

**EXAM 5**

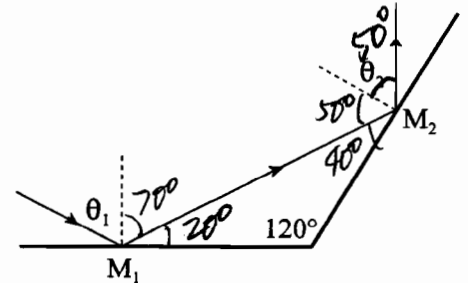
1

Name: Famion unid: u \_\_\_\_\_

Discussion TA (circle): Adam Bill Doug Eric

- A. [6 pts.] Two plane mirrors are separated by  $120^\circ$ , as the drawing illustrates. If a ray strikes mirror  $M_1$  at a  $\theta_1 = 70^\circ$  angle of incidence, at what angle  $\theta_2$  does it leave mirror  $M_2$ ?

50°



- B. [7 pts.] An object is placed in front of a converging lens in such a position that the lens ( $f = 13.0$  cm) creates a real image located 24.0 cm from the lens. Then, with the object remaining in place, the lens is replaced with another converging lens ( $f = 17.0$  cm). A new, real image is formed. What is the image distance of this new image?

$$\frac{1}{d_o} = \frac{1}{f_1} - \frac{1}{d_i}$$

$$\frac{1}{d_i} = \frac{1}{f_2} - \frac{1}{d_o} = \frac{1}{f_2} - \frac{1}{f_1} + \frac{1}{d_i}$$

$$= \frac{1}{17} - \frac{1}{13} + \frac{1}{24}$$

$$\Rightarrow d_i = 42.4 \text{ cm}$$

- C. [6 pts.] A convex mirror has a radius of curvature of 72 cm. The image formed by this mirror is 10.1 cm from the mirror. What is the object distance?

$$\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i}$$

$$= \frac{1}{(-\frac{1}{2}R)} - \frac{1}{d_i} = -\frac{1}{36} - \frac{1}{(10.1)}$$

$$\Rightarrow d_o = 14.04 \text{ cm}$$

- D. [6 pts.] A farsighted woman breaks her current eyeglasses and is using an old pair whose refractive power is 1.655 diopters. Since these eyeglasses do not completely correct her vision, she must hold a newspaper 42.00 cm from her eyes in order to read it. She wears the eyeglasses 2.50 cm from her eyes. How far is her near point from her eyes?

$$\frac{1}{f} = 1.655 \text{ (diopters)}$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}, \quad d_o = 42 - 2.5 = 39.5 \text{ cm}$$

$$\frac{1}{d_i} = +1.655 - \frac{1}{39.5 \times 10^{-2}} \Rightarrow d_i = -1.1407 \text{ (m)}$$

(from the eyeglasses)

so  
 $N_p = 114.07 + 2.5$   
 $= 116.07 \text{ cm}$

# EXAM 5

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Name: \_\_\_\_\_ unid: u \_\_\_\_\_

Discussion TA (circle): Adam Bill Doug Eric

- A. [6 pts.] A ray of light impinges from air onto a block of ice ( $n = 1.309$ ) at a  $52.0^\circ$  angle of incidence. Assuming that this angle remains the same, find the difference  $\theta_{ice} - \theta_{water}$  in the angles of refraction when the ice turns to water ( $n = 1.333$ ).



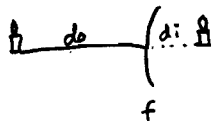
$$n_1 \sin \theta_i = n_{ice} \sin \theta_{ice} \rightarrow \theta_{ice} = \sin^{-1} \left( \frac{(1)}{(1.309)} \sin 52 \right)$$



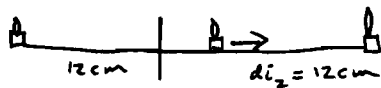
$$n_1 \sin \theta_i = n_{water} \sin \theta_{water} \rightarrow \theta_{water} = \sin^{-1} \left( \frac{(1)}{(1.333)} \sin 52 \right)$$

$$\theta_{ice} - \theta_{water} = 37.012^\circ - 36.239^\circ = \boxed{0.774^\circ}$$

- B. [6 pts.] A candle is placed 12.0 cm in front of a convex mirror. When the convex mirror is replaced with a plane mirror, the image moves 8.5 cm farther away from the mirror. Find the focal length of the convex mirror.



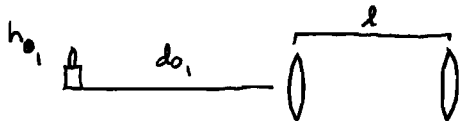
$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \quad \text{and} \quad d_i = -(12\text{cm} - 8.5\text{cm})$$



plane mirror has exact reflection  $\rightarrow -d_i = d_o$

$$\boxed{f = -4.94\text{cm}}$$

- C. [13 pts.] Two identical converging lenses with  $f = 30.0$  cm are 70.0 cm apart. A 12.0 cm tall object is placed 100.0 cm in front of the first lens. What is the final height of the object (including sign)?



1st lens:

$$\frac{1}{f_1} = \frac{1}{d_{i1}} + \frac{1}{d_{o1}} \rightarrow d_{i1} = 42.857\text{cm}$$

$$d_{o2} = L - d_{i1} = 70\text{cm} - 42.857\text{cm} = 27.14\text{cm}$$

magnification

$$M = m_1 m_2$$

2nd lens:

$$\frac{1}{f_2} = \frac{1}{d_{i2}} + \frac{1}{d_{o2}} \rightarrow d_{i2} = -284.68\text{cm}$$

$$m_1 = \frac{-d_{i1}}{d_{o1}}$$

$$h_{2i} = M_2 h_{2o} = M_2 M_1 h_{o1} = -4.5 (12\text{cm})$$

$$m_2 = \frac{-d_{i2}}{d_{o2}}$$

$$= \boxed{-54\text{cm}}$$

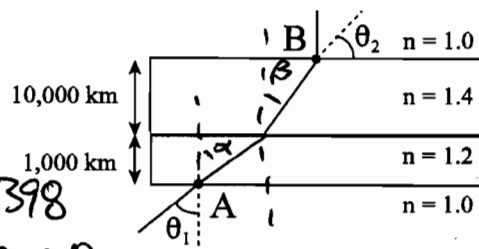
# EXAM 5

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Name: \_\_\_\_\_ unid: u \_\_\_\_\_

Discussion TA (circle): Adam Bill Doug Eric

A. The drawing shows the path of a beam of light through several layers of different indices of refraction. Let  $\theta_1 = 62^\circ$ . Show each step and calculate each intermediate angle.



1. [9 pts.] What is  $\theta_2$ ?

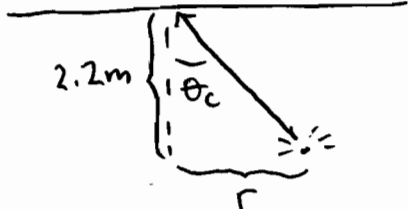
$$\begin{aligned} (1) \quad \sin 62 &= (1.2) \sin \alpha & \alpha &= 47.37398 \\ (1.2) \sin (47.37) &= (1.4) \sin \beta & \beta &= 39.10008 \\ (1.4) \sin (39.10008) &= (1) \sin \theta_2' & \theta_2' &= 62 \\ \theta_2 &= 90 - 62 = \boxed{28^\circ} \end{aligned}$$

2. [7 pts.] How much time does it take for light to go from A to B?

$$\begin{aligned} t_{\text{tot}} &= \frac{d_1}{v_1} + \frac{d_2}{v_2} = \frac{(1000000\text{m})(1.2)}{(3e8\frac{\text{m}}{\text{s}}) \cos(47.37)} + \frac{(10000000\text{m})(1.4)}{(3e8\frac{\text{m}}{\text{s}}) \cos(39.10008)} \\ &= 5.906675 \times 10^{-3} + 6.0134542 \times 10^{-2} = \boxed{6.604 \times 10^{-2} \text{ s}} \end{aligned}$$

B. [9 pts.] A point source of light is submerged 2.2 m below the surface of a lake ( $n = 1.33$ ) and emits rays in all directions. On the surface of the lake, directly above the source, the area illuminated is a circle. What is the maximum area that this circle could have?

Max area occurs at critical angle



$$\sin \theta_c = \frac{n_1}{n_2} = \frac{1}{1.33} \Rightarrow \theta_c = 48.75347^\circ$$

$$\tan \theta_c = \frac{r}{2.2} \Rightarrow r = (2.2\text{m})(\tan 48.75) = 2.50893\text{m}$$

$$\text{Area} = \pi r^2 = \pi (2.50893\text{m})^2 = \boxed{19.775 \text{ m}^2}$$

EXAM 5

4

Name: F. C. W. 101 unid: u \_\_\_\_\_

Discussion TA (circle): Adam Bill Doug Eric

A. [7 pts.] A shaving/makeup mirror produces an upright image that is magnified by a factor of 2.0 when your face is 25 cm from the mirror. Find the radius of curvature of the mirror.

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$m = -d_i/d_o \Rightarrow d_i = -m d_o$$

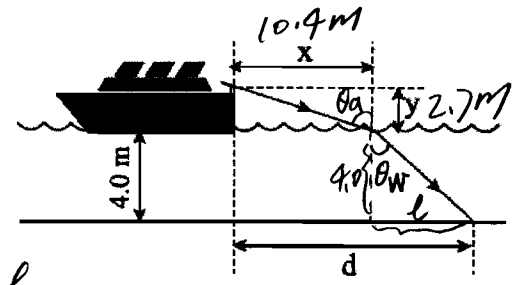
$$\frac{1}{f} = \frac{1}{d_o} - \frac{1}{m d_o} = \frac{1}{d_o} \left(1 - \frac{1}{m}\right)$$

$$= \frac{1}{d_o} \left(1 - \frac{1}{2}\right) = \frac{1}{2d_o}$$

$$f = 2d_o$$

Concave:  $R = 2f = 4d_o$   
 $= 4 \times 25 = 100 \text{ cm} = 1.0 \text{ m}$

B. [11 pts.] A spotlight on a boat is  $y = 2.7 \text{ m}$  above the water ( $n = 1.33$ ), and the light strikes the water at a point that is  $x = 10.4 \text{ m}$  horizontally displaced from the spotlight (see the drawing). The depth of the water is  $4.0 \text{ m}$ . Determine the distance  $d$ , which locates the point where the light strikes the bottom from the boat.



$$n_a \sin \theta_a = n_w \sin \theta_w$$

$$\theta_w = \sin^{-1} \left( \frac{1}{n_w} \sin \theta_a \right)$$

$$\sin \theta_a = \frac{x}{\sqrt{x^2 + y^2}} = \frac{10.4}{\sqrt{(10.4)^2 + (2.7)^2}}$$

$$= 0.968$$

$$\theta_w = \sin^{-1} \left( \frac{1}{1.33} \times 0.968 \right) = 46.7^\circ$$

$$l = 4.0 \tan \theta_w = 4 \tan 46.7^\circ = 4.245 \text{ m}$$

$$d = x + l = 10.4 + 4.245 = 14.645 \text{ m}$$

C. [7 pts.] A tourist takes a picture of a mountain 14 km away using a camera that has a lens with a focal length of 50 mm. She then takes a second picture when she is only 6.0 km away. What is the ratio of the height of the mountain's image on the film for the second picture to its height on the film for the first picture?

First:  $\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$

Second:  $\frac{1}{d_i'} = \frac{1}{f} - \frac{1}{d_o'}$

$$\frac{h_i'}{h_i} = \left( \frac{-d_i' h_o}{d_o'} \right) / \left( \frac{-d_i h_o}{d_o} \right) = \frac{d_i'}{d_i} \frac{d_o}{d_o'}$$

$$d_i' = \frac{d_o' f}{d_o' - f}, \quad d_i = \frac{d_o f}{d_o - f}$$

$$\frac{h_i'}{h_i} = \frac{d_o'}{d_o' - f} \cdot \frac{d_o - f}{d_o} \cdot \frac{d_o}{d_o'} = \frac{d_o - f}{d_o' - f}$$

$$= \frac{14 \times 10^3 - 50 \times 10^{-3}}{6 \times 10^3 - 50 \times 10^{-3}} \approx 2.33$$