The Black Marble Problem

Discuss with your group:

• The outside of the marble is made out of glass.
• Do you think that the internal composition of the marble is the same as the material you see and feel on the outside, or is the inside made out of something different?
• Can you think of any simple tests or experiments that you can do to verify or rule out different internal compositions (eg. metal, wood, plastic, glass)?

Hypothesis: The inside of the marble is composed of _____.

Testing the hypothesis. Prediction: If the marble is composed of _____, then it must have ______ physical property(ies).

What experiment or measurement can we make to test our hypothesis?

Based on our results, do we need to modify (or toss out) our hypothesis?
The Black Marble Problem

- Density = Mass / Volume
- Volume of a sphere = \( \frac{4}{3} \pi \text{ radius}^3 \)

Densities of common materials
- Glass = 2.65 gm/cm\(^3\)
- Steel = 7.88 gm/cm\(^3\)
- Wood = 0.5 gm/cm\(^3\)
- Plastic = 1.0 gm/cm\(^3\)

What is the inside of the Earth made out of?

Is the inside made out of the same stuff as the outside?
How can we answer this question?

Compare the average density of the crust of the Earth with the average density of the whole Earth.

- Hypothesis 1: The Earth is homogeneous
  - Prediction: density crust = density whole Earth
  - If true, then rock of crust is the same as rock in the deep Earth.
- Hypothesis 2: The Earth is heterogeneous
  - Prediction: density crust <> density whole Earth
  - If true, then deep Earth made of different materials than crust. Density will be clue to deep composition.
The composition of the Crust of the Earth (the outside):

- Continents
- Granite
- Quartz
- Ocean Basins
- Basalt

### Density of the Earth’s Crust

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
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<td>Quartz</td>
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### What is the volume of the Earth?

- We can measure the Circumference (distance around the equator).
- C = 40,000 km (25,000 miles)
- C = 2 * \(\pi\) * radius
- r = C / 2 * \(\pi\)
- Volume = \(\frac{4}{3}\) * \(\pi\) * \(r^3\)
What is the mass of the Earth?

- Not an easy question to answer! We can’t just “weigh” the Earth on a balance.
- Need some physical property that we can measure that is proportional to mass.
- Any ideas?

According to Newton, the Force of gravity between two objects is directly proportional to their masses

\[ F = \frac{m_1 \times m_2}{r^2} \times G \]

According to Newton, the Force of gravity between two objects is directly proportional to their masses

\[ F = \frac{m_{\text{Earth}} \times m_{\text{rock}}}{r^2} \times G \]
We can rewrite the equation to solve for the mass of the Earth

\[
\frac{F}{m_{\text{rock}}} = \frac{m_{\text{Earth}}}{r^2} \times G
\]

Force = Mass × Acceleration
Acceleration = Force / Mass

\[
\frac{F}{m_{\text{rock}}} = a
\]

We can replace force and mass with acceleration in the equation for the mass of the Earth

\[
\frac{F}{m_{\text{rock}}} = a = \frac{m_{\text{Earth}}}{r^2} \times G
\]
We can replace force and mass with acceleration in the equation for the mass of the Earth

\[ a = \frac{m_{\text{Earth}}}{r^2} \times G \]

Rearrange the new equation to solve for the mass of the Earth

\[ \frac{r^2 \times a}{G} = m_{\text{Earth}} \]

If we can measure acceleration we can solve the equation for the mass of the Earth

\[ \frac{r^2 \times a}{G} = m_{\text{Earth}} \]
Acceleration of an object due to Earth's gravity can be measured using a pendulum.

\[ a = \frac{4 \times \pi^2 \times \text{Length}}{\text{Time}^2} \]
Acceleration of an object due to Earth’s gravity can be measured using a pendulum.

$$a = \frac{4 \times \pi^2 \times \text{Length}}{\text{Time}^2}$$

T = time for one full swing

Simple Model for the Structure of the Earth:

$$D_{\text{whole}} = \frac{D_{\text{inner}} + D_{\text{outer}}}{2}$$

$$6 = \frac{D_{\text{inner}} + 3}{2}$$
## Densities of Common Geological Materials:

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<th>Metals</th>
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