(75 points)
Earthquake energy release and body wave travel times

Gutenberg and Richter (two famous seismologists from the early 20th century) determined empirical relationships for the relationship between energy release and body and surface wave magnitudes:

\[ \log E = 5.8 + 2.4m_b \]
\[ \log E = 11.8 + 1.5M_s \]

5-1. Compute the % difference in seismic energy release comparing surface wave and body wave magnitudes for a “magnitude 6.0” earthquake.

5-2. Calculate how many \( M_s=5.0 \) earthquakes must occur to equal the energy release of an \( M_s=7.5 \) earthquake.

5-3. a) Show that the travel time from a surface source to a surface receiver in a uniform sphere with velocity \( v \), radius \( r \), and an angular (epicentral) distance \( \Delta \) is:

\[ T = \frac{2r}{v} \sin \frac{\Delta}{2} \]

**Hint**: draw a diagram using simple trigonometry. The problem is much easier if you consider half of the path at a time.

b) From the IASP91 travel time chart (attached), read the travel time for a P-wave at \( \Delta=90^\circ \) for a surface source. Assuming a uniform sphere, what is the P-velocity of the sphere in km/s?

c) Using a travel time for \( \Delta=30^\circ \), repeat the calculation.

d) Comparing the 2 results, what is the implication for the change in velocity with depth in the earth?

e) Determine the S-wave travel time at 90\(^\circ\). What is the typical ratio of P-wave velocity to S-wave velocity in the earth?
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