AP® PHYSICS B (Form B)
2007 SCORING GUIDELINES

General Notes About 2007 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point, and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive and expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics Course Description* .

4. The scoring guidelines typically show numerical results using the value $g = 9.8\ \mathrm{m/s^2}$, but use of $10\ \mathrm{m/s^2}$ is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 7

10 points total | **Distribution of points**

(a) 3 points

For using the correct equation for energy — 1 point

$E_e = m_e c^2$

For a correct calculation of the energy in joules — 1 point

$E_e = \left(9.11\times10^{-31}\text{ kg}\right)\left(3.00\times10^{8}\text{ m/s}\right)^2 = 8.20\times10^{-14}\text{ J}$

$E_e = \left(8.20\times10^{-14}\text{ J}\right)\big/\left(1.60\times10^{-19}\text{ J/eV}\right)$

For the correct answer in eV as instructed in the question — 1 point

$E_e = 5.12\times10^{5}\text{ eV}$ (answers in keV and MeV also accepted)

(b) 2 points

For recognizing that the photon energy must be twice that of one of the particles — 1 point

$E_\gamma = 2E_e$

For substituting the value of energy from part (a) — 1 point

$E_\gamma = 2\left(5.12\times10^{5}\text{ eV}\right)$

$E_\gamma = 1.02\times10^{6}\text{ eV}$

(c) 2 points

For a correct relationship between photon energy and wavelength — 1 point

$E_\gamma = hf = \dfrac{hc}{\lambda}$

For substituting the value of energy from part (b) — 1 point

$\lambda = \dfrac{hc}{E_\gamma} = \dfrac{1.24\times10^{3}\text{ eV}\bullet\text{nm}}{1.02\times10^{6}\text{ eV}}$

$\lambda = 1.22\times10^{-3}\text{ nm} = 1.22\times10^{-12}\text{ m}$

Question 7 (continued)

Distribution of points

(d) 3 points

For a correct relationship between photon wavelength and momentum — 1 point

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

For substituting the value of wavelength from part (c) — 1 point

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}\ \text{J}\bullet\text{s}}{1.22 \times 10^{-12}\ \text{m}}$$

For the correct answer with units consistent with the values substituted — 1 point

$p = 5.43 \times 10^{-22}\ \text{kg}\bullet\text{m/s}$ or equivalent (such as $3.39 \times 10^{-3}\ \text{eV}\bullet\text{s/m}$)

Alternate solution — *Alternate points*

For a correct relationship between photon energy and momentum — *1 point*

$$E_\gamma = pc$$

$$p = \frac{E_\gamma}{c} \quad \left(= \frac{2E_e}{c} = \frac{2m_e c^2}{c} = 2m_e c \right)$$

For substituting the value of energy from part (b) — *1 point*

$$p = \frac{\left(1.02 \times 10^6\ \text{eV}\right)\left(1.6 \times 10^{-19}\ \text{J/eV}\right)}{3.00 \times 10^8\ \text{m/s}} \qquad \left(\text{or}\ \ 2\left(9.11 \times 10^{-31}\ \text{kg}\right)\left(3 \times 10^8\ \text{m/s}\right)\right)$$

For units on the final answer consistent with the values substituted — *1 point*

$p = 5.44 \times 10^{-22}\ \text{kg}\bullet\text{m/s}$ $\left(\text{or } 5.46 \times 10^{-22}\ \text{kg}\bullet\text{m/s}\right)$ *or equivalent*

7. (10 points)

In the vicinity of a heavy nucleus, a high-energy photon can be converted into two particles: an electron and a positron. A positron has the same mass as the electron and equal but opposite charge. This process is called pair production.

(a) Calculate the rest energy of an electron, in eV.

$E = mc^2 = 9.11 \times 10^{-31} \times 9 \times 10^{16}$

$= 8.199 \times 10^{-14}\ J / 1.6 \times 10^{-19}\ c$

$E = 512,437.5\ eV$

(b) Determine the minimum energy, in eV, that a photon must have to give rise to pair production.

$E_{positron} = E_{electron}$, $E_{photon} = 2E_{electron}$.

$E_{photon} = 1.025 \times 10^6\ eV$

(c) Calculate the wavelength corresponding to the photon energy found in part (b).

$c = \lambda f \Rightarrow \lambda = c/f \Rightarrow f = c/\lambda$

$E = hf = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{1.24 \times 10^3\ eVnm}{1.025 \times 10^6\ eV}$

$\lambda = 1.210 \times 10^{-3}\ nm. = 1.210\ pm$

(d) Calculate the momentum of the photon.

$\lambda = \frac{h}{p} \Rightarrow p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{1.210 \times 10^{-3} \times 10^{-9}}$

$p = 5.48 \times 10^{-22}\ J$

$= 3.425 \times 10^{-3}\ eV$

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7. (10 points)

In the vicinity of a heavy nucleus, a high-energy photon can be converted into two particles: an electron and a positron. A positron has the same mass as the electron and equal but opposite charge. This process is called pair production.

(a) Calculate the rest energy of an electron, in eV.

$V=0$

$E = hf = pc = (mv)c$

$E = mc^2$

$= (9.11\times10^{-31})(3.0\times10^{8})$

$= 2.73\times10^{-22}\ J\left(\frac{1eV}{1.6\times10^{-19}J}\right) = .00171\ eV$

(b) Determine the minimum energy, in eV, that a photon must have to give rise to pair production.

$E_{required} = 2E$

$= 2(.00171eV)$

$E_{required} = .00342\ eV$

(c) Calculate the wavelength corresponding to the photon energy found in part (b).

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

$= \frac{1.24\times10^{3}}{.00342} = 362573\ nm$

$= 3.62\times10^{-4}\ m$

$= 36.2\ mm$

(d) Calculate the momentum of the photon.

$p = mv$

$= (9.11\times10^{-31})(3.0\times10^{8})$

$p = 2.73\times10^{-22}\ Kg\cdot m/s$

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7. (10 points) $\rightarrow e^{+}_{+}$

In the vicinity of a heavy nucleus, a high-energy photon can be converted into two particles: an electron and a positron. A positron has the same mass as the electron and equal but opposite charge. This process is called pair production.

(a) Calculate the rest energy of an electron, in eV.

$E = hf$

(b) Determine the minimum energy, in eV, that a photon must have to give rise to pair production.

$E = hf$

(c) Calculate the wavelength corresponding to the photon energy found in part (b).

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

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

from (b)

(d) Calculate the momentum of the photon.

$E = pc$

$E = (mc)c$

$E = mc^2$

$E =$

GO ON TO THE NEXT PAGE.

Question 7

Sample: B7A
Score: 9

The only deduction in this response was the loss of 1 point in part (d) for expressing the numerical answers using units of energy instead of momentum.

Sample: B7B
Score: 5

Part (a) received 1 point for the correct equation for energy; but in neglecting to square the speed of light, the student lost the point for the correct calculation for the energy in joules, and thus the final answer point was also not earned. Parts (b) and (c) each received 2 points full credit for consistent substitutions into correct equations, but part (d) received no credit.

Sample: B7C
Score: 3

The only points awarded for this response were 1 point each in parts (c) and (d) for the correct equations needed to start the calculations, and an additional point in part (c) for indicating that the energy to be used is the value from part (b).