Announcements

- HW #2 Due online at masteringastronom.com by 11pm tonight!

- Even more generous late homework policy: 5% per day, 50% max penalty.

- Extra Credit write-ups (Nova or R. Dempsey talk): Type-written or emailed, at least 3 full paragraphs, by next Mon.
Public Service Announcement

**Last day to register!!!**

You can register and vote (1 stop shopping) anytime up until 9pm tonight:

EMS Training Center
2127 Jefferson Ave.
Newton’s law of gravity: falls off as distance squared.

Newton’s law of Motion & Gravity explains Kepler’s laws: same physics on earth and in the heavens.

Force of gravity exerted by one object on another is the same as the force the other exerts on it (even a grain of sand and the earth).

Response (acceleration) due to that force can be very different.
Last Times

- **Tides caused by gravity**: moon pulls on one side of earth harder than the other.

- **High tides raised on side towards and away from moon**.

- **When sun and moon work together** (full or new moon), the highest high and lowest low tides are found (spring tides).
Tides vary with the phase of the moon. Spring tides are the most extreme because the gravity of the Sun and moon combine.
Energy comes in various types:

- **Potential** *(Rock held up high).*
- **Motion** *(Rock moving at high speed).*
- **Radiation** *(Rock getting cooked by sunlight).*
- **Matter-energy** *(Atom bomb).*

Energy is conserved: can be converted from one type to another, but never disappears.
The Solar System
(planet size to scale!)
Earth and the terrestrial planets
Basic Properties

Terrestrial planet (the original!)

Composition
- silicon, oxygen, and iron (heavy elements)
- very different from Sun and Jovian planets

Orbit nearly circular

Climate
- Not too hot, not too cold: JUST RIGHT!
- only planet with liquid water (probably necessary for life!)
Earth: The Water Planet
Geological Activity
Shaping Worlds

- Cratering
- Volcanism
- Plate Tectonics
- Erosion
Why is Earth geologically active?

- **Core**: composed of nickel and iron

- **Mantle**: composed of minerals containing silicon, oxygen, etc.

- **Crust**: composed of granite, basalt
INTERNAL HEAT SOURCES

- Internal $T=1000s$ K
- Leftover gravitational potential energy
- Radioactivity
- Differentiation
What is differentiation?

- Oil and water separate because oil is less dense than water. It therefore floats on water.

- The inside of planets have a similar layering.

- Gravity sorts material so that the highest density stuff is at the center.

- In the process, gravitational potential energy is converted into heat.
The heat stored in the Earth drives geological activity.

Convection: Hot rock rises and cooler rock falls.

1 cycle takes 100 million years.
Earth's Magnetic Field

Besides driving geological activity, the interior is also responsible for the Earth's magnetic field.

Moving currents create magnetic fields, so the charged particles moving in the Earth's mantle create a magnetic field.
Is North really North?

The Earth's Magnetic Field

North Magnetic Pole

Geographic North Pole

Geographic South Pole

South Magnetic Pole

Larger versions of this image are available: contact peter.reid@ed.ac.uk

Peter Reid (SCI-FUN), 2003
Earth’s magnetic field protects us from high energy charged particles emanating from the Sun.
Some particles get through, spiral along the magnetic field lines, and crash into the atmosphere near the North and South Pole.
Auroras!
Volcanism

- Erase geological features
- Provides constant supply of gases for our atmosphere
Erosion

Wearing down or building up of geological features by weather (ice, water, wind)
Plate Tectonics

Volcanic and earthquake activity occurs on plate boundaries.
Plate Tectonics
Plate Tectonics
**Subduction**

Occurs when plates pushed together.

Pacific Northwest

Mt. St. Helens Eruption
Uplift: Building Mountain Ranges
**Slip Fault**

- Occurs where plates slip sideways

San Andreas Fault
**Rift Zone**

- Occurs when crust is split apart

**East African Rift Zone**
East African Rift Zone
Perils from Space
Impact Cratering

Meteor Crater, AZ
50,000 yrs old
50 m object
1 km diameter
Impact Cratering

- The Moon has many more craters than the Earth, but must be hit about as many times. Where are Earth’s craters?

- Earth’s craters are erased by volcanic activity and erosion.

- The more craters, the older the surface.

Manicouagan, Canada
200 million years old
70 km diameter
Earth’s Atmosphere: Radiation Protection

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The diagram illustrates the interaction of different types of radiation with the Earth's atmosphere. Different types of radiation are represented by arrows of varying lengths and colors:

- **Gamma ray**
- **X ray**
- **Ultraviolet**
- **Visible**
- **Infrared**
- **Radio**

The diagram shows how these types of radiation penetrate the atmosphere at different altitudes:

- **100 km**
- **10 km**
- **Sea level**

The diagram also includes representations of objects at various altitudes, indicating the points at which these radiations are intercepted or attenuated.
Certain molecules, called greenhouse gases, such as $\text{H}_2\text{O}$, carbon dioxide ($\text{CO}_2$), and methane ($\text{CH}_4$) absorb escaping infrared light heating the lower atmosphere.
The Greenhouse Effect: Good or Bad?

Without the greenhouse effect, the Earth's surface temperature would be -17° C (-1° F).

So is the greenhouse effect a good thing?

Taken in moderation, yes.
**The Carbon Cycle**

**Eroded minerals react with dissolved CO₂ to form carbonate rocks.**

**Rainfall erodes rocks on land, and rivers carry eroded minerals to the oceans.**

**Volcanoes outgas CO₂.**

**CO₂ dissolves in ocean.**

**CO₂ in the atmosphere.**

**Carbonate rocks subduct and melt.**

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- An extended cold spell causes oceans to start freezing.
- Growing polar caps.
- Lowered reflectivity causes further cooling, ending.
- Frozen oceans stop CO₂ cycle so CO₂ outgassed by volcanism builds up in atmosphere.
- Strong greenhouse effect melts “snowball Earth,” results in “hothouse Earth.”
- CO₂ cycle restarts, pulling CO₂ into oceans, reducing greenhouse effect to normal.
Global Warming

- Humans are now “part of” the carbon cycle.

- By burning fossil fuels, humans have increased CO$_2$ levels to highest level in 400,000 years.
Global Warming

Graphs showing the increase in carbon dioxide concentration and global temperature changes from 1880 to 1999.
Cratered Worlds:
The Moon & Mercury
The Moon

- Mass 1/80 of Earth’s mass
- Gravity 1/6 of Earth’s
- Atmosphere
  - No real atmosphere
  - Few volatiles (elements that evaporate; e.g. water)
The Moon

Some molten rock existed: flooded craters to make the "maria".

The moon is now geologically dead.
**Crater Counts**

- **Number of craters indicates age**
  - Many craters = old
  - Few craters = young

- **Ongoing impacts**
  - During last 3.8 billion yrs

- **Compare: highlands vs. maria**
  - Maria formed 3.8 billion years ago
  - Based on number of craters
  - Highlands have many more craters
  - Highlands older

**Conclude:**
- **Period of heavy bombardment**
  - Prior to 3.8 billion years ago
Mercury

- Closest planet to sun
- Smallest planet (only Pluto is smaller!)
- Surface similar to Moon
  - Heavily cratered
  - No atmosphere
**Mercury: Surface**

- **No evidence of tectonic activity** (dead)

- **Scarps** (cliffs, 2km high!) in middle of craters: crust shrunk and cracked (after craters formed)
Comparing the Planets

Key: 
- **crust**
- **mantle**
- **lithosphere**
- **core**
Earth-Like Planets: Venus and Mars
**Highlights**

**Venus:**
- Seems a “twin” of Earth (but not!)
- Massive atmosphere
  - Large greenhouse effect
  - Surface temp about 750 K

**Mars:**
- Quite cold
  - Once much warmer
- Very thin atmosphere
  - Once much thicker
- Had flowing water in past
  - Possibility of life?
Venus: General Properties

- **Mass**
  - 82% of Earth’s mass

- **Radius**
  - About same as Earth

- **Density** (5.3 g/cm³)
  - About same as Earth

- **Rotation**
  - Retrograde (E to W)
  - Slow (Period 243 days)
  - Longer than orbital period!
  - Venustian solar day = 117 Earth days

- Due to collision?
Surface of Venus

Problem: how to see through cloud cover?

Spacecraft exploration

Venera 7
- Landed on surface (1970)
- Lasted 23 minutes!

Magellanic Orbiter
- Use radar imaging (from orbit)
- Mapped surface at 100m resolution
Atmospheric Conditions

- **Extreme atmospheric pressure / density**
  - 100x greater than Earth

- **Very high surface temps**
  - around 750 K

- **Little day/night variation**, due to thick atmosphere

- **Generally hot and dry, no water**

- **Occasional “acid rain”**
  - Sulfuric acid clouds
Atmosphere of Venus

Layers of sulfuric acid clouds
- 30-60 km above surface

Composition
- 96% carbon dioxide
- 3% nitrogen
- Remove $\text{CO}_2$, then atmos. like Earth’s

Runaway greenhouse effect
- Greenhouse gases $\Rightarrow$ high temps
- Water evaporates
- Carbon dioxide $\text{CO}_2$ released from rocks
- Increases greenhouse
Mars: General Properties

- **Half the size of earth**
- **Density** $3.9 \text{ g/cm}^3$
  - less than Earth; more than Moon
  - mostly silicates
  - possible metal core
- **Rotation**
  - period 24 hours, 37 min (like Earth)
- **Tilt of axis about 25°; orbital period 1.88 years**
  - seasons similar to Earth’s
  - duration ~ 6 months (instead of 3)
Is Mars geologically active?
Is Mars geologically active?

180 million years old
Is Mars geologically active?
Is Mars geologically active?

180 million years old
**Surface Conditions**

- **Temperatures**
  - **Summer:**
    - Day 240 K (-33 C)
    - Night 190 K (-83 C)
    - Coldest 173 K (-100 C)
    - Water frost deposits

- **Surface winds mostly moderate**
  - But giant dust storms can occur
Water, Water, Everywhere

Surface of Mars appears to have ancient river beds
Water, Water, Everywhere

WHY DID MARS CHANGE?

Early Mars:
- Warmer core generated stronger magnetic field.
- Warmer interior caused extensive volcanism and outgassing.
- Thicker early atmosphere created warmer and possibly wetter climate.

Mars Today:
- Solidified core no longer generates a strong magnetic field.
- Weaker magnetosphere has allowed solar wind stripping to remove much of the atmosphere.
- Thinner atmosphere reduces greenhouse warming.
- Some remaining gases condense or react with surface.

Cooler interior no longer drives significant volcanism or outgassing.
Assignments

- Do Workbook “Earth’s Changing Surface” on your own for Wed.
- HW#2 Due Tonight at 11pm!
- Read Chapter 8 for next time.