Name:
Student Number:

Physics 200 Midterm #1

October 8, 2008

Questions 1-8: Multiple Choice/Short Answer: 1 point each
Questions 9-10: Show your work

15 points total

MULTIPLE CHOICE ANSWERS:

#1	C
#2	D
#3	C
#4	C
#5	C
#6	D
#7	A
#8	D

Formula sheet at the back (you can remove it)

1) The picture at the right represents an observation of an object moving at $v = \sqrt{\frac{3}{4}}c$. Which of the following pictures best represents the actual shape of the object (in its own frame).

$\gamma = 2$ for $v = \sqrt{\frac{3}{4}}c$

transverse distances unaffected
∴ actual height = observed height

length contraction along direction of motion
⇒ actual width = 2× observed width

A)

B)

[✓ C)]

D)

E)

2) An unstable particle has an average lifetime of 10^{-8} seconds in its rest frame. A beam of these particles is produced with speed 4/5c. How far on average do the particles travel before decaying?

A) 1.44 m
B) 2.4 m
C) 3 m
[✓ D) 4 m]

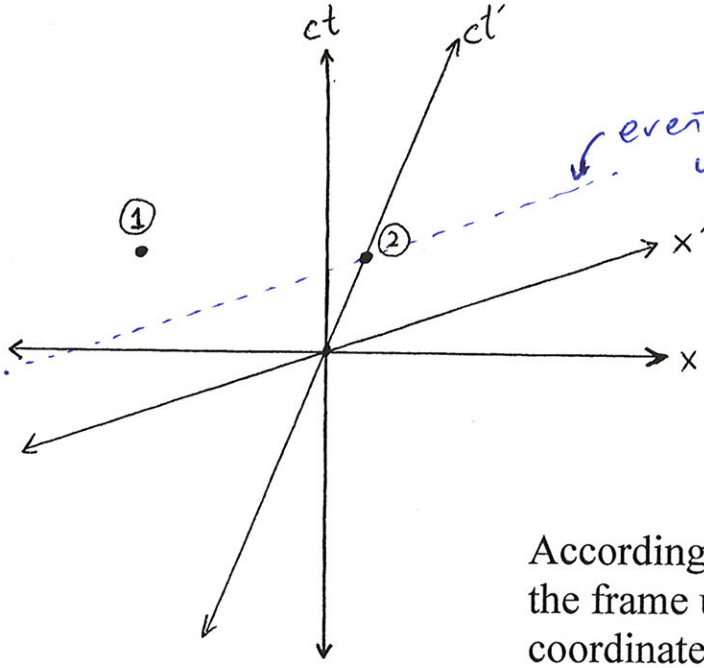
$o \longrightarrow \frac{4}{5}c$

observed lifetime $= \gamma \times$ proper lifetime $= \frac{5}{3} \times 10^{-8}$ s

distance traveled $= \frac{4}{5}c \times \frac{5}{3} \times 10^{-8}$ s $= 4$ m

$\uparrow$ 3×10^8 m/s

3)

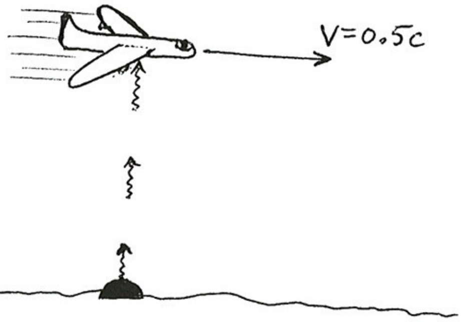


✓ events simultaneous with 2 in x′,t′ frame

According to an observer in the frame using the x’ and t’ coordinates, event 1 happens:

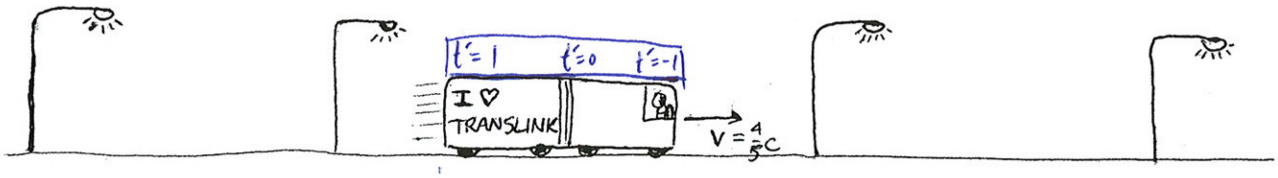
A) Earlier than event 2
B) At the same time as event 2
[✓ C)] Later than event 2
D) None of the above: the concepts of earlier and later do not apply when we consider velocities comparable to the speed of light

4) A signal on the ground sends pulses of light directly upwards. If one of these pulses is observed by a plane traveling at 0.5c parallel to the ground, what speed do the observers in the plane measure for the pulse?



A) $\sqrt{c^2-(0.5c)^2}$
B) $0.5c$
[✓ C)] c
D) $1.5c$
E) $\sqrt{c^2+(0.5c)^2}$

speed of light = c in All frames



5) The 98 B-Line bus travels down Granville Street at speed 4/5c. At 7:00pm, streetlights on Granville Street all turn on simultaneously (in the frame of the street). In the reference frame of the bus, the streetlights ahead of the bus turn on

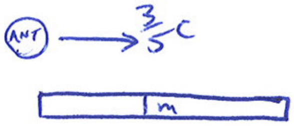
clocks on bus toward direction of motion observed to read earlier times

A) At the same time as the streetlights behind the bus
B) After the streetlights behind the bus
[✓ C) Before the streetlights behind the bus]

OR: $t' = \gamma\left(t - \frac{v}{c^2}x\right)$ greater for lights in front.
↑ same for all lights

6) A flying ant traveling at v=3/5c passes a meter stick. How much time elapses on the ant's clock between the time it passes the front of the stick and the time it passes the back of the stick?

A) 1m/c
B) 5/3 m/c
C) 25/12 m/c
[✓ D) 4/3 m/c]
E) 4/5 m/c



OUR clock: time elapsed

$$t_{RULER} = \frac{1m}{\frac{3}{5}c} = \frac{5}{3}\,m/c$$

ANT's clock observed to run slow:

$$t_{ANT} = \frac{1}{\gamma} t_{RULER} = \frac{4}{5} \times \frac{5}{3}\,m/c = \frac{4}{3}\,m/c$$

7) In a certain frame of reference, two firecrackers explode at times 10^{-8} seconds apart at locations separated by 4 meters. Which of the following is true:

$$I = (\Delta x)^2 - c^2(\Delta t)^2 = (4m)^2 - (3\times10^8 m/s \times 10^{-8} s)^2$$
$$= 7m^2 > 0$$

[✓ A) There is a frame of reference in which both firecrackers explode at the same time.]
B) There is a frame of reference in which both firecrackers explode at the same location.
C) Both A and B are true.
D) Neither A nor B are true.

$I > 0 \Rightarrow$ there is a frame where simultaneous.

8) What is the velocity of ball 1 in the reference frame of ball 2?

A) - 0.5c $\hat{x}$
B) - 0.3c $\hat{x}$
C) 0.3c $\hat{x}$
[✓ D) 0.5c $\hat{x}$]
E) None of the above

$$u' = \frac{u - v}{1 - \frac{uv}{c^2}}$$

$u = -0.5c$

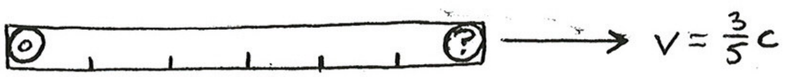
$V = -0.8c$

$$u' = \frac{-0.5c + 0.8c}{1 - 0.5 \cdot 0.8}$$

$$= \frac{0.3c}{0.6}$$

$$= 0.5c$$

PART II) SHOW YOUR WORK!



9) A ruler with proper length of 6m travels at v=3/5c in the direction along its length. If the clock at the back end of the ruler is observed to read time 0, what is the clock at the front end of the ruler observed to read at the same instant? Assume that the two clocks are synchronized in the frame of the ruler. (3 points)

FIRST WAY: Observed length of the ruler will be

$$6m \times \frac{1}{\gamma} = 6m \times \frac{4}{5} = 4.8m$$

Time on clock in picture is

$$t' = \gamma\left(t - \frac{v}{c^2}x\right)$$

$$= \frac{5}{4}\left(0 - \frac{3}{5}c \cdot \frac{4.8m}{c^2}\right)$$

$$= -\frac{3.6m}{3\times10^8 m/s} = -1.2\times10^{-8}s$$

ANOTHER WAY: Call S: frame of ruler S′: Frame of picture

then $v = -\frac{3}{5}c$ (rel. velocity between frames)

know: $t' = 0$ $x = 6m$ want: t

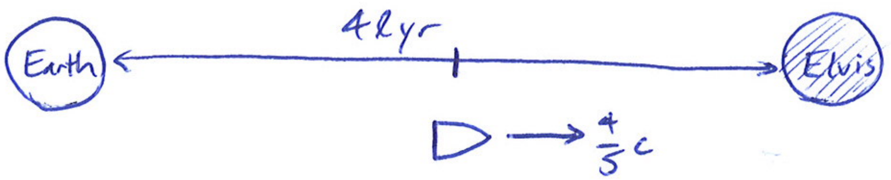
USE: $t' = \gamma\left(t - \frac{v}{c^2}x\right)$

$$\therefore 0 = \gamma\left(t - \frac{v}{c^2}x\right)$$

$$t = \frac{6m \cdot v}{c^2} = -1.2\times10^{-8}s$$

10) A spaceship passes the Earth traveling at speed 4/5c towards planet Elvis, 4 light years away.

a) In the Earth's frame of reference, planet Elvis suddenly turns blue when the ship is halfway there. In the ship's frame of reference, how far away is the ship from planet Elvis when the planet turns blue? Assume that planet Elvis is stationary in the frame of the Earth. (3 points)



FIRST WAY:

Call $x=t=0$ event when ship is halfway between planets.

Planet ~~a~~ Elvis turns blue at: $x = 2\ell yr$, $t=0$.

In ship's frame, coordinates of this event are

$$x' = \gamma(x - vt)$$
$$= \frac{5}{3} \times 2\ell yr$$
$$= \frac{10}{3}\ell yr$$

$\therefore$ Planet Elvis is $\frac{10}{3}\ell yr \approx 3.33\ell yr$ away.

ANOTHER WAY:

If we said $x=t=0$ was event where ship passes Earth, then

- planet Elvis turns blue at $x = 4\ell yr$, $t = \frac{2\ell yr}{\frac{4}{5}c} = 2.5yrs$
- in ship's frame x' for this event is

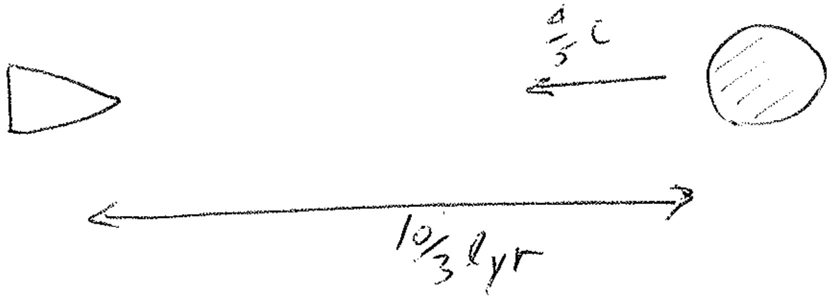
$$x' = \gamma(x-vt) = \frac{5}{3}\left(4\ell yr - 2.5yrs \times \frac{4}{5}c\right)$$
$$= \frac{10}{3}\ell yr. \quad \text{(SAME AS ABOVE)}$$

b) How much do the people on board the ship age between the time planet Elvis turns blue (in their frame) and the time they reach the planet? (1 point)

In the ship's frame, Elvis turns blue when the ship is $\frac{10}{3}$ lyr away, so the time elapsed before they reach planet Elvis is

$$\Delta t_{SHIP} = \frac{\Delta X_{SHIP}}{V_{PLANET}} = \frac{10/3 \text{ lyr}}{\frac{4}{5} c}$$

$$= \frac{25}{6} \text{ years}$$



see next page
for another solution

ANOTHER WAY:

b) How much do the people on board the ship age between the time planet Elvis turns blue (in their frame) and the time they reach the planet? (1 point) Use coordinates of 1st solution:

Planet Elvis turns blue in ship's frame

at $$t' = \gamma\left(t - \frac{v}{c^2}x\right)$$

$$= \frac{5}{3}\cdot\left(-\frac{4}{5}\,\frac{2\ell yr}{c}\right)$$

$$= -\frac{8}{3}\,yrs$$

Ship reaches planet at:

$$t = \frac{2\ell yr}{\frac{4}{5}c} = 2.5yrs \quad \text{(Earth's frame)}$$

$$x = 2\ell yr$$

In ship's frame:

$$t' = \gamma\left(t - \frac{v}{c^2}x\right)$$

$$= \frac{5}{3}\times\left(2.5yrs - \frac{4}{5}\cdot\frac{2\ell yr}{c}\right)$$

$$= 1.5\,yrs$$

∴ The people age $1.5\,yrs + \frac{8}{3}\,yrs$

$$= \frac{25}{6}\,yrs \approx 4.17\,yrs.$$