Name: Mark
Student Number:

Physics 200 Midterm #1 SOLUTIONS

October 14, 2009

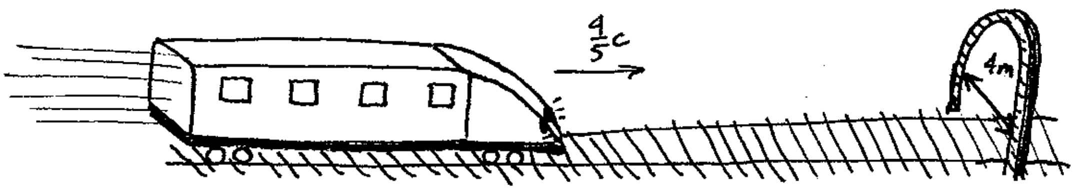
Questions 1-8: Multiple Choice/Short Answer: 1 point each
Questions 9-10: Show your work

16 points total

MULTIPLE CHOICE ANSWERS:

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

Formula Sheet at the Back
(you can remove it)

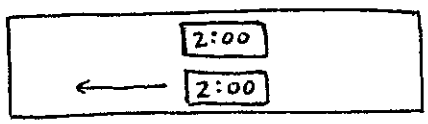


Problem 1

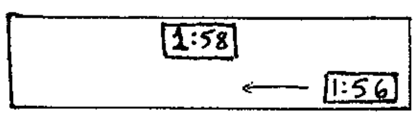
A train is 5m wide in its own frame of reference. If the train travels at velocity 4/5c towards an archway that is 4m wide (in the frame of the track), then:

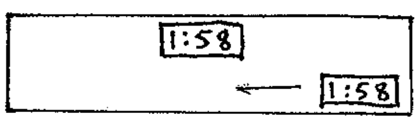
A) the train will fit through the archway.
B) the train will not fit through the archway. transverse distances unaffected. (same in both frames)
C) observers in the frame of reference of the track will see the train fit through the archway, but observers on the train will not
D) people on the train will observe it to fit through the archway, but observers on the track will find that it does not fit.

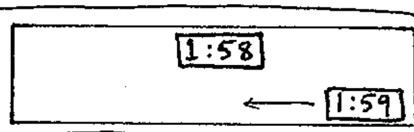
Problem 2

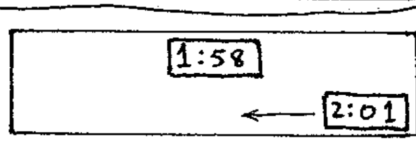


The picture above shows two clocks moving at a large relative velocity. Which of the pictures below represents a possible observation of the clocks at some earlier time (assume the readings on the clocks are exact)?

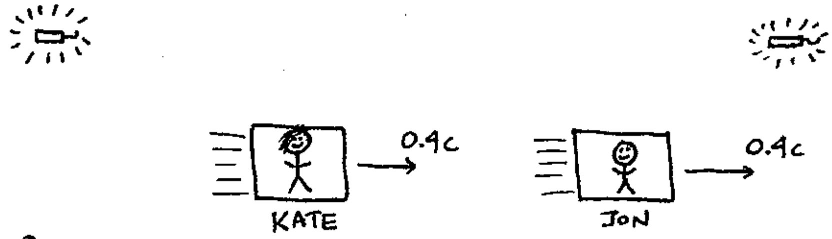
A)


B)


C)


D)


Moving clock appears to run slow
∴ less than 2 minutes pass from lower picture to upper picture. on bottom clock



Problem 3

Jon and Kate are both traveling at velocity 0.4c in the positive x direction, with Jon 1km ahead of Kate. In Kate's frame of reference two firecrackers separated by 3 km along the x direction explode simultaneously. In Jon's frame, the firecracker at a larger value of x explodes

A) before the other firecracker.
B) after the other firecracker.
C) at the same time as the other firecracker.

both in same frame of reference ∴ events are simultaneous in Jon's frame too.

Problem 4

On her 50th birthday, Oprah leaves Earth traveling at 3/5c towards a planet 3 light years away. When she reaches the planet, she immediately returns to Earth at the same speed. How old is Oprah when she arrives back on Earth?

A) 56 years old
B) 56.4 years old
C) 58 years old
D) 60 years old
E) 62.5 years old

on Earth, time for journey measured to be $2\times\frac{3 ly}{3/5 c} = 5\text{ years}\times 2 = 10\text{ years}$

On ship, time passed is $\frac{10\text{ years}}{\gamma} = \frac{10}{5/4}\text{ years}$

$= 8\text{ years}$

Problem 5

$u = -10 m/s$

Two cars approach each other, each travelling at speed 10m/s relative to the street. In the frame of one of the cars, the other car is travelling at

A) exactly 20m/s
B) slightly less than 20m/s
C) slightly more than 20m/s
D) exactly 10m/s

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

$$= \frac{-20 m/s}{1 + \left(\frac{10 m/s}{c}\right)^2}$$

speed a little less than 20m/s

$t = \gamma(t' + \frac{v}{c^2}x')$ ⇒ larger t for larger x'

⇒ front light turns on later in frame of track.

Problem 6

The Canada Line train is traveling at 0.5c. Lights at the front and the back of the train turn on simultaneously in the frame of the train. In the frame of the track, the lights at the front of the train turn on

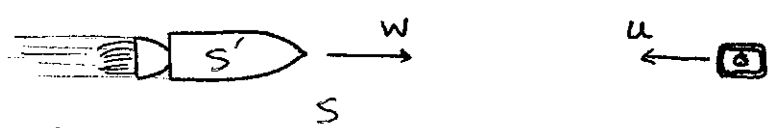
A) at the same time as the lights at the back of the train
B) before the lights at the back of the train
C) after the lights at the back of the train
D) before or after, depending on where the observer is located on the track.

Problem 7

An electron is fired from a particle accelerator and hits a target 1km away. For the events where the electron is fired and where it hits the target, the invariant (spacetime) interval *I* is → same location in frame of electron

∴ $I < 0$

A) positive
B) zero
C) negative
D) Not enough information to determine the answer.



Problem 8

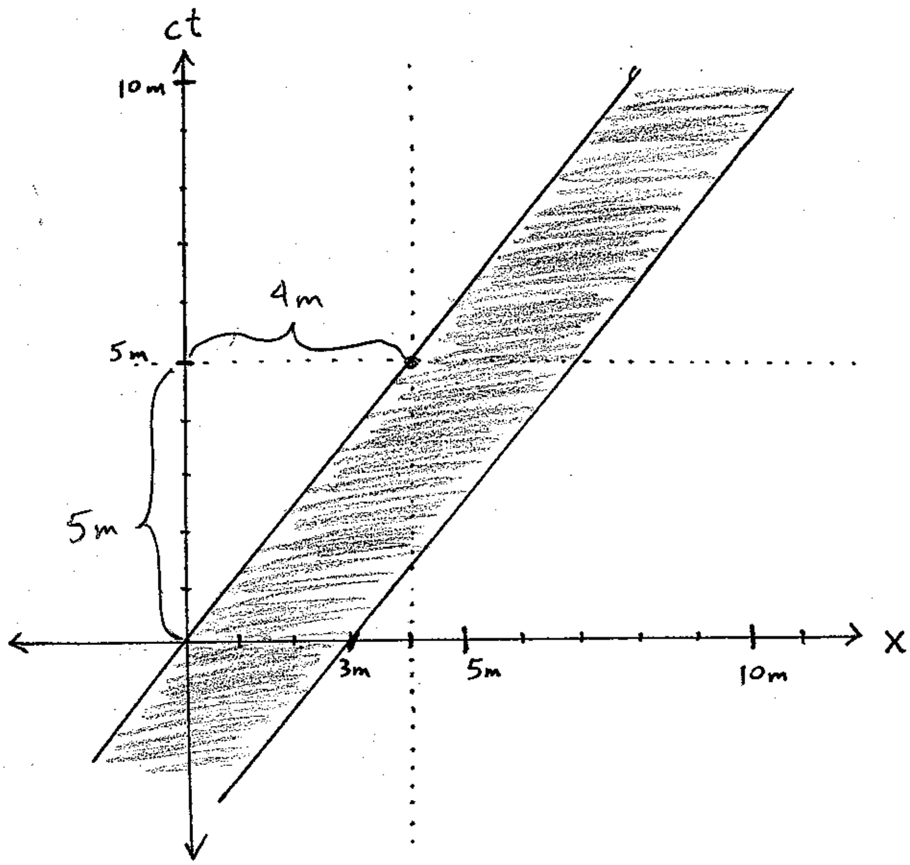
A rocket and an iPhone approach each other, at speeds w and u as shown. In the frame of the picture, the iPhone rings at $x=L$ and $t=T$. In the frame of the rocket, the phone rings at position $x' = \gamma(L - v\,T)$, where v is equal to

A) w $\qquad$ v : velocity of S' in S.
B) $w + u$
C) $(w + u)/(1 + uw/c^2)$
D) $-(w + u)/(1 + uw/c^2)$
E) $-u$

Assume that origin of coordinates in the rocket's frame ($x'=t'=0$) agrees with the origin of coordinates in the frame of the picture ($x=t=0$).

Problem 9 (Explain your work). (3 points)

The spacetime diagram below represents an object travelling in the $+\hat{x}$ direction. How long is the object in its own frame of reference?



Velocity of object : $\frac{\Delta x}{c\Delta t} = \frac{4m}{5m} \Rightarrow v = \frac{4}{5}c$

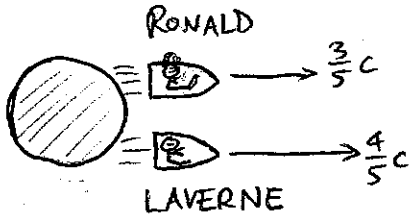
Observed length of object : 3m

Proper length of object :

$$L_{prop} = L_{observed} \times \gamma$$

$$= 3m \times \frac{5}{3}$$

$$= 5m$$



Problem 10 (Explain your work)

Ronald McDonald and his sister Laverne both leave home at the same time and travel towards their favorite restaurant, 5 light year away. Ronald travels at 3/5c and the Laverne travels at 4/5c.

a) In Ronald's frame, at what time does Laverne reach the restaurant? (3 points)

Assume Ronald's clock reads time ∅ when he leaves home.

S = Frame of restaurant:

S' = Frame of Ronald. ($v = \frac{3}{5}c$ relative to S)

$x = t = 0$; event where Ronald leaves home.

event where Laverne reaches restaurant

$$t = \frac{5\,\ell yr}{\frac{4}{5}c} = \frac{25}{4} \text{ years}$$

$$x = 5\,\ell yrs.$$

time for this event in Ronald's frame:

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

$$= \frac{5}{4}\left(\frac{25}{4}\text{years} - \frac{3}{5}\cdot 5 \text{ years}\right)$$

$$= \frac{65}{16} \text{ years.}$$

b) In the frame of the restaurant, what time does Ronald's clock read when Laverne reaches the restaurant (*hint: this is a different question than part a*)?

(2 points)

In frame of restaurant, Laverne reaches restaurant in $\frac{25}{4}$ years.

During this time, Ronald's clock observed to run slow by a factor of $\gamma = \frac{5}{4}$.

$\therefore$ Ronalds clock will read

$$t_{Ron} = \frac{\frac{25}{4}\text{ years}}{\frac{5}{4}} = 5\text{ years.}$$

Scrap

scrap

POSSIBLY USEFUL FORMULAE:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad x' = \gamma(x - vt) \qquad x = \gamma(x' + vt')$$

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

$$u' = \frac{u - v}{1 - \frac{uv}{c^2}} \qquad e^{i\pi} = -1$$

$$f' = f\gamma\left[1 - \cos\theta \, \frac{v}{c}\right] \qquad \vec{p} = \gamma m \vec{v}$$

$$I = (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2 - c^2(\Delta t)^2$$

$$d\tau = dt\sqrt{1 - \frac{v^2}{c^2}}$$

$$E = mc^2 \qquad c \approx 3 \times 10^8 \, m/s$$

1 light year = $c \times 1$ year

$$-\frac{\hbar^2}{2m}\frac{\partial^2 \psi}{\partial x^2} + V\psi = i\hbar\frac{\partial \psi}{\partial t}$$

$$PV = nRT$$