



AP[®] Physics B 2003 Sample Student Responses Form B

The materials included in these files are intended for use by AP teachers for course and exam preparation; permission for any other use must be sought from the Advanced Placement Program[®]. Teachers may reproduce them, in whole or in part, in limited quantities for noncommercial, face-to-face teaching purposes. This permission does not apply to any third-party copyrights contained herein. This material may not be mass distributed, electronically or otherwise. These materials and any copies made of them may not be resold, and the copyright notices must be retained as they appear here.

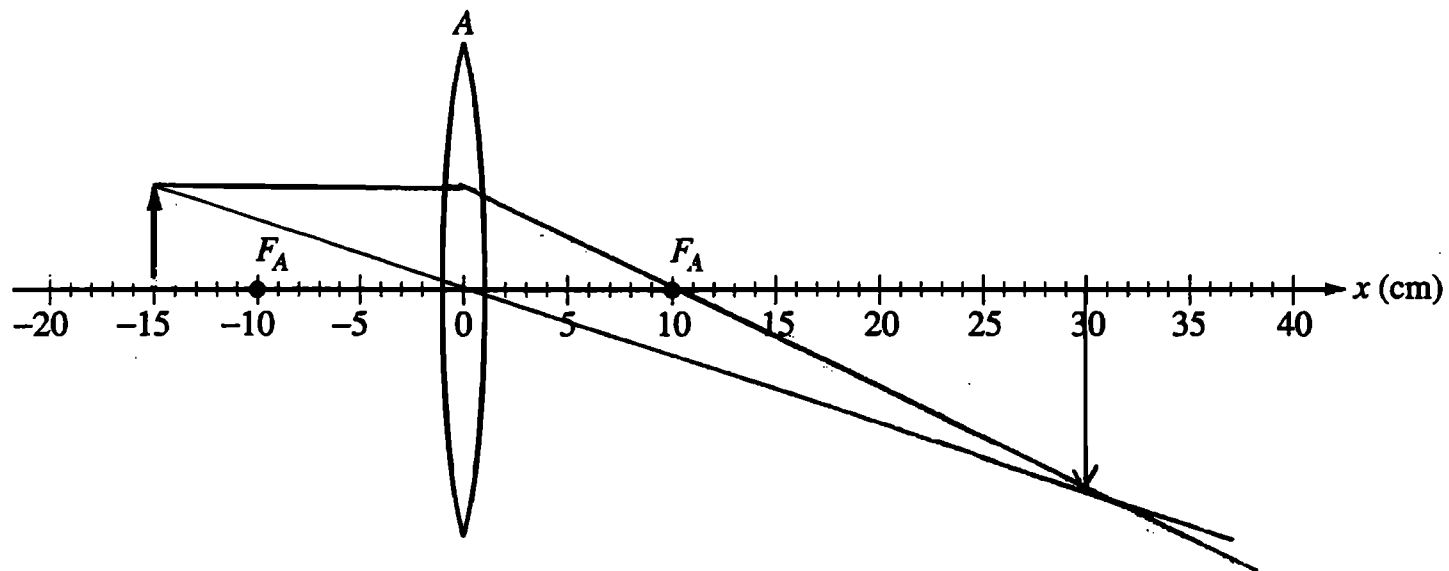
These materials were produced by Educational Testing Service[®] (ETS[®]), which develops and administers the examinations of the Advanced Placement Program for the College Board. The College Board and Educational Testing Service (ETS) are dedicated to the principle of equal opportunity, and their programs,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

The College Board is a national nonprofit membership association whose mission is to prepare, inspire, and connect students to college and opportunity. Founded in 1900, the association is composed of more than 4,300 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 admissions, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT[®], the PSAT/NMSQT[®], and the Advanced Placement Program[®] (AP[®]). 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.

For further information, visit www.collegeboard.com

Copyright © 2003 College Entrance Examination Board. All rights reserved. College Board, Advanced Placement Program, AP, AP Vertical Teams, APCD, Pacesetter, Pre-AP, SAT, Student Search Service, and the acorn logo are registered trademarks of the College Entrance Examination Board. AP Central is a trademark owned by the College Entrance Examination Board. PSAT/NMSQT is a registered trademark jointly owned by the College Entrance Examination Board and the National Merit Scholarship Corporation. Educational Testing Service and ETS are registered trademarks of Educational Testing Service. Other products and services may be trademarks of their respective owners.

For the College Board's online home for AP professionals, visit AP Central at apcentral.collegeboard.com.



3. (15 points)

A thin convex lens A of focal length $f_A = 10$ cm is positioned on an x -axis as shown above. An object of height 5 cm, represented by the arrow, is positioned 15 cm to the left of lens A .

(a) On the figure above, draw necessary rays and sketch the image produced by lens A .

(b) Calculate the location of the image produced by lens A .

Cal S_i

$$\frac{1}{S_i} + \frac{1}{S_o} = \frac{1}{f}$$

$$\frac{1}{S_i} = \frac{1}{f} - \frac{1}{S_o}$$

$$= \frac{1}{10\text{cm}} - \frac{1}{15\text{cm}}$$

$$S_i = 30\text{cm}$$

$$\therefore S_i = 30\text{cm}$$

(c) Calculate the height of the image produced by lens A .

Cal h_i

$$M = \frac{h_i}{h_o} \quad M = -\frac{S_i}{S_o}$$

$$\frac{h_i}{h_o} = -\frac{S_i}{S_o}$$

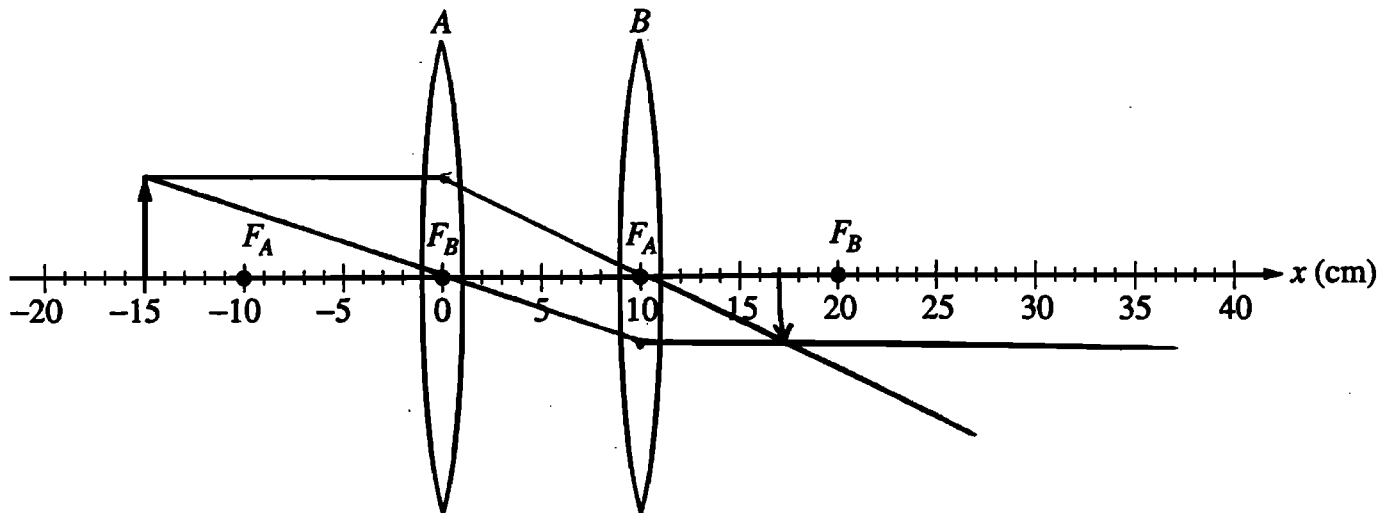
$$h_i = -\frac{S_i \cdot h_o}{S_o}$$

$$= -\frac{30\text{cm} \times 5\text{cm}}{15\text{cm}}$$

$$= -10\text{cm}$$

$$\therefore h_i = 10\text{cm downwards} \\ (= -10\text{cm})$$

GO ON TO THE NEXT PAGE.



A second thin convex lens B of focal length $f_B = 10$ cm is now positioned 10 cm to the right of lens A , as shown above.

(d) Determine the location on the x -axis given above of the final image produced by the combination of lenses.

Let's assume F_A is at 0 cm.

→ $F_B = -10$ cm & object is at -25 cm

Cal S_i

$$\frac{1}{S_i} + \frac{1}{S_o} = \frac{1}{f}$$

$$\frac{1}{S_i} = \frac{1}{f} - \frac{1}{S_o}$$

$$= \frac{1}{f_B} - \frac{1}{S_o}$$

$$= \frac{1}{10\text{cm}} - \left(\frac{1}{25\text{cm}} \right)$$

$$S_i \approx 17\text{cm}$$

$$\therefore S_i = 17\text{cm}$$

(e) Check the appropriate spaces below to indicate the characteristics of the final image produced by the combination of lenses.

inverted

larger than the original object

upright

smaller than the original object

Explain your answers.

Inverted: Rays start from the tip of the arrow (upright) and they meet at one point below x -axis. This indicates the tip of the arrow points downwards, thus inverted.

Smaller: According to the calculation below determining the length of the image, the final image is 3.4 cm, thus smaller than the real object.

Cal h_i

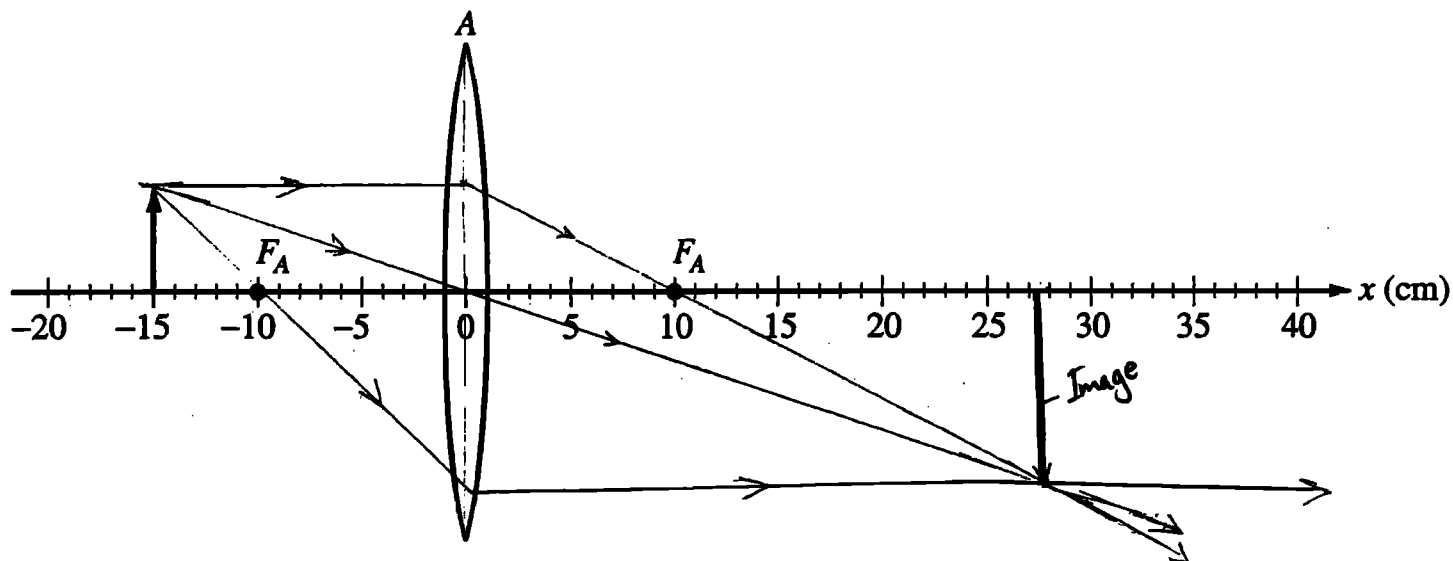
$$\frac{h_i}{h_o} = -\frac{S_i}{S_o}$$

$$h_i = -\frac{S_i h_o}{S_o}$$

$$= -\frac{(17\text{cm})(5\text{cm})}{25\text{cm}}$$

$$= -3.4\text{cm}$$

GO ON TO THE NEXT PAGE.



3. (15 points)

A thin convex lens A of focal length $f_A = 10$ cm is positioned on an x -axis as shown above. An object of height 5 cm, represented by the arrow, is positioned 15 cm to the left of lens A.

(a) On the figure above, draw necessary rays and sketch the image produced by lens A.

(b) Calculate the location of the image produced by lens A.

$$\begin{aligned} \frac{1}{d_o} + \frac{1}{d_i} &= \frac{1}{f} \\ \therefore \frac{1}{d_i} &= \frac{1}{f} - \frac{1}{d_o} \\ \frac{1}{d_i} &= \frac{1}{10} - \frac{1}{15} = \frac{1}{30} \\ \therefore d_i &= 30 \text{ cm.} \end{aligned}$$

\therefore Image position = 30 cm behind the lens.

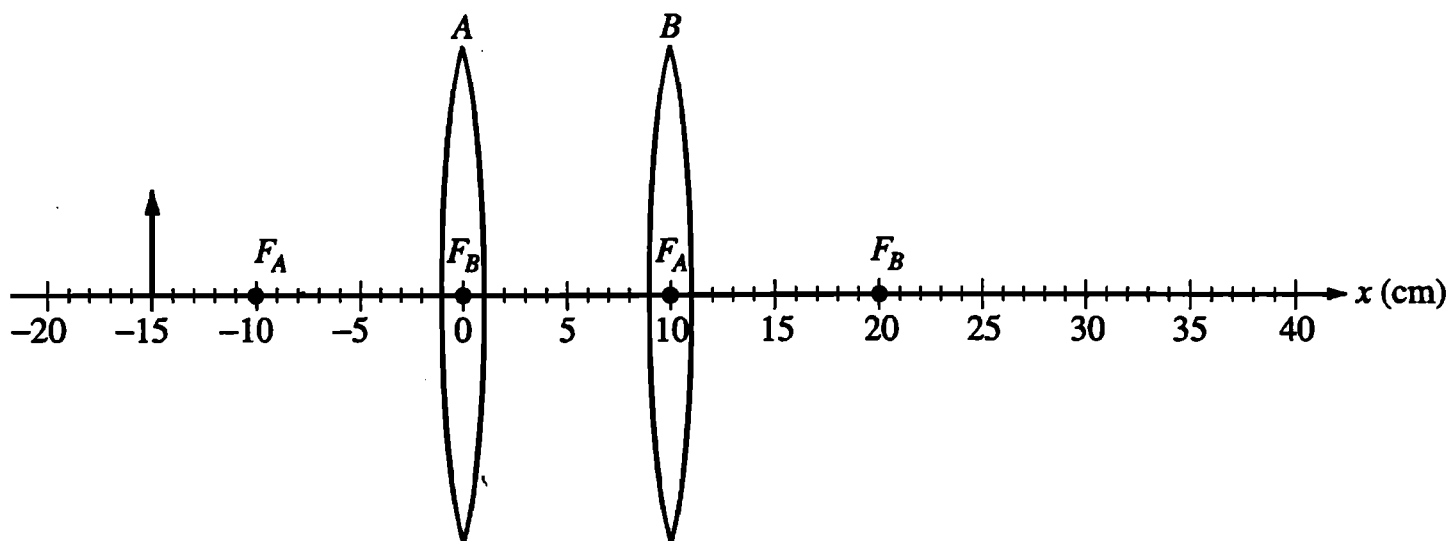
(c) Calculate the height of the image produced by lens A.

$$M = \frac{-d_i}{d_o} = \frac{-30}{15} = -2$$

$$\begin{aligned} \therefore h_o &= |M| d_i \\ &= 2 \times 5 \text{ cm} = 10 \text{ cm.} \end{aligned}$$

\therefore Height of the image = 10 cm.

GO ON TO THE NEXT PAGE.



A second thin convex lens B of focal length $f_B = 10$ cm is now positioned 10 cm to the right of lens A , as shown above.

(d) Determine the location on the x -axis given above of the final image produced by the combination of lenses.

$\therefore d_o = 20$ cm from lens B , virtual image.

$$\begin{aligned} \therefore \frac{1}{d_i} &= \frac{1}{f} - \frac{1}{d_o} \\ &= \frac{1}{10} + \frac{1}{20} = \frac{3}{20} \end{aligned}$$

$$\frac{d_i}{d_o} = -\frac{f}{20}$$

$$\therefore d_i = 6.67 \text{ cm}$$

\therefore Image position = 6.67 cm to the right of lens B .

(e) Check the appropriate spaces below to indicate the characteristics of the final image produced by the combination of lenses.

inverted

larger than the original object

upright

smaller than the original object

Explain your answers.

GO ON TO THE NEXT PAGE.