ES322 In-Class Exercise
Part 1. Estimating Lithostatic Pressure inside the Earth

Let's consider an area of the Earth's surface 1 km x 1 km square, and project it as a rectangular prism of rock to a depth of 5 km inside the crust. Assume a uniform average rock density of 2.9 g/cm3, from top to bottom in the rectangular slice of rock. Draw a block diagram to illustrate the above relationships. Using your conversion tables and rock property equation lists, calculate the following values (SHOW ALL OF YOUR MATH WORK AND UNIT ALGEBRA):

Total of mass of rock in the prism in kg $\quad$ 1.45×10^{13} kg

Total mass of rock in the prism in metric tons (t) $\quad$ 1.45×10^{10} t

The total weight of rock in Newtons (N) $\quad$ 1.42×10^{14} N

Total pressure equivalent at base of prism in Pascals (Pa) $\quad$ 1.42×10^{8} Pa

Total pressure equivalent at base of prisim in MPa $\quad$ 142 MPa

Hints / Equations and conversions:

$\quad$ Vol = A x d $\qquad$ D = M/V $\qquad$ Wt = Mg $\qquad$ g = 9.8 m/sec^2 $\quad$ P = F/A

$\qquad\quad$ 1 Pa = 1 N/m^2 $\qquad\quad$ 1 N = 1 kg-m/sec^2 $\qquad\qquad$ 1 MPa = 1 x 10^6 Pa

Part 2. Understanding Erosion Rates and the Power of Big Geologic Time

Assuming that the mass of rock at the very bottom of the rectangular prism in Part 1 above, is subject to long-term uplift and erosion, with long term average erosion rates on the order of 100 mm/ka. How many years would it take to exhume and expose the basement rocks at the foot of the rectangular prism in Part 1 above? SHOW ALL OF YOUR UNIT ALGEBRA.

$$5 \times 10^{7} \text{ yrs} = 50 \text{ m.y.}$$

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PART 1 SOLUTION — LITHOSTATIC PRESSURE

$A = 1 \, Km^2$

1 Km ⟶ ⟵ 1 Km

5 Km DEPTH

ROCK DENSITY $= 2.9 \dfrac{g}{cm^3}$

SURFACE AREA = 1 km x 1 Km

TOTAL DEPTH = 5 Km

$VOL = A \cdot d = 1 Km^2 \cdot 5 Km = 5 Km^3$

$DENSITY = \dfrac{MASS}{VOLUME}$
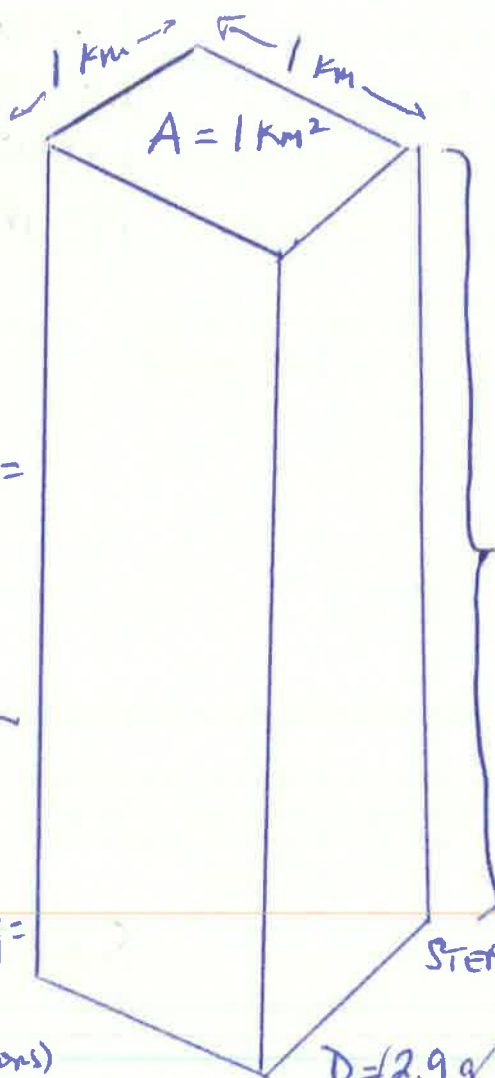
NEWTON'S SECOND LAW

$Wt = mg$ where

m = mass in Kg

g = acceleration due to gravity = 9.8 m/sec²

WT UNITS $= \dfrac{Kg-m}{Sec^2} = N$ (newtons)

$PRESSURE = \dfrac{F}{A} = \dfrac{Wt}{A}$

$UNITS = \dfrac{N}{m^2} = 1 \, Pa$

$1 \, MPa = 1 \times 10^6 \, Pa$

STEP 1: CONVERT UNITS TO Kg-m-sec

$D = \left(2.9 \dfrac{g}{cm^3}\right)\left(\dfrac{1 \times 10^6 \, cm^3}{m^3}\right)\left(\dfrac{1 \, Kg}{1000 \, g}\right) =$

$2900 \dfrac{Kg}{m^3}$ ✓

$DEPTH = 5 Km \left(\dfrac{1000 m}{Km}\right) = 5000 \, m$

$AREA = 1 Km^2 \left(\dfrac{1 \times 10^6 \, m^2}{1 Km^2}\right) = 1 \times 10^6 \, m^2$ ✓

STEP 2   SOLVE FOR MASS   ②

$$D = \frac{mass}{VOLUME} = \frac{mass}{A \cdot d}$$ D . A . d = mass

REARRANGE:

$$MASS = D \cdot A \cdot d = \left(\frac{2900 \, kg}{m^3}\right)(1 \times 10^6 m^2)(5000m) =$$

$$m = 1.45 \times 10^{13} \, kg \quad V$$

STEP 3.   CONVERT MASS FROM kg to t (metric tons)

$$m = 1.45 \times 10^{13} \, kg \, \frac{1 \, t}{1000 \, kg} = 1.45 \times 10^{10} \, t$$

STEP 4.   CALCULATE WEIGHT

$$Wt = mg = \left(1.45 \times 10^{13} \, kg\right)\left(9.8 \, \frac{m}{sec^2}\right) = 1.42 \times 10^{14} \, N$$

STEP 5.   CALCULATE PRESSURE

$$P = \frac{F}{A} = \frac{Wt}{A} = \frac{1.42 \times 10^{14} \, N}{1 \times 10^6 \, m^2} = 1.42 \times 10^8 \, Pa$$

STEP 6.   CONVERT TO MPa

$$P = 1.42 \times 10^8 \, Pa \left(\frac{1 \, MPa}{1 \times 10^6 \, Pa}\right) = 142 \, MPa$$

PART 2 SOLUTION — EXHUMATION RATES

EROSION RATE $= 100 \, mm/ky = \frac{100 \, mm}{1000 \, yrs}$

TOTAL EXHUMATION THICKNESS $= 5 \, km \left(\frac{1000 \, m}{km}\right)\left(\frac{1000 \, mm}{m}\right) =$

$\{ 5 \times 10^6 \, mm \}$

TOTAL TIME $= \frac{EXHUMED \, THICKNESS}{EROSION \, RATE} = \frac{5 \times 10^6 \, mm}{100 \, mm/1000 y's} = 5 \times 10^7 \, yrs = 50 \, M.y.$