PHYSICS 323 - Fall Semester 2017 - ODU

Modern Physics - Problem Set 1 – DUE THURSDAY, SEPTEMBER 7

GENERAL INSTRUCTIONS:

There are two ways you can submit your solution to all HW problems:

1. As **email** to skuhn@odu.edu. Your submission **must** be sent **before 11:59 p.m.** on the day on which the Problem Set is due. The email must contain the ***complete*** solution, if at all possible typed or typeset. If a question requires you to display mathematical formulas (e.g., some algebraic manipulations), you can either write those in the form of some programming language (e.g., "4*3 = 12") or you can attach a document (Mathematica, Word, .pdf, LaTex,…) or a scanned hand-written solution. Similarly, graphs and plots have to be either computer-generated or (neatly!) drawn by hand. Any hand-written material must be scanned or photographed and attached to your email as a .pdf or .jpg file.
2. As a hardcopy at the beginning of class. I still encourage you to use computer typeset printout as much as possible (to increase readability), or at least write clearly and neatly!

IN ALL CASES, make sure that your full name and student UIN appears on all your submissions (in the **body** of the email and **inside any attached file** for case 1) 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.

Please follow the following format: 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" (or "T"/"F" for "true/false" questions), for multiple choice questions, enter the correct choice ("1" or "2" etc.) without any additional characters, and for numerical questions, enter the result in the form "3.1415" or "3.1415e12" (to within ±10% accuracy at least). For conceptual and computational questions, just enter the text and equations (see above).

Problem 1

Please answer the following questions with "Y" or "N":

1a) Can we improve our knowledge of the magnitude of the speed of light in vacuum by executing more precise measurements?

1b) Was Einstein the first one to realize that quantities like velocity can only be defined relative to some coordinate system?

1c) Is there anything that is "absolute" (i.e., frame-independent) in the Special Theory of Relativity?

Problem 2

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

2a) How come we don't notice the strange effects of (Einstein's) "relativity" in everyday life?

1 – Because Earth is moving only slowly (compared to the speed of light)

2 – Because "relativity" affects only light

3 – Because our senses only record objects moving "slowly" (compared to the speed of light) relative to ourselves (i.e. our own rest frame)

4 – Because "relativity" is just an abstract concept that doesn't apply in reality

2b) A 50 ft sailboat is passing you (standing on shore) at a leisurely pace of 6 kn (3 m/s). Which of the following statements is **not** true?

1 – No matter how precisely you measure, you could not find any relativistic effects.

2 – The boat's clock appears to go slightly slower than your own (by about 4.5 pico-seconds / day), as measured by you

3 – The boat is measured by you to be slightly shorter than 50 ft (by about 0.8 femto-meter)

4 – If the crew sets off two flares, one at the bow and one at the stern, at exactly the same time (according to their reckoning), the bow one appears to be a tad later than the stern one to you (by about 0.5 femto-seconds).

2c) Which of the following statements is true?

1 – A fast-moving object is "squeezed" to a shorter length by the electromagnetic interaction

2 – Fast-moving clocks go slow because the high speed messes with their internal workings

3 – Your (fast-moving) friend says you are aging more slowly than him. You claim the opposite – he is aging more slowly than you. Both he and you may be correct!

4 – If the clocks at the opposite ends of a spaceship (moving away from Earth at high speed) appear slightly unsynchronized to an observer on Earth, this is because the captain didn't take the finite speed of light into account when he set them.

Problem 3

A 500 m long spaceship is moving with 90% of the speed of light relative to Earth. Every second (according to the ship's clock) two lasers send simultaneous flashes of light back to Earth – one from the front tip of the spaceship and one from the rear end. Calculate the following:

3a) According to Earth's measurement (correcting for the motion and length of the spaceship), what is the apparent time interval between the "simultaenous" (according to the space ship) emission from the tip and the rear end?

3b) Using best measurement practices, what appears to be the length of the spaceship as measured from Earth?

Problem 4

In 2047, NASA sends the first spaceship to Alpha Centauri, the closest star outside our solar system (at 4 light-years distance). Assume the spacecraft can go at 80% of the speed of light (relative to Earth). Ignoring the (short) periods of acceleration and deceleration at each end of the trip, explain why the astronauts age by less than what an Earth-based observer would expect for the trip. (How many years would the trip take, according to Earth? How many years according to the astronauts?) How can the astronauts explain the fact that they covered a distance of 4 light-years in less than 4 years? How would THEY describe the trip, from their own reference frame? ***Extra Credit:*** Attach a space-time diagram of the trip (all axes and lines to scale!)

Problem 5

In lecture, we derive the Lorentz Transformation (in 1 spatial dimension) describing the time *t* and position *x* in coordinate system S, expressed in terms of the same coordinates *t*' and *x*' in S':

$$x = \frac{x' + \frac{v}{c}\,ct'}{\sqrt{1 - {v^2}/{c^2}}}\,;\; ct = \frac{ct' + \frac{v}{c}\,x'}{\sqrt{1 - {v^2}/{c^2}}}$$

Using simple algebra, derive the equations for the coordinates *t*' and *x*' in S' expressed in terms of the coordinates t and x in S. Show your work.