DPP – 4 (Waves)

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Q 1. Equation of a stationary wave is given by
(a) $y = A\sin(kx - \omega t)$ (b) $y = 2A\sin(kx)\cos(\omega t)$
(c) $y = A\cos 2\pi\left(kx - \frac{t}{T}\right)$ (d) $y = A\cos\left(\frac{2\pi t}{T}\right)$

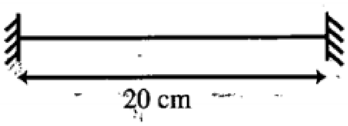
Q 2. The standing waves set upon a string are given by $y = 4\sin\left(\frac{\pi x}{12}\right)\cos(52\pi t)$. If x and y are in centimeters and t is in seconds, what is the amplitude of the particle at x = 2 cm?
(a) 12 cm (b) 4 cm (c) 2 cm (d) 1 cm

Q 3. Standing waves cannot be produced:
(a) on a string clamped at both ends
(b) on a string clamped at one end and free at the other
(c) when incident wave gets reflected from a wall
(d) when two identical waves with a phase difference of π are moving in the same direction

Q 4. The equation of a stationary wave in a medium is given as $y = \sin\omega t\cos kx$. The length of a loop in fundamental mode is
(a) $\frac{\pi}{2K}$ (b) $\frac{\pi}{K}$ (c) $\frac{2\pi}{K}$ (d) $\frac{K}{\pi}$

Q 5. A standing wave having 3 nodes and 2 antinodes is formed between two atoms having a distance 1.21 Å between them. The wavelength of the standing wave is
(a) 1.21 Å (b) 3.63 Å (c) 4.48 Å (d) 5.86 Å

Q 6. A 20 cm long string, having a mass of 1.0 g, is fixed at both the ends. The tension in the string is 0.5 N. The string is set into vibrations using an external vibrator of frequency 100 Hz. Find the separation (in cm) between the successive nodes on the string.



(a) 10 cm (b) 20 cm (c) 5 cm (d) 15 cm

Q 7. One end of a taut string of length 3m along the x axis is fixed at x = 0. The speed of the waves in the string is 100 m/s. The other end of the string is vibrating in the y direction so that stationary waves are set up in the string. The possible waveform(s) of these stationary waves is (are)

(a) $y(t) = A\sin\frac{\pi x}{6}\cos\frac{50\pi t}{6}$ (b) $y(t) = A\sin\frac{\pi x}{3}\cos\frac{100\pi t}{3}$

(c) $y(t) = A\sin\frac{5\pi x}{6}\cos\frac{250\pi t}{3}$ (d) $y(t) = A\sin\frac{5\pi x}{2}\cos 50\pi t$

Q 8. A standing wave on a string is given by $y = (4\ cm)\cos\pi x\sin 50\pi t$, where x is in meters and t is in seconds. The velocity of the string section at x = $\frac{1}{3}$ m at t = $\frac{1}{5}$ s is:

(a) zero (b) π m/s

(c) 840π m/s (d) none of these

Q 9. A stretched string is 1 m long. Its liner density is 0.5 gm/m. It is stretched with a force of 20 N. If plucked at a distance of 25 cm from one end, the frequency of the tone emitted by it is

(a) 100 Hz (b) 200 Hz

(c) 300 Hz (d) 400 Hz

Q 10. If n, 2n, 3n are the fundamental frequencies of the three segments into which a string is divided by placing required number of bridges below it. If n_0 is the fundamental frequency of the string, then

(a) $n_0 = 3n$ (b) $n_0 = 6n$

(c) $n_0 = \frac{3n}{5}$ (d) $n_0 = \frac{6n}{11}$

Q 11. The second harmonic for a standing wave in a string fixed at both the ends is 50 Hz. What will be its 5th harmonic?

(a) 50 Hz (b) 150 Hz

(c) 175 Hz (d) 125 Hz

Q 12. In sonometer experiment, the bridges are separated by a fixed distance. The wire which is slightly elastic, emits a tone of frequency 'n' when held by tension 'T'. If the tension is increased to '4T', the tone emitted by the wire will be of frequency

(a) n (b) 2n

(c) Slightly greater than 2n (d) Slightly less than n

Q 13. The length of the wire between two ends of a sonometer is 100cm. What should be the (in cm) of two bridges below the wire so that the three segments of the wire have their fundamental frequencies in the ratio 1:3:5

(a) $\frac{1500}{23}, \frac{2000}{23}$ (b) $\frac{1500}{23}, \frac{500}{23}$

(c) $\frac{1500}{23}, \frac{300}{23}$ (d) $\frac{300}{23}, \frac{1500}{23}$

Q 14. Length of sonometer wire stretched between two points is 105cm. Two bridges are kept between two ends so that sonometer wire is divided into three parts whose fundamental frequencies are in ratio of 1:3:15. The lengths of three parts are:

(a) 5 cm, 20 cm, 80 cm (b) 20 cm, 35 cm, 50 cm

(c) 25 cm, 35 cm, 45 cm (d) 75 cm, 25 cm, 5 cm

Q 15. Which of the following cannot be the frequency of vibration of 20cm length of a sonometer wire (linear density is 0.0294 gm/cm) under a tension 3kg wt is?
(a) 750 Hz (b) 500 Hz
(c) 250 Hz (d) 125 Hz

Q 16. Calculate the fundamental frequency of a sonometer wire of length 20cm, tension 25N, cross sectional area $10^{-2}\ cm^2$ and density of material = 10^4 kg/m^3
(a) 200 Hz (b) 120 Hz
(c) 125 Hz (d) 75 Hz

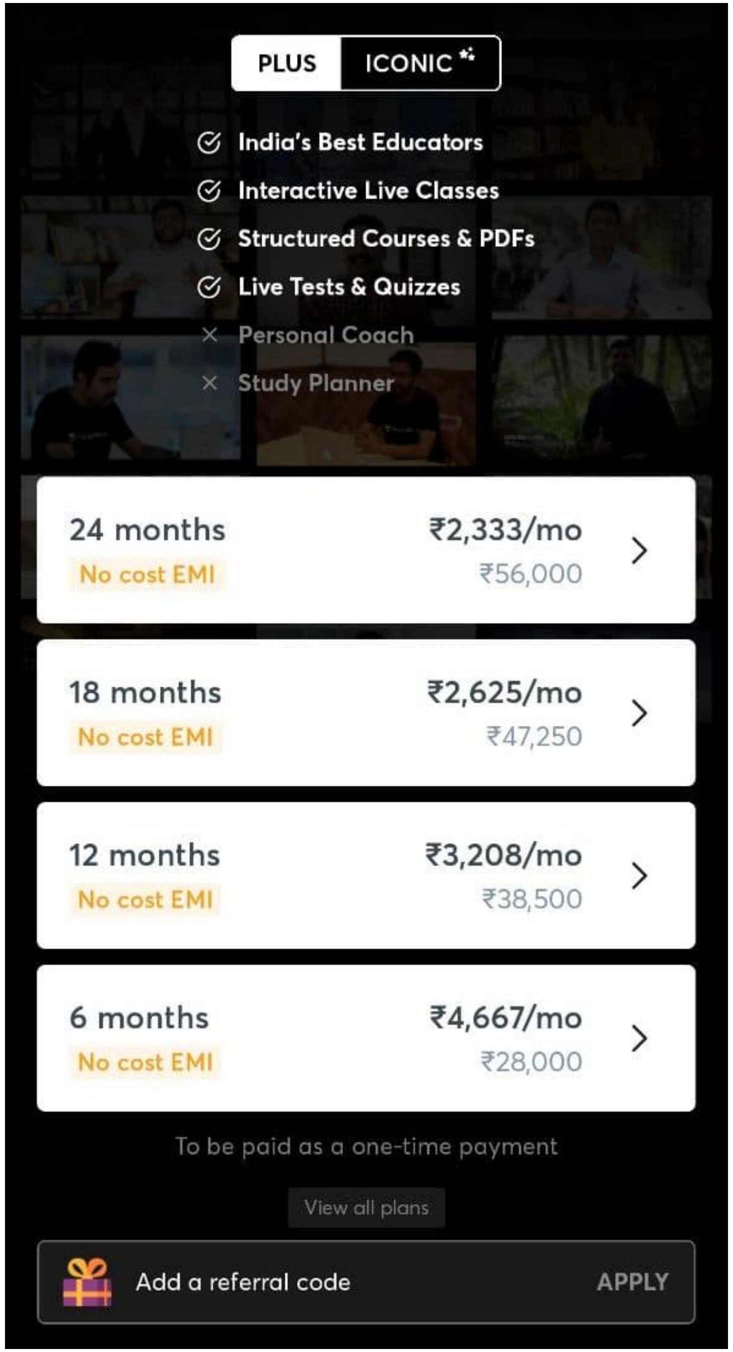
Q 17. A stretched string is vibrating in the second overtone, then the number of nodes and anti-nodes between the ends of the string are respectively
(a) 3 & 4 (b) 4 & 3
(c) 2 & 3 (d) 3 & 2

Q 18. The first overtone of a stretched string of given length is 320 Hz. The first harmonic is
(a) 320 Hz (b) 640 Hz
(c) 160 Hz (d) 480 Hz

Q 19. An elastic string of length 2 m is fixed at its end. The string starts to vibrate in third overtone with a frequency 1200 Hz. The ratio of frequency of lower (first)overtone and fundamental is
(a) 1 (b) 2
(c) 3 (d) 4

Answer Key

Q.1 b	Q.2 c	Q.3 d	Q.4 b	Q.5 a
Q.6 c	Q.7 c	Q.8 b	Q.9 b	Q.10 d
Q.11 d	Q.12 c	Q.13 a	Q.14 d	Q.15 d
Q.16 c	Q.17 b	Q.18 c	Q.19 b	



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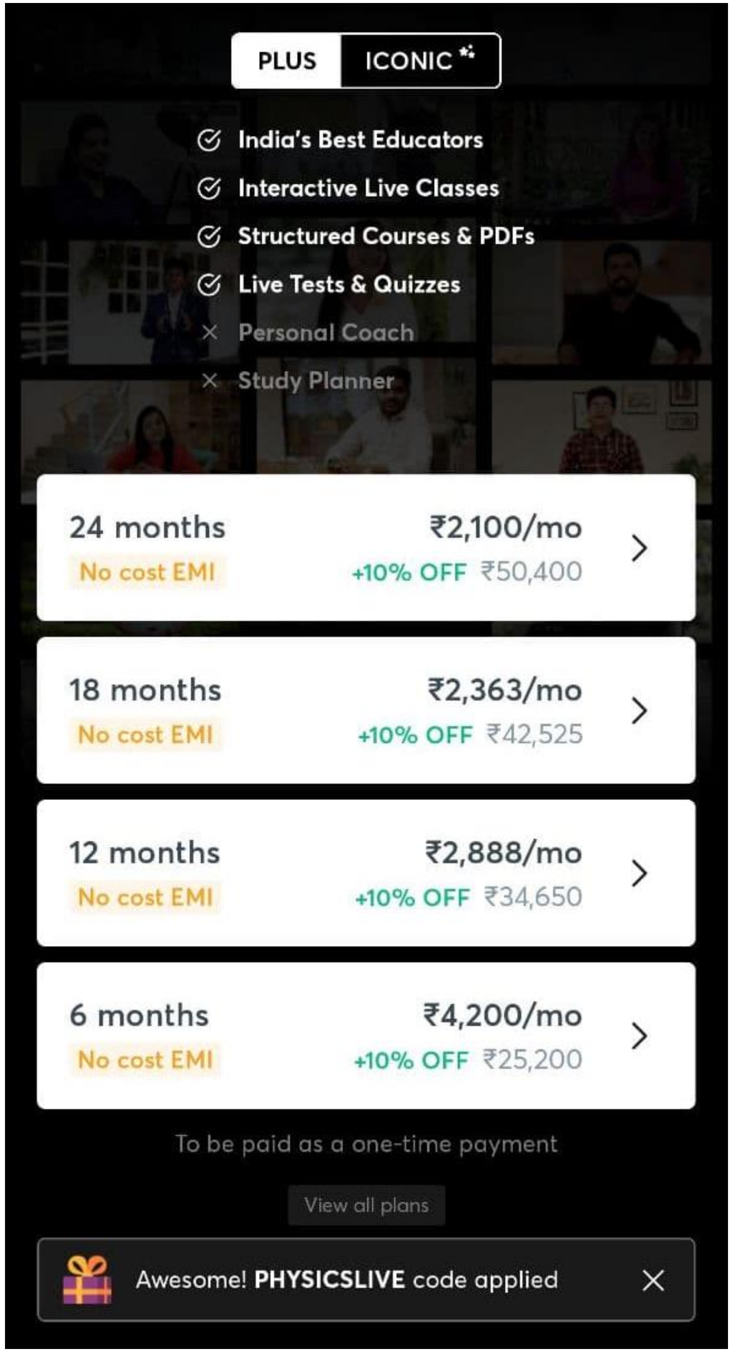

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Written Solution

DPP-4 Waves: Standing Waves

By Physicsaholics Team

Solution: 1

∵ In standing waves; amplitude of wave changes with position 'x'

(a) $y = A\sin(kx - \omega t)$

Amplitude $= A =$ fixed

⇒ Not standing wave

(b) $y = 2A\sin(kx)\cos\omega t$

Amplitude $= 2A\sin(kx)$

depends on 'x'

⇒ Standing wave ✓

(c) $y = A\cos 2\pi\left(kx - \frac{t}{T}\right)$

Amplitude $= A =$ fixed

⇒ Not standing wave

(d) $y = A\cos\left(\frac{2\pi t}{T}\right)$

Amplitude $= A =$ fixed

⇒ Not standing wave

Ans. b

Solution: 2

$$y = 4\sin\left(\frac{\pi}{12}x\right)\cos(52\pi t)$$

Amplitude ;

$$A = 4\sin\left(\frac{\pi}{12}x\right)$$

at $x = 2$ cm

$$A = 4\sin\left(\frac{\pi}{12}\times 2\right)$$

$$= 4\sin\left(\frac{\pi}{6}\right)$$

$$= 4\times\frac{1}{2}$$

$$\boxed{A = 2\ \text{cm}}$$ Ans.

Ans. c

Solution: 3

Standing waves can be produced only when two similar type of waves (same frequency and speed and amplitude) travel in opposite directions.

Ans. d

Solution: 4

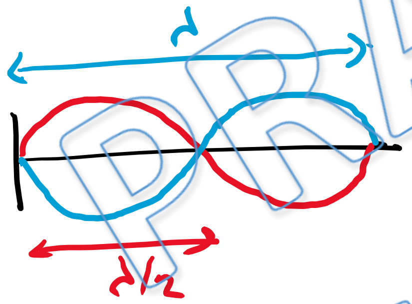
$$y = \sin \omega t \cos kx$$

$$y = \cos kx \sin \omega t$$

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

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

in fundamental mode



length of loop

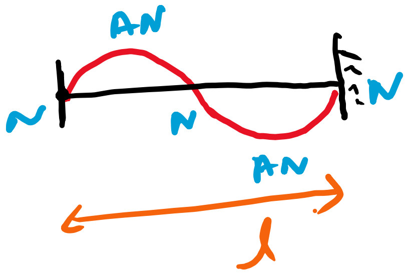
$$l = \lambda/2$$

$$l = \frac{1}{2}\left(\frac{2\pi}{k}\right)$$

$$\boxed{l = \frac{\pi}{k}}$$ Ans

Ans. b

Solution: 5



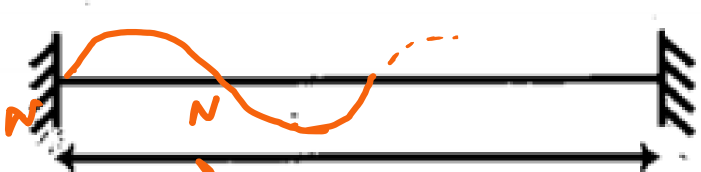
$l = \lambda$

$\lambda = l$

so; $\lambda = 1.21\ A^{\circ}$ Ans

Ans. a

Solution: 6



$d = \lambda/2$

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

$\mu = \frac{0.1 gm}{20 cm} = \frac{10^{-3}}{20 \times 10^{-2}}$ kg/m

$\mu = 5 \times 10^{-3}$ kg/m

$v = \sqrt{\frac{0.5}{5 \times 10^{-3}}}$

$v = 10$ m/s

$f = 100$ Hz

$\because$ Node to Node distance

$d = \lambda/2$

$\because v = f\lambda \Rightarrow \lambda = \frac{v}{f}$

$d = \frac{v}{2f}$

$d = \frac{10}{2 \times 100} = \frac{0.1}{2}$

$d = 0.05$ m

$d = 5$ cm Ans.

Ans. c

Solution: 7

at $x=0$; string is fixed

so; at $x=0$; Amplitude $=0$

so; eq^n of standing wave

$y = A \sin kx \cos \omega t$

$v = 100\ m/s$

one end fixed & one end free

so; $L = (2n+1)\frac{\lambda}{4}$

as; $L = 3m$

$$\lambda = \frac{12}{(1+2n)}$$

$\therefore k = \frac{2\pi}{\lambda} = \frac{2\pi}{12/(1+2n)}$

$k = \frac{2\pi(1+2n)}{12} = \frac{\pi(1+2n)}{6}$

$$k = \frac{\pi}{6}(1+2n)$$

$\omega = vk = 100 \times \frac{\pi(1+2n)}{6}$

$$\omega = \frac{50\pi}{3}(1+2n)$$

so, $n=0 \Rightarrow k = \frac{\pi}{6}$, $\omega = \frac{50\pi}{3}$

$y = A \sin\left(\frac{\pi}{6}x\right) \cos\left(\frac{50\pi}{3}t\right)$

for $n=1 \Rightarrow k = \frac{\pi}{2}$, $\omega = 50\pi$

$y = A \sin\left(\frac{\pi}{2}x\right) \cos(50\pi t)$

for $n=2 \Rightarrow k = \frac{5\pi}{6}$, $\omega = \frac{250\pi}{3}$

$$y = A \sin\left(\frac{5\pi}{6}x\right) \cos\left(\frac{250\pi}{3}t\right)$$ Ans

Ans. c

Solution: 8

$$y = (4\,cm)\cos\pi x \cdot \sin 50\pi t$$

$$v = \frac{\partial y}{\partial t} = [(4\,cm)\cos\pi x]\frac{d}{dt}[\sin 50\pi t]$$

$$= [(4\,cm)\cos\pi x](\cos 50\pi t) \cdot 50\pi$$

$$v = (200\pi\,cm)\cos\pi x \cdot \cos 50\pi t$$

so; at $x = \frac{1}{3}\,m$ & $t = \frac{1}{5}\,sec$

$$v = (200\pi\,cm)\cos\left(\frac{\pi}{3}\right)\cdot\cos\left(50\pi \times \frac{1}{5}\right)$$

$$= (200\pi\,cm)\left(\frac{1}{2}\right)\cdot\cos(10\pi) \quad [\cos(10\pi) = 1]$$

$$v = 100\pi\,cm/s$$

$$\boxed{v = \pi\,m/s}$$ Ans.

Ans. b

Solution: 9

$l = 1\ m$

$\mu = 0.5\ gm/m$

$\mu = 5 \times 10^{-4}\ kg/m$

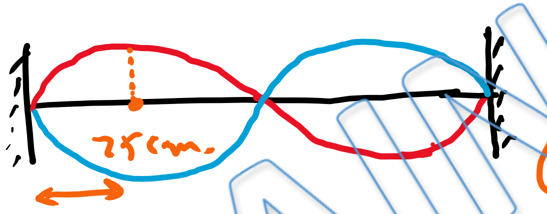
$F = 20\ N$

$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{20}{5 \times 10^{-4}}}$

$v = \sqrt{4 \times 10^4}$

$\boxed{v = 200\ m/s}$

If at $x = 25\ cm$, string is plucked; so there will be antinode



(2nd harmonic)

$d/4 = 25\ cm.$

$\boxed{d = 1\ m.}$

$f = \frac{nv}{2l}$

$f = \frac{2v}{2l} = \frac{v}{l}$

$f = \frac{200}{1}$

$\boxed{f = 200\ Hz}$ Ans

Ans. b

Solution: 10

Let length of segments l_1, l_2 & l_3

$n_1 = \frac{v}{2l_1} = n \Rightarrow l_1 = \frac{v}{2n}$

$n_2 = \frac{v}{2l_2} = 2n \Rightarrow l_2 = \frac{v}{4n}$

$n_3 = \frac{v}{2l_3} = 3n \Rightarrow l_3 = \frac{v}{6n}$

Let total string, fundamental Frequency $= n_0$

then; $n_0 = \frac{v}{2l}$

where; $l = l_1 + l_2 + l_3$

So; $l = l_1 + l_2 + l_3$

$\frac{v}{2n_0} = \frac{v}{2n} + \frac{v}{4n} + \frac{v}{6n}$

$$\boxed{\frac{1}{n_0} = \frac{1}{n} + \frac{1}{2n} + \frac{1}{3n}}$$

$\frac{1}{n_0} = \frac{1}{n}\left(1 + \frac{1}{2} + \frac{1}{3}\right)$

$= \frac{1}{n}\left(\frac{6+3+2}{6}\right)$

$= \frac{1}{n}\left(\frac{11}{6}\right)$

$$\boxed{n_0 = \frac{6n}{11}}$$ Ans.

Ans. d

Solution: 11

frequency for string fixed at both ends:

$$f = \frac{nv}{2l}$$

2^{nd} Harmonic

$$f_2 = \frac{2v}{2l} = 50 \text{ Hz} \quad \text{---} (1)$$

5^{th} Harmonic

$$f_5 = \frac{5v}{2l} \quad \text{---} (2)$$

$$\frac{(1)}{(2)} \Rightarrow \frac{50}{f_5} = \frac{2v/2l}{5v/2l} = \frac{2}{5}$$

$$\boxed{f_5 = 125 \text{ Hz}} \text{ Ans}$$

Ans. d

Solution: 12

initially;

Tension = T

length = L

distance between two bridges = l = fixed

$v = \sqrt{\frac{T}{\mu}}$; $\mu = \frac{m}{L}$

$$\boxed{n = \frac{NV}{2l}}$$

Now tension = 4T

then length = $L' > L$

& $v' = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{TL'}{M}}$

$\therefore v' = \sqrt{\frac{4TL'}{M}}$

$v' = 2\sqrt{\frac{TL'}{M}}$

$\because L' > L$

so; $\boxed{v' > 2v}$

so; $f_2 = \frac{nv'}{2l}$

[$\because l$ = fixed]

so; $n_2 = \frac{Nv'}{2l}$

$\because v' > 2v$

so; $\boxed{n_2 > 2n}$

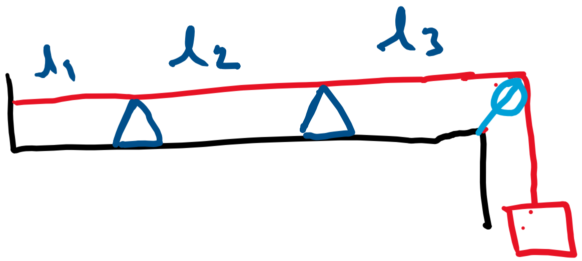
& $L' > L$ [but L' is slightly more than L]

so; n_2 is slightly greater than $2n$

Ans. c

Solution: 13

$l = 100\,cm$



$\because V = $ Same [vel. of wave]

$$f = \frac{nV}{2l}$$

for fundamental frequency; $n = 1$

So; $f \propto \frac{1}{l}$ or $l \propto \frac{1}{f}$

$\Rightarrow l_1 : l_2 : l_3 = \frac{1}{f_1} : \frac{1}{f_2} : \frac{1}{f_3}$

$\Rightarrow l_1 : l_2 : l_3 = \frac{1}{1} : \frac{1}{3} : \frac{1}{5}$

$l_1 : l_2 : l_3 = 15 : 5 : 3$

$$l_1 = \frac{15}{23} \times l = \frac{15}{23} \times 100\,cm$$

$l_1 = \frac{1500}{23}$; Same as; $l_2 = \frac{500}{23}$, $l_3 = \frac{300}{23}$

So; first bridge at $l_1 = \frac{1500}{23}$

2nd bridge at $l_1 + l_2 = \frac{1500}{23} + \frac{500}{3}$

$$= \frac{2000}{23}$$

Ans

Ans. a

Solution: 14

$L = 105\ cm$

$\because f \propto \frac{1}{l}$ or $l \propto \frac{1}{f}$

$l_1 : l_2 : l_3 = \frac{1}{1} : \frac{1}{3} : \frac{1}{15}$

$l_1 : l_2 : l_3 = 45 : 15 : 3$

$l_1 = \frac{45}{63} \times 105$

$l_1 = 75\ cm$

$l_2 = \frac{15}{63} \times 105$

$l_2 = 25\ cm$

$l_3 = \frac{3}{63} \times 105$

$l_3 = 5\ cm$

Ans. d

Solution: 15

Fundamental frequency

$$f_1 = \frac{V}{2l}$$

$$V = \sqrt{\frac{T}{\mu}}\ ; \quad \mu = 0.0294\ g/cm$$

$$\mu = 0.00294\ kg/m$$

$$T = 3\ kg.wt = 3g = 3 \times 9.8 = 29.4\ N$$

$$V = \sqrt{\frac{29.4}{0.00294}}$$

$$= \sqrt{\frac{29.4}{29.4 \times 10^{-4}}} = \sqrt{10^4}$$

$$\boxed{V = 100\ m/s}$$

so; $f_1 = \frac{V}{2l} = \frac{100}{2 \times 0.2} = \frac{1000}{4}$

$$\boxed{f_1 = 250\ Hz}$$

next frequency;

$$f_2 = 2f_1 = 500\ Hz$$

next frequency;

$$f_3 = 3f_1 = 750\ Hz$$

Ans. d

Solution: 16

(ρ) density = 10^4 kg/m³

$A = 10^{-2}\ cm^2 = 10^{-6}\ m^2$

Linear mass density

$\mu = \rho A$

$\mu = 10^4 \times 10^{-6}$

$\boxed{\mu = 10^{-2}\ kg/m}$

$\boxed{T = 25 N}$

$f_0 = \frac{V}{2l}$ [n=1]

$f_0 = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

$f_0 = \frac{1}{2 \times 0.2}\sqrt{\frac{25}{10^{-2}}}$

$= \frac{1}{4 \times 10^{-1}}\sqrt{25 \times 10^2}$

$= \frac{1}{4 \times 10^{-1}} \times 5 \times 10$

$= \frac{5}{4} \times 10^2$

$f_0 = \frac{500}{4}$

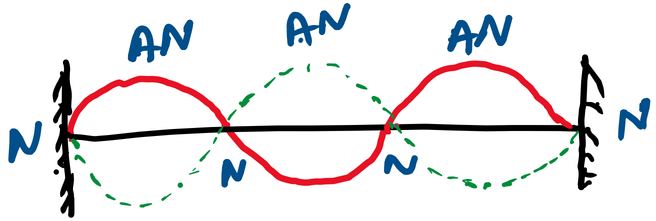
$\boxed{f_0 = 125\ Hz}$ Ans

Ans. c

Solution: 17

2nd overtone = 3rd harmonic

so; n = 3 waves



Node = 4

Antinode = 3

Ans. b

Solution: 18

n^{th} overtone = $(n+1)^{th}$ Harmonic

so; 1^{st} overtone = 2^{nd} harmonic = 320 Hz

2^{nd} harmonic = 2 × (first Harmonic)

$$f_2 = 2 \times f_1$$

$$f_1 = \frac{f_2}{2}$$

$$f_2 = \frac{320}{2}$$

$$f_2 = 160 \text{ Hz}$$ Ans

Ans. c

Solution: 19

3rd overtune = 4th harmonic = $4 f_0$

f_0 = fundamental frequency

$$f_0 = \frac{3^{rd} \text{ overtude frequency}}{4}$$

$$f_0 = \frac{1200}{4}$$

$$\boxed{f_0 = 300 \text{ Hz}}$$

Lower overtune = 1st overtune

$$f_1 = 2f_0 = 600 \text{ Hz}$$

$$\boxed{\frac{f_1}{f_0} = \frac{2}{1}} \text{ Ans.}$$

Ans. b

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