Modern Physics
Problem Set 3

JC-12) **Momentum of an Electron**
(10 points) Make a ***table*** showing the electron's momentum, both the correct relativistic momentum and the classical form, at speeds 0.100c, 0.500c, 0.900c and 0.990c. Express momenta in units of kg•m/s.

JC-13) **Energy and Momentum of a Proton**
(10 points) Find the momentum, kinetic energy and total energy of a proton moving at a speed of 0.756*c*. Express your answer in units of eV.

JC-14) **Accelerating an Electron and a Proton**
An electron and a proton are accelerated starting from rest through a potential difference of 10.0 million volts.

a) (15 points) Calculate the relativistic kinetic energy (in MeV) and relativistic momentum (in MeV/c) and velocity for each of the particles.
b) (10 points) Use the velocity you found in part a to calculate the classical kinetic energy (in MeV) and classical momentum (in MeV/c) for each of the particles.
c) (5 points) Compare the results and comment on your answer.

JC-15) **Fission of Uranium Atoms**
(10 points) In a nuclear reactor, each atom of uranium releases about 200 MeV when it fissions. What is the change in mass when 1.00 kg of ^{235}U is fissioned? Express your answer in units of kg. *Hint: The atomic mass of uranium is 235 u.*

JC-16) **Electron-Positron Collision**
(10 points) An electron and a positron (an anti-electron), each moving at $v = 0.99999c$, make a head-on collision. In the collision the electrons disappear and are replaced by two muons, which move off in opposite directions. What is the kinetic energy of each of the muons? *Hint: The rest mass energy of a muon is 105.7 MeV/c^2.*

JC-17) **A Clock on a Satellite**
A clock is placed on a satellite that orbits Earth with a period of 90.0 minutes at an altitude of 3.00 x10^2 km.

a) (10 points) Considering *only special relativistic effects*, by what time interval will this clock differ from an identical clock on Earth after exactly one year?
b) (10 points) Considering *only general relativistic effects*, by what time interval will this clock differ from an identical clock on Earth after exactly one year?
c) (10 points) Taking into account *both special and general relativistic effects*, by what time interval will this clock differ from an identical clock on Earth after exactly one year?

(over)

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JC-18) **Cause and Effect**

(10 points) As we have learned there is no such thing as absolute simultaneity. Two observers in relative motion may disagree on which of two events A and B occur first. Suppose, however, that an observer in reference frame S measures that event *A* occurs first and *caused* event *B*. For example, event *A* is the flipping of a light switch and event *B* is the light bulb turning on. Prove that the observer in another reference frame S′ cannot measure event *B* (the effect) before event *A* (the cause). *Hint: Use the Lorentz transformation to find* $t_2'-t_1'$ *and show that* $t_2'-t_1'>0$.