PHYSICS 2D QUIZ 1 WINTER QUARTER 2012
PROF. HIRSCH JANUARY 23rd, 2012

Formulas:

Time dilation; Length contraction : $\Delta t = \gamma \Delta t' \equiv \gamma\, \Delta t_p$; $L = L_p / \gamma$; $c = 3\times 10^8 m/s$

Lorentz transformation :

$$x' = \gamma(x - vt) \qquad x = \gamma(x' + vt')$$

$$y' = y\ ,\ z' = z \qquad \gamma = \frac{1}{\sqrt{1 - v^2/c^2}} \qquad y = y',\ z = z'$$

$$t' = \gamma(t - vx/c^2) \qquad t = \gamma(t' + vx'/c^2)$$

Velocity transformation :

$$u_x' = \frac{u_x - v}{1 - u_x v/c^2} \qquad u_x = \frac{u_x' + v}{1 + u_x' v/c^2}$$

$$u_y' = \frac{u_y}{\gamma(1 - u_x v/c^2)} \qquad u_y = \frac{u_y'}{\gamma(1 + u_x' v/c^2)}$$

Spacetime interval : $(\Delta s)^2 = (c\Delta t)^2 - [\Delta x^2 + \Delta y^2 + \Delta z^2]$

Relativistic Doppler shift : $f_{obs} = f_{source}\sqrt{1 + v/c}\ /\ \sqrt{1 - v/c}$

Momentum : $\vec{p} = \gamma m \vec{u}$; Energy : $E = \gamma mc^2$; Kinetic energy : $K = (\gamma - 1)mc^2$

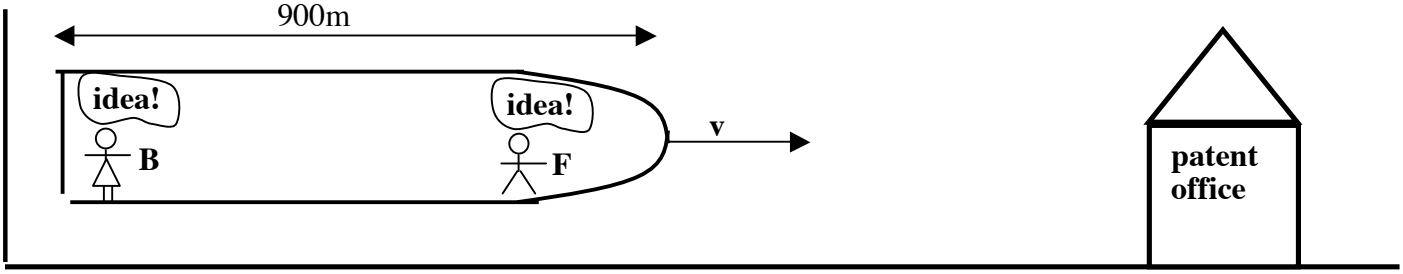
Rest energy : $E_0 = mc^2$; $E = \sqrt{p^2c^2 + m^2c^4}$

Electron : $m_e = 0.511\ MeV/c^2$ Proton : $m_p = 938.26\ MeV/c^2$ Neutron : $m_n = 939.55\ MeV/c^2$

Atomic mass unit : $1\ u = 931.5\ MeV/c^2$; electron volt : $1\text{eV} = 1.6\times 10^{-19}$ J

Justify all your answers to all problems. Write clearly.

Problem 1 (10 points)



In a spaceship of proper length 900m traveling at speed v, Frank (**F**) sitting in the **front** suddenly has a great idea for a new product. Exactly 1 μs later (as measured by clocks on the spaceship), Bonnie (**B**) in the **back** of the ship comes up with the same idea. When the spaceship reaches the patent office on the ground, **F** and **B** run in to get a patent. Patent law says that the patent goes to whoever thought of the idea first. The patent officer decides according to clocks on the ground. Who gets the patent?

(a) If Frank gets the patent, how fast was the spaceship going? Give a range of v/c.

(b) If Bonnie gets the patent, how fast was the spaceship going? Give a range of v/c.

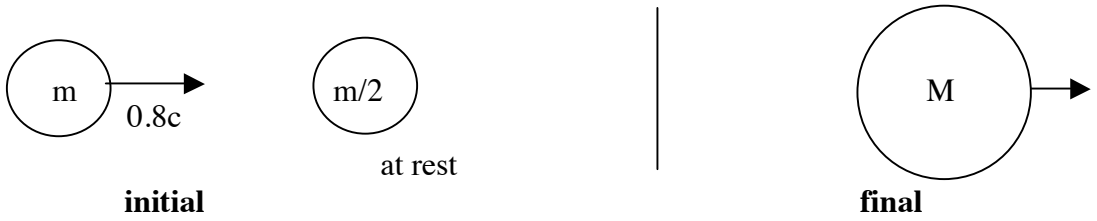
(c) Is it possible that B stole the idea from F? Justify clearly your answer.

Hint: use Lorentz transformation to do this problem.

Problem 2 (10 points)

An electron and a proton are moving towards each other. The kinetic energy of the electron is 0.511 MeV and the kinetic energy of the proton is 938.26 MeV.
(a) Find the speed of the electron, u_e. Give the answer as u_e/c.
(a) Find the speed of the proton, u_p. Give the answer as u_p/c.
(c) Find the speed of the proton relative to the electron. Give your answer in terms of c.

Problem 3 (10 points)



A particle of mass m moving at speed 0.8c hits another particle of mass m/2 at rest and they stick together. The resulting mass is M.
(a) Find the speed at which M moves (in terms of c) (i) assuming classical (non-relativistic) mechanics is valid and (ii) using relativistic mechanics. Note: in classical mechanics mass is conserved.
Do (b), (c) and (d) using relativistic mechanics:
(b) Find the value of M in terms of m.
(c) Find the initial and final total kinetic energies and their difference, expressed as a factor times mc^2.
(d) Find the product of c^2 times the mass difference in the final and initial states, and compare with the difference in kinetic energies computed in (c).

Justify all your answers to all problems. Write clearly.