Formulas:

**Lorentz transformation:**

\[
x' = \gamma (x - vt) \quad x = \gamma (x' + vt')
\]
\[
y' = y, \quad z' = z \quad y = y', \quad z = z
\]
\[
t = \gamma (t - vx/c^2) \quad t = \gamma (t + vx'/c^2)
\]

**Velocity transformation:**

\[
u_x' = \frac{u_x - v}{1 - u_xv/c^2} \quad u_x = \frac{u_x' + v}{1 + u_x'v/c^2}
\]
\[
u_y' = \frac{u_y}{\gamma (1 - u_xv/c^2)} \quad u_y = \frac{u_y'}{\gamma (1 + u_x'v/c^2)}
\]

**Relativistic Doppler shift:**

\[f_{\text{obs}} = f_{\text{source}} \frac{\sqrt{1 + v/c}}{\sqrt{1 - v/c}}\]

**Problem 1**

An elementary particle moving at speed 0.8c travels 800m from the position where it is created to the position where it decays (in the lab frame). What is its lifetime (in its own reference frame)?

A: 4\(\mu\)s; B: 1\(\mu\)s; C: 3\(\mu\)s; D: 2\(\mu\)s; E: not sure  \textbf{(E always counts 0.2 points)}

**Problem 2**

You are standing on the ground watching a train go by. The train is moving at speed \(v=0.6c\). There are clocks in the front and back of the train, that are synchronized in the frame of reference of the train. When the front of the train passes by you, the clock on the front of the train shows that it is noon, and your wristwatch also shows it is noon. When the back of the train passes by you, your wristwatch shows 1second past noon; the clock on the back of the train shows that it is how many seconds past noon?

A: 1.25; B: 0.8; C: 1; D: 2; E: not sure
Problem 3

Two cars, each moving at speed 0.6c, are approaching you from opposite directions. The driver of the car coming from the left lights up a cigarette. You measure the frequency of that light to be $f_0$. What is the frequency of that light as measured by a passenger on the back seat of that car? (of the car coming from the left).

A: $1.25f_0$; B: $0.75f_0$; C: $1.5f_0$; D: $0.5f_0$; E: not sure

Problem 4

Referring to Problem 3, what is the frequency of that light as measured by the driver of the other car? (the car coming from the right).

A: $f_0$; B: $1.5f_0$; C: $2f_0$; D: $4f_0$; E: not sure

Problem 5

Referring to Problem 3, at what speed is the car on the right approaching the car on the left, as seen by the driver of the car on the left?

A: 0.66c; B: 0.88c; C: c; D: 1.2c; E: not sure

Problem 6

The spaceship is moving at speed $v=0.8c$ with respect to the ground. As seen by an observer on the spaceship, the chicken was born in the back of the ship at the same time as the egg was laid in the front of the ship. For an observer on the ground, the chicken was born $t_0$ seconds before the hen laid the egg. How long is this spaceship, as measured on the spaceship? (Use Lorentz transformation) (Note that $ct_0$ has units of length).

A: $ct_0$; B: $0.5ct_0$; C: $0.75ct_0$; D: $1.25ct_0$; E: not sure