1. Find the speed of a transverse wave that has a frequency of 20 Hz and a wavelength of 1.5 m.

$v = \lambda f$ $\quad v = (1.5)(20)$ $\quad v = 30$ m/s

2. A longitudinal sound wave has a speed of 340 m/s in air. If this produces a tone having a frequency of 5000 Hz, what is the wavelength?

$v = \lambda f$ $\quad 340 = \lambda\ 5000$ $\quad \lambda = 340 / 5000$ $\quad \lambda = 0.068$ m/cycle

3. Find the wavelength of the radio station K-100 that has a broadcasting frequency of 100.5 MHz.

$v = \lambda f$ $\quad 3 \cdot 10^8 = \lambda (100.5 \cdot 10^6)$ $\quad \lambda = \frac{3 \cdot 10^8}{100.5 \cdot 10^6}$

$\lambda = 2.99$ m/cycle

4. The frequency of red light is 3.8 x 10^{14} Hz. Find the wavelength.

$v = \lambda f$ $\quad 3 \cdot 10^8 = \lambda (3.8 \cdot 10^{14})$ $\quad \lambda = \frac{3 \cdot 10^8}{38 \cdot 10^{14}}$ $\quad \lambda = 7.9 \cdot 10^{-7}$ m/cycle

5. A sonar generator on a submarine produces an ultrasonic frequency of 2.5 MHz. The wavelength of the waves in water is 5.6 x 10^{-4} m. When the generator is directed downward, an echo reflected from the ocean floor is received 16.7 s later. How deep is the ocean at this point?

$v = \lambda f$ $\quad v = (5.6 \cdot 10^{-4})(2.5 \cdot 10^6)$ $\quad v = 1400$ m/s

$v = \frac{d}{t}$ $\quad 1400 = \frac{d}{8.35}$ $\quad d = (1400)(8.35)$ $\quad d = 11,690$ m

6. Find the wavelength of a 512 Hz tuning fork when the air temperature is 20°.

$v = v_o + 0.6T$ $\quad v = 331.5 + 0.6\ (20)$ $\quad v = 343.5$ m/s

$v = \lambda f$ $\quad 343.5 = \lambda\ (512)$ $\quad \lambda = \frac{343.5}{512}$ $\quad \lambda = 0.671$ m/cycle

7. A hiker shouts and hears the echo reflected from a cliff 5.0 s later. If the air temperature is 30°C, find the distance to the cliff.

$v = v_o + 0.6T$ $\quad v = 331.5 + 0.6\ (30)$ $\quad v = 349.5$ m/s

$v = \frac{d}{t}$ $\quad 349.5 = \frac{d}{2.5}$ $\quad d = (349.5)(2.5)$ $\quad d = 874$ m

8. Find the frequency of a tuning fork if it produces a wave 125 cm long when the air temperature is 20°.

$v = v_o + 0.6T$ $\quad v = 331.5 + 0.6\ (20)$ $\quad v = 343.5$ m/s

$v = \lambda f$ $\quad 343.5 = 1.25\ f$ $\quad f = \frac{343.5}{1.25}$ $\quad f = 275$ Hz

9. A closed tube having a diameter of 3.0 cm resonates with a 1024 Hz tuning fork. If the air temperature is 25°C, find the length of the tube.

$v = v_o + 0.6T$ $\quad v = 331.5 + 0.6(25)$ $\quad v = 346.5$

$v = \lambda f$ $\quad 346.5 = \lambda(1024)$ $\quad \lambda = \frac{346.5}{1024}$ $\quad \lambda = 0.338\ m$ $\quad \lambda = 33.8\ cm$

$\lambda = 4l + 1.6d$ $\quad 33.8 = 4l + 1.6(3)$ $\quad 33.8 = 4l + 4.8$

$4l = 33.8 - 4.8$

$l = \frac{29.0}{4}$ $\quad l = 7.25\ cm$

10. Calculate the frequency that the average human ear would resonate with assuming the air temperature to be 20°. The average ear is a closed tube 2.5 cm long and 0.6 cm in diameter.

$v = v_o + 0.6T$ $\quad v = 331.5 + 0.6(20) = 343.5\ m/s$

$\lambda = 4l + 1.6d$ $\quad \lambda = 4(2.5) + 1.6(0.6) = 10.96\ cm/cycle$

$= 0.1096\ m/cycle$

$v = \lambda f$ $\quad 343.5 = 0.1096f$ $\quad f = \frac{343.5}{0.1096}$ $\quad f = 3134\ Hz$

11. At 20°C, find the correct length of an open organ pipe that is 3.0 cm in diameter if it is to resonate with a 264 Hz note.

$v = v_o + 0.6T$ $\quad v = 331.5 + 0.6(20) = 345.5$

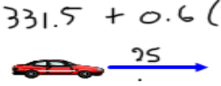
$v = \lambda f$ $\quad 343.5 = \lambda\ 264$ $\quad \lambda = \frac{343.5}{264}$ $\quad \lambda = 1.30\ m/cycle$ $\quad \lambda = 130\ cm$

$\lambda = 2l + 1.6d$ $\quad 130 = 2l + 1.6(3)$ $\quad 130 = 2l + 4.8$

$2l = 130 - 4.8$ $\quad l = \frac{125.2}{2}$ $\quad l = 62.6\ cm$

12. A factory whistle emits a sound having a frequency of 900 Hz. What frequency would the driver of a car travelling at 25 m/s hear if he were moving toward the factory, moving away from the factory, and circling the factory? air temperature is 25°C.

$v = v_o + 0.6T$ $\quad v = 331.5 + 0.6(25)$ $\quad v = 346.5\ m/s$

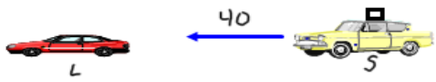


a $f_l = f_s\left(\frac{v + v_l}{v - v_s}\right)$ $\quad f_L = 900\left(\frac{346.5 + (+25)}{346.5 - 0}\right)$ $\quad f_L = 965\ Hz$

b $f_l = f_s\left(\frac{v + v_l}{v - v_s}\right)$ $\quad f_L = 900\left(\frac{346.5 + (-25)}{346.5 - 0}\right)$ $\quad f_L = 835\ Hz$

c No Doppler Shift because car not getting closer/further from factory

13. A police car travelling 40 m/s is in pursuit of a car. If the driver of the car hears the siren's frequency to be 5% higher than the police officer, how fast is the driver's car moving? The air temperature is 20°C. Assume that the police car produces a frequency of 100 Hz.



$$v = v_o + 0.6T$$

$v = 331.5 + 0.6(20)$ $v = 343.5$

$$f_l = f_s\left(\frac{v + v_l}{v - v_s}\right)$$

$105 = 100\left(\frac{343.5 + v_L}{343.5 - (+40)}\right)$

$1.05 = \frac{343.5 + v_L}{303.5}$

$(1.05)(303.5) = 343.5 + v_L$

$318.7 = 343.5 + v_L$

$-24.8 \text{ m/s} = v_L$

away

14. A fire engine is travelling west at 35 m/s and is emitting a sound having a frequency of 500 Hz. If the air temperature is 30°C, What frequency would the driver of a car travelling eastward at 25 m/s toward the fire engine hear?

$$v = v_o + 0.6T$$

$v = 331.5 + 0.6(30)$ $v = 349.5$ m/s

$$f_l = f_s\left(\frac{v + v_l}{v - v_s}\right)$$

$f_L = 500\left(\frac{349.5 + (+25)}{349.5 - (+35)}\right)$ $f_L = 500\left(\frac{374.5}{324.5}\right)$ $f_L = 577$ Hz

15. An ambulance travelling west at 30 m/s has just passed a car travelling west at 25 m/s. If the siren of the ambulance has a frequency of 1000 Hz but the driver of the car hears 986 Hz (as the ambulance pulls away), find the air temperature.

$$f_l = f_s\left(\frac{v + v_l}{v - v_s}\right)$$

$986 = 1000\left(\frac{v + (+25)}{v - (-30)}\right)$

$986 = 1000\left(\frac{v + 25}{v + 30}\right)$

$0.986 = \frac{v + 25}{v + 30}$

$0.986(v + 30) = v + 25$

$0.986v + 29.58 = v + 25$

$4.58 = 0.014v$

$v = \frac{4.58}{0.014}$

$v = 327.1$ m/s

$$v = v_o + 0.6T$$

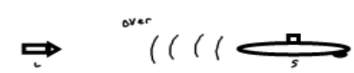
$327.1 = 331.5 + 0.6T$

$-4.4 = 0.6T$

$\frac{-4.4}{0.6} = T$

$T = -7.3\,^\circ C$

16. A stationary sub sends out a frequency of 50,000 Hz towards an approaching torpedo. If the return signal has a frequency of 50,200 Hz, what is the speed of the torpedo? The speed of sound in water is 1450 m/s.



$$f_l = f_s\left(\frac{v+v_l}{v-v_s}\right)$$

$$f_l = f_s\left(\frac{v+v_l}{v-v_s}\right)$$

$x = 50000\left(\frac{1450+y}{1450-0}\right)$

$x = 50000\,\frac{(1450+y)}{(1450)}$

$50{,}200 = x\left(\frac{1450+0}{1450-y}\right)$

$50{,}200 = x\,\frac{(1450)}{(1450-y)}$

$50{,}200 = \frac{50000\,(1450+y)}{(1450)}\;\frac{(1450)}{(1450-y)}$

$50200 = \frac{50000\,(1450+y)}{(1450-y)}$

$1.004 = \frac{1450+y}{1450-y}$

$(1.004)(1450-y) = 1450+y$

$1455.8 - 1.004y = 1450 + y$

$5.8 = 2.004\,y$

$y = \frac{5.8}{2.004}$

$y = 2.89$ m/s

$v = 1.97\cdot10^{8}$ m/s

$t = 5.1\cdot10^{-10}$ s

17. Find the time it would take light to pass through a piece of crown glass 10 cm thick.

$$n = \frac{c}{v} \qquad 1.52 = \frac{3\cdot10^{8}}{v} \qquad 1.52v = 3\cdot10^{8} \qquad v = \frac{3\cdot10^{8}}{1.52}$$

18. An object is placed 25 cm from a convex mirror. If the radius of curvature of the mirror is 40 cm, find the image distance and the focal length. If the object is 2.0 cm tall, find the image height.

$d_o = +25$ cm
$r = -40$ cm
$d_i = ?$
$f = ?$
$h_o = +2$ cm
$h_i = ?$

$f = -20$ cm

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \qquad -\frac{1}{20} = \frac{1}{25} + \frac{1}{d_i}$$

$-\frac{1}{20} - \frac{1}{25} = \frac{1}{d_o}$

$\frac{-25-20}{(20)(25)} = \frac{1}{d_o}$

$\frac{-45}{500} = \frac{1}{d_o}$

$d_o = 500/-45$

$d_o = -11.1$ cm

$$M = \frac{h_i}{h_o} = \frac{d_i}{d_o} \qquad \frac{h_i}{2} = \frac{-11.1}{25}$$

$h_i = \frac{-22.2}{25}$

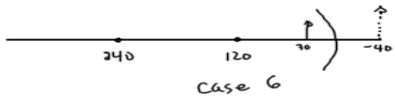
$h_i = -0.89$ cm

19. An object is placed 30 cm in front of a curved mirror and an image is formed 40 cm behind the mirror. Find the focal length and identify the type of mirror and the case number if applicable.

$d_o = +30$ cm
$d_i = -40$ cm
$f = ?$

$$\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i} \qquad \frac{1}{f} = \frac{1}{30} - \frac{1}{40} \qquad \frac{1}{F} = \frac{40-30}{(30)(40)} \qquad \frac{1}{F} = \frac{10}{1200}$$

$f = 1200/10$
$f = +120$ cm
concave



Case 6

20. A virtual image is formed 20 cm from a convex mirror having a radius of curvature of 50 cm. Find the object distance and the magnification.

$d_i = -20$ cm
$r = -50$ cm
$f = -25$ cm
$d_o = ?$
$m = ?$

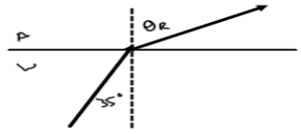
$$\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i} \qquad -\frac{1}{25} = \frac{1}{d_o} - \frac{1}{20} \qquad -\frac{1}{25} + \frac{1}{20} = \frac{1}{d_o}$$

$$-\frac{20+25}{(25)(20)} = \frac{1}{d_o} \qquad \frac{5}{500} = \frac{1}{d_o} \qquad d_o = 500/5 \qquad d_o = +100\text{cm}$$

$$M=\frac{h_i}{h_o}=\frac{d_i}{d_o} \qquad m = -\frac{20}{100}$$

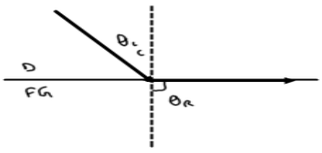
$m = -0.2$

21. A beam of light travelling in water strikes the surface at an angle of 35°. Find the angle of refraction in air.



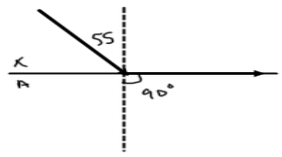
$$n_i \sin\theta_i = n_R \sin\theta_R$$
$1.33 \sin 35 = 1 \sin\theta_R$
$0.763 = \sin\theta_R$
$\theta_R = 49.7°$

22. Find the critical angle between diamond and flint glass.



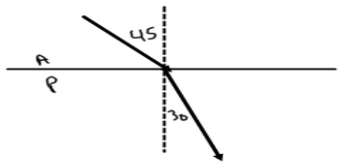
$$n_i \sin\theta_i = n_R \sin\theta_R$$
$2.42 \sin\theta_i = 1.61 \sin 90$
$\sin\theta_{i_c} = \frac{1.61}{2.42}$
$\sin\theta_{i_c} = 0.665$
$\theta_{i_c} = 41.7°$

23. Find the index of refraction for a substance that has a critical angle of 55° with air.



$$n_i \sin\theta_i = n_R \sin\theta_R$$
$n_x \sin 55 = 1 \sin 90$
$n_x = \frac{1}{0.819}$
$n_x = 1.22$

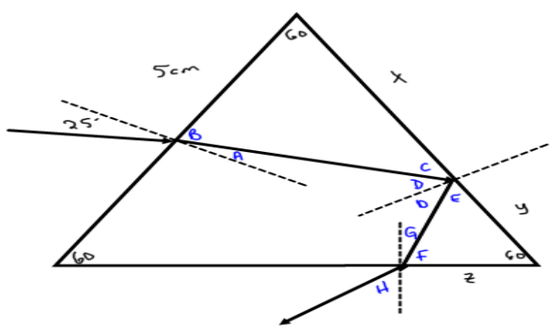
24. A ray of light passing from air into plastic at 45°, is refracted at an angle of 30°. Find the index of refraction for the plastic.



$$n_i \sin\theta_i = n_R \sin\theta_R$$
$1 \sin 45 = n_p \sin 30$
$\frac{0.707}{0.500} = n_p$
$1.41 = n_p$

25. A ray of light enters an equilateral crown glass prism that measures 10.0 cm on each side, with an incidence angle of 25°. If the light ray enters 5.0 cm from one corner, find where and at what angle the light ray exits the prism.

Find angles A, B, C, D, E, F in order



$$n_i \sin\theta_i = n_R \sin\theta_R$$
$1 \sin 25 = 1.52 \sin\theta_R$
A $\theta_R = 16°$

$B = 90 - 16 = 74°$
$C = 180 - (60 + B) = 46°$
$D = 90 - C = 44°$

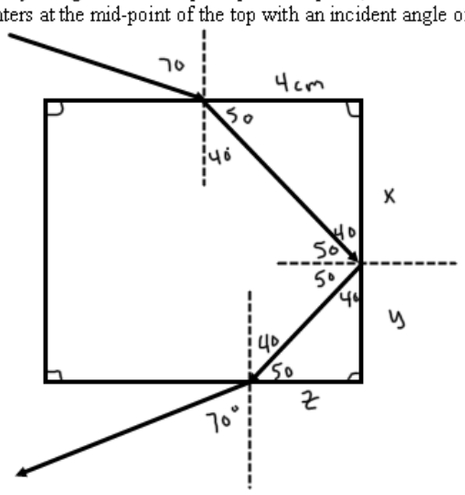
$$n_i \sin\theta_i = n_R \sin\theta_R$$
$1.52 \sin 44 = 1 \sin\theta_R$
θ_R = undefined
$E = C = 46°$
$F = 180 - (60 + E) = 74°$
$G = 90 - F = 16°$

$$n_i \sin\theta_i = n_R \sin\theta_R$$
$1.52 \sin 16° = 1 \sin\theta_R$
H → $\theta_R = 25°$

$$\frac{x}{\sin 74} = \frac{5}{\sin 46} \qquad x = 6.7\text{ cm}$$
$y = 10 - 6.7$
$y = 3.3$ cm

$$\frac{z}{\sin 46°} = \frac{3.3}{\sin 74} \qquad z = 2.5\text{ cm}$$

26. A ray of light enters a square piece of quartz, index of refraction 1.46. The square measures 8.0 cm on each side and the light ray enters at the mid-point of the top with an incident angle of 70°. Find where and at what angle the light ray exits the quartz.



$$n_i \sin\theta_i = n_R \sin\theta_R$$

$1 \sin 70 = 1.46 \sin\theta_2$

$\theta_R = 40°$

$\frac{x}{\sin 50} = \frac{4}{\sin 40}$

$x = 4.8$ cm

$y = 8 - 4.8 = 3.2$ cm

$$n_i \sin\theta_i = n_R \sin\theta_R$$

$1.46 \sin 50 = 1 \sin\theta_2$

θ_R = undefined

$$n_i \sin\theta_i = n_R \sin\theta_R$$

$1.46 \sin 40 = 1 \sin\theta_2$

$\theta_R = 70°$

$\frac{z}{\sin 40} = \frac{3.2}{\sin 50}$

$z = 2.7$ cm

27. A projectionist wishes to show an image on a screen 4.0 m from the slide projector. Find the size of the image if the object is placed 6.0 cm from the lens and the object is 1.0 cm tall.

$d_i = +400$ cm

$d_o = +6$ cm

$f = ?$

$h_o = +1$ cm

$h_i = ?$

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

$\frac{1}{f} = \frac{1}{6} + \frac{1}{400} = \frac{400+6}{(6)(400)} = \frac{406}{2400}$

$f = \frac{2400}{406}$

$f = +5.91$ cm

$$M = \frac{h_i}{h_o} = \frac{d_i}{d_o}$$

$\frac{h_i}{1} = \frac{400}{6}$

$h_i = +66.7$ cm

28. A photocopier has a lens with a focal length of 10 cm. If the distance between the original and the copy paper is 50 cm, find the magnification assume that a reduced size copy is being made.

$f = +10$ cm

$d_o + d_i = 50$

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

$\frac{1}{10} = \frac{1}{d_o} + \frac{1}{50 - d_o}$

$\frac{1}{10} = \frac{(50 - d_o) + (d_o)}{d_o(50 - d_o)}$

$\frac{1}{10} = \frac{50}{50 d_o - d_o^2}$

$50 d_o - d_o^2 = 500$

$0 = d_o^2 - 50 d_o + 500$

$d_o = \frac{-(-50) \pm \sqrt{(-50)^2 - 4(1)(500)}}{2(1)}$

$d_o = \frac{50 \pm \sqrt{2500 - 2000}}{2}$

$d_o = \frac{50 \pm \sqrt{500}}{2}$

$d_o = \frac{50 \pm 22.4}{2}$

$d_o = \frac{72.4}{2}$ or $\frac{27.6}{2}$

$d_o = 36.2$ or 13.8

since it is a reduced copy

$d_o = 36.2$ cm and

$d_i = 13.8$ cm

29. A photographer wishes to take a picture of a crater on the moon with a camera having a converging lens with a focal length of 1000 mm. The diameter of the Moon is 5,000 km and the distance from the Earth to the Moon is 384,000 km. Find the size of the image produced on the film.

typo

$f = +1000\ mm$

$h_o = +5 \cdot 10^9\ mm$

$d_o = +3.84 \cdot 10^{11}\ mm$

$d_i = ?$

$h_i = ?$

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

$$\frac{1}{1000} = \frac{1}{3.84 \cdot 10^{11}} + \frac{1}{d_i}$$

$$\frac{1}{d_i} = \frac{1}{1000} - \frac{1}{3.84 \cdot 10^{11}}$$

$d_i = 1000\ mm$

$$M = \frac{h_i}{h_o} = \frac{d_i}{d_o}$$

$$\frac{h_i}{5 \cdot 10^9} = \frac{1000}{3.84 \cdot 10^{11}}$$

$h_i = +13\ mm$

500 000 000
km m mm

30. A real image is formed 50.0 cm from an object. If the image is five times the size of the object, find the focal length of the lens.

$d_o + d_i = 50$

$5 = \frac{d_i}{d_o}$

$d_i = 5d_o$

$d_o + 5d_o = 50$

$6d_o = 50$

$d_o = \frac{50}{6}$

$d_o = +8.3\ cm$

$8.3 + d_i = 50$

$d_i = 41.7\ cm$

$$\frac{1}{f} = \frac{1}{8.3} + \frac{1}{41.7}$$

$$\frac{1}{f} = \frac{41.7 + 8.3}{(8.3)(41.7)}$$

$$\frac{1}{f} = \frac{50}{346}$$

$$f = \frac{346}{50}$$

$f = +6.9\ cm$

30. A real image is formed 50.0 cm from an object. If the image is five times the size of the object, find the focal length of the lens.

$d_o + d_i = 50$ $\quad 5 = \frac{d_i}{d_o}$ $\quad d_i = 5d_o$

$d_o + 5d_o = 50$

$6d_o = 50$

$d_o = \frac{50}{6}$

$d_o = +8.3$ cm

$8.3 + d_i = 50$

$d_i = 41.7$ cm

$\frac{1}{f} = \frac{1}{8.3} + \frac{1}{41.7}$

$\frac{1}{f} = \frac{41.7 + 8.3}{(8.3)(41.7)}$

$\frac{1}{f} = \frac{50}{346}$

$f = \frac{346}{50}$

$f = +6.9$ cm

31. An upright image is formed 24 cm from a lens. If the image is one quarter the size of the object, find the focal length and the type of lens.

$d_i = -24$ cm

$m = -0.25$

$M = \frac{h_i}{h_o} = \frac{d_i}{d_o}$ $\quad -0.25 = \frac{-24}{d_o}$ $\quad d_o = +96$ cm

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ $\quad \frac{1}{f} = \frac{1}{96} - \frac{1}{24} = \frac{24 - 96}{(96)(24)} = \frac{-72}{2304}$

$f = 2304 / -72$

$f = -32$ cm

CONVEX

32. Complete the lens table below.

#	do	di	f	M	image	lens	case #
A	+4.4	−8	+10	−1.8	V	C	6
B	+1.4	+5.5	+1.1	+4.0	R	C	4
C	+80	+20	+16	+0.25	R	C	2
D	+0.50	−0.625	+2.5	−1.25	V	C	6
E	+0.25	−0.0625	−0.083	−0.25	V	D	—
* F	+10	−10	∞	−1	V	PLANE	—
G	+1.17	+0.88	+0.5	+0.75	R	C	2