AP® Physics B
2002 Sample Student Responses

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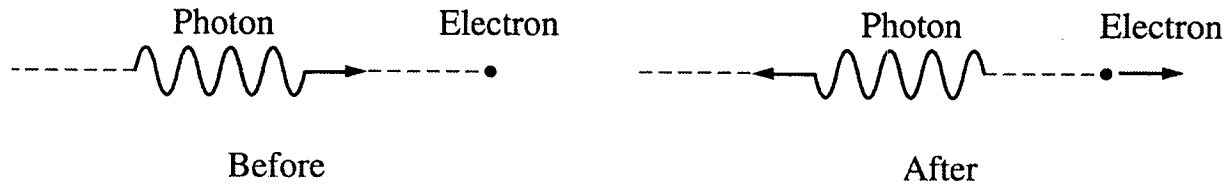

7. (10 points)

A photon of wavelength 2.0×10^{-11} m strikes a free electron of mass m_e that is initially at rest, as shown above left. After the collision, the photon is shifted in wavelength by an amount $\Delta\lambda = 2h/m_e c$, and reversed in direction, as shown above right.

(a) Determine the energy in joules of the incident photon.

$c = \lambda f$

$f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{2 \times 10^{-11}} = 1.5 \times 10^{19}\ Hz$

$E = hf$

$= (6.63 \times 10^{-34})(1.5 \times 10^{19}) = 9.95 \times 10^{-15}\ J$

(b) Determine the magnitude of the momentum of the incident photon.

$p = \frac{h}{\lambda}$

$E = hf = mc^2$

$hf = pc$

$p = \frac{hf}{c} = \frac{h}{\lambda}$

$p = \frac{6.63 \times 10^{-34}}{2 \times 10^{-11}}$

$p = 3.32 \times 10^{-23}\ \frac{kgm}{s}$

GO ON TO THE NEXT PAGE.

(c) Indicate below whether the photon wavelength is increased or decreased by the interaction.

✓ Increased ____Decreased

Explain your reasoning.

$E = hf \qquad f = \frac{c}{\lambda}$

$E = \frac{hc}{\lambda}$

- When the photon and the electron collide, the electron gains some energy from the photon, leaving the photon w/ less. B/c energy and λ are inversely proportional, when energy decreases, wavelength increases.

(d) Determine the magnitude of the momentum acquired by the electron.

$\Sigma \vec{p}_0 = \Sigma \vec{p}_f$

$\vec{p}_p + \vec{p}_e = \vec{p}_e' - \vec{p}_p'$

$\vec{p}_e' = \vec{p}_p + \vec{p}_p'$

$= \frac{h}{\lambda} + \frac{h}{\lambda'}$

$= 3.32 \times 10^{-23} + \frac{h}{2.49 \times 10^{-11}}$

$= 3.32 \times 10^{-23} + 2.67 \times 10^{-23}$

$\vec{p}_e' = 5.99 \times 10^{-23} \ \frac{kg\,m}{s}$

$\lambda' = \lambda + \frac{2h}{mc}$

$= 2 \times 10^{-11} + \frac{2(6.63 \times 10^{-34})}{(9.11 \times 10^{-31})(3 \times 10^{8})}$

$= 2.49 \times 10^{-11}$

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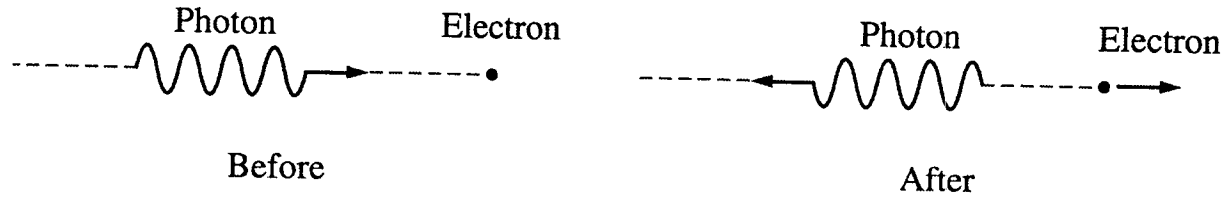

7. (10 points)

A photon of wavelength 2.0×10^{-11} m strikes a free electron of mass m_e that is initially at rest, as shown above left. After the collision, the photon is shifted in wavelength by an amount $\Delta\lambda = 2h/m_e c$, and reversed in direction, as shown above right.

(a) Determine the energy in joules of the incident photon.

$E = hf$ or $E = \frac{hc}{\lambda}$

$E = \frac{(6.63 \times 10^{-34}\ J \cdot s)(3 \times 10^{8})}{2.0 \times 10^{-11}}$

$E = 9.9 \times 10^{-15}\ J$

(b) Determine the magnitude of the momentum of the incident photon.

$p = \frac{h}{\lambda}$

$p = \frac{(6.63 \times 10^{-34})}{(20 \times 10^{-11})}$

$p = 3.3 \times 10^{-23}\ N \cdot s$

GO ON TO THE NEXT PAGE.

(c) Indicate below whether the photon wavelength is increased or decreased by the interaction.

X Increased ____Decreased

Explain your reasoning.

When the photon hit the electron it gave up some of it's energy to the electron. This energy is shown in the electrons Kinetic energy. If the photon looses energy then according to $E = \frac{hc}{\lambda}$ the wavelenght must have increased.

(d) Determine the magnitude of the momentum acquired by the electron.

$\Delta p = \frac{h}{\Delta \lambda}$

$\Delta p = \frac{h}{(2h/mec)}$

$\Delta p = 1.367 \times 10^{-22}$

according to the conservation of momentum

P_{lost} must equal P_{gained}

so the electron must gain 1.367×10^{-22} N·S

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