Astronomy 12 Final Review Sheet

Sun
- Mostly hydrogen and helium
- Surface temperature of 5800 K, heat converted to light (and some IR, UV) by blackbody radiation.
- Generates energy in core by nuclear fusion of hydrogen into helium (core temp: 15,000,000 K)
- Sends off "solar wind" of charged particles (protons, helium nuclei, electrons)
- Formed by collapse of a large gas cloud: "extra" material flattened into disk and formed planets.
- 4.6 billion years old (as is Solar System in general); slowly increasing in luminosity
- Runs out of hydrogen in core 5 billion years from now, expands into a red giant and eventually sheds most of its mass and shrinks to a white dwarf.

Mercury
- No atmosphere. Gravity is too weak, and temperature too high, for gases not to escape.
- Similar to Moon in appearance (old, cratered), but much denser and with a large iron core.
- In spin-orbit resonance: spins three times for every two times it orbits the Sun.
- Relatively elliptical orbit compared to most planets.
- Large cliffs (scarps) due to "crinkling" of the crust as the planet cooled in its early history.
- Weak residual magnetic field.

Venus
- Thick, crushing carbon dioxide atmosphere. Thick clouds block view of surface.
- Hottest surface in the Solar System due to greenhouse effect.
- Deuterium abundances hint at large bodies of water that were boiled away long ago.
- Runaway greenhouse effect: catastrophic rise in temperatures as oceans vaporize and water vapor traps more heat in atmosphere, boiling more water, until all water is vapor.
- Rotates slowly, and retrograde.
- Low crater count: surface "repaved" about 800 Myr ago by massive episode of volcanic activity.
- Similar size as Earth but no plate tectonics, possibly due to slow rotation.
- Very weak magnetic field compared to Earth, also possibly due to slow rotation.

Earth
- Only planet with plate tectonics
- Only planet with liquid surface water today
- Only terrestrial planet with strong magnetic field
- Surface kept "young" due to tectonics and erosion
- Atmosphere of mostly nitrogen and oxygen; oxygen is due to presence of life (plants).
- Inner core of solid iron, outer core of molten iron, mantle of solid (but "flows" over long timescales) rock
- Life began as soon as frequent large meteor impacts stopped. Only bacterial for most of Earth's history.

Moon
- No atmosphere or erosion; heavily cratered.
- Highlands are oldest regions; maria (large lava flows) formed somewhat later.
- Similar composition to Earth's mantle.
- Probably formed from ejecta blasted from Earth when impacted by a Mars-sized planetesimal.

Mars
- Very thin atmosphere of predominantly carbon dioxide
- Immense dust storms generated seasonally despite thin atmosphere.
- Largest volcanoes in the solar system (due to low surface gravity); huge rift valley.
- Polar caps of mostly carbon dioxide ice (dry ice) with some water ice; seasonal variation.
- Evidence of past water: runoff channels and signs of erosion; chemical signatures (hematite, salts). Most now locked as water-ice below surface.
- Water not currently stable in liquid form on surface: can be only solid or gas.
- Viking lander found no signs of current life. Past life still a possibility.
- No plate tectonics or significant magnetic field (planet too small?)

Phobos, Deimos
- Small moons of Mars; appear to be captured asteroids.

Asteroid Belt
- Region of small mini-planets (asteroids) and smaller bodies (meteoroids) between Mars and Jupiter.
- Composition varies: both metallic asteroids and rocky ones are known.
- Most current asteroids are fragments of larger, differentiated bodies (metallic interior, rocky exterior) that broke apart.
- Asteroids sometimes collide and break off fragments. Pieces that fall to Earth are meteorites: iron meteorites come from metallic asteroids; stony meteorites come from rocky asteroids. Chrondritic meteorites (similar to stony) formed mostly as they are, and were not differentiated; used to estimate overall composition of solar system.
- Kirkwood gaps in Asteroid Belt due to resonance interactions with Jupiter.

Jupiter
- Largest planet in Solar System
- Predominantly hydrogen and helium (like the Sun); rocky core at center
- Hydrogen in planet's interior is in metallic form
- No distinct surface
- Colorful bands due to Coriolis forces arising from very rapid rotation (10 hour period).
- Great Red Spot – long-lived storm.
- Extremely strong magnetic field: generated by convecting metallic hydrogen in Jupiter's interior
- Thin rings formed from material blasted off surface of inner moons by micrometeorites.

Io
- Most volcanically active body in Solar System
- Constantly distended back and forth by tides from Jupiter; heats satellite's interior

Europa
- Surface covered in sheet of water ice riddled with fractures.
- Probable liquid ocean hidden beneath surface ice.

Ganymede
- Largest moon in the Solar System
- Low density: dense rocky center, but mostly icy outer layers with possible liquid water deep in interior.

Callisto
- Uniform, undifferentiated mix of rock and ice
- Old surface, no recent geological activity.

Saturn
- Similar in composition and internal structure to Jupiter; slightly smaller and less dense
- Predominantly hydrogen and helium; rocky core at center (like Jupiter)
- Hydrogen in planet's interior is in metallic form (like Jupiter)
- No distinct surface (like Jupiter)
- Horizontal bands and color variations are less noticeable than on Jupiter but are still present
- Strong magnetic field: generated by convecting metallic hydrogen in Saturn's interior
- Large, extensive ring system: moons within Roche limit would be torn apart by tidal forces; material instead collects into a ring of small chunks of icy material orbiting Saturn.
- Gaps in rings due to (1) resonance interactions with large moons outside the rings, (2) direct gravitational interaction with small moons orbiting inside the gaps.
- Very narrow rings (F ring) due to shepherd moons on either side of the ring that keep material confined to a narrow band between them.
- Thin rings not stable for more than a few hundred million years: must be recent, or constantly generated

Titan
- Only moon with an atmosphere (mostly nitrogen)
- Shrouded in hydrocarbon haze, surface hidden from view
- Very cold (90 K), all water is frozen as ice.
- Probable hydrocarbon rain on surface (erosion features seen by Huygens probe).

Uranus
- Giant planet, but much smaller than Jupiter/Saturn
- Composed of hydrogen, helium, water, ammonia
- Interior is probably an ionic "slush" of water, ammonia, methane; rocky core at center
- No distinct surface (like Jupiter, Saturn)
- Rotation axis perpendicular to orbital axis
- Magnetic field not aligned with rotation axis and offset from planet's center; may originate from convecting solution of water and ammonia
- System of narrow rings, mostly dark sooty material
- Narrow rings kept narrow by influence of shepherding moons
- Numerous small moons

Neptune
- Giant planet, but much smaller than Jupiter/Saturn (like Uranus)
- Composed of hydrogen, helium, water, ammonia (like Uranus)
- Interior is probably an ionic "slush" of water, ammonia, methane; rocky core at center (like Uranus)
- No distinct surface (like Jupiter, Saturn, Uranus)
- Magnetic field not aligned with rotation axis and offset from planet's center; may originate from convecting solution of water and ammonia (like Uranus)
- Faint system of narrow rings, mostly dark sooty material; rings often arc-like.

Triton
- Large moon, evidence of water geysers and ice volcanoes
- Orbits Neptune in the opposite direction the planet rotates: slowly spiraling towards the planet.

Kuiper Belt, Oort Cloud, Comets
- Pluto: tiny "planet" with moon Charon; very little known about it
- Kuiper belt of icy bodies in a disk outside Neptune's orbit; source of short-period comets
- Oort Cloud of icy bodies in a sphere far, far outside Neptune's orbit; source of long-period comets
- Comet: "dirty snowball" of icy material that is perturbed from the Kuiper Belt or Oort cloud into inner solar system. Volatile materials are boiled off by sunlight into coma; then swept into ion and dust tails by solar wind.

Extrasolar Planets
- Detected by Doppler technique: shift in wavelengths in light from star as a planet tugs it back and forth
- All known to date are giant planets (smallest detected so far is mass of Neptune); many are huge (many times the mass of Jupuiter)
- Most orbit in elliptical orbits and/or very, very close to central star

Big Bang / Stellar Evolution
- Big bang: theory that the universe began an extremely hot and dense state 13 billion years ago and expanded and cooled to its present state. (It is still expanding and cooling.)
- Big Bang generated only hydrogen and helium: cannot form planets.
- Low-mass stars (like our Sun) eventually hydrogen into helium and (later) helium into carbon and oxygen, but no other elements.
- High-mass stars fuse elements up to iron. They then explode as supernovae; these explosions can generate all other elements on periodic table.

Important Concepts

Blackbody Radiation – Opaque objects radiate light according to their temperature. The higher the temperature, the more energy they emit and the shorter the wavelength of the light. Objects at planetary temperatures radiate mostly in the infrared; stars radiate mostly in the visible.

Volatile vs. Refractory – Measure of a material's melting point. Low melting point = volatile; high melting point = refractory. Refractory elements are also normally more dense than volatile ones.

Differentiation – In a molten or partially molten object that is large enough to have its own gravity, dense material will sink to the center and light material will float to the top. This is why most of the planets are "layered".

Primordial Heat – Generation of heat from infall (and differentiation) of the objects that formed a planet. This only happened early in the Solar System history as planets were accreting, so this heat is "primordial".

Tidal Heating – Generation of heat by the stretching back and forth of a moon by tidal forces (gravity stronger on one side than another).

Radioactive Heating – Generation of heat by decay of radioactive elements inside a planet.

Greenhouse effect – Certain gases (like CO_2 and water) let visible light through, but absorb infrared radiation. So light from the Sun can heat Earth's surface, but the infrared radiated by the warm ground cannot escape into space; this increases the temperature near the ground. Do not confuse with ozone depletion.

Convection – Hot materials expand, become less dense, and so float to the top. Cool material contracts, gets more dense, and sinks. If an object is hotter inside than it is outside (typical, since planets lose energy to space) material will rise in some places and sink in others, generating circular convection cells.

Coriolis forces – Object close to the equator of a planet are actually rotating. If an object moves towards the poles (where the rotation is slower) it will acquire a sideways "motion" because it was moving around the planet faster than material nearer the poles. Convection cells can therefore generate strong lateral winds in a rapidly rotating planet.

Dynamo – Theory of the generation of a planet's magnetic field as a result of the convective motion of an electrically conductive substance deep in its interior. No net magnetic field is generated unless the cells are "aligned" by Coriolis forces (rotation).

Aurorae – Charged particles can only travel along magnetic field lines. When solar wind particles reach the vicinity of a planet, they are captured by the magnetic field and funneled towards the poles (where the field lines originate). Eventually they hit the atmosphere and knock electrons from atoms; when these recombine the air emits emission lines that are visible as aurorae.

Shepherd Moons – Generally small moons that orbit between a planet's rings. Material orbiting near these moons ultimately gets pushed away by the moon's gravitational effects. A single moon will clear a gap in the rings, two moons will confine material into a very narrow ring in between them.

Resonance – "Alignment" of two periodic processes in an integer ratio: for example, one planet may orbit three times in the same amount of time another planet orbits twice. This can have various effects; it can either stabilize or destabilize a system depending on the process and the configuration. Systems are often driven towards resonance in cases where it is stable, so we often see resonance patterns in the Solar System (Mercury, moons of Jupiter, Neptune/Pluto, etc.)