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 $g = 9.8 \text{ m}/\text{s}^2$, but use of $10 \text{ m}/\text{s}^2$ 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 5

10 points total | **Distribution of points**

(a) 2 points

Using the relationship for the speed of light inside a material: $n = c/v$

For correct substitutions — 1 point

$v_{oil} = c/n = \left(3.00 \times 10^8 \text{ m/s}\right)/1.7$

For the correct answer — 1 point

$v_{oil} = 1.8 \times 10^8 \text{ m/s}$

(b) 2 points

For using the relationship for the wavelength of light inside a material, which can be derived as follows: — 1 point

$f_{oil} = f_{air}$, and $f = v/\lambda$

$v_{oil}/\lambda_{oil} = v_{air}/\lambda_{air}$

$(c/n)/\lambda_{oil} = c/\lambda_{air}$

$\lambda_{oil} = \lambda_{air}/n$

For correct substitutions — 1 point

$\lambda_{oil} = \left(5.2 \times 10^{-7} \text{ m}\right)/1.7$

$\lambda_{oil} = 3.1 \times 10^{-7} \text{ m}$

(c) 3 points

There is a $180°$ phase shift when light is reflected at the lower interface, so for constructive interference the path length in the film must be an odd multiple of a half wavelength.

For any indication of the phase shift (e.g., a description as above or a $\lambda_{oil}/2$ correction in an equation such as $2t + \lambda_{oil}/2 = \lambda_{oil}$, where *t* is the thickness of the film) — 1 point

For work that correctly accounts for constructive interference (e.g., a description as in the first statement above for the net path length, or correct factors of λ in an equation as in the second statement above) — 1 point

$2t = \lambda_{oil}/2$

For substituting the correct value for the wavelength — 1 point

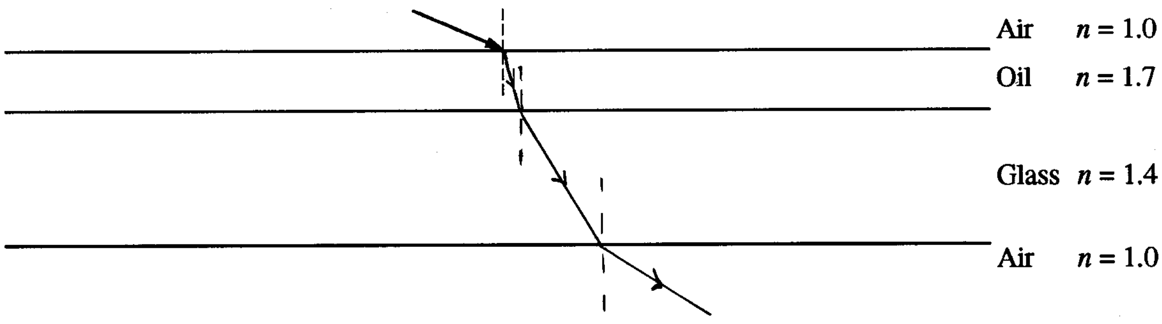
$t = \lambda_{oil}/4 = \left(3.1 \times 10^{-7} \text{ m}\right)/4$

$t = 7.8 \times 10^{-8} \text{ m}$

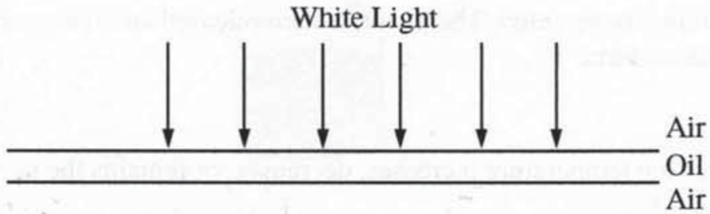
Question 5 (continued)

Distribution of points

(d) 3 points



For a ray at the first interface that bends toward the normal	1 point
For a ray at the second interface that bends away from the normal	1 point
For a ray at the third interface that bends away from the normal (This ray does <u>not</u> have to be parallel to the initial ray.)	1 point



5. (10 points)

A wide beam of white light is incident normal to the surface of a uniform oil film. An observer looking down at the film sees green light that has maximum intensity at a wavelength of 5.2×10^{-7} m. The index of refraction of the oil is 1.7.

(a) Calculate the speed at which the light travels within the film.

$$n_{AO} = \frac{n_o}{n_A} = \frac{V_A}{V_o} \Rightarrow \frac{1.7}{1.0} = \frac{3.0 \times 10^8}{V_o} \Rightarrow V_o \approx 1.8 \times 10^8 \text{ m/s}$$

(b) Calculate the wavelength of the green light within the film.

$$n_{AO} = \frac{n_o}{n_A} = \frac{\lambda_A}{\lambda_o} \Rightarrow \frac{1.7}{1.0} = \frac{5.2 \times 10^{-7}}{\lambda_o} \Rightarrow \lambda_o \approx 3.1 \times 10^{-7} \text{ m}$$

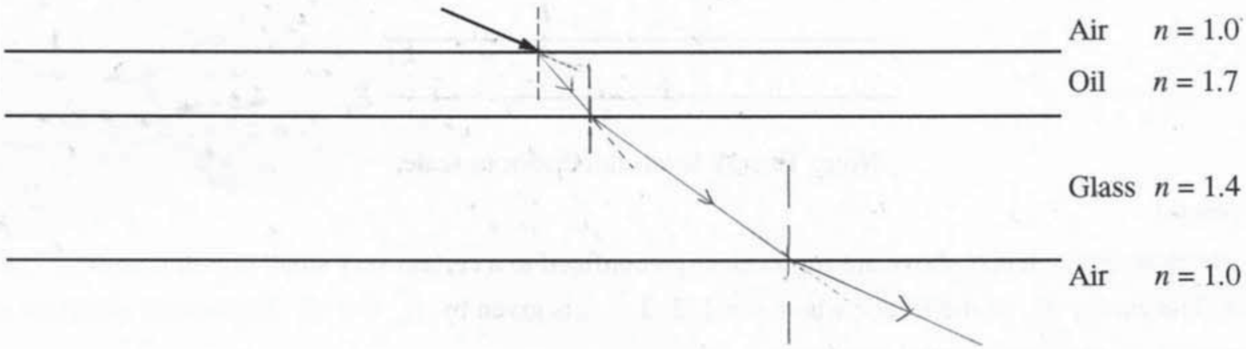
(c) Calculate the minimum possible thickness of the film.

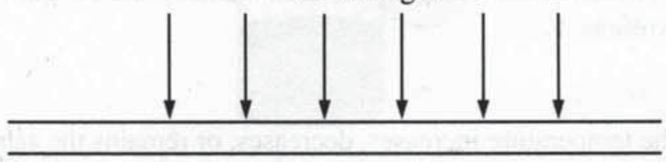
As light travels from a less dense to a denser material, the reflected light ray has a half-wavelength shift. Since a green light is observed when looking at the film, the light ray that comes out of the oil film must interfere constructively with the 1st light ray. ∴ It must undergo a $\frac{1}{2}$ wavelength shift as well.

$$\frac{1}{2}\lambda_o = 2d \Rightarrow d = \frac{1}{4}\lambda_o = \frac{1}{4}(3.1 \times 10^{-7})$$

$$\approx 0.76 \times 10^{-7} \text{ m}$$

(d) The oil film now rests on a thick slab of glass with index of refraction 1.4, as shown in the figure below. A light ray is incident on the film at the angle shown. On the figure, sketch the path of the refracted light ray that passes through the film and the glass slab and exits into the air. Clearly show any bending of the ray at each interface. You are NOT expected to calculate the sizes of any angles.





5. (10 points)

A wide beam of white light is incident normal to the surface of a uniform oil film. An observer looking down at the film sees green light that has maximum intensity at a wavelength of 5.2×10^{-7} m. The index of refraction of the oil is 1.7.

(a) Calculate the speed at which the light travels within the film.

$n = \frac{c}{v}$

$\Rightarrow v = \frac{c}{n} = \frac{3\times10^8}{1.7} = \boxed{1.7647\times10^8 \text{ m/s}}$

(b) Calculate the wavelength of the green light within the film.

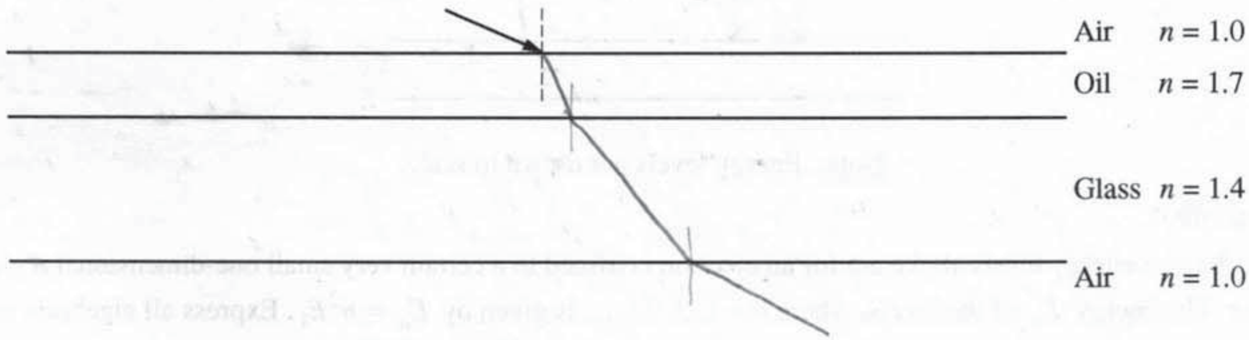
$c = f\lambda \Rightarrow f = \frac{c}{\lambda} = \frac{3\times10^8}{5.2\times10^{-7}} = 5.769\times10^{14}$ Hz.

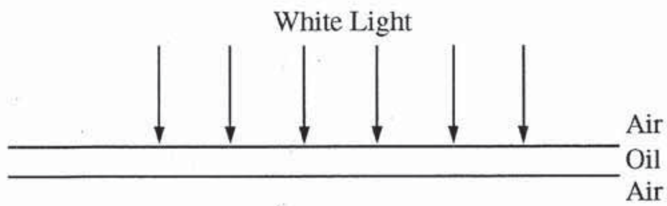
$\Rightarrow v' = f\times\lambda' \Rightarrow \lambda' = \frac{v'}{f} = \frac{1.7647\times10^8}{5.769\times10^{14}} = \boxed{3.06\times10^{-7} \text{ m.}}$

(c) Calculate the minimum possible thickness of the film.

$\boxed{3.06\times10^{-7} \text{ m}}$

(d) The oil film now rests on a thick slab of glass with index of refraction 1.4, as shown in the figure below. A light ray is incident on the film at the angle shown. On the figure, sketch the path of the refracted light ray that passes through the film and the glass slab and exits into the air. Clearly show any bending of the ray at each interface. You are NOT expected to calculate the sizes of any angles.





5. (10 points)

A wide beam of white light is incident normal to the surface of a uniform oil film. An observer looking down at the film sees green light that has maximum intensity at a wavelength of 5.2×10^{-7} m. The index of refraction of the oil is 1.7.

(a) Calculate the speed at which the light travels within the film.

$$\frac{V_{\text{light in vac}}}{V_{\text{oil}}} = 1.7 \qquad V_{\text{oil}} = \frac{3.00 \times 10^8}{1.7}$$

$$= 1.76 \times 10^8 \text{ m/s}$$

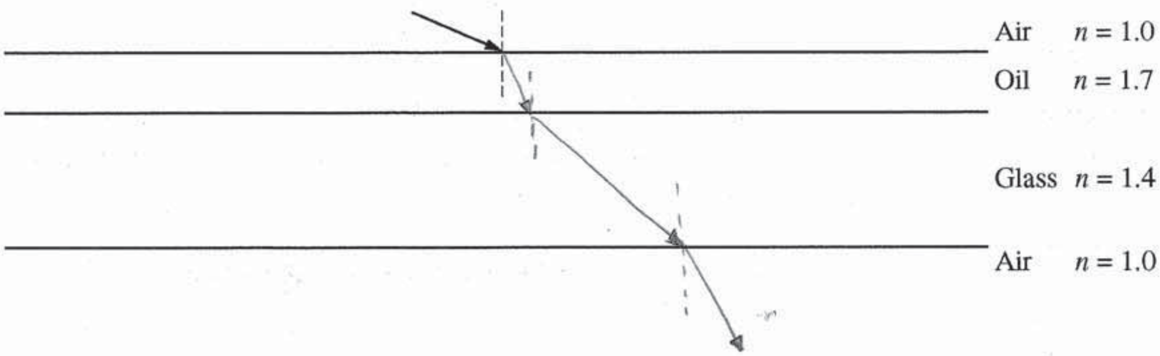
(b) Calculate the wavelength of the green light within the film.

$$\lambda = v/f$$

(c) Calculate the minimum possible thickness of the film.

$$t = \lambda = 5.2 \times 10^{-7} \text{ m}$$

(d) The oil film now rests on a thick slab of glass with index of refraction 1.4, as shown in the figure below. A light ray is incident on the film at the angle shown. On the figure, sketch the path of the refracted light ray that passes through the film and the glass slab and exits into the air. Clearly show any bending of the ray at each interface. You are NOT expected to calculate the sizes of any angles.



Question 5

Sample: B-5A
Score: 10

In the first two parts, the response explicitly includes the index of refraction of air and earned 2 points in each part. The paragraph describing the phase shift and interference condition in part (c) is very well written and earned all 3 points. Part (d) also earned 3 points. The dashed lines marking the continuation of rays make it very easy to see that each refraction is in the correct direction.

Sample: B-5B
Score: 7

Parts (a) and (b) each earned 2 points, and part (d) earned 3 points. In part (b) the student uses equations that allow substitution of the answer to part (a) in the calculation. All 3 points were lost in part (c), where the response consists of only the wavelength in the film.

Sample: B-5C
Score: 4

Part (a) earned the full 2 points. Parts (b) and (c) earned no points. Part (d) earned only 2 points since the last ray bends in the wrong direction.