WAVE MOTION

1. Speed of a transverse wave on a straight wire (mass 6.0 g, length 60 cm and area of cross-section 1.0 mm^2) is 90 ms^{-1}. If the Young's modulus of wire is 16×10^{11} Nm^{-2}, the extension of wire over its natural length is :

(1) 0.02 mm (2) 0.04 mm
(3) 0.03 mm (4) 0.01 mm

2. A stationary observer receives sound from two identical tuning forks, one of which approaches and the other one recedes with the same speed (much less than the speed of sound). The observer hears 2 beats/sec. The oscillation frequency of each tuning fork is ν_0 = 1400 Hz and the velocity of sound in air is 350 m/s. The speed of each tuning fork is close to :

(1) $\frac{1}{8}$ m/s (2) $\frac{1}{2}$ m/s (3) 1 m/s (4) $\frac{1}{4}$ m/s

3. A one metre long (both ends open) organ pipe is kept in a gas that has double the density of air at STP. Assuming the speed of sound in air at STP is 300 m/s, the frequency difference between the fundamental and second harmonic of this pipe is ________ Hz.

4. A transverse wave travels on a taut steel wire with a velocity of v when tension in it is 2.06×10^4 N. When the tension is changed to T, the velocity changed to v/2. The value of T is close to :

(1) 10.2×10^2 N
(2) 5.15×10^3 N
(3) 2.50×10^4 N
(4) 30.5×10^4 N

5. Three harmonic waves having equal frequency ν and same intensity I_0, have phase angles 0, $\frac{\pi}{4}$ and $-\frac{\pi}{4}$ respectively. When they are superimposed the intensity of the resultant wave is close to :

(1) 5.8 I_0 (2) 0.2 I_0
(3) I_0 (4) 3 I_0

6. A wire of length L and mass per unit length 6.0×10^{-3} kgm^{-1} is put under tension of 540 N. Two consecutive frequencies that it resonates at are : 420 Hz and 490 Hz. Then L in meters is :

(1) 8.1 m (2) 5.1 m
(3) 1.1 m (4) 2.1 m

7. Two identical strings X and Z made of same material have tension T_X and T_Z in them. It their fundamental frequencies are 450 Hz and 300 Hz, respectively, then the ratio T_X/T_Z is :

(1) 0.44 (2) 1.5
(3) 2.25 (4) 1.25

8. A wire of density 9×10^{-3} kg cm^{-3} is stretched between two clamps 1 m apart. The resulting strain in the wire is 4.9×10^{-4}. The lowest frequency of the transverse vibrations in the wire is (Young's modulus of wire Y = 9×10^{10} Nm^{-2}), (to the nearest integer),__________.

9. A uniform thin rope of length 12 m and mass 6 kg hangs vertically from a rigid support and a block of mass 2 kg is attached to its free end. A transverse short wavetrain of wavelength 6 cm is produced at the lower end of the rope. What is the wavelength of the wavetrain (in cm) when it reaches the top of the rope ?

(1) 9 (2) 12 (3) 6 (4) 3

10. For a transverse wave travelling along a straight line, the distance between two peaks (crests) is 5 m, while the distance between one crest and one trough is 1.5 m. The possible wavelengths (in m) of the waves are :

(1) 1, 2, 3, ...
(2) $\frac{1}{2}, \frac{1}{4}, \frac{1}{6}, ...$
(3) 1, 3, 5, ...
(4) $\frac{1}{1}, \frac{1}{3}, \frac{1}{5}, ...$

11. The driver of a bus approaching a big wall notices that the frequency of his bus's horn changes from 420 Hz to 490 Hz, when he hears it after it gets reflected from the wall. Find the speed of the bus if speed of the sound is 330 ms^{-1}.

(1) 91 kmh^{-1}

(2) 71 kmh^{-1}

(3) 81 kmh^{-1}

(4) 61 kmh^{-1}

12. In a resonance tube experiment when the tube is filled with water up to height of 17.0 cm from bottom, it resonates with a given tuning fork. When the water level is raised the next resonance with the same tuning fork occurs at a height of 24.5 cm. If the velocity of sound in air is 330 m/s, the tuning fork frequency is:

(1) 1100 Hz

(2) 3300 Hz

(3) 2200 Hz

(4) 550 Hz

13. Assume that the displacement(s) of air is proportional to the pressure difference (Δp) created by a sound wave. Displacement(s) further depends on the speed of sound (v), density of air (ρ) and the frequency (f). If $\Delta p \sim 10 Pa$, $v \sim 300$ m/s, $p \sim 1$ kg/m^3 and $f \sim 1000 Hz$, then s will be the order of (take multiplicative constant to be 1)

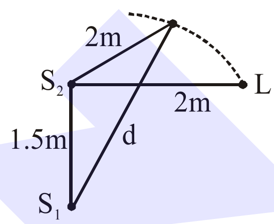
(1) 10 mm

(2) $\frac{3}{100}$ mm

(3) 1 mm

(4) $\frac{1}{10}$ mm

14. Two coherent sources of sound, S_1 and S_2, produce sound waves of the same wavelength, $\lambda = 1$ m, in phase. S_1 and S_2 are placed 1.5 m apart (see fig.) A listener, located at L, directly in front of S_2 finds that the intensity is at a minimum when he is 2m away from S_2. The listener moves away from S_1, keeping his distance from S_2 fixed. The adjacent maximum of intensity is observed when the listener is at a distance d from S_1. Then, d is :



(1) 12m

(2) 3m

(3) 5m

(4) 2m

15. A driver in a car, approaching a vertical wall notices that the frequency of his car horn, has changed from 440 Hz to 480 Hz, when it gets reflected from the wall. If the speed of sound in air is 345 m/s, then the speed of the car is

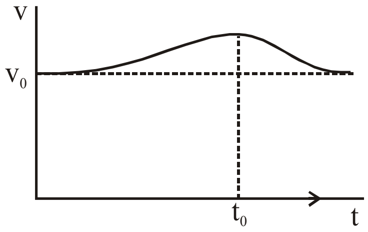
(1) 36 km/hr

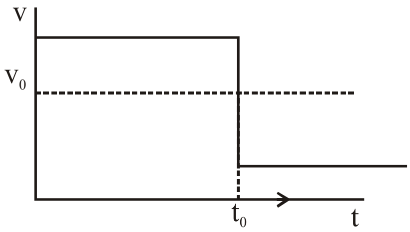
(2) 24 km/hr

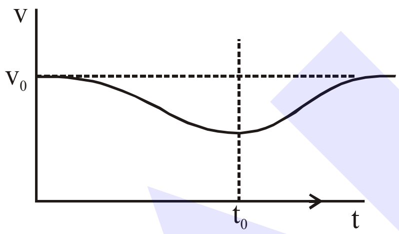
(3) 18 km/hr

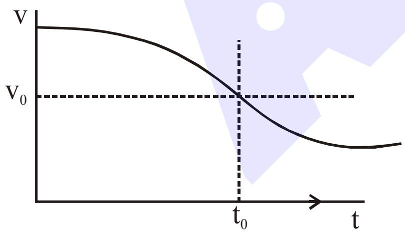
(4) 54 km/hr

16. A sound source S is moving along a straight track with speed v, and is emitting sound of frequency ν_0 (see figure). An observer is standing at a finite distance, at the point O, from the track. The time variation of frequency heard by the observer is best represented by :
(t_0 represents the instant when the distance between the source and observer is minimum)

(1) 

(2) 

(3) 

(4) 

SOLUTION

1. NTA Ans. (3)

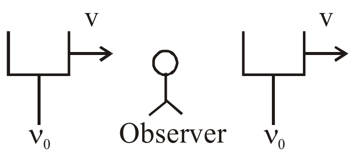
Sol. $v = \sqrt{\frac{T}{\mu}}$

$$90 = \sqrt{\frac{\frac{YA}{l}\Delta l}{\frac{m}{l}}} = \sqrt{\frac{16\times10^{11}\times10^{-6}\times\Delta l}{6\times10^{-3}}}$$

$$= \frac{8100\times3}{8}\times10^{-8} = \Delta l$$

2. NTA Ans. (4)

Sol.



$$\nu_1 = \left(\frac{c}{c-v}\right)\nu_0$$

$$\nu_2 = \left(\frac{c}{c+v}\right)\nu_0$$

beat frequency $= \nu_1 - \nu_2$

$$= c\nu_0\left(\frac{1}{c-v} - \frac{1}{c+v}\right)$$

$$= c\nu_0\left(\frac{c+v-c+v}{c^2-v^2}\right) = \frac{2c\nu_0^2 v}{c^2-v^2}$$

$$\approx \frac{2c\nu_0 v}{c^2} = \frac{2\nu_0 v}{c} = 2$$

$$\Rightarrow \frac{2\times1400\times v}{350} = 2$$

$$\Rightarrow v = \frac{1}{4}\text{ m/s}$$

3. NTA Ans. (106.00 to 107.20)

Sol. $v_s = \sqrt{\frac{\gamma P}{\rho}}$

$$\frac{v_{gas}}{v_{air}} = \sqrt{\frac{\rho_{air}}{\rho_{gas}}} \qquad \Rightarrow \frac{v_{gas}}{300} = \frac{1}{\sqrt{2}}$$

$$\Rightarrow v_{gas} = \frac{300}{\sqrt{2}} \qquad \Rightarrow \therefore\ v_{gas} = 150\sqrt{2}$$

Now $n_2 - n_1 = \frac{v_{gas}}{2\ell} = \frac{150\sqrt{2}}{2(1)} = 75\sqrt{2}$

$\Rightarrow \Delta n = 106.06$ Hz

4. NTA Ans. (2)

Sol. Velocity of transverse wave $V \propto \sqrt{T}$

$$V \to \frac{V}{2} \Rightarrow T \to T' = \frac{T}{4}$$

$$T' = \frac{2.06\times10^4}{4} = 5.15\times10^3\text{N}$$

5. NTA Ans. (1)

Sol. Let amplitude of each wave is A.

Resultant wave equation

$$= A\sin\omega t + A\sin\left(\omega t - \frac{\pi}{4}\right) + A\sin\left(\omega t + \frac{\pi}{4}\right)$$

$$= A\sin\omega t + \sqrt{2}A\sin\omega t$$

$$= \left(\sqrt{2}+1\right)A\sin\omega t$$

Resultant wave amplitude $= \left(\sqrt{2}+1\right)A$

as $I \propto A^2$

so $\frac{I}{I_0} = \left(\sqrt{2}+1\right)^2$

$I = 5.8\ I_0$

6. NTA Ans. (4)

Sol. $\frac{nv}{2\ell} = 420$

$$\frac{(n+1)v}{2\ell} = 490$$

$$\frac{v}{2\ell} = 70$$

$$\ell = \frac{v}{140} = \frac{1}{140}\sqrt{\frac{540}{6\times10^{-3}}} = \frac{1}{140}\sqrt{90\times10^3}$$

$$\ell = \frac{300}{140} = 2.142$$

$\therefore$ Correct answer (4)

7. Official Ans. by NTA (3)

Sol. $f = \frac{1}{2\ell}\sqrt{\frac{T}{\mu}}$

For identical string l and μ will be same

$f \propto \sqrt{T}$

$$\frac{450}{300} = \sqrt{\frac{T_x}{T_y}}$$

$$\frac{T_x}{T_y} = \frac{9}{4} = 2.25$$

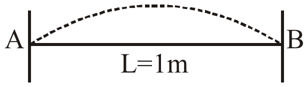
8. Official Ans. by NTA (35.00)

Sol. $\rho_{wire} = 9\times10^{-3}\dfrac{kg}{cm^3} = \dfrac{9\times10^{-3}}{10^{-6}} kg/m^3$

$= 9000\ kg/m^2$

(A = CSA of wire)

($Y = 9 \times 10^{10}\ Nm^2$)



(Strain = 4.9×10^{-4})

$\Rightarrow L = 1m = \dfrac{\lambda}{2} \Rightarrow \lambda = 2m$

$\Rightarrow v = f\lambda \Rightarrow \sqrt{\dfrac{T}{\mu}} = f\lambda$

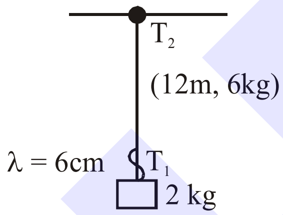
Where $Y = \dfrac{T/A}{strain} \Rightarrow T = Y.A.strain$

9. Official Ans. by NTA (2)

Sol. $V \propto \lambda$ $T_2 = 8g$

$T_1 = 2g$

$\dfrac{V_1}{V_2} = \dfrac{\lambda_1}{\lambda_2}$



$\lambda_2 = \dfrac{V_2}{V_1}\lambda_1 = \sqrt{\dfrac{T_2}{T_1}} \times \lambda_1$

$= \sqrt{\dfrac{8g}{2g}}\lambda_1 = 2 \times 6 = 12\ cm$

10. Official Ans. by NTA (4)

Sol. Given T to C 1.5 m

C to C 5m

T to C = $(2n_1 + 1)\dfrac{\lambda}{2}$

C to C = $n_2\lambda$

$\dfrac{1.5}{5} = \dfrac{(2n_1+1)}{2n_2} \Rightarrow 3n_2 = 10n_1 + 5$

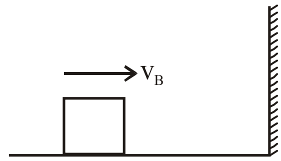
$n_1 = 1, n_2 = 5 \rightarrow \lambda = 1$

$n_1 = 4, n_2 = 15 \rightarrow \lambda = 1/3$

$n_1 = 7, n_2 = 25 \rightarrow \lambda = 1/5$

11. Official Ans. by NTA (1)

Sol.



$f_1 = \left(\dfrac{330}{330 - v_B}\right)420$

$f_2 = \left(\dfrac{330 + v_0}{330}\right)\left(\dfrac{330}{330 - v_B}\right)420$

$490 = \left(\dfrac{330 + v_B}{330 - v_B}\right)420$

$\dfrac{7}{6} = \dfrac{330 + v_B}{330 - v_B}$

$v_B = \dfrac{330}{13}\ m/s$

$= \dfrac{330}{13} \times \dfrac{18}{5} \approx 91\ km/hr$

12. Official Ans. by NTA (3)

Sol. $\Rightarrow \lambda = 2(l_2 - l_1) \Rightarrow 2 \times (24.5 - 17)$

$\Rightarrow 2 \times 7.5 = 15\ cm$

& $v = f\lambda \Rightarrow 330 = \lambda \times 15 \times 10^{-2}$

$\lambda = \dfrac{330}{15} \times 100 \Rightarrow \dfrac{1100 \times 100}{5}$

$\Rightarrow 2200\ Hz$

13. Official Ans. by NTA (2)

Sol. $\Delta p = BkS_0$

$= \rho v^2 \times \dfrac{\omega}{v} \times S_0$

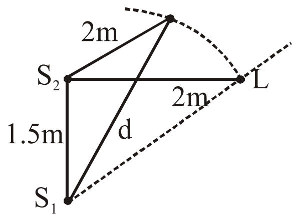
$\Rightarrow S_0 = \dfrac{\Delta p}{\rho v \omega}$

$\approx \dfrac{10}{1 \times 300 \times 1000} m$

$= \dfrac{1}{30} mm \approx \dfrac{3}{100} mm$

14. Official Ans. by NTA (2)

Sol.



Initially $S_2L = 2m$

$S_1L = \sqrt{2^2 + (3/2)^2}$

$S_1L = \frac{5}{2} = 2.5$ m

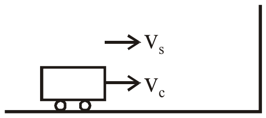
$\Delta x = S_1L - S_2L = 0.5$ m

So since $\lambda = 1m \quad \therefore \Delta x = \frac{\lambda}{2}$

So while listener moves away from S_1
Then, Δx (= $S_1L - S_2L$) increases
and hence, at $\Delta x = \lambda$ first maxima will appear.
$\Delta x = \lambda = S_1L - S_2L$
$1 = d - 2 \Rightarrow d = 3m$

15. Official Ans. by NTA (4)

Sol.



f_1 = frequency heard by wall = $f_s = \left(\frac{v_s}{v_s - v_c}\right)$

f_2 = frequency heard by driver after reflection from wall

$$f_2 = \left(\frac{v_s + v_c}{v_s}\right) f_1 = \left(\frac{v_s + v_c}{v_s - v_c}\right) f_0$$

$$\frac{f_2}{f_0} = \frac{v_s - v_c}{v_s + v_c}$$

$$\frac{48}{44} = \frac{v_s - v_c}{v_s + v_c}$$

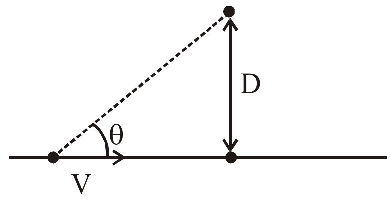
$12(v_s + v_c) = 11(v_s - v_c)$
$23v_c = v_s$

$$v_c = \frac{v_s}{23} = \frac{345}{23} = 15m/s$$

$$= \frac{15 \times 18}{5} = 54 \text{ km/hr}$$

16. Official Ans. by NTA (4)

Sol.



$$f_{observed} \Rightarrow \left(\frac{v_{sound}}{v_{sound} - v\cos\theta}\right) f_0$$

initially θ will be less $\Rightarrow \cos\theta$ more
$\therefore f_{observed}$ more, then it will decrease.
$\therefore$ Ans. (4)