General Notes About 2008 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 1 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 an 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 $g = 9.8 \text{ m/s}^2$, but use of 10 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 a correct equation relating energy and wavelength — 1 point

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

For correct substitutions (and conversions if necessary) — 1 point

$\lambda = \dfrac{hc}{E_\gamma} = \dfrac{\left(6.63 \times 10^{-34}\ \text{J}\cdot\text{s}\right)\left(3.00 \times 10^{8}\ \text{m/s}\right)}{\left(1.02 \times 10^{6}\ \text{eV}\right)\left(1.60 \times 10^{-19}\ \text{J/eV}\right)}$ OR

$\lambda = \dfrac{hc}{E_\gamma} = \dfrac{\left(1.24 \times 10^{3}\ \text{eV}\cdot\text{nm}\right)\left(10^{-9}\ \text{m/nm}\right)}{1.02 \times 10^{6}\ \text{eV}}$

For the correct answer with units — 1 point

$\lambda = 1.22 \times 10^{-12}\ \text{m}$

(b) 2 points

For correct use of the equation relating wavelength and momentum (or energy and momentum) and correct substitution of values — 1 point

$\lambda = \dfrac{h}{p_\gamma}$ (or $E = pc$)

$p_\gamma = \dfrac{h}{\lambda} = \dfrac{6.63 \times 10^{-34}\ \text{J}\cdot\text{s}}{1.22 \times 10^{-12}\ \text{m}}$ OR $p = \dfrac{E}{c} = \dfrac{\left(1.02 \times 10^{6}\ \text{eV}\right)\left(1.6 \times 10^{-19}\ \text{J/eV}\right)}{3.0 \times 10^{8}\ \text{m/s}}$

For the correct answer with units — 1 point

$p_\gamma = 5.43 \times 10^{-22}\ \text{kg}\cdot\text{m/s}$

(c) 3 points

For an indication that momentum is conserved — 1 point

$p_\gamma = p_{nuc}$

For a correct expression for the momentum of the nucleus — 1 point

$p_{nuc} = m_{nuc}\upsilon_{nuc}$

For either a correct substitution from part (b) or the correct answer — 1 point

$\upsilon_{nuc} = \dfrac{p_{nuc}}{m_{nuc}} = \dfrac{p_\gamma}{m_{nuc}} = \dfrac{5.43 \times 10^{-22}\ \text{kg}\cdot\text{m/s}}{4.48 \times 10^{-26}\ \text{kg}} = 1.21 \times 10^{4}\ \text{m/s}$

Question 7 (continued)

Distribution of points

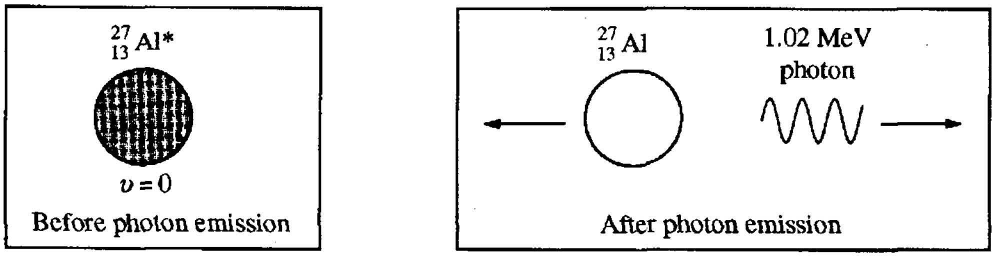
(d) 2 points

For correct use of the expression for kinetic energy — 1 point

$K_{nuc} = \frac{1}{2}mv_{nuc}^2$

For a correct substitution from part (c) — 1 point

$K_{nuc} = \frac{1}{2}\left(4.48 \times 10^{-26}\ \text{kg}\right)\left(1.21 \times 10^{4}\ \text{m/s}\right)^2 = 3.28 \times 10^{-18}\ \text{J}$



7. (10 points)

Following a nuclear reaction, a nucleus of aluminum is at rest in an excited state represented by $^{27}_{13}Al^*$, as shown above left. The excited nucleus returns to the ground state $^{27}_{13}Al$ by emitting a gamma ray photon of energy 1.02 MeV, as shown above right. The aluminum nucleus in the ground state has a mass of 4.48×10^{-26} kg. Assume nonrelativistic equations apply to the motion of the nucleus.

(a) Calculate the wavelength of the emitted photon in meters.

$$E = hf = h\frac{c}{\lambda}$$
$$\lambda = \frac{hc}{E} = \frac{1.24 \times 10^3 \, eV \cdot nm}{1.02 \times 10^6 \, eV} = 0.00122 \, nm$$

(b) Calculate the momentum of the emitted photon in kg•m/s.

$$\lambda = \frac{h}{p}$$
$$p_p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34} \, J \cdot s}{0.00122 \times 10^{-9} \, m} = 5.43 \times 10^{-22} \, kg \cdot m/s$$

(c) Calculate the speed of the recoiling nucleus in m/s.

$$p_{Al} + p_{Al} = p_{Al}' + p_p$$
$$p_{Al} = -p_p$$
$$m_{Al} v_{Al} = -5.43 \times 10^{-22} \, kg \cdot m/s$$
$$v_{Al} = \frac{-5.43 \times 10^{-22} \, kg \cdot m/s}{4.48 \times 10^{-26} \, kg} = 1.213 \times 10^4 \, m/s$$

(d) Calculate the kinetic energy of the recoiling nucleus in joules.

$$KE = \frac{1}{2} m_{Al} v_{Al}^2 = \frac{1}{2}(4.48 \times 10^{-26} \, kg)(1.213 \times 10^4 \, m/s)^2$$
$$= 3.296 \times 10^{-18} \, J$$

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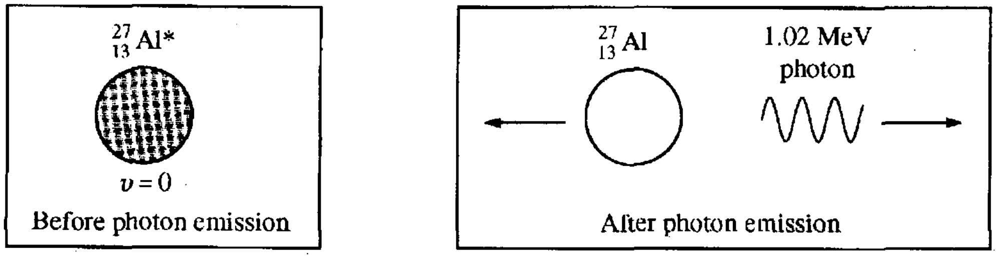

7. (10 points)

Following a nuclear reaction, a nucleus of aluminum is at rest in an excited state represented by $^{27}_{13}Al^*$, as shown above left. The excited nucleus returns to the ground state $^{27}_{13}Al$ by emitting a gamma ray photon of energy 1.02 MeV, as shown above right. The aluminum nucleus in the ground state has a mass of 4.48×10^{-26} kg. Assume nonrelativistic equations apply to the motion of the nucleus.

(a) Calculate the wavelength of the emitted photon in meters.

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

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

$E = (1.02 \times 10^6)(1.6 \times 10^{-19} J) = 1.632 \times 10^{-13}$

$\frac{hc}{E} = 1.22 \times 10^{-19}$ m

(b) Calculate the momentum of the emitted photon in kg•m/s.

$E = pc$

$\frac{E}{c} = p = \frac{1.632 \times 10^{-13} J}{3 \times 10^8} = p = 5.44 \times 10^{-22} \frac{kgm}{s}$

(c) Calculate the speed of the recoiling nucleus in m/s.

$0 = P_i = P_f = P_{pf} + P_{nf}$

$mv = P_{pf} = 5.44 \times 10^{-22}$

$(4.48 \times 10^{-26} kg)v = -5.44 \times 10^{-22}$

$V = -12100 m/s^2$

(d) Calculate the kinetic energy of the recoiling nucleus in joules.

$\frac{1}{2}mv^2 = \frac{1}{2}(4.48 \times 10^{-26} kg)(-12100)^2$

$= 3.30 \times 10^{-18} J$

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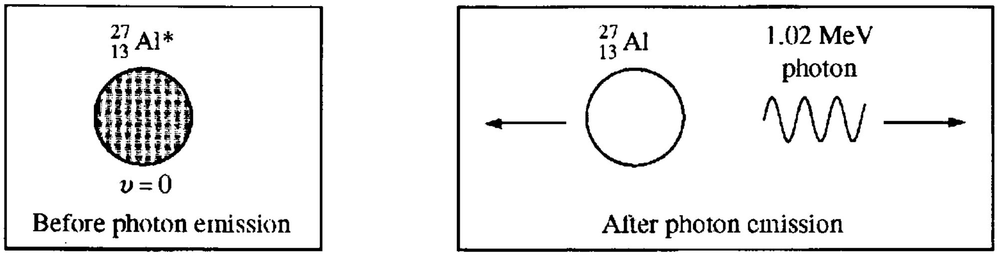

7. (10 points)

Following a nuclear reaction, a nucleus of aluminum is at rest in an excited state represented by $^{27}_{13}\text{Al}^*$, as shown above left. The excited nucleus returns to the ground state $^{27}_{13}\text{Al}$ by emitting a gamma ray photon of energy 1.02 MeV, as shown above right. The aluminum nucleus in the ground state has a mass of 4.48×10^{-26} kg. Assume nonrelativistic equations apply to the motion of the nucleus.

(a) Calculate the wavelength of the emitted photon in meters.

$1.02\ \text{MeV} = hf$

$1.02 * (10^6 * 1.6 * 10^{-19}) = 6.63 * 10^{-34} f$

$f = 2.46 * 10^{20} = \frac{c}{\lambda} \longrightarrow \lambda = \frac{c}{f} = \frac{3 * 10^8}{2.46 * 10^{20}} = \underline{1.219 * 10^{-12}\ \text{m}}$

(b) Calculate the momentum of the emitted photon in kg•m/s.

$hf = pc$

$2.46 * 10^{20} * 6.63 * 10^{-34} = pc$

$pc = 1.631 * 10^{-13}$

$p = 5.437 * 10^{-22}\ \text{kg} \cdot \text{m/s}$

(c) Calculate the speed of the recoiling nucleus in m/s.

(d) Calculate the kinetic energy of the recoiling nucleus in joules.

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AP® PHYSICS B
2008 SCORING COMMENTARY (Form B)

Question 7

Sample: B7A
Score: 10

The calculations in all four parts are correct, so full credit was awarded.

Sample: B7B
Score: 8

One point was awarded in part (a) for the correct equation relating energy and wavelength. The energy conversion is correct, but since the value for hc/E is incorrect no substitution or answer points were received. The remaining parts are correct and received full credit.

Sample: B7C
Score: 5

Full credit was awarded for parts (a) and (b). No work is performed in parts (c) and (d).