PHYSICS - SOLUTION

1. **d)** In a sonometer,

$\nu \propto \sqrt{T} \therefore \quad \frac{\nu_1}{\nu_2} = 2 = \sqrt{\frac{T_1}{T_2}} \quad \Rightarrow \quad T_2 = \frac{T_1}{4}$

$\therefore \quad \% \text{change will be:} \quad \frac{T_1 - T_2}{T_1} \times 100 = \frac{T_1 - \frac{T_1}{4}}{T_1} \times 100 = 75\%$

2. **d)** For waves along a string :

$\upsilon \alpha \sqrt{T} \quad \Rightarrow \quad \lambda \alpha \sqrt{T}$

Now, for 6 loops : $3\lambda_1 = L \Rightarrow \lambda_1 = L/3$

& for 4 loops : $2\lambda_1 = L \Rightarrow \lambda_2 = L/2$

$\Rightarrow \quad \frac{\lambda_1}{\lambda_2} = \frac{2}{3} \quad \Rightarrow \quad T_2 = \frac{9}{4} \times T_1 = \frac{9}{4} \times 36 =$ 81 N.

3. **c)** Velocity of sound is inversely proportional to the square root of density of the medium.

i.e., $V\sqrt{\rho} = \text{constant} \quad \Rightarrow \quad \frac{V_1}{V_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{2\rho}{\rho}} = \sqrt{2}$

4. **c)** $y = \log \frac{x^2 - t^2}{x - t} = \log(x + 1)$ $\left(\because \log a - \log b = \log\frac{a}{b}\right)$

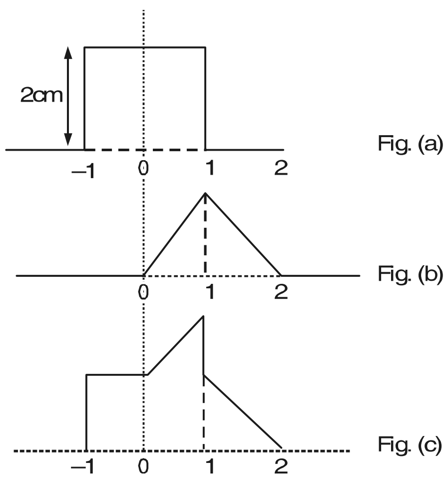
$\frac{\partial y}{\partial x} = \frac{1}{(x+t)}$

$\frac{\partial^2 y}{\partial x^2} = \frac{1}{(x+t)^2}$ and $\frac{\partial y}{\partial t} = \frac{(\partial x/\partial t)}{(x+t)} = \frac{v}{(x+t)}$

$\frac{\partial^2 y}{\partial t^2} = -\frac{v^2}{(x+t)^2} \quad \Rightarrow \quad \frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$

Which is the general form of wave equation.

5. **d)** At t = 2 second, the position of both pulses are separately given by fig. (a) and fig. (b); the superposition of both pulses is given by fig. (c)



6. **b)** $dm.\omega^2 R = 2T \sin\frac{d\theta}{2}$

$\mu R d\theta \omega^2 R = 2T\frac{d\theta}{2}$

$\Rightarrow \mu\omega^2 R^2 = T$ $\Rightarrow v_w = \sqrt{\frac{T}{\mu}} = \sqrt{\omega^2 R^2} = \omega R$

Also speed of string is ωR

$\therefore$ The velocity of disturbance w.r.t. ground = $\omega R + \omega R = 2\omega R$.

7. **c)** Let ℓ be the length of rope. Then tension in the string at height h will be:

$T = \frac{m}{\ell}hg$ $u = \sqrt{\frac{T}{\mu}}$

Here, μ = mass per unit length = $\frac{m}{\ell}$

$\therefore$ $u = \sqrt{gh}$ or $u^2 = gh$

i.e., u versus h graph is a parabola.

8. **b)** Let a_i and a_r be the amplitudes of incident and reflected wave. Then

$\frac{a_i + a_r}{a_i - a_r}$ = n (Given)

$\therefore$ $\frac{a_r}{a_i} = \left(\frac{n-1}{n+1}\right)$

$\therefore$ Fraction of energy reflected is

$$\frac{E_r}{E_i} = \left(\frac{a_r}{a_i}\right)^2 = \left(\frac{n-1}{n+1}\right)^2$$

9. **a)** $f_0 = \frac{v}{2\ell}$

Now beat frequency = $f_1 - f_2$

$$= \frac{v}{2\left(\frac{\ell}{2} - \Delta\ell\right)} - \frac{v}{2\left(\frac{\ell}{2} + \Delta\ell\right)} = \frac{v}{2}\left[\frac{1}{\frac{\ell}{2} - \Delta\ell} - \frac{1}{\frac{\ell}{2} + \Delta\ell}\right]$$

$$= (f_0\ell)\left[\frac{2}{\ell - 2\Delta\ell} - \frac{2}{\ell + 2\Delta\ell}\right] = (f_0\ell)\left[\frac{1 + 2\Delta\ell - \ell + 2\Delta\ell}{\ell^2 - 4(\Delta\ell)^2}\right] \approx 2f_0\ell\left(\frac{4\Delta\ell}{\ell^2}\right) \approx \frac{8f_0\Delta\ell}{\ell}$$

10. **c)** $v = \sqrt{T/\mu}$ or $v \propto \frac{1}{\mu}$ 1 $\rightarrow$ RP, 2 $\rightarrow$ PQ, 3 $\rightarrow$ QS

Here μ is mass per unit length.

$\mu_1 = \frac{0.1}{2} = 0.05\,kg/m$

$\mu_2 = \frac{0.1}{3} = 0.067 kg/m$ and $\mu_3 = \frac{0.15}{4} = 0.0375 kg/m$

$\mu_3 < \mu_1 < \mu_2$

Between string RP and PQ, medium of string PQ is denser. Therefore, wave-2 will suffer a phase change of π. Between string PQ and QS, medium of string PQ is denser. Therefore wave 4 will not 4 will not suffer any phase change.

11. **c)** This problem is a Doppler effect analogys
where f = 20/min, v = 300 m/min
and v_s = 30 m/min

□ $f_d^c = f\left(\frac{v}{v - v_s}\right) = (20)\left(\frac{300}{300 - 30}\right) = 22.22\ min^{-1}$

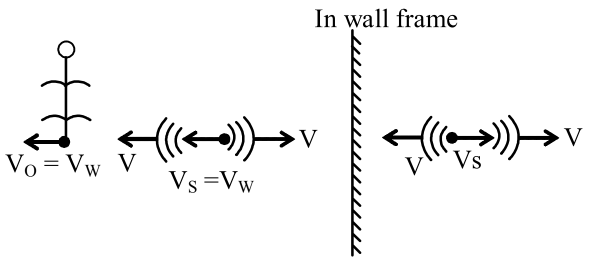
12. **c)** The wavelength of sound source = $\frac{330}{110}$ = 3 metre.

The phase difference between interfering waves at P is

= ⨯□ = $\frac{2\pi}{\lambda}(S_2P - S_1P) = \frac{2\pi}{3}(5-4) = \frac{2\pi}{3}$

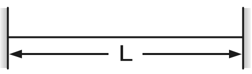
□ Resultant intensity at P = $I_0 + 4I_0 + 2\sqrt{I_0}\sqrt{4I_0}\cos\frac{2\pi}{3} = 3\ I_0$

13. D) 330 Hz



$$F_{echo} = f_{ac}\left[\frac{V - V_0}{V + V_S}\right] = 334\left[\frac{330-2}{330+2}\right]$$

$$= 334 \times \frac{328}{332} = 330\ Hz$$

14. **b)** 

Fundamental frequency of wire (f_{wire}) = $\frac{v}{2\ell}$

a) 

$f = \frac{v}{4\ell}, \frac{3v}{4\ell}, \frac{5v}{4\ell}$ cannot match with f_{wire}

b)  $f = \frac{v}{2(2\ell)}, \frac{v}{2(2\ell)}, \frac{3v}{2(2\ell)}$ its second harmonic $\frac{2v}{2(2\ell)}$ matches with f_{wire}.

c)  $f = \dfrac{v}{2(\ell/2)}, \dfrac{2v}{2(\ell/2)}$ cannot match with f_{wire}

d)  $f = \dfrac{v}{4(\ell/2)}, \dfrac{3v}{4(\ell/2)}$ ... cannot match with f_{wire}

15. **b)** V_s = 4 km/sec $\quad v_P = \sqrt{\dfrac{y}{\rho}} = \sqrt{\dfrac{12.8 \times 10^{10}}{2000}}$ = 8000 m/sec = 8 km/sec

$\dfrac{\ell}{v_s} - \dfrac{\ell}{v_P}$ = 3 min = 3 × 60 sec.

$\dfrac{\ell}{4} - \dfrac{\ell}{8}$ = 3 × 60 $\quad \ell$ = 1440 km

16. **b)** Towards right wavelength gets compressed, towards left, wavelength gets expended.

17. **d)** x_1 and x_2 are in successive loops of std. waves.
so ϕ_1 = 4⟌12

and $\phi_2 = K(⨯x) = K\left(\dfrac{3\pi}{2K} - \dfrac{\pi}{3K}\right) = \dfrac{7\pi}{6} = \dfrac{\phi_1}{\phi_2} = \dfrac{6}{7}$

18. **b)** $V_s = \sqrt{\dfrac{Y}{\rho}} = \sqrt{\dfrac{10^{11}}{10.0 \times 10^4}} = 10^3$ m/sec.

$t = \dfrac{2\ell}{V} = \dfrac{2 \times 100}{1000}$ = 0.2 sec

19. **c)** $V_{max} = w_n A$
= (24⟌12f) A
= (24⟌12) (440) (10^{-6})
= 2.76 × 10^{-3} m/sec.

20. **c)** Apparent frequency

$n_d^c = n\dfrac{(u + v_w)}{(u + v_w - v_s \cos 60°)} = \dfrac{510\,(330 + 20)}{330 + 20 - 20 \cos 60°} = 510 \times \dfrac{350}{340}$ = 525 Hz

21. **a)** For minimum,

$⨯x = (2n - 1)\dfrac{\lambda}{2}$

The maximum possible path difference = distance between the sources = 3m.
For no minimum

$\dfrac{\lambda}{2} > 3$

2⟌21 > 6 $\quad \therefore f = \dfrac{V}{\lambda} < \dfrac{330}{6}$ = 55

∴ If f < 55 Hz, no minimum will occur.

22. **a)** The speed of sound in air is $v = \sqrt{\frac{\gamma RT}{M}}$

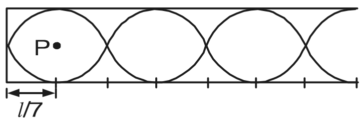
$\frac{\gamma}{M}$ of H_2 is highest, hence speed of sound in H_2 shall be maximum.

23. **b)** As $y = A_b \sin (2pn_{av}t)$
where A_b = 2 A cos (24)12nAt)

where $n_A = \frac{n_1 - n_2}{2}$

24. a) The figure shows variation of displacement of particles in a closed organ pipe for 3rd overtone.

For third overtone $\ell = \frac{7\lambda}{4}$ or 2)21 = $\frac{4\ell}{7}$ or $\frac{\lambda}{4} = \frac{\ell}{7}$



Hence, the amplitude at P ata distance $\frac{\ell}{7}$ from closed end is 'a' because there is an antinode at that point.

Alternate: a)

Because there is node at x = 0 the displacement amplitude as function of x can be written as

$A = a \sin \quad kx = a \sin \frac{2\pi}{\lambda} x$

For third overtone $\ell = \frac{7\lambda}{4}$ or 2)21 = $\frac{4\ell}{7}$

$\therefore \quad A = a \sin \frac{7\pi}{2l} \frac{\ell}{7} = a \sin \frac{\pi}{2} = a \quad$ at $x = \frac{\ell}{7} \quad$ □ $\quad A = a$

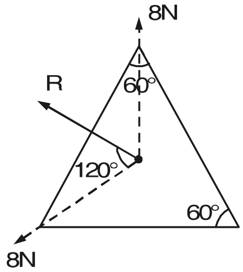
25. **d)** For a stationary observer between wall and source,

frequency, from direct source = $\left(\frac{V}{V - V_s}\right) f_0$

frequency, from reflected sound = $\left(\frac{V}{V - V_s}\right) f_0$

So no beats will be heard.

26. **d)** $R = \sqrt{8^2 + 8^2 + 2.8.8 \cos 120°}$ = 8 N



27. **b)** Speed will be maximum when acceleration becomes zero.

i.e., when kx = EQ □ $X = \dfrac{EQ}{K}$

By work-energy theorum: $W_{all} = \Delta KE$ □ $EQX - \dfrac{1}{2}KX^2 = 0$; $X_{max} = \dfrac{2EQ}{K}$

28. **c)** The acceleration of centre of mass of system of particles is

$$a_{cm} = \frac{(q_1 + q_2)}{2m}E$$

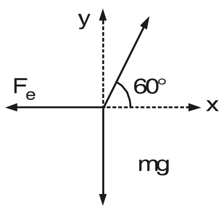
□ x-coordinate of centre of mass at t = 2 second is

$$X_{cm} = \frac{1}{2}a_{cm}t^2 = \frac{1}{2}\frac{q_1 + q_2}{2m}E \times 2^2 = \frac{q_1 + q_2}{m}E$$

Let the x-coordinates of q_1 and q_2 at t = 2 sec be x_1 and x_2 [$x_1 = 2a$ at t = 2 sec.]

$$\square\ X_{cm} = \frac{mx_1 + mx_2}{2m} = \frac{x_1 + x_2}{2} \text{ or } x_2 = 2x_{cm} - x_1 = 2\frac{(q_1 + q_2)}{m}E - 2a.$$

29. **a)** The bowl, exerts a normal force N on each bead, directed along the radius line or at 60° above the horizontal. Consider the free-body diagram of the bead on the left with the electric force F_e applied.



□ $F_y = N \sin 60° - mg = 0$, □ $N = mg/\sin 60°$

□ $F_x = -F_e + N\cos 60° = 0$, □ $\dfrac{Kq^2}{R^2} = N\cos 60° = \dfrac{mg}{\tan 60°} = \dfrac{mg}{\sqrt{3}}$

$$k = \frac{1}{4\pi\varepsilon_0}$$

Thus $q = R\left(\dfrac{mg}{k\sqrt{3}}\right)^{1/2}$

30. **a)** We have centripetal force equation

$$q\left(\frac{2k\lambda}{r}\right) = \frac{mv^2}{r}$$

so $v = \sqrt{\dfrac{2kq\lambda}{m}}$ Now, $T = \dfrac{2\pi r}{v} = \sqrt{\dfrac{m}{2k\lambda q}}$

where, $k = \dfrac{1}{4\pi\varepsilon_0}$