# AP® PHYSICS B
# 2009 SCORING GUIDELINES

## 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.

## Question 6

**10 points total** | **Distribution of points**

(a) 2 points

For a meaningful attempt to use the equation $f = c/\lambda$ — 1 point

$f = (3.00 \times 10^8 \text{ m/s})/(550 \times 10^{-9} \text{ m})$

For the correct answer, with correct units — 1 point

$f = 5.5 \times 10^{14} \text{ Hz}$

(b) 3 points

For writing one or more equations that can be used to solve the problem — 1 point

$x \approx m\lambda L/d$ OR $d\sin\theta = m\lambda$ and $\sin\theta \approx x/L$ (or $\tan\theta \approx x/L$ )

For indicating that the calculation is for the spacing between fringes, rather than the position of a single fringe — 1 point

$\Delta x = \Delta m\lambda L/d$

Adjacent fringes means $\Delta m = 1$

$\Delta x = \lambda L/d$

For correct substitutions into the correct expression — 1 point

$\Delta x = (550 \times 10^{-9} \text{ m})(2.2 \text{ m})/(1.8 \times 10^{-5} \text{ m})$

$\Delta x = 0.067 \text{ m}$

(c) 2 points

For indicating that the frequency is the same as in part (a) — 2 points

$f = 5.5 \times 10^{14} \text{ Hz}$

Note: If there was no answer in part (a) and a calculation was done in this part, the scoring guideline for part (a) was applied.

(d) 3 points

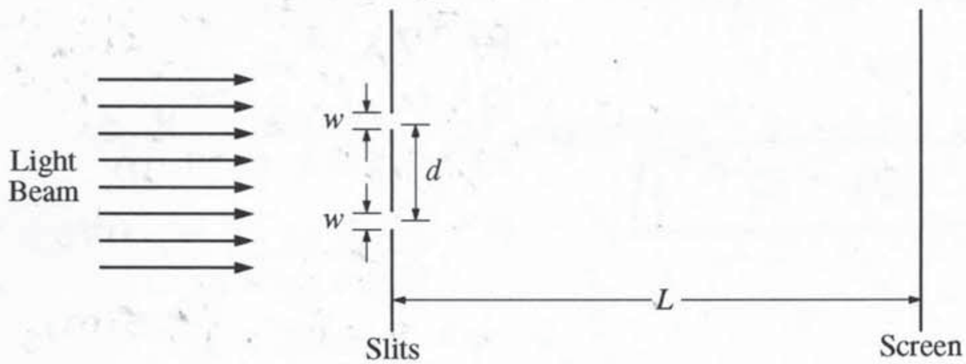
For correctly indicating that the fringe spacing decreases — 1 point

For indicating in the explanation that the wavelength decreases — 1 point

For indicating in the explanation that $\Delta x$ is proportional to the wavelength — 1 point

6. (10 points)

In a classroom demonstration, a beam of coherent light of wavelength 550 nm is incident perpendicularly onto a pair of slits. Each slit has a width $w$ of $1.2 \times 10^{-6}$ m, and the distance $d$ between the centers of the slits is $1.8 \times 10^{-5}$ m. The class observes light and dark fringes on a screen that is a distance $L$ of 2.2 m from the slits. Your notebook shows the following setup for the demonstration.




Note: Figure not drawn to scale.

(a) Calculate the frequency of the light.

$v = f\lambda$

$f = v/\lambda$

$f = c/\lambda$

$f = \dfrac{3.0 \times 10^{8}\ m/s}{550 \times 10^{-9}\ m}$

$f = 5.455 \times 10^{14}$ Hz

(b) Calculate the distance between two adjacent dark fringes on the screen.

$x_m \approx \dfrac{m\lambda L}{d}$

$x_m = \dfrac{1\ (550 \times 10^{-9}\ m)(2.2\ m)}{1.8 \times 10^{-5}\ m}$

$x_m = 0.067$ m

The entire apparatus is now immersed in a transparent fluid having index of refraction 1.4.

(c) What is the frequency of the light in the transparent fluid?

The frequency of the light will remain the same, $5.455 \times 10^{14}$ Hz.

(d) Does the distance between the dark fringes increase, decrease, or remain the same?

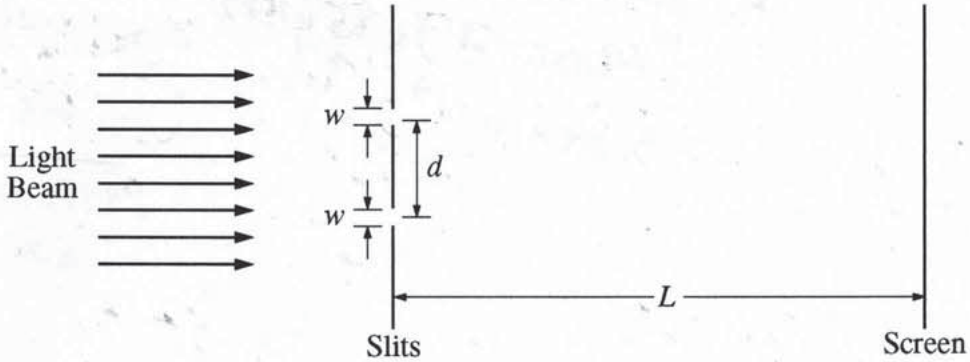
_____ Increase ✓ Decrease _____ Remain the same

Explain your reasoning.

In the liquid, the wavelength of the light will decrease, leading the distance between the fringes of light to be closer together as in the equation $x_m \approx \dfrac{m\lambda L}{d}$.

6. (10 points)

In a classroom demonstration, a beam of coherent light of wavelength 550 nm is incident perpendicularly onto a pair of slits. Each slit has a width $w$ of $1.2 \times 10^{-6}$ m, and the distance $d$ between the centers of the slits is $1.8 \times 10^{-5}$ m. The class observes light and dark fringes on a screen that is a distance $L$ of 2.2 m from the slits. Your notebook shows the following setup for the demonstration.




Note: Figure not drawn to scale.

(a) Calculate the frequency of the light.

$v = f\lambda$

$(3\times10^{8}) = f(550\times10^{-9})$

$f = 5.45\times10^{14}$ Hz

(b) Calculate the distance between two adjacent dark fringes on the screen.

$x_m = \frac{m\lambda L}{d}$

$= \frac{0.5(550\times10^{-9})(2.2)}{1.8\times10^{-5}}$

$= 0.0336$ m

$x_m = \frac{m\lambda L}{d}$

$= \frac{1.5(550\times10^{-9})(2.2)}{1.8\times10^{-5}}$

$= 0.1008$ m

$(0.1008) - (0.0336) = 0.0672$ m

The entire apparatus is now immersed in a transparent fluid having index of refraction 1.4.

(c) What is the frequency of the light in the transparent fluid?

$f = 5.45\times10^{14}$ Hz

(d) Does the distance between the dark fringes increase, decrease, or remain the same?

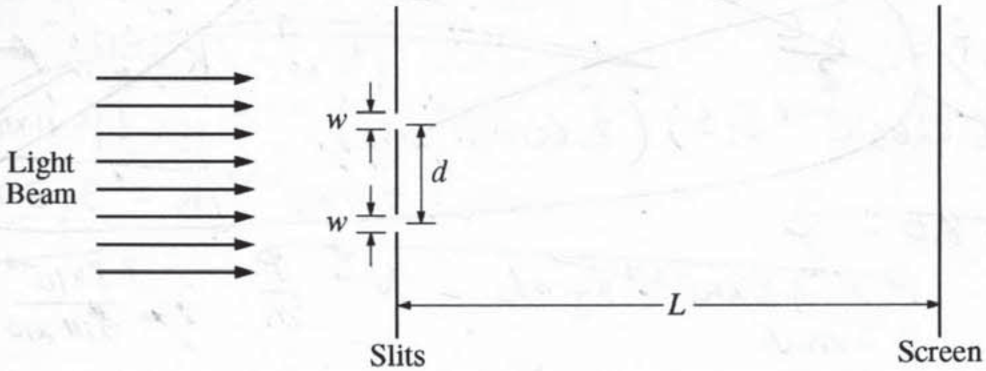
✓ Increase ______ Decrease ______ Remain the same

Explain your reasoning.

The immersion of the apparatus into a fluid with greater refraction causes the slits to become more spaced out, making the dark fringes more separated.

6. (10 points)

In a classroom demonstration, a beam of coherent light of wavelength 550 nm is incident perpendicularly onto a pair of slits. Each slit has a width $w$ of $1.2 \times 10^{-6}$ m, and the distance $d$ between the centers of the slits is $1.8 \times 10^{-5}$ m. The class observes light and dark fringes on a screen that is a distance $L$ of 2.2 m from the slits. Your notebook shows the following setup for the demonstration.




Note: Figure not drawn to scale.

(a) Calculate the frequency of the light.

$f = \frac{c}{\lambda}$ $\lambda = 5.50 \times 10^{-7}$ m

$c = 3.00 \times 10^{8}$ m/s

$f = \frac{3.00 \times 10^{8} \text{ m/s}}{5.50 \times 10^{-7} \text{ m}} =$ $5.45 \times 10^{14}$ HZ

(b) Calculate the distance between two adjacent dark fringes on the screen.

$x_m \sim \frac{m\lambda L}{d}$ $d = 1.8 \times 10^{-5}$ m

$\lambda = 5.50 \times 10^{-7}$ m

$x_m \sim$ $L = 2.2$ m

$m = 1$

$x_m \sim \frac{(5.5 \times 10^{-7})(2.2)}{(1.8 \times 10^{-5})}$

$x_m \sim .067$ m

The entire apparatus is now immersed in a transparent fluid having index of refraction 1.4.

(c) What is the frequency of the light in the transparent fluid?

$n = \frac{c}{v}$ $n = 1.4$ $\lambda = 550$ nm

$c = 3.00 \times 10^{8}$

$v = 2.1 \times 10^{8}$ m/s

$v = f\lambda$ $\frac{2.1 \times 10^{8} \text{ m/s}}{5.5 \times 10^{-7} \text{ m}} =$ $3.9 \times 10^{14}$ HZ

(d) Does the distance between the dark fringes increase, decrease, or remain the same?

_____ Increase _____ Decrease __✓__ Remain the same

Explain your reasoning.

The distance between the fringes relies on the wavelength. The wavelength of light never changes, so the distance would not change.

$x_m \sim \frac{m\lambda L}{d}$

## Question 6

### Overview

This question probed students' comprehension of optical waves and two-source (Young's) interference.

**Sample: B-6A**
**Score: 9**

The response earned all available points except in part (b), where there is no explicit indication of the use of $\Delta m$ and 1 point was lost. In part (d) the student nicely uses the equation from part (b) to establish the proportionality between spacing and wavelength.

**Sample: B-6B**
**Score: 7**

The responses to parts (a), (b), and (c) are correct and earned the maximum 7 points for those parts. Note that in part (b) the student calculates the positions of the first and second dark fringes and then subtracts to find the spacing. Part (d) is incorrect and earned no points.

**Sample: B-6C**
**Score: 4**

In part (a) the response earned both points. Part (b) lost 1 point because there is no explicit indication of the use of $\Delta m$. The errors in parts (c) and (d) both depend on the incorrect assumption that the wavelength remains the same, so these parts earned no points.