# PHYSICS 313 - Winter/Spring Semester 2017 - ODU

## <u>Astrophysics - Problem Set 7 – DUE Thursday, March 2</u>

Please submit your solution using the following format. You can submit it as an email to skuhn@odu.edu anytime before midnight on the day on which the Problem Set is due; in this case, you **must** use an electronic file format (like MS Word, LaTeX, .pdf, Mathematica etc.) or simple text (follow the rules of some programming language like Fortran or C to write mathematical expressions like x**2 for the square of *x* etc.). Alternatively, you can write your solution by hand on paper and turn it in **in class** on the same day (no late submissions); please write clearly and cleanly!

For each problem (part), type the problem number (e.g., "1a." or "2c"), followed by a space, and then your solution. For "yes/no" questions, enter "Y" or "N", for multiple choice questions, enter the correct choices ("1" or "3" or…) without any additional characters, and for numerical questions, quote the result in the form "3.1415" or "3.1415e12". For conceptual questions, just write the text (no special formatting needed). Some problems require mathematical derivations or equations in addition to text or numbers (clearly stated in the problem text). **Only** for those cases may you use a **clean** scanned image of a handwritten derivation, included in your electronic submission (if you choose that route).

IN ALL CASES, make sure that your full name appears on all your submissions to guarantee you get credit for your work! Also, do NOT simply copy someone else's solution (honor code!) – you can ask for help if you get stuck, but you must submit your OWN work. (I will randomly ask questions during class to check whether you understand the solution you submitted.

### <u>Problem 1</u>

Mark each of the following statements with "Y" or "T" if they are correct, and with "F" or "N" if they are incorrect:

1a) In General Relativity, coordinate systems that are at absolute rest have preferential status ("Inertial System").

1b) In General Relativity, freely falling systems (on which no force other than gravity acts) have a preferential status ("Inertial System"), even if they accelerate according to Newtonian interpretation.

1c) In General Relativity, the concept of "straight line" has no meaningful interpretation.

1d) In General Relativity, the concept of "straight line" is generalized to a "geodesic" which is the path followed by a freely falling object.

1e) Two observers that start at the same point in space and time and then meet again at a later time may experience different elapsed proper ("eigen") times in their own rest frames.

1f) In the scenario under 1e) above, the observer who traveled while being accelerated by a non-gravitational force tends to age less than the observer in a freely falling rest frame.

1g) The statement in 1e) can even be true if both observers are freely falling (i.e., follow "straight lines"). In other words, two straight lines can intersect twice, with different "lengths" between the intersection points.

PHYSICS 313 - Winter/Spring Semester 2017 - ODU

## Problem 2

The following is a set of multiple choice questions. Answer each with one single digit:

2a) Which of the following examples is **not** a direct consequence of space-time curvature, according to the General Theory of Relativity?

1 – If you see two images of the same object (e.g., a quasar) at slightly different spots in the sky

2 – The bending (refraction) of the light from a setting sun in Earth's atmosphere

3 – The existence of black holes with event horizons

4 – The motion of a weight that is dropped from 1m height above the surface of Earth.

2b) How can we observe stellar sized black holes in the universe, in spite of their "blackness"?

1 – Through the gamma rays emitted from their event horizons.

2 – Through their Hawkins radiation

3 – Through a regular train of radio frequency pulses they emit

4 – Through the gravitational waves emitted when two of them coalesce

## Problem 3

Calculate the time that appears to elapse at the surface of

a) Earth

b) Sun

c) a neutron star of 2 solar masses and 9 km radius

during one second, according to an observer very far away from all these objects. (Numerical results only required, but you can show your work for partial credit).

## Problem 4

Calculate the Schwarzschild radius $R_s$ of a hypothetical particle with mass $m = 1.088 \cdot 10^{-8}$ kg (one-half of the so-called Planck mass). Now calculate the minimum momentum uncertainty $\Delta p$, according to the Heisenberg uncertainty principle, that an object must have if we know its position with a precision of at least the value of $R_s$ you calculated. Show that this momentum uncertainty is equal to the mass of the particle times $c$.