11th Physics 7 : Oscillations and Waves 2018-19

(Pearson pp452 – 491)

1. Oscillations and Periodic Motion

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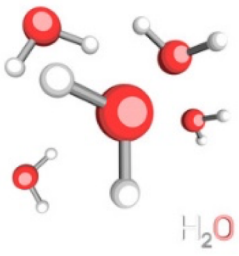
f2



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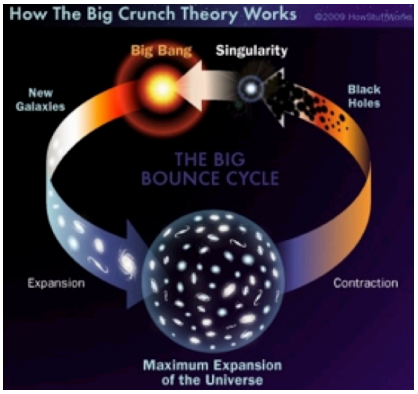

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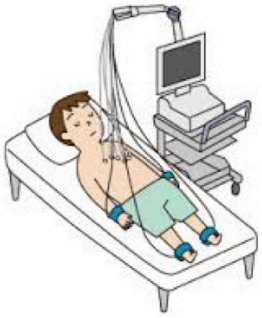

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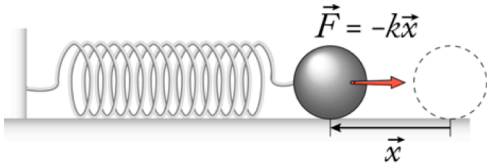
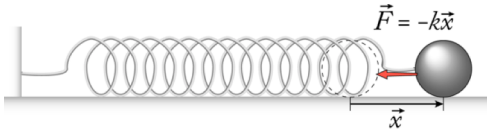
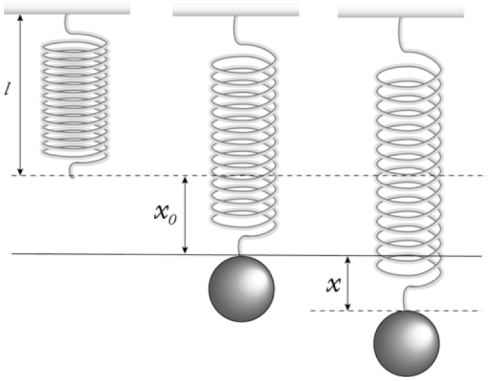
2. Periodic Motion





3. Period and Frequency

4. Simple Harmonic Motion
Horizontal Spring Pendulum



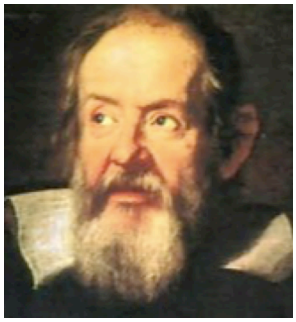
5. Restoring force

"Simple harmonic motion occurs when the restoring force is *proportional to the displacement* from equilibrium."

6. Amplitude is a key characteristic of periodic motion

9. The Pendulum

Galileo's work on pendulum



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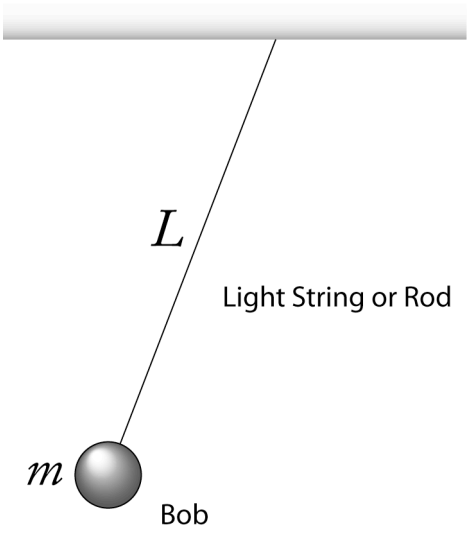
10. Properties of Pendulums



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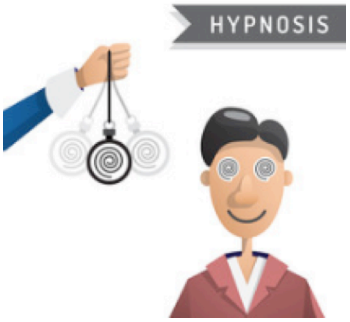
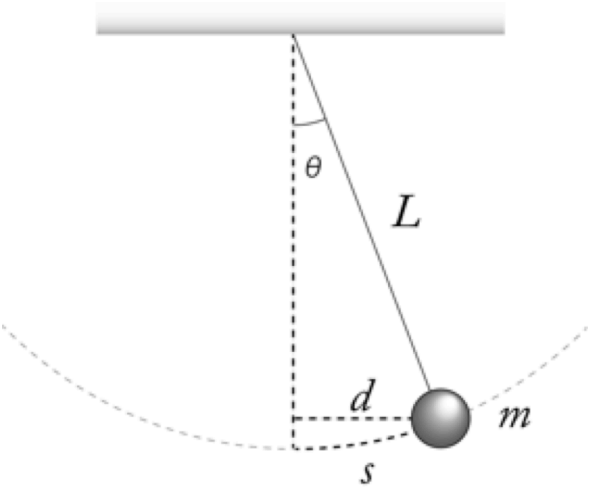


11.

Pendulums move with simple harmonic motion



14. Resonance

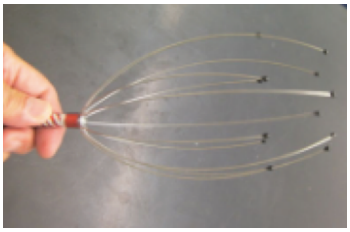
{Demo-1} *Driven oscillation*

f1

Natural frequency

Resonance

{Demo-2} Head Massager



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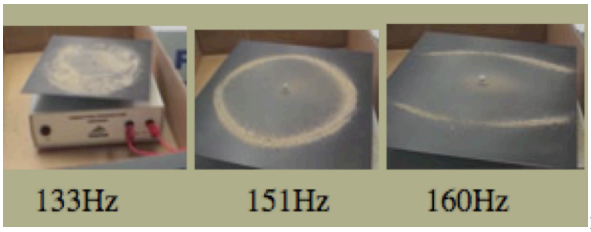
{Demo-3} Chladni Plate



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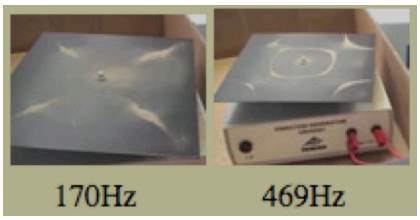

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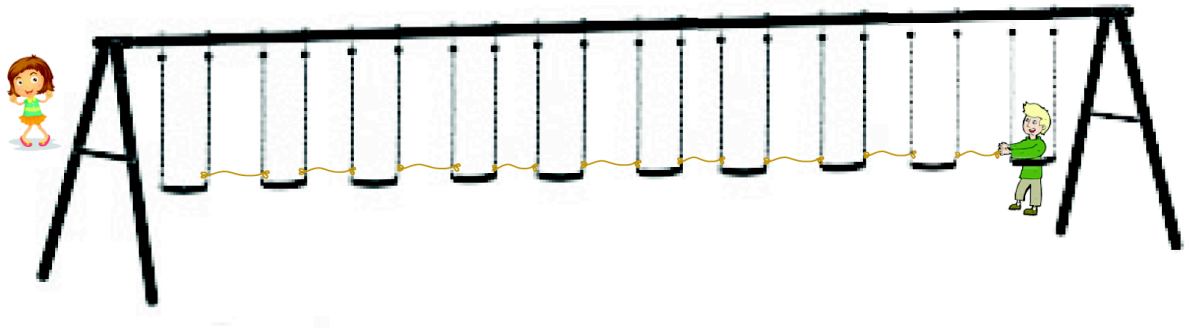
[Q] Benkei, a strong man, and Ushiwaka-maru, a clever but powerless boy, matched their wits against each other in a Buddhism temple. The game is about ringing a great and heavy bell just by swinging it with bare hands. Finally Ushiwaka-maru won. How do you think he did?

22. Wave Formation and Wave Types



f

[w1]Disturbing equilibrium

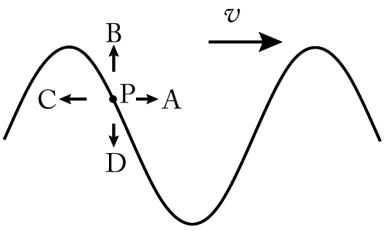
[w2] You have created a traveling disturbance.

22. A wave is a traveling disturbance

[w3] Propagate

[w2] is transmitted

[Question] The figure shows a wave on a rope moving in the direction shown by velocity vector v. Which direction is it moving to at the next moment, A~D?



[w3] Motion of the wave itself vs. the motion of the individual particles in the wave.

In general, waves travel from place to place, but the particles in wave oscillate back and forth about one location.

23. Perpendicular motion occur in transverse waves

{Demo 1} A wave on a string - "pulse" and "continuous wave"

{Demo 2} A wave on a spring –

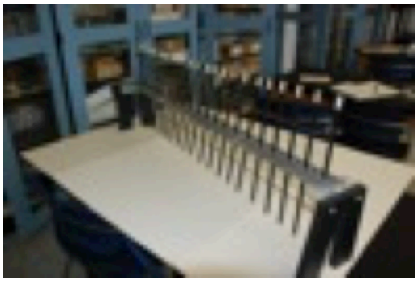
{Demo 3} A wave on a Wave Machine #1 –

[Question] **What kind of wave is called a transverse wave?**

24. Parallel motion occur in longitudinal waves

{Demo 4} A wave on a spring –

{Demo 5} A wave on a Wave Machine #2 –



[Question] **What kind of wave is called a longitudinal wave?**

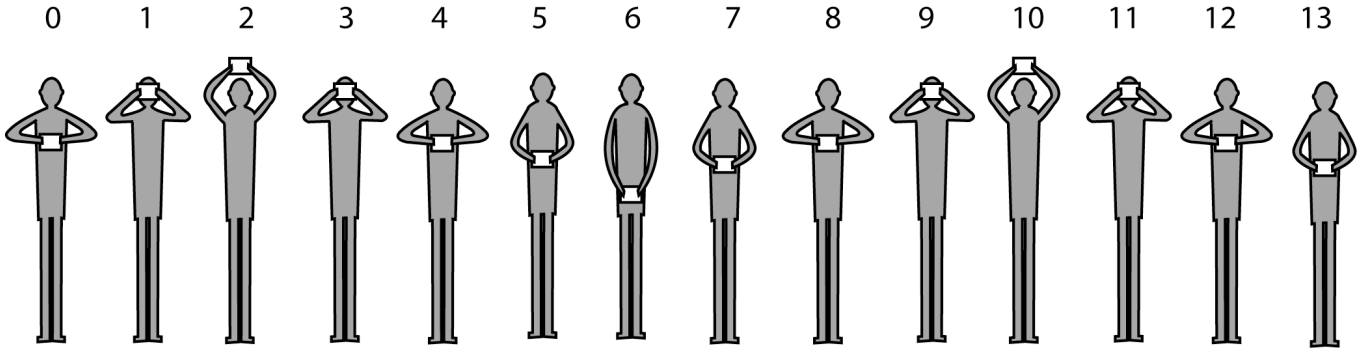
25. Water waves have a combination of properties

[Practice Problems 34, 35]

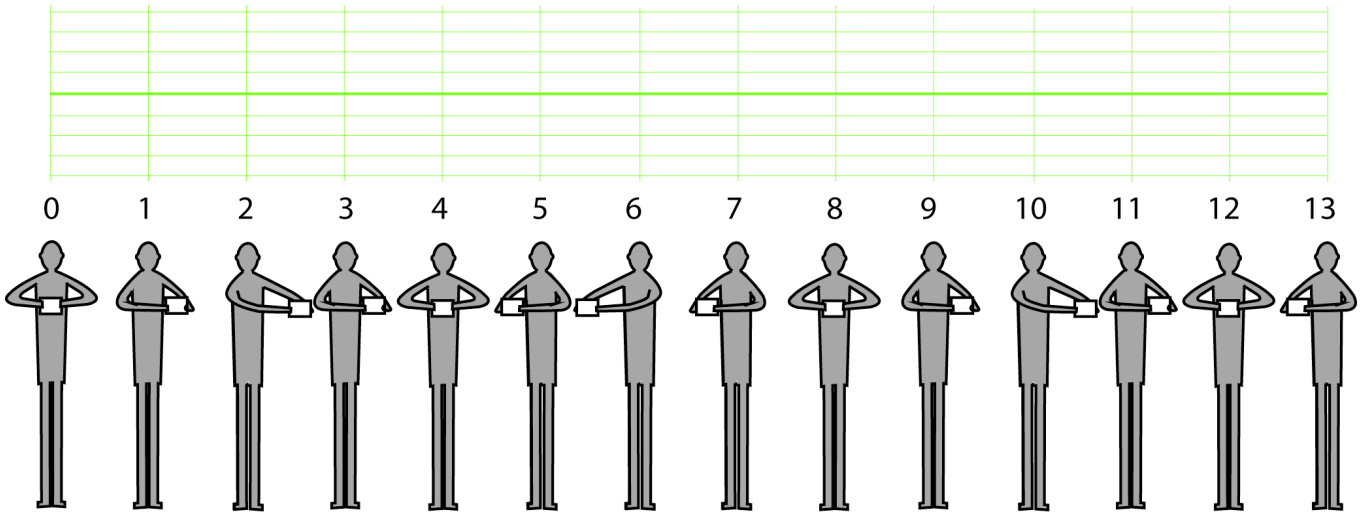
*26. Human waves

[Question 20] In the figures below, A, B and C, you are observing students making a line to make "human waves" by moving paper in their hands. How can each wave be categorized as transverse, longitudinal or combination?

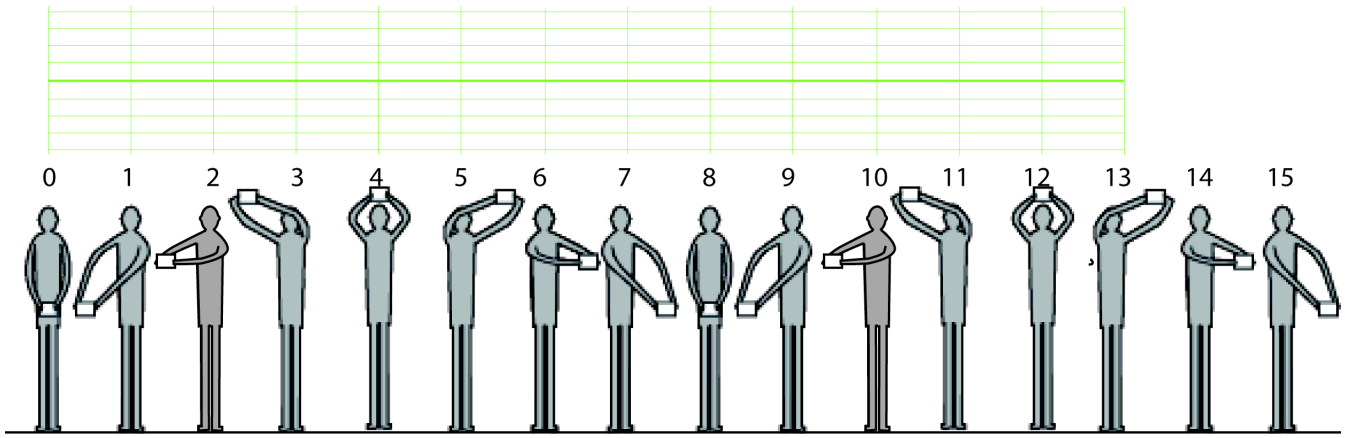
A



B



C



27. Wave Properties and Behavior

[w1] Continuous wave

Crest
Trough

Wavelength	λ lambda	[m]
Period (repeat time)	T	[s]
Frequency	f	Hz]
Amplitude	A	
Speed	v	[m/s]

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

$$speed = \frac{wavelength}{period} \qquad v = \frac{\lambda}{T}$$

$$v = f\lambda$$

[Q6] Which wave diagram has both wavelength (λ) and amplitude (A) labeled correctly?

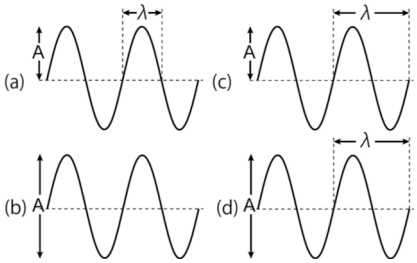


Fig. 6

[Q7]Fig. 4 shows a wave traveling toward the positive x direction. Find the amplitude and wave length of the wave.

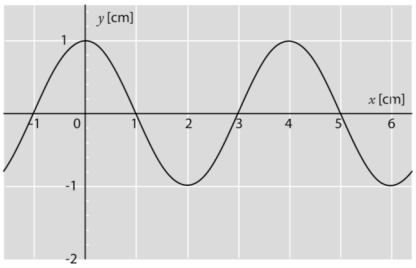


Fig. 7

[Q8] The reciprocal of the frequency of a periodic wave is the wave's
(1) period, (2) amplitude, (3) intensity, (4) speed

[Q9] There is a wave where its speed is 6.0 m/s and the vibration period of the medium is 0.50 s. Find the wavelength of the wave.

[Q10] There is a wave where its wavelength and frequency are 4.0 m and 8.0 Hz, respectively. Find the speed of the wave.

[Q11] Sound waves travel in air with a speed of 343 m/s. The lowest frequency sound we can hear is 20.0 Hz; the highest frequency is 20.0 kHz. Find the wavelength of the sound for frequencies of 20.0 Hz and 20.0 kHz.

[Q12] Periodic waves are produced by a wave generator at the rate of on wave every 0.50 seconds. What is the period of the wave?

[Q14] Find the displacement of the medium at the points, A, B and C.

[

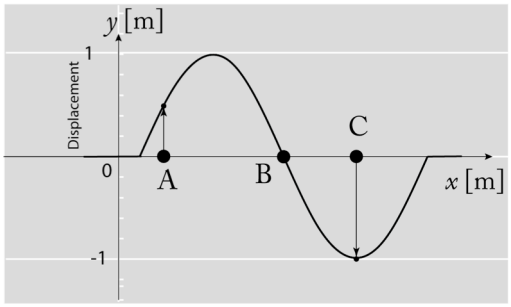


Fig.14

28. Longitudinal Waves

[Q18] Choose transverse and longitudinal waves from the list shown in the right.

Various waves
1) Ripple
2) Tsunami
3) Compression waves in a spring
4) Waves of a string
5) Seismic waves
6) Sound
7) Wave machines
8) Light
9) Electric waves (Radio wave)
10) Human wave at a ballpark

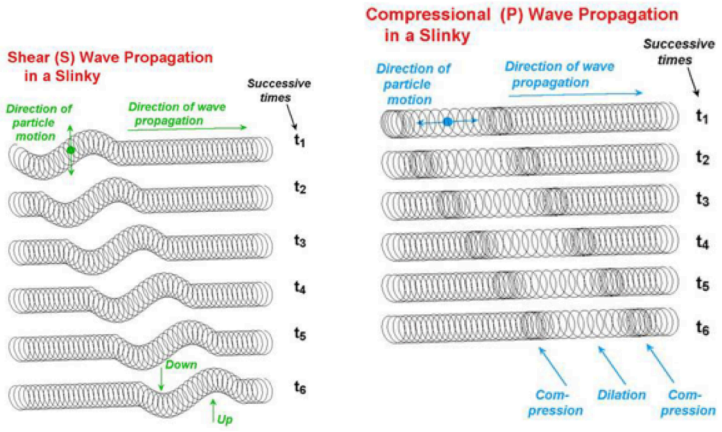
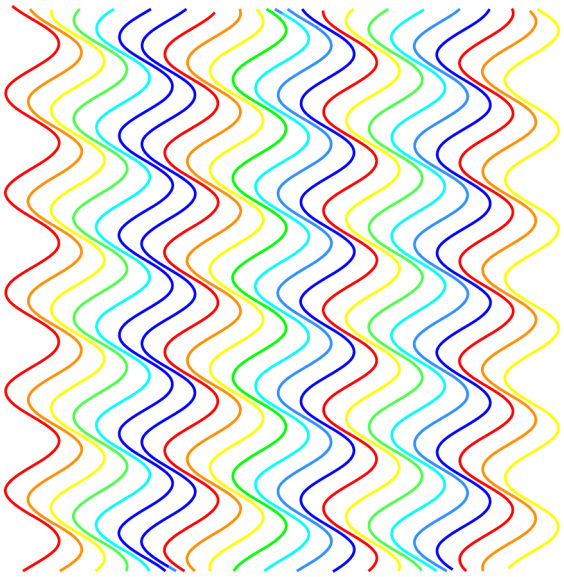


Fig. Wave Propagation in Slinky



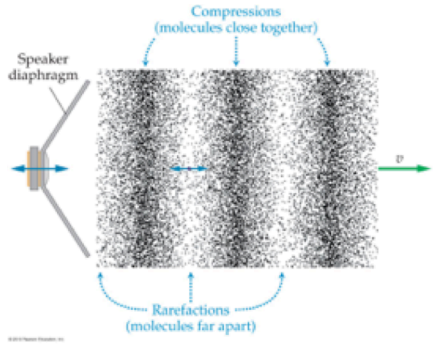
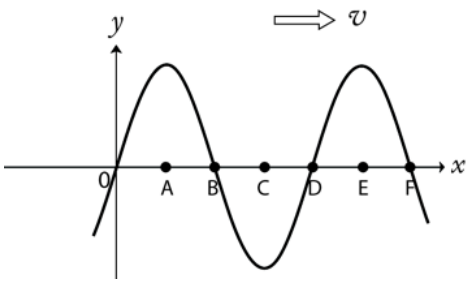


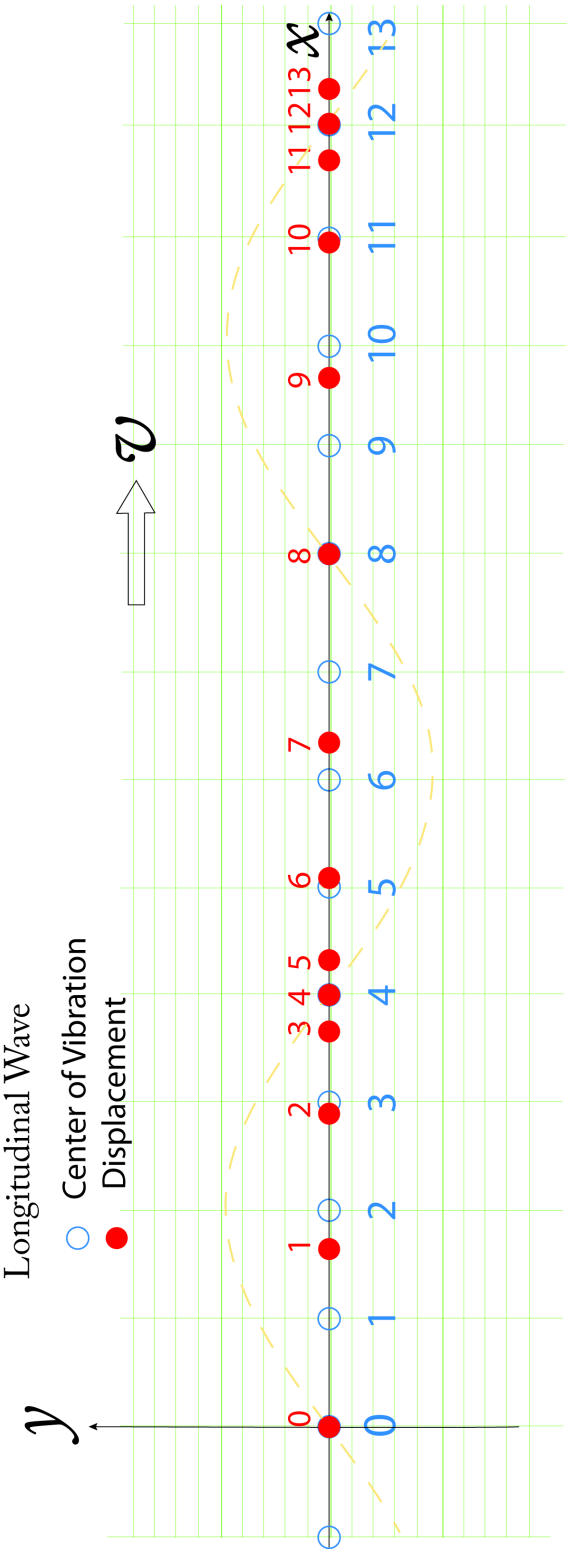
Fig. Sound produced by a speaker

[Q19] The figure shows the graph of a longitudinal wave expressing as a transverse wave.
(1) Which points are of compressions or rarefactions?
(2) Which point has the largest displacement to the right?
(3) Which point has the speed of zero?

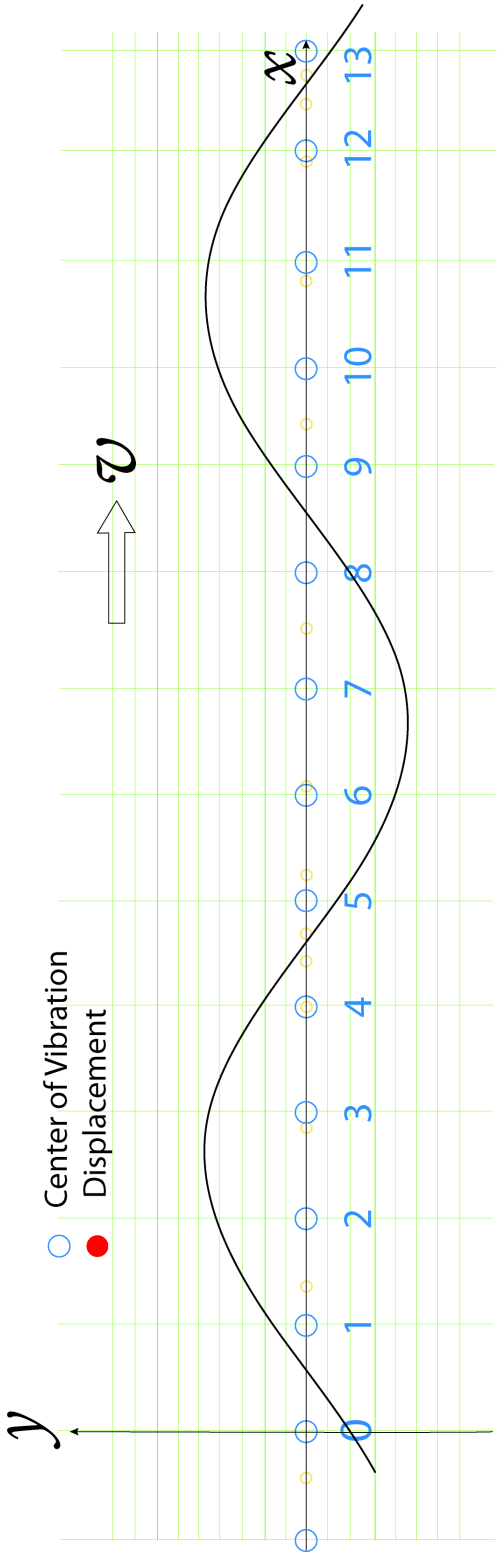


*29. Graph of Longitudinal Waves

Make a corresponding transverse wave from the displacements of a longitudinal wave shown by a red points.



Find and plot the original displacements of a longitudinal wave from the graph of its corresponding transverse wave shown by a solid curve.



*30. Phases

In-Phase points –

Opposite-Phase points -

[Q16] Fig. 16 shows a periodic wave with a wavelength of 2.0 m moving toward positive x at the speed of 4.0 m/s. The points, A to F, represent media.

(1) Which direction the point B is moving in?
(2) Find the points that are in identical phase with the point B.
(3) Find the points that are in opposite phase with the point B.
(4) How long does it take for the phase of the point B to transfer to the point D.
(5) Find the period of this wave.

Fig. 16 の波は、波長 2.0 m、x 軸の正の向きに速さ 4.0 m/s で進んでいる。点 A~F は媒質である。(I-60)

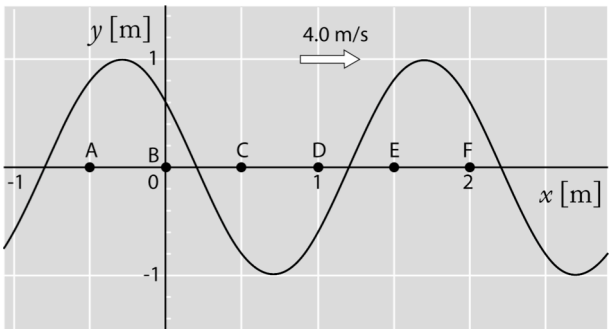


Fig.16

(Q17] In Fig. 17, the solid and broken lines represent the wave at t=0 s and t=0.50 s, respectively. Find the followings:

(1) Wavelength
(2) Amplitude
(3) Period
(4) Frequency
(5) Speed
(6) The location where the speed of vibration is zero at t=0.

(7) The time of propagation that the phase of the origin transfers to x=30 cm.

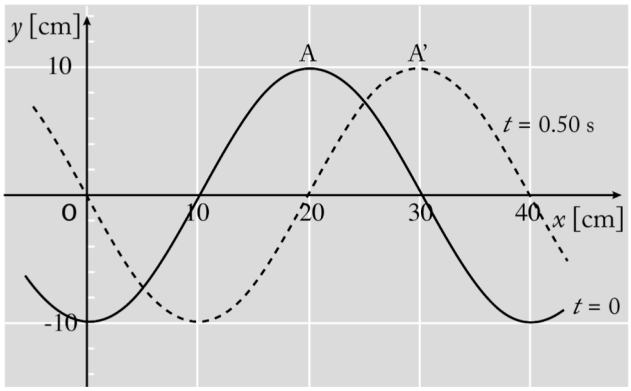


Fig. 17

*31. Human waves (2)

[Q20,21] In the figures below, you are observing students making a line to make "human waves" by moving paper in their hands. The distance between adjoining students is 1.5m. Every student moves paper by 25cm at a bang of a drum once per 0.50 s to shift to the next step.

	Fig. 20	Fig. 21
(1) The left-end or #0 student moves paper upward in Fig. 20 or to the left as you face in Fig. 21. Which direction is the right movement for the #4 student?		
(2) Is this wave transverse or longitudinal?		
(3) Find the amplitude of the waves.		
(4) Find the wavelength of the waves.		
(5) Find the period of the waves.		
(6) Find the frequency of the waves.		
(7) Find the speed of the waves.		
(8) Name all the students on the wave that are in identical phase with the #1 student.		
(9) Name all the students on the wave that are in opposite phase with the #1 student.		
(10) Which direction does the "human wave" move?		

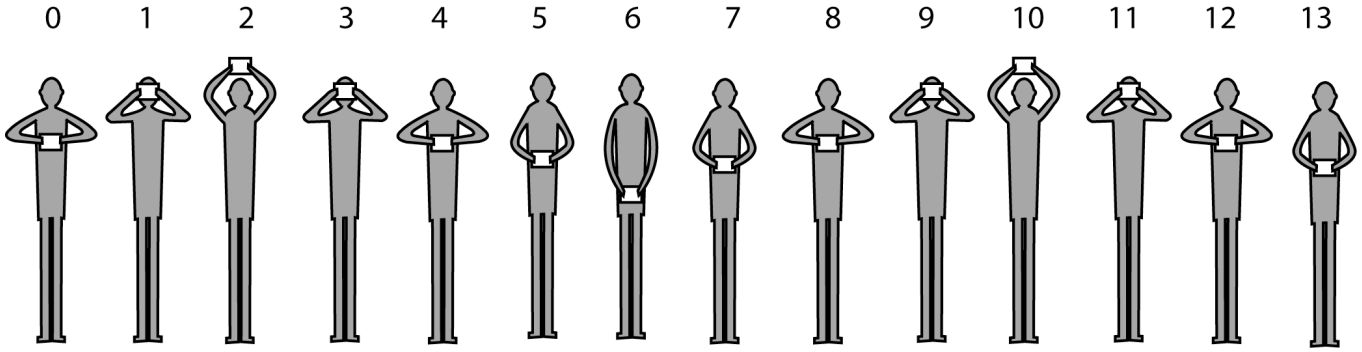


Fig. 20

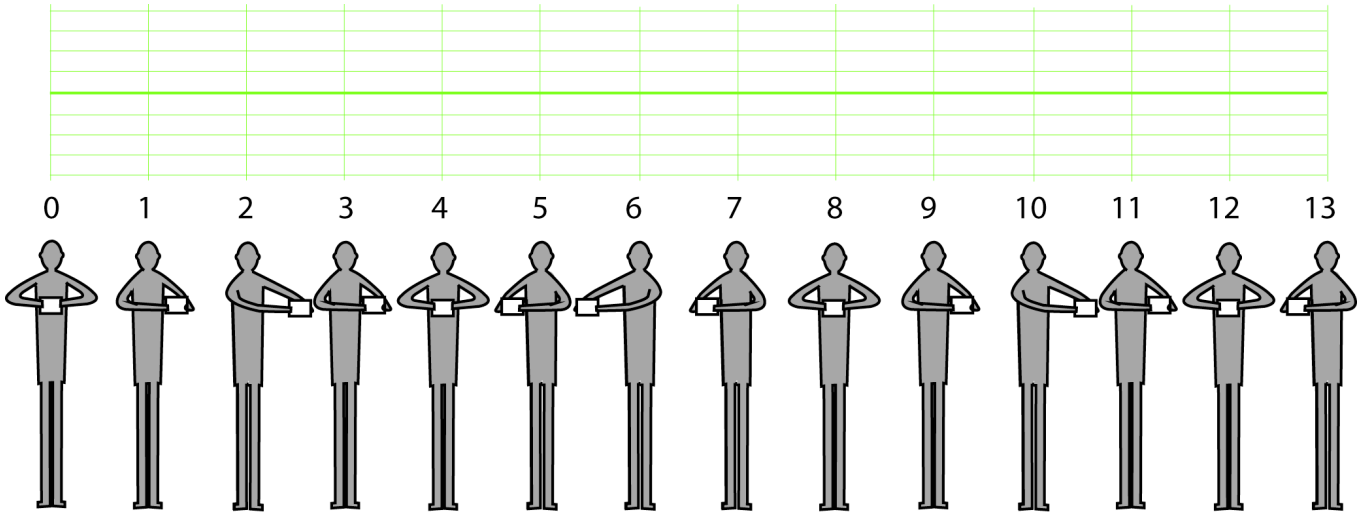


Fig. 21

*32. Graphs of Vibration

[Q18] Fig. 18-a and –b are the graphs of a wave and the graph of vibration at origin of the wave, respectively. Explain about phase for each graph.

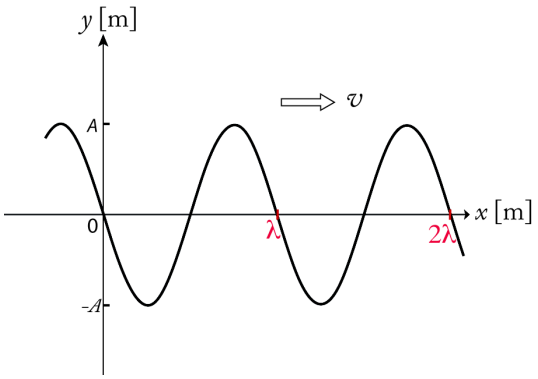


Fig.18-a

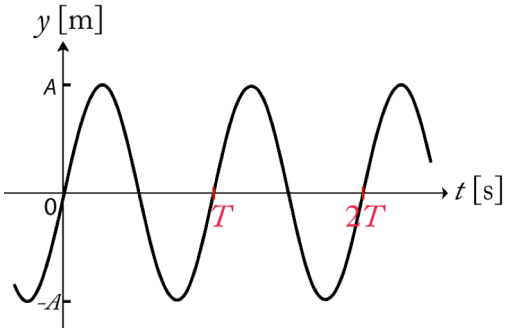


Fig.18-b

33. Waves have different speeds in different materials (Pearsonp474)

[w1] Medium

34. Superposition and Interference (Pearson p476)

[w1] Resultant wave

[w2] Principle of superposition

[w3] Independent property of a wave in superposition

[w4] Constructive interference

[w5] Destructive interference

[Q22] The following figure represents red and blue pulses. Make a careful sketch of the resulting wave, assuming that the superposition principle holds for these waves.

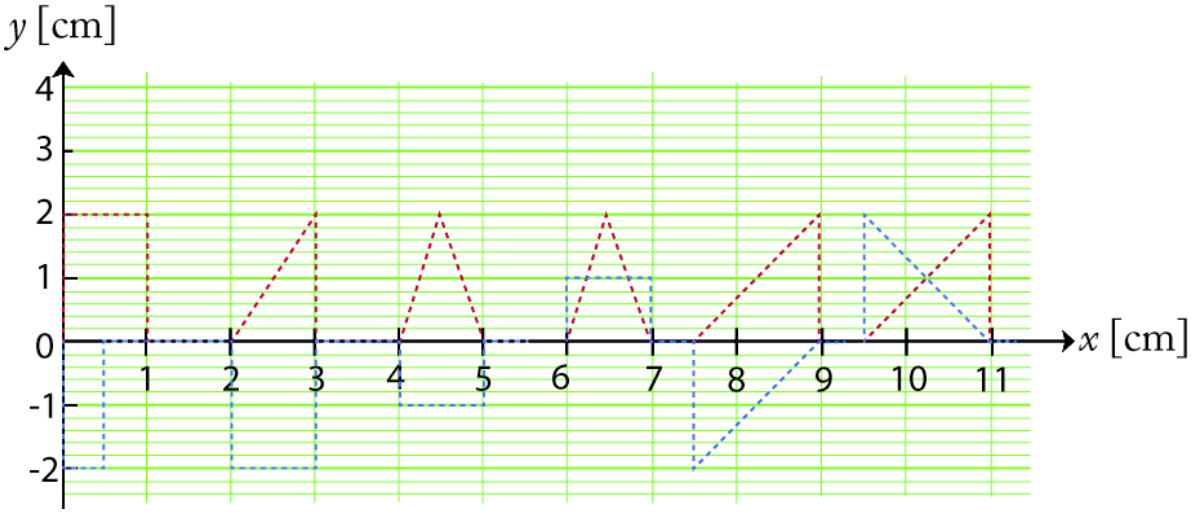


Fig. 22

[Q23] Two pulse waves move at the speed of 1 cm/s as shown. Draw the pattern of the waves after 2 seconds.

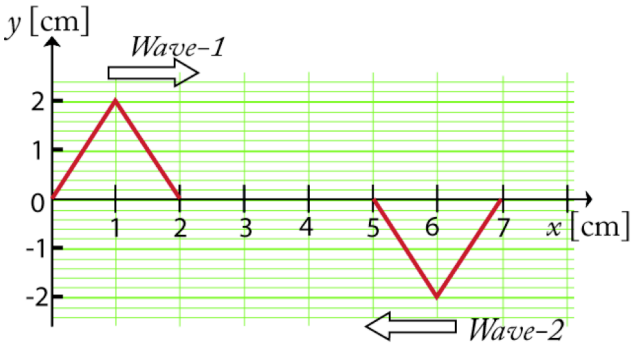
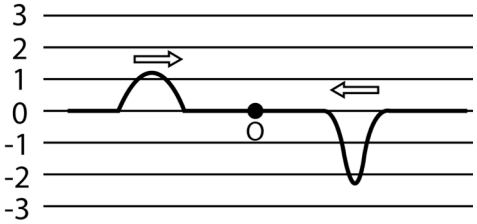


Fig. 23

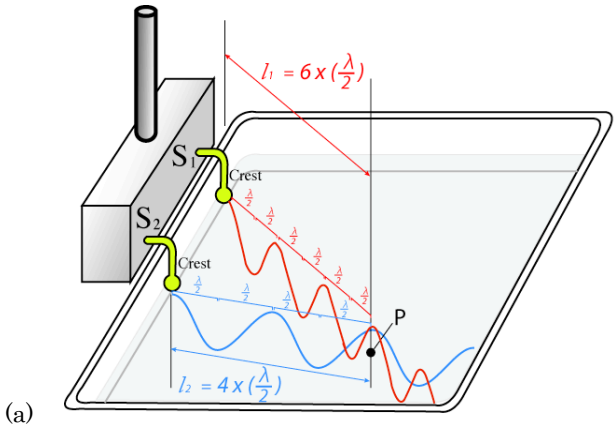
[Q24] Fig. 25 shows a rope with two pulses moving along it in the direction shown. What is the resultant wave pattern at the instant when the maximum displacement of both pulses is at point O on the rope? (PS56)



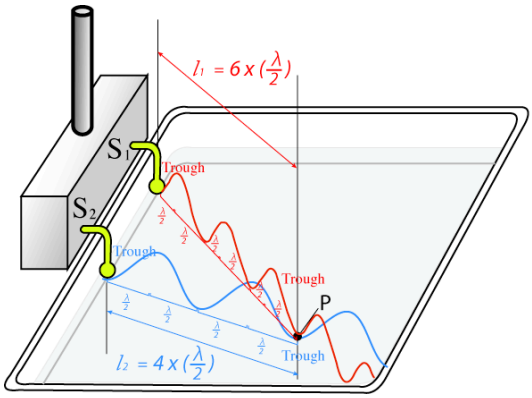
*35. Interference of Waves

(I) In-Phase Vibration

Constructive Interference $\left|\ell_1 - \ell_2\right| = 2m \times \left(\frac{\lambda}{2}\right)$ $(m = 0, 1, 2, \cdots)$

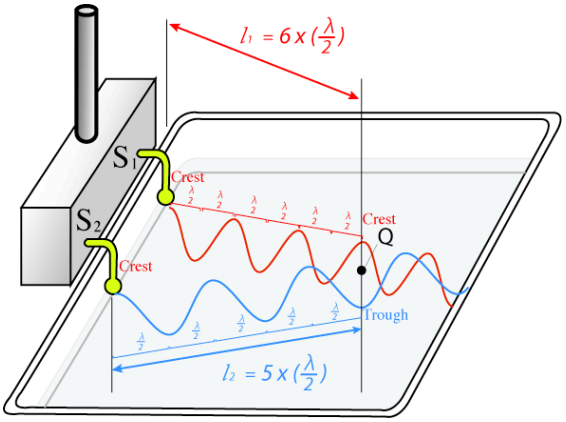


(a)



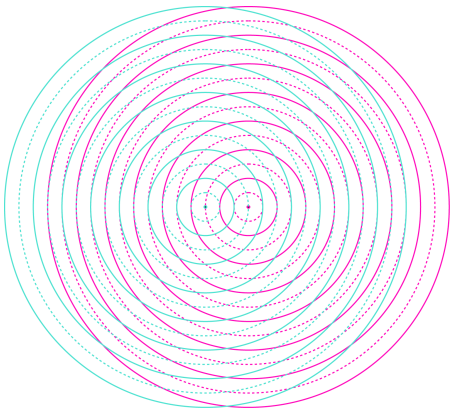
(b)

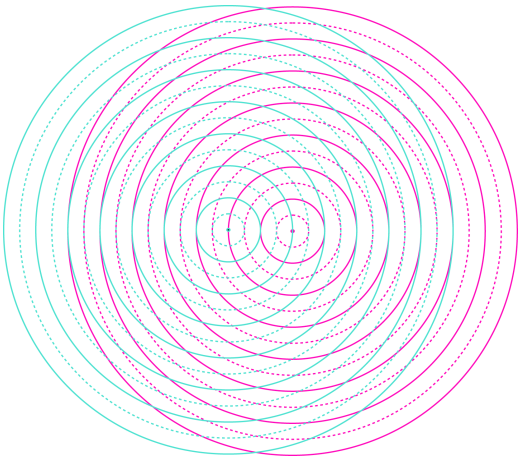
Destructive Interference $\left|\ell_1 - \ell_2\right| = (2m + 1) \times \left(\frac{\lambda}{2}\right)$ $(m = 0, 1, 2, \cdots)$



(c)

[Q41] The figures show two sets of circular waves. Find the lines of "constructive" and "destructive" interferences.

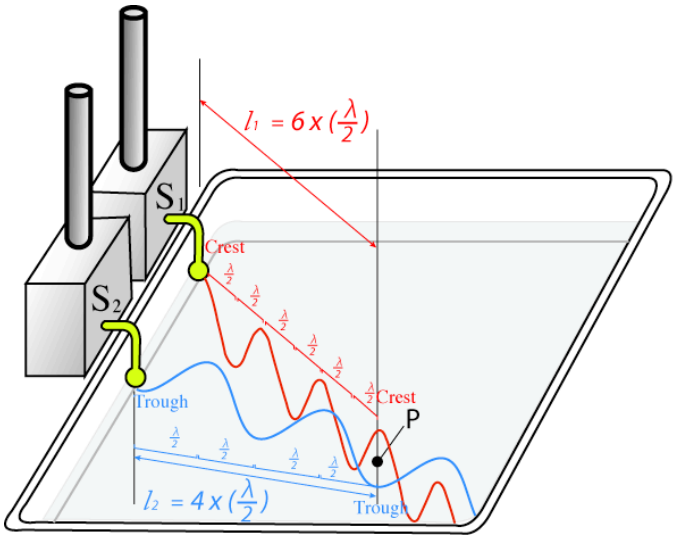




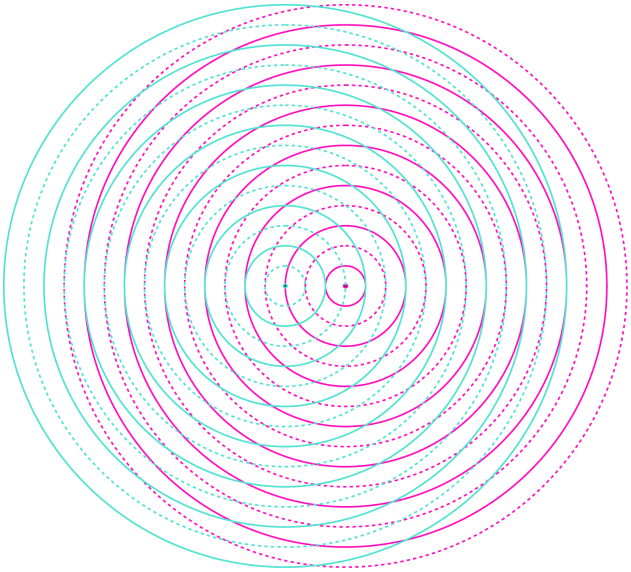
(II) Opposite-Phase Vibration

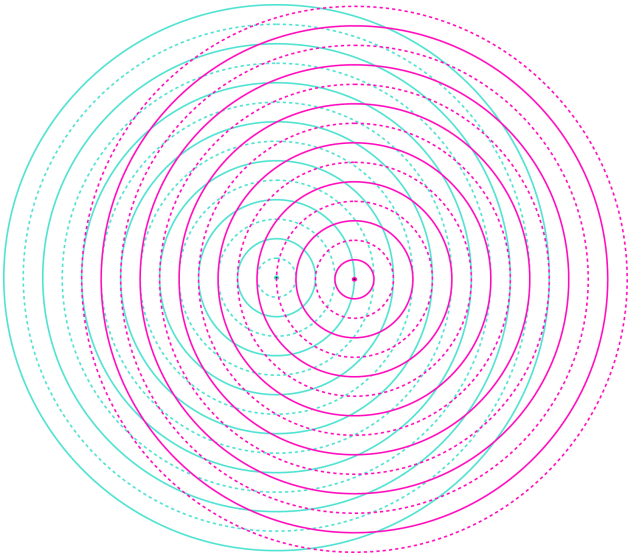
Constructive Interference $\left|\ell_1 - \ell_2\right| = (2m+1) \times \left(\frac{\lambda}{2}\right)$ $(m = 0, 1, 2, \cdots)$

Destructive Interference $\left|\ell_1 - \ell_2\right| = 2m \times \left(\frac{\lambda}{2}\right)$ $(m = 0, 1, 2, \cdots)$



[Q42] The figures show two sets of circular waves. Find the lines of "constructive" and "destructive" interferences.





[Q43] Two sources on water surface, S_1 and S_2, separated by a distance of 2.0 cm vibrate in phase with one another, The produced wave has a wavelength of 1.0 cm. Are the waves constructive or destructive at the point located 6.5 cm far from S_1 and 7.5 cm far from S_2?

[Q44] Two sources on water surface, S_1 and S_2, separated by a distance of 2.0 cm vibrate out of phase with one another, The produced wave has a wavelength of 1.0 cm. Are the waves constructive or destructive at the point located 6.5 cm far from S_1 and 7.5 cm far from S_2?

[Q45] Two speakers separated by a distance of 4.30 m emit sound of 221 Hz. The speakers are in phase with one another. A person listens from a location 2.80 m directly in front of the speakers. Does the person hear constructive or destructive interference. (Speed of sound: 343 m/s)

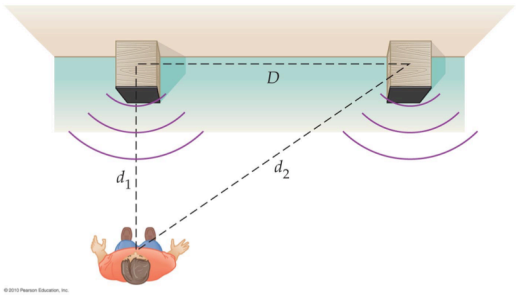


Fig. 45

[Q46] The Speakers shown to the right have opposite phase. They are separated by a distance of 5.20 m and emit sound with a frequency of 104 Hz. A person stands 3.00 m in front of the speakers and 1.30 m to one side of the center line between them. What type of interference occurs at the person's location?

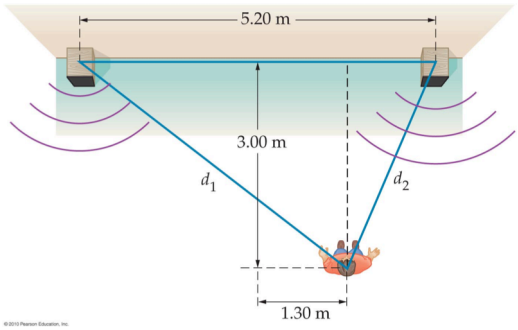
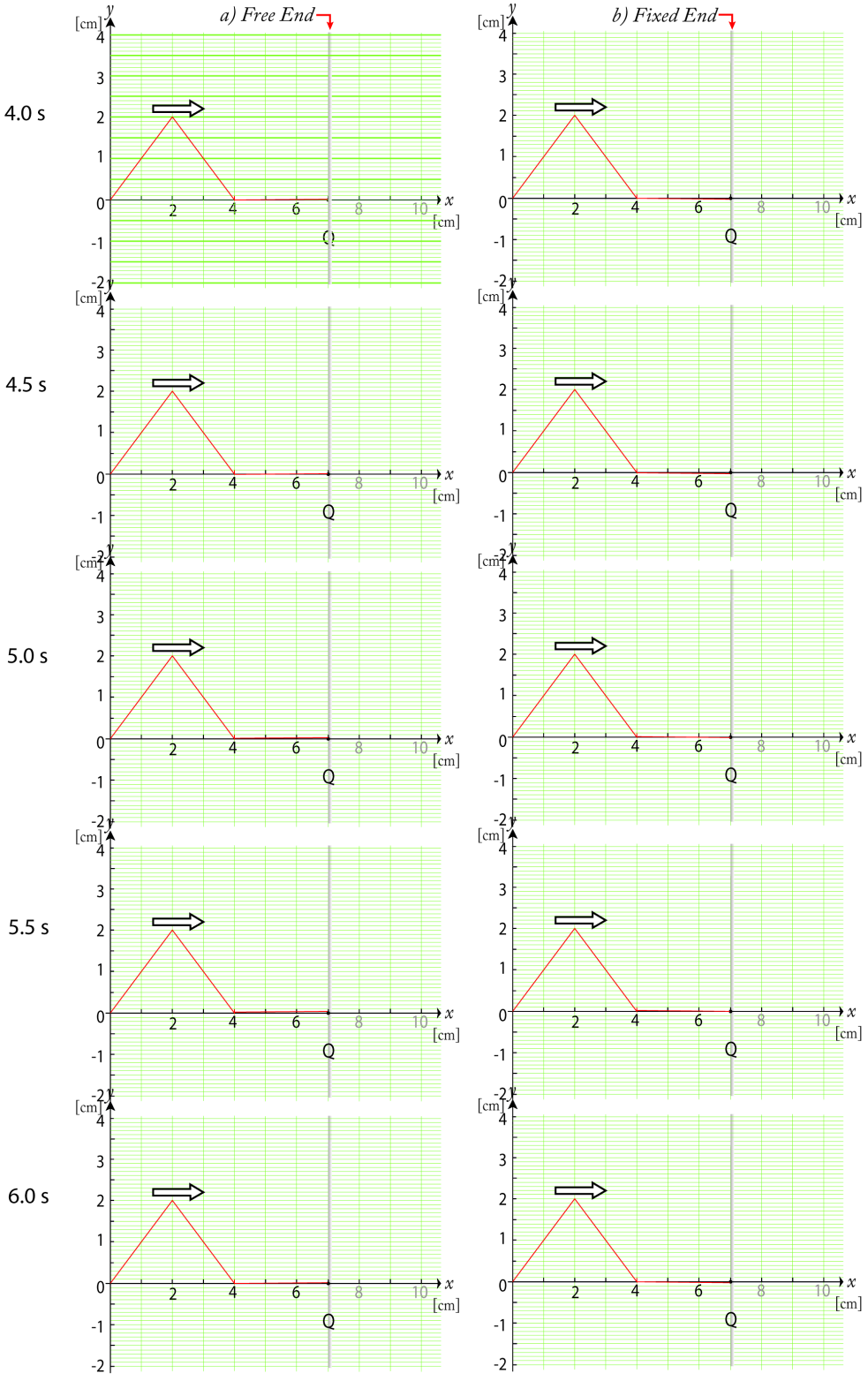


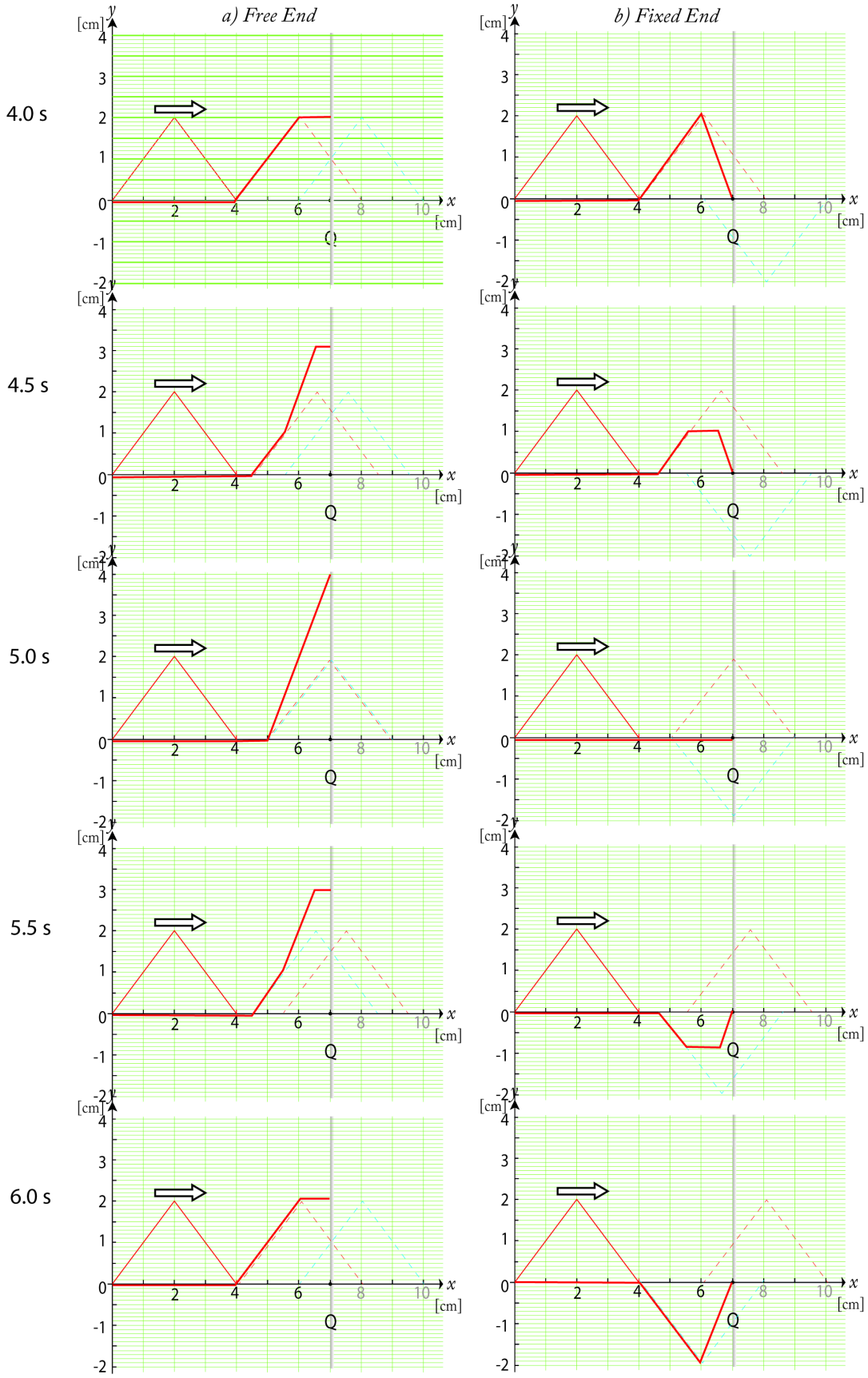
Fig. 46

36. Wave can reflect in different ways (Pearson p475)

[Q26] In Fig. 26-a and -b, a pulse approaches toward a free and fixed end Q, respectively, with a speed of 1.0 cm/s. Illustrate the pattern for the waves at a time 4.0, 4.5, 5.0, 5.5, 6.0 and 6.5 s later.

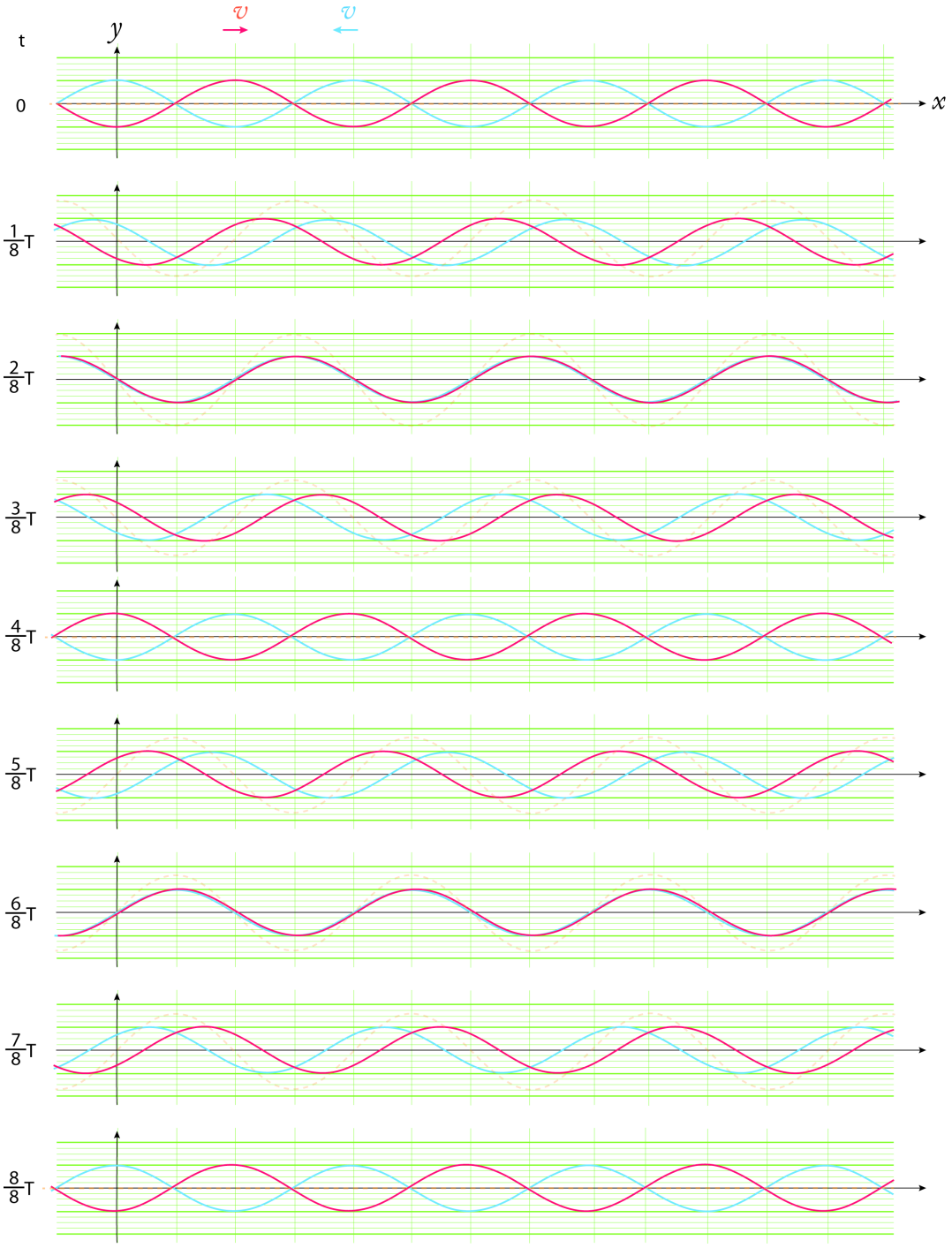


[Q26]
Answer



37. Standing Wave (Pearson p478)

[Q] In the figure shown below, two waves having the same amplitude and wavelength travel in opposite directions. Illustrate the resultant wave pattern formed by the superposition of the two waves (A standing wave is formed.)



[Q51] Standing waves are produced by two waves traveling in opposite directions in the same medium. The two wave must have
(1) the same amplitude and the same frequency
(2) the same amplitude and different frequencies
(3) different amplitudes and the same frequency
(4) different amplitudes and different frequencies
(PS 160)

[Q52] The diagram P represents a wave moving toward the right side. Which wave from (a) to (d) could produce a standing wave with the wave P?

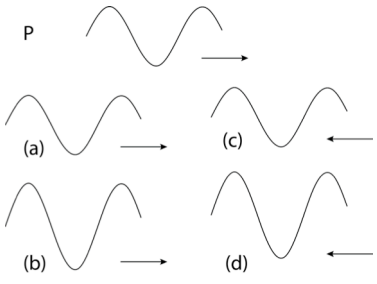
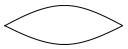
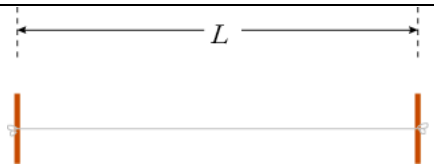
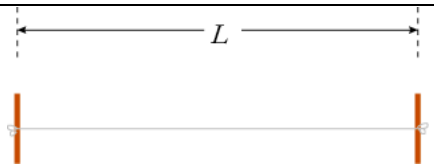
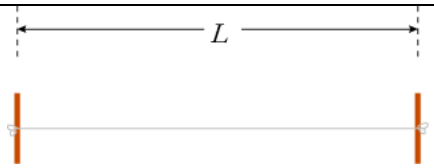
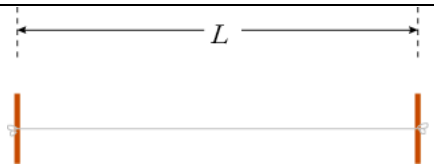
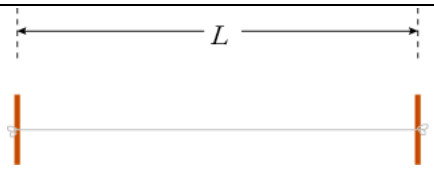
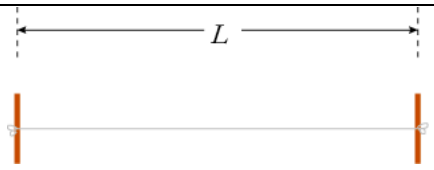


Fig. 52

[Q53] Two sources, S_1 and S_2, separated by a distance of 4.0 cm emit the identical traveling wave toward the each other. The wave has the wavelength of 4.0 cm, the amplitude of 0.50 cm, the speed of 2.0 cm/s and in phase with one another, They produce a standing wave between S_1 and S_2.
(1) Find the period and amplitude of the vibration of the antinodes.
(2) Illustrate the pattern of the standing wave.

38. Standing Waves on a String

	Shape of Standing Wave	Number of Antinodes  $\frac{\lambda}{2}$	Wavelength λ [m]	Frequency f [Hz]
Fundamental				
2nd Harmonic				
3rd Harmonic				
4th Harmonic				
5th Harmonic				
mth Harmnic m 倍振動				

[Q15] There is a string 0.800 m long. (a) What is the wavelength for the fundamental harmonic? (b) What is the wavelength for the second harmonic? (c) What is the wavelength for the third harmonic?

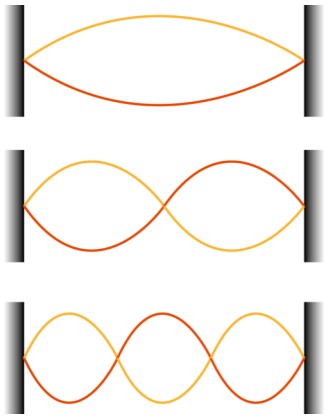


Fig.15

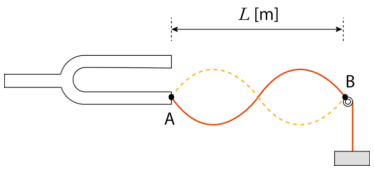
[Q16] There is a string 0.800 m long where the speed of waves on the string is 704 m/s. (a) What is the fundamental frequency? (b) What is the frequency of the second harmonic? (c) What is the frequency of the third harmonic?

[Q17] One of the harmonics on a string 1.30 m long has a frequency of 15.60 Hz. The next higher harmonic has a frequency of 23.40 Hz. Find (a) the fundamental frequency, and (b) the speed of waves on this string.

[Q19] A string, L [m] long, is placed between a frequency-variable tune fork and a pulley. A weight is placed on the one end of the string. Vibrating the tune fork produces a standing wave with two antinodes as shown in the figure. The point A can be assumed to be a node although it shows small vibration. Assume the speed of the wave on the string, v [m/s], does not change when the frequency is changed.

(a) Express the frequency of the tune fork, f [Hz], using L and v.

(b) When the frequency of the tune fork is changed to f_2, the standing wave shows only one antinode. By what factor does f_2 change with respect to f.



39. Diffraction, Reflection, Refraction

Huygens's Principle

[w1]
Wave Front
Plane Wave,
Spherical Wave
Elementary Wave
Surface Envelope
Huygens' Principle

Diffraction

[Q28] Fig. 41 represents water waves interacting with two slits in a barrier. Identify two wave phenomena illustrated in the figure.

[Q29] Which diagram in Fig. 42 best illustrates diffraction of waves incident on a barrier?

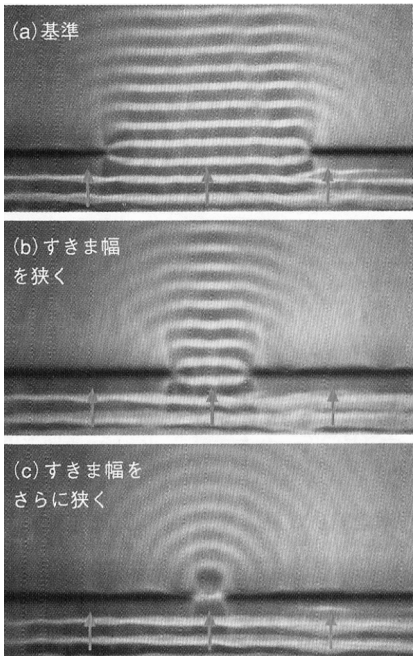


Fig. 39

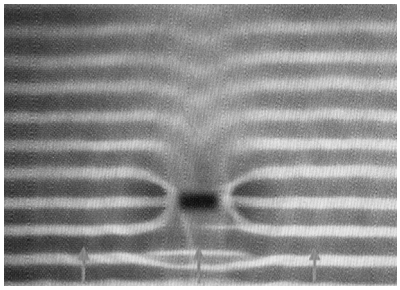


Fig. 40

[Q30] A wave is diffracted as it passes through an opening in a barrier. The amount of diffraction that the wave undergoes depends on both of the followings:

(a) amplitude and frequency of the incident wave

(b) wavelength and speed of the incident wave

(c) wavelength of the incident wave and the size of the opening

(d) amplitude of the incident wave and the size of the opening

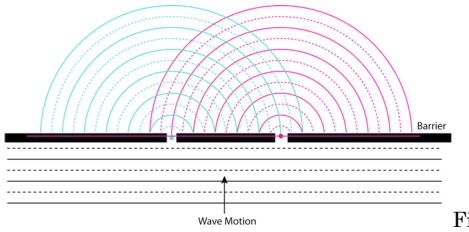


Fig. 41

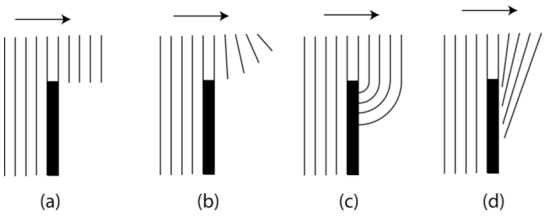


Fig. 42

Reflection

[w2]
Incident wave
Reflected wave
Normal
Incidence angle
Reflection angle
Law of reflection

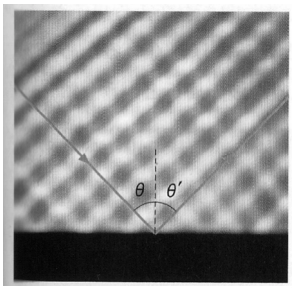


Fig. 31 Reflection

[Q32] Do the wavelength, frequency and speed of an incident wave change with reflection?

Refraction

[Q33] Do the wavelength, frequency and speed of an incident wave change with refraction?

[Q34] Find the relative refractive index, $n_{1\to 2}$ of a medium 2 with respect to another medium 1 in terms of incidence and refraction angles.

[Q35] Find the relative refractive index, $n_{1\to 2}$ of a medium 2 with respect to another medium 1 in terms of the speed of waves in the mediums.

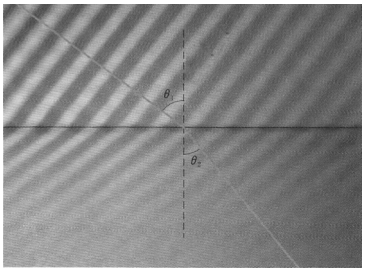
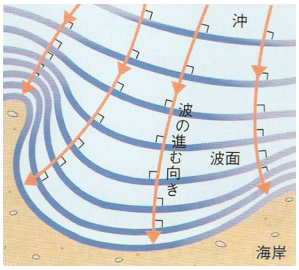


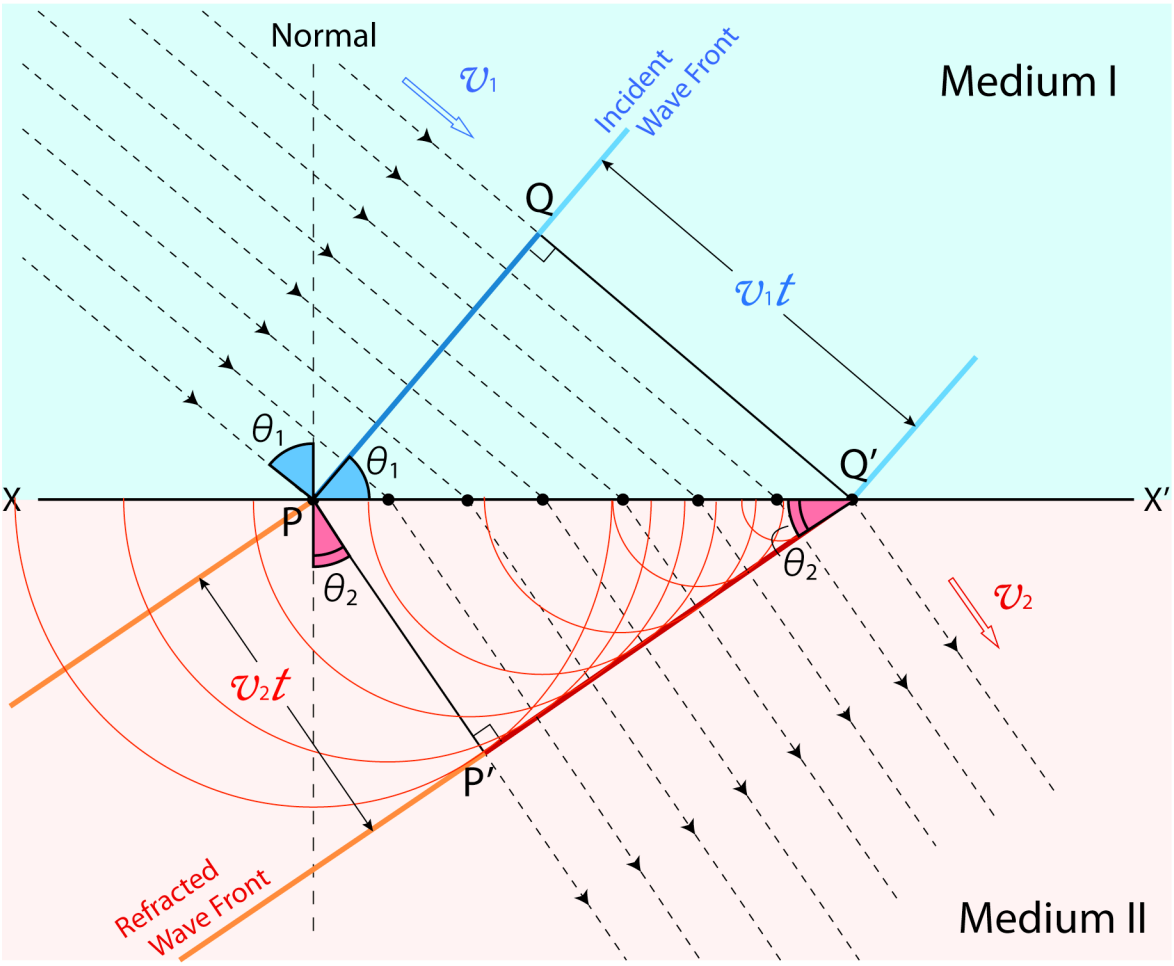
Fig. 33 Refraction

[Q36] Find the relative refractive index, $n_{1\to 2}$ of a medium 2 with respect to another medium 1 in terms of the wavelength of waves in the mediums.

[Q37] Why are the wave fronts lapping toward the beach always parallel with the beach line?

[Q38] Derive the law of refraction using the Huygens'





. θ_1: θ_2: $\boldsymbol{v}_1$: $\boldsymbol{v}_2$:

- $\boldsymbol{t}$:
- $\boldsymbol{v}_1\boldsymbol{t}$:
- $\boldsymbol{v}_2\boldsymbol{t}$:
- $\sin\theta_1 =$
- $\sin\theta_2 =$
- $n_{1\to2} = \dfrac{\sin\theta_1}{\sin\theta_2} =$

[Q39] Fig. 39 shows the wave fronts of a wave of 2.8 m wavelength traveling from a medium 1 to another medium 2. The refractive index of the medium 2 with respect to the medium 1 is 1.4. Find the wavelength of the refracted wave. Illustrate the refracted wave in the figure.

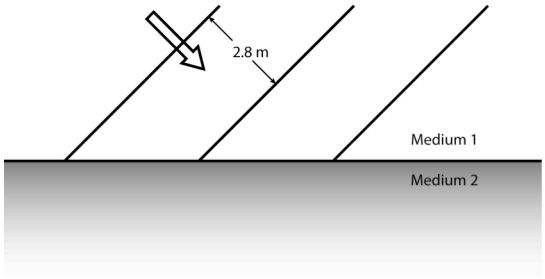
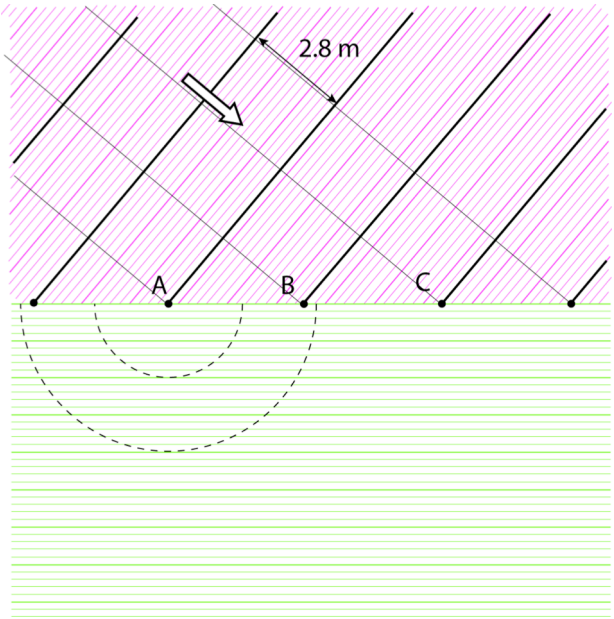
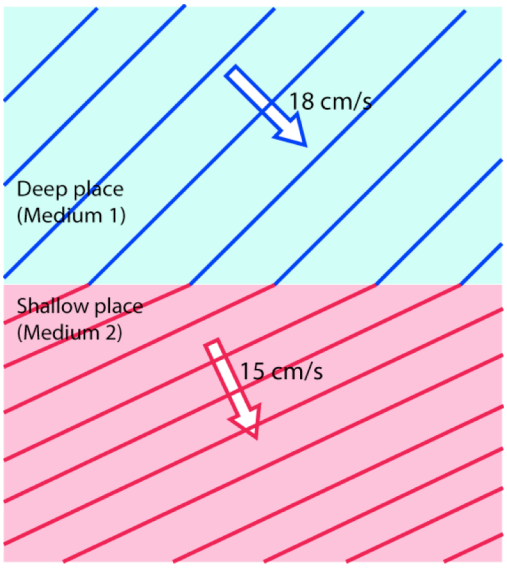
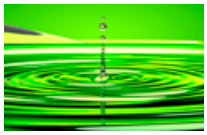


Fig. 39



[Q40] There are two parts of place in a water tank, deep (medium 1) and shallow (medium 2). A wave of 6.0 Hz frequency travels at 18 cm/s in the deep place toward the shallow place. The wave travels in the shallow place at 15 cm/s. (a) Find the refractive index of the medium 2 with respect to the medium 1. (b) Find the wavelength in the two media.





1. Waves 波
Wave Motion 波動
Water Waves 水面波
Medium 媒質
Source 波源
Ripple 波紋
Pulse パルス波
Periodic Waves 連続波
Crest 山
Trough 谷

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

Speed $$v = \frac{WaveLength}{Period} = \frac{\lambda}{T} = f\lambda$$

Superposition $$y = y_1 + y_2$$

$$\left|l_1 - l_2\right| = m\lambda = 2m \times \frac{\lambda}{2} \qquad (m = 0,1,2,\cdots)$$

$$\left|l_1 - l_2\right| = m\lambda + \frac{1}{2}\lambda = (2m+1) \times \frac{\lambda}{2} \qquad (m = 0,1,2,\cdots)$$

$$n_{1\to 2} = \frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

２. Wavelength 波長
Amplitude 振幅
Period 周期
Frequency 振動数

３. Displacement 変位
Phase 位相
In identical phase 同位相
In opposite phase 逆位相

４. Transverse Wave 横波
Longitudinal Wave 縦波、疎密波

５. Superposition 重ね合わせ
Independency （波の）独立性
Interference 干渉
Interfare Constructively 強め合う干渉
Interfare Destructively 打ち消しあう干渉
Standing Wave 定常波
Traveling Wave 進行波
Node 節
Antinode 腹
Free Edge 自由端
Fixed Edge 固定端

６. Huygens's Principle ホイヘンスの原理
Wave Front 波面
Plane Wave 平面波
Spherical Wave 球面波
Elementary Wave 素元波
Surface Envelope 包絡面

Diffraction 回折

Reflection 反射
Reflection Angle 反射角
Law of Reflection 反射の法則
Normal 法線
Incidence Angle 入射角
Refraction 屈折
Refraction Angle 屈折角
Refractive Index 屈折角
Relative Refractive Index 相対屈折率