Name:
Student Number:

Physics 200 Midterm #2

November 12, 2008

Questions 1-7: Multiple choice: 1 point each
Questions 8-10: Show your work

15 points available

PLEASE WRITE YOUR MULTIPLE CHOICE ANSWERS HERE! →

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

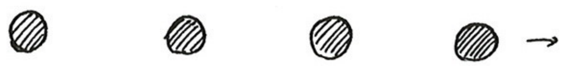
★formula sheet at the back (can be removed)★

Problem 1

The figure above represents the photons in a beam of light with some fixed wavelength and intensity. If size represents photon energy in the picture, which of the pictures below best representes a beam of light with half the wavelength but double the intensity?

A) 

B) 

C) 

D) 

half wavelength:
⇒ double frequency ($f = \frac{c}{\lambda}$)
⇒ double energy/photon ($E = hf$)

since each photon has twice the energy, need same #/second to get twice the intensity

Problem 2

A physicist sets up a series of polarizers and finds that photons which are initially polarized in the vertical direction pass through all the polarizers with a net probability of exactly one quarter. If we send in a beam of vertically polarized light with an intensity 1600 W/m^2 through this series of polarizers, the intensity of the transmitted beam will be

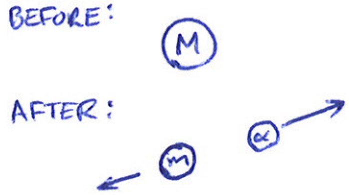
A) 100 W/m^2
B) 400 W/m^2
C) 800 W/m^2
D) 1600 W/m^2
E) 6400 W/m^2

Intensity reduction
= probability that any single photon will go through.

$\therefore I_{transm} = \frac{1}{4} I_0 = 400 W/m^2$

Problem 3

An unstable nucleus of mass M decays into another nucleus of mass m by emitting an α particle. The original mass M is



A) Greater than $m + m_\alpha$
B) Less than $m + m_\alpha$
C) Equal to $m + m_\alpha$
D) Could be any of the above.

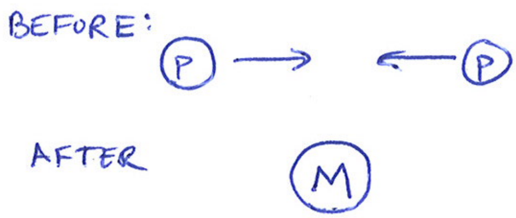
energy conservation:

$$Mc^2 = mc^2 + m_\alpha c^2 + \text{kinetic energy}$$

$$\therefore M > m + m_\alpha$$

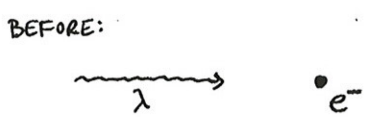
Problem 4

Two protons (each with mass 938 GeV/c^2.) traveling with equal speeds close to the speed of light in opposite directions collide to produce a new particle of mass M. Assuming that no other particles are produced in the collision, the mass M must be



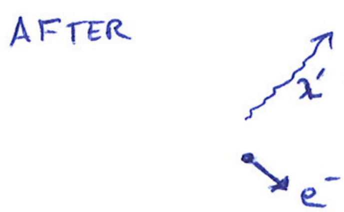
A) less than 1876 GeV/c^2.
B) equal to 1876 GeV/c^2.
C) greater than 1876 GeV/c^2.
D) Any of the above are possible.

energy cons: $M = 2\gamma m_p > 1876$ GeV/c^2 (↑ greater than 1)



Problem 5

A photon of wavelength λ scatters off an electron that is initially stationary. After the collision, the photon's wavelength will be



A) equal to λ
B) greater than λ
C) less than λ
D) any of the above are possible

photon gives some of its energy to electron $\therefore \lambda' > \lambda$

Problem 6

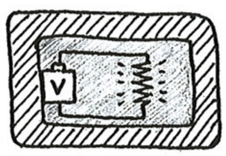
Four photons are sent into a polarizer oriented at 90° to the vertical. Their polarization states are

$|90°\rangle$, $|0°\rangle$, $|45°\rangle$, and $\frac{1}{\sqrt{2}}|0°\rangle - \frac{1}{\sqrt{2}}|90°\rangle$

What are the possibilities for how many photons will pass through the polarizer?

A) exactly 1 photon will pass through
B) either 1 or 2 photons will pass through
C) either 1, 2, or 3 photons will pass through
D) either 2 or 3 photons will pass through
E) any number (0, 1, 2, 3, or 4) might pass through

$|90°\rangle \rightarrow$ definitely through
$|0°\rangle \rightarrow$ definitely not
$|45°\rangle \rightarrow$ maybe (50% prob) $= \frac{1}{\sqrt{2}}|0°\rangle + \frac{1}{\sqrt{2}}|90°\rangle$
$\frac{1}{\sqrt{2}}|0°\rangle - \frac{1}{\sqrt{2}}|90°\rangle \rightarrow$ maybe (50% prob)



Problem 7

Suppose we build a sealed box which contains a battery connected to a heater which gradually heats the air inside the box. Assuming the box is completely isolated, and that the box neither absorbs nor emits any particles or radiation, what happens to the mass of the box (including its contents) as time passes?

A) The mass increases.

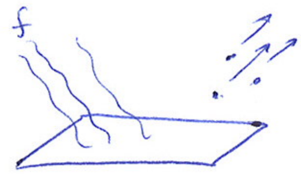
B) The mass decreases.

C) The mass stays the same.

Mass = total energy of object in its rest frame

total energy of box must be conserved

$\therefore$ mass doesn't change with time



Problem 8

A beam of light with frequency $7.5\times 10^{14}\,s^{-1}$ is incident on a metal, and photoelectrons are observed with maximum velocity 5×10^{5} m/s. The same sample of metal is illuminated with a new light source, but this time electrons are observed with maximum velocity 10^{6} m/s. What is the frequency of the new light source? (3 points)

Have: $E_K^{max} = hf - W$

$v_1 = 5\times 10^5\, m/s$

$f_1 = 7.5\times 10^{19}\, s^{-1}$

$\therefore \frac{1}{2} m v_1^2 = hf_1 - W$

$\Rightarrow W = hf_1 - \frac{1}{2} m v_1^2$

$\frac{1}{2} m v_2^2 = hf_2 - W$

$v_2 = 10^6\, m/s$

$$\Rightarrow f_2 = \frac{1}{h}\left(\frac{1}{2} m v_2^2 + W\right)$$

$$= \frac{1}{h}\left(\frac{1}{2} m v_2^2 + hf_1 - \frac{1}{2} m v_1^2\right)$$

$$= f_1 + \frac{m}{2h}\left(v_2^2 - v_1^2\right)$$

$$= 7.5\times 10^{14}\, s^{-1} + \frac{9.1\times 10^{-31}\,kg}{2\times 6.6\times 10^{-34}\, J\cdot s}\left((10^6\, m/s)^2 - (5\cdot 10^5\, m/s)^2\right)$$

$$\Rightarrow \boxed{f_2 \approx 1.3\times 10^{15}\, s^{-1}}$$

Problem 9

A photon with energy 100MeV is incident on a stationary particle of mass 200MeV/c^2. If the photon is completely absorbed to form a new particle, what is the speed of this new particle (relative to the speed of light)?

(3 points)

BEFORE:

AFTER:

let $\tilde{M}$ = mass of final particle.

Energy conservation ⇒

$$E + Mc^2 = E_f$$

$$100\text{MeV} + 200\text{MeV} = \gamma \tilde{M} c^2 \qquad (*)$$

Momentum conservation ⇒ $p_i = p_f$

$$\frac{E}{c} = \gamma \tilde{M} v$$

$$\Rightarrow \frac{100\text{MeV}}{c} = \gamma \tilde{M} v \qquad (+)$$

Divide (+) by (*):

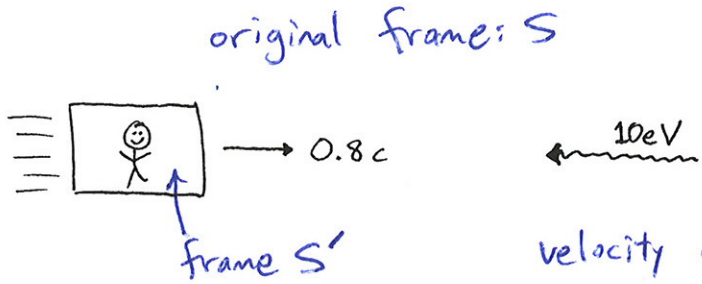
$$\frac{v}{c^2} = \frac{100\text{MeV}/c}{300\text{MeV}}$$

$$\Rightarrow \boxed{v = \frac{1}{3}c}$$

OR: $E_f = E_i = 300\text{MeV}$

$$p_f = p_i = \frac{100\text{MeV}}{c}$$

$$v_f = \frac{p_f}{E_f} \cdot c^2 = \frac{1}{3}c$$



velocity of S' in S

$v = 0.8c \qquad \gamma = \frac{5}{3}$

Problem 10

In some frame of reference, a photon with energy 10eV is traveling in the negative x direction. According to an observer traveling at speed 0.8c in the positive x direction relative to the original frame, what is the energy of the photon? (2 points)

Use Lorentz Transform. for energy:

$E = 10eV$

$p_x = -\frac{10eV}{c}$

$$E' = \gamma(E - v p_x)$$

$$= \frac{5}{3}\left(10eV - (0.8c)\left(-\frac{10eV}{c}\right)\right)$$

$$= \frac{5}{3}(10eV + 8eV)$$

$$\Rightarrow \boxed{E' = 30eV}$$