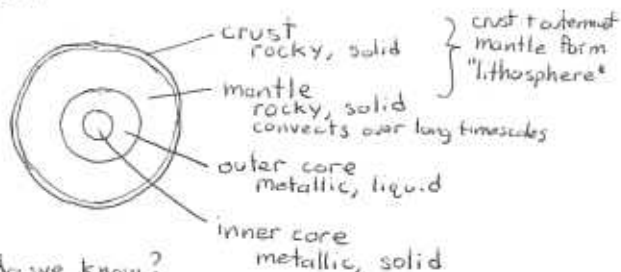


# Astro/EPS C12 Midterm 2 Review Sheet

## 9. Geology of rocky planets

### Interiors:



how do we know?

- seismic waves travel through/bounce off layers
  - P waves go through liquid & solid } from earthquakes
  - S waves go through solid only
- xenoliths: grains of mantle material in rocks
- magnetic field, overall density

why this structure?

- differentiation: dense material (iron) sinks to center of liquid Earth shortly after formation, light material (rock) goes to top
- pressure/temperature: Earth interior is very hot due to radioactivity and under high pressure + phase changes (eg, outer & inner core)

sources of internal heat

- gravitational potential
  - accretion (planetesimals falling to surface)
  - differentiation (dense material sinking to center)
- radioactivity
- tidal (insignificant for Earth)
- heat drives geological activity via convection
- larger the planet, slower it cools

origin of magnetic field

- need 1) conductive material (eg. metal) in a
- 2) liquid form with 3) rotation → dynamo
- Earth: outer core generates field

### Surfaces:

Four processes affect surfaces.

#### 1. Impacts

- asteroids/comets strike surface, leave craters (always circular)
- eroded by other processes: use # craters to estimate age.
- famous impact on Earth 65 Myr ago K/T extinction (dinosaurs) Chicxulub crater (Yucatan)

#### 2. Volcanism

- effusive: lava flows
- explosive: mass eruptions

#### 3. Tectonics

- surface reshaping from lithosphere
- internal heat required
- e.g. faults, rifts, mountain chains
- plate tectonics: pieces of lithosphere

#### 4. Erosion

- physical
- chemical

### Radioactivity

$$N = N_{\text{initial}} \left(\frac{1}{2}\right)^{t/t_{\text{half}}}$$

measure  $N$ ,  $t_{\text{half}}$ , use isochron methods to get  $N_{\text{initial}} \rightarrow$  solve for age  $t$

### Mercury

- heavily cratered
- steep cliffs, ridges, faults (from early shrinkage)
- no plate tectonics, geologically dead, thick lithosphere
- large core
- Caloris impact



### Venus

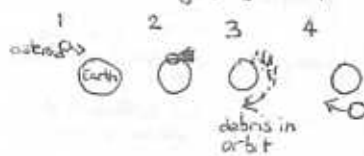
- thick sulfuric acid clouds: can't see surface
- heavy volcanism 800 Myr ago but nothing since → basalt surface
- lava domes
- slow, backwards rotation
- no plate tectonics

### Earth

- plate tectonics
- volcanism: plate boundaries, hot spots
- wind, water erosion
- magnetic field
- continental plates "float" on mantle
- hot-spot plumes
- continents - granite (basalt + water)
- young surface

### Moon

- heavily cratered
- maria: large dark regions of basalt, from early lava flows
- highlands: rest of moon
- small core, little iron
- low gravity
- marequakes due to tidal deformation
- micrometeorites → slow erosion
- Origin: giant impact



### Mars

- moderately cratered
- elliptical orbit
- N. hemisphere - S. hemisphere - variable!
- polar caps CO<sub>2</sub>, some H<sub>2</sub>O
- dichotomy: south - high, many features; north - low, mostly flat
- Tharsis: region of huge dormant volcanoes
- Evidence of past liquid water: eroded valleys, crater rim layering, satellite readings: water ice channels, deltas, ice evidence on plains, shorelines, MAR rovers no longer stable in thin atmosphere.

# 10. Planetary Atmospheres

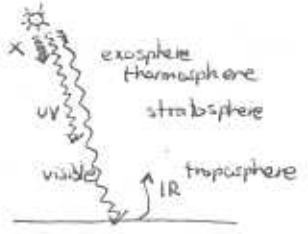
Atmosphere - outer, gaseous layer  
 Supported by hydrostatic pressure  
 (motion of air molecules)  
 Origin: volcanic outgassing  
 O<sub>2</sub> from plants (photosynthesis)  
 can lose atmosphere to chemical reactions and to space

Wind patterns:  
 warm air rises at equator and descends at poles  
 Coriolis effect splits into cells (3/hemisphere)

Weather patterns  
 Venus: none  
 Earth: rain (water: solid, liquid, gas all states)  
 Mars: polar caps grow/shrink, wind storms (dust)

	pressure	surface temp	constituents
Mercury	10 <sup>-14</sup>	-175 to 425	-
Venus	90	470	96% CO <sub>2</sub> , 3% N <sub>2</sub>
Earth	1	15	77% N <sub>2</sub> , 21% O <sub>2</sub>
Moon	10 <sup>-14</sup>	-175 to 125	-
Mars	0.007 (bars)	-50 (°C)	95% CO <sub>2</sub> , 3% N <sub>2</sub>

Temperature structure of Earth atmosphere  
 top layer absorbs X-rays: thermosphere (& exosphere)  
 middle layer absorbs UV (ozone): stratosphere  
 bottom layer absorbs IR re-radiated by the surface: troposphere



Greenhouse effect:  
 Sun radiates mostly visible  
 → CO<sub>2</sub> transparent, so energy heats surface  
 Planetary surface radiates IR  
 → CO<sub>2</sub> opaque to IR: energy cannot escape easily!  
 other greenhouse gases: methane (CH<sub>4</sub>), water (H<sub>2</sub>O)

Ozone:  
 O<sub>2</sub> → O<sub>3</sub> in upper atmosphere  
 O<sub>3</sub> absorbs UV light, heating this layer (but not surface)

Global warming:  
 due to rising CO<sub>2</sub> levels from burning of fossil fuels

Runaway greenhouse:  
 temp increases → water evaporates → H<sub>2</sub>O is a greenhouse gas!  
 Happened on Venus. Probably not on Earth anytime soon, but we are running a dangerous experiment...

# 11. Jovian Planets, Icy Moons

## General properties of "Gas Giants"

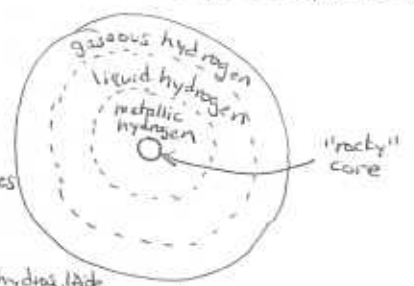
No solid surface:  
 temp, pressure, density increase gradually as you go inward  
 Distinct interior layers (but boundaries are fuzzy) due to phase changes  
 Large cores "rocky" - original planetesimal that grabbed gas  
 Rotational distortion → flattens shape → exaggerated  
 Strong magnetic fields  
 Formation: planetesimals beyond frost line accreted gas, formed "mini-solar system" → moons

Small moons:  
 Captured asteroids/comets  
 Orbits often eccentric, tilted, backwards, etc. - no pattern

Large moons:  
 Formed with their planet in the disks surrounding them  
 Circular, equatorial orbits

## Jupiter, Saturn

mostly H<sub>2</sub>, He  
 300, 100 Earth masses  
 core ~ 5-10 Earth masses

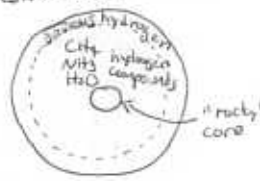


cloud layers: condensation of ammonia, ammonium hydrosulfide, water: form bands due to convection → higher up in Jupiter, lower in Saturn (closer to the core)

cyclones: e.g. Great Red Spot - huge storms releasing energy from gravitational contraction

## Uranus, Neptune

mostly hydrogen compounds (methane, etc)  
 ~15 Earth masses



## Important moons:

Jupiter - Io: most volcanically active body in SS (tidal heating) rocky → extensive activity  
 Europa: liquid water ocean under ice layer, tectonics in ice  
 Ganymede: possible deep subsurface ocean  
 Callisto: not differentiated: never got hot enough icy → no geologic activity

Saturn - Titan: only moon with thick atmosphere, chemical reactions, rain and lakes of liquid methane!  
 Enceladus: recent geologic activity - water & ice ejected from surface, past tectonic heating?  
 Neptune - Triton: probably a captured Kuiper belt object: orbits clockwise, strange surface features, geologic activity (cryovolcanism)