Optics Review Sheet Solutions

1. answer: D

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \qquad \frac{1}{-15} = \frac{1}{10} + \frac{1}{d_i}$$

$d_i = -6$ cm

2. answer: C

image is virtual since d_i is negative

$$M = -\frac{d_i}{d_o} = -\frac{-6}{10} = +0.6$$

so image is smaller since $|M| < 1$

and upright since M is positive

3. answer: B

A converging lens (convex) and a converging mirror (concave) *can* produces enlarged images when the object is inside the focal point.

4. answer: A

Parallel rays of light will diverge from the focal point of a diverging lens, or converge to the focal point of a converging lens. Only the first diagram shows this correctly.

5. answer: A

A mirage usually occurs on a hot day when the air temperature near the ground is influenced by the absorption of the sun's radiant heat. The air near the ground has less optical density (n) than the air above it, and light bends in a curved path giving the observer a refracted image.

6. answer: C

A lens' focal length is not dependent on the distance of an object. A lens of higher index of refraction has a shorter focal length; a lens with more curvature has a shorter focal length; and a lens focuses violet light at a shorter focal length.

7. answer: A

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad f = (24^{-1} + 16^{-1})^{-1} = 9.6 \text{ cm}$$

the mirror is turned around, so now it is diverging:

$$\frac{1}{-9.6} = \frac{1}{16} + \frac{1}{d_i} \quad d_i = (-9.6^{-1} - 16^{-1})^{-1} = -6 \text{ cm}$$

8. answer: C

Spherical aberration prohibits rays of reflected light from converging to a single-point focus.

9. answer: B

As the light moves from medium 1 to medium 2 it speeds up into a medium with lower index of refraction, so it must bend away from the normal line. Only ray F is a possible refracted ray. Snell's Law proves this: $n_1 \sin\theta_1 = n_2 \sin\theta_2$. A lower n, demands a larger θ.

10. answer: C

Consider the mirror equation:

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

With f positive, d_i must be positive (real) for all values of d_o greater than f. As d_o is increased beyond f, the value for d_i decreases. So as an object moves from the focal point towards the center of curvature, the image has to remain real and becomes smaller.

11. answer: B

Only answer B shows an upright image that is the same height as the object, and the image distance that is the same as the object distance.

12. answer: A

The parallel ray must diverge away from the principal axis as if from the virtual (left) focus.

13. answer: A

Light will always partially reflect off a transparent surface, so the bird is illuminated by the law of refraction. Light will also partially refract into the water and bend towards the normal line since $n_{water} > n_{air}$ so the fish is also illuminated.

14. answer: C

The focus of a mirror is a point that if rays of light are emitted at the focus, they will reflect back parallel to the mirror. A car headlight designed to produce parallel rays of light, must have the light filament at the mirror's focus.

15. answer: B

Near-sighted means that rays are focused too near; that is, in front of the retina of the eye. Thus, a diverging lens sends the rays slightly apart, and then the eyes properly converges them onto the retina.

16. answer: C

A convex mirror can only make a virtual image because rays must diverge off a convex mirror.

17. answer: A
The cornea does about 75% of the focusing of light, and the lens does the other 25%.

18. answer: C
Most people who become far-sighted at an older age have lost some use of the ciliary muscle that controls the shape (convexity) of the lens. When trying to see an object at close range, then lens cannot be made enough convex, and the rays are not focused (converged) onto the retina.

19. answer: B
To minimize chromatic aberration in a lens, use a material with the least range of index of refraction within the visible light spectrum. Material B has the least range: 1.71 – 1.70

20. answer: A
To maximize dispersion in a prism, use a material with the greatest range of index of refraction within the visible light spectrum. Material A has the most range: 1.66 – 1.6

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24.

$$n = \frac{c}{v} = \frac{3.0\times10^8 \text{ m/s}}{2.2\times10^8 \text{ m/s}} = 1.36$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \quad 1.0\sin 30^\circ = 1.36\sin\theta_2$$

$$\theta_2 = 21.5^\circ$$

25.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \quad 1.9\sin 30^\circ = 1.5\sin\theta_2$$

$$\theta_2 = 39.3^\circ$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \quad 1.9\sin 60^\circ = 1.5\sin\theta_2$$

$$\theta_2 = \text{error!} \quad \text{(Not possible - T.I.R.)}$$

$$\theta_i = \theta_r = 60^\circ$$

26.

$$\sin\theta_c = \frac{n_2}{n_1} \Rightarrow \sin\theta_3 = \frac{1.44}{1.48}$$

$\theta_3 \geq 76.7^\circ$ for TIR to occur

$\theta_2 \leq 90^\circ - \theta_3 = 90^\circ - 76.7^\circ = 13.3^\circ$ for TIR

$$1.0\sin\theta_1 = 1.48\sin 13.3^\circ$$

$\theta_1 \leq 20.0^\circ$ for TIR to occur inside core

27.

$$M = -\frac{d_i}{d_o} = +0.25 \Rightarrow d_i = -0.25 d_o \Rightarrow \frac{1}{-30} = \frac{1}{d_o} + \frac{1}{-0.25 d_o}$$

$$\frac{1}{-30} = \frac{1}{d_o} + \frac{-4}{d_o} \Rightarrow d_o = 90 \text{ cm} \quad \frac{1}{-30} = \frac{1}{90} + \frac{1}{d_i} \Rightarrow d_i = -22.5 \text{ cm}$$

$M = -\dfrac{d_i}{d_o} = -5$ (for an image that is real)

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad \frac{1}{30} = \frac{1}{d_o} + \frac{1}{5d_o} = \frac{6}{5d_o}$$

$$d_o = 36 \text{ cm}$$

$M = -\dfrac{d_i}{d_o} = +5$ (for an image that is virtual)

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad \frac{1}{30} = \frac{1}{d_o} + \frac{1}{-5d_o} = \frac{4}{5d_o} \Rightarrow d_o = 24 \text{ cm}$$

28.

$$\frac{1}{f} = \frac{1}{d_{o1}} + \frac{1}{d_{i1}} \quad \frac{1}{20} = \frac{1}{60} + \frac{1}{d_{i1}} \quad d_{i1} = 30 \text{ cm}$$

$$\frac{1}{f} = \frac{1}{d_{o2}} + \frac{1}{d_{i2}} \quad \frac{1}{-10} = \frac{1}{40-30} + \frac{1}{d_{i2}} \quad d_{i2} = -5 \text{ cm}$$

$$M_1 = -\frac{d_{i1}}{d_{o1}} = -\frac{30}{60} = -0.5 \quad M_2 = -\frac{d_{i2}}{d_{o2}} = -\frac{-5}{10} = +0.5$$

$$M = M_1 \times M_2 = (-0.5)\times(+0.5) = -0.25$$

The final image is virtual since d_{i2} is negative.
The final image is inverted since M is negative.
The final image is smaller since $|M| < 1$.

29.

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad \frac{1}{f} = \frac{1}{25-1.9} + \frac{1}{-(50-1.9)} \quad f = 44.4 \text{ cm}$$

$$P = \frac{1}{f} = \frac{1}{0.444 \text{ m}} = +2.25 \text{ diopter (converging lens)}$$

30.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \Rightarrow 1.0\sin 60^\circ = 1.5\sin\theta_2$$

$$\theta_2 = 35.3^\circ$$

$$180^\circ = 80^\circ - (90^\circ - 35.3^\circ) - (90^\circ - \theta_3) \Rightarrow \theta_3 = 44.7^\circ$$

$$n_3 \sin\theta_3 = n_4 \sin\theta_4 \Rightarrow 1.5\sin 44.7^\circ = 1.0\sin\theta_4$$

$$\theta_4 = \text{error} \Rightarrow \text{(not possible - T.I.R.)}$$

$\theta_3 = \theta_4 = 44.7^\circ$ (law of reflection)

$$180^\circ = 60^\circ - (90^\circ - 44.7^\circ) - (90^\circ - \theta_5) \Rightarrow \theta_5 = 15.3^\circ$$

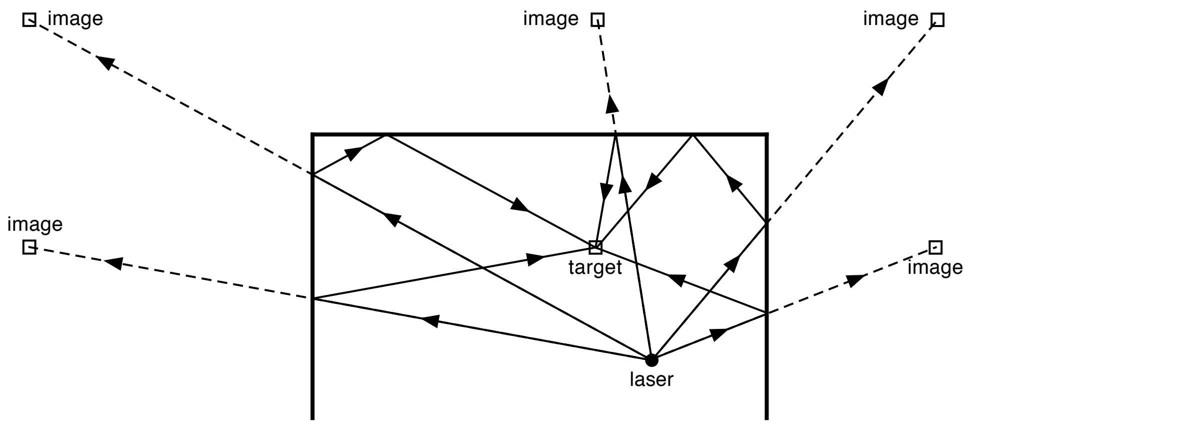
$$n_5 \sin\theta_5 = n_6 \sin\theta_6 \Rightarrow 1.5\sin 15.3^\circ = 1.0\sin\theta_6$$

$$\theta_6 = 23.3^\circ$$

21. Using the mirror/lens equation and the magnification equation, being careful with sign conventions:

	shape	type	*f* (cm)	d_o (cm)	d_i (cm)	h_o (cm)	h_i (cm)	*M*
a.	concave mirror	converging	50	40	-200	1.2	6	5
b.	convex mirror	diverging	-50	75	-30	5	2	0.4
c.	concave lens	diverging	-4	12	-3	16	4	0.25
d.	convex lens	converging	12	15	60	2	-8	-4

22. Each target is a virtual image of the original target. The top right and top left targets are "images of images" formed by a ray bouncing off two mirrors. The results are much like Plane Mirror Lab – Part B.



23. The scale used here is 2 to 1, so that it fits on the page. For example, the focal length representing 10 cm is actually 5 cm long. The image distances and heights agree approximately with the calculated values using the mirror/lens equation and magnification equation, but ray diagrams do not give exact results.