

HW2

due February 5, 2026

Show all your work and indicate your reasoning in order to receive the full credit.

Name: _____

Date: _____

Collaborators: _____

(Collaborators submit their individually written assignments together, in class, in person)

Question:	1	2	Total
Points:	20	15	35
Score:			

Instructor/grader comments:

1. (20 points) **Falling through the center of the Earth**

Suppose you drill a tunnel through the Earth's center. Then you drop an object into the tunnel.

Use the dimensional analysis to find the time, τ , required for the object's passage from one side of the Earth to the other. Assume that the Earth is a uniform sphere. Neglect the effects of Earth's rotation and the resistance of the air in the tunnel. τ possibly depends on the gravitational constant G , the average density of the Earth ρ , and the Earth's radius R .

As the first step of your solution, determine the dimension of gravitational constant G . Use the Newton's law of gravity $F = G \frac{m_1 m_2}{r^2}$ and compare the dimensions of both sides of the equation. Show your derivation.

Verify the dimension of your answer for τ .

How the passage time is going to change if you repeat the experiment on a planet twice the radius of the Earth, all other parameters being the same?

Estimate the passage time for Earth: $\rho \approx 5.5 \times 10^3 \text{ kg/m}^3$, $R \approx 6.4 \times 10^6 \text{ m}$, $G = 6.67 \times 10^{-11} \text{ SI units}$ (use the dimension of G you found in earlier).

For extra credit, use a programming language to conduct numerical calculations. Provide a printout of your code.

2. (15 points) A stress tensor is given by (the units are Pa):

$$\sigma = \begin{pmatrix} 100 & 100 & 160 \\ 100 & 0 & -150 \\ 160 & -150 & -60 \end{pmatrix}.$$

For the surface element with the unit normal vector

$$\vec{q} = \begin{pmatrix} \frac{1}{2} \\ \frac{1}{2} \\ \frac{1}{\sqrt{2}} \end{pmatrix}$$

(a) find the stress vector, \vec{p}_q .

(b) find the angle, α , between \vec{p}_q and \vec{q} . Hint: $\cos \alpha = \frac{\vec{q} \cdot \vec{p}_q}{|\vec{q}| |\vec{p}_q|}$, where $|\vec{a}|$ denotes the length of vector \vec{a} , and $\vec{a} \cdot \vec{b}$ denotes the scalar product of two vectors.

For extra credit, use a programming language to conduct numerical calculations. Provide a printout of your code.