



General Studies Department

Course Code: PHYS 121 Title: General Physics II Semester: 472

CH\_16\_Q (Waves-I)

**Tutorial Problems:**

Q1. Problem No: 23 Page No: 420

The linear density of a string is  $1.9 \times 10^{-4} \text{ kg/m}$ . A transverse wave on a string is described by the equation  $y = (0.021 \text{ m}) \sin[2.0 \text{ m}^{-1} x + (30 \text{ s}^{-1}) t]$ . What are (a) the wave speed and (b) the tension in the string?

Solution:

$$\mu = 1.9 \times 10^{-4} \text{ kg/m}$$

$$y = 0.021 \sin(2x + 30t)$$

$$y_m = 0.021 \text{ m}$$

$$k = 2 \text{ m}^{-1}$$

$$\omega = 30 \text{ s}^{-1}$$

a) find  $v$

$$v = \frac{\omega}{k} = \sqrt{\frac{T}{\mu}} = \lambda f$$

$$v = \frac{\omega}{k} = \frac{30}{2} = 15 \text{ m/s}$$

b) find  $T$

$$v = \sqrt{\frac{T}{\mu}} \Rightarrow v^2 = \frac{T}{\mu}$$

$$T = v^2 \mu = (15)^2 \times 1.9 \times 10^{-4}$$

$$T = 4.275 \times 10^{-2} \text{ N}$$



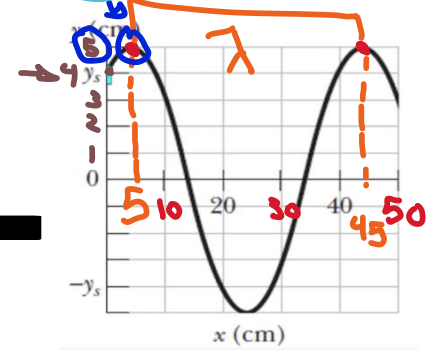
Q2. Problem No: 55 Page No: 422

A sinusoidal transverse wave is travelling along a string in the negative direction of an  $x$ -axis. Figure shows a plot of the displacement as a function of position At time  $t = 0$ ; the scale of the  $y$ -axis is set by  $y_s = 4.0 \text{ cm}$ . The string tension is  $3.6 \text{ N}$ , and its linear density is  $28 \text{ g/m}$ . Find (a) amplitude, (b) Wavelength

(c) Wave speed, and (d) Period of the wave. (e) Find the maximum transverse speed of a particle in the string.

If the wave is of the form  $y(x, t) = y_m \sin(kx \pm \omega t + \phi)$ , What are (f)  $k$ , (g)  $\omega$ , (h)  $\phi$ , and

(i) the correct choice of sign in front of  $\omega$   $\oplus$



Solution:

$$T = 3.6 \text{ N}$$

$$\mu = 28 \times 10^{-3} \text{ kg/m}$$

a)  $y_m$

$$y_m = 5 \text{ cm} = 5 \times 10^{-2} \text{ m}$$

b)  $\lambda$

$$\lambda = 45 - 5 = 40 \text{ cm} = 0.4 \text{ m}$$

f)  $k$

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{0.4}$$

$$k = 15.7$$

c)  $v$

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{3.6}{28 \times 10^{-3}}} = 11.34 \text{ m/s}$$

g)  $\omega$

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.035}$$

$$\omega = 179.51 \text{ s}^{-1}$$

d)  $T$

$$T = \frac{\lambda}{v} = \frac{0.4}{11.34} = 0.035 \text{ s}$$

h)  $\phi$

$$\phi = -\frac{\pi}{2} = 90$$

$\rightarrow +x$   $\boxed{-\omega}$

$\leftarrow -x$   $\boxed{+\omega}$

e)  $v_{max}$

$$v_{max} = \omega y_m = \frac{2\pi}{T} y_m = \frac{2\pi}{0.035} \times 5 \times 10^{-2}$$

$$v_{max} = 8.97 \text{ m/s}$$



**Self-Study Problems:**

**Q1. Problem No: 4 Page No: 419**

$$y = y_m \sin(kx - \omega t)$$

The equation of a transverse wave on a string is  $y = (2.0 \text{ mm}) \sin[15 \text{ m}^{-1}x - (900 \text{ s}^{-1})t]$ . The linear density is  $4.17 \text{ g/m}$ . (a) What is the wave speed? (b) What is the tension in the string?

**Solution:**

$$\begin{aligned} \mu &= 4.17 \times 10^{-3} \text{ kg/m} \\ y_m &= 2 \times 10^{-3} \text{ m} \\ k &= 15 \text{ m}^{-1} \\ \omega &= 900 \text{ s}^{-1} \end{aligned}$$

a)  $v$

$$v = \frac{\omega}{k} = \frac{900}{15} = 60 \text{ m/s}$$

b)  $T$

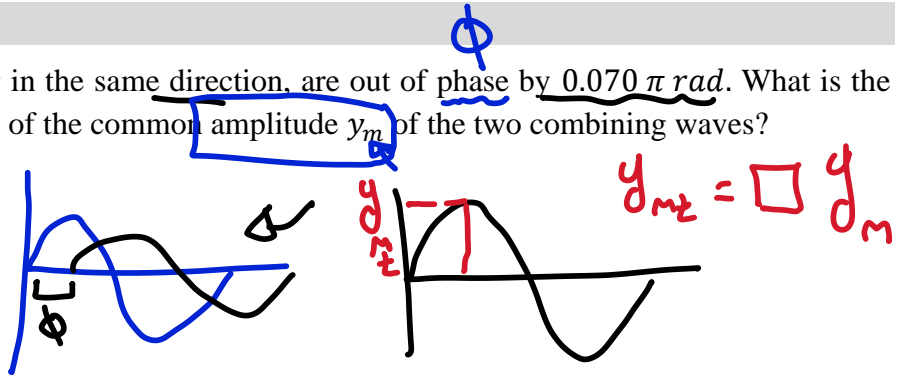
$$\begin{aligned} v &= \sqrt{\frac{T}{\mu}} \Rightarrow v^2 = \frac{T}{\mu} \Rightarrow T = v^2 \mu \\ T &= (60)^2 \times 4.17 \times 10^{-3} = 15.01 \text{ N} \end{aligned}$$

**Q2. Problem No: 11 Page No: 419**

Two identical travelling waves, moving in the same direction, are out of phase by  $0.070 \pi \text{ rad}$ . What is the amplitude of the resultant wave in terms of the common amplitude  $y_m$  of the two combining waves?

**Solution:**

$$\begin{aligned} \phi &= 0.070 \pi \text{ rad} \\ y_m &= ?? \end{aligned}$$



$$(y_m)_{total} = 2 y_m \cos\left(\frac{\phi}{2}\right)$$

$$= 2 y_m \cos\left(\frac{0.07 \times 180}{2}\right)$$

$$(y_m)_{total} = 1.99 y_m$$





**Q3. Problem No: 33 Page No: 421**

A wave has an angular frequency of  $110 \text{ rad/s}$  and a wave length of  $1.50 \text{ m}$ . Calculate (a) the angular wave number and (b) the speed of the wave?

Solution:

$$\omega = 110 \text{ rad/s}$$

$$\lambda = 1.5 \text{ m}$$

a)  $k$

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{1.5} = 4.19 \text{ m}^{-1}$$

b)  $v$

$$v = \frac{\omega}{k} = \frac{110}{4.19} = 26.3 \text{ m/s}$$

**Q4. Problem No: 45 Page No: 421**

What are (a) the lowest frequency, (b) the second lowest frequency, and (c) the third lowest frequency for standing waves on a wire that is  $10.0 \text{ m}$  long, has a mass of  $100 \text{ g}$ , and is stretched under a tension of  $275 \text{ N}$ ?

Solution:

$$L = 10 \text{ m}$$

$$M = 100 \times 10^{-3} \text{ g}$$

$$T = 275 \text{ N}$$

$$f_n = \frac{n v}{2L}, \quad n = 1, 2, 3, \dots$$

$$v = \sqrt{\frac{T}{\mu}} \rightarrow \mu = \frac{M}{L} = \frac{100 \times 10^{-3}}{10} = 0.01 \text{ kg/m}$$

$$v = \sqrt{\frac{275}{0.01}} = 165.8 \text{ m/s}$$

a)  $n=1$

$$f_1 = \frac{1 \times 165.8}{2 \times 10} = 8.29 \text{ Hz}$$

b)  $f_2 = 2f_1$

$$f_2 = 2 \times 8.29 = 16.6 \text{ Hz}$$

c)  $f_3 = 3f_1$

$$f_3 = 3 \times 8.29 = 24.9 \text{ Hz}$$



**Q5. Problem No: 52 Page No: 422**

A string along which waves can travel is 2.70 m long and has a mass of 130 g. The tension in the string is 36.0 N. What must be the frequency of travelling waves of amplitude 7.70 mm for the average power to be 170 W?

**Solution:**

$$L = 2.7 \text{ m}$$

$$M = 130 \times 10^{-3} \text{ kg}$$

$$T = 36 \text{ N}$$

$$P = ?$$

$$y_m = 7.7 \times 10^{-3} \text{ m}$$

$$P = 170 \text{ W}$$

$$f = \frac{1}{T} = \frac{2\pi}{\omega}$$

$$P = \frac{1}{2} \mu \omega^2 y_m^2 v$$

$$\omega^2 = \frac{2P}{\mu y_m^2 v} \Rightarrow \omega = \sqrt{\frac{2P}{\mu y_m^2 v}}$$

$$\mu = \frac{m}{L} = \frac{130 \times 10^{-3}}{2.7} = 0.048 \text{ kg/m}$$

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{36}{0.048}} = 27.386 \text{ m/s}$$

$$\omega = \sqrt{\frac{2 \times 170}{0.048 \times (7.7 \times 10^{-3})^2 \times 27.39}} = 2088.49 \text{ s}^{-1}$$

$$f = \frac{\omega}{2\pi} = \frac{2088.49}{2\pi} = 332.38 \text{ Hz}$$

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