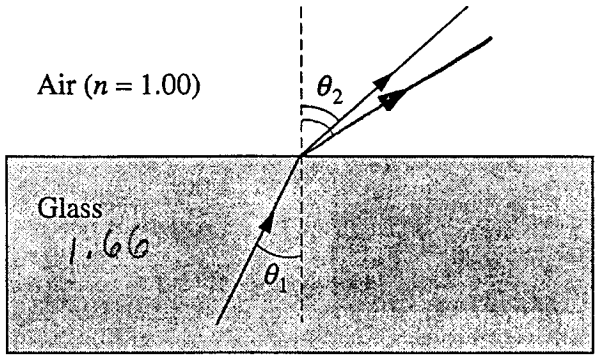
AP® Physics B
2001 Sample Student Responses

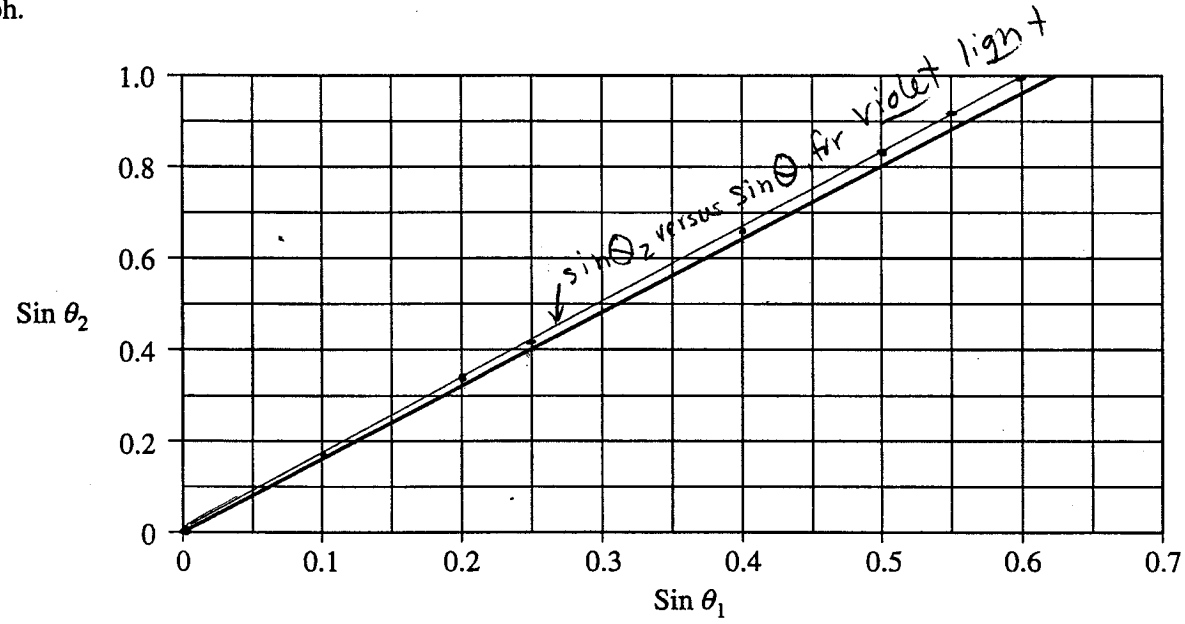
These materials were produced by Educational Testing Service (ETS), which develops and administers the examinations of the Advanced Placement Program for the College Board. The College Board and Educational Testing Service (ETS) are dedicated to the principle of equal opportunity, and their programs, services, and employment policies are guided by that principle.

The College Board is a national nonprofit membership association dedicated to preparing, inspiring, and connecting students to college and opportunity. Founded in 1900, the association is composed of more than 3,900 schools, colleges, universities, and other educational organizations. Each year, the College Board serves over three million students and their parents, 22,000 high schools, and 3,500 colleges, through major programs and services in college admission, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT®, the PSAT/NMSQT™, the Advanced Placement Program® (AP®), and Pacesetter®. The College Board is committed to the principles of equity and excellence, and that commitment is embodied in all of its programs, services, activities, and concerns.



4. (15 points)

In an experiment a beam of red light of wavelength 675 nm in air passes from glass into air, as shown above. The incident and refracted angles are θ_1 and θ_2, respectively. In the experiment, angle θ_2 is measured for various angles of incidence θ_1, and the sines of the angles are used to obtain the line shown in the following graph.



(a) Assuming an index of refraction of 1.00 for air, use the graph to determine a value for the index of refraction of the glass for the red light. Explain how you obtained this value.

I used Snells law → $N_1\sin\theta_1 = N_2\sin\theta_2$, and plugged in N_2 (The index of refraction given for glass), & $\sin\theta_1$ & $\sin\theta_2$ which I acquired from the graph. With this information I was able to determine N_1 (the index of refraction of the glass)

$N_1\sin\theta_1 = N_2\sin\theta_2$

$N_1(.25) = (1.00)(.4)$

$\frac{.25N_1}{.25} = \frac{.4}{.25}$

$N_1 = 1.6$

$N_1 = 1.6$

GO ON TO THE NEXT PAGE.

(b) For this red light, determine the following. $675\text{nm} = 675\text{m} \times 10^{-9} = 6.75\text{m} \times 10^{-7}$

i. The frequency in air

$N = \frac{c}{v}$ $\quad v = 3.0\times10^{8}\text{ m/s}$

$1.0 = \frac{3.0\times10^{8}\text{ m/s}}{v}$ $\quad v = f\lambda$

$3.0\times10^{8}\text{ m/s} = f(675\text{nm})$

$\frac{3.0\times10^{8}\text{ m/s}}{6.75\times10^{-7}\text{m}} = \frac{f(6.75\times10^{-7}\text{m})}{6.75\times10^{-7}\text{m}}$

$4.4\times10^{14}\text{ 1/sec} = f$

ii. The speed in glass

$N = \frac{c}{v}$ $\quad 1.6 = \frac{3.0\times10^{8}\text{ m/s}}{v}$

$\frac{1.6v}{1.6} = \frac{3.0\times10^{8}\text{ m/s}}{1.6}$

$v = 1.875\times10^{8}\text{ m/s}$

iii. The wavelength in glass

$v = f\lambda$

$\frac{1.875\times10^{8}\text{ m/s}}{4.4\times10^{14}\text{ 1/sec}} = \frac{(4.4\times10^{14}\text{ 1/sec})\lambda}{4.4\times10^{14}\text{ 1/sec}}$

$\lambda = 4.26\times10^{-7}\text{ m}$

frequency does not change!

(c) The index of refraction of this glass is 1.66 for violet light, which has wavelength 425 nm in air.

i. Given the same incident angle θ_1, show on the ray diagram on the previous page how the refracted ray for the violet light would vary from the refracted ray already drawn for the red light.

(the angle θ_2 would be slightly larger)

ii. Sketch the graph of sin θ_2 *versus* sin θ_1 for the violet light on the figure on the previous page that shows the same graph already drawn for the red light.

(d) Determine the critical angle of incidence θ_c for the violet light in the glass in order for total internal reflection to occur.

$\sin\theta_c = \frac{N_{low}}{N_{high}}$

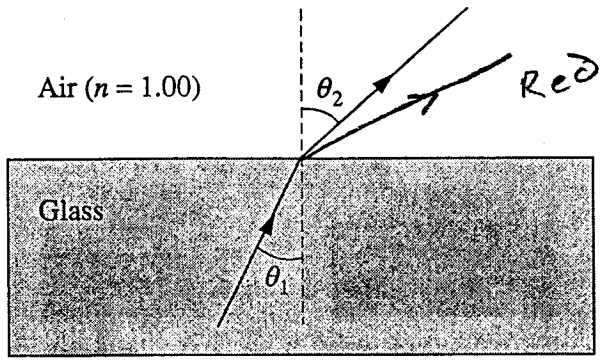
$\sin\theta_c = \frac{1.00}{1.66}$

$\theta_c = 37.04267\ldots$

$\theta_c \approx 37^\circ$

$\theta_c = 37^\circ$

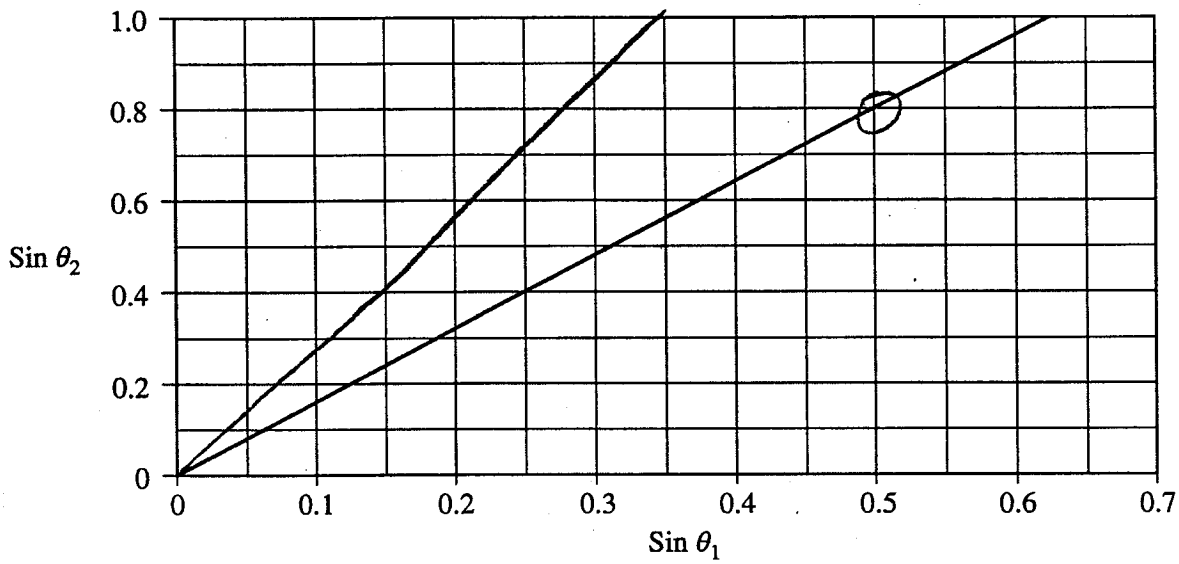
GO ON TO THE NEXT PAGE.



4. (15 points)

In an experiment a beam of red light of wavelength 675 nm in air passes from glass into air, as shown above. The incident and refracted angles are θ_1 and θ_2, respectively. In the experiment, angle θ_2 is measured for various angles of incidence θ_1, and the sines of the angles are used to obtain the line shown in the following graph.

Red light



(a) Assuming an index of refraction of 1.00 for air, use the graph to determine a value for the index of refraction of the glass for the red light. Explain how you obtained this value.

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n_2 = 1$

$1 \cdot .8 = n_1 \cdot .5$

$n_1 = \frac{.8}{.5}$

$n = 1.6$

GO ON TO THE NEXT PAGE.

(b) For this red light, determine the following.

i. The frequency in air

$$c = \lambda f$$
$$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{6.75 \times 10^{-7}} = 4.44 \times 10^{14}\ Hz$$

ii. The speed in glass

$$n = \frac{c}{v} \qquad v = \frac{c}{n} \qquad v = \frac{3 \times 10^8}{1.6}$$
$$v = 1.88 \times 10^8$$

iii. The wavelength in glass

$$n = \frac{\lambda_n}{\lambda_0} \qquad \lambda_n = n\lambda_0 \qquad \lambda_n = 1.6 \cdot 675 nm$$
$$\lambda_n = 1080 nm$$

(c) The index of refraction of this glass is 1.66 for violet light, which has wavelength 425 nm in air.

i. Given the same incident angle θ_1, show on the ray diagram on the previous page how the refracted ray for the violet light would vary from the refracted ray already drawn for the red light.

ii. Sketch the graph of sin θ_2 *versus* sin θ_1 for the violet light on the figure on the previous page that shows the same graph already drawn for the red light.

(d) Determine the critical angle of incidence θ_c for the violet light in the glass in order for total internal reflection to occur.

$$\sin\theta_c = \frac{n_2}{n_1}$$
$$\sin\theta_c = \frac{1}{1.66}$$
$$\theta_c = 37.0^\circ$$

GO ON TO THE NEXT PAGE.