ASTRONOMY 2110 – TEST #1 REVIEW
You will have 50 minutes to do the test. No books or notes or homeworks (problems, your solutions, or mine) or any other written materials may be used. Calculators are allowed and are encouraged. The test will consist of calculational problems similar to those on the homework (about 2/3 of the credit), and qualitative problems (about 1/3 of the credit).

TOPICS

Introduction
  Gamma Ray Bursts — An Astronomical Mystery Story
  Astronomy and the Nature of Science
  Units: SI, CGS, and Astronomical

The Visible Sky
  Coordinate Systems
    Horizon, Zenith
    Angles
    Rotation of Earth
    Hour Angle
    Vernal Equinox
    Right Ascension, Declination
    Precession of Earth’s Axis
    Constellations
  Time
    Solar Time
    Sidereal Time
    When and Where Can You See What Stars?

Calendars
  Gregorian Calendar
  Julian Date

Motions of Planets
  Retrograde Motion
  Inferior and Superior Planets

Greeks
  Aristotle
    Earth at center
    Circular orbits
  Aristarchus — Sun at Center
  Hipparchus — can’t detect parallax; Earth doesn’t move?

Ptolemy
  Earth offset
  Epicycles
  Inferior planets tied to Earth-Sun line
  Problems: not predictive, very complex
**Copernicus**
- Sun at Center of Solar System
- Planets Further from Sun Move Slower
- Explains Retrograde Motion
  - Due to combined motion of planet and Earth
  - At “passing”, closest to Earth
- Sidereal and Synodic Periods
- Legacy of Copernicus
  - We are not special
  - Complex phenomena, but simple physical laws
  - Predictive power of theories

**Galileo**
- First Great Experimenter
- Inertia and motion
- Gravity
- Astronomical Use of Telescope
  - Surface features of Moon
  - Sun spots
  - Moons of Jupiter
  - Rings of Saturn
  - Milky Way = stars
- Phases of Venus → proved Copernicus Correct
- Problems with Authorities

**Tycho Brahe**
- Accurate Measurements of Planetary Motion

**Kepler**
- Three Laws, Motion of Planets
  - Ellipse, focus, semimajor axis
  - Polar coordinate equation
  - Conic sections
  - Equal areas in equal times
  - $(P/\text{years})^2 = (A/\text{AU})^3$
- Astronomical Unit, AU
**Newton**

Discoveries and Inventions Include:
- Calculus
- Basic laws of physics and mechanics
- Theory of gravity
- Theory of light and color
- Reflecting telescope

**Laws of Motion**
- Force, acceleration, mass, inertia
  - First law: no force → straight line motion, constant speed
  - Second law: \( F = ma \)
  - Third law: equal and opposite forces

**Conservation Laws**
- Conservation of momentum
- Center of mass
- Conservation of energy
- Conservation of angular momentum
- Relation to symmetries

**Theory of Gravity**
- Gravity depends on masses and distance
  \[ F = -\frac{GMm}{d^2} \]

**Two-Body Problem**

**Planetary Motion**
- Force is gravity
- Derived Kepler’s laws
- General orbit is conic section
- Energy \(<, =, > 0 \) → bound or unbound, shape

**Virial Theorem**

**Electromagnetic Forces and Light**

**Maxwell’s Equations**

**Light** = **Electromagnetic Waves**
- Energy, Brightness, and Luminosity
- Wavelength, Frequency, Speed
  - Wavelength increases \( \rightarrow \) frequency decreases

**Electromagnetic Spectrum**
- Radio, Infrared, Visible, Ultraviolet, X-ray, Gamma-ray (Increasing Frequency)
  - Only radio and visible easily penetrate atmosphere

**Wave Properties of Light**
- Reflection
- Refraction
- Diffraction
  - Limiting resolution of telescopes
- Value of Space Telescopes

**Doppler Effect**
- Non-relativistic, Relativistic Limits
- Redshift
- Measures Radial Velocity \( v_r \)
Basic Stellar Properties

*Motions*
- Radial Velocity \( v_r \)
- Proper Motion \( \mu \)

*Distance and Parallax*
- Parallax
- Stellar Distances
- Parsec (pc)
  - Difficulty with Measuring Distances

*Brightness and Magnitude*
- Apparent Magnitudes
- Colors and Temperatures
- Bolometric Magnitudes
- Luminosities and Absolute Magnitudes

*Luminosities of Stars*
- Wide Range, \( 10^{-4} \) to \( 10^6 \) \( L_\odot \)

*Radii of Stars*
- Main Sequence, Giants, Supergiants, White Dwarfs

*Surface Temperatures of Stars*
- Effective Temperature, \( T_{\text{eff}} \)
- \( L = 4\pi R^2\sigma T_{\text{eff}}^4 \)
  - Narrower Range, 3000 K to 50000 K

*Binary Stars*
- Visual, Spectroscopic, Eclipsing

*Visual Binaries*
- Apparent Orbit
- Semimajor Axis \( a \), Period \( P \) → Masses
  - \( (M_1 + M_2)/M_\odot = a_{\text{AU}}^3/P_{\text{yr}}^2 \)
  - \( M_1/M_2 = a_2/a_1 \)

*Spectroscopic Binaries*
- Single-lined, Double-lined
- Velocity Curve
  - Can’t determine inclination angle \( i \)
  - Mass function \( f \), upper limit on unseen star

*Eclipsing Binaries*
- Inclination \( i \approx 90^\circ \)
- Light Curve
- Hotter Star Behind at Primary Eclipse
- Unequal Durations and Spacings Give Eccentricity (\( e \) and \( \Omega \))
- Duration of Eclipses → Radii of Stars
- Variation in Brightness → Radii, Temperatures of Stars

*Stellar Masses*
- Relatively Narrow Range, 0.1 \( M_\odot \) to 100 \( M_\odot \)
- Mass-Luminosity Relation, roughly \( L \propto M^3 \)
The Sun

*Ordinary Star*

Solar composition = H, He, heavy elements

Radioactivity → Age = 4.6 billion years

*Solar Rotation*

About once a month

Differential rotation

*Solar Atmosphere*

Photosphere

Optical depth very large, photosphere = where light comes from

Granulation = convection cells

Photospheric spectrum = continuum + absorption lines

Implies Sun hotter inside

Chromosphere

Corona, very hot

Solar wind

Heating due to magnetic fields

*Magnetic Fields and Plasma*

Microscopic motions

Charged particles → helical motion in magnetic field

Gyro radius

Bulk properties

Frozen-in condition, $B$ and plasma locked together

Bigger pressure is boss

*Solar Activity*

Sunspots

Plages, prominences, filaments, flares

Magnetic origin

*Solar Magnetic Field*

Dynamo like Earth, planets

Reverses every 11 years

*Solar Cycle and Sunspots*

Sunspots

Solar cycle

Bipolar groups

Butterfly diagram

*Dynamo Model for Solar Magnetic Field and Activity*