11th Physics 8 : Sound 2017-18

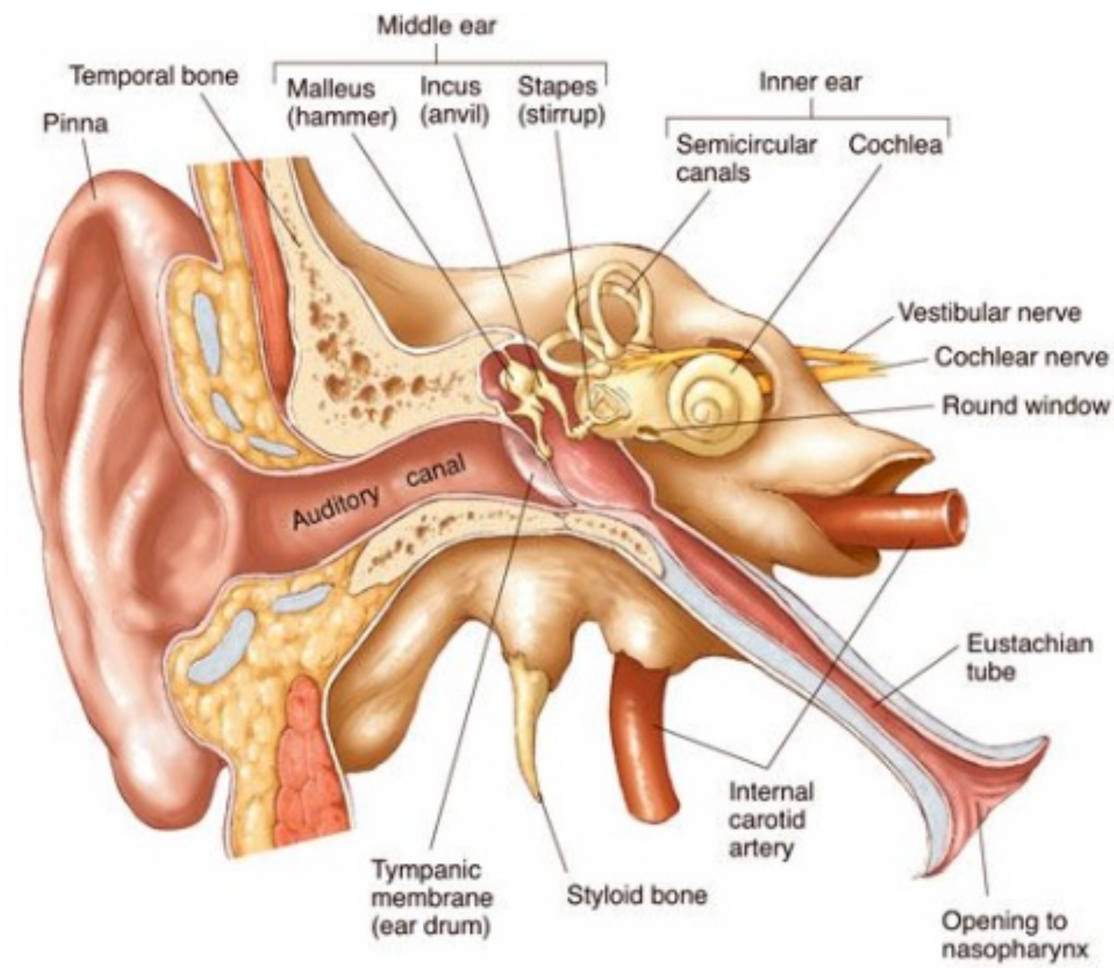
(Pearson pp 492-527)

V=331.5 + 0.6t (t is temperature [℃])

1. Sound Wave

[Q1] The first thing we do when we come into this world is making a sound. Explain the physics on how a sound propagates through the air.

We produce sound by oscillating (A)________________, The sound generated is a wave propagating through (B)__________as a medium. When (A) oscillate, the air contacting (A) also oscillates and this generates the part of a wave with lower (C)____________ (rarefaction) and the part of a wave with higher (C)____________ (compression). Sound propagates by repeating rarefaction and compression. In a sound wave, the direction of (D)____________ of air molecules is parallel to the direction of the (E)____________of the wave. A sound wave, therefore, is a (F)________________ wave. Air molecules do not travel with sound but just (G)__________ . When a sound wave arrives at ears, it oscillates (H)____________. The oscillation of (H) generates the oscillation of an incus and lymph inside a cochiea. The oscillation is perceived by acoustic nerves and propagated to the brain, that finally recognizes sound.



[Q1]　5.0 seconds after a brilliant flash of lightning, thunder shakes the house.　How far was the lightning?　The temperature was 20℃.

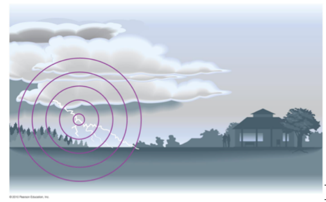


Fig.1

[Q2] You drop a stone from rest into a well that is 7.35 m deep. How long does it take before you hear the splash?　It is 20.0℃.

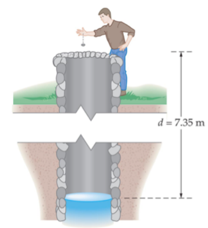
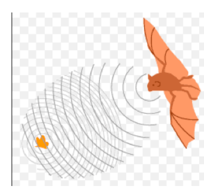


Fig. 2

[Q3] Humans can hear sounds between 20 Hz on the low-frequency end and 20,000 Hz on the high-frequency end. (a) Find the wavelength range of sounds humans can hear. (b) What do you call the sounds more than 20,000 Hz and less than 20 Hz?

[Q4] Bats use ultrasound of 100 ~ 200 kHz to detect their prey. Explain why do they use such high frequencies.



2　　Interference of Sound

[Q6] In Fig. 6, two speakers separated by a distance of 3.00 m emit sound of 343 Hz, in phase with one another, at 20.0℃. You stand at the location 6.00 m far from the middle point between the speakers and hear a constructive sound.　As you walk in front of the speakers, you hear constructive and destructive sounds repeatedly.　Find the approximate distance between the first and second places giving constructive sounds.

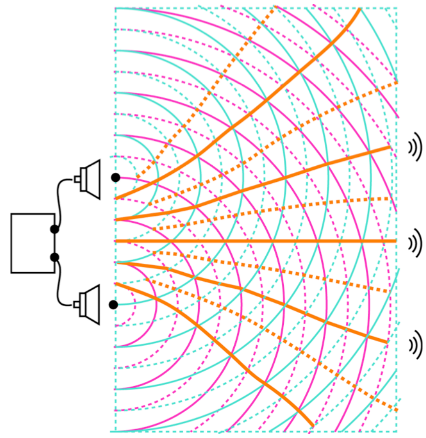


Fig.6

[Q7] Two speakers, A and B, connected to one oscillator are separated by a distance of 3.0 m and emit sound of frequency 1000 Hz.　Is the sound at the location 6.7 m from A and 5.0 m from B constructive or destructive?　How about another sound of 1500 Hz?　Assume the speed of sound as 340 m/s.

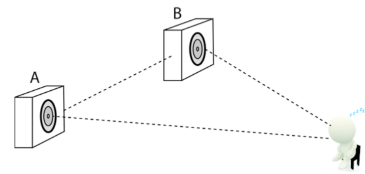


Fig.7

[Q8] In the Quincke tube shown in Fig. 8, a sound continuously emits at the opening P as the part B is slowly sliding and being pulled out of the part A.　At another opening Q, destructive sounds are heard at every 8.5 cm sliding.　(a) Find the wavelength of the sound.　(b) Find the speed of sound assuming the frequency of the sound is 2000 Hz.

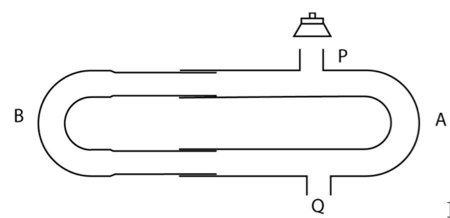


Fig. 8

[Q9] Two speakers separated by a distance of 3.0 m emit sound of frequency 340 Hz.　The two sounds are in phase with one another.　Interference is investigated using a microphone.　Assume the speed of sound as 340 m/s.　(a) Find the conditions to give constructive sound at a location on the line between A and B.　(b) How many points are there between A and B except A and B?

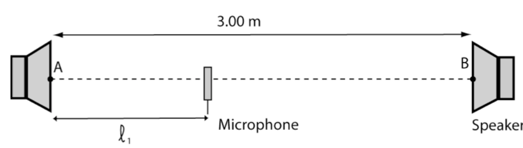


Fig.9

3 Beats

[Q10] In Fig. 10, A and B are sounds of frequencies 100 Hz and 110 Hz, respectively. Illustrate the wave that is obtained by superposing the two sounds, A +B.

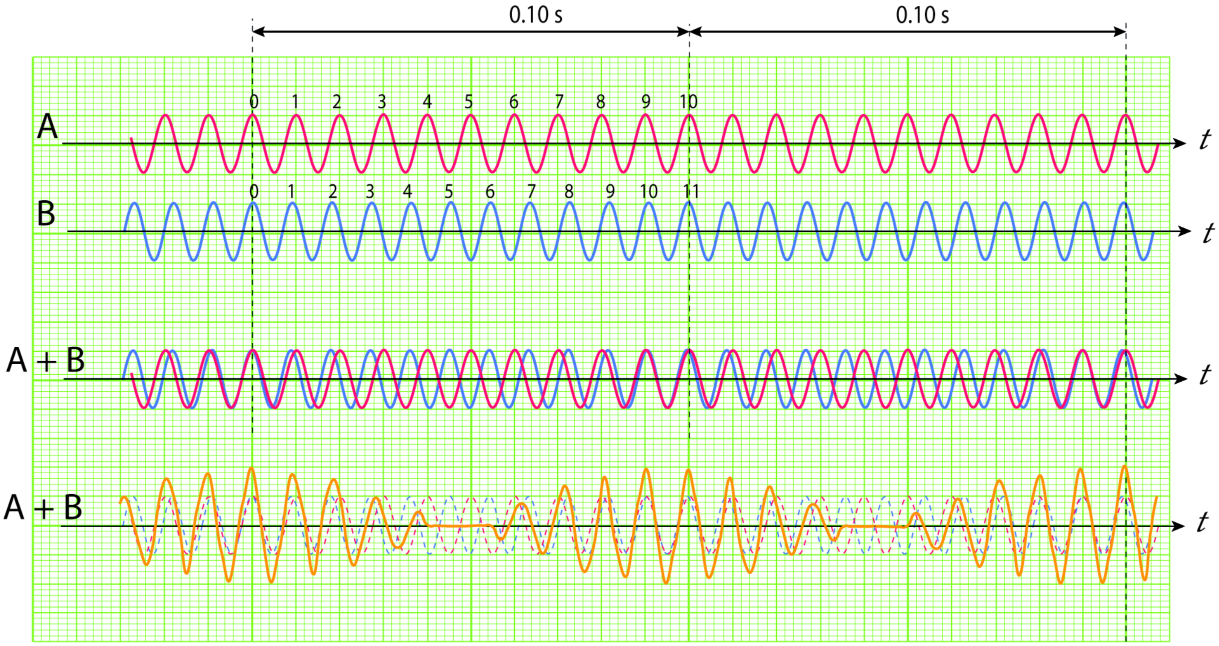


Fig. 10

$y_1 = A\cos(2\pi f_1 t), \quad y_2 = A\cos(2\pi f_2 t)$

$y = A\cos(2\pi f_1 t) + A\cos(2\pi f_2 t)$

$= 2A\cos\{\pi(f_1 + f_2)\}\cos\{\pi(f_1 - f_2)\}$

Beats

$\cos(\alpha + \beta) = \cos\alpha\cos\beta - \sin\alpha\sin\beta$

$\cos(\alpha - \beta) = \cos\alpha\cos\beta + \sin\alpha\sin\beta$

$\cos(\alpha + \beta) + \cos(\alpha - \beta) = 2\cos\alpha\cos\beta$

$\theta = \alpha + \beta, \quad \varphi = \alpha - \beta$

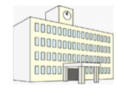
$\cos\theta + \cos\varphi = 2\cos\left(\frac{\theta + \varphi}{2}\right)\cos\left(\frac{\theta - \varphi}{2}\right)$

[Q11] Two musicians are comparing their clarinets. The first clarinet produces a tone that is known to be 441 Hz. When the two clarinets play together they produce eight beats every 2.00 seconds. If the second clarinet produces a higher pitched tone than the first clarinet, what is the second clarinet's frequency?

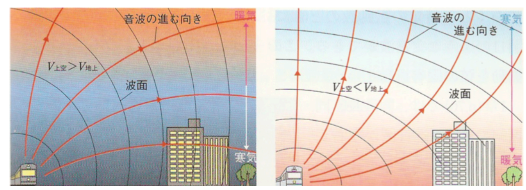
Fig.11

4 Reflection, Refraction and Diffraction

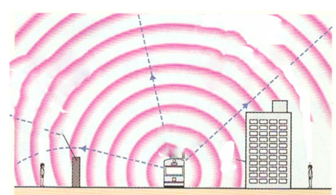
[Q13] As you beat a drum at a place 70m from the wall of the school building, you are listening to the direct sound from the drum and the reflected sound from the wall at the same time. You beat the drum slowly in the beginning and gradually decrease the period. Now you hear the reflected and the direct ones at the same time when you beat 17 times per 7 seconds. Find the speed of sound.



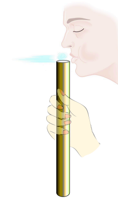
[Q14] It is said that we can hear the sound from remote places at clear night. Explain why.

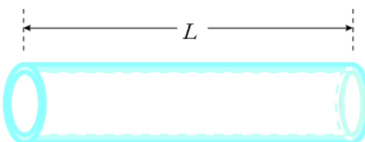
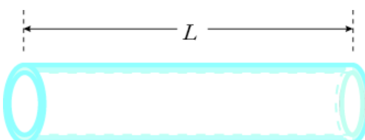
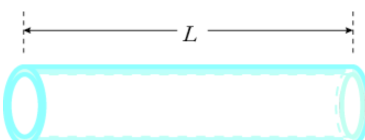
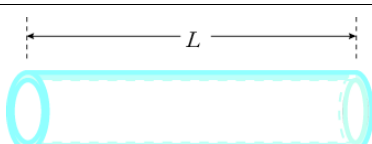
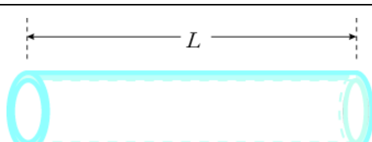
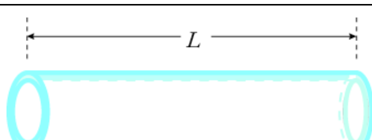


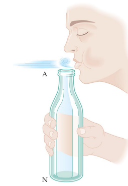
[Q14'] You can hear sounds at the backside of a wall but it is hard to hear sounds at the backside of a tall building. Explain this in terms of diffraction.



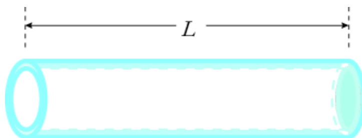
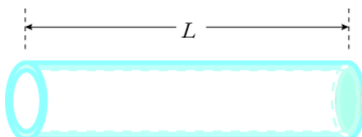
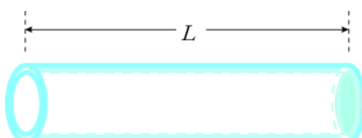
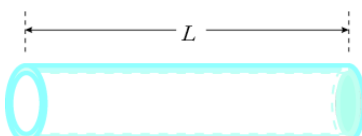
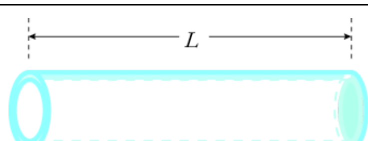
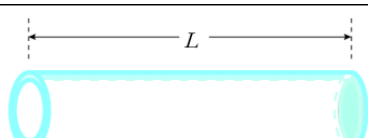
5. Standing Waves in a Column that is open at Both Ends



	Shape of Standing Wave	Nodes	Number of $\frac{\lambda}{4}$	Wavelength λ [m]	Frequency f [Hz]
Fundamental	 [L = 1.00 m]			[ ]	[ ]
2nd Harmonic	 [L = 1.00 m]			[ ]	[ ]
3rd Harmonic	 [L = 1.00 m]			[ ]	[ ]
4th Harmonic	 [L = 1.00 m]			[ ]	[ ]
5th Harmonic	 [L = 1.00 m]			[ ]	[ ]
mth Harmonic	 [L = 1.00 m]			[ ]	[ ]



6. Standing Waves in a Column that is open at One-End

	Shape of Standing Wave	Nodes	Number of $\frac{\lambda}{4}$	Wavelength λ [m]	Frequency f [Hz]
Fundamental	 [L = 1.00 m]			[ ]	[ ]
3rd Harmonic	 [L = 1.00 m]			[ ]	[ ]
5th Harmonic	 [L = 1.00 m]			[ ]	[ ]
7th Harmonic	 [L = 1.00 m]			[ ]	[ ]
9th Harmonic	 [L = 1.00 m]			[ ]	[ ]
2m-1th Harmonic	 [L = 1.00 m]			[ ]	[ ]

[Q19] An empty soda pop bottle is to be used as a musical instrument in a band.　In order to be tuned up properly, the fundamental frequency of the bottle must be 440.0 Hz.　(a) If the bottle is 26.0 cm tall, how high should it be filled with water to produce the desired frequency?　Treat the bottle as a pipe that is closed at one end (the surface of the water) and open at the other end.　(b) What is the frequency of the next higher harmonic for this bottle?

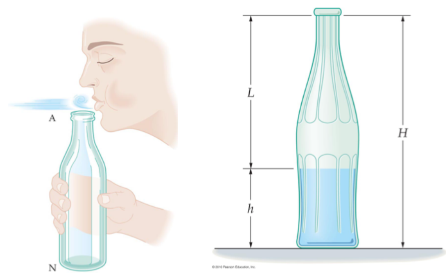


Fig.20

[Q20] (a) Find the wavelength and frequency of the fundamental harmonic for a column of air that are open at both ends, assuming the speed of sound as 340 m/s.　(b) Next find the fundamental frequency when this pipe is used as a pipe closed at one end.

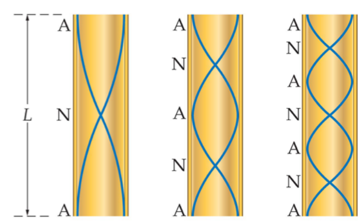


Fig. 20-a

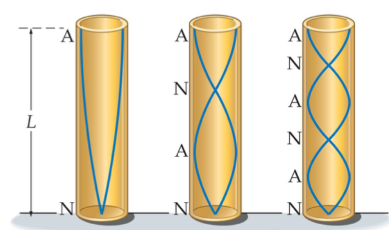
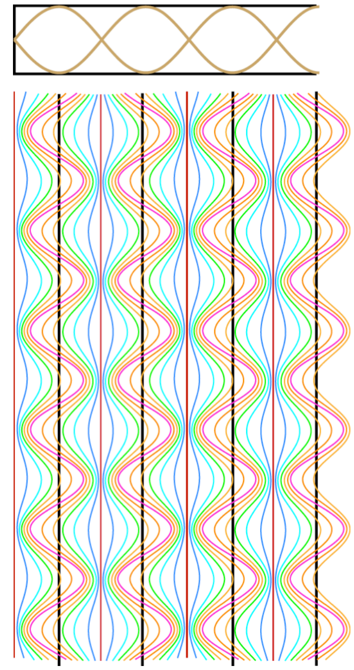


Fig. 20-b

7. Density Changes in the Standing Waves in a Column



[Q21] Fig. 21 shows a change of a standing wave inside a pipe that is open at one end. The vibration of air is indicated by its density as well as by the corresponding transverse expression. As shown in the transverse expression, the point a is a node whereas the point b is an antinode. Explain how density changes at nodes and antinodes.

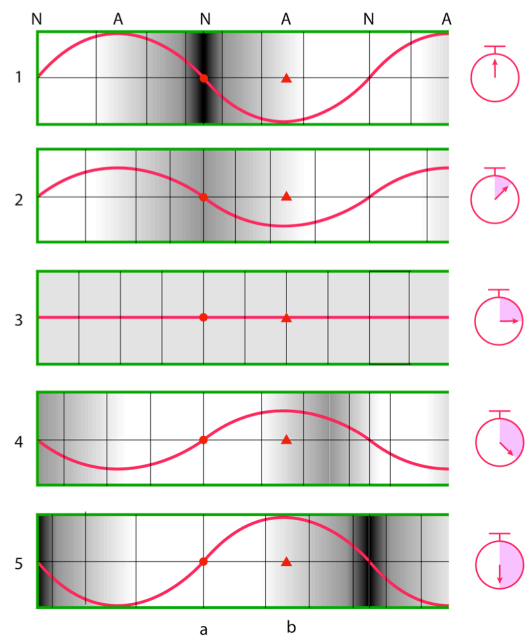
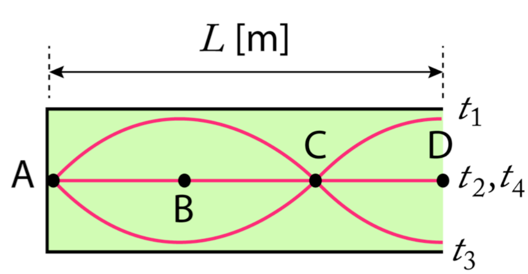


Fig. 2

[Q22] A standing wave is formed in a pipe that is open at one end. Fig. 22 shows the transverse-wave like expression of the wave at times, t_1, t_2, t_3, t_4 ($t_1 < t_2 < t_3 < t_4$), where the displacement to the right is drawn to the upper side. (a) Find the place where the displacement of air shows the maximum. (b) Find the place and time where the displacement to the right is largest. (c) Find the place that shows the largest change in density during one period.



8 . Sympathetic Vibration and Resonance

[Q23] You are doing the experiment of resonance tube using a tuning fork with an unknown frequency. As you lower the water level, the first resonance was observed at the place of 22.8 cm from the top of the tube. The second resonance was observed at the place of 70.7 cm from the top of the tube. The temperature inside the tube was 19.2℃.

(1) Find the frequency of the tuning fork. The temperature dependence of sound speed is calculated by the equation: V=331.5 + 0.6t (t is temperature [℃])

(2) Find the place of the third resonance.

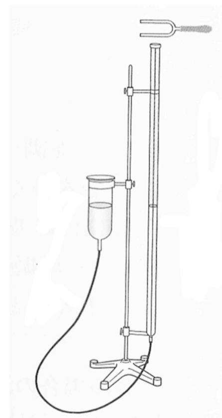


Fig. 23-a

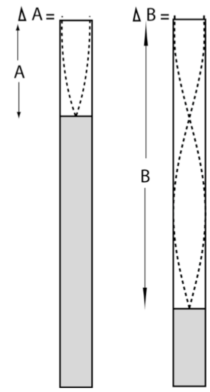
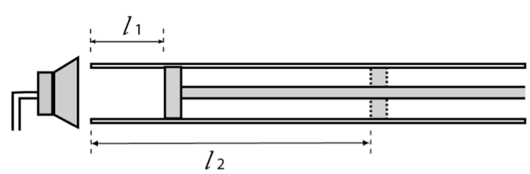


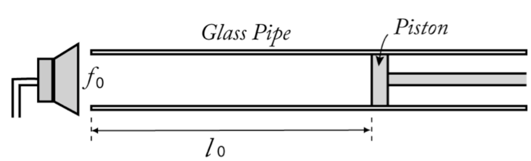
Fig. 23-b

[Q24] A sound of 500 Hz is emitted as a piston is being pulled to the right. The first and second resonances are observed at $l1$ = 15.8 cm and $l2$ = 50.2 cm, respectively. (a) Find the wavelength. (b) Find the speed of sound inside the pipe. (c) Find the place that the density change is the biggest when the piston is placed at $l1$. (d) When the piston is placed at $l1$, the frequency is increased. Find the next resonance frequency.



[Q25] In the figure, the sound source emits a sound wave of the frequency f_0 as the piston is moving. The resonance is observed at l_0 and 9/7 l_0. (a) Find the wavelength of the sound using l_0.

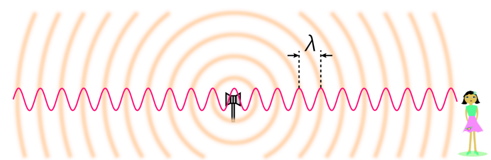
(b) If the location of the piston is kept at l_0 and the frequency of the sound is increased, and then another resonance is observed at f. By what factor is f' with respect to f_0.



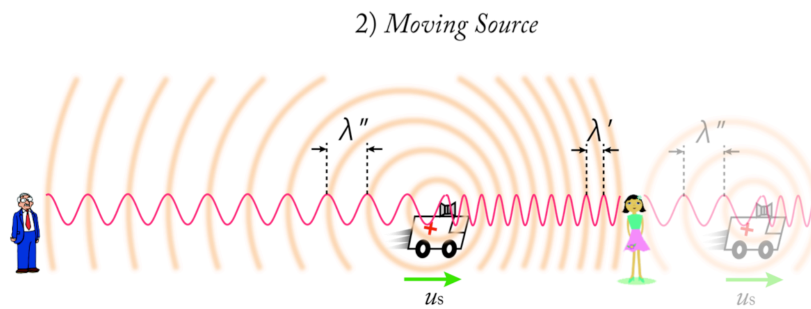
9. Doppler Effect

V: Speed of sound
f, λ : Frequency and wavelength of source 音
f', λ' : Frequency and wavelength of observed sound

1) 

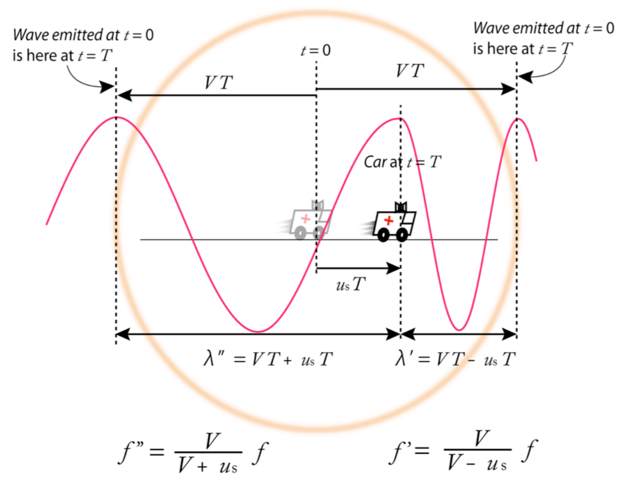


2) <u>Moving Source and Stationary Observer</u>



You hear the high pitch of the approaching ambulance, and notice that its pitch drops suddenly as the ambulance passes you and recedes from you. This is called the Doppler effect.

The speed of sound is determined by the medium in which it is traveling, and is the same for a moving source.



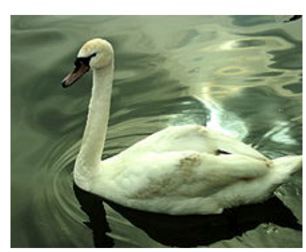
Therefore, the approaching sound is compressed resulting in the sound of shorter wavelength, higher frequency, higher pitch.

$$f' = \frac{V}{\lambda'} = \frac{V}{VT - u_s T}$$

$$= \frac{V}{(V - u_s)T} = \frac{V}{V - u_s} f$$

The receding sound, conversely, is stretched resulting in the sound of longer wavelength, lower frequency, lower pitch. 遠ざかる音は、逆に引き伸ばされて波長が長く、周波数は小さく、低い音になる。

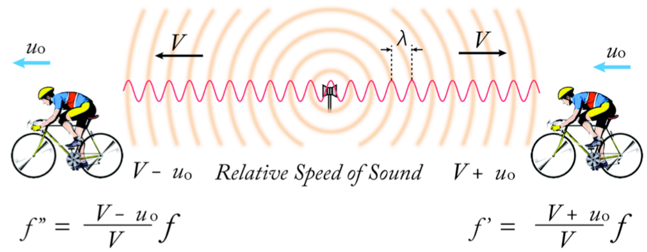
$$f'' = \frac{V}{\lambda''} = \frac{V}{VT + u_s T} = \frac{V}{(V + u_s)T} = \frac{V}{V + u_s} f$$



Doppler effect of water flow around a swan

3)　Moving Observer and Stationary Source

3) *Moving Observer*



A similar frequency change is observed for a moving observer and a stationary source.

◦

For an observer moving at a speed of u_o toward a source, the speed of sound the observer hears appears higher as $V + u_0$ though the speed of sound relative to the air is always the same.　The wavelength does not change.　Then,

$f' = (V + u_0)/\lambda, \quad f = V/\lambda$

which yields,

$$f' = \frac{V + u_0}{V} f$$

To the observer, then, the sound has a higher frequency, f', that is higher than the frequency of the source, f.

Oppositely, if the observer is moving away from the source the sound has a lower frequency, f'', than the source frequency, f.

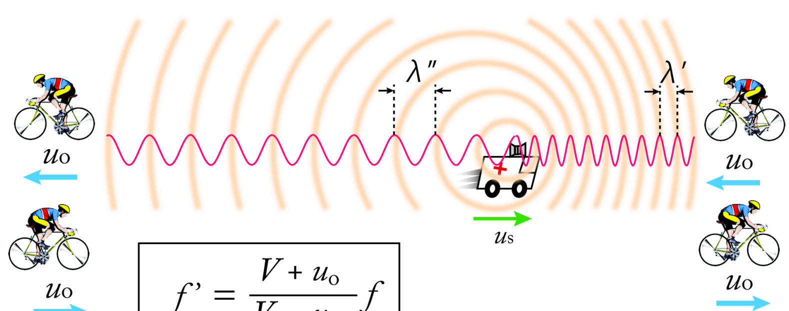
4)　Moving Observer and Moving Source

The results derived above can be combined to give the Doppler effect for the situations in which both observer and source move.　Letting u_s be the speed of the source, and u_o be the speed of the observer, we have the equation shown at the right.　In the equation,

$u_o, u_s > 0$: the observer (source) moves in the direction of source (observer).

$u_o, u_s < 0$: the observer (source) moves in the opposite direction of source (observer).

4) *Moving Source and Observer*



$$f' = \frac{V + u_o}{V - u_s} f$$

u_o, $u_s > 0$　Observer (Source) moves in the direction of Source (Observer)

u_o, $u_s < 0$　Observer (Source) moves in the opposite direction of Source (Observer)

[Q30] One of the most common physical phenomena involving sound is the change in pitch of a train whistle or an ambulance siren as the vehicles moves past us. Explain your experience.

[Q31] A train moves past an observer at a speed of 20 m/s emitting a whistle of 640 Hz. The speed of sound is 340 m/s.

(a) Find the frequency and wavelength of the whistle that the observer hear as the train is approaching.

(b) Find the frequency of the whistle that the observer hear as the train is receding.

(c) Which is the correct graph in Fig. 2 expressing the change of frequency the observer hears.

(d) Find the frequency of the whistle that the observer hear as the train is approaching when wind is blowing in the moving direction of the train.

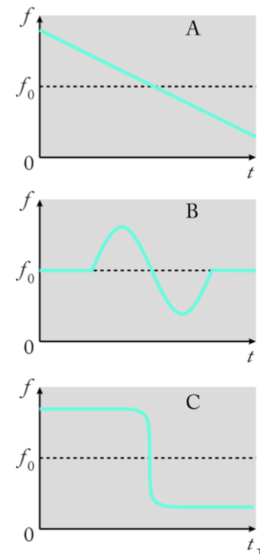


Fig. 2

[Q32] A street musician sounds the A string of his violin, producing a tone of 440 Hz. What frequency does a bicyclist hear as he (a) approaches and (b) recedes from the musician with a speed of 11.0 m/s?

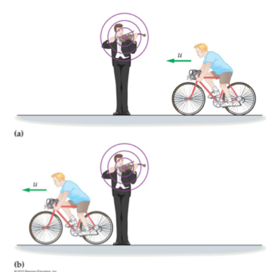


Fig. 3

[Q33] A train sounds its whistle as it approaches a tunnel in a cliff. The whistle produces a tone of 650.0 Hz, and the train travels with a speed of 21.2 m/s. (a) Find the frequency heard by an observer standing near the tunnel entrance. (b) The sound from the whistle reflects from the cliff back to the engineer in the train. What frequency does the engineer hear?

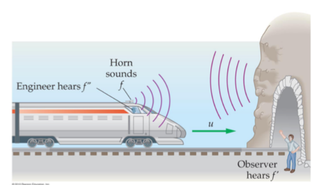
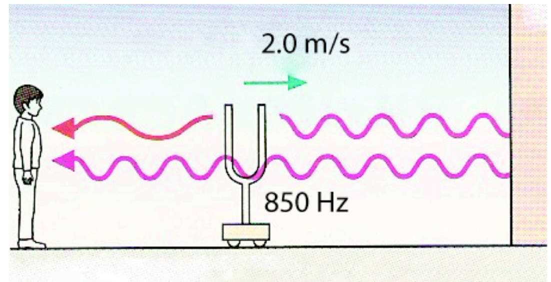
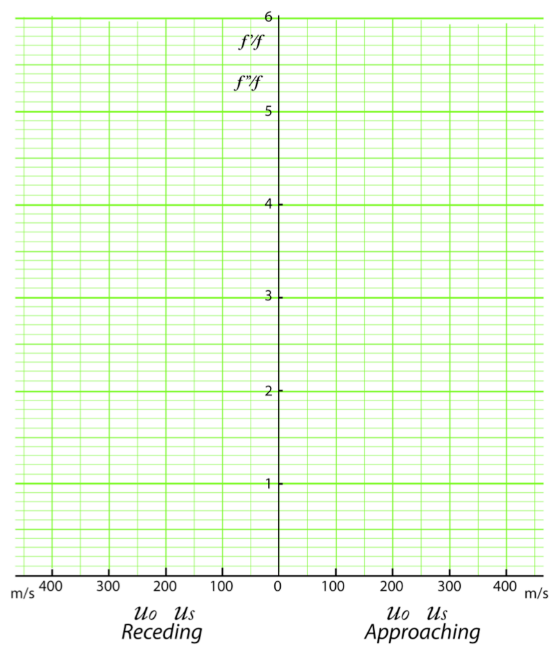


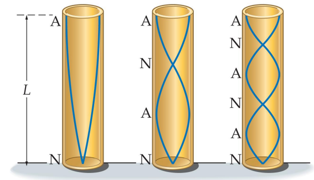
Fig. 4

[Q34] A tune fork on a cart is approaching a wall at a speed of 2.0 m/s.　The frequency is 850 Hz.　The observer hears beats that is produced by the direct sound from the tune fork and reflected sound from the wall. Find how many beats per second the observer hears assuming the speed of sound is 340 m/s.



[Q36] Draw a curve showing the relation between the speed of a source, and the ratio of the perceived frequency and the source frequency, f'/f.　Also draw a curve showing the relation between the speed of an observer, and the ratio of the perceived frequency and the source frequency, f''/f.　Let the speed of sound be 350 m/s.





1. Sound　音
   Sound Waves　音波
   Sound Body　発音体
   Sound Source　音源
   Speed of Sound　音速
   Three Components of Sound　音の３要素
   Sound Intensity　音の強さ
   Pitch　音の高さ
   Tone　音色

2. Interference　干渉
   Beats　うなり
   Reflection　反射
   Refraction　屈折
   Diffraction　回折

3. Waves on a String　弦の波
   Standing Waves　定常波
   Nodes, Antinodes　節、腹
   Natural Vibration　固有振動
   Frequencies of Harmonics　固有振動数
   Fundamental Mode　基本振動
   Overtone Mode　倍振動
   The Second Harmonic　倍振動数

4. Vibrating Columns of Air　気柱の振動
   Closed Pipe　閉管
   Open Pipe　開管

5. Pendulum　振り子
   Sympathetic Vibration　共振
   Resonance　共鳴
   Tune Forks　おんさ

7. Doppler Effect　ドップラー効果

Speed of Sound　$V = 331.5 + 0.6t$

$V = f\lambda$

Beat　$f = |f_1 - f_2|$

String:

$\frac{\lambda_m}{2} = \frac{L}{m}$ (m: Number of <u>Antinodes</u>), $f_m = \frac{v}{\lambda_m}$

Fundamental　$\lambda_1 = 2L$, $f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$

m*th* harmonics　$\lambda_m = \frac{2L}{m}$　($m = 1, 2, 3 \cdots$)

$f_m = m \cdot \frac{v}{2L}$　($m = 1, 2, 3 \cdots$)

Closed Pipe:

$\frac{\lambda_m}{4} = \frac{L}{2m-1}$ (m: Number of <u>Nodes</u>), $f_m = \frac{V}{\lambda_m}$

$f_m = (2m-1) \times \frac{V}{4L}$　($m = 1, 2, 3 \cdots$)

Open Pipe:

$\frac{\lambda_m}{4} = \frac{L}{2m}$ (m: Number of <u>Nodes</u>),　$f_m = \frac{V}{\lambda_m}$

$f_m = m \cdot \frac{V}{2L}$　($m = 1, 2, 3 \cdots$)

Resonance in Pipe　$f = \frac{V}{2(L_2 - L_1)}$

Doppler Effect – Moving Source　$f' = \frac{V}{V - u_s} f$

Doppler Effect – Moving Observer　$f' = \frac{V + u_o}{V} f$

Doppler Effect – General　$f' = \frac{V + u_o}{V - u_s} f$

(Source and observer are approaching.)