AP® PHYSICS B
2009 SCORING GUIDELINES (Form B)

General Notes About 2009 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 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 $10\ \text{m/s}^2$ 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.

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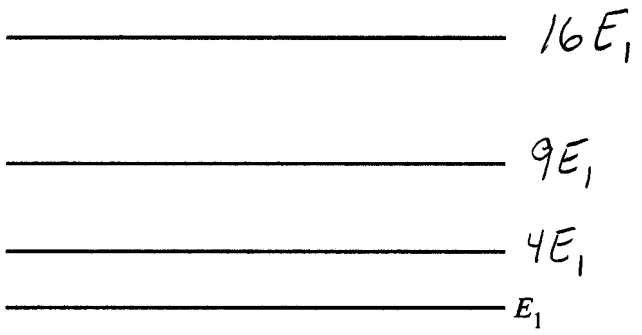
Question 6

10 points total **Distribution of points**

(a) 3 points



Note: Energy levels not drawn to scale.

The given equation, $E_n = n^2 E_1$, is used to calculate the other energies

One point for each correctly labeled energy level 3 points

(b) 2 points

From the relationship between frequency and energy, $\Delta E = hf$, it is seen that the smallest frequency corresponds to the smallest energy difference.

For a correct determination of the energy difference 1 point

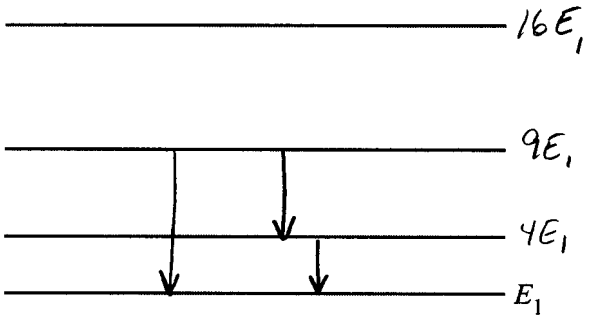
$\Delta E = 4E_1 - E_1 = 3E_1$

For a correct relationship between the minimum energy difference and the frequency 1 point

$hf = 3E_1$

$f = 3E_1/h$

(c) 2 points



Note: Energy levels not drawn to scale.

For the transition from $9E_1$ to E_1 1 point

For the pair of transitions from $9E_1$ to $4E_1$ and $4E_1$ to E_1 1 point

One point earned for this part was deducted for one extraneous line, and two or more extraneous lines resulted in no credit for this part.

Question 6 (continued)

Distribution of points

(d) 3 points

For a correct relationship between the maximum energy difference and the frequency 1 point

$hf = 9E_1 - E_1 = 8E_1$

$f = 8E_1/h$

For a correct relationship between the wavelength and frequency of the light 1 point

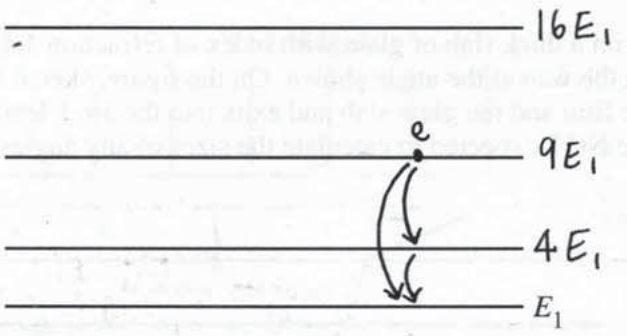
$f = c/\lambda$

A single equation that directly relates energy and wavelength could earn both points.

$c/\lambda = 8E_1/h$

For the correct answer 1 point

$\lambda = hc/8E_1$



Note: Energy levels not drawn to scale.

6. (10 points)

The electron energy levels above are for an electron confined to a certain very small one-dimensional region of space. The energy E_n of the levels, where $n = 1, 2, 3, \ldots$, is given by $E_n = n^2 E_1$. Express all algebraic answers in terms of E_1 and fundamental constants.

(a) On the diagram above, label the three excited energy levels with the values for their energies in terms of E_1, the energy of the ground state.

(b) Calculate the smallest frequency of light that can be absorbed by an electron in this system when it is in the ground state, $n = 1$.

$E = hf$ [h = Plank's constant]

→ smallest transition

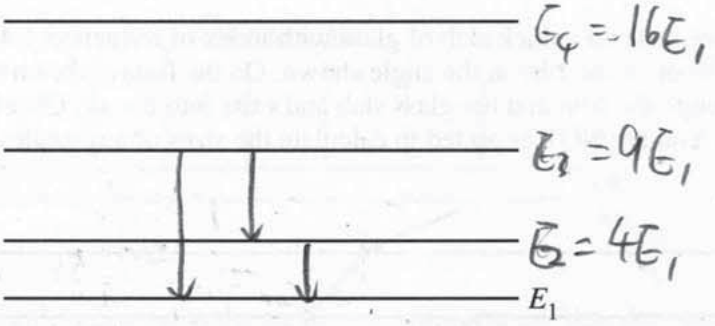
$$f = \frac{E}{h} = \frac{(4E_1 - E_1)}{h} = \frac{3E_1}{h}$$

(c) If an electron is raised into the second excited state, draw on the diagram all the possible transitions that the electron can make in returning to the ground state.

(d) Calculate the wavelength of the highest energy photon that can be emitted in the transitions in part (c).

$\lambda = \frac{hc}{E}$ highest energy = transition from $9E_1$ to E_1

$$\lambda = \frac{hc}{8E_1} \quad \text{or} \quad \frac{1240}{8E_1}$$



Note: Energy levels not drawn to scale.

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(a) On the diagram above, label the three excited energy levels with the values for their energies in terms of E_1, the energy of the ground state.

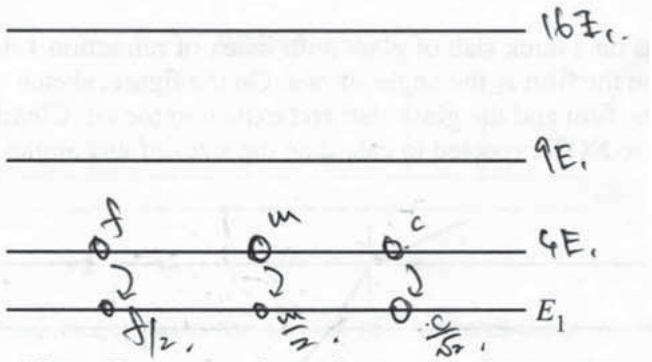
(b) Calculate the smallest frequency of light that can be absorbed by an electron in this system when it is in the ground state, $n = 1$.

$$hf = E_1$$
$$f = \frac{E_1}{h}$$

(c) If an electron is raised into the second excited state, draw on the diagram all the possible transitions that the electron can make in returning to the ground state.

(d) Calculate the wavelength of the highest energy photon that can be emitted in the transitions in part (c).

$$E_{max} = hf = 9E_1 - E_1 = 8E_1$$



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(a) On the diagram above, label the three excited energy levels with the values for their energies in terms of E_1, the energy of the ground state.

(b) Calculate the smallest frequency of light that can be absorbed by an electron in this system when it is in the ground state, $n = 1$.

$E = hf$. $\quad f = \frac{E_1}{h}$.

(c) If an electron is raised into the second excited state, draw on the diagram all the possible transitions that the electron can make in returning to the ground state.

(d) Calculate the wavelength of the highest energy photon that can be emitted in the transitions in part (c).

$\lambda = \frac{h}{p} = \frac{2h}{4E_1} = \frac{h}{2E_1}$.

AP® PHYSICS B
2009 SCORING COMMENTARY (Form B)

Question 6

Sample: B-6A
Score: 10

This response earned all possible points and exemplifies the expected responses to the question (except perhaps for the unconventional curved lines noting the transitions).

Sample: B-6B
Score: 6

Part (a) earned all 3 points. Part (b) earned no points since the energy difference must be used in the equation to receive credit. Part (c) earned both points. Part (d) earned 1 point for the correct energy difference.

Sample: B-6C
Score: 3

Part (a) received all 3 points, but no other points were earned. Part (b) required that the energy difference be used in the equation, which the response does not do. In part (c) it is not clear what is intended by the three identical transitions drawn with different labeling. While they could be interpreted as correct for one of the possible transitions, the pair of transitions in the two-step process must both be there to earn the point. Part (d) has the wrong equation.