HC VERMA Solutions for Class 11 Physics Chapter 16 Sound Waves

Question 1
A steel tube of length 1.00 m is struck at one end person with his ear close to the other end hears the sound of the blow twice, one travelling through the body of the tube and the other through the air in the tube. Find the time gap between the two hearings. Use the table in the text for speeds of sound in various substances.

Solution 1
Time gap = $t_{air} - t_{steel}$
$= d/v_{air} - d/v_{steel}$
$=1/330 - 1/5200$
$= 2.75 \times 10^{-3}$ sec
$\Delta t = 2.75$ ms

Question 2
At a prayer meeting, the disciples sing *JAI-RAM JAI-RAM*. The sound amplified by a loudspeaker comes back after reflection from a building at a distance of 80 m from the meeting. What maximum time interval can be kept between one *JAI-RAM* and the next *JAI-RAM* so that the echo does not disturb a listener sitting in the meeting. Speed of sound in air is 320 m s^{-1}.

Solution 2
Distance travelled by sound to come back = 80×2 = 160 m
Time interval = distance/speed
= 160/320
= 0.5 sec

Question 3
A man stands before a large wall at a distance of 50.0 m and claps his hands at regular intervals. Initially, the interval is large. He gradually reduces the interval and fixes it at a value when the echo of a clap merges every 3 seconds, find the velocity of sound in air.

Solution 3
Time gap between two claps = 3/10 =0.3 sec
Distance travelled by sound between two claps = 50+50
= 100 m
Velocity = distance/time
= 100/0.3
V≈333 m/s

Question 4
A person can hear sound waves in the frequency range 20 Hz to 20 kHz. Find the minimum and the maximum wavelengths of sound that is audible to the person. The speed of sound is 360 m s^{-1}.

Solution 4
$v = f \times \lambda$
For $\lambda_{max} = v/f_{min}$
$=360/20$
$=18$m
For $\lambda_{min} = v/f_{max}$
$=360/20\times10^3$
$\lambda_{min} = 18$ mm

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Question 5

Find the minimum and maximum wavelengths of sound in water that is in the audible range (20-20000 Hz) for an average human ear. Speed of sound in water = 1450 m s^{-1}.

Solution 5

$V = f \times \lambda$

For $\lambda_{max} = V/f_{min}$

$=1450/20$

$\lambda_{max} = 72.5$ m

For $\lambda_{min} = V/f_{max}$

$=1450/20000$

$\lambda_{min} = 7.25$ cm

Question 6

Sound waves from a loudspeaker spread nearly uniformly in all directions if the wavelength of the sound is much larger than the diameter of the loudspeaker. (a)Calculate the frequency for which the wavelength of sound in air is ten times the diameter of the speaker if the diameter is 20 cm. (b) Sound is essentially transmitted in the forward direction if the wavelength is much shorter than the diameter of the speaker. Calculate the frequency at which the wavelength of the sound is one tenth of the diameter of the speaker described above.

Solution 6

(a)$\lambda_{sound} = 10.d_{speaker}$

$=10(20)$

$=200$ cm$=2$m

$V=f \times \lambda$

$f=340/2 = 170$ Hz

(b) $\lambda_{sound} = d/10$

$=20/10$

$=2$cm

$=0.02$ m

$V= f \times \lambda$

$F=340/0.02$

$=17000$ Hz

Question 7

Ultrasonic waves of frequency 4.5 MHz are used to detect tumour in soft tissue. The speed of sound in tissue is 1.5 km s^{-1} and that in air is 340 m s^{-1}. Find the wavelength of this ultrasonic wave in air and in tissue.

Solution 7

$V=f \times \lambda$

In air

$\lambda = v/f$

$\lambda_{air} = 340/4.5 \times 10^6$

$\lambda_{air} = 7.6 \times 10^{-5}$m

In tissue

$\lambda = v/f$

$\lambda_{issue} = 1.5 \times 10^3/4.5 \times 10^6$

$\lambda_t = 3.3 \times 10^{-4}$m

Question 8

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The equation of a travelling sound wave is $y = 6.0 \sin (600\,t - 1.8\,x)$ where y is measured in 10^{-5} m, t in second and x in metre. (a) Find the ratio of the displacement amplitude of the particles to the wavelength of the wave. (b) Find the ratio of the velocity amplitude of the particles to the wave speed

Solution 8

$y=6\sin(600t-1.8x)$

Comparing equation with $y=A\sin(wt \pm Kx)$

$K=1.8$; $w=600$; $A=6\times10^{-5}$m

$2\pi/\lambda=1.8$

$\lambda=2\pi/1.8$

(a)

$A/\lambda = 6\times10^{-5}/(2\pi/1.8)=1.7\times10^{-5}$

(b)

Wave speed = (coefficient of t)/(coefficient of x)

$V_w=600/1.8 = 100/3$ m/s

Velocity Amplitude = $A\omega$

$=(6\times10^{-5})(600)$

$V_p=36\times10^{-3}$m/sec

Ratio$=V_p/V_w=36\times10^{-3}/(100/3) = 1.1\times10^{-4}$

Question 9

A sound wave frequency 100 Hz is travelling in air. The speed of sound in air is 350 m s^{-1}. (a) By how much is the phase changed at a given point in 2.5 ms? (b) What is the phase difference at a given instant between two points separated by a distance of 10.0 cm along the direction of propagation?

Solution 9

$V=f\times\lambda$

$350=100\times\lambda$

$\lambda=3.5$m

(a)

$\triangle \varnothing=\frac{2\pi}{T}.t$

$=(2\pi f)t$

$=(2\pi)(100)(2.5\times10^{-3})$

$=\pi/2$

(b)

$\triangle \varnothing=\frac{2\pi}{\lambda}.\triangle x$

$=\frac{2\pi}{3.5}.x(0.1)$

$=2\pi/35$

Question 10.(a)

Two point sources of sound are kept at a separation of 10 cm. They vibrate in phase to produce waves of wavelength 5.0 cm. What would be the phase difference between the two waves arriving at a point 20 cm from one source (a) on the line joining the sources and (b) on the perpendicular bisector of the line joining the sources?

Solution 10.(a)

(a)Path difference of two waves = 30-20

$\triangle$=10 cm

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$Ø = \frac{2\pi}{\lambda} . \triangle$

$= \frac{2\pi}{5} \times 10$

$Ø = 4\pi$

Since $Ø = 2n\pi$ i.e., constructive interference
So phase difference is zero
(b) Path difference = 0
So, Ø=0

Question 11

Calculate the speed of sound in oxygen from the following data. The mass of 22.4 litre of oxygen at STP (T = 273 K and p = 1.0 $\times 10^5$ N m^{-2}) is 32 g, the molar heat capacity of oxygen at constant volume is C_v = 2.5 R and that at constant pressure is C_p = 3.5 R.

Solution 11

Density= mass/volume

$\rho = \frac{32*10^{-3}}{22.4*10^{-3}}$

Adiabetic Constant = C_p/C_v

γ=3.5R/2.5R

$v = \sqrt{\frac{\gamma p}{\rho}}$

$= \sqrt{\frac{35*10^5*22.4}{25*32}}$ =310m/s

Question 12

The speed of sound as measured by a student in the laboratory on a winter day is 340 m s^{-1} when the room temperature is C17°. What speed will be measured by another student repeating the experiment on a day when the room temperature is 32°C?

Solution 12

$v \alpha \sqrt{T}$

$V_1/V_2 = \sqrt{\frac{T_1}{T_2}}$

$340/V_2 = \sqrt{\frac{273+17}{273+32}}$

V_2=349m/s

Question 13

At what temperature will the speed of sound be double of its value at 0°C?

Solution 13

$V \alpha \sqrt{T}$

$V_1^2/V_2^2 = T_1/T_2$

$v_1^2/(2v_1)^2 = (0+273)/T_2$ [$\because v_2 = 2v_1$]

$T_2 = 273 \times 4K$

$T_2 = 273 \times 4 - 273$

T_2=819°C

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Question 14

The absolute temperature of air in a region linearly increases from T_1 to T_2 in a space of width d. Find the time taken by a sound wave to go through the region in terms of T_1, T_2, d and the speed v of sound at 273 K. Evaluate this time for T_1 = 280 K, T_2 = 310 K, d = 33 m and v = 330 m s^{-1}.

Solution 14

The variation of temperature at a distance x from surface of T_1 temperature

$T = \frac{T2-T1}{d}.x+T_1$

Velocity of sound $V \alpha \sqrt{T}$

$\frac{V_T}{V} = \sqrt{\frac{T}{273}}$

$V_T = \frac{dx}{dt} = v\sqrt{\frac{T}{273}}$

$$\int_0^d \frac{dx}{\sqrt{\left(\frac{T_2-T_1}{d}\right)x+T_1}} = \int_0^t \frac{dt}{\sqrt{273}} \text{ x } V$$

$$\frac{2d}{T_2-T_1}\left[\left(\frac{T_2-T_1}{d}\right)x+T_1\right]_0^d = \frac{V\ X\ t}{\sqrt{273}}$$

$$t = \frac{2d}{V}\ \frac{\sqrt{273}}{\sqrt{T_2}+\sqrt{T_1}}$$

Putting T_1=280K, T_2=310K, d=33m and v=330m/s

t= 96 ms

Question 15

Find the change in the volume of 1.0 litre kerosene when it is subjected to an extra pressure of 2.0×10^5 N m^{-2} from the following data. Density of kerosene = 800 kg m^{-3} and speed of sound in kerosene = 1330 ms^{-1}.

Solution 15

$v = \sqrt{\frac{\beta}{\rho}}$

$\beta = v^2\rho$

$\frac{P}{\frac{\Delta V}{V}} = v^2\rho$

$\triangle V = \frac{PV}{v^2\rho}$

$= \frac{(2x10^5)(10^{-3})}{(1330)^2(800)}$

$\triangle V = 0.14\ cm^3$

Question 16

Calculate the bulk modulus of air from the following data about a sound wave of wavelength 35 cm travelling in air. The pressure at a point varies between $(1.0 \times 10^5 \pm 14)$ Pa and the particles of the air vibrate in simple harmonic motion of amplitude 5.5×10^{-6} m.

Solution 16

$P = \beta AK$

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$\beta=\frac{\frac{\Delta P}{A\,2\pi}}{\lambda}$

$\beta=\frac{14\text{x}35\text{x}10^{-2}}{5.5\text{x}10^{-6}\text{x}2\text{x}3.14}/\triangle$

$\beta=1.4\times10^{5}N/m^{2}$

Question 17

A sources of sound operates at 2.0 kHz, 20 W emitting sound uniformly in all directions. The speed of sound in air is 340 m s^{-1} and the density of air is 1.2 kg m^{-3}. (a) What is the intensity at a distance of 6.0 m from the source? (b) What will be the pressure amplitude at this point? (c) What will be the displacement amplitude at this point?

Solution 17

(a) $I=P/A=P/4\pi r^{2}$

$I=\frac{20}{4\text{x}3.14\text{x}(6)^{2}}$

I=44 mW/m^{2}

(b) $I=(\text{pressure amp.})^{2}/2\rho v$

$P_{max=}\sqrt{I\times2\rho v}$

$=\sqrt{2\times1.2\times340\times44\times10^{-3}}$

$P_{max=}6\ N/M^{2}$

(c) $I=2\pi^{2}f^{2}A^{2}\rho v$

$A=\sqrt{\frac{44*10^{-3}}{2\pi^{2}*(2000)^{2}*(1.2)*340}}$

$A=1.2*10^{-6}$ m

Question 18

The intensity of sound from a point source is 1.0×10^{-8} W m^{-2} at a distance of 5.0 m from the source. What will be the intensity at a distance of 25 m from the source?

Solution 18

$I\ \alpha\ \frac{1}{r^{2}}$

$I_1/I_2=r_2^{2}/r_1^{2}$

$10^{-8}/I_2=(25)^{2}/(5)^{2}$

$I_2=4\times10^{-10}w/m^{2}$

Question 19

The sound level at a point 5.0 m away from a point source is 40 dB. What will be the level at a point 50 m away from the source?

Solution 19

$\triangle L=10\log\frac{I_2}{I_1}$

$=10\log\frac{r_1^{2}}{r_2^{2}}$

$=10\log(5/50)^{2}$

40-L=-20dB

L=20dB

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Question 20
If the intensity of sound is doubled, by how many decibels does the sound level increase?

Solution 20
$\triangle L=10\log^{\frac{I_2}{I_1}}$

$=10\log^{\frac{2I}{I}}$

$\triangle L=3dB$

Question 21
Sound with intensity larger than 120 dB appears pain full to a person. A small speaker delivers 2.0 W of audio output. How close can the person get to the speaker without hurting his ears?

Solution 21
$I=P/A=P/4^{\pi}r^2$

$r=\sqrt{\frac{\rho}{4\pi I}}$

$=\sqrt{\frac{2}{4*3.14*1}}$ [$\because$ when L=120dB then $I=1w/m^2$]

r=0.4m=40cm

Question 22
If the sound level in a room is increased from 50 dB to 60 dB, by what factor is the pressure amplitude increased?

Solution 22
$\triangle L=10\log^{\frac{I_2}{I_1}}$

$(60-50)=10\log^{\frac{I_2}{I_1}}$

$\frac{I_2}{I_1}=10$

$I^{\alpha}\rho^2$

$\frac{p_2}{p_1}=\sqrt{10}$

Question 23
The noise level in a classroom in absence of the teacher is 50 dB when 50 students are present. Assuming that on the average each student output same sound energy per second, what will be the noise level if the number of students is increased to 100?

Solution 23
$\triangle L=10\log^{\frac{I_2}{I_1}}$

Let I be the intensity produced by each student

$\triangle L=10\log\frac{100I}{50I}$

L-50=10×0.3

L=53dB

Question 24

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In Quincke's experiment the sound detected is changed from a maximum to a minimum when the sliding tube is moved through a distance of 2.50 cm. Find the frequency of sound if the speed of sound in air is 340 m s^{-1}.

Solution 24

Path difference between consecutive maxima and minima=λ/2
If tube is slided by x, then

2×=λ /2

λ =2×(2.5*10^{-2})*2

λ =10^{-1}m

V=f*λ
f=340/10^{-1}
f=3.4kHz

Question 25

In Quincke's experiment, the sound intensity has a minimum value *I* at a particular position. As the sliding tube is pulled out by a distance of 16.5 mm, the intensity increases to a maximum of 9 *I*. Take the speed of sound in air to be 330 m s^{-1}. (a) Find the frequency of the sound source. (b) Find the ratio of the amplitudes of the two waves arriving at the detector assuming that it does not change much between the positions of minimum intensity and maximum intensity.

Solution 25

(a)

Path difference between consecutive maxima and minima=λ /2
If tube is slided by x

2x=λ /2

λ =4×16.5×10^{-3}

λ =66×10^{-3}m

V=f*λ
330=f×66×10^{-3}
f=5kHz
(b)
$I_{max}/I_{min}=(A_1+A_2)^2/(A_1-A_2)^2$
$9I/I=(A_1+A_2)^2/(A_1-A_2)^2$
$A_1/A_2=2$

Question 26

Two audio speakers are kept some distance apart and are driven by the same amplifier system. A person is sitting at a place 6.0 m from one of the speakers and 6.4 m from the other. If the sound signal is continuously varied from 500 Hz to 5000 Hz, what are the frequencies for which there is a destructive interference at the place of the listener? Speed of sound in air = 320 m s^{-1}.

Solution 26

Path difference of the sound waves = 6.4-6
$\triangle$=0.4m
For destructive interference

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

$0.4=\frac{(2n+1)}{2}\frac{v}{f}$

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$f = \frac{320}{2x0.4} \times (2n+1)$
f=400(2n+1)
Putting n=1,2,3… till f<5000Hz
So, frequencies are 1200 Hz, 2000Hz, 2800Hz, 3600Hz and 4400Hz

Question 27
A source of sound *S* and detector *D* are placed at some distance from one another. a big cardboard is placed near the detector and perpendicular to the line *SD* as shown in figure. It is gradually moved away and it is found that the intensity changes from a maximum to a minimum as the board is moved through a distance of 20 cm. Find the frequency of the sound emitted. Velocity of sound in air is 336 m s^{-1}.

Figure 16-E1

Solution 27
If board is moved by x then extra path difference between waves is 2x.
Path difference between consecutive maxima and minima is λ/2
So, λ/2=2x
$\lambda = 4 \times 20 \times 10^{-2}$
λ =0.8m
v=f× λ
f=336/0.8
f=420Hz

Question 28
A source *S* and a detector *D* are placed at a distance *d* apart. A big cardboard is placed at a distance √2*d* from the source and the detector as shown in figure. The source emits a wave of wavelength = *d*/2 which is received by the detector after reflection from the cardboard. It is found to be in phase with the direct wave received from the source. By what minimum distance should the cardboard be shifted away so that the reflected wave becomes out of phase with the direct wave?

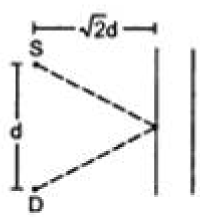

Figure 16-E2

Solution 28
Initially, path difference is $=2[\sqrt{(\sqrt{2}d)^2 + (d/2)^2}]- d$
$\triangle i = 2d$

Let cardboard is shifted by distance x, then final path difference = $2[\sqrt{(\sqrt{2d} + x)^2 + (d/2)^2}]- d$

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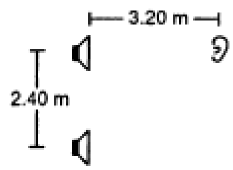
Path difference between consecutive maxima and minima is $\lambda/2 = \frac{d}{2}.\frac{1}{2}$
$\Delta_{net}=\Delta_f-\Delta_i$
$d/4 = 2[\sqrt{(\sqrt{2d}+x)^2+(d/2)^2}$ -d]- 2d
On solving
X=0.13d

Question 29
Two stereo speakers are separated by a distance of 2.40 m. A person stands at a distance of 3.20 m directly in front of one of the speakers as shown in figure. Find the frequencies in the audible range (20-2000 Hz) for which the listener will hear a minimum sound intensity. Speed of sound in air = 320 m s^{-1}.



Solution 29
Path difference = $\sqrt{(3.2)^2+(2.4)^2}$ - 3.2
$\triangle$=0.8m
For destructive interference,
$\triangle = \frac{(2n+1)\lambda}{2} = 0.8$
(2n+1)(320/f) = 2×0.8
f=200(2n+1)
Lowest frequency heard when n=0 will be f=200Hz
For Highest frequency f=20,000Hz=200(2n+1)
N=49.5
So maximum value of n is 49
On putting n=0,1,2,…..49 person will hear in audible range.

Question 30
The two sources of sound, S_1 and S_2, emitting waves of equal wavelength 20.0 cm, are placed with a separation of 20.0 cm between them. A detector can be moved on a line parallel to S_1 S_2 and at a distance of 20.0 cm from it. Initially, the detector is equidistant from the two sources. Assuming that the waves emitted by the sources are in detector should be shifted to detect a minimum of sound.

Solution 30

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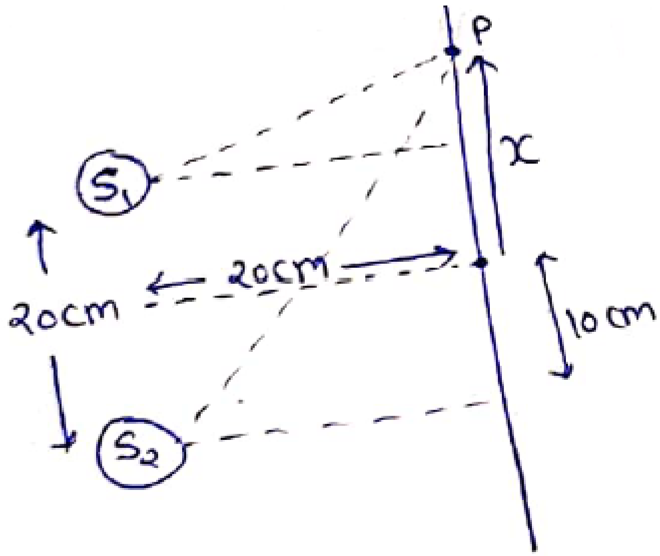

Let detector is moved by x at point P
Path difference between consecutive maxima and minima is λ/2 = 20/2 = 10cm
$\triangle = S_2P - S_1P$
$10 = \sqrt{(20)^2 + (10+x)^2} - \sqrt{(20)^2 + (x-10)^2}$
On solving,
X=12.6cm

Question 31

Two speakers S_1 and S_2, driven by the same amplifier, are placed at y = 1.0 m and y = -1.0 m. The speakers vibrate in phase at 600 Hz. A man stands at a point on the X-axis at a very large distance from the origin and starts moving parallel to the Y-axis. The speed of sound in air is 330 m s^{-1}. (a) At what angle θ will the intensity of sound drop to a minimum for the first time? (b) At what angle will he hear a maximum of sound intensity for the first time? (c) If he continues to walk along the line, how many more can he hear?

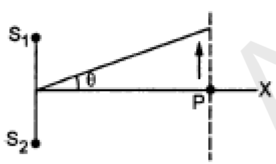

Figure 16-E4

Solution 31

V=fxλ
λ=330/600 = 11/20 m
(a)
D-1 will be observed here
$\triangle = d\sin\theta$
$\lambda/2 = d\sin\theta$
½ x 11/20 = 2sinθ
sinϴ = 11/8
ϴ=11/80 rad. [∵ angle is small sin≈ϴ]
ϴ=11/80×180°/π=7.9°

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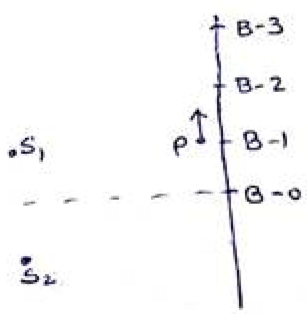
(b)
B-1 will be formed
$\triangle = d\sin\Theta$
$\lambda = d\sin\Theta$
$11/20 = 2\sin\Theta$
$\sin\Theta = 11/40$
$\Theta = 11/40 \times 180°/\pi = 16°$
(c)
Let n^{th} be last maxima obtained at $\theta = 90°$
$\triangle = d\sin\Theta$
$n\lambda = d\sin 90°$
$N(11/20) = 2$
$n = 3.63$
So, last maxima is for n=3.
So, he get two maxima from point P along the line as he walks.



Question 32
Three sources of sound S_1, S_2 and S_3 of equal intensity are placed in a straight line with $S_1S_2 = S_2S_3$. At a point P, far away from the sources, the wave coming from S_2 is 120° ahead in phase of that from S_1. Also, the wave coming from S_3 is 120° ahead of that from S_2. What would be the resultant intensity of sound at *P*?

Figure 16-E5

Solution 32
$\because I \propto A^2$
$\because A_1 = A_2 = A_3 = A$

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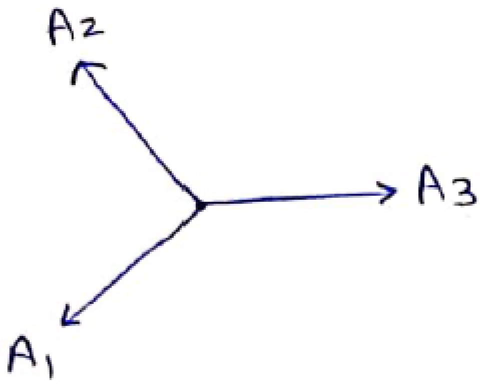


By vector method,
Resultant Amplitude =0
So,
I_N=0

Question 33
Two coherent narrow slits emitting sound of wavelength λ in the same phase are placed parallel to each other at a small separation of 2λ. The sound is detected by moving a detector on the screen Σ at a distance *D*(>>λ) from the slit S_1 as shown in figure. Find the distance *x* such that the intensity at *P* is equal to the intensity at *O*.

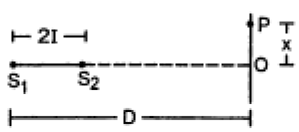
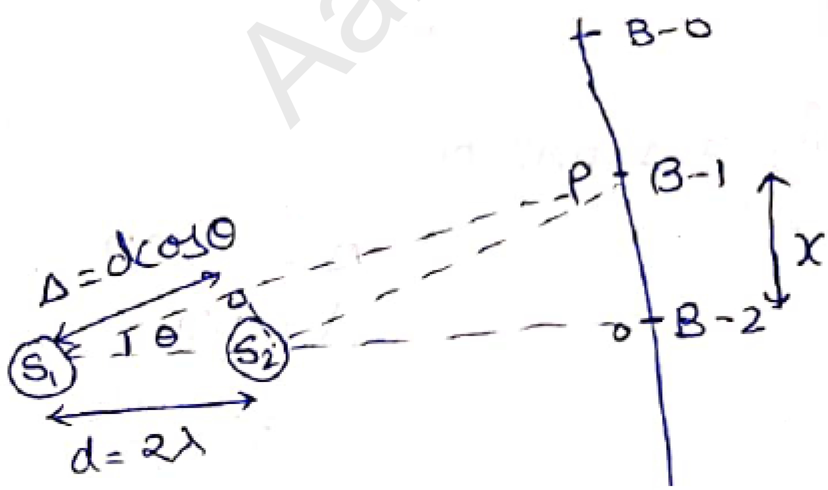


Figure 16-E6

Solution 33



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At point O,
$\triangle = S_1O - S_2O$
$\triangle = 2\lambda$(constructive interference B-2 order)
So,
At point P, B-1 will be formed
$\triangle = d\cos\Theta$
$1\times\lambda = 2\lambda\cos\Theta$
$\Theta = 60°$
In $\triangle S_1PO$
$\tan 60° = x/D$
$X = \sqrt{3}D$

Question 34

Figure shown two coherent sources S_1 and S_2 which emit sound of wavelength λ in phase. The separation between the sources is 3λ. A circular wire of large radius is placed in such way that S_1,S_2 is at the centre of the wire. Find the angular positions θ on the wire for which constructive interference takes place.

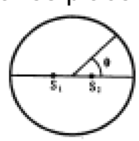
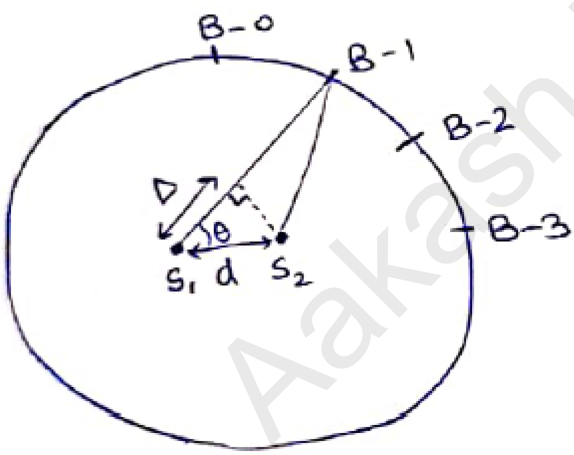


Figure 16-E7

Solution 34



$\Delta = d\cos\Theta$
$\Theta = \cos^{-1}(\triangle/3\lambda)$
B-0; $\triangle = 0 \Rightarrow \Theta = 90°$
B-1; $\triangle = \lambda \Rightarrow \Theta = 70.5°$
B-2; $\triangle = 2\lambda \Rightarrow \Theta = 48.2°$
B-3; $\triangle = 3\lambda \Rightarrow \Theta = 0°$

Question 35

Two sources of sound S_1 and S_2 vibrate at same frequency and are in phase. The intensity of sound detected at a point *P* as shown in the figure is I_0. (a) If Θ equals 45°, what will be the intensity of sound detected at this point if one of the sources is switched off? (b) What will be the answer of the previous part if $\Theta = 60°$?

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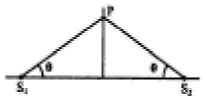

Figure 16-E8

Solution 35
Let intensity of each source be I
(a)
At P
$\Delta=S_2P-S_1P=0$
So, $\varnothing=0$ (constructive interference)
$I_{max}=(\sqrt{I_1}+\sqrt{I_2})^2 = (\sqrt{I}+\sqrt{I})^2$
$I_o=4I$
Now, when one source is switched off intensity at this point will be I i.e., $I_o/4$
(b)
If $\Theta=60°$ then also $\Delta=0$
So, no change in answer

Question 36
Find the fundamental, first overtone and second overtone frequencies of an open organ pipe of length 20 cm. Speed of sound in air is 340 ms^{-1}.

Solution 36
Fundamental frequency of O.O.P $=V/2l$
$=340/2(0.2)$
$=850Hz$
I^{st} overtone frequency $=2f$
$f_1=2(850)$
$f_1=1700Hz$
II^{nd} overtone frequency $= 3f$
$f_2=3(850)$
$f_2=2550Hz$

Question 37
A closed organ pipe can vibrate at a minimum frequency of 500 Hz. Find the length of the tube. Speed of sound in air = 340 m s^{-1}.

Solution 37
Fundamental frequency of C.O.P.$=V/4l$
$500=(340)/4l$
$l=0.17m=17cm$

Question 38
In a standing wave pattern in a vibrating air column, nodes are formed at a distance of 4.0 cm. If the speed of sound in air is 328 m s^{-1}, what is the frequency of the source?

Solution 38
Distance between consecutive nodes = $\lambda/2$ = 4cm
$V=f\times\lambda$
$328=f\times8/100$
$f=4.1KHz$

Question 39

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The separation between a node and the next antinode in a vibrating air column is 25 cm. If the speed of sound in air is 340 m s^{-1}, find the frequency of vibration of the air column.

Solution 39
Distance between consecutive node and antinode is λ/4

$\lambda/4=25cm$

$\lambda=1m$

$v=f x \lambda$

$f=340Hz$

Question 40
A cylindrical metal tube has a length of 50 cm and is open at both ends. Find the frequencies between 1000 Hz and 2000 Hz at which the air column in the tube can resonate. Speed of sound in air is 340 m s^{-1}.

Solution 40
Frequency in O.O.P.

$f=nv/2l$

$f=n(340)/2(0.5)$

$f=n(340)$

So, frequencies between 1000Hz and 2000Hz will be when n=3,4,5 i.e. f=1020,1360,1700Hz respectively.

Question 41
In a resonance column experiment, a tuning fork of frequency 400 Hz is used. The first resonance is observed when the air column has a length of 20.0 cm and the second resonance is observed when the air column has a length of 62.0 cm. (a) Find the speed of sound in air. (b) How much distance above the open end does the pressure node form?

Solution 41
$L_2-L_1= \lambda /2$

$62-20= \lambda /2$

$\lambda =84cm=0.84m$

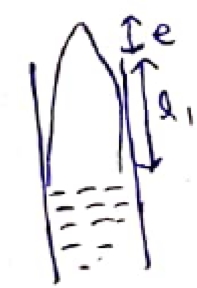
(a)

$V=f x \lambda$

$V=400(0.84)$

$V=336m/s$

(b)



$L_1+e= \lambda /4$

$20+e=84/4$

$e=1cm$

Question 42

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The first overtone frequency of a closed organ pipe P_1 is equal to the fundamental frequency of a open organ pipe P_2. If the length of the pipe P_1 is 30 cm, what will be the length of P_2?

Solution 42

I_{st} overtone frequency of cop=fundamental frequency of oop

$3\times v/4l_c = v/2l_o$

$3/(4\times 30) = 1/2\times l_o$

L_o=20cm

Question 43

A copper rod of length 1.0 m is clamped at its middle point. Find the frequencies between 20 Hz and 20,000 Hz at which standing longitudinal waves can be set up in the rod. The speed of sound in copper is 3.8 km s^{-1}.

Solution 43

For fundamental frequency

$\lambda/2=1$

λ=2m

$v=f\times\lambda$

$3800=f\times 2$

f=1.9kHz

Other frequency are given by = n×1.9KHz

where n=1,2,…. 10 in range of 20Hz-20,000Hz

Question 44

Find the greatest length of an organ pipe open at both ends that will have its fundamental frequency in the normal hearing range (20 - 20,000 Hz). Speed of sound in air = 340 m s^{-1}.

Solution 44

f=v/2l

$L_{max}=v/2f_{min}$

L_{max}=340/(2)(20) = 8.5m

Question 45

An open organ pipe has a length of 5 cm. (a) Find the fundamental frequency of vibration of this pipe. (b) What is the highest harmonic of such a tube that is in the audible range? Speed of sound in air is 340 m s^{-1} and the audible range is 20-20,000 Hz.

Solution 45

(a)

Fundamental frequency of o.o.p = v/2l

=340/2(0.05)

f=3.4KHz

(b)

Let n^{th} harmonic be highest in audible range

f'=nf

20,000=n(3400)

n=5.8

So,n=5

Question 46

An electronically driven loudspeaker is placed near the open end of a resonance column apparatus. The length of air column in the tube is 80 cm. The frequency of the loudspeaker can be varied between 20 Hz and 2 kHz. Find the frequencies at which the column will resonate. Speed of sound in air = 320 m s^{-1}.

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Solution 46

Fundamental frequency f cop=$\frac{v}{4l}$= $\frac{320}{4 X 0.8}$=100Hz
Higher harmonics frequencies = (2n+1)100
Where n=0,1,…….. 9

Question 47
Two successive resonance frequencies in an open organ pipe are 1944 Hz and 2592 Hz. Find the length of the tube. The speed of sound in air is 324 ms^{-1}.

Solution 47

Difference between two successive resonance frequency in O.O.P. = $\frac{(n+1)v}{2l}$ - $\frac{v}{2l}$= $\frac{v}{2l}$

(2592-1944) = $\frac{324}{2l}$
l=0.25m
l=25cm

Question 48
A piston is fitted in a cylindrical tube of small cross section with the other end of the tube open. The tube resonates with a tuning fork of frequency 512 Hz. The piston is gradually pulled out of the tube and it is found that a second resonance occurs when the piston is pulled out through a distance of 32.0 cm. Calculate the speed of sound in the air of the tube.

Solution 48
Path difference between two consecutive maxima = λ=2×32 cm
λ=0.64m
v=f×λ
=512(0.64)
v=328m/s

Question 49
A U-tube having unequal arm-lengths has water in it. A tuning fork of frequency 440 Hz can set up the air in the shorter arm in its fundamental mode of vibration and the same tuning fork can set up the air in the longer arm in its first overtone vibration. Find the length of the air columns. Neglect any end effect and assume that the speed of sound in air = 330 m s^{-1}.

Solution 49

Fundamental frequency in shorter arm for cop=$\frac{v}{4l}$

440=$\frac{330}{4l_s}$

l_s=18.8cm

In longer arm, Ist overtone frequency = $\frac{3v}{4l}$

440= $\frac{3 \times 330}{4l_l}$

l_l=0.563m or l_l=56.3cm

Question 50
Consider the situation shown in figure. The wire which has a mass of 4.00 g oscillates in its second harmonic and sets the air column in the tube into vibrations in its fundamental mode. Assuming that the speed of sound in air is 340 m s^{-1}, find the tension in the wire.

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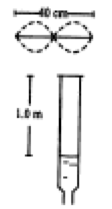

Figure 16-E9

Solution 50

II^{nd} harmonic of wire = fundament frequency of cop

$$2 X \frac{v}{2l_W}\sqrt{\frac{T}{\mu}} = \frac{v}{4l_T}$$

$$\frac{1}{0.4}\sqrt{\frac{T X 0.4}{4 X 10^{-3}}} = \frac{340}{4(1)}$$

[$\because \mu$ =mass/length]

T=11.6N

Question 51

A 30.0-cm-long wire having a mass of 10.0 g is fixed at the two ends and is vibrated in its fundamental mode. A 50.0-cm-long closed organ pipe, placed with its open end near the wire, is set up into resonance in its fundamental mode by the vibrating wire. Find the tension in the wire. Speed of sound in air = 340 m s^{-1}.

Solution 51

Fundamental frequency of wire = fundamental frequency of cop

$$\frac{v}{2l_W}\sqrt{\frac{T}{\mu}} = \frac{v}{4l_p}$$

$$\frac{1}{2(0.3)}\sqrt{\frac{T X 0.3}{10 X 10^{-3}}} = \frac{340}{4(0.5)}$$

T=347N

Question 52

Show that if the room temperature changes by a small amount from *T* to *T* + $\triangle T$, the fundamental frequency of an organ pipe changes from *f* to *f* + $\triangle f$, where

$$\frac{\Delta f}{f} = \frac{\Delta T}{2T}$$

Solution 52

$f \alpha\ v\ \alpha\ \sqrt{T}$

$f \alpha\ \sqrt{T}$

by error

$$\frac{\Delta f}{f} = \frac{\Delta T}{2T}$$

Question 53

The fundamental frequency of a closed pipe is 293 Hz when the air in it is a temperature of 20°C. What will be its fundamental frequency when the temperature changes to 22°C?

Solution 53

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f $\alpha\ v\ \alpha\ \sqrt{T}$

$$\frac{f_1}{f_2} = \sqrt{\frac{T_1}{T_2}}$$

$$\frac{293}{f_2} = \sqrt{\frac{273+20}{273+22}}$$

f_2=294Hz

Question 54
A Kundt's tube apparatus has a copper rod of length 1.0 m clamped at 25 cm from one of the ends. The tube contains air in which the speed of sound is 340 m s^{-1}. The powder collects in heaps separated by a distance of 5.0 cm. Find the speed of sound waves in copper.

Solution 54
$\lambda_{Rod}/4$ = 25cm= 100cm=1m
$\lambda_{air}/2$ = 5cm =10cm=0.1m
$v_{air}/\lambda_{air}=v_{rod}/\lambda_{red}$
340/0.1 = $v_{rod}/1$
v_{rod}=3400m/s

Question 55
A Kundt's tube apparatus has a steel rod of length 1.0 m clamped at the centre. It is vibrated in its fundamental mode at a frequency of 2600 Hz. The lycopodium powder dispersed in the tube collects into heaps separated by 6.5 cm. Calculate the speed of sound in steel and in air.

Solution 55
$L_{rod}=\lambda_r/2$
λ_r =2m
$\lambda_{gas}/2$=6.5cm
λ_{gas}=13cm
$f=v_{air}/\lambda_a=v_{rod}/\lambda_r$
$2600=v_{air}/13\times10^{-2}=v_{rod}/2$
V_{air}=338m/s and v_{rod}=5200m/s

Question 56
A source of sound with adjustable frequency produces 2 beats per second with a tuning fork when its frequency is either 476 Hz of 480 Hz. What is the frequency of the tuning fork?

Solution 56
Frequency of source is 476Hz or 480Hz
Number of beats is 2
So, possible frequency of tuning fork=476±2 or 480 ±2
=474,478 or 478,482
So, common frequency of tuning fork=478Hz

Question 57
A tuning fork produces 4 beats per second with another tuning fork of frequency 256 Hz. The first one is now loaded with a little wax and the beat frequency is found to increase to 6 per second. What was the original frequency of the tuning fork?

Solution 57

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Frequency of tuning fork 'A'=256Hz
No. of beats=4
So, frequency of tuning fork 'B'=256±4
'B'=252Hz or 260Hz
Now, on waxing fork 'B', its frequency will decrease and will produce and beats with A which is possible when frequency of fork B is 252 Hz

Question 58
Calculate the frequency of beats produced in air when two sources of sound are activated, one emitting a wavelength of 32 cm and the other of 32.2 cm. The speed of sound in air is 350 m s^{-1}.

Solution 58
Beat frequency = f_2-f_1
$=v/\lambda_2-v/\lambda_1$
$=\frac{350}{(0.32)}-\frac{-350}{(0.322)}$
≈7Hz

Question 59
A tuning fork of unknown frequency makes 5 beats per second with another tuning fork which can cause a closed organ pipe of length 40 cm to vibrate in its fundamental mode. The beat frequency decreases when the first tuning fork is slightly loaded with wax. Find its original frequency. The speed of sound in air is 320 m s^{-1}.

Solution 59
Fundamental frequency of cop=v/4l
=(320)/[(4)(0.4)]
=200Hz
Tuning fork produces 5 beats with cop
f_{fork}=205 or 195Hz
When loaded with wax, frequency will decrease.
∵Beat frequency decreases
f_{fork}=205Hz

Question 60
A piano wire *A* vibrates at a fundamental frequency of 600 Hz. A second identical wire *B* produces 6 beats per second with it when the tension in *A* is slightly increased. Find the the ratio of the tension in *A* to the tension in *B*.

Solution 60
Initially,
$F_A=f_B$=600Hz
∵$f \alpha \sqrt{T}$
As tension increases, frequency increases
So, f_A=606Hz; f_B=600Hz
$f_A/f_B=\sqrt{T_A}/\sqrt{T_B}$
$606/600 = \sqrt{T_A}/\sqrt{T_B}$
T_A/T_B=1.02

Question 61
A tuning fork of frequency 256 Hz produces 4 beats per second with a wire of length 25 cm vibrating in its fundamental mode. The beat frequency decreases when the length is slightly shortened. What could be the minimum length by which the wire we shortened so that it produces no beats with the tuning fork?

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Solution 61

Frequency of wire=256±4

=252Hz or 260Hz

$f_{wire}=\frac{1}{2l}\sqrt{\frac{T}{\mu}}$ = f_{wire} $\alpha\,\frac{1}{l}$

By shortening, the length of wire, f_{wire} increases.

∵Beat frequency decreases

So, f_{wire} = 252Hz

Initially, f_{wire}=252Hz and length of wire = 25cm

Later, f_{wire}=256Hz and length of wire = l_f

$f_i/f_f=l_f/l_i$

252/256 = l_f/25

l_f=24.6cm

Length shortened = 25-24.6

=0.6cm

Question 62

A traffic policeman standing on a road sounds a whistle emitting the main frequency of 2.00 kHz. What could be the apparent frequency heard by a scooter-driver approaching the policeman at a speed of 36.0 km h^{-1}? Speed of sound in air = 340 m s^{-1}.

Solution 62

S

$f_o = 2000\,Hz$

$V_o = 36 \times \frac{5}{18}$ ← O

$V_o = 10\,m/s$

V_o=10m/s

f_o=2000Hz

f_{app}= f_o [$\frac{v+vo}{v}$]= 2000 [$\frac{340+10}{10}$]

f_{app}=2.06KHz

Question 63

The horn of a car emits sound with a dominant frequency of 2400 Hz. What will be the apparent dominant frequency heard by a person standing on the road in front of the car if the car is approaching at 18.0 km h^{-1}? Speed of sound in air = 340 m s^{-1}

Solution 63

S → $V_s = 18 \times \frac{5}{18} = 5\,m/s$

O

rest

$f_o = 2400\,Hz$

$v_s=18\times\frac{5}{18}$ = 5m/s

f_o=2400Hz

$f_{app}=f_o[\frac{v}{v-v_s}]$

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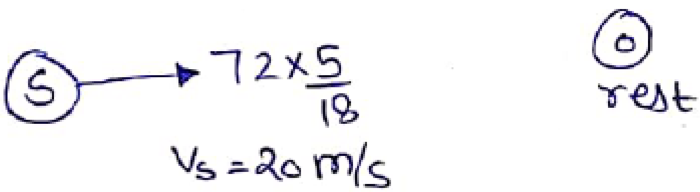
$2400\left[\frac{340}{340-5}\right]$
$f_{app}=2436Hz$

Question 64
A person riding a car moving at 72 km h^{-1} sound a whistle emitting a wave of frequency 1250 Hz. What frequency will be heard by another person standing on the road (a) in front of the car (b) behind the car? Speed of sound in air = 340 m s^{-1}.

Solution 64
(a)



$V_s=20m/s$
$f_o=1250Hz$
$f_{app}= f_o\left[\frac{v}{v-v_s}\right]$
$=1250\left[\frac{340}{340-20}\right]$
$=1328Hz$

(b)

$f_o=1250Hz$
$f_{app}= f_o\left[\frac{v}{v+v_s}\right]$
$=_{1250}\left[\frac{340}{340+20}\right]$
$f_{app}=1181Hz$

Question 65
A train approaching a platform at a speed of 54 km h^{-1} sounds a whistle. An observer on the platform finds its frequency to be 1620 Hz. the train passes the platform keeping the whistle on and without slowing down. What frequency will the observer hear after the train has crossed the platform? The speed of sound in air = 332 m s^{-1}

Solution 65
Initially,

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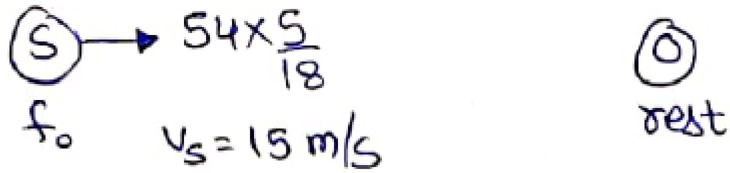


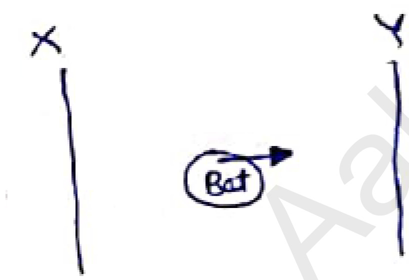
$f_{app}=f_o[\frac{v}{v-v_s}]=1620$ ---(1)

$F_{app}=f_o[[\frac{v}{v+v_s}]$----(2)
Divide(1) and(2),
$1620/F_{app}=v+v_s/v-v_s$
$1620/F_{app}=340+15/340-15$
$F_{app}=1480Hz$

Question 66

A bat emitting an ultrasonic wave of frequency 4.5×10^4 Hz flies at a speed of 6 m s^{-1} between two parallel walls. Find the fractional heard by the bat and the beat frequencies heard by the bat and the beat frequency between the two. The speed of sound is 330 m s^{-1}.

Solution 66



Apparent frequency received by wall Y is

$f' = f_o[\frac{v}{v-v_b}]$

Apparent frequency received by bat after reflection from the wall Y is

$f'' = f'[\frac{v+v_b}{v}]$

$=4.5\times10^4\times\frac{330}{330-6}\times\frac{330+6}{330}$

$f''=4.66\times10^4Hz$

Apparent frequency received by wall x is

$n'=fo[\frac{v}{v+v_b}]$

Apparent frequency received by bat after reflection from the wall x is

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$n''=n'\left[\frac{v-v_b}{v}\right]$

$=4.5\times10^4\times\frac{330-6}{330}\times\frac{330}{330+6}$

$n''=4.33\times10^4$Hz

Beat frequency = $4.66\times10^4-4.33\times10^4$

=3300Hz

Question 67

A bullet passes past a person at a speed of 220 m s^{-1}. Find the fractional change in the frequency of the whistling sound heard by the person as the bullet crosses the person. Speed of sound in air = 330 m s^{-1}.

Solution 67

Apparent frequency heard before bullet crosses person

$f_1=f_o\left[\frac{v}{v-v_s}\right]$

$=f_o\left[\frac{330}{330-220}\right]$

$=3\ f_o$

Apparent frequency heard after bullet crosses person

$f_2=f_o\left[\frac{v}{v+v_s}\right]$

$=f_o\left[\frac{330}{330+220}\right]$

$F_2=0.6f_o$

So, $f_2/f_1=0.6f_o\ /3f_o=0.2$

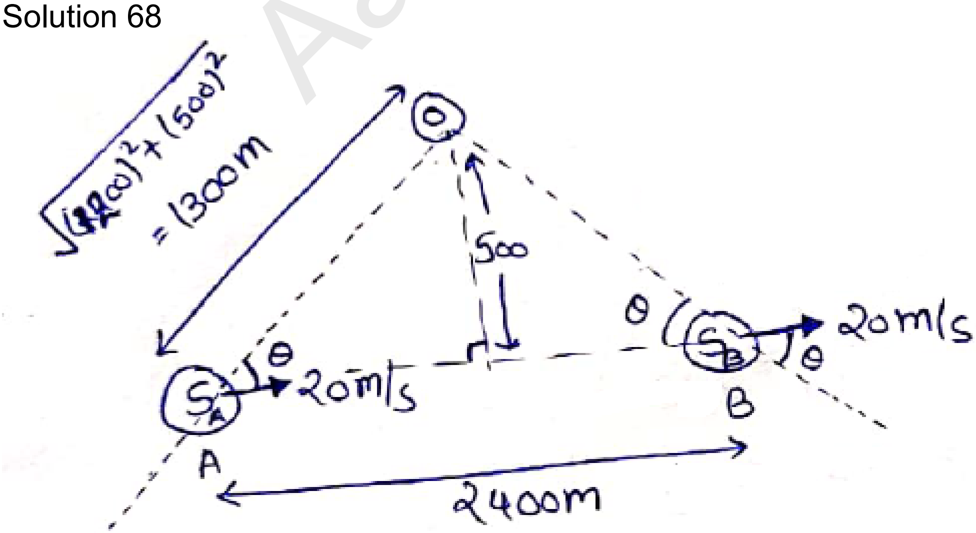
∴Fractional change = 1-0.2

=0.8

Question 68

Two electric trains run at the same speed of 72 km h^{-1} along the same track and in the same direction with separation of 2.4 km between them. The two trains simultaneously sound brief whistles. A person is situated at a perpendicular distance of 500 m from the track and is equidistant from the two trains at the instant of the whistling. If both the whistles were at 500 Hz and the speed of sound in air is 340 m s^{-1}, find the frequencies heard by the person.

Solution 68



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Velocity of train = 72kmph

$=72\times\frac{5}{18}$

$=20m/s$

Frequency heard by person from train A=$f_o[\frac{v}{v-v_s\cos\theta}]$

$=500[\frac{340}{340-20*\frac{1200}{1800}}]$

$=529Hz$

Frequency heard by person from train B = $f_o[\frac{v}{v+v_s\cos\theta}]$

$=500[\frac{340}{340+20*\frac{1200}{1800}}]$

$=474Hz$

Question 69

A violin player riding on a slow train plays a 440 Hz note. Another violin player standing near the track plays the same note. When the two are closed by and the train approaches the person on the ground, he hears 4.0 beats per second. The speed of sound in air = 340 m s^{-1}. (a) Calculate the speed of the train. (b) What beat frequency is heard by the player in the train?

Solution 69

(a)

Beat frequency for standing man = 4

So, apparent frequency heard by standing man = 440± 4

=444Hz or 430Hz

Since, source is coming towards observer so f_{app}=444Hz

$f_{app}=[\frac{v}{v-v_s}]f_o$

$444=[\frac{340}{340-v_s}].440$

$V_s=3.09m/s$

$=3.09\times\frac{18}{5}=11kmph$

(b)

The sitting man will listen to fewer than 4 beats/sec

Question 70

Two identical tuning forks vibrating at the same frequency 256 Hz are kept fixed at some distance apart. A listener runs between the forks at a speed of 3.0m s^{-1} so that he approaches one tuning fork and recedes from the other figure. Find the beat frequency observed by the listener. Speed of sound in air = 332 m s^{-1}.

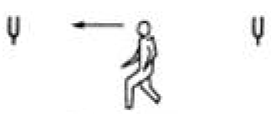

Figure 16-E10

Solution 70

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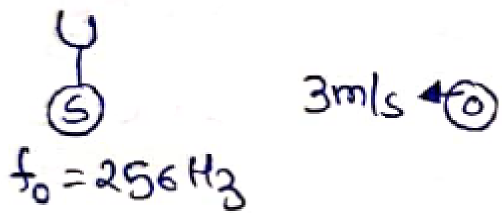


$f_1 = f_o[\frac{v+v_o}{v}]$
$=256[\frac{332+3}{332}]$
=258.3Hz

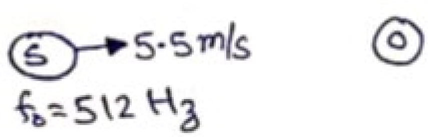
$f_2 = f_o[\frac{v-v_o}{v}]$
$=256[\frac{332-3}{332}]$
f_2=253.7Hz
Beat frequency = $f_1 - f_2$
=4.6Hz

Question 71

Figure shows a person standing somewhere in between two identical tuning forks. each vibrating at 512 Hz. If both the tuning forks move towards right a speed of 5.5 m s^{-1}, find the number of beats heard by the listener. Speed of sound in air = 330 m s^{-1}.

Figure 16-E11

Solution 71



$f_1 = f_o[\frac{v}{v-v_s}]$
$=512[\frac{330}{330-5.5}]$
=520.6Hz

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$f_2 = f_o\left[\frac{v}{v+v_s}\right]$

$F_2 = 512\left[\frac{330}{330+5.5}\right] = 503.6\text{Hz}$

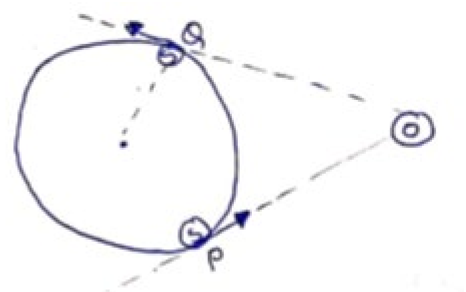
$\therefore$ Beats = $f_1 - f_2$

=17.5Hz

Question 72

A small source of sound vibrating at frequency 500 Hz is rotated in a circle of radius 100/π cm at a constant angular speed of 5.0 revolutions per second. A listener situation situates himself in the plane of the circle. Find the minimum and the maximum frequency of the sound observed. Speed of sound in air = 332 m s^{-1}.

Solution 72



Velocity of source = Rw $= \frac{100}{\pi\times100}\times 5\times 2\pi$ =10m/s

Maximum and Minimum frequency will be observed at point PandQ respectively

$f_{app\ /max} = f_o\left[\frac{v}{v-v_s}\right]$

$=500\left[\frac{332}{332-10}\right] = 515.5\text{Hz}$

$f_{app/min} = f_o\left[\frac{v}{v+v_s}\right]$

$=500\left[\frac{332}{332+10}\right] = 485\text{Hz}$

Question 73

Two trains are travelling towards each other both at a speed of 90 km h^{-1}. If one of the trains sounds a whistle at 500 Hz, what will be the apparent frequency heard in the other train? Speed of sound in air = 350 m s^{-1}.

Solution 73

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S → $V_s = 90\times\frac{5}{18} = 25 m/s$ $V_o = 25\frac{m}{s}$ ← O

$f_o = 500Hz$

$v_s=90\times\frac{5}{18}=25m/s$ $v_o=25m/s$
$F_o=500Hz$
Apparent frequency = $f_o[v+v_o/v-v_s]$
$=500[350+25/350-25]$
$=577Hz$

Question 74

A traffic policeman sounds a whistle to stop a car-driver approaching towards him. The car-driver does not stop and takes the plea in court that because of the Doppler shift, the frequency of the whistle reaching him might have gone beyond the audible limit of 25 kHz and he did not hear it. Experiments showed that the whistle emits a sound with frequency closed to 16 kHz. Assuming that the claim of the driver is true, how fast was he driving the car? Take the speed of sound in air to be 330 m s^{-1}. Is this speed practical with today's technology?

Solution 74

O → $V_o = ???$ S $f_o = 16 KHz$

$f_{app} = 20KHz$ (rest)

$f_o=16Hz$
$f_{app}=20KHz$
$f_{app}=f_o[\frac{v+v_o}{v}]$
$20\times10^3=16\times 10^3\times [\frac{330+v_o}{330}]$
$V_o=330/4$ m/s
$=330/4\times18/5=297$Kmph
This speed is not practically attainable for ordinary cars

Question 75

A car moving at 108 km h^{-1} finds another car in front it going in the same direction at 72 km h^{-1}. The first car sounds a horn that has a dominant frequency of 800 Hz. What will be the apparent frequency heard by the driver in the front car? Speed of sound in air = 330 m s^{-1}.

Solution 75

S → $108\times\frac{5}{18} = 30 m/s$ O → $72\times\frac{5}{18} = 20 m/s$

$f_o = 800Hz$

$f_o=800Hz$
$f_{app}=f_o[(v-v_o)/(v-v_s)]$

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f_{app}=800[(330-20)/(330-30)]≈827Hz

Question 76

Two submarines are approaching each other in a calm sea. The first submarine travels at a speed of 36 km h^{-1} and the other at 54 km h^{-1} relative to the water. The first submarine sends a sound signal (sound waves in water are also called *sonar*) at a frequency of 2000 Hz. (a) At what frequency is this signal received from the second submarine. At what frequency is this signal received by the first submarine. Take the speed of the sound wave in water to be 1500 m s^{-1}.

Solution 76

(a)

Frequency received by second submarine

$F_{app}=f_o[(v+v_o)/(v-v_s)]$

=2000[(1500+15)/(1500-10)]=2034hz

(b)frequency heard by first submarine

F'_{app}=2034[(1500+10)/(1500-15)]

=2068Hz

Question 77

A small source of sound oscillates in simple harmonic motion with an amplitude of 17 cm. A detector is placed along the line of motion of the source. The source emits a sound of frequency 800 Hz which travels at a speed of 340 m s^{-1}. If the width of the frequency band detected by the detector is 8 Hz, find the time period of the source.

Solution 77

Maximum and minimum frequency will be observed at mean position P and Q respectively as velocity of source will be maximum

$f_{max}=f_o[\frac{v}{v-vs}]$; $f_{min}=f_o[\frac{v}{v+vs}]$

$f_{max}-f_{min}=8$

$f_o[\frac{v}{v-vs}] - f_o[\frac{v}{v+vs}] = 8$

$2f_o v v_s/v^2-v_s^2=8$

$\frac{2x800x340xvs}{(340)2-vs2}$

V_s=1.7m/s

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Aw=1.7

$W=\frac{1.7}{17x10^{-2}}=10$

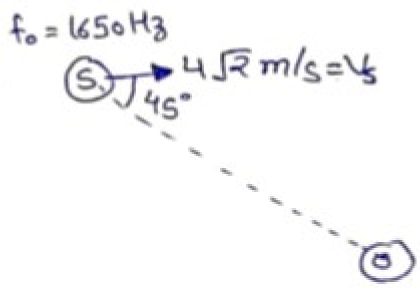
$T=2\pi/w=2\pi/10$

T=0.63sec

Question 78

A boy riding on his bike is going towards east at a speed of 4√2 m s^{-1}. At a certain point he produces a sound pulse of frequency 1650 Hz that travels in air at a speed of 334 m s^{-1}. A second boy stands on the ground 45° south of east from his. Find the frequency of the pulse as received by the second boy.

Solution 78



f_o=1650Hz

$f_{app}=f_o\left[\frac{v}{v-v_s\cos45}\right]$

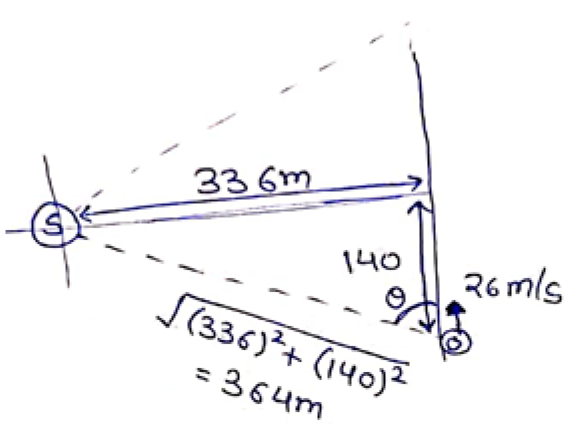
$=1650\left[\frac{334}{334-4\sqrt{2}*\frac{1}{\sqrt{2}}}\right]$

f_{app}=1670Hz

Question 79

A sound source, fixed at the origin, is continuously emitting sound at a frequency of 660 Hz. The sound travels in air at a speed of 330 m s^{-1}. A listener is moving along the lien *x* = 336 m at a constant speed of 26 m s^{-1}. Find the frequency of the sound as observed by the listener when he is (a) at *y* = - 140 m, (b) at y = 0 and (c) at y = 140 m.

Solution 79



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(a)

$f_{app}=f_o\left[\frac{v+v_o\cos\theta}{v}\right]$

$=660\left[\frac{330+26*\frac{140}{364}}{330}\right]$

$=680Hz$

(b)

No. relative velocity along line joining source and observer

So, no. Doppler effect $f_{app}=660Hz$

(c)

$f_{app}=f_o\left[\frac{v-v_o\cos\theta}{v}\right]$

$=660\left[\frac{330-26*\frac{140}{364}}{330}\right]$

$=640Hz$

Question 80

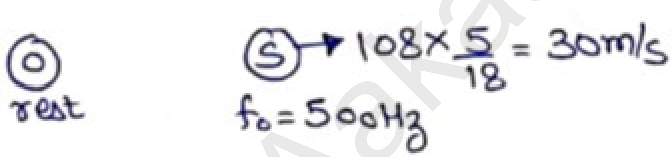
A train running at 108 km h^{-1} towards east whistles at a dominant frequency of 500 Hz. Speed of sound in air is 340 m/s. What frequency will a passenger sitting near the open window hear? (b) What frequency will a person standing near the track hear whom the train has just passed? (c) A wind starts blowing towards east at a speed of 36 km h^{-1}. Calculate the frequencies heard by the passenger in the train and by the person standing near the track.

Solution 80

(a)

No relative motion between passenger and train Hence $f_{obs}=500Hz$

(b)



$f_o=500Hz$

$f_{app}=f_o\left[\frac{v}{v+v_s}\right]$

$=500\left[\frac{340}{340+30}\right]$ = 459Hz

(c)

When wind starts blowing,

Frequency heard by passenger is unaffected as no relative motion,

Frequency heard by person standing near track

$F_{app}=f_o\left[\frac{(v+v_W)-0}{(v+v_W)+v_S}\right]$

$=500\left[\frac{(340+10)}{(340+10)+30}\right]$

$=458Hz$

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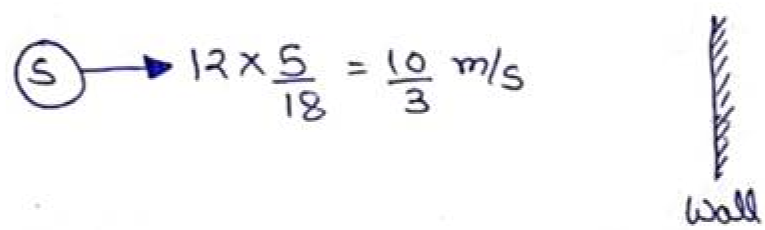
Question 81

A boy riding on a bicycle going at 12 km h^{-1} towards a vertical wall whistles at his dog on the ground. If the frequency of the whistle is 1600 Hz and the speed of sound in air is 330 m s^{-1}, find (a) the frequency of the whistle as received by the wall (b) the frequency of the reflected whistle as received by the boy.

Solution 81



(a)

Frequency received by wall

$f_{app}=f_o\left[\frac{(v-0)}{(v-v_S)}\right]$

$=1600\left[\frac{(330)}{\left(330-\frac{10}{3}\right)}\right]$

=1616Hz

(b)

Reflected frequency received by boy = $f\left[\frac{(v+v_O)}{(v)}\right]$

$=1616\left[\frac{\left(330+\frac{10}{3}\right)}{(330)}\right]$

=1632Hz

Question 82

A person standing on a road sends a sound signal to the driver of a car going away from him at a speed of 72 km h^{-1}. The signal travelling at 330 m s^{-1} in air and having a frequency of 1600 Hz gets reflected from the body of the car and returns. Find the frequency of the reflected signal as heard by the person.

Solution 82

Frequency received by car

$F_{app}=f_o\left[\frac{(v-v_C)}{(v)}\right]$

$=1600\left[\frac{\left(330-72*\frac{5}{18}\right)}{330}\right]$

=1503Hz

Reflected frequency received by boy

$f'_{app}=f_{app}\left[\frac{v}{(v+v_S)}\right]$

$=1503\left[\frac{330}{(330+20)}\right]$

=1417Hz

Question 83

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A car moves with a speed of 54 km h^{-1} towards a cliff. The horn of the car emits sound of frequency 400 Hz at a speed of 335 m s^{-1}. (a) Find the wavelength of the sound emitted by the horn in front of the car. (b) Find the wavelength of the wave reflected from the cliff. (c) What frequency does a person sitting in the car hear for the reflected sound wave? (d) How many beats does he hear in 10 seconds between the sound coming directly from the horn and that coming after the reflection?

Solution 83

Velocity of car = $54\times\frac{5}{18}$ = 15m/s

(a)

Net velocity of wave in front of the car = $v_{air}-v_{car}$=335-15=320m/s

V=f×λ

320=400×λ

Λ=0.8m or λ=80cm

(b)

Frequency received by the diff

$f_{diff}=f_o[\frac{v}{(v+v_{car})}]$

$=400[\frac{335}{(335-15)}]$

=418.75Hz

V=fxλ

335=418.75×λ

λ=80cm

(c)

Frequency of the reflected sound wave heard by the person sitting in the car

$f_{app}=f_{cliff}[\frac{v+v_o}{(v)}]$

$=418.75(\frac{335+15}{335})$

f_{app}=437Hz

(d)

Beat frequency =437-400

=37

But a human-being can hear maximum of 10 beats in one second

So, he will not hear beats but continuous sound.

Question 84

An operator sitting in his base camp sends a sound signal of frequency 400 Hz. The signal is reflected back from a car moving towards him. The frequency of the reflected sound is found to be 410 Hz. Find the speed of the car. Speed of sound in air = 324 m s^{-1}.

Solution 84

Frequency of sound heard at car

$f=f_o[\frac{v+v_o}{(v)}]$

$f=400[\frac{324+v_{car}}{324}]$

Frequency of the reflected sound by observer

$f'=f[\frac{v}{v-v_s}]$

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$$410=400\left[\frac{324+v_{car}}{324}\right]\left[\frac{324}{324-v_{car}}\right]$$

$V_{car}=4 m/s$

Question 85

Figure shows a source of sound moving along *X*-axis at a speed of 22 m s^{-1} continuously emitting a sound of frequency 2.0 kHz which travels in air at a speed of 330 m s^{-1}. A listener *Q* stands on the *Y*-axis at a distance of 330 m from the origin. At *t* = 0, the sources crosses the origin *P*. (a) When does the sound emitted from the source at *P* reach the listener *Q*? (b) What will be the frequency heard by the listener at this instant? (c) Where will the source be at this instant?

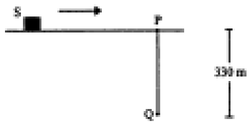


Figure 16-E12

Solution 85

(a)

Speed=distance/time

330=330/t

t=1sec

(b)

Frequency of sound heard by listener = 2khz

Since, no velocity is along line joining source and observer hence, no Doppler effect

(c)

For source

$V_s=d/t$

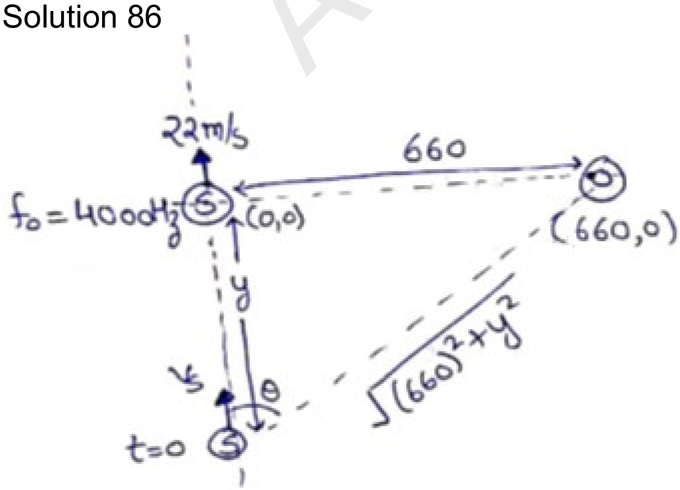
d=22×1

d=22m away from P on x-axis

Question 86

A source emitting sound at frequency 4000 Hz, is moving along the *Y*-axis with a speed of 22 m s^{-1}. A listener is situated on the ground at the position (660 m, 0). Find the frequency of the sound received by the listener at the instant the source crosses the origin. Speed of sound in air = 330 m s^{-1}.

Solution 86



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At t=0, let the source be at a distance of y from origin. Now, time taken by source to reach origin is same as time taken by sound to reach observer

$y/22=\sqrt{\frac{(660)^2+y^2}{330}}$

6=660/√224

Frequency heard by the observer

$f_{app}=f_o[\frac{v}{v-v_s cos\theta}]$

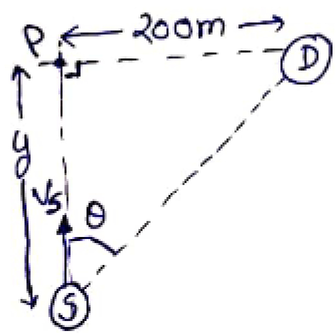
$=4000[\frac{330}{330-22\times\frac{y}{\sqrt{(660)^2+y^2}}}]$

$f_{app}\approx 4018Hz$

Question 87

A source of sound emitting a 1200 Hz note travels along a straight line at a speed of 170 m s^{-1}. A detector is placed at a distance 200 m from the line of motion of the source. (a) Find the frequency of sound receive by the detector at the instant when the source gets closest to it. (b) Find the distance between the source and the detector at the instant in detects the frequency 1200 Hz. Velocity of sound in air = 340 m s^{-1}.

Solution 87



(a)

Time taken by source to reach intersection point is equal to the time taken by sound to reach detector

$y/170 = \frac{\sqrt{(200)^2+y^2}}{340}$

y=200/√3

Frequency of sound heard by detector

$f_{app}=f_o[\frac{v-0}{v-v_s cos\theta}]$

$=1200[\frac{340}{340-170*cos60}$

=1600Hz

(b)

Detector will detect frequency of 1200Hz when sound was produced at intersection point.

Time to by sound to reach detector

T=200/340

In this time source moves by a distance of

V=d/t

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$D = 170 \times \frac{200}{340} = 100m$

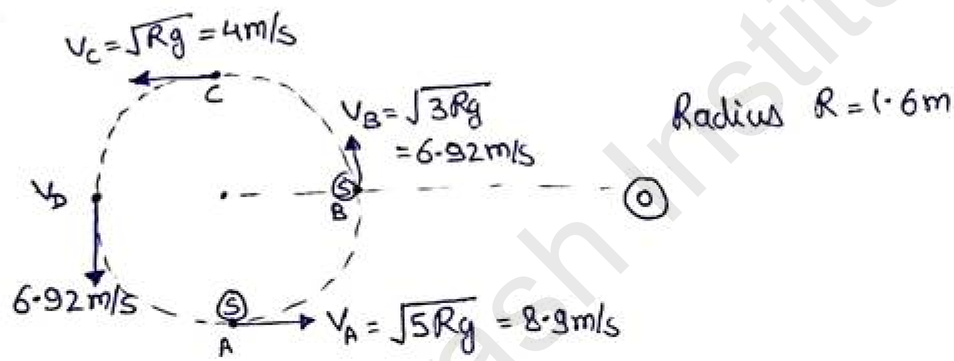
So, source-detector.distance = $\sqrt{(200)^2 + (100)^2}$
=224m

Question 88

A small source of sound *S* of frequency 500 Hz is attached to the end of a light string and is whirled in a vertical circle of radius 1.6 m. The string just remains tight when the source is at the highest point. (a) An observer is located in the same vertical plane at a large distance and at the same height as the centre of the circle. The speed of sound in air = 330 m s^{-1} and g = 10 m s^{-2}. Find the maximum frequency heard by the observer. (b) An observer is situated at a large distance vertically above the centre of the circle. Find the frequency heard by the observer corresponding to the sound emitted by the source when it is at the same height as the centre.

Figure 16-E13

Solution 88



(a)
Maximum frequency observed when maximum velocity of source is towards observer

$f_{app)A} = f_o\left[\frac{v}{v - v_s}\right]$

$= 500\left[\frac{330}{330 - 8.9}\right]$

$f_{app)A} \approx 514Hz$

(b)

$f_{app)D} = f_o\left[\frac{v}{v + v_s}\right]$

$= 500\left[\frac{330}{330 + 6.92}\right]$

=490Hz

$F_{app)B} = f_o\left[\frac{v}{v - v_s}\right]$

$= 500\left[\frac{330}{330 - 6.92}\right]$

=511Hz

Question 89

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A source emitting a sound of frequency *f* is placed at a large distance from an observer. The source starts moving towards the observer with a uniform acceleration *a*. Find the frequency heard by the observer corresponding to the wave emitted just after the source starts. The speed of sound in the medium is *v*.

Solution 89

Let the distance between the source and observer is x at t=0

Time taken for 1st pulse to reach observer $t_1=x/v$

II_{nd} pulse starts after T(where T=1/f)

and it travels a distance of ($x-\frac{1}{2}aT^2$)

So, $t_2=T+\frac{(x-\frac{1}{2}aT^2)}{v}$

Now, $t_2-t_1=(T+\frac{x}{v}-\frac{1}{2}\frac{aT^2}{v})-(\frac{x}{v})$

$t_2-t_1=T-\frac{1aT^2}{2v}$

Putting T=1/f

$t_2-t_1=(2fv-a)/(2fv^2)$

Beat frequency = $1/t_2-t_1=2fv^2/2fv-a$

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