PHYSICS 2D QUIZ 1 FALL QUARTER 2020
PROF. HIRSCH

Justify all your answers to all three problems. Write clearly.
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:

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

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

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

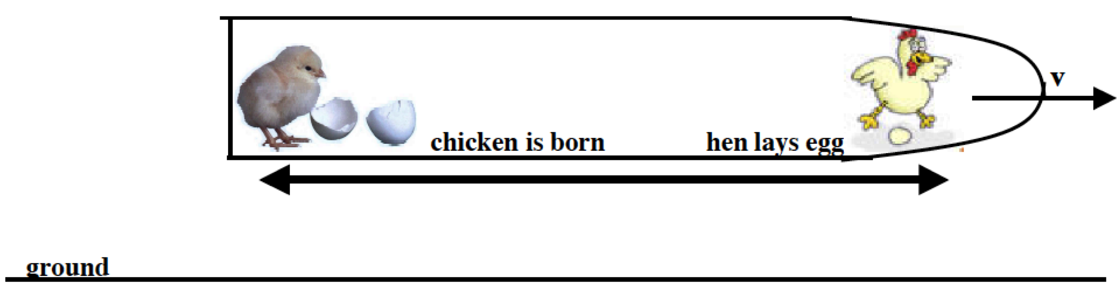
Velocity transformation :

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

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

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

Problem 1 (10 points)



The spaceship shown in the figure is moving at speed v with respect to the ground. According to an observer on the ground, the event in the back of the ship (chicken is born) happened 1μs (=10^{-6}s) earlier than the event in the front of the ship (hen lays egg). The length of the spaceship measured by an observer on the ground is 600m.

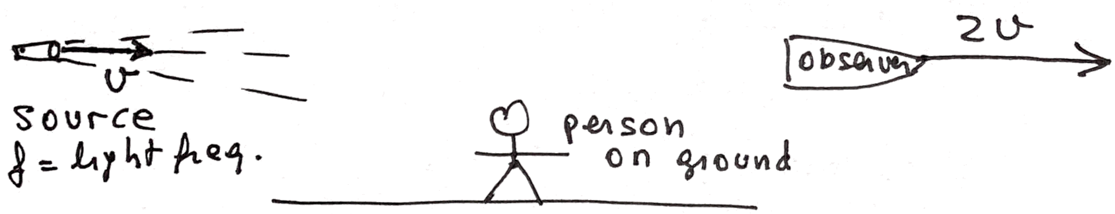
(a) How fast is this ship moving if these two events were simultaneous for an observer on the spaceship? Give your answer as v/c. Hint: Use Lorentz transformation to find the answer.

(b) What is the length of this spaceship as measured by an observer on the spaceship?

(c) Assume now that v=0.8c rather than the value found in (a), with the same spaceship. Again assume that as seen from the ground chicken event occurs 1μs earlier than egg event. Now the events as seen from the spaceship are not simultaneous: how much later was the chicken event than the egg event as seen from the spaceship, in μs?

Problem 2 (10 points)
When twins A and B turn 20 years old, twin B departs on a spaceship traveling at speed 0.6c, twin A stays on Earth. On their respective 21st birthday, both twins A and B lit candles to celebrate.
(a) How old is twin A when twin B lits up her candle, as measured by clocks in the Earth's reference frame?
(b) How old is A when the light from the candle lit by B reaches him (as measured in A's reference frame)?
(c) How old is B when the light from the candle lit by A reaches her (as measured in B's reference frame)?
Hint: ignore any effects that could have resulted from the fact that B was undergoing acceleration for a short period until it reached its traveling speed 0.6c.

Problem 3 (10 points)
A light source is moving at speed v with respect to the ground. An observer on a spaceship is moving in the same direction as the light source, moving away from the light source at speed 2v with respect to the ground, as shown in the picture. Assume v=0.25c.



(a) Find the speed of the spaceship relative to the light source.
(b) If the frequency of the emitted light is f, what is the frequency measured by the observer on the spaceship, f'?
(c) Assume a person on the ground is standing between source and spaceship. Find the frequency f_g that this person measures, in terms of f. Then, assuming this person on the ground emits light with frequency f_g, find the frequency that the spaceship observer would measure for this light, f''. Show all steps in your calculations. Explain why f'' is larger, smaller or equal to f'.