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Milestone report 3

- First let’s look at my code: Part 3_moi_gravity.ipynb
- Flashback to milestone 1:
- I am using some of the equations I detailed in milestone report 1: here is our function for mass

$$M = 4\pi \int_0^{R_e} \rho(r) r^2 \, \mathrm{d}r.$$

- We can also calculate the moment of inertia of the Earth. Utilizing the density distribution, the code calculates the total mass of the Earth and its moment of inertia. These calculations offer insights into the Earth's bulk properties and mass distribution throughout its interior.

$$I = \frac{2}{3} 4\pi \int_0^{R_e} \rho(r) r^4 \, \mathrm{d}r.$$

- Another very familiar equation, we can use this to evaluate the acceleration due to gravity at the surface (or inside) a planet

$$g(r) = \frac{GM(r)}{r^2}$$

- The code further determines the gravitational field g and pressure P at different depths within the Earth. These metrics provide an understanding of the gravitational force and pressure variations experienced at different layers of the planet.
- P(r) is the integral of g(r).

$$P(r) = \int_{R_e}^{r} -g(r)\rho(r) \, \mathrm{d}r$$

- With this data, we can make an acute comparison between the structures of Earth and Mars and use it to make exciting conclusions.

1. Mass and Moment of Inertia

- Determining the mass distribution inside a planet helps understand its density variations and the distribution of materials. Differences in mass at various depths signify variations in composition and state (solid, liquid, or gaseous).
- Calculating the moment of inertia provides insights into the planet's rotational dynamics. The value of I/MR^2 (where I is the moment of inertia, M is mass, and R is the radius) indicates how mass is distributed relative to the

planet's size. For a homogeneous sphere, this value is 0.4, but deviations from this value suggest non-uniformity in density, which could be due to a core or uneven distribution of materials.

2. Surface Gravity
   - The surface gravity value is indicative of a planet's mass and radius. A higher surface gravity often corresponds to a more massive and dense planet. Variations in gravity can point towards the presence of denser materials or larger masses in certain regions.
3. Pressure
   - Understanding pressure variations with depth provides information about the planet's internal conditions. Higher pressures at greater depths suggest denser and more compact materials or possibly different phases of matter (solid, liquid, or gas).
4. Mass Inside a Given Radius
   - Examining how mass changes concerning depth helps discern the distribution and composition of layers within a planet. Sudden changes or anomalies in the mass profile may indicate the presence of distinct layers like a core or mantle.
5. Gravity and Pressure
   - Graphed representations of gravity and pressure with depth offer a visual understanding of how these parameters change internally. Discontinuities or irregularities in these profiles may signal transitions between different layers, such as the crust, mantle, or core.

Next:

- I have a crude model of heat flow in the earth, as well as some newly added functions to look at moment of inertia as well as pressure and gravity at different depths. I spent a VERY long time compiling data from InSights missions structure of Mars papers so I could finally start my Mars calculations. This is pretty bare-boned, but it has the essentials to model the planetary structure of Mars!
- https://www.science.org/doi/10.1126/science.abf8966
- https://www.science.org/doi/full/10.1126/science.abf2966
- https://www.science.org/doi/10.1126/science.abi7730

Layer	Radius (km)	Depth (km)	P-wave velocity (km/s)	S-wave velocity (km/s)	Temperature (K)	Mineral Composition	Thermal Gradient (K/k	Thermal conductivity (W/m/	Density (g/cm^3)

							m)	K)	
Crust	3390	0	4.25	2.5	500	iron, magnesium, aluminum, calcium, and potassium	25	158.2	2.9
Crust-Mantle Boundary	3340	50	-	-	1400	-	-	-	-
Mantle	1830	1560	5	4	1500	silicon, oxygen, iron, and magnesium	2	96.5	3.4
Core-Mantle Boundary	1830	1560	-	-	1900	-	-	-	-
Core	0	3390	6	-	2000	Iron, nickel, 16–17 % sulfur	0.5	56.7	6

- If you want to consider the prem data table for Earth instead of Mars, you'll notice that this table is much less filled out. This is because we have 1 seismometer on Mars. Our data would be much better and more accurate if we are able to detect seismic waves from several points on the planet
- Now that I have this data, now what, you ask? Oh boy, this week is gonna be rough. Time to do the earth stuff for mars. Oh man
- Time to re graph the seismic velocities , temperature, density, and then recalculate the gravity, pressure, moment of inertia, and mass
- When they are graphed, we will be able to make direct comparisons against data we have found on Earth, giving us insight on the planetary structure of Mars.

- From our data, we can conclude that there are at least 3 distinctive layers in Mars, consisting of the core, mantle, and crust.
- We see the propagation of the P and S waves in the Earth versus in Mars, which allow us to visualize how the layers come together.
- Our moment of inertia calculation tells us how close the value is to a homogeneous sphere; if it is less than 0.4, then it most likely has a core, or a larger distribution of mass in the center of the planet.
- Variances in pressure and gravity
- The core is molten liquid- we know that because we have no s-waves that propagate there, and because Mars is not still generating a magnetosphere.

Mars!.ipynb:

- Mars Structure Data Definition: Layer Data for Mars:
    - A structured representation of Mars' layers is defined in layer_data_mars, including properties such as depth, radius, velocities (P-wave and S-wave), temperature, mineral composition, thermal gradient, thermal conductivity, and density.
- Velocity and Density Functions: Stepwise Functions: Vp, Vs, density:
    - These functions calculate P-wave velocity, S-wave velocity, and density based on specific depth ranges for each layer. Each function handles the respective property based on the depth.
- Plotting Velocity and Density Profiles: Generation of Depth Values:
    - Using numpy.linspace, an array of depth values ranging from 0 to Mars' radius is created.
- Calculating Values for Each Depth:
    - The Vp, Vs, and density functions are used to calculate P-wave velocity, S-wave velocity, and density at each depth point.
- Plotting Velocity and Density Profiles:
    - Two plots are generated, one showing P-wave and S-wave velocities against depth, and the other showing density against depth.
- Temperature Profile: Temperature Profile Plot:
    - A plot displays the temperature profile of Mars, with temperature on the y-axis and radius on the x-axis.
- Heat Flow Calculation and Plotting:
    - Thermal conductivity and thermal gradient values for each layer are provided. Depth ranges for layers are specified.
    - Heat flow for each layer is computed using the formula heat_flow = k * gradient * depth_diff * 1000.
- Plotting Heat Flow:

    - A stepwise plot displaying the heat flow in different layers of Mars.

- Next steps:
    - Calculate mass, moment of inertia, acceleration due to gravity, and pressure of Mars under the surface.
    - Generate better model for heat flow for earth, generate mars heat flow representation using fourier series calculate q(t).
    - I’m gonna try really hard on the models I promise
    - Compare the two!