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

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?

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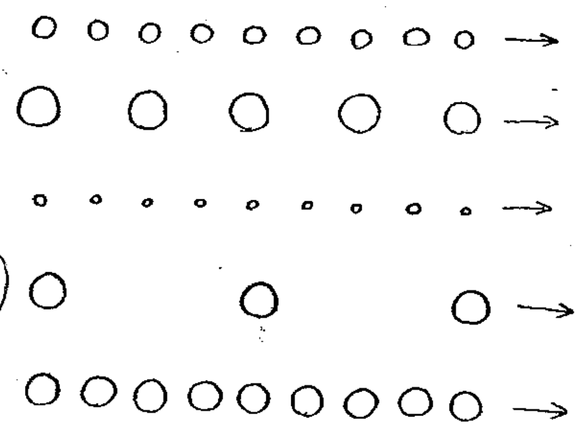
(3) An α particle is a bound state of two protons and two neutrons. The mass of an α particle is

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

(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?

A) B) C) D) E)



NOTE: size represents energy in the pictures to the right

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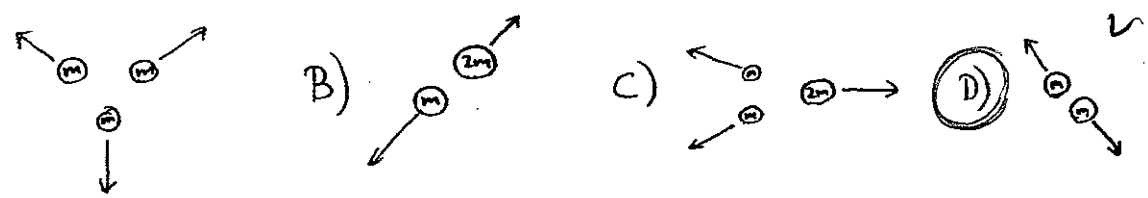
(5)

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

A) B) C) D)



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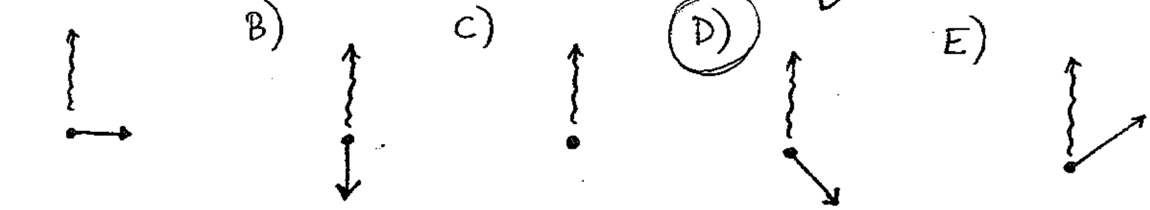
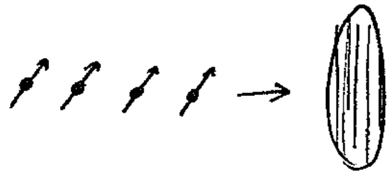
(6)

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

A) B) C) D) E)

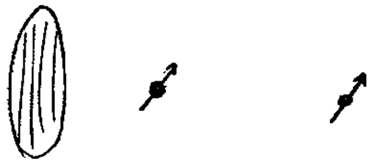


7.

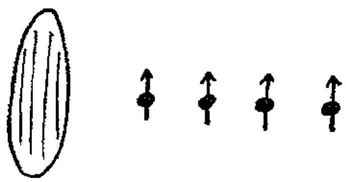


Four equally spaced photons polarized at 45° to the vertical are incident upon a vertically oriented polarizer, as shown. Which of the following pictures represent(s) a possible outcome of this experiment?

A)

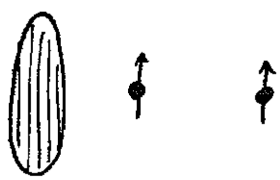


B)

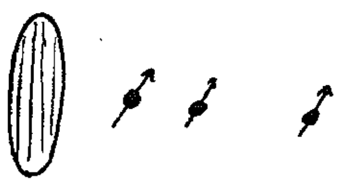


GIVE ALL ANSWERS THAT APPLY.

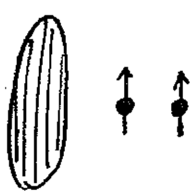
C)



D)



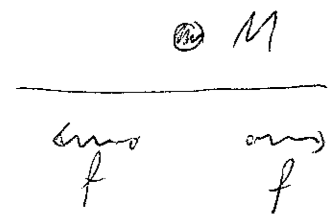
E)



(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)

ENERGY CONSERVATION :



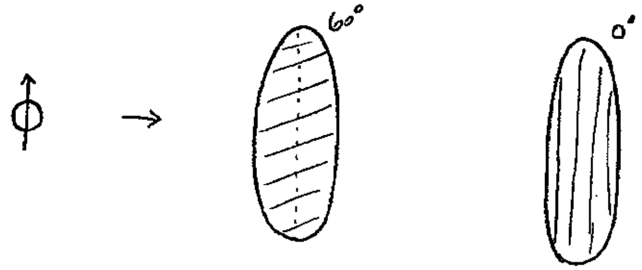
↓

$$Mc^2 = 2hf \Rightarrow f = \frac{Mc^2}{2h}$$

$$\lambda = \frac{c}{f} = \frac{2ch}{Mc^2} = \frac{2h}{Mc} = \frac{2 \cdot 6.62 \cdot 10^{-34} \cdot c}{(140 \frac{MeV}{c^2})(1.6 \cdot 10^{-19} \frac{J}{eV})}$$

$$= 1.77 \cdot 10^{-14} \text{ m} = 17.7 \text{ fm}$$

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)

~~ANGLE VERT~~ ANGLE BETWEEN VERTICAL & 60°: 60°

$\cos^2 60° = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$ ← PROB TO GET THROUGH 1ST

COMES OUT AT 60°!

ANGLE BETWEEN 60° & VERTICAL = 60°

$\cos^2 60° = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$ ← PROB FOR 2ND

PASS THROUGH BOTH:

$\left(\frac{1}{4}\right)\left(\frac{1}{4}\right) = \boxed{\frac{1}{16}}$

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)

$$p_{ch} = \gamma M v = \frac{1}{\sqrt{1-(4/5)^2}} M \frac{4}{5} c = \frac{4}{3} Mc$$

$$E_{ch} = \gamma M c^2 = \frac{5}{3} Mc^2$$

IN FRAME OF PLAIN DONUT: , $v = \frac{3}{5}c$, $\gamma(v) = \frac{5}{4}$

$$\tilde{p}_{ch} = \gamma \left(p_{ch} + \frac{v}{c^2} E_{ch} \right)$$

$$= \frac{5}{4} \left(\frac{4}{3} Mc + \frac{3}{5} \frac{5}{3} Mc \right)$$

$$= \frac{5}{4} \frac{7}{3} Mc = \frac{35}{12} Mc \ (-\hat{x})$$

$$(-\hat{x})\left(\frac{35}{12} Mc\right)$$

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).

$$E_p = \gamma M c^2 = \frac{5}{4} M c^2$$

$$p_p = \gamma M v = \frac{5}{4} M \frac{3}{5} c = \frac{3}{4} M c$$

$$p_{TOT} = p_p - p_{CM} = \left(\frac{3}{4} - \frac{4}{3}\right) M c = -\frac{7}{12} M c$$

$$E_{TOT} = E_p + E_{CM} = \frac{35}{12} M c^2$$

$$(c^2 M_{NEW})^2 = E_{TOT}^2 - (c\,p_{TOT})^2$$

$$= \left[\left(\frac{35}{12}\right)^2 - \left(\frac{7}{12}\right)^2\right] M^2 c^4$$

$$M_{NEW} = \sqrt{\frac{7^2(25-1)}{144}}\, M = ~~\frac{25/4}{12} M = \frac{25}{3} M~~$$

$$\frac{7 \cdot 2\sqrt{6}}{12} = \boxed{\frac{7\sqrt{6}}{6}} M$$