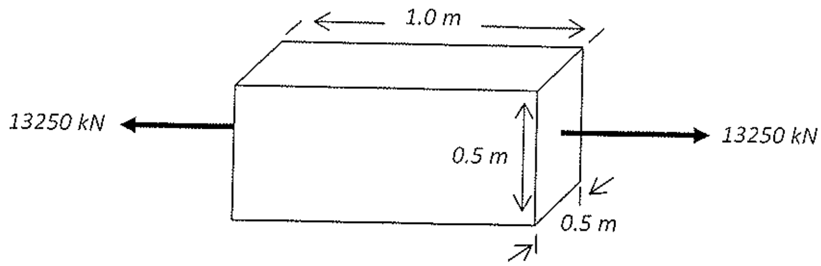
Name: ____________________

QUESTION #1: A 1m long by 0.5m wide by 0.5m tall specimen of granite was put into tension with a force of 13250 kN. Under that load, the specimen stretched by 1 mm. Calculate Young's Modulus (E) for the granite.



$E = \frac{\text{STRESS}}{\text{STRAIN}}$ ||

$\text{STRESS} = \frac{\text{FORCE}}{\text{AREA}}$ ||

$= \frac{13250\,000 \text{ N}}{0.25 \text{ m}^2}$

$= 53\,000\,000 \text{ N/m}^2$

$= 5.3 \times 10^7 \text{ Pa.}$ |

$\text{STRAIN} = \frac{L_1 - L_0}{L_0}$ ||

$= \frac{1.001\text{m} - 1\text{m}}{1\text{m}}$

$= 0.001$ |

$\therefore E = \frac{5.3 \times 10^7 \text{ Pa}}{0.001}$

$E = 5.3 \times 10^{10} \text{ Pa}$ ||

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QUESTION #2: Determine the P-wave speed (V_P), S-wave speed (V_S), and estimate the Rayleigh wave speed (V_R) be for the granite in Question #1. Assume that the specimen has a density (ρ) of 2750 kg/m^3, and a Poisson's ratio (ν) of 0.25.

$$V_P = \sqrt{\frac{E}{\rho}} \quad ||$$

$$= \sqrt{\frac{5.3\times10^{10}\ Pa}{2750\ kg/m^3}}$$

$$= \sqrt{19{,}272{,}727.27}$$

$$= 4390.07\ m/s \quad |$$

$$V_S = \sqrt{\frac{\mu}{\rho}} \quad ||$$

$$\mu = \frac{E}{2(1+\nu)} \quad |$$

$$= \frac{5.3\times10^{10}\ Pa}{2(1+0.25)}$$

$$= 2.12\times10^{10}\ Pa \quad |$$

$$\therefore V_S = \sqrt{\frac{2.12\times10^{10}\ Pa}{2750\ kg/m^3}}$$

$$= 2776.5\ m/s \quad |$$

$$V_R \approx 0.9\,V_S \quad |$$

$$\approx 2498.9\ m/s \quad |$$

NOTE: units

$$V = \sqrt{\frac{E}{\rho}}$$

$$\sqrt{\frac{Pa}{kg/m^3}}$$

$$\sqrt{\frac{N/m^2}{kg/m^3}}$$

$$\sqrt{\frac{kg\ m\cdot s^{-2}\cdot m^{-2}}{kg\cdot m^{-3}}}$$

$$\sqrt{s^{-2}\cdot m\cdot m}$$

$$\sqrt{\frac{m^2}{s^2}}$$

$$Pa = \frac{N}{m^2} = \frac{kg\cdot m/s^2}{m^2}$$

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QUESTION #3: A government geophysicist knew that there was a large explosion at exactly 1:46pm at quarry site 10 km away from a sensitive seismic station. When reviewing the seismograph for the day of the explosion, which type of wave would have arrived first? How long after would the next wave arrive? Assume that the rock between the quarry and the station is granite with the properties from the previous questions.

P wave faster, ∴ arrives 1st. ‖

$$\Delta T = \frac{D}{V_s} - \frac{D}{V_p} \quad |||$$

$$= \frac{10\,000\ m}{2776.5\ m/s} - \frac{10\,000\ m}{4390\ m/s} \quad ||$$

$$= 3.60166\ s - 2.27790\ s$$

$$= 1.32376\ s \quad ||$$

∴ The S wave arrives 1.32 s after the P wave.

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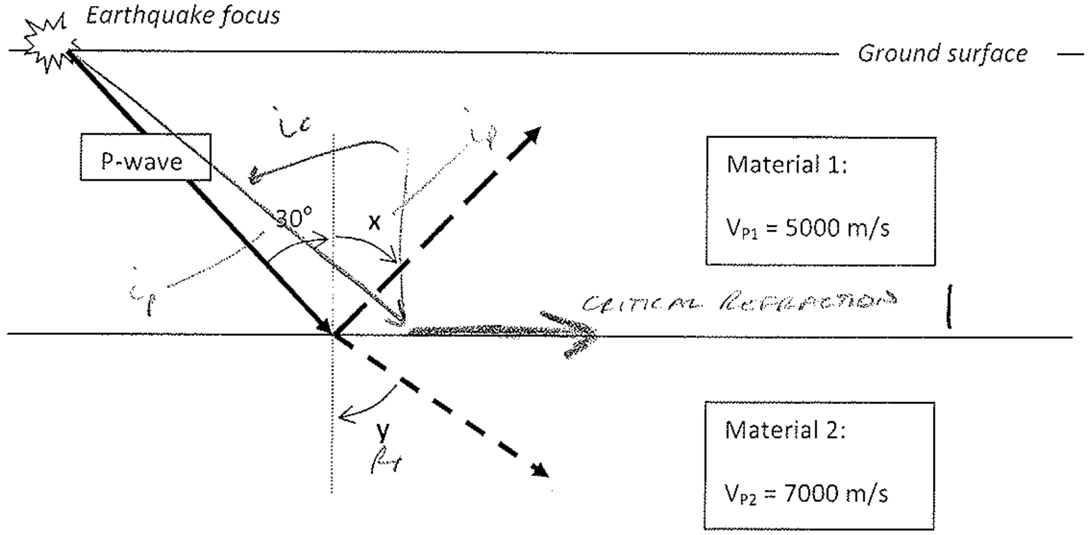
QUESTION #4: Determine the value (in degrees) of the reflection (x) and refraction (y) angles in the following situation. Then, add the path of the critically refracted wave to the diagram, and determine the critical angle of incidence that generates it. *Note: the diagram below is not to scale.*



x = REFLECTION ANGLE = i_p

∴ x = 30° |

Snell's Law:

$\frac{\sin i_p}{V_{P1}} = \frac{\sin R_p}{V_{P2}}$ ||

$\frac{\sin 30}{5000} = \frac{\sin R_p}{7000}$

$(7000)\left(\frac{\sin 30}{5000}\right) = \sin R_p$

$0.7 = \sin R_p$

$\sin^{-1}(0.7) = R_p$

$44.42° = R_p$ ||

∴ angle of refraction = 44.42°.

$\sin i_c = \frac{V_{P1}}{V_{P2}}$ ||

$\sin i_c = 0.71$

$i_c = 45.6°$

∴ critical incidence is 45.6° ||

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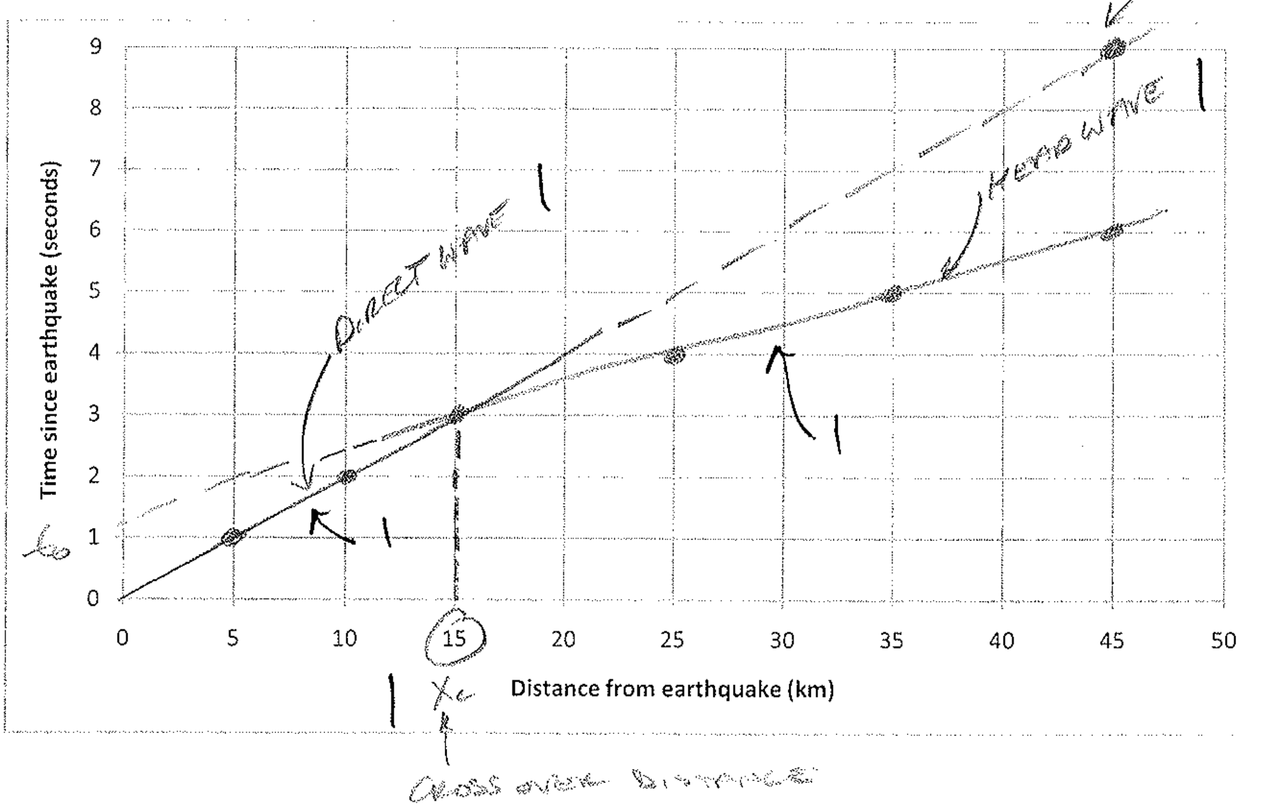
QUESTION #5: The first P-wave arrivals from an earthquake arrived at different seismic stations at the following times after the earthquake:

Station	Distance from earthquake (km)	Time since earthquake (s)
A	5	1
B	10	2
C	15	3
D	25	4
E	35	5
F	45	6

1) Plot the data on the graph.
2) Identify the following on the graph: **head wave, direct wave, crossover distance.**
3) Determine the speeds of the direct wave and head wave.
4) How long after the head wave would the direct wave arrive at Station F?



$V_{Direct\ wave} = \frac{1}{0.2 s/km}$ | $V_{Head\ wave} = \frac{1}{0.1 s/km}$ |

$= 5000 m/s$ | $= 10\,000 m/s$ |

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Direct wave arrives 3 sec after head @ F |
(extrapolate)

QUESTION #6: The moon has a radius of approximately 1737.5 km, and the acceleration due to gravity at the moon's surface is 1.62 m/s^2. The total volume of the moon is approximately 2.197x10^{10} km^3.

What is the average density of the moon?

The surface of the moon is composed of basalt and 'anorthosite' with densities of around 2700 kg/m^3. Is the moon layered? Why?

ρ = mass/volume. ||

where Mass = $\frac{g \times r^2}{G}$ ||

$= \frac{1.62 \text{ m/s}^2 \times (1737.5 \text{ km})^2}{6.67 \times 10^{-11} \text{ m}^3/\text{kg.s}^2}$

$= \frac{4,890,628.18}{6.67 \times 10^{-11}}$

$= 7.33 \times 10^{22}$ kg. ||

$\rho = \frac{7.33 \times 10^{16} \text{ kg.}}{2.197 \times 10^{10} \text{ km}^3}$ |

$= \frac{7.33 \times 10^{22} \text{ kg.}}{2.197 \times 10^{19} \text{ m}}$

= 3336.37kg/m3 ||

∴ ρ average > ρ surface, moon is layered. |

1 km^2 = 1000m x 1000m
= 1 000 000 m^2
= 1x10^6 m^2

1 km^3 = 1000m x 1000m x 1000m
= 1,000,000,000 m^3
= 1x10^9 m^3

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QUESTION 7: Explain how a ship sailing on the ocean could traverse a 'hole' in the geoid (e.g. from a positive height to a negative height and back to a positive height) and never be going downhill or uphill. Illustrate your explanation with a sketch.

Downhill/uphill travel = work against or by gravity – since geoid is equipotential, no work against gravity, ∴ no uphill or downhill.

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