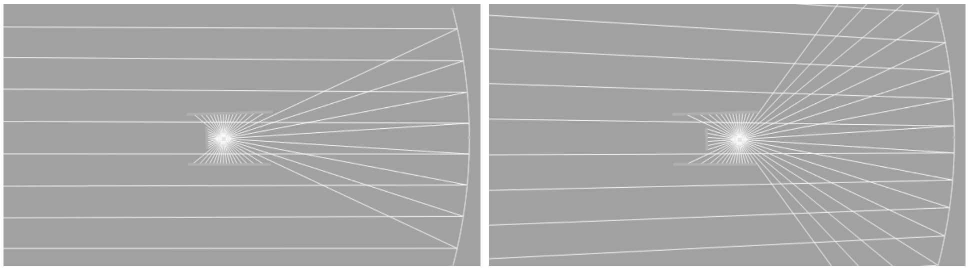
Answers – AP Physics 2 Optics Assignment

1. a. 40.0°
   b. 70.0°
2. a. $2.26 \times 10^8$ m/s, $3.05 \times 10^{-7}$ m
   b. 40.6°
   c. 79.4°
   d. 1.50
3. a. 48.3°
   b. 6.73 m
   c. At the edges of the "window", light is being bent the maximum amount, entering the water at an angle of incidence approaching 90 degrees (rays parallel to surface). In principle even light from a "distant shore" could bend "into the window". Therefore everything from the horizon to the zenith should be "visible" in the window on all sides.
4. 
5. a. 19.6°
   b. Angle of incidence with the bottom is 79.6°, which is greater than the critical angle 42.1°, therefore total internal reflection occurs!
   c. 0.995 cm
   d. 44.9°
6. a. Refraction is caused by the change in speed. Because red light bends less its change in speed is less and it must be moving faster through the prism.
   b. Violet is the shortest wavelength visible light, but it is being bent the most by the prism and must therefore have a higher index of refraction (meaning it is traveling slower) than the other colors. Index of refraction decreases as wavelength increases.
   c. The separation of colors occurs as soon as the light enters because the angle of refraction is slightly different for each color. However, the amount of separation increases and the colors become even more spread out when the light exits the prism.
7. a. $\frac{\sin\theta_1}{v_1} = \frac{\sin\theta_2}{v_2}$
   b. 49.4°
   c. Total "internal" reflection can occur with sound going from air into water. As illustrated in answer to previous question sound would bend away from the normal upon entering the water. At a critical angle of 13.2° this angle would be 90° and any angle of incidence greater than that there would be no sound transmitted – *i.e.* total reflection!
8. a. 50 cm
   b. –37.5 cm
   c. 1.5 m
   d. –0.2, real, inverted
9. a. 25.0 cm
   b. 2.95 cm away from secondary mirror
10. a. Light exiting the headlight would be moving in parallel rays one direction – a narrow beam with diameter same as reflector.
    b. The filament should be located at a distance slightly less than the focal length.

c. 

diagrams from Rik Tu, Johnson

11. a. –6.0 in
    b. 138 in, 5.8 in behind surface
12. a. $d_i$ = –0.48 m, $h_i$ = 0.20 m
    b. The virtual image of the truck is actually closer to your eye than the truck itself. It is the smallness of the image that tricks your mind into thinking it is far away. (Viewing a 0.20 m truck image from a distance roughly 1 m away would be roughly equivalent to viewing a 4.3 m truck from a distance about 22 m away ($1/0.2 = x/4.3$). Therefore it seems to be about twice as far away as it really is.)
13. a. In order to project an image onto a screen the rays of light must focus and actually converge at a point in space where the screen is placed. Because a convex mirror causes light to diverge it does not focus light. A plane mirror does not cause light to converge or diverge either way and so also is incapable of focusing light.
    b. A concave mirror produces an upright virtual image whenever the object is located at a distance less than the focal length.
14. a. 13 cm
    b. 80 cm from wall
    c. 28.4
    d. 13 cm
15. a. To start a fire with a lens it must be converging. Only a converging lens causes light to converge and focus – into an intense spot, hot enough to start a fire.
    b. A converging lens is always convex or at least "more convex" on one side than it is concave on the other. The middle part of the lens must be thicker than the perimeter of the lens.
    c. The Sun is so far away it is essentially an object distance of infinity, therefore its image would appear at the focal point. Also, rays of light from the distant Sun are moving in essentially parallel directions and by definition should converge on the focal point after passing through the lens.
    d. The Sun itself is not a point, but rather a large spherical object. The spot of light on the paper would actually be an image of the Sun – a small circle of light (not an actual *point* of light).
16. a. 5.1 cm
    b. 0.65 mm
17. a. $h_i \approx \frac{f}{d_o} h_o$
    b. Height of image is proportional to focal length for a given object at a given distance from the camera. Doubling the focal length therefore yields an image twice as large.

18. a. $d_i$ = –29.3 cm, $h_i$ = 4.8 cm

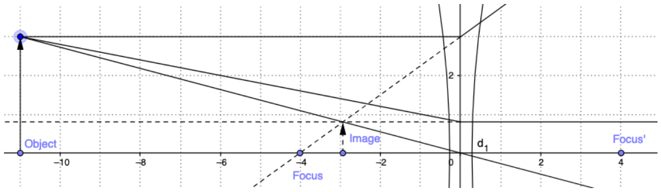
b. 

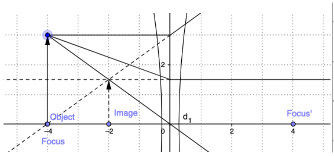
diagram from oPhysics

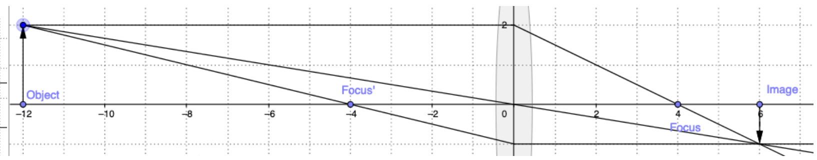
Looking at the image, the eyes are focusing light that appears to come from an object much closer.

19. a. –41 ft

b. $d_o$ = 21 ft ($d_i$ = –14 ft)

c. This is a virtual image made by a diverging lens – it appears upright and normal, just reduced in size.

20. a. 



diagrams from oPhysics

b. For the converging lens or mirror and the real images – the diagrams would be correct if reversing object, image, and direction of rays. This is because the laws of reflection and refraction are the same "both ways" and all the angles would be the same, just opposite in the sense of occurred first. For the diverging lens or mirror and virtual images, reversing object and image does not make sense because no light *actually* converges at the image and thus its path can't be reversed.

21. a. 490 nm

b. 0.75

c. Light reflected from the front surface of the water film is "inverted" and undergoes a half-cycle phase change. Light reflected from the back surface of the water film is not inverted and undergoes zero phase change. The light that has traveled "over and back" through the film has traveled a distance equal to 2 times ¾ the wavelength, or 1.5 wavelengths and emerges into the air in phase with the reflected light due to its 0.5 cycle inversion.

d. If the second reflection is at the boundary with glass it will also be inverted because the index of refraction of glass is greater than that of water. Therefore the light emerging this time will be exactly out of phase with the light reflecting off the front surface and result in destructive interference.

22. 102 nm

23. a. The path difference is essentially zero as the thickness of air approaches zero where the two panes are in contact. However, light reflected off the first surface (going from glass to air) undergoes zero phase change, whereas light reflected off the second surface (going from air to glass) is inverted by one half-cycle and therefore undergoes destructive interference with the first reflection.

b. As described above there is always a "built in" one half-cycle phase change due to the difference in reflection types – this would occur anywhere along the "wedge of air". But, when the path difference is ½ wavelength the two waves would be in phase – this distance is

"over and back" across the air gap. Therefore the distance one way across the gap is one half ½ wavelength – the thickness of the gap at the first bright band is ¼ the wavelength.
c. 526 nm