$$\psi(x,t) = \psi_0 \operatorname{Sen}(\underbrace{Kx - \omega t + \phi}_{\phi})$$

fase da onda

$$\boxed{\varphi = Kx - \omega t + \phi}$$

$$\left|\left(\frac{\partial \varphi}{\partial t}\right)_x\right| = \omega = \text{frequência angular}$$

$$\left|\left(\frac{\partial \varphi}{\partial x}\right)_t\right| = K = \text{número de onda}$$

$$v = \left(\frac{\partial x}{\partial t}\right)_\varphi = \frac{\partial x}{\partial \varphi} \cdot \frac{\partial \varphi}{\partial t} = -\frac{\left(\frac{\partial \varphi}{\partial t}\right)}{\left(\frac{\partial \varphi}{\partial x}\right)} = -\frac{\frac{\partial \varphi}{\partial t}}{\frac{\partial \varphi}{\partial x}}$$

positiva do $\hat{x}$

$+$

$$v = \frac{+\omega}{+K} = \frac{2\pi f}{\frac{2\pi}{\lambda}} = \boxed{\lambda f = v}$$

$$\psi = \psi_0 \operatorname{Sen}[Kx - \omega t + \phi]$$

$$\boxed{\psi = \psi_0 \operatorname{Sen}[K(x - vt) + \phi]}$$

2,7

2.7* Find the wavelength of electromagnetic waves emitted from a 50-Hz electrical grid. Compare it with the wavelength of a 5-GHz radiation used for WiFi communication and the standard 540-THz light used in the definition of the candela.

$v = \lambda f$

$\lambda_1 = \dfrac{c}{f}$ $\qquad \dfrac{3\cdot10^8\ m/s}{50\ Hz}$ / $\dfrac{3\cdot10^8\ m/s}{5\cdot10^9\ Hz}$ / $\dfrac{3\cdot10^8\ m/s}{540\cdot10^{12}\ 1/s}$

$\lambda_1 = 6.000\ Km$ / $\boxed{\lambda_2 = 6\ cm}$ / $\lambda_3 = 0,55\ \mu m$ $\boxed{550\ nm}$ Verde

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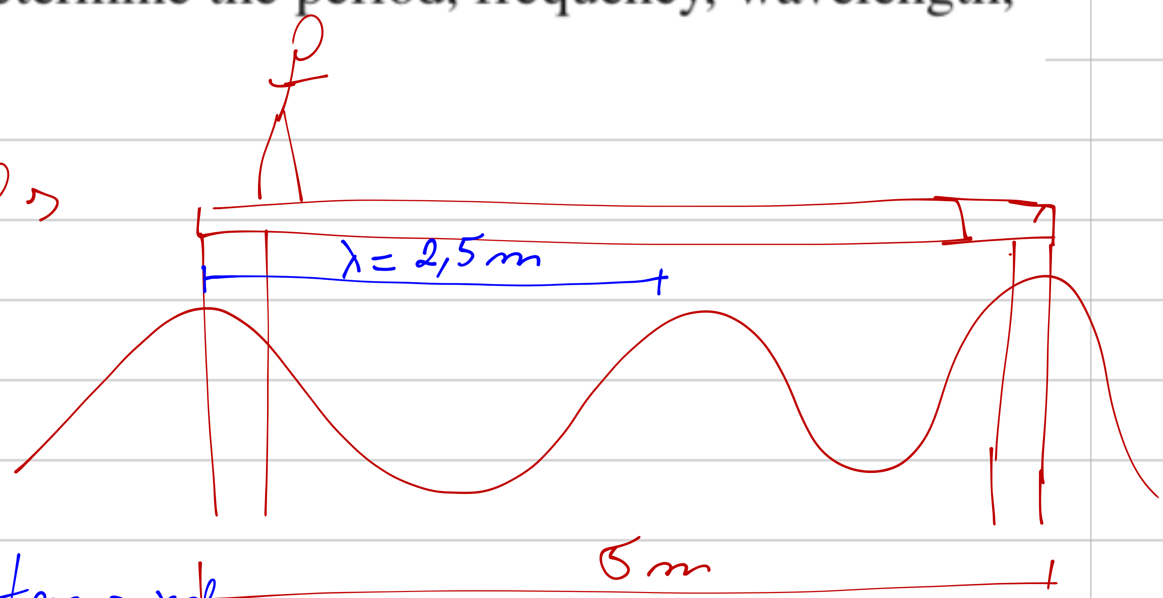
2.9* Sitting on the end of a pier, you observe the waves washing along and notice they are very regular. Using a stopwatch, you record 20 waves passing by in 10 seconds. If when one crest washes by a column of the pier, another crest is also washing by the next column 5 meters away, with another in between, determine the period, frequency, wavelength, and speed of the wave.

20 ondas $\longrightarrow$ 10 s



T = período temporal

f = frequência temporal

ω = frequência angular temporal

$\omega = 2\pi \cdot f$ $\qquad \omega = \dfrac{2\pi}{T}$

λ = período espacial ou comprimento de onda

K = frequência angular espacial ou número de onda

$\boxed{K = \dfrac{2\pi}{\lambda}} \iff \boxed{\omega = \dfrac{2\pi}{T}}$

observação $\Rightarrow$ outra definição $\boxed{K = \dfrac{1}{\lambda}} \rightarrow$ frequência espacial

$[K] = m^{-1}$

$[K] = \left[\dfrac{rad}{m}\right] \qquad [\omega] = \left[\dfrac{rad}{s}\right]$

$$\boxed{f = 2\ Hz} \rightarrow T = \frac{1}{f} = 0,5\,s$$

$$\omega = 2\pi f = 4\pi\ rad/s$$

$$\boxed{\lambda = 2,5\,m}$$

$$\boxed{K = \frac{2\pi}{2,5}\ \frac{rad}{m}}$$

$$v = \lambda \cdot f = \frac{2\pi}{K} f = \frac{\omega}{K}$$

$$v = (2,5)(2) = 5\ m/s$$

2.28 Write the expression for the wavefunction of a harmonic wave of amplitude 10^3 V/m, period 2.2×10^{-15} s, and speed 3×10^8 m/s. The wave is propagating in the negative x-direction and has a value of 10^3 V/m at $t = 0$ and $x = 0$.

$-\hat{x}$

$$E(x,t) = E_0 \operatorname{Sen}[Kx + \omega t + \phi]$$

$$\omega = \frac{2\pi}{T}$$

$$T = 2,2 \times 10^{-15}\,s$$

$$E_0 = 10^3\ V/m \qquad K = \frac{2\pi}{\lambda}$$

$$v = \lambda \cdot f$$

$$\lambda = \frac{v}{f} = \frac{3 \cdot \times 10^8\ m/s}{\frac{1}{2,2 \times 10^{-15}}}$$

$$\lambda = (3 \cdot 10^8) \cdot (2,2 \times 10^{-15})\ m$$

$$E(0,0) = 10^3 \frac{V}{m} = E_0 = E_0 \operatorname{Sen}(K \cdot 0 + \omega \cdot 0 + \phi)$$

$$= E_0 \operatorname{Sen} \phi$$

$$\phi = \pi/2$$

2.37 Create an expression for the *profile* of a harmonic wave traveling in the z-direction whose magnitude at $z = -\lambda/12$ is 0.866, at $z = +\lambda/6$ is 1/2, and at $z = \lambda/4$ is 0.

$$\psi = \psi_0 \operatorname{Sen}(Kz - \omega t + \phi)$$

$$0{,}866 = \psi_0 \operatorname{Sen}\left[\left(\frac{2\pi}{\lambda}\right)\left(\frac{-\lambda}{12}\right) - \cancel{\omega t} + \phi\right]$$

$$1/2 = \psi_0 \operatorname{Sen}\left[\left(\frac{2\pi}{\lambda}\right)\left(\frac{\lambda}{6}\right) - \cancel{\omega t} + \phi\right]$$

$$0 = \psi_0 \operatorname{Sen}\left[\left(\frac{2\pi}{\cancel{\lambda}}\right)\left(\frac{\cancel{\lambda}}{4}\right) - \cancel{\omega t} + \phi\right] = \psi_0 \operatorname{Sen}\left(\frac{\pi}{2} + \phi\right) = 0$$

$$\phi = \pm \pi/2$$

$$\frac{1}{2} = \psi_0 \operatorname{Sen}\left(\frac{\pi}{3} + \frac{\pi}{2}\right)$$

$$\boxed{\psi_0 = 1}$$

$$\boxed{\psi = 1 \operatorname{Sen}(Kx - \omega t \pm \pi/2)}$$

2.50* The electric field of an electromagnetic plane wave is given in SI units by

$$\vec{\mathbf{E}} = \vec{\mathbf{E}}_0 e^{i(3x - \sqrt{2}\,y - 9.9 \times 10^8 t)}$$

(a) What is the wave's angular frequency? (b) Write an expression for $\vec{\mathbf{k}}$. (c) What is the value of k? (d) Determine the speed of the wave.

$$\vec{E} = E_0\, e^{i(3x - \sqrt{2}y - 9{,}9 \times 10^8 t)}$$

$$\vec{E} = \vec{E}_0 \operatorname{Sen}(\underbrace{3x - \sqrt{2}y}_{\vec{K} \cdot \vec{r}} - 9{,}9 \cdot 10^8 t)$$

$$\omega = 9{,}9 \cdot 10^8 \ \frac{rad}{s}$$

$$\vec{K} = K_x \hat{i} + K_y \hat{j} + K_z \hat{k}$$

$$\vec{r} = x \hat{i} + y \hat{j} + z \hat{k}$$

$$\vec{K} \cdot \vec{r} = K_x x + K_y y + K_z z \Leftrightarrow 3x - \sqrt{2}y$$

$$K_x = 3$$
$$K_y = -\sqrt{2}$$
$$K_z = 0$$

$$\boxed{\vec{K} = 3\hat{i} - \sqrt{2}\hat{j}}$$

$$K = \sqrt{3^2 + (-\sqrt{2})^2} = \sqrt{11} \ \frac{rad}{m}$$

$$v = \lambda \cdot f = \frac{2\pi}{K} \cdot f = \frac{\omega}{K}$$

$$v = \frac{9{,}9 \times 10^8}{\sqrt{11}} \ m/s = 2{,}98 \cdot 10^8 \ m/s$$

— x — x — x —

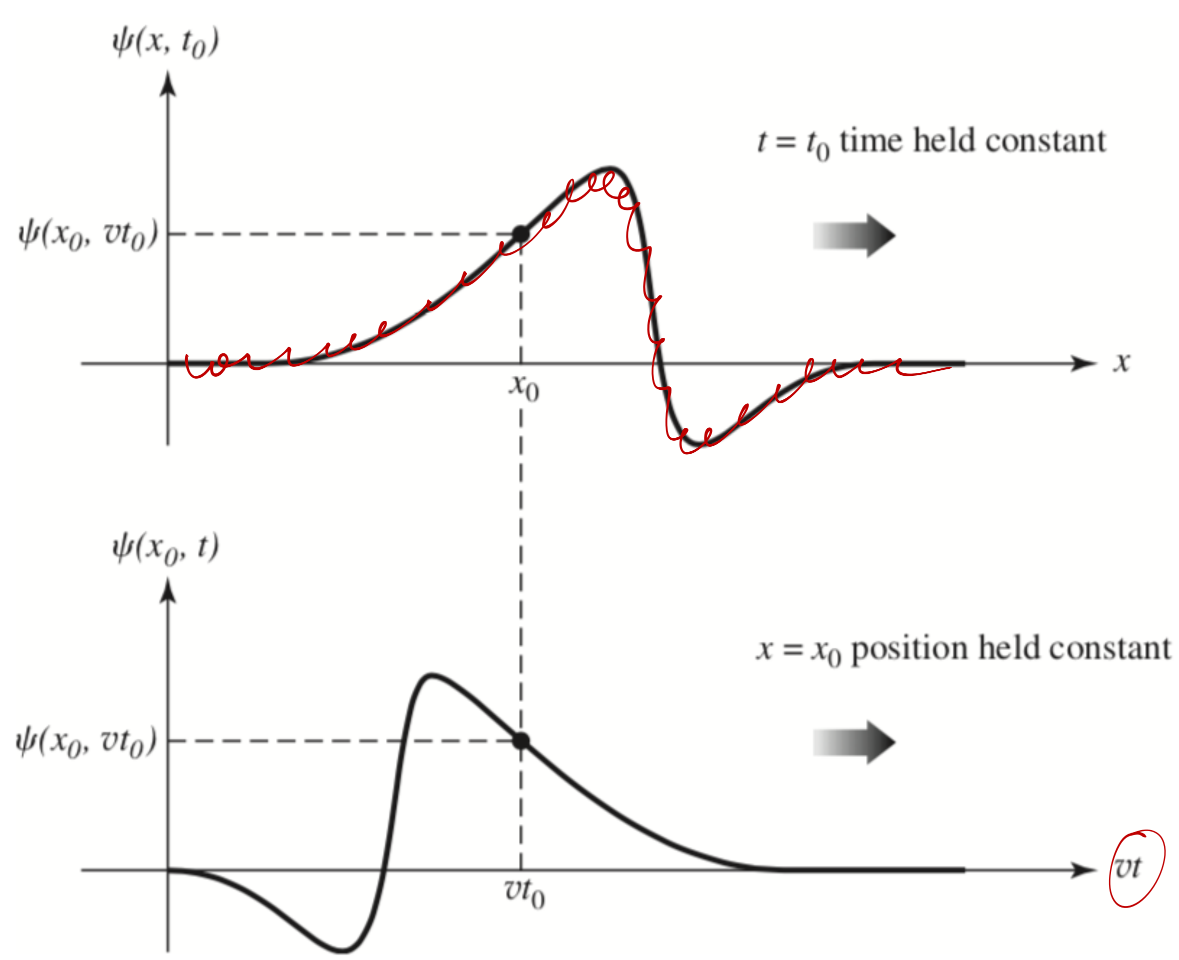


Figure 2.5 Variation of ψ with x and t.

$$\left[\frac{\partial^2 \psi}{\partial x^2}\right] = \left(\frac{1}{v^2}\right)\left[\frac{\partial^2 \psi}{\partial t^2}\right]$$

$$\left(\frac{\partial \psi}{\partial t}\right) = (-v)\left(\frac{\partial \psi}{\partial x}\right)$$

— x — x — x —

Frequencia Espacial (não angular)

$$K \equiv \frac{1}{\lambda}$$

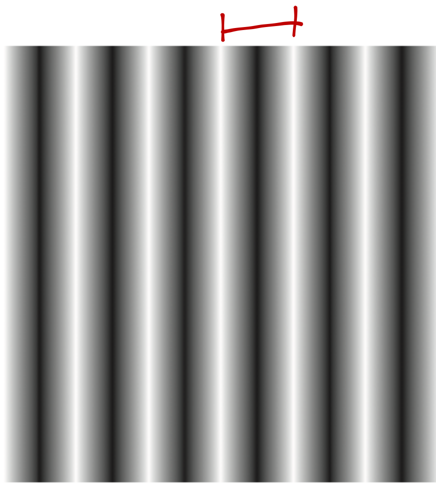
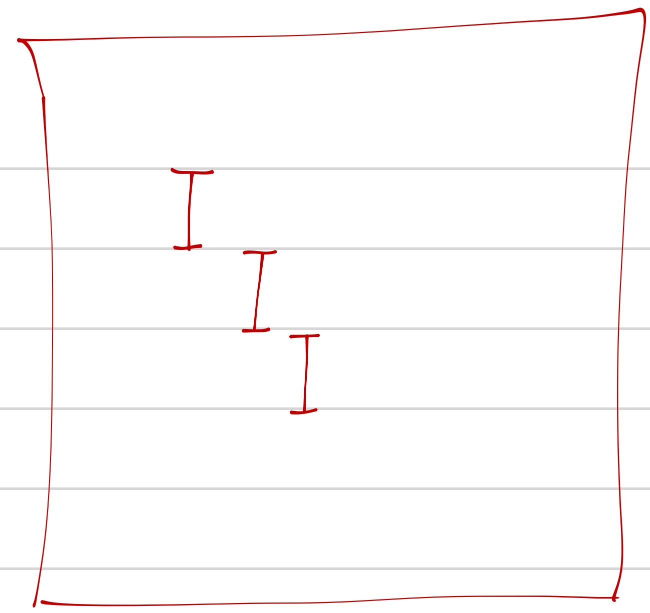


Figure 2.11 A sinusoidal brightness distribution of relatively high spatial frequency.



p/ uma folha de pixel

$I \; \lambda = 7 \, mm$

$K \equiv \dfrac{1}{\lambda} = \dfrac{1}{7mm}$

$\boxed{K = \frac{1}{7} \, mm^{-1}} = 0{,}14 \, mm^{-1}$

$K = \dfrac{16}{120 \, mm} = 0{,}133 \, mm^{-1}$