WAVES & OPTICS REVIEW KEY

1. $f = 4.0$ Hz

a) $A = \frac{1.5}{2} = 0.75$ m $\qquad \lambda = 4(0.60) = 2.4$ m $\qquad T = \frac{1}{f} = \frac{1}{4.0} = 0.25$ s

b) $v = \lambda f = (2.4)(4.0) = 9.6$ m/s

c) $A = 0.75$ m, $T = 0.25$ s, $t = 8.0$ s

$$d = \frac{t}{T}(4A) = \frac{8.0}{0.25}(4)(0.75) = 96 \text{ m}$$

2. $v = 3.0 \times 10^8$ m/s, $f = 6.0 \times 10^5$ Hz

a) $T = \frac{1}{f} = \frac{1}{6.0\times10^5} = 1.7 \times 10^{-6}$ s

b) $\lambda = \frac{v}{f} = \frac{3.0\times10^8}{6.0\times10^5} = 5.0 \times 10^2$ m

3. $v_1 = 0.16$ m/s, $v_2 = 0.24$ m/s, $\lambda_1 = 0.014$ m

a) $\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} \qquad \lambda_2 = \frac{\lambda_1 v_2}{v_1} = \frac{(0.014)(0.24)}{0.16} = 0.021$ m

b) $f_1 = \frac{v_1}{\lambda_1} = \frac{0.16}{0.014} = 11$ Hz $\qquad f_2 = \frac{v_2}{\lambda_2} = \frac{0.24}{0.021} = 11$ Hz

The frequency does not change when the water wave enters deep water from shallow water.

4. $A_1 = 1.2$ m, $A_2 = 0.7$ m

a) The maximum resultant amplitude occurs when the two water waves interfere constructively.

maximum resultant amplitude = $|A_1 + A_2| = |1.2 + 0.7| = 1.9$ m

b) The minimum resultant amplitude occurs when the two water waves interfere destructively.

minimum resultant amplitude = $|A_1 - A_2| = |1.2 - 0.7| = 0.5$ m

5. $t = 3.8$ s, $v_S = 343$ m/s

$d = v_S t = (343)(3.8) = 1300$ m

6. $t = 8.7$ yr x 365 days x 24 hr x 60 min x 60 s

$d = ct = (3.0 \times 10^8)(8.7 \times 365 \times 24 \times 60 \times 60) = 8.2 \times 10^{16}$ m

7. $\lambda_A = 4.4 \times 10^{-7}$ m, $n_A = 1.0$, $n_O = 1.48$, $n_G = 1.52$

a) $\lambda_A n_A = \lambda_O n_O \qquad \lambda_O = \dfrac{\lambda_A n_A}{n_O} = \dfrac{(4.4\text{x}10^{-7})(1.0)}{1.48} = 3.0 \times 10^{-7}$ m

$\lambda_A n_A = \lambda_G n_G \qquad \lambda_G = \dfrac{\lambda_A n_A}{n_G} = \dfrac{(4.4\text{x}10^{-7})(1.0)}{1.52} = 2.9 \times 10^{-7}$ m

b) $f = \dfrac{v}{\lambda} = \dfrac{c/n}{\lambda} = \dfrac{c}{\lambda n}$

$f_O = \dfrac{c}{\lambda_O n_O} = \dfrac{3.0\text{x}10^8}{(3.0\text{x}10^{-7})(1.48)} = 6.8 \times 10^{14}$ Hz

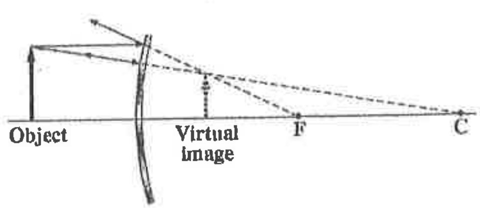
$f_G = \dfrac{c}{\lambda_G n_G} = \dfrac{3.0\text{x}10^8}{(2.9\text{x}10^{-7})(1.52)} = 6.8 \times 10^{14}$ Hz

8. $d_V = 2.8 \times 10^5$ m, $d_S = 2.2 \times 10^5$ m

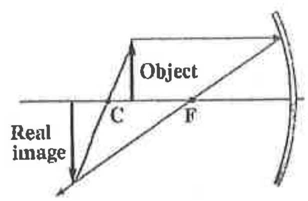
$c = \dfrac{d_V}{t} \qquad v = \dfrac{d_S}{t} \qquad n = \dfrac{c}{v} = \dfrac{d_V/t}{d_S/t} = \dfrac{d_V}{d_S} = \dfrac{2.8\text{x}10^5}{2.2\text{x}10^5} = 1.27$

9. The focal point and center of curvature can be located by ray tracing.

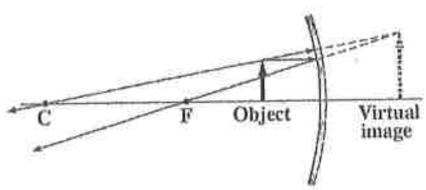
a)



b)



c)

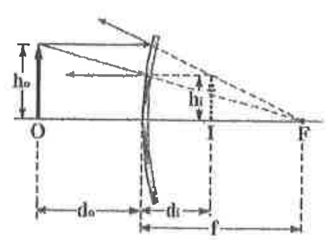


10. R = 4.0 m, $h_o = 1.5$ m, $d_o = 12$ m

a) $f = -\dfrac{R}{2} = -\dfrac{4.0}{2} = -2.0$ m

$\dfrac{1}{f} = \dfrac{1}{d_o} + \dfrac{1}{d_i} \qquad \dfrac{1}{d_i} = \dfrac{1}{f} - \dfrac{1}{d_o} \qquad \dfrac{1}{d_i} = \dfrac{1}{-2.0} - \dfrac{1}{12}$

$d_i = -1.7$ m



b) $m = -\dfrac{d_i}{d_o} = -\dfrac{(-1.7)}{12} = 0.14$

$m = \dfrac{h_i}{h_o} \qquad h_i = mh_o = (0.14)(1.5) = 0.21$ m

c) Since $d_i < 0$, the image is virtual.

d) Since $m > 0$, the image is upright.

11. $d_{o1} = 148$ cm, $d_{i1} = 32$ cm

a) Since the image of his chin is inverted, the mirror is a concave mirror.

$$\frac{1}{f} = \frac{1}{d_{o1}} + \frac{1}{d_{i1}} = \frac{1}{148} + \frac{1}{32} \qquad f = 26.3 \text{ cm}$$

$R = 2f = 2(26.3) = 52.6$ cm

b) $m = 2$

$$m = -\frac{d_{i2}}{d_{o2}} \qquad 2 = -\frac{d_{i2}}{d_{o2}} \qquad d_{i2} = -2d_{o2}$$

$$\frac{1}{f} = \frac{1}{d_{o2}} + \frac{1}{d_{i2}} = \frac{1}{d_{o2}} + \frac{1}{(-2d_{o2})} = \frac{1}{2d_{o2}} \qquad \frac{1}{26.3} = \frac{1}{2d_{o2}}$$

$$d_{o2} = \frac{f}{2} = \frac{26.3}{2} = 13.15 \approx 13 \text{ cm}$$

12. $d_{o1} = 36$ cm, $d_{i1} = -18$ cm, $h_{o2} = (1.5)h_{o1}$, $h_{i1} = h_{i2}$

a) $$\frac{1}{f} = \frac{1}{d_{o1}} + \frac{1}{d_{i1}} = \frac{1}{36} + \frac{1}{(-18)} \qquad f = -36 \text{ cm}$$

$R = -2f = -2(-36) = 72$ cm

b) $$h_i = mh_o = \left(-\frac{d_i}{d_o}\right)h_o$$

$$h_{i1} = h_{i2} \qquad \left(-\frac{d_{i1}}{d_{o1}}\right)h_{o1} = \left(-\frac{d_{i2}}{d_{o2}}\right)h_{o2}$$

$$h_{o2} = (1.5)h_{o1} \qquad \left(-\frac{d_{i1}}{d_{o1}}\right)h_{o1} = \left(-\frac{d_{i2}}{d_{o2}}\right)(1.5)h_{o1} \qquad \frac{-18}{36} = \frac{d_{i2}}{d_{o2}}(1.5) \qquad d_{i2} = -\frac{d_{o2}}{3}$$

$$\frac{1}{f} = \frac{1}{d_{o2}} + \frac{1}{d_{i2}} \qquad -\frac{1}{36} = \frac{1}{d_{o2}} - \frac{3}{d_{o2}} = -\frac{2}{d_{o2}} \qquad d_{o2} = 72 \text{ cm}$$

$$d_{i2} = -\frac{d_{o2}}{3} = -\frac{72}{3} = -24 \text{ cm}$$

13. $R = 60$ cm, $d_o - d_i = 80$ cm

$$f = \frac{R}{2} = \frac{60}{2} = 30 \text{ cm} \qquad d_i = d_o - 80$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \qquad \frac{1}{30} = \frac{1}{d_o} + \frac{1}{d_o - 80} \qquad d_o^2 - 140d_o + 2400 = 0 \qquad (d_o - 120)(d_o - 20) = 0$$

$d_o = 120$ cm, 20 cm

a) $d_o = 120$ cm
$d_i = d_o - 80 = 120 - 80 = 40$ cm

b) $d_o = 20$ cm
$d_i = d_o - 80 = 20 - 80 = -60$ cm

14. $f = +24$ cm, $d_o = 16$ cm

a) $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ $\quad \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{24} - \frac{1}{16}$ $\quad d_i = -48$ cm

b) $m = -\frac{d_i}{d_o} = -\frac{(-48)}{16} = 3.0$

c) Since $d_i < 0$, the image is virtual.

15. $d_o = 12$ cm, $d_i = -4.0$ cm, $h_o = 5.0$ cm

a) $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{12} + \frac{1}{(-4.0)}$ $\quad f = -6.0$ cm

b) $m = -\frac{d_i}{d_o} = -\frac{(-4.0)}{12} = 0.33$

Since $|m| < 1$, the image is reduced.

16. $f = +14$ cm

a) $m = -2.5$ (inverted image)

$m = -\frac{d_i}{d_o}$ $\quad d_i = -md_o$

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ $\quad \frac{1}{f} = \frac{d_i + d_o}{d_o d_i}$ $\quad \frac{1}{f} = \frac{-md_o + d_o}{d_o(-md_o)} = \frac{d_o(-m+1)}{d_o(-md_o)} = \frac{m-1}{md_o}$ $\quad f(m-1) = md_o$

$d_o = \frac{f(m-1)}{m} = \frac{14(-2.5-1)}{-2.5} = 19.6$ cm

$d_i = -md_o = -(-2.5)(19.6) = 49$ cm

b) $m = 2.5$ (upright image)

$d_o = \frac{f(m-1)}{m} = \frac{14(2.5-1)}{2.5} = 8.4$ cm

$d_i = -md_o = -(2.5)(8.4) = -21$ cm

17. $d_{o1} = 32$ cm, $d_{o2} = 32 + 4 = 36$ cm, $d_{i2} = d_{i1} - 24$

a) $\frac{1}{f} = \frac{1}{d_{o1}} + \frac{1}{d_{i1}}$ $\quad \frac{1}{d_{i1}} = \frac{1}{f} - \frac{1}{d_{o1}} = \frac{1}{f} - \frac{1}{32} = \frac{32-f}{32f}$ $\quad d_{i1} = \frac{32f}{32-f}$

$$\frac{1}{f} = \frac{1}{d_{o2}} + \frac{1}{d_{i2}} = \frac{1}{36} + \frac{1}{d_{i1} - 24} = \frac{1}{36} + \frac{1}{\frac{32f}{32-f} - 24} = \frac{1}{36} + \frac{32-f}{56f - 768} = \frac{5f+96}{72(7f-96)}$$

$f(5f + 96) = 72(7f - 96)$ $\quad 5f^2 - 408f + 6912 = 0$

$f = \frac{408 \pm \sqrt{(-408)^2 - 4(5)(6912)}}{2(5)}$ $\quad f = 24$ cm, 57.6 cm

Since the image appears on a screen, the image is real, and the focal length must be smaller than the object distance. Thus, the answer 57.6 cm is rejected.

$f = 24$ cm

b) $d_{i1} = \frac{32f}{32-f} = \frac{32(24)}{32-24} = 96$ cm $\quad d_{i2} = d_{i1} - 24 = 96 - 24 = 72$ cm

c) $m_1 = -\frac{d_{i1}}{d_{o1}} = -\frac{96}{32} = -3.0$ $\quad m_2 = -\frac{d_{i2}}{d_{o2}} = -\frac{72}{36} = -2.0$