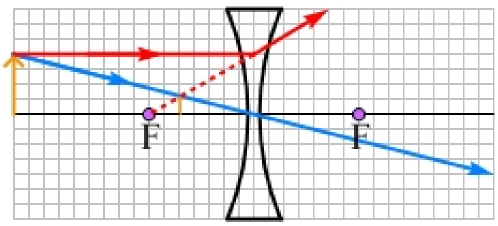
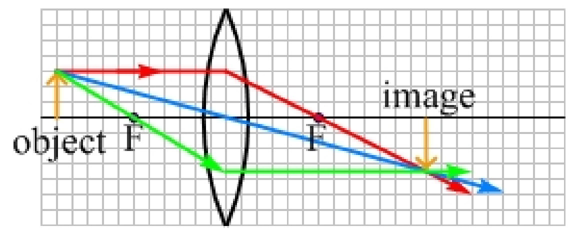
Answers to selected problems from Essential Physics, Chapter 24

1. This is not possible. If the incident beam comes in along the normal, the part of the beam that is transmitted into the second medium will also follow the normal.

3.



5.



7. The critical angle is larger for red light, because the index of refraction for the glass is smaller for red light than it is for violet light. The smaller the index of refraction of the higher-*n* medium (the glass), the larger the sine of the critical angle, and the larger the critical angle is.

9. No. The lenses are designed to refract light properly coming from air to glass and back to air. When the light goes from water to glass to water, it will not refract as much, and thus will not compensate correctly for your vision issue.

11. (a) It could be either kind of lens – both can produce virtual images. (b) It must be a diverging lens. Moving an object closer to a diverging lens causes the image to increase in size (this is what is observed), while moving an object closer to a converging lens, when it is giving a virtual image, will cause the image to decrease in size. (c) There's nothing we can say about the focal length, given the information here, aside from the fact that the focal length is negative.

13. 62.8°

15. (a) The refracted beam refracts away from the normal, which happens when light passes from a medium with a higher index of refraction to a medium with a lower index of refraction. Thus, medium 1 has a higher index of refraction than medium 2. (b) Medium 2 has an index of refraction of 1.10, which means that medium 1 has an index of refraction of 2.15. If medium 1 had an index of 1.10, medium 2 would have to have an index of refraction of 0.56, which is not possible – values of the index of refraction are greater than or equal to 1, in general.

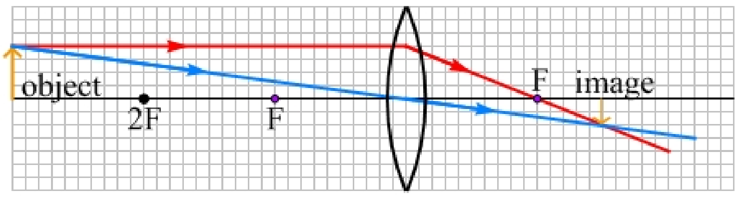
17. The index of refraction of medium 1 is less than or equal to $\sqrt{2.0}$.

19. 34.2°, although the light must come from the other side of the interface to experience total internal reflection.

21. (a) $\frac{1}{f} = \frac{7}{+120 \text{ cm}}$ (b) $f = \frac{+120 \text{ cm}}{7} = +17.1 \text{ cm}$ (c) converging lens

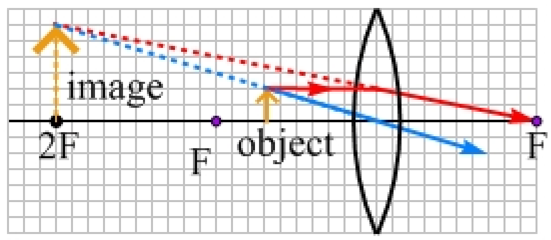
23. (a) $\frac{1}{f} = +\frac{1}{30 \text{ cm}}$ (b) f = +30 cm (c) converging lens

25. (a)



(b) +15 cm (c) –0.5

27. (a) –30 cm (b) +15 cm (c)



29. (a) 8.6 cm (b) –0.71 (c) 5.1 cm (d) –0.017

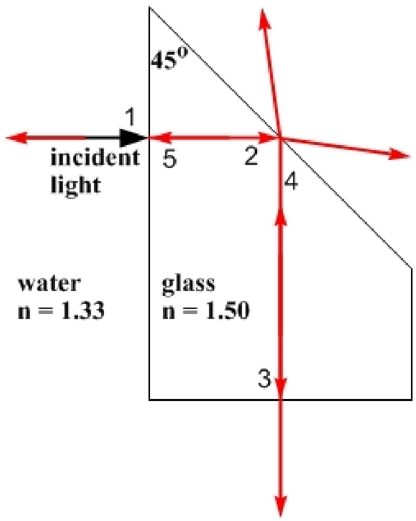
31. What happens with diamond is that the light generally experiences quite a bit of total internal reflection. Total internal reflection occurs when light is traveling in a high-n medium, and it encounters an interface with a low-n medium. If the angle of incidence exceeds the critical angle, the light will be totally internally reflected. Because diamond has such a high index of refraction, the critical angle for a diamond-air interface is particularly small (about 24.6°). Thus, it is very likely that light will be incident on the interface at an angle exceeding the critical angle, and the light will travel a relatively long distance inside the diamond, reflecting internally a number of times, before it emerges from the diamond back to air. It is important that diamond exhibits dispersion, too, which means that the index of refraction of diamond varies with wavelength. The larger the path length traveled, the larger the difference in angle there will be between light of different wavelengths emerging from the diamond. Thus, when white light enters the diamond, it is immediately split into different colors, which bounce around a few times inside the diamond before emerging, at different places on the diamond and at different angles.

33. (a) The wood should be at the focal point of the lens. Thus, it should be a distance equal to the focal length away from the lens. (b) This method only works with a converging lens, which is the type of lens used to correct far-sightedness.

35. Path C is the best path to take. Just like the path that a light beam takes when it travels from a point in a lower-n (higher speed of light) medium to a point in a higher-n (lower speed of light) medium, the lifeguard should not take the straight-line path, but should travel a longer distance (longer than that for the straight-line path) on the beach (the fast medium) and a shorter distance in the water. Path D is not the minimum-time path, however – path C is the one that balances the distances appropriately to minimize the total travel time.

37. 3 > 2 > 1

39.



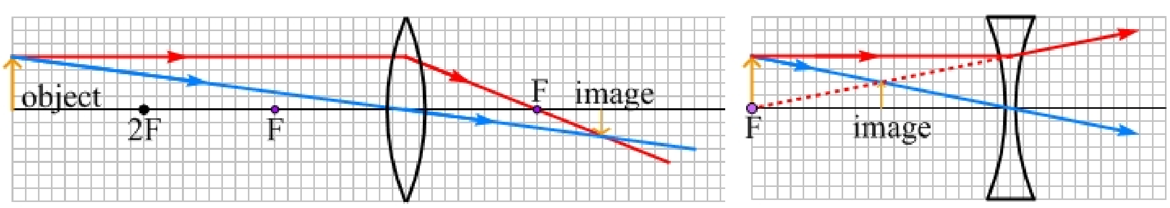
At 1, some light reflects straight back, and some light is transmitted into the glass without changing direction, because the light is incident along the normal.
At 2, some light reflects straight down, and some light refracts back into the air, making an angle of 53° with respect to the normal when it emerges into the air.
At 3, some light reflects straight back, and some light is transmitted into the air without changing direction.
At 4, some light reflects horizontally to the left, and some light refracts back into the air, making an angle of 53° with respect to the normal when it emerges into the air.
At 5, some light reflects straight back, and some light is transmitted into the air without changing direction.

41. (a) The device can only be a converging lens. It is the only kind of lens or mirror that produces a larger image on the same side of the lens or mirror as the object. (b) +24 cm

43. (a) –80 cm (b) +26.7 cm

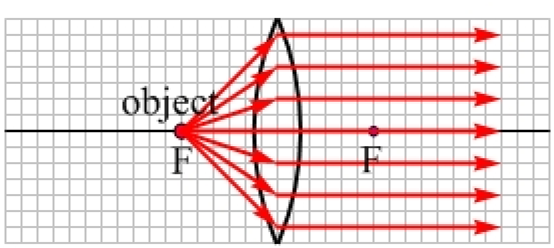
45. (a) One solution is that the lens is a converging lens, with an object distance of 60 cm and an image distance of +30 cm. The image is real and inverted. (b) The second solution is that the lens is a diverging lens, with an object distance of 20 cm and an image distance of –10 cm. The image is virtual and upright.

(c)



47. The lens is a diverging lens located 150 cm to the right of the object and 90 cm to the right of the image. The lens has a focal length of –225 cm.

49.



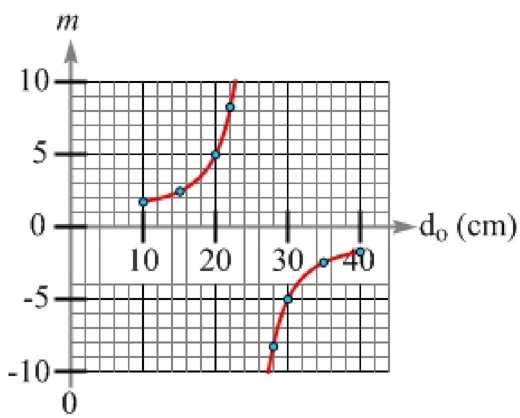
51. (a) The image is 4.8 cm to the left of the lens, and 2.4 cm above the principal axis.

53. (a) d_i = +45 cm (b) h_i = –10 cm   (c) real (d) inverted

55. (a) d_i = –12.9 cm (b) h_i = +2.9 cm   (c) virtual (d) upright

57.   The image moves a little closer to the lens, and gets a little smaller.

61. (a)



(b) The focal point corresponds to the value of d that gives a magnification of infinity. From the graph, we can see that the magnification approaches infinity as the object distance approaches 25 cm, so f = +25 cm.

65. (a) The first image is 10 cm to the right of the lens. It is inverted and the same size as the original object. (b) The mirror creates a second image that is 8 cm to the right of the lens. It is also inverted (in comparison to the original object) and the same size as the original object. (c) The lens creates a third image that is 13.3 cm to the left of the lens. It is upright (in comparison to the original object) and has a height of 6.7 cm. (d) The first image is virtual, because the mirror prevents the light from reaching the image position. The second and third images are real because the light actually passes through the image position.