Answers – AP Physics 2 Optics Assignment

1. a. 2.8×10^{-6} T
   b. 4.6×10^{14} Hz, 6.5×10^{-7} m
   c. $E = 1.7\sin(9.67 \times 10^{6}x)$, $B = 5.7\sin(9.67 \times 10^{6}x)$ (in units kV/m, μT, and m)
2. a. $B = 0.24 \sin(4.08 \times 10^{9}t)$ or $B = 0.24 \cos(4.08 \times 10^{9}t)$, B in nT and t in s
   b. 1.28×10^{-10} s
   c. 29 mV
   d. The magnetic flux would be maximized if the radio signal travels along a diameter of the loop.
3. a. The microwaves must be polarized with a particular orientation of electric and magnetic fields in order for the metal grate to completely block the beam. An unpolarized beam would have random orientations and at least some amount of energy would pass through the grate no matter how it is turned.
   b. Electric fields in the microwave must be horizontal and electrons to move (i.e. current) in the metal bars of the grate. When the field and bars align there is significant current in the metal and the resistance of the metal causes energy to be dissipated in the form of heat. Because it is always perpendicular to the electric field in any electromagnetic wave, the magnetic field must be vertical in this situation.
4. a. Shine a red laser at a reflective surface such that the reflected beam moves through the incoming beam in the opposite direction. This is the condition that causes standing waves – when two identical waves travel in opposite directions through the same medium.
   b. Though nodes and antinodes would surely exist, it would not be possible to actually see this, partly because the pattern would be miniscule – bright spots (antinodes) would be half a wavelength apart – in this case only about 300 nm.
5. When two electromagnetic waves occur in the same place the electric field of one would occur in the same place as the electric field of the other. Accordingly by the "rules of physics" the net electric field is found by the vector sum of these two fields – something known as the superposition principle. The same applies to the magnetic fields of the two waves.
6. Radio waves in the AM band have wavelengths roughly 100 times greater than that in the FM band. This allows AM signals to "wrap around" obstacles more readily. FM tends to be more "line of sight" because of its smaller wavelength.
7. As in the previous question, because sound has a much greater wavelength than light (about a million times longer) it much more readily diffracts around the corner of the building and spreads out on the other side. In principle the light should also bend around the corner but because of its much smaller wavelength it does not spread out nearly as much.
8. a. 451 nm
   b. 5.71 cm
   c. The bright lines are a superposition of waves coming from each slit. Because of diffraction the slits are essentially like point sources of light, the intensity of which diminishes with increasing distance and/or deviation from original direction of travel. For both of those reasons the intensity of the light is greatest at the central line and decreases

moving outward on either side, increasing the distance from the slits and deviating further from the original direction of wave travel.

9. a. 16.3 μm
   b. Double the distance to the screen, double the wavelength, or halve the separation of the slits – this is assuming the small angle approximation holds such that sin $\theta \approx$ tan θ.
10. 1.2 m
11. 15.8°
12. 626 nm
13. a. 2.5 μm
    b. Six total – three on either side. At $n = 4$ wavelengths beyond 625 nm yield an undefined result, meaning that the red end of the spectrum from 625 to 750 nm would not appear. A partial rainbow in theory should be visible at an angle a little less than 90°.
14. red: 49.3°; blue: 30.3°
15. a. Home A has constructive interference on an antinodal line (path difference = 3λ).
    b. Home B has destructive interference on a nodal line (path difference = 1.5 λ).
    c. Home C has constructive interference but it is not maximal like home A. (Δ = 0.2λ).
16. a. 457 Hz, 915 Hz, 1370 Hz, . . .
    b. 229 Hz, 686 Hz, 1140 Hz, . . .
17. a. 0.30°
    b. 2.1 cm
18. a. 7.58×10^{-7} m
    b. 0.18 cm × 0.900 cm
19. a. 40.0°
    b. 70.0°
20. a. 2.26×10^{8} m/s, 3.05×10^{-7} m
    b. 40.6°
    c. 79.4°
    d. 1.50
21. 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.
22.
23. 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°
24. 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.

25. 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!

26. a. 50 cm

    b. –37.5 cm

    c. 1.5 m

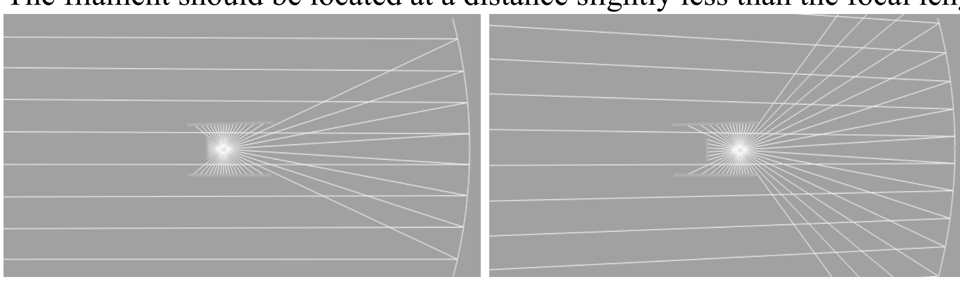
    d. –0.2, real, inverted

27. a. 25.0 cm

    b. 2.95 cm away from secondary mirror

28. 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

29. a. –6.0 in

    b. 138 in, 5.8 in behind surface

30. 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.)

31. 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.

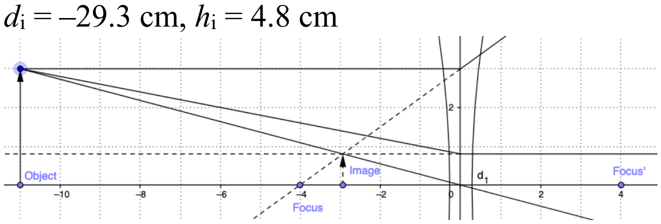
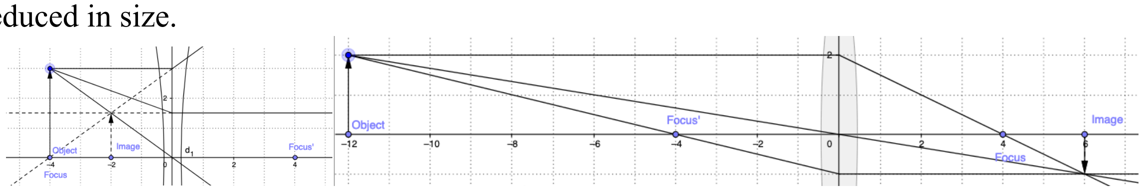
32. a. 13 cm
b. 80 cm from wall
c. 28.4
d. 13 cm
33. a. To start a fire with a lens it must be converging. Only a converging lens causes light to converge and focus – into an intense spot, hot enough to start a fire.
b. A converging lens is always convex or at least "more convex" on one side than it 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).
34. a. 5.1 cm
b. 0.65 mm
35. 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.
36. 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.
37. 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.
38. 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.