PHYSICS 200
MIDTERM #2

Friday, Nov. 9th, 2007

Name: Mark Van Raamsdonk

Student Number: 5830 1912

Questions 1-7: short answer/multiple choice.
1 point each. Write answers in boxes here →

Questions 8-10: SHOW YOUR WORK
9 points total

16 total points available

ANSWERS:

#1	C
#2	E
#3	C
#4	D
#5	D
#6	D
#7	B C E

write ALL that apply for these ones

Formula sheet at the back (may be removed)

① A massless particle has energy 13 MeV. What is its velocity?

All massless particles must have velocity c to have nonzero energy

Answer : c

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② 

A metal surface is illuminated with light whose wavelength is short enough to produce photoelectrons. If we now switch to light with half the wavelength but keep the total power of the beam the same, what happens to the maximum kinetic energy of the electrons?

initially:

$$E_k^{max} = \frac{hc}{\lambda} - W$$

after:

$$\tilde{E}_k^{max} = \frac{2hc}{\lambda} - W$$

$$\frac{\tilde{E}_k^{max}}{E_k^{max}} = \frac{2 - \frac{W\lambda}{hc}}{1 - \frac{W\lambda}{hc}} > 2$$

a) It stays the same

b) It doubles (increases by 100%)

c) It increases, but by less than 100%

d) It is cut in half

[✓ e) It increases by more than 100%]

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③ An α particle is a bound state of two protons and two neutrons. The mass of an α particle is

a) greater than $2m_p + 2m_n$

b) equal to $2m_p + 2m_n$

[✓ c) less than $2m_p + 2m_n$]

d) any of the above, depending on its velocity

Since the α particle is a bound state, it would require adding energy to the system to separate the α into protons & neutrons. So the total energy of the α at rest is less than the total energy of the 2 protons & 2 neutrons at rest.

④

The picture on the right above represents the photons making up an electromagnetic wave. Which of the pictures below best represents the photons making up a wave with the same amplitude and half the wavelength? smaller wavelength = greater energy per photon

Same amplitude = same energy density ∴ smaller density of photons

A) 

B) 

C) 

[✓ D)] 

E) 

NOTE: size represents energy in the pictures to the right

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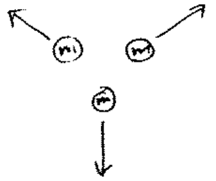
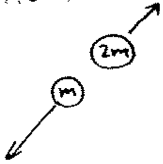
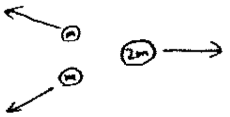
⑤

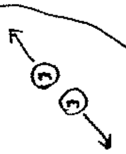
A nucleus of mass 3m decays into smaller nuclei. Which of the following represent(s) a possible final state? GIVE ALL ANSWERS THAT APPLY

Mass 3m = TOTAL ENERGY OF INITIAL NUCLEUS AT REST

A) 

B) 

C) 

[✓ D)] 

∴ All have greater energy than the original nucleus at rest except D.

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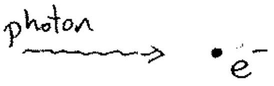
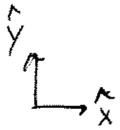
⑥



A photon scatters off an initially stationary electron. Which of the following represent(s) a possible final state? GIVE ALL ANSWERS THAT APPLY

MOMENTUM IS A VECTOR
∴ all components conserved.



A) 

B) 

C) 

[✓ D)] 

E) 

Need momentum to be conserved, so final state must have 0 momentum in ŷ direction, +ve momentum in x̂ direction. Only D is possible.

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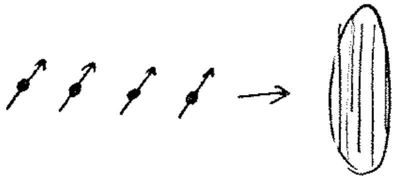
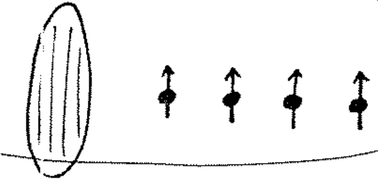


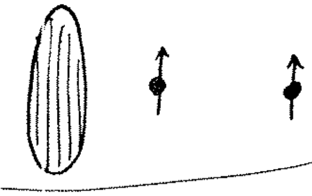
Four equally spaced photons polarized at 45° to the vertical are incident upon a vertically oriented polarizer, as shown. Which of the following pictures represent(s) a possible outcome of this experiment?

A)

[✓ B)]

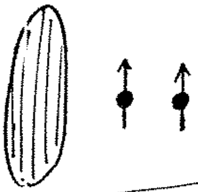


[✓ C)]



D)

[✓ E)]

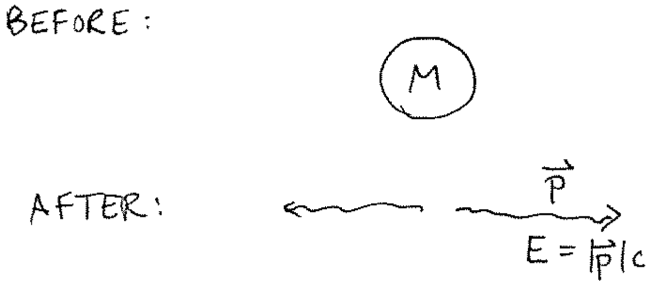


GIVE ALL ANSWERS THAT APPLY.

Photons must be polarized vertically after passing through polarizer, but B, C, and E are all okay, since each photon has some probability of passing through.

(note: E represents a case where the 1st 2 photons are absorbed & the last 2 are transmitted, while in C, the 2nd and 4th photons are transmitted)

⑧ A particle of mass 140 MeV/c^2 decays into 2 photons. If the particle was initially at rest, what are the wavelengths of the photons? (2 points)



By momentum conservation, the momenta of the two photons must be of the same magnitude but in opposite directions. They therefore have the same energy, which must be half the energy of the original particle. Thus, we have:

$$E_{\text{photon}} = \frac{1}{2} M c^2$$

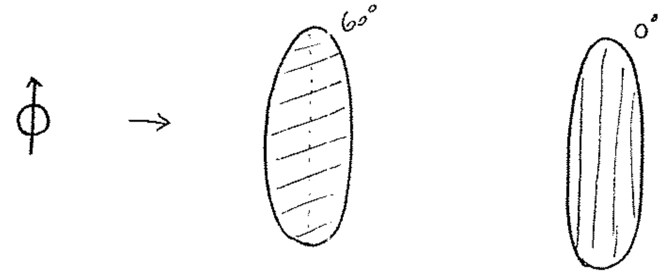
$$\Rightarrow \frac{hc}{\lambda_{\text{photon}}} = \frac{1}{2} M c^2$$

$$\Rightarrow \lambda_{\text{photon}} = \frac{2h}{Mc}$$

$$= \frac{2 \times 6.6 \times 10^{-34}\,\mathrm{J \cdot s}}{3 \times 10^{8}\,\mathrm{m/s} \times \frac{140\,\mathrm{MeV}}{(3 \times 10^{8}\,\mathrm{m/s})^2} \times 1.6 \times 10^{-13}\,\mathrm{J/MeV}}$$

$$\approx 1.77 \times 10^{-14}\,\mathrm{m}$$

⑨



A vertically polarized photon is incident on a polarizer oriented at 60° to the vertical, followed by a polarizer oriented vertically. What is the probability that the photon will pass through both polarizers? (3 points)

Prob of passing through 1st one $= \cos^2(60°)$

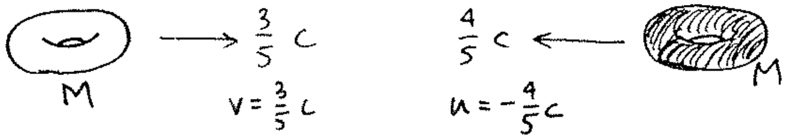
$= \frac{1}{4}$

After this, the photon is ~~oriented~~ polarized at 60°, so the prob of such a photon passing through the 2nd polarizer is also $\frac{1}{4}$. The total probability is

$$P = \frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$$

(i.e. one in four pass through the first, and one in four of the ones passing through the first pass through the second, so one in 16 pass through both).

10)



A plain donut of mass M is travelling in the $+\hat{x}$ direction at velocity $\frac{3}{5}c$ while a chocolate donut is travelling in the $-\hat{x}$ direction with speed $\frac{4}{5}c$.

a) What is the momentum of the chocolate donut in the frame of the plain donut? (3 points)

Alternate soln:
we can calculate $u' = -\frac{35}{37}c$ using velocity tform, then

$$\begin{aligned} P_{choc} &= \gamma_{u'} M u' \\ &= \frac{37}{12} \cdot M \cdot \left(-\frac{35}{37}c\right) \\ &= -\frac{35}{12} Mc \end{aligned}$$

Original frame:

$$\begin{aligned} P_{choc.} &= \gamma m u \\ &= \frac{5}{3} \cdot M \cdot \left(-\frac{4}{5}c\right) \\ &= -\frac{4}{3} Mc \end{aligned}$$

$$\begin{aligned} E_{choc} &= \gamma m c^2 \\ &= \frac{5}{3} M c^2 \end{aligned}$$

Frame of plain donut:

these are for the velocity of the new frame in the old frame i.e.

$v = \frac{3}{5}c$

$\gamma = \frac{4}{3}$

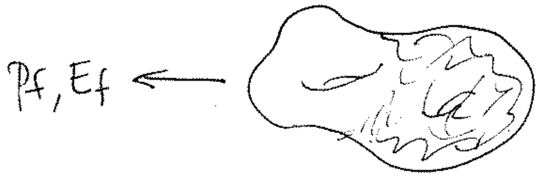
$$\begin{aligned} p' &= \gamma \left(p - \frac{v}{c^2} E\right) \\ &= \frac{5}{4}\left(-\frac{4}{3}Mc - \frac{3}{5} \cdot \frac{5}{3} Mc\right) \end{aligned}$$

$$\Rightarrow \boxed{p' = -\frac{35}{12} Mc} \approx -2.92 Mc$$

b) If the two donuts collide inelastically and stick together, what is the mass of the resulting object? (1 point)

(NOTE: this question isn't worth much for the amount of work required, so it's best to do everything else first).

AFTER:



By energy conservation,

$$E_f = E_{plain} + E_{choc}$$
$$= \frac{5}{4} Mc^2 + \frac{5}{3} Mc^2$$
$$= \frac{35}{12} Mc^2$$

By momentum conservation

$$p_f = p_{plain} + p_{choc}$$
$$= \gamma_p m v_p + \gamma_c m v_c$$
$$= \frac{3}{4} Mc - \frac{4}{3} Mc$$
$$= -\frac{7}{12} Mc$$

Now we can use $E_f^2 = p_f^2 c^2 + m_f^2 c^4$

$$\Rightarrow m_f = \sqrt{\left(\frac{E_f}{c^2}\right)^2 \cancel{A} - \left(\frac{p_f}{c}\right)^2}$$
$$= M \sqrt{\left(\frac{35}{12}\right)^2 - \left(\frac{7}{12}\right)^2} = \frac{7\sqrt{6}}{6} M = 2.86 M$$

Alternate soln:

- we can find the velocity of the frame where the total mom. is 0 via

$$0 = \gamma\left(p_f - \frac{v}{c^2} E_f\right)$$
$$\Rightarrow v = \frac{p_f c^2}{E_f} = -\frac{1}{5} c$$

This is the final velocity of the object in the original frame, so

$$E_f = \frac{35}{12} Mc^2 = \gamma_{(-\frac{1}{5}c)} \cdot M_f c^2$$

$$\Rightarrow M_f = M \cdot \frac{35}{12 \cdot \gamma\boxed{-\frac{1}{5}c}}$$