Midterm Topics for PHY 490 – Black Holes **Spring 2021**

I. Astophysical Objects
   a. White Dwarfs
      i. Discovery
      ii. Examples
      iii. Chandrasekhar limit
   b. Neutron stars
      i. Discovery
      ii. Formation
      iii. Size
      iv. Examples
   c. Binary Pulsars
   d. Black Holes
      i. history, size, observations
      ii. "Black holes have no hair."
      iii. Hawking radiation
      iv. Recent discoveries
   e. Accretion Disks
   f. AGNs
   g. Quasars
   h. Jets
   i. Massive Black Holes
   j. Types of telescopes/astronomy

II. Classical Physics
   a. Newtonian Gravity
   b. Escape Velocity
   c. Einstein's contributions
   d.

III. Special Relativity
   a. Postulates
   b. Lorentz transformation
   c. Simultaneity, Time dilation, Length Contraction
   d. Relativistic Doppler Effect
   e. Minkowski Diagrams
   f. Minkowski metric
   g. Timelike, Spacelike, Null spacetime intervals
   h. Four Vectors, Scalar Product
   i. Motion in Spacetime, World Lines, Proper Time
   j. 4-Velocity,4-Momentum, 4- Force
   k. Addition of Velocities

IV. General Relativity
   a. Equivalence Principle
   b. Gravitational Time Dilation and Redshift
   c. GPS Systems
   d. Curved Space and Spacetime Line elements
   e. Different Coordinate Systems – Polar, Cylindrical, Spherical
   f. Sum of Angles of Triangles, Relate Circumference to Radius
   g. Gravity = Geometry
   h. Gaussian Curvature of Surfaces
   i. Length of Curves

j. Geodesics, Euler Lagrange Equations, Christoffel Symbols

V. Geometric Concepts
   a. Vector, Directional Derivative Operator, Basis
   b. Covector, One-Forms, How forms act on vectors.
   c. Change of Basis for Vectors, Covariant and Contravariant Tensors
   d. Covariant Derivative

VI. Schwarzschild Metric
   a. General features: Symmetries, Singularities, time dilation-red shift parameter
   b. Particle Orbits
      i. Conservation Laws
      ii. Effective Potential, orbit classification
      iii. Radial Plunge Orbit (or Infall)
      iv. Circular, Stable, Unstable, ISCO
      v. Killing Vector, equation
      vi. Precession of Mercury
   c. Light Ray Orbits
      i. Conservation Laws
      ii. Classify Orbits
      iii. Deflection of Light Rays
   d. Spacetime Diagrams
      i. Find Null Curves and Light Cones
      ii. Schwarzschild Geometry
      iii. Eddington-Finkelstein Coordinates
      iv. Tortoise Coordinates
      v. Kruskal-Szekeres Coordinates
      vi. Maximally Extended Spacetime
      vii. Wormhole, Einstein-Rosen Bridge, White Hole
      viii. Penrose Diagrams
   e. Falling Into a Blackhole – What do observers see?
   f. Light Ray Capture
   g. Black Hole Shadow
   h. Stellar Collapse

Resources:

I. Texts
   a. Raine and Thomas, *Black Holes A Student Text*
   b. Begelman and Ress, *Gravity's Fatal Attraction (Black Holes in the Universe)*

II. Handouts
   a. Introduction http://people.uncw.edu/hermanr/BlackHoles/Physics_of_Black_Holes.pdf
   b. Introduction http://people.uncw.edu/hermanr/BlackHoles/Physics_of_Black_Holes.pdf
   c. Lorentz Transformations and Minkowski diagrams http://people.uncw.edu/hermanr/BlackHoles/Lorentz_Transformations.pdf
   d. Geodesics http://people.uncw.edu/hermanr/GRcosmo/geodesicproblem.pdf
   e. Wormhole geodesics http://people.uncw.edu/hermanr/BlackHoles/GeodesicGR2.pdf
   f. Classic test (Perihelion shift) http://people.uncw.edu/hermanr/GR/Precession.pdf
   g. Classic test (First part on deflection of light) http://people.uncw.edu/hermanr/BlackHoles/Light_Deflection_II.pdf
   h. Spacetime diagrams http://people.uncw.edu/hermanr/BlackHoles/penrose.pdf