PHY293 Modern Physics Fall 2015 Mid-Term Test (1hour) Thu. Nov. 19, 2015

Name:______________________________ Student#:______________________

Tutorial Group & TA name: ____

Before you begin, **read these instructions fully**, and fill in the requested information above. Please put also put your name and student number on all test booklets. All of your work should be done in the exam booklet.

This test has two multiple-choice questions and two problems. Do **all** of them. One page of formulae is provided. The value of each question in indicated. For the two multiple-choice questions (Q1, Q2), please write the answer to each question (a, b, c, d or e) clearly on the **first page** of the exam booklet. If you do rough work for these, please do it on another page. These two questions will be graded solely on whether or not you have obtained the correct answer, so only the answers should appear on the first page.

For the two problems (Q3, Q4), s*how all of your work and explain all of your answers*.

A calculator from the list of approved calculators (as issued by the Faculty Registrar) is permitted. No other aids are allowed.

Test papers are to be returned inside your test booklets.

Multiple-choice questions (see instructions above)

Q1 [10 points] A distant light source travels (in some direction) with some velocity of magnitude 0.4c relative to an observer on Earth. If the source emits light of wavelength 500nm in its rest frame, and the observer on Earth observes a wavelength of 500nm, which of the following statements is correct?

a) the object is getting further away from the observer
b) the object is getting closer to the observer
c) the object is in a circular orbit around the Earth
d) the proposed scenario is not possible
e) not enough information has been provided to answer this question

Q2 [10 points] In the case where light with wavelength of 250nm is incident on a zinc plate (work function 4.3 eV), what is the approximate maximum velocity of the produced photo-electrons?

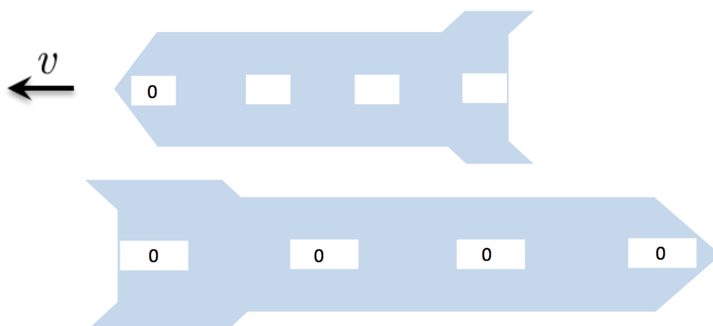
a) 482,000 m/s
b) 622,000 m/s
c) 296,000 m/s
d) there are no photo-electrons produced in this case
e) not enough information has been provided to answer this question

Problems (see instructions on page 1)

Q3 [40 points]

The diagram below shows Bob's view of the passing of two identical spaceships, Anna's and his own. Each ship has proper length (e.g. in its own rest frame) of L and carries four equally spaced clocks along its length (don't be confused by the drawing: to be clear, the four clocks are equally spaced and the front and rear clocks are separated by distance L in each ship's rest frame). At the moment illustrated, the clock at the front of Anna ship is aligned with the clock at the rear of Bob's ship and both read 0; since Bob's clocks are synchronized in his reference frame, all of them read 0 for Bob, as shown.

a) [25 points] If the clock at the rear of Anna's ship is aligned with the second clock from the front of Bob's (as illustrated) if Bob looks through a window and reads Anna's other clocks, what values does he see?
b) [15 points] What time will Bob read on the clock at the tail of Anna's ship when it is aligned with the one at the tail of his?



Q4 [40 points]

Particle 1 (mass m_1) moving at $0.8c$ to the right, collides head on with particle 2 (mass m_2) travelling at $0.6c$ to the left, to produce a single particle of mass M, at rest. In terms of m_1 find:

a) [10 points] the mass (m_2) of particle 2
b) [10 points] the mass (M) of the particle in the final state
c) [10 points] the change in kinetic energy in this reaction
d) [10 points] the invariant mass of the system in the initial state

End of Exam Questions

Some formulae are provided on the next page

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Equations / Constants: (note that you will not need all of these)

Lorentz transformations (from frame S to a frame S' with relative velocity $v\hat{x}$):

$$x' = \gamma\left(x - \beta ct\right) \quad t' = \gamma\left(t - \frac{\beta}{c}x\right) \quad y' = y \quad z' = z \quad u'_x = \frac{u_x - v}{1 - (v/c^2)u_x} \quad \gamma = \frac{1}{\sqrt{1-\beta^2}} \quad \beta = \frac{v}{c}$$

Photoelectric Effect: $\left(K.E.\right)_{\max} = h\nu - \phi$

Relativistic Doppler Effect: $f_{obs} = f_{source} \cdot \dfrac{\sqrt{1 - \frac{v^2}{c^2}}}{1 + \frac{v}{c}\cos\theta}$

Photons: $E = h\nu \quad c = \nu\lambda$

Energy and Momentum:

Non-relativistic: Kinetic energy (K.E.) = $\frac{1}{2}mu^2 \quad \vec{p} = m\vec{u}$

Relativistic: $E = \gamma mc^2 \quad \vec{p} = \gamma m\vec{u} \qquad E^2 = p^2c^2 + m^2c^4$

Four-vectors: Position-time: $\left(x, y, z, ct\right)$ Energy-momentum: $\left(p_x, p_y, p_z, \frac{E}{c}\right)$

Lorentz Invariants: for any four-vector $A = \left(A_x, A_y, A_z, A_t\right)$

$A \cdot A = A^2 \equiv A_t^2 - A_x^2 - A_y^2 - A_z^2$ is a Lorentz invariant

$$(\Delta s)^2 = c^2(\Delta t)^2 - (\Delta x)^2 - (\Delta y)^2 - (\Delta z)^2$$

$$\left(\frac{E}{c}\right)^2 - p_x^2 - p_y^2 - p_z^2 = m^2c^2$$

Constants/conversions

$m_e = 9.1\times10^{-31}\,\mathrm{kg} = 511\times10^3\,\dfrac{\mathrm{eV}}{c^2} \qquad h = 6.626\times10^{-34}\,\mathrm{J\cdot s} = 4.14\times10^{-15}\,\mathrm{eV\cdot s}$

$c = 3\times10^8\,\mathrm{m/s} \qquad 1\mathrm{eV} = 1.6\times10^{-19}\,\mathrm{J} \qquad hc = 1240\,\mathrm{eV\cdot nm}$