12.002 Physics and Chemistry of the Earth and Terrestrial Planets
Fall 2008

Planets

Overview

Terrestrial planets: Earth, Mars, Moon, Mercury, Venus

Bulk gross products have regular features, but the Moon does not fit the other trends – origin different?

Each of these objects except for Venus have timescales

Earth: originally based fossils, now radiometric dating
Moon: radiometric dating of returned samples and crater counting
Venus - not enough craters to do crater counting: young (half a billion years old surface)...so no time scale.

Uncompressed density – density of a planet if all material was at zero pressure

I/MR^2 --> normalized moment of inertia - very important to measure. Relates to the mass distribution inside the planet

$$I = \int_v \rho r_0^2 \, dv$$

r is cylindrical distance, defined with respect to an axis (not a point). Usually use rotation axis.

Moment of Inertia of a disk of radius *y*, and thickness *dz*

$$I_{disk} = \int \rho y'^2 dv \qquad dv = 2\pi y' dz dy'$$

$$= \int 2\pi\rho y'^2 y' dz dy'$$

$$= 2\pi\rho dz \int_0^y y'^3 dy' \qquad \rho = \frac{m}{v}$$

$$= \frac{1}{2}\pi\rho y^4 dz$$

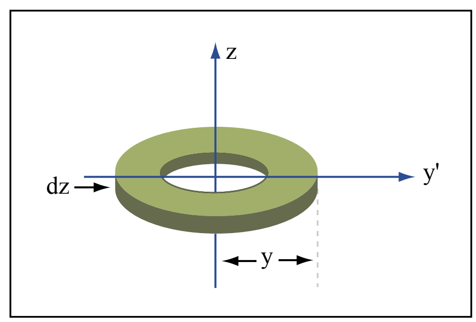

Figure by MIT OpenCourseWare.

$$I_{sphere} = \int_{-R}^{R} I_{disk} dz$$

$$= \int_{-R}^{R} \frac{1}{2}\pi\rho y^4 dz$$

$$= \frac{1}{2}\pi\rho \int_{-R}^{R} (R^2 - z^2)^2 dz$$

$$= \frac{8}{15}\pi\rho R^5$$

Using $\rho = \frac{m}{v} = \frac{m}{\frac{4}{3}\pi R^3}$ this becomes

$I_{sphere} = \frac{2}{5} m R^2$ for a sphere of uniform density.

For a centrally condensed body, $I < 2/5\ MR^2$

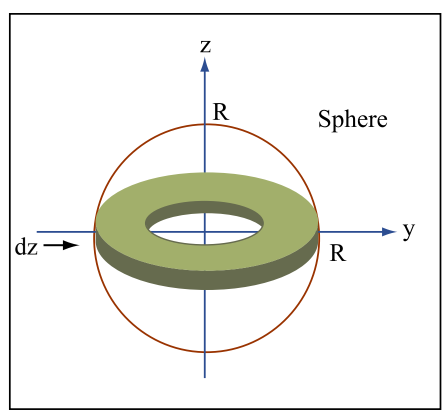

Figure by MIT OpenCourseWare.

For a hollow body $I > 2/5\ MR^2$
To get I, measure procession rate of spin pole

Density and Composition of Planets

The planets have different densities, and different mass distributions...

-can we understand these from first principles?

-why are there differences? (if everything is made of CI chondrites)

Two possibilities:

1. Different initial compositions (all planets are not made of CI chondrites) (Urey, Lewis)
2. All have the same initial composition (CI chondrites) but divergent evolution (Ringwood)

Lewis - showed how gross compositions (densities) of the terrestrial planets (giant planets as well) can be explained at least partly by where they formed in the solar nebula (which determined the temperatures of the condensing materials which they ultimately accreted, which determines abundance of elements)

Lewis predictions:
1. Mercury should be Fe-metal rich, FeO poor, and H20 poor (low FeO/Fe)
2. Mars should have high FeO / Fe. Mars should be relativel enriched in volatiles (like oxygen and water...minerals enriched in OH)
3. Earth and Venus should be in the middle - the Earth should be a little more dense that Venus due to iron sulfide condensation -- Moon as well

	Fe Wt%	**Uncompressed Density (g/cm^3)**	**I/MR^2**	**H_2O Rich?**
Mercury	3	5.3	0.33	low
Venus	8	4.0	0.33	low
Earth	8	4.05	0.33	high
Mars	18	3.74	0.37	???
Moon	5 to 10	3.33	0.39	low

Only Moon does not fit Lewis' predictions well.

Wetherill - condensation of planet modeling

Accreted material from a large range of heliocentric distance