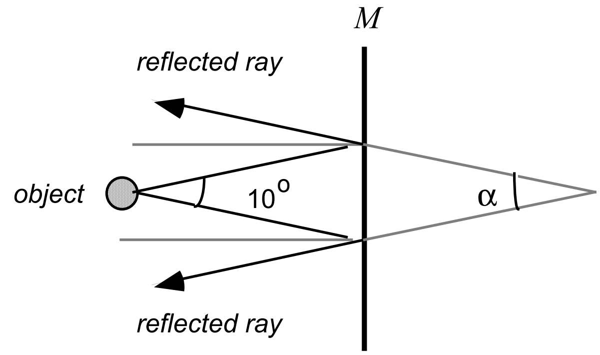
1. SSM WWW ***REASONING AND SOLUTION*** The drawing at the right shows a ray diagram in which the reflected rays have been projected behind the mirror. We can see by inspection of this drawing that, after the rays reflect from the plane mirror, the angle α between them is still $\boxed{10°}$.



---

2. ***REASONING AND SOLUTION***

a. The height of the shortest mirror would be one-half the height of the person. Therefore,

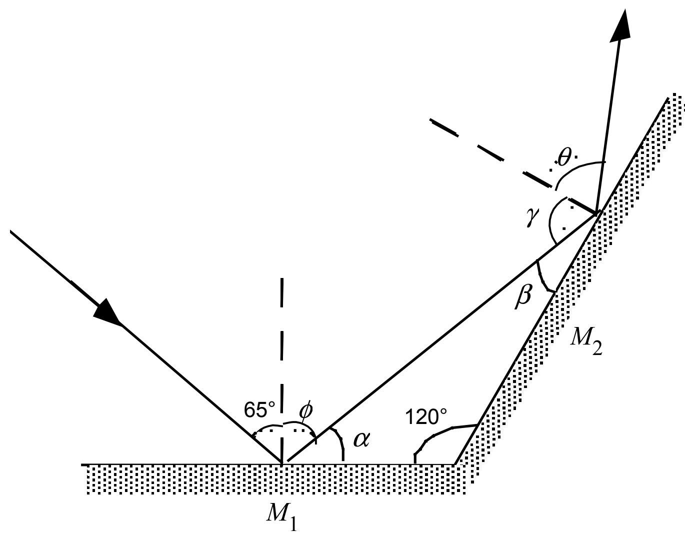
$$h = H/2 = (1.70\text{ m} + 0.12\text{ m})/2 = \boxed{0.91\text{ m}}$$

b. The bottom edge of the mirror should be above the floor by

$$h' = (1.70\text{ m})/2 = \boxed{0.85\text{ m}}$$

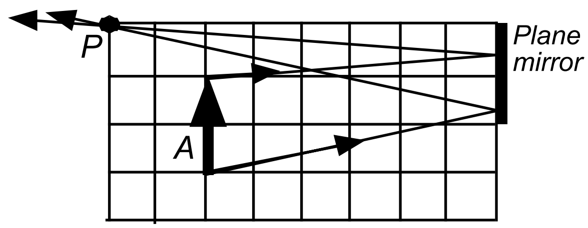
---

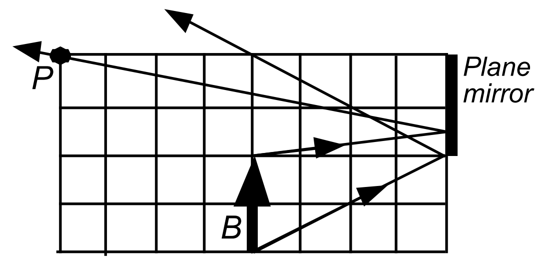
5. SSM ***REASONING*** The geometry is shown below. According to the law of reflection, the incident ray, the reflected ray, and the normal to the surface all lie in the same plane, and the angle of reflection θ_r equals the angle of incidence θ_i. We can use the law of reflection and the properties of triangles to determine the angle θ at which the ray leaves M_2.



SOLUTION From the law of reflection, we know that $\phi = 65°$. We see from the figure that $\phi + \alpha = 90°$, or $\alpha = 90° - \phi = 90° - 65° = 25°$. From the figure and the fact that the sum of the interior angles in any triangle is 180°, we have $\alpha + \beta + 120° = 180°$. Solving for β, we find that $\beta = 180° - (120° + 25°) = 35°$. Therefore, since $\beta + \gamma = 90°$, we find that the angle γ is given by $\gamma = 90° - \beta = 90° - 35° = 55°$. Since γ is the angle of incidence of the ray on mirror M_2, we know from the law of reflection that $\boxed{\theta = 55°}$.

6. ***REASONING AND SOLUTION*** The two arrows, *A* and *B* are located in front of a plane mirror, and a person at point *P* is viewing the image of each arrow. As discussed in Conceptual Example 1, light emanating from the arrow is reflected from the mirror and is reflected toward the observer at *P*. In order for the observer to see the arrow in its entirety, both rays, the one from the top of the arrow and the one from the bottom of the arrow, must pass through the point *P*.





According to the law of reflection, all rays will be reflected so that the angle of reflection is equal to the angle of incidence. The ray from the top of arrow *A* strikes the mirror and reflects so that it passes through point *P*. Likewise, the ray from the bottom of the arrow is reflected such that it too passes through point *P*. Therefore, the observer at *P* **sees the arrow at *A* in its entirety**.

Similar reasoning shows that the ray from the top of arrow *B* passes through point *P*. However, as the drawing shows, the ray from the bottom of the arrow does not pass through *P*. This conclusion is true no matter where the bottom ray strikes the mirror. The observer **does *not* see the arrow at *B* in its entirety**.

---

9. SSM ***REASONING AND SOLUTION***

a. We know from the law of reflection (Section 25.2), that the angle of reflection is equal to the angle of incidence, so the reflected ray is reflected at $\boxed{43°}$.

b. Snell's law of refraction (Equation 26.2: $n_1 \sin \theta_1 = n_2 \sin \theta_2$ can be used to find the angle of refraction. Table 26.1 indicates that the index of refraction of water is 1.333. Solving for θ_2 and substituting values, we find that

$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2} = \frac{(1.000)\,(\sin 43°)}{1.333} = 0.51 \qquad \text{or} \qquad \theta_2 = \sin^{-1} 0.51 = \boxed{31°}$$

---

11. ***REASONING AND SOLUTION*** The angle of incidence is found from the drawing to be

$$\theta_1 = \tan^{-1}\left(\frac{8.0 \text{ m}}{2.5 \text{ m}}\right) = 73°$$

Snell's law gives the angle of refraction to be

$$\sin\,\theta_2 = (n_1/n_2)\,\sin\,\theta_1 = (1.000/1.333)\,\sin 73° = 0.72 \qquad \text{or} \qquad \theta_2 = 46°$$

The distance d is found from the drawing to be

$$d = 8.0 \text{ m} + (4.0 \text{ m})\tan\,\theta_2 = \boxed{12.1 \text{ m}}$$

12. ***REASONING AND SOLUTION*** Using Equation 26.3, we find

$$d = \left(\frac{n_1}{n_2}\right)d' = \left(\frac{1.546}{1.000}\right)2.5\text{ cm} = \boxed{3.9\text{ cm}}$$

---

23. **SSM** ***REASONING AND SOLUTION*** According to Equation 26.4, the critical angle is related to the refractive indices n_1 and n_2 by $\sin\theta_c = n_2/n_1$, where $n_1 > n_2$. Solving for n_1, we find

$$n_1 = \frac{n_2}{\sin\theta_c} = \frac{1.000}{\sin 40.5°} = \boxed{1.54}$$

24. ***REASONING AND SOLUTION*** Only the light which has an angle of incidence less than or equal θ_c can escape. This light leaves the source in a cone whose apex angle is $2\theta_c$. The radius of this cone at the surface of the water (n = 1.333, see Table 26.1) is $R = d \tan \theta_c$. Now

$$\theta_c = \sin^{-1}\left(\frac{1.000}{1.333}\right) = 48.6°$$

so

$$R = (2.2 \text{ m}) \tan 48.6° = \boxed{2.5 \text{ m}}$$

---

25. ***REASONING*** The refractive index n_{Liquid} of the liquid can be less than the refractive index of the glass n_{Glass}. However, we must consider the phenomenon of total internal reflection. Some of the light will enter the liquid as long as the angle of incidence is less than or equal to the critical angle. At incident angles greater than the critical angle, total internal reflection occurs, and no light enters the liquid. Since the angle of incidence is 75.0º, the critical angle cannot be allowed to fall below 75.0º. The critical angle θ_c is determined according to Equation 26.4:

$$\sin\theta_c = \frac{n_{\text{Liquid}}}{n_{\text{Glass}}}$$

As n_{Liquid} decreases, the critical angle decreases. Therefore, n_{Liquid} cannot be less than the value calculated from this equation, in which θ_c = 75.0º and n_{Glass} = 1.56.

SOLUTION Using Equation 26.4, we find that

$$\sin\theta_c = \frac{n_{\text{Liquid}}}{n_{\text{Glass}}} \quad \text{or} \quad n_{\text{Liquid}} = n_{\text{Glass}}\sin\theta_c = (1.56)\sin 75.0° = \boxed{1.51}$$
