PHYSICS 2D QUIZ 1 FALL QUARTER 2023
PROF. HIRSCH

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

Time dilation; Length contraction: $\Delta t = \gamma \Delta t_0$; $L = L_0 / \gamma$; $c = 3 \times 10^8 \, m/s$

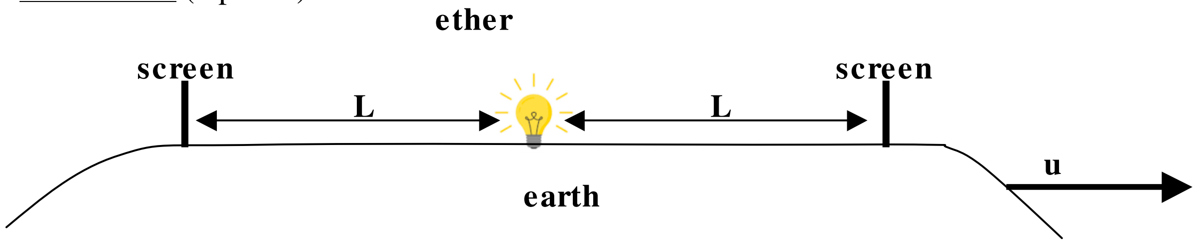
Lorentz transformation: $x' = \gamma(x - ut)$; $y' = y$; $t' = \gamma(t - ux/c^2)$

Velocity: $v_x' = \dfrac{v_x - u}{1 - uv_x / c^2}$; $v_y' = \dfrac{v_y}{\gamma(1 - uv_x/c^2)}$; $\gamma = \dfrac{1}{\sqrt{1 - u^2/c^2}}$

Inverse transformations: $u \to -u, \textit{primed} \leftrightarrow \textit{unprimed}$; Doppler: $f' = f\sqrt{\dfrac{1 \pm u/c}{1 \mp u/c}}$

See other side of this page for problems 3, 4 and 5.

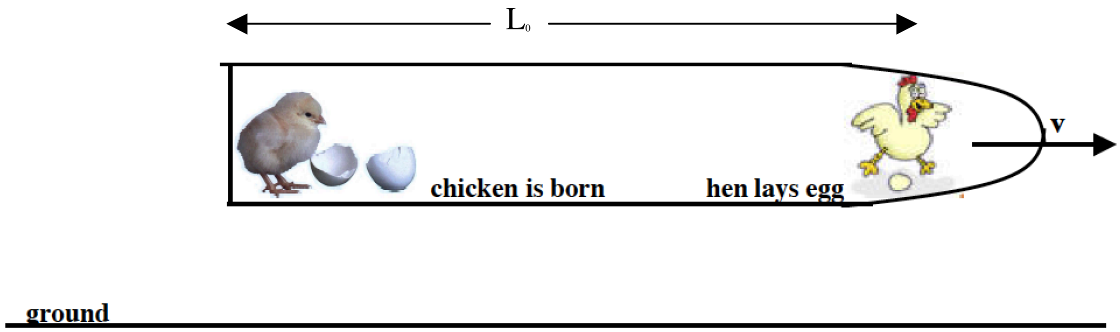
Problem 1 (6 points)



Suppose Einstein was wrong, and there is an ether medium where light waves propagate with speed c, and the Galilean transformation is correct, and the earth is moving at speed u relative to the ether as shown on the figure. In a simplified Michelson-Morley experiment, you measure the time difference for light to travel from a light bulb to screens located at a distance L=150m to the right and to the left, as shown in the figure.
(a) After you turn the light on, which screen does the light reach first: right screen, left screen, or both at the same time? Time is measured on the earth. Explain why, in words.
(b) Assume you measure a time difference between the times the light reaches both screens, and it is 10^{-14} s. What would you deduce is approximately the speed u of the earth relative to the ether? Give your answer in m/s.
Assume u<<c, you can make justified approximations to simplify the calculation.

Problem 2 (6 points)
Assume you just became pregnant and would like your child to be born on the planet Andromeda that is 9 light years away, so that your child gets an andromedian passport. How fast should you travel in order to reach Andromeda just before your child is born? Give your answer as u/c, where u is the speed at which you travel, to 4 decimal places.

Problem 3 (6 points)



At the front end of a spaceship of length $L_0 = 300m$ (as measured in the spaceship) a hen lays an egg. At the back end, a chicken is born. The ship is moving at speed v=0.8c with respect to the ground. According to an observer on the ship, the hen first laid the egg, and x μs later the chicken was born ($1\mu s = 10^{-6} s$). According to an observer on the ground, the chicken was born first, and x μs later the hen laid the egg. Find the value of x in μs. Hint: use the Lorentz transformation.

Problem 4 (6 points)
On their 20th birthday, twin B departs earth on a spaceship traveling at speed 0.8c with respect to the earth, twin A remains on earth. On their 21st birthday, as measured in each own's reference frame, they both light candles to celebrate.
(a) How old is twin A when the light from twin B's candle reaches him/her, as measured in twin A's reference frame?
(b) How old is twin B when the light from twin A's candle reaches him/her, as measured in twin B's reference frame?
Justify your answers.

Problem 5 (6 points)
You are driving at speed 0.5c relative to the ground, a police car is chasing you at speed u with respect to the ground. There is a red light blinking on top of the police car (as seen from the police car), but the light looks blue to you, so you don't worry about it.
(a) Will the police car catch up with you or will you get away? Justify your answer.
(b) How fast is the police car moving with respect to you?
(c) How fast is the police car moving with respect to the ground?
Give your answers as a number times c.

Wavelengths: $\lambda_{red} = 700nm$, $\lambda_{blue} = 500nm$. Frequency $f = c / \lambda$