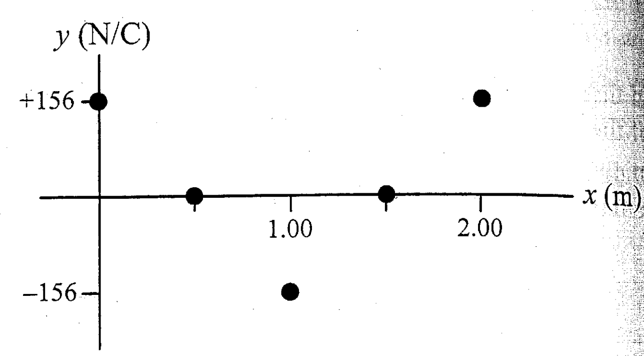
of the position x. The term πx is in radians when x is in meters, and conversion radians to degrees is accomplished using the fact that $2\pi \text{ rad} = 360°$.

x	$y = 156 \cos(\pi x)$
0 m	$156 \cos(0) = 156 \cos(0°) = +156$
0.50 m	$156 \cos(0.50\ \pi) = 156 \cos(90°) = 0$
1.00 m	$156 \cos(1.00\ \pi) = 156 \cos(180°) = -156$
1.50 m	$156 \cos(1.50\ \pi) = 156 \cos(270°) = 0$
2.00 m	$156 \cos(2.00\ \pi) = 156 \cos(360°) = +156$

These values for the electric field are plotted in the graph shown at the right.



6. ***REASONING AND SOLUTION*** The average flux change through the coil in one fourth of the wave period is, according to Faraday's law, $\Delta\Phi = NAB = NB_0A$. The magnitude of the average emf is then emf $= \Delta\Phi/\Delta t = NB_0A/\Delta t$. Now $\Delta t = T/4 = 1/(4f)$, so

$$\text{Emf} = 4NfB_0A = 4(450)(1.2 \times 10^6 \text{ Hz})(2.0 \times 10^{-13} \text{ T})(\pi)(0.25 \text{ m})^2 = \boxed{8.5 \times 10^{-5} \text{ V}}$$

7. ***REASONING*** The wavelength λ of a wave is related to its speed v and frequency f by $\lambda = v/f$ (Equation 16.1). Since blue light and orange light are electromagnetic waves, they travel through a vacuum at the speed of light c; thus, $v = c$.

SOLUTION
a. The wavelength of the blue light is

$$\lambda = \frac{c}{f} = \frac{3.00\times10^{8} \text{ m/s}}{6.34\times10^{14} \text{ Hz}} = 4.73\times10^{-7} \text{ m}$$

Since 1 nm $= 10^{-9}$ m,

$$\lambda = \left(4.73\times10^{-7} \cancel{\text{m}}\right)\left(\frac{1 \text{ nm}}{10^{-9} \cancel{\text{m}}}\right) = \boxed{473 \text{ nm}}$$

In a similar manner, we find that the wavelength of the orange light is

$$\lambda = \frac{c}{f} = \frac{3.00\times10^{8} \text{ m/s}}{4.95\times10^{14} \text{ Hz}} = 6.06\times10^{-7} \text{ m} = \boxed{606 \text{ nm}}$$

REASONING The frequency f of the UHF wave is related to its wavelength by $c = f\lambda$ (Equation 16.1), where c is the speed of light in a vacuum and λ is the wavelength. The electric and magnetic fields are both zero at the same positions, which are separated by a distance d equal to half a wavelength (see Figure 24.3). Therefore, we can express the wavelength in terms of the distance between adjacent positions of zero field as

$$\lambda = 2d \qquad (1)$$

SOLUTION Solving $c = f\lambda$ (Equation 16.1) for f yields

$$f = \frac{c}{\lambda} \qquad (2)$$

Substituting Equation (1) into Equation (2), we obtain

$$f = \frac{c}{\lambda} = \frac{c}{2d} = \frac{3.00\times10^{8} \text{ m/s}}{2(0.34 \text{ m})} = \boxed{4.4\times10^{8} \text{ Hz}}$$

9. SSM WWW ***REASONING AND SOLUTION*** According to Equation 16.1, the wavelength is $\lambda = c/f$. Since the rods can be adjusted so that each one has a length of $\lambda/4$, the length of each rod is

$$L = \frac{\lambda}{4} = \frac{c/f}{4} = \frac{\left(3.00\times10^{8} \text{ m/s}\right)/\left(60\times10^{6} \text{ Hz}\right)}{4} = \boxed{1.25 \text{ m}}$$

10. ***REASONING AND SOLUTION*** The VHF wavelength is

$$\lambda = \frac{c}{f} = \frac{3.00\times10^{8} \text{ m/s}}{63.0\times10^{6} \text{ Hz}} = 4.76 \text{ m}$$

The UHF wavelength is

$$\lambda = \frac{c}{f} = \frac{3.00\times10^{8} \text{ m/s}}{527\times10^{6} \text{ Hz}} = 0.569 \text{ m}$$

The ratio of the wavelengths is (4.76 m)/(0.569 m) = $\boxed{8.37}$

11. SSM ***REASONING AND SOLUTION*** The number of wavelengths that can fit across the width W of your thumb is W/λ. From Equation 16.1, we know that $\lambda = c/f$, so

$$\text{No. of wavelengths} = \frac{W}{\lambda} = \frac{Wf}{c} = \frac{(2.0\times10^{-2}\ \text{m})(5.5\times10^{14}\ \text{Hz})}{3.0\times10^{8}\ \text{m/s}} = \boxed{3.7\times10^{4}}$$

12. ***REASONING*** The length of each pulse is equal to the product of its speed and the time, or $x = ct_0$. According to Equation 16.1, the wavelength λ in a vacuum is related to the frequency f by $\lambda = c/f$, where c is the speed of light in a vacuum. When the light travels in water, the speed is no longer c, but its value v is given. The wavelength in water, then, is $\lambda = v/f$. The frequency in a vacuum and in water is the same.

SOLUTION
a. The number of wavelengths in one pulse is equal to the length of the pulse divided by the wavelength. The length of each pulse is $x = ct_0$ and the wavelength is $\lambda = c/f$, so

$$\text{Number of wavelengths} = \frac{x}{\lambda} = \frac{ct_0}{c/f}$$

$$= f\,t_0 = \left(5.2\times10^{14}\ \text{Hz}\right)\left(2.7\times10^{-11}\ \text{s}\right) = \boxed{1.4\times10^{4}}$$

b. When the light is traveling in water, its speed is v, which is less than the speed of light in a vacuum. The length of each pulse is now $x = vt_0$ and the wavelength is $\lambda = v/f$, so

$$\text{Number of wavelengths} = \frac{x}{\lambda} = \frac{vt_0}{v/f}$$

$$= f\,t_0 = \left(5.2\times10^{14}\ \text{Hz}\right)\left(2.7\times10^{-11}\ \text{s}\right) = \boxed{1.4\times10^{4}}$$

13. ***REASONING*** To determine the difference in frequencies, we will calculate each frequency and subtract one from the other. Each frequency f is related to the wavelength λ and the speed of light c according to $f = c/\lambda$ (Equation 16.1).

SOLUTION Using Equation 16.1 to calculate each frequency, we find that

$$f_2 - f_1 = \frac{c}{\lambda_2} - \frac{c}{\lambda_1} = \left(2.9979\times10^{8}\ \text{m/s}\right)\left(\frac{1}{0.34339\ \text{m}} - \frac{1}{0.36205\ \text{m}}\right) = \boxed{4.500\times10^{7}\ \text{Hz}}$$

REASONING According to $\omega = \sqrt{\dfrac{k}{m}}$ (Equation 10.11), the angular oscillation frequency depends upon the mass m of the oscillator and the spring constant k. The angular frequency ω (in rad/s) of the motion of the oscillating mass is related to the frequency f (in Hz) of the resulting ELF radio waves by $\omega = 2\pi f$ (Equation 10.6). We will use $c = f\lambda$ (Equation 16.1) to determine the frequency of the ELF radio waves, where c is the speed of light in a vacuum and λ is the wavelength.

SOLUTION Squaring both sides of $\omega = \sqrt{\dfrac{k}{m}}$ (Equation 10.11) and solving for k, we obtain

$$\frac{k}{m} = \omega^2 \qquad \text{or} \qquad k = m\omega^2 \tag{1}$$

Substituting $\omega = 2\pi f$ (Equation 10.6) into Equation (1) yields

$$k = m(2\pi f)^2 = 4\pi^2 m f^2 \tag{2}$$

Solving $c = f\lambda$ (Equation 16.1) for f gives $f = \dfrac{c}{\lambda}$. Substituting this result into Equation (2), we find that

$$k = 4\pi^2 m\left(\frac{c}{\lambda}\right)^2 = 4\pi^2(0.115\ \text{kg})\left(\frac{3.00\times10^{8}\ \text{m/s}}{4.80\times10^{7}\ \text{m}}\right)^2 = \boxed{177\ \text{N/m}}$$

15. SSM ***REASONING*** We proceed by first finding the time t for sound waves to travel between the astronauts. Since this is the same time it takes for the electromagnetic waves to travel to earth, the distance between earth and the spaceship is $d_{\text{earth-ship}} = ct$.

SOLUTION The time it takes for sound waves to travel at 343 m/s through the air between the astronauts is

$$t = \frac{d_{\text{astronaut}}}{v_{\text{sound}}} = \frac{1.5\ \text{m}}{343\ \text{m/s}} = 4.4\times10^{-3}\ \text{s}$$

Therefore, the distance between the earth and the spaceship is

$$d_{\text{earth-ship}} = ct = (3.0\times10^{8}\ \text{m/s})(4.4\times10^{-3}\ \text{s}) = \boxed{1.3\times10^{6}\ \text{m}}$$