Physics 262 Spring 2013 Midterm Exam 2 Name SOLUTIONS

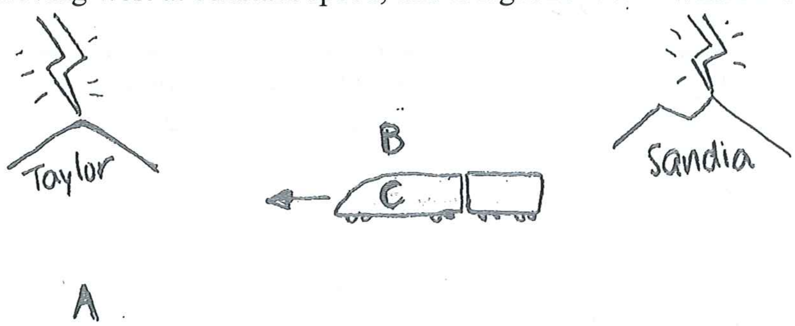
For the purpose of this exam, ignore the rotation of the Earth—assume the Earth is moving at a constant velocity through space. Also ignore General Relativity.

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \qquad f = f_0\sqrt{\frac{1-v/c}{1+v/c}} \qquad v_{o/a} = \frac{v_{o/b} + v_{b/a}}{1+\frac{v_{o/b}v_{b/a}}{c^2}} \qquad \vec{P}_4 = (\gamma mc, \gamma mv_x, ..) = (E/c, p_x ..)$$

$$\Delta s = \sqrt{c^2t^2 - x^2}$$

$c = 3 \times 10^8$ m/s.

Lightning strikes Sandia Peak and Mt. Taylor, 150 km west, at the same time, as seen by stationary observer B who is halfway in between the peaks and stationary with respect to the earth. Stationary observer A is 50 km south of Mt. Taylor. Observer C is in a high speed train moving west at constant speed, and is right next to B **when B sees the lightning**.



1. What observers are in the same inertial reference frame?
a) A & B
b) B & C
c) A & C
d) all are in the same reference frame
e) each is in a different reference frame

2. According to observer A, what is true?
a) He sees lightning from Mt. Taylor first, and Mt. Taylor lightning struck first
b) He sees lightning from Mt. Taylor first, but Sandia lightning struck first
c) He sees lightning from Mt. Taylor first, but the lightning strikes were simultaneous

d) He sees lightning from Sandia first, and Sandia lightning struck first
e) He sees lightning from Sandia first, but Mt. Taylor lightning struck first
f) He sees lightning from Sandia first, but the lightning strikes were simultaneous

g) He sees the lightning strikes at the same time, but Mt. Taylor struck first
h) He sees the lightning strikes at the same time, but Sandia struck first
i) He sees the lightning strikes at the same time, and the strikes were simultaneous.

3. According to observer C on the train, what is true? (choose from above)

g

Event A occurs at the origin and event B happens 4 seconds later at a coordinate of + 5 light seconds (in the Earth frame).

4. In what frame are these events simultaneous?

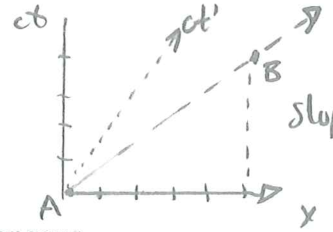
a) in a frame moving toward B at 0.2c

b) in a frame moving toward B at 0.8c from A → B

c) in a frame moving toward A at 0.2c

d) in a frame moving toward A at 0.8c

e) there is no reference frame in which these events are simultaneous



Slope $= \frac{v}{c} = 0.8$

5. What is the **smallest** possible spatial separation between these events, in light seconds?

$c^2\Delta t^2 - \Delta x^2 =$ inv. $= 4^2 - 5^2 = -3^2$ if $\Delta t = 0$ $\Delta x = 3$.

6. What is the **largest** possible time separation between these events, in seconds?

∞. Can make Δt as large as you want by making Δx longer. (Moving clocks run as slow as you like!)

7. An 11 m pole moving at 0.9 c is able to fit into a 10 m barn, owing to Lorentz contraction. A farmer and his assistant show this by closing both a front and back door at the same time (for a brief interval) while the pole is in the barn.

What is true in the frame of reference of the pole?

a) The barn is Lorentz contracted, and the pole crashes into the front or back door

b) The barn is Lorentz contracted, but the doors are never closed at the same time

c) The barn is normal, because it's not moving, but it looks longer because the moving pole got shorter

d) The barn gets longer in the pole's reference frame, since a meter stick moving with the pole gets shorter

8. A child on a spaceship moving at 0.6 c in the +x direction shines a beam of light straight up (+y') in the spaceship frame. What angle does the beam of light make with the spaceship velocity in the Earth frame? (Choose the closest answer.)

a) 90° (it also goes straight up)

b) 59°

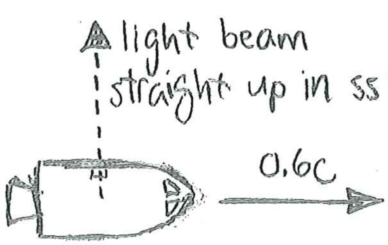
c) 53°

d) 45°

e) 39°

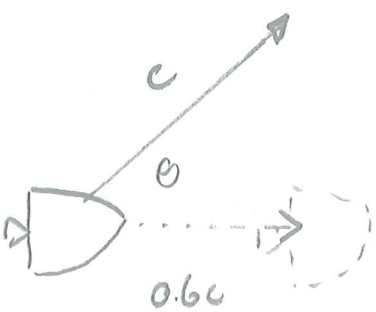
f) 31°

g) 0° (it goes straight ahead)



In Earth frame

$\cos\theta = 0.6$



9. (6 pts). a) The graph below shows x and ct axes for the Earth frame. On the graph, draw the x' and ct' axes for a spaceship passing earth at t=t'=0, moving at 0.6 c in the +x direction. Draw the axes with their correct slope(s).

b) An explosion occurs in the earth frame at x= 5 light-seconds, t = 11 seconds. Indicate this event on the Minkowski diagram. Use 1 division = 1 light-second.

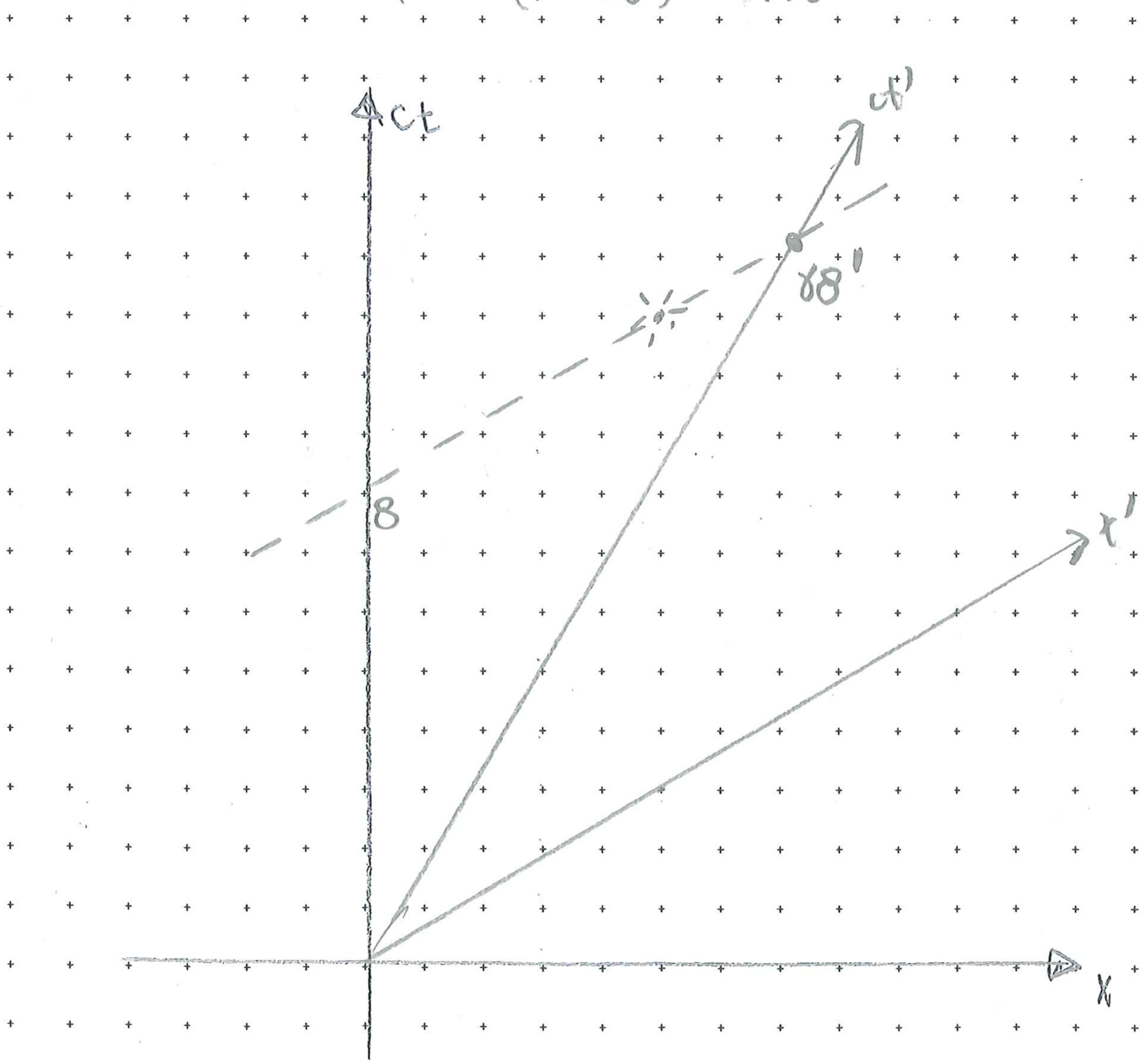
c) Draw a **dashed line** on the diagram that shows all events that simultaneous with this explosion, according the spaceman.

d) If the spaceman observes an earth-frame clock simultaneous (according to the spaceman) with the explosion, what time does it read (in seconds.)

Earth frame clocks all read different times! (They are not synchronized in the ss frame.) So any answer is correct! Outside the ship, the clock reads about 12.4 s (read off the graph). That number won't help us get primed coordinates, though… we need the time on Earth, which is 8 s.

e) What time do clocks in the spaceship frame read when the explosion occurs?

$\gamma \cdot 8 = 10 \qquad (\gamma = (1 - 0.6^2)^{-1/2} = 1.25)$



10. (6 pts) A particle Ψ of rest mass 4 MeV/c^2 moves with the world line shown.

a) Draw the energy-momentum 4-vector at points A,B,C. Be accurate in your lengths, 1 division = 1 MeV/c.

b) At C, the particle decays into two particles. One is stationary and has mass 2 MeV/c^2. Draw the energy-momentum 4-vectors for both decay products on the diagram.

c) What is the rest mass and velocity of second decay particle? $V = c$, Rest mass $= 0$.

d) Suppose instead that Ψ decays into two identical particles at C, one of which is stationary. What is the mass of each of these decay products?

Conserve P $(5,3) = (m,0) + (E,p)$ also $E^2 - p^2 = m^2$ since identical ptcl!

so

$$\left.\begin{array}{l} E^2 - 3^2 = m^2 \\ m + E = 5 \end{array}\right\}$$

$$25^2 - 10m + m^2 - 3^2 = m^2$$

$$m = \frac{16}{10} = 1.6 \text{ MeV}$$

$V_A = \frac{4}{5}c$ $\gamma_A = \frac{5}{3}$

$V_B = 0$ $\gamma_B = 1$

$V_C = \frac{3}{5}c$ $\gamma_C = \frac{5}{4}$