PHYSICS

BOOKS - VIKRAM PUBLICATION (ANDHRA PUBLICATION)

WAVES

Textual Examples

1. Given below are some examples of wave motion. Statein each case if the wave motion

is transverse, longitudinal or a combinatin of both.

(a) Motion of kink in a longitudinal spring produced by displacing one end of the spring sideways.

(b) Waves produced in a cylinder containing a liquid by moving its piston back and forth.

(c) Waves produced by a motorboat sailing in water.

(d) Ultrasonic waves in air produced by a vibrating quartz crystal.

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2. A wave travelling along a string is described by, y(x,t) = 0.005 sin (80.0x - 3.0 x). In which the numerical constants are in SI units (0.005m, 80.0 rad m^{-1} , and 3.0 rad s^{-1}) . Calculate (a) the amplitude , (b) the wavelength , and (c) the period and frequency of the wave. Also,calculate the displacement of the wave. Also, calaculate the displacement y of the wave at a distance x = 30.0 cm and time t =20s ?

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3. A steel wire 0.72 m long has a mass of $5.0 \times 10^{-3} kg$.If the wire is under a tension of 60N , what is the speed of transverse waves on the wire?

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4. Estimate the speed of sound in air at standard temperature and pressure. The mass 1 mole of air is $29.0 \times 10^{-3} kg$

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5. A pipe , 30.0 cm long is open at bothends. Which harmonic mode of the pipe resonates a 1.1 kHz source ?Will resonance with the same source be observed if one end of the pipe is closed ? Take the speed of sound in air as $330ms^{-1}$

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6. Two sitar strings A and B playing the not 'Dha' are slightly out of tune and produce beats of frequency 5Hz. The tension of the

string B is slightly increased and the beat frequency is found to decrease to 3 Hz. What is the original frequency of B if the frequency of A is 427 Hz?

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7. A rocket is moving at a speed of $200ms^{-1}$ towards a stationary target. While moving , it emits a wave of frequency 1000 Hz.Some of the sound reaching the target gets reflected back to the rocket as an echo.Calculate (1) the

frequency of the sound as detected by the target and (2) the frequency of the echo as detected by the rocket.

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Problems

1. A stretched wireof length 0.6m is observed to vibrate with a frequency of 30 Hz in the fundamental mode. If the string has a linear massof 0.05 kg/m. Find (a) the velocity of

propagation of transverse wave in the string (b) the tension in the string.

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2. A steel cable of diameter 3cm is kept under a tension of 10KN. The density of steel is $7.8g/cm^3$.With what speed would transverse waves propagate along the cable ?

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3. Two progressive transverse waves given by $y_1 = 0.007 \sin \pi(12x - 500t)$ and $y_2 = 0.07 \sin \pi(12x + 500t)$ travelling along a stretched string from nodes and antinodes . What is the displacement at the (a) nodes (b) antinodes ? What is the wavelength of the standing wave ?

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4. A string has a length of 0.4m and a mass of0.16g.If the tension in the string is 70N,what are the three lowest frequencies it produces when plucked ?

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5. A metal bar when clamped at its centre resonantes in the fundamental frequency with longitudinal waves of frequency 4kHz. If the

clamps is moved to one end.What will be its fundamental resonanace frequency ?

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6. A closed organ pipe 70 cm long is sounded .If the velocity of sound is $331 m / s$,what is the fundamental frequency of vibration of the air column ?

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7. A vertical tube is made to stand in water so that the waterlevel can be adjusted . Sound waves of frequency 320 Hz are sent into the top of the tube.If standing waves are produced at two successive water levels of 20cm and 73cm, what is the speed of sound waves in the air in the tube ?

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8. Two organ pipes of lengths 65cm and70 cm respectively , are sounded simultaneosly. How many beats per second will be produced between the fundamental of the two pipes ? (Velocity of sound $= 330m/s$)

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9. A train sounds its whistle as it approaches and crosses a level crossing. An observer at the crossing measures a frequency of 219 Hz

as the train approaches and a frequency of 184 Hz as it leaves. If the speed of sound is taken to be $340 m / s$, find the speed of the train and the frequency of its whistle

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10. Two trucks heading in opposite directions with speeds of 60 kmph and 70 kmph respectively, approach each other. The driver of the first truck sounds his horn of frequency 400Hz. What frequency does the driver of the

second truck hear ? (Velocity of sound $= 330 m / s$).After the two trucks have passed each other, what frequency does the driver of the second truck hear ?

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Very Short Answer Questions

1. What does a wave represent ?

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2. Distinguish between transverse and longitudinal waves

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3. What are the parameters used to describe a progressive harmonic wave ?

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4. Obtain an expression for the wave velocity in terms of these parameters.

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5. Using dimensional analysis obtain an expression for the speed of transverse waves in a stretched string.

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6. Using dimensional analysis obtain an expression for the speed of transverse waves in a stretched string.

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7. What is the principle of superposition of waves ?

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8. Under what conditions will a wave be reflected ?

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9. What is the phase difference between the incident and reflected wave when the wave is reflected by a rigid boundary.

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10. What is the stationary or standing wave ?

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11. What do you understand by the terms 'node' and 'antinode ' ?

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12. What is the distance between a node and an antinode in a stationary wave ?

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13. What do you understand by'natural frequency 'or'normal mode of vibration'?

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14. What are harmonics?

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15. A string is stretched between two rigit supports.What frequencies of vibration are possible in such a string ?

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16. The air column in a long tube, closed at one end, is set in vibration. What harmonics are possible in the vibrating air column ?

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17. If the air column in a tube, open at both ends, is set in vibration , what harmonics are possible ?

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18. What are 'beats'?

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19. Write downan expression beat frequency and explain the terms there in.

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20. What is 'Doppler effect' ?

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21. Write down an expression for the observer frequency when both source and observer are

moving relative to each other in the same direction.

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Short Answer Questions

1. What are transverse waves? Give illustrative examples of such waves.

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2. What are longitudinal waves ? Give illustrative example of such waves.

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3. Write an expression for a progressive harmonic wave and explain the various parameters used in the expression.

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4. Explain the modes of vibration of a streched string with examples.

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5. Explain the modes of vibration of an air column in an open pipe .

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6. What do you understand by 'resonance '? How would you use resonanceto determine the velocity of sound in air ?

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7. What are standing waves ? Explain how standing waves may be formed in a stretched string.

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8. Describe a procedure for measuring the velocity of sound in a stretched string.

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9. Explain, using suitable digrams, the formation of standingwaves in a closed pipe.How may this be used to determine the frequency of a source of sound ?

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10. What are 'beats'? When do they occur ? Explain their use, if any.

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11. What is 'Doppler effect' ?

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Long Answer Questions

1. Explain the formation of stationary waves in stretched strings and hence deduce the laws of transverse wave in stretched strings.

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2. Explain the formation of stationary waves in an air column enclosed in open pipe . Derive the equations for the frequencies of the harmonics produced.

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3. How are stationary waves formed in closed pipes ? Explain the various modes of vibrations and obtain relations for their frequencies.

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4. What are beats ? Obtain an expression for the beat frequency ? Where and how are beats made us of ?

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5. What is Dopper effect ? Obtain an expression for the apparent frequency of sound heard when the source is in motion with respect to an observer at rest.

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6. What is Doppler effect ? Obtain an expression for the apparent frequency of

sound heard when the observer is in motion with respect to a source at rest.

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Textual Exercises

1. A stringof mass 2.50kg is under a tension of 200N. The length of the stretched string s 20.0 m . If the transverse jerk is caused at one end of the string, how long does the disturbance take to reach the other end ?

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2. A stone dropped from the top of a tower of height 300 m high splashes into the a pond of water near the base of the tower.When is the splash heard at the top given that the speed of sound air is $340ms^{-1}$. $(g = 9.8ms^{-2})$

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3. A steel wire has a length of 12.0 m and a mass of 2.10 kg . What should be the tension in

the wire so that speed of a transverse wave on the wire equals the speed of sound in dry air at $20^{\circ} C = 343 ms^{-1}$

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4. Use the formula $v = \sqrt{\frac{\gamma P}{\rho}}$ to explain why the speed of sound in air

(a) is independent of pressure.

(b) increases with temperature.

(c) increases with humidity.

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5. You have learnt that a travelling wave in one dimension is represented by a function $y = f(x, t)$ where x and t must appear in the combination $x - vt$ or $x + vt$, i.e., $y = f(x \pm vt)$. Is the converse true ? Examine if the following function for y can possibly represent a travelling wave :

(a) $(x - vt)2$

(b) $\log[(x + vt) / x_0]$

(c) $1 / (x + vt)$

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6. A bat emits ultrasonic sound a frequency 1000kHz in air. If the sound meets a water surface, what is the wavelength of (a) the reflected sound, (b) the transmitted sound ? Speed of sound in air is $340ms^{-1}$ and in water $1486ms^{-1}$

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7. A hospital uses an ultrasonic scanner to locate tumours in a tissue.What is the wavelength of sound in the tissue in which the speed of sound is $1.7kms^{-1}$? The operating frequency of the scanner is 4.2 MHz .

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8. A transverse harmonic wave on a string is described by

$y(x, t) = 3.0\sin(36t + 0.018x + \pi/4)$

where x and y are in cm and t in s. The positive direction of x is from left to right.

(a) Is this a travelling wave or a stationary wave?

If it is travelling , what are the speed and direction of its propagation ?

(b) What are its amplitude and frequency ?

(c) What is the initial phase at the origin ?

(d) What is the least distance between two successive crests in the wave ?

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9. For the wave described in the last problem plot the displacement (y) versus (t) graphs for x = 0.2 and 4 cm. What are the shapes of these graphs ? In which aspects doesthe oscillatory motion in travelling wave differ from one point to another : amplitude, frequency or phase ?

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10. For the travelling harmonic wave

$$y(x, t) = 2.0 \cos 2\pi(10t - 0.0080x + 0.35)$$

where x and yare in cm and t in s. Calculate the phase differencebetween oscillatory motion of two points separated by a distance of

a) 4m, (b) 0.5m

(c) $\lambda/2$ (d) $3\lambda/4$

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11. The transverse displacement of a string (clamped at its both ends) is givenby $y(x,t) = 0.06\sin\left(\frac{2\pi}{3}x\right)\cos(120\pi t)$ where x and y are in m and t in s. The length of

the string is 1.5m and its mass is $3.0 \times 10^{-2} kg$

Answer the following :

(a) Does the function represent a travelling wave or a stationary wave ?

(b) Interpret the wave as a superposition of two waves travelling in opposite directios. What is the wavelength, frequency,and speed of each wave ?

(c) Determine the tension in the string.

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12. (i) For the wave on a string described in previous problem do all the points on the string oscillate with the same (a)frequency, (b) phase, (c) amplitude ? Explain your answers. (ii) What is the amplitude of a point 0.375m away from one end ?

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13. Given below are some functions of x and t to represent the displacement the

displacement (transverseor longitudinal) of an elastic wave. State which of these represent (i) atravelling wave, (ii) a stationary wave or (iii) none at all :

(a) $y = 2\cos(3x)\sin(10t)$

(b) $y = 2\sqrt{x - vt}$

(c) $y = 3\sin(5x - 0.5t) + 4\cos(5x - 0.5t)$

(d) $y\cos x \sin t + \cos 2x \sin 2t$

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14. A wire stretched betweentwo right supports vibrates in its fundamental mode with a frequency of 45 Hz. The mass of the wire is $3.5 \times 10^{-2} kg$ and its linear mass density is $4.0 \times 10^{-2} kgm^{-1}$. What is (a) the speed of transverse wave on thestring . and (b) the tension in the string ?

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15. A metre- long tube open at one end,with a movable pistonat the other end, shows resonance with a fixed frequency source(a tuning fork of frequency 340 Hz) when the tube length is 25.5cm or 79.3 cm.Estimate the speed of sound in air at the temperature of the experiment.The edge effect may be neglected.

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16. A steel rod 100cm long is clamped at its middle. The fundamental frequency of longitudinal vibrations of the rod are given to be 2.53kHz. What is the speed of sound in steel ?

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17. A pipe 20cm long is closed at one end. Which harmonic mode of the pipe is resonantly excited by a 430 Hz source ? Will

the same source be in resonance with the pipe if both ends are open ? (speed of sound in air is $340 ms^{-1}$)

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18. Two sitar string A and B playing the note 'Ga' are slightly out of tune and produce betas of frequency 6 Hz.The tension in the string A is slightly reduced and the beat frequency is found to reduceto 3Hz.If the origianl

frequency of Ais 324 Hz. What is the frequency of B ?

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19. Explain why (or how) :

(a) in a sound wave, a displacement node is a pressure antinode and vice versa,

(b) bats can ascertain distances, directions,nature and sizes of the obstacles without any "eyes".

(c) a violine note and sitar note may have the

same frequency,yet we can distinguish between the two notes.

(d) Soils can support both longitudinal and transverse waves, but only longitudinal waves can propagate in gases and

(e) The shape ofa pulse gets distorted during during propagation in a dispersive medium.

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20. A train , standing at the outer signal of a railway station blows a whistle of frequency

400 Hz in still air, (i) What is thefrequency of the whistle for a platform observer when the train (a) approaches the platform with a speed of $10ms^{-1}$, (b) recedes from the platform with a speed of $10ms^{-1}$? (ii) What is the speed of sound in still air can be taken as $340ms^{-1}$.

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21. A train, standing in a station -yard, blows a whistle of frequency 400 Hzin still air. The wind starts blowing in the direction from the

yard to the station with a speed of $10ms^{-1}$. What are the frequency, wavelength and speed of sound for an observer standing on the station's platforms ? Is the situation exactly identical to the case when the air is still and the observer runs towards the yard at a speedof $10ms^{-1}$?The speed of sound in still air can be taken as $340ms^{-1}$.

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Additional Exercises

1. A travelling harmonic wave on a string is described by

$$y(x, t) = 7.5 \sin(0.0050x + 12t + \pi/4)$$

(a) What are the displacement and velocity of oscillation of a point at x=1cm, and t =1s ? Is this velocity equal to the velocity of wave propagation ?

(b) Locate the points of the string whcih have the same transverse displacements and velocity as the x=1 cm point at t=2s, 5s and 11s.

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2. A narrow sound pulse (for example , a short pip by a whistle) is sent across a medium. (a) Does the pusle have a definite (I) frequency , (ii) wavelength, (iii) speed of propagation ?(b) If the pulse rate is 1 afterevery 20s (that is the whistle blown for a split of second after every 20s) , is the frequency of the note produced by the whistle equal to $1/20$ or 0.05 H z ?

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3. One end of a long string of linear mass density $8.0 \times 10^{-3} kgm^{-1}$ is connected to an electrically driven tuning fork of frequency 256Hz. The other end passes over a pulley and is tied to a pan containing a mass of 90 kg. The pulley end absorbs all the incoming energy so that reflected waves at this end have negligible amplitude. At t=0, the leftend (fork end)of the string x=0 has zero transverse displacement (y = 0) and is moving along positive y-direction. The amplitude of the wave is 5.0 cm.Write down the transverse

displacement y as function of x and t that describes the wave on the string.

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4. A SONAR system fixed in a submarine operates at a frequency40.0 kHz. An enemy submarine moves towards the SONAR with a speed of $360 kmh^{-1}$.What is the frequency of sound reflected by the submarine? Take the speed of sound in water to be $1450 ms^{-1}$

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5. Earthquakes generate sound waves inside the earth.Unlike a gas, theearth can experience both transverse (S) and longitudinal (P) sound waves.Typically the speed of S wave is about $4.0kms^{-1}$ .and that of P is $8.0kms^{-1}$ .A seismograph records P and S waves from an earthquake.The first P wavearrives 4 min before the first wave.Assuming the waves travel in straight line, at what distance does the earthquake occur ?

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6. A bat is flitting about in a cave, navigating via ultrasonic beeps.Assume that the sound emission frequency of the bat is 40 kHz. During one fast swoop directly toward a flat wall surface, the bat is moving at 0.03 times the speed of sound in air. What frequency does the bat hear reflected off the wall ?

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