kilometers from the epicenter of an earthquake. At what time did the earthquake occur?

A) 2:05 p.m.  
B) 2:11 p.m.  
C) 2:14 p.m.  
D) 2:36 p.m.

145. Earthquakes generate compressional waves (P-waves) and shear waves (S-waves). Compared to the speed of shear waves in a given earth material, the speed of compressional waves is

A) always slower  
B) always faster  
C) always the same  
D) sometimes faster and sometimes slower
146. Compared to the velocity of an earthquake's $P$-waves, the velocity of the $S$-waves in the same material is

A) less  
B) greater  
C) the same

147. When the seafloor moves as a result of an underwater earthquake and a large tsunami develops, what will most likely occur?

A) Deep-ocean sediments will be transported over great distances.  
B) No destruction will occur near the origin of the earthquake.  
C) The direction of the tsunami will be determined by the magnitude of the earthquake.  
D) Severe destruction will occur in coastal areas.

148. The seismogram below shows the arrival times of $P$- and $S$-waves at a seismic station in hours, minutes, and seconds.

Approximately how far from the earthquake epicenter is this seismic station?

A) 1,650 km  
B) 1,900 km  
C) 2,200 km  
D) 4,100 km

149. The diagrams below represent seismograms of the same earthquake recorded in four different locations. Which seismogram was recorded closest to the epicenter of the earthquake?

150. An earthquake's $P$-wave traveled 4,800 kilometers and arrived at a seismic station at 5:10 p.m. At approximately what time did the earthquake occur?

A) 5:02 p.m.  
B) 5:08 p.m.  
C) 5:10 p.m.  
D) 5:18 p.m.
151. An earthquake recorded by seismic stations around the world created the pattern of seismic wave recordings shown in the diagram below.

Which statement best explains this pattern of wave recordings?

A) Some seismic waves cannot travel through oceans to reach every location on Earth.
B) S-waves are too weak to travel very far from the earthquake focus.
C) Mountain ranges and tectonic plate boundaries absorb or bend seismic waves.
D) **Layers with different properties inside Earth absorb or bend seismic waves.**
152. Which seismogram was recorded approximately 4,000 kilometers from an earthquake epicenter?