Wave

(1) Basics Properties of Wave

-2006 1(3)

A transverse wave is travelling in the positive x direction. The displacement of the medium at a certain moment is shown as Figure 2. The displacement in the positive x direction takes a positive value of y. At which point does the medium has the maximum acceleration in the positive x direction?

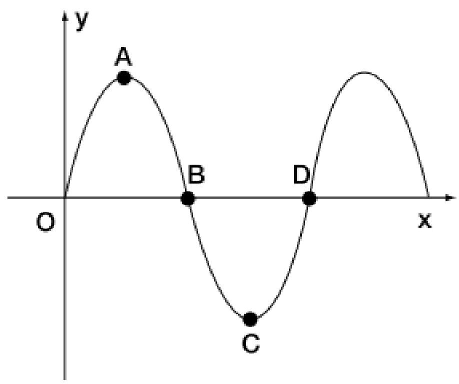



Figure 2

-2007 1(4)

(4) Spherical waves of wavelength 8cm are generated in the same phase from two point sources $S_1$ and $S_2$ which are separated by a distance 12cm as shown in Fig.4. Point $A$ is separated from $S_2$ by 16cm and $S_2A$ is perpendicular to $S_1S_2$. Are the spherical waves generated from $S_1$ and $S_2$ constructive or destructive at point $A$?

(a) constructive (b) destructive

(c) neither constructive nor destructive

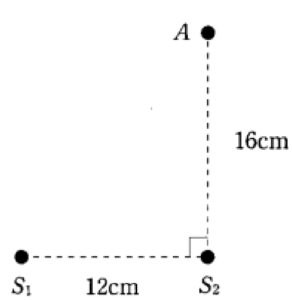



Fig. 4

-2010 IIIA

**A** It is observed that the wave front of ocean waves takes on the same shape as the shoreline as the waves move toward the beach. In order to examine the reason for this, the following experiment is conducted.

As shown in Figure 1, a thick sheet of glass was submerged in a shallow tank filled with water. When plane waves were propagated from the deep side toward the shallow side, the wave-front pattern shown in Figure 2 was observed.

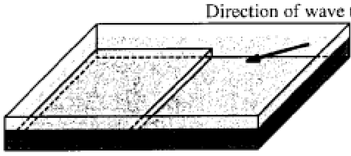



Figure 1

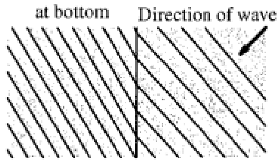



Figure 2 Wave-front pattern seen from above

Q1 Based on the result of the experiment above, what reason can be inferred for why the wave front takes on the same shape as the shoreline? From ①-⑤ below choose the best answer.

$\boxed{11}$

① Wave speed increases as water depth decreases.

② Wave speed decreases as water depth decreases.

③ Wave frequency increases as water depth decreases.

④ Wave frequency decreases as water depth decreases.

⑤ Wave speed and frequency remain constant even if water depth decreases.

-2010 IIIB

**B** On cloudless winter nights, the sound from a distant sound source is sometimes heard more clearly than during the daytime.

Q2 Given the condition above, from ①-④ below choose the answer that correctly indicates the relationship between air temperature in the upper sky ($t_h$) and air temperature near the ground ($t_g$), and between the speed of sound in the upper sky ($v_h$) and the speed of sound near the ground ($v_g$). $\boxed{12}$

① $t_h < t_g$, $v_h < v_g$

② $t_h < t_g$, $v_h > v_g$

③ $t_h > t_g$, $v_h < v_g$

④ $t_h > t_g$, $v_h > v_g$

-2013 1(5)

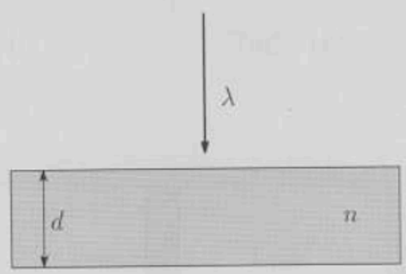
(5) As seen in Fig.1-5, light with a wavelength of $\lambda$ irradiates normally onto a thin film that has a thickness of $d$ and a refraction index of $n$ ($n > 1$). The thin film is placed in the air where the refraction index is unity. Choose the correct formula which holds when the light reflected at the upper surface of the thin film interferes constructively with the light reflected at the bottom surface. $m$ indicates either 0 or positive integer numbers.

(a) $2d/n = \left(m + \frac{1}{2}\right)\lambda$ (b) $2dn = \left(m + \frac{1}{2}\right)\lambda$

(c) $2d/n = m\lambda$ (d) $2dn = m\lambda$

(e) $2\lambda/n = \left(m + \frac{1}{2}\right)d$ (f) $2\lambda n = \left(m + \frac{1}{2}\right)d$

(g) $2\lambda/n = md$ (h) $2\lambda n = md$




-2013 5(1)

(1) The sound speed in the air at 273.15 K and 288.15 K is denoted as $T_0$ and $T_{15}$ respectively. Then the ratio $T_{15}/T_0$ is approximately

(a) 1.000 (b) 1.027 (c) 1.055

**5.** Two small speakers are driven in phase by the same oscillator. They are placed at A and B separated by 6 m as shown in Fig. 5. An observer listens to the sound from the speakers at a position along a straight line PQ which is parallel to and separated by 8 m from the straight line AB. A point O on PQ is at the same distance from A and B. The observer moves from O toward Q. The position of the observer is described by $x$. At O, the observer hears the sound of constructive interference from the two speakers. As the observer moves from O, the sound becomes weaker. At $x = 3$ m, the observer hears the minimum sound for the first time. In the questions (1) - (3) below, the speed of sound in the air is $3.4 \times 10^2$ m/s. Answer the following questions.

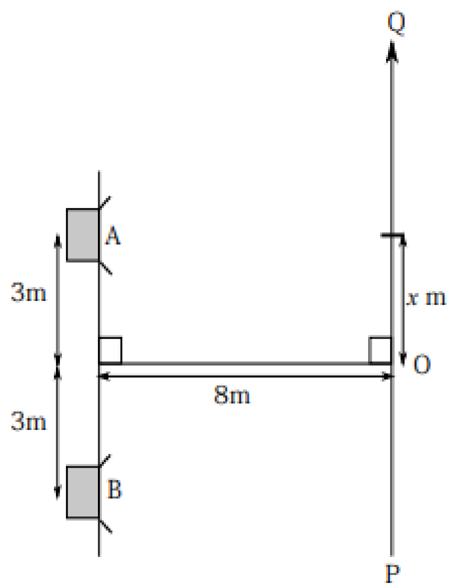



Fig. 5

**(1)** Find the wavelength of the sound wave.

(a) 8 m (b) 4 m (c) 3 m

(d) 2 m (e) 1 m

**(2)** Find the frequency of the sound wave.

(a) $4.3 \times 10^1$ Hz (b) $8.5 \times 10^1$ Hz (c) $1.1 \times 10^2$ Hz

(d) $1.7 \times 10^2$ Hz (e) $2.6 \times 10^2$ Hz (f) $3.4 \times 10^2$ Hz

(g) $6.8 \times 10^2$ Hz (h) $1.0 \times 10^3$ Hz (i) $1.4 \times 10^3$ Hz

**(3)** As the frequency of the speakers is increased, the observer at $x = 3$ m experiences an increase in the sound. Further increasing the frequency, the sound reaches its maximum and then decreases, and finally returns to its minimum again. Find the closest frequency of the sound wave when the sound reaches its minimum again.

(a) $4.3 \times 10^1$ Hz (b) $8.5 \times 10^1$ Hz (c) $1.1 \times 10^2$ Hz

(d) $1.7 \times 10^2$ Hz (e) $2.6 \times 10^2$ Hz (f) $3.4 \times 10^2$ Hz

(g) $6.8 \times 10^2$ Hz (h) $1.0 \times 10^3$ Hz (i) $1.4 \times 10^3$ Hz

**(4)** The frequency of the speakers is fixed at the value of problem (2). Find the correct description for the change of the value of $x$ at which the observer hears minimum sound when the temperature of the air increases and the speed of sound in the air changes.

(a) Increase (b) No change (c) Decrease

-2018 1(4)

**(4)** A screen is placed at a large distance $L$ from a plate where two slits $S_1$ and $S_2$ are notched. These slits are separated by a distance of $d$ as shown in Fig. 1-3. A monochromatic light from a single slit $S_0$ with a wavelength of $\lambda$ passes through the two slits $S_1$ and $S_2$. Bright and dark interference fringes appear on the screen. Find the distance from the screen center O to the third dark line.

(a) $\frac{L\lambda}{d}$ (b) $\frac{2L\lambda}{d}$ (c) $\frac{3L\lambda}{d}$

(d) $\frac{L\lambda}{2d}$ (e) $\frac{3L\lambda}{2d}$ (f) $\frac{5L\lambda}{2d}$

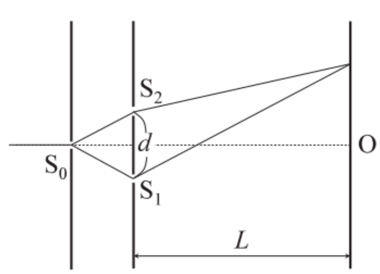



Fig. 1-3

-2018 5

5. A sound wave travels in the positive $x$-direction. As the sound wave propagates the air pressure $P$ changes above and below the normal atmospheric pressure, $P_0$. At $x = 0$, $\Delta P = P - P_0$ varies time-dependently in a sinusoidal manner as shown in Fig. 5-1. The horizontal axis represents time $t$. Answer the following questions.

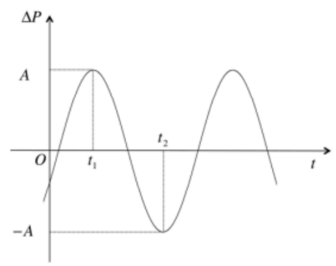



Fig. 5-1

**(1)** Find the amplitude of $\Delta P$.

(a) $A/3$ (b) $A/2$ (c) $A$

(d) $2A$ (e) $3A$ (f) $4A$

**(2)** Find the period of the oscillation.

(a) $(t_2 - t_1)/2$ (b) $t_2 - t_1$ (c) $2(t_2 - t_1)$

(d) $3(t_2 - t_1)$ (e) $4(t_2 - t_1)$ (f) $5(t_2 - t_1)$

**(3)** The speed of the sound wave is $v$. Find the wavelength of the sound wave.

(a) $2v(t_2 - t_1)$ (b) $v(t_2 - t_1)$ (c) $\frac{v(t_2 - t_1)}{2}$

(d) $\frac{v(t_2 - t_1)}{\pi}$ (e) $\frac{v(t_2 - t_1)}{2\pi}$ (f) $\frac{v(t_2 - t_1)}{4\pi}$

**(4)** A snapshot of $\Delta P$ as a function of $x$ at a certain time $t$ is shown in Fig. 5-2. Which is the highest density point?

(a) a (b) b

(c) c (d) d

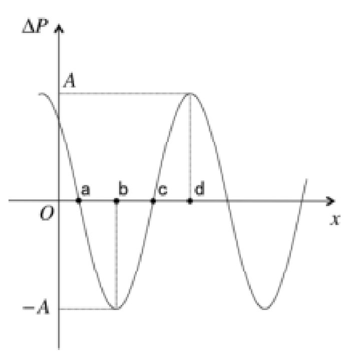



Fig. 5-2

-2019 1(4)

**(4)** A sinusoidal wave travels in the positive $x$-direction with a constant speed of 2 m/s. Figure 1-3 shows a snapshot of the wave at $t = 0$ s as a function of $x$. Find the formula for the displacement $y$ at time $t$.

| | | | | | |
|---|---|---|---|---|---|
| (a) | $2\sin\pi(x-2t)$ | (b) | $3\sin\frac{\pi}{2}(x-2t)$ | (c) | $3\sin\frac{\pi}{4}(x-2t)$ |
| (d) | $3\sin\frac{\pi}{2}(2x-t)$ | (e) | $3\sin\pi(x-t)$ | (f) | $3\sin\frac{\pi}{4}(2x-t)$ |

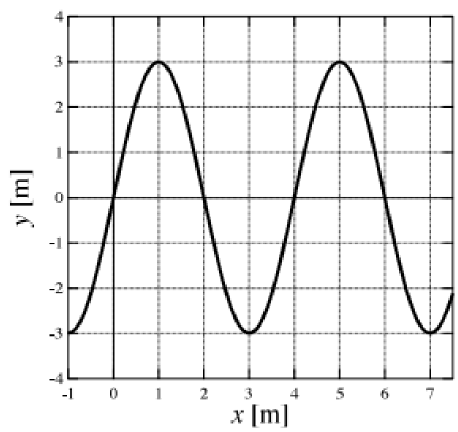



Fig. 1-3

-2019 5

5. A light ray of wavelength $\lambda$ traveling through air is incident on a flat thin soap film at an angle $\theta$ to the normal, as shown in Fig. 5. The thickness of the film is $d$. The path of the light ray is bent toward the normal in the film with the refraction angle $\phi$. We assume that the index of refraction of air is 1 and denote the index of refraction of the film by $n$. Answer the following questions.

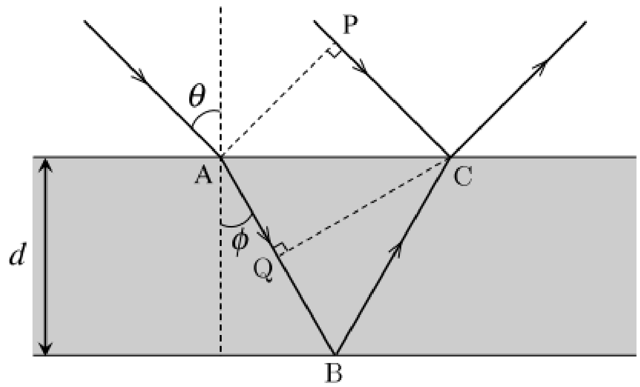



Fig. 5

**(1)** Find the wavelength of the light ray in the film.

(a) $\dfrac{\lambda}{n^2}$ (b) $\dfrac{\lambda}{n}$ (c) $\dfrac{\lambda}{\sqrt{n}}$

(d) $n\lambda$ (e) $\sqrt{n}\lambda$ (f) $\lambda$

**(2)** Find the relationship between $\theta$ and $\phi$.

(a) $\tan\theta = n\tan\phi$ (b) $\cos\theta = n^2\cos\phi$ (c) $\cos\theta = n\cos\phi$

(d) $\sin\theta = n\sin\phi$ (e) $\sin\theta = \dfrac{\sin\phi}{n}$ (f) $\cos\theta = \dfrac{\cos\phi}{n}$

**(3)** If a certain condition is satisfied, constructive interference occurs between the light reflected at C and the light traveling through the path ABC. The condition is expressed using a non-negative integer, $m$. Find this condition.

(a) $\mathrm{QB} + \mathrm{BC} = \left(m + \dfrac{1}{2}\right)\dfrac{\lambda}{n}$ (b) $\mathrm{AB} + \mathrm{PC} = m\lambda$

(c) $\mathrm{QB} + \mathrm{BC} = m\lambda$ (d) $\mathrm{AB} + \mathrm{BC} = \left(m + \dfrac{1}{2}\right)\dfrac{\lambda}{n}$

**(4)** Find the expression of $d$ when the condition in (3) is satisfied, and constructive interference occurs.

(a) $\dfrac{m\lambda}{2n\cos\phi}$ (b) $\dfrac{(2m+1)\lambda}{4n\cos\phi}$ (c) $\dfrac{(2m+1)\lambda}{4n\sin\phi}$

(d) $\dfrac{(2m+1)\lambda}{4\cos\phi}$ (e) $\dfrac{m\lambda}{4n\sin\phi}$ (f) $\dfrac{m\lambda}{2\cos\phi}$

-2020 1(4)

**(4)** A sinusoidal wave travels in the positive $x$-direction with a constant speed of 0.30 m/s. Figure 1-3 shows a snapshot of the wave at $t = 0$ s as a function of $x$. The wave is reflected at a fixed end at $x = 0.90$ m. Find an appropriate graph for the wave at $t = 2.0$ s from Fig. 1-4.

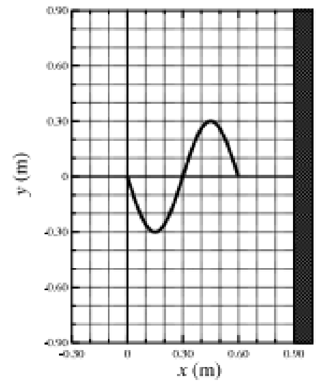



Fig. 1-3

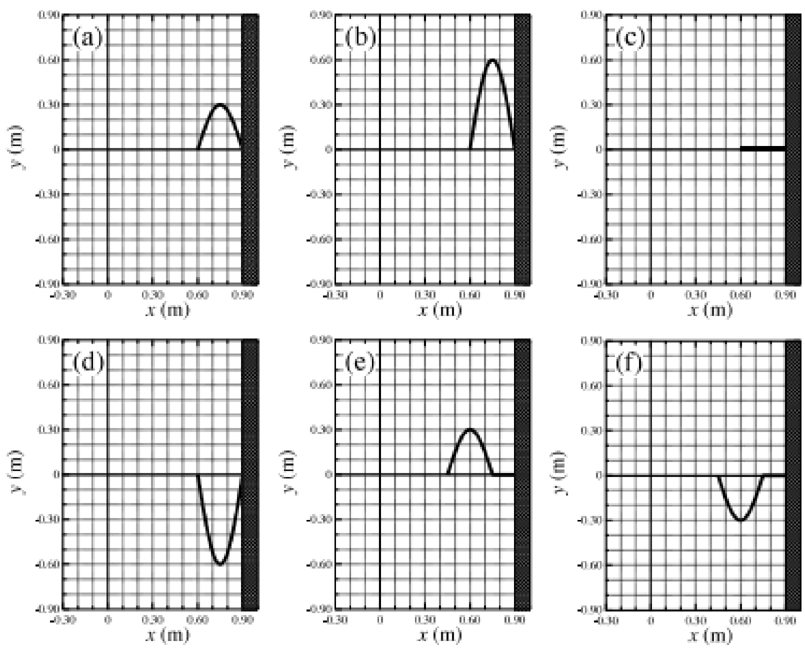



Fig. 1-4

-2020 5(1)

5. Two loudspeakers $S_1$ and $S_2$ are placed on a plane as shown in Fig. 5. The $x$ and $y$ axes are defined as shown in the figure, and an observer is located at the origin O of the $x-y$ plane. The speed of the sound is constant and denoted by $v$. The distances $\overline{OS_1}$ and $\overline{OS_2}$ are denoted by $d_1$ and $d_2$, respectively.

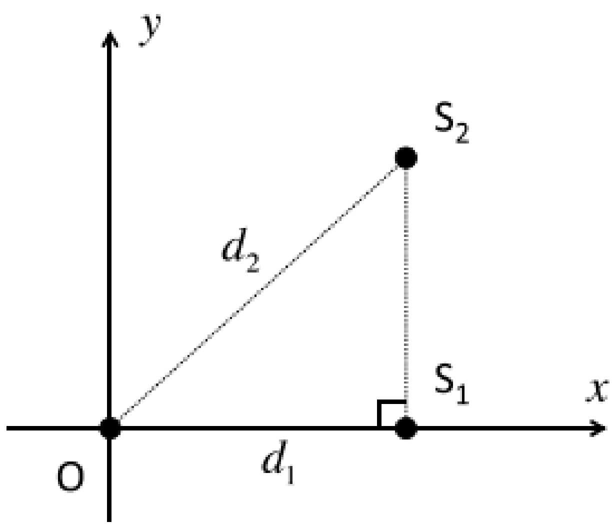



Fig. 5

Initially, both speakers are at rest and the $x$ coordinates of $S_1$ and $S_2$ are the same. They emit sound waves with the same frequency $f$ and the same amplitude. There is no phase difference between their sound waves.

**(1)** Starting from a frequency, which is lower than $v/(d_1+d_2)$, the frequency is increased gradually. At a certain frequency, the observer first heard the sound with maximum intensity. Find the formula for this frequency.

(a) $\dfrac{v}{d_1+d_2}$ (b) $\dfrac{v}{d_1}$ (c) $\dfrac{v}{d_2}$

(d) $\dfrac{v}{\sqrt{d_2^2-d_1^2}}$ (e) $\dfrac{v}{|d_1-d_2|}$ (f) $\dfrac{v}{\sqrt{d_1^2+d_2^2}}$

## (2) Stationary Wave

-2008 5

5 It is assumed that standing water waves are generated in a channel of two vertical parallel side walls (separated by distance $L$) with mean water depth $h$, where water waves are reflected at the walls and the channel length is sufficiently large compared with $L$. Assume that the frequency of the standing waves is the lowest of the possible values.

(1) The number of observed nodes in the channel (including nodes on the walls if any) is

(a) 0 (b) 1 (c) 2 (d) 3 (e) 4

(2) The number of observed antinodes in the channel (including antinodes on the walls if any) is

(a) 0 (b) 1 (c) 2 (d) 3 (e) 4

(3) The wave length of the corresponding water wave is

(a) $L$ (b) $2L$ (c) $3L$ (d) $4L$

**5.** A glass tube is lying horizontally with the left end open and the right end closed using a movable piston. A speaker with a frequency of $f$ is placed on the left-hand side of the tube, as shown in Fig. 5. The position of the piston is expressed by the variable $x$ which measures the distance from the left end of the tube. Moving the piston slowly from the position at $x = 0$ to the right while the speaker is on, a large sound is heard for the first time at $x = l$. Moving the piston further, a large sound is heard for the second time at $x = 3l$. Answer the following questions.

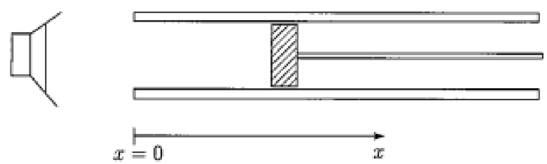



Fig. 5

(1) A large sound is heard because a stationary wave is formed inside the glass tube. Indicate the wave length of the stationary wave.

| | | |
|---|---|---|
| (a) $\frac{1}{4}l$ | (b) $\frac{1}{3}l$ | (c) $\frac{1}{2}l$ |
| (d) $l$ | (e) $\frac{3}{2}l$ | (f) $2l$ |
| (g) $\frac{5}{2}l$ | (h) $3l$ | (i) $4l$ |

(2) Find the expression of the speed of sound.

| | | |
|---|---|---|
| (a) $\frac{1}{2}fl$ | (b) $\frac{f}{2l}$ | (c) $\frac{l}{2f}$ |
| (d) $fl$ | (e) $\frac{f}{l}$ | (f) $\frac{l}{f}$ |
| (g) $2fl$ | (h) $\frac{2f}{l}$ | (i) $\frac{2l}{f}$ |
| (j) $4fl$ | (k) $\frac{4f}{l}$ | (l) $\frac{4l}{f}$ |

(3) Indicate the distance from the left end of the glass tube to the position where the time variation of the air density is at a maximum when the large sound is heard for the second time.

| | | |
|---|---|---|
| (a) $\frac{1}{2}l$ | (b) $l$ | (c) $\frac{3}{2}l$ |
| (d) $2l$ | (e) $\frac{5}{2}l$ | |

(4) How does the value $l$ change when the temperature rises?

| | | |
|---|---|---|
| (a) It increases | (b) No change | (c) It decreases |

(5) Increase the frequency of the speaker from $f$ while the position of the piston is fixed at $x = 3l$. Indicate the frequency when a large sound would next be heard.

| | | |
|---|---|---|
| (a) $\frac{1}{5}f$ | (b) $\frac{1}{3}f$ | (c) $\frac{1}{2}f$ |
| (d) $f$ | (e) $\frac{4}{3}f$ | (f) $\frac{3}{2}f$ |
| (g) $\frac{5}{3}f$ | (h) $2f$ | (i) $\frac{5}{2}f$ |

-2019 1(5)

**(5)** A movable piston is fitted in a tube as shown in Fig. 1-4. A speaker near the open end of the tube emits sound waves with a frequency of 555 Hz. When the piston moves from the left end to the right, the first and second resonances are produced at distances 14 cm and 44 cm from the open end, respectively. Find the speed of the sound waves.

| | | | | | |
|---|---|---|---|---|---|
| (a) | 344 m/s | (b) | 338 m/s | (c) | 333 m/s |
| (d) | 328 m/s | (e) | 322 m/s | (f) | 311 m/s |

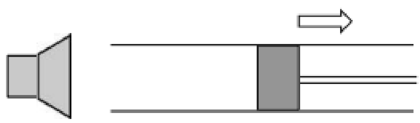


Fig. 1-4

## (3) Light

-2009 1(5)

(5) A plane mirror is placed horizontally at the bottom of a transparent liquid of 10 cm depth. When one looks at the image of a small object floating at the surface of the liquid right above the object, the image is seen at 14 cm below the surface of the liquid. Find the approximate value of the index of refraction of the liquid.

(a) 0.63 (b) 0.80 (c) 1.43 (d) 1.60

-2010 IIIC

**C** As shown in Figures 1 and 2 below, light from a white light source passes through a slit and then passes through a prism (Fig. 1) or a diffraction grating (Fig. 2). As a result, a band of continuously varying colors appears between points a and b on the screen in Fig. 1 and between points c and d on the screen in Fig. 2.

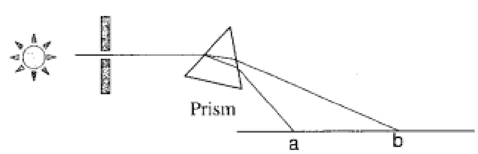



Figure 1 Dispersion of light by a prism

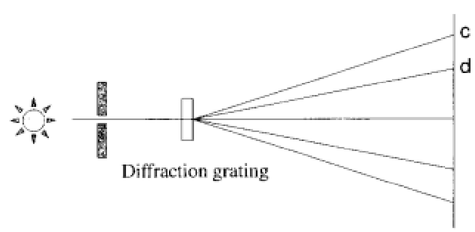



Figure 2 Dispersion of light by a diffraction grating

Q3 In the two experiments above, what color of light is observed at the edges of the colored bands on the screens (points a, b, and c, d)? From ①-④ below choose the correct combination. **13**

| | a | b | c | d |
|---|---|---|---|---|
| ① | red | violet | red | violet |
| ② | violet | red | violet | red |
| ③ | red | violet | violet | red |
| ④ | violet | red | red | violet |

-2012 1(4)

(4) Object 2 with an index of refraction $n_2$ is placed on object 1 with an index of refraction $n_1$, as shown in Fig. 1-4. $n_2 > n_1$ is assumed. When a light is incident on object 2 at point A with the incidence angle $\theta$, there occurs total internal reflection at point B. Find the relationship fulfilled by $\theta$, $n_1$, and $n_2$.

(a) $\sin\theta < \frac{n_1}{n_2}$ (b) $\sin\theta < \frac{n_2}{n_1}$ (c) $\sin\theta < \sqrt{n_2 - n_1}$
(d) $\sin\theta < \sqrt{n_2^2 - n_1^2}$ (e) $\cos\theta < \frac{n_1}{n_2}$ (f) $\cos\theta < \frac{n_2}{n_1}$
(g) $\cos\theta < \sqrt{n_2 - n_1}$ (h) $\cos\theta < \sqrt{n_2^2 - n_1^2}$

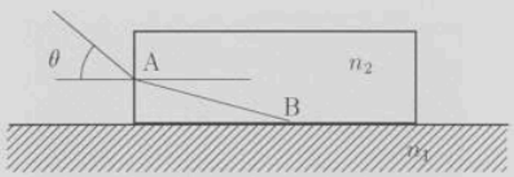



Fig. 1-4

-2014 1(5)

(5) Figure 1-5 shows light entering a water droplet with radius $r$ in the air. The light ray enters the droplet at $P$ and the point $O$ is the center of the droplet. Let $n$ be the index of refraction for water. Find the formula for the angle of refraction $\phi$.

(a) $\cos\phi = \frac{nr}{h}$ (b) $\cos\phi = \frac{h}{nr}$ (c) $\cos\phi = \frac{nh}{r}$
(d) $\sin\phi = \frac{nh}{r}$ (e) $\sin\phi = \frac{nr}{h}$ (f) $\sin\phi = \frac{h}{nr}$

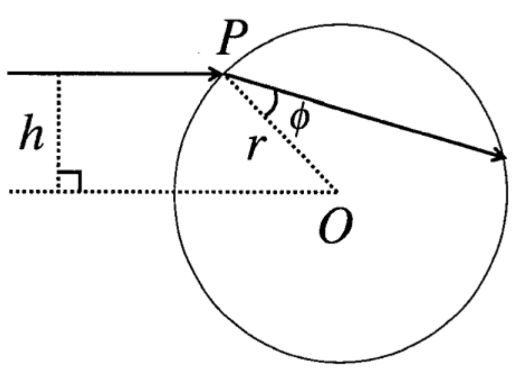



Fig. 1-5

-2015 1(5)

**(5)** A light ray travels through two parallel slabs having different indices of refraction $n_1$ and $n_2$ as shown in Fig. 1-3. Which of the following choices is true regarding the relative size of indices of refraction?

(a) $n_1 > n_2$ (b) $n_1 < n_2$ (c) $n_1 = n_2$

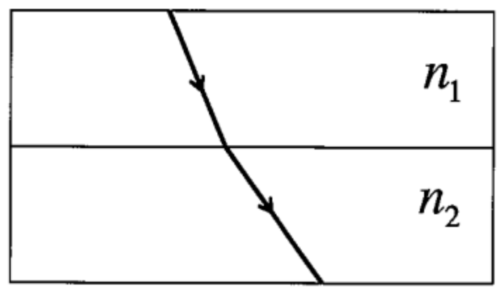



Fig. 1-3

-2016 5

**5.** As shown in the figure, rectangular glass blocks with an index of refraction of $n_2$ are attached to the upper and lower planes of a rectangular glass block with an index of refraction of $n_1$. A light ray enters the glass block at point A from the vacuum in the incident angle $\theta$. The light ray reaches point B after repeating total internal reflections in the block. The speed of light in the vacuum is denoted as $c$. Answer the following questions.

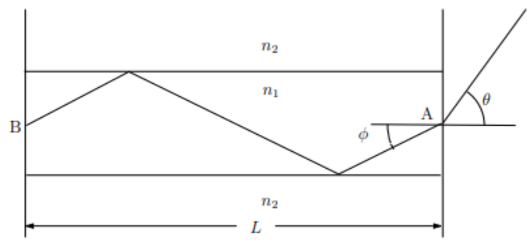



Fig. 5

**(1)** An angle of refraction of the light ray entered at point A is denoted as $\phi$. Find the correct expression for $\sin\phi$.

(a) $n_1 \sin\theta$ (b) $n_1 \cos\theta$ (c) $\frac{\sin\theta}{n_1}$

(d) $\frac{\cos\theta}{n_1}$ (e) $\frac{n_1}{\sin\theta}$ (f) $\frac{n_1}{\cos\theta}$

(g) $\frac{1}{n_1 \cos\theta}$ (h) $\frac{1}{n_1 \sin\theta}$

**(2)** Find the condition that $n_1$ and $n_2$ should satisfy in order that total internal refractions take place in the upper and lower planes of the glass block.

(a) $n_1 n_2 > 1$ (b) $n_1 n_2 < 1$ (c) $\frac{n_1}{n_2} > 1$

(d) $\frac{n_1}{n_2} < 1$

**(3)** Find the condition that $\phi$ should satisfy in order that total internal reflections take place in the upper and lower panels of the glass block.

(a) $\sin\phi > \frac{n_2}{n_1}$ (b) $\sin\phi > n_1 n_2$ (c) $\sin\phi > \frac{n_1}{n_2}$

(d) $\sin\phi > \frac{1}{n_1 n_2}$ (e) $\cos\phi > \frac{n_2}{n_1}$ (f) $\cos\phi > n_2 n_1$

(g) $\cos\phi > \frac{n_1}{n_2}$ (h) $\cos\phi > \frac{1}{n_1 n_2}$

**(4)** Find the time at which the light entering at point A reaches point B penetrating through the glass block. The distance between the two planes including points A and B is denoted as $L$.

(a) $\frac{Ln_1}{c\cos\phi}$ (b) $\frac{L}{cn_1 \cos\phi}$ (c) $\frac{Ln_1 \cos\phi}{c}$

(d) $\frac{L\cos\phi}{n_1 c}$ (e) $\frac{Ln_1}{c\sin\phi}$ (f) $\frac{L}{cn_1 \sin\phi}$

(g) $\frac{Ln_1 \sin\phi}{c}$ (h) $\frac{L\sin\phi}{n_1 c}$

-2017 1(5)

**(5)** A person looking into an empty container is able to see the far edge of the container's bottom surface as shown in Fig. 1-4 (a). The height of the container is $h$ and its width is $d$. When the container is completely filled with a fluid of index of refraction $n$, the person viewing it from the same angle $\theta$ shown in Fig. 1-4 (a) and (b) can see the center of a coin placed on the bottom as shown in Fig. 1-4 (b). The distance between the center of the coin and the far edge is $x$. Find the formula for the refractive index $n$.

(a) $\dfrac{d-x}{d}$ (b) $\sqrt{\dfrac{h^2+(d-x)^2}{h^2+d^2}}$

(c) $\dfrac{d-x}{d}\sqrt{\dfrac{h^2+d^2}{h^2+(d-x)^2}}$ (d) $\dfrac{d}{d-x}\sqrt{\dfrac{h^2+(d-x)^2}{h^2+d^2}}$

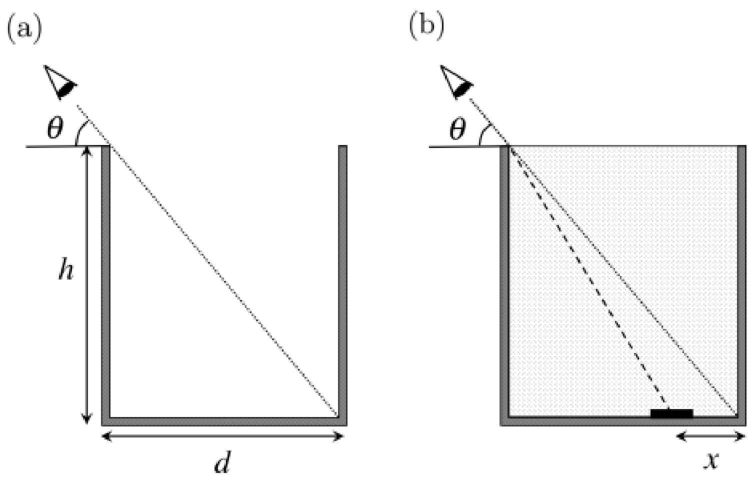



Fig. 1-4

(4) Doppler Effect

-2006 5

An anchored ship is undergoing pitching motion (period T) and generating water waves of speed bT (where b>0 is a constant) in a river with the water stationary. By that time, the ship is moving slowly with a speed V0 whereas the period of the pitching motion remains unchanged.

(1) First, select the suitable value of $\frac{\text{The wavelength in front of the ship}}{\text{The wavelength when the ship is stationary}}$ .

(a) $\frac{V_0}{bT}$ (b) 1 (c) $\frac{bT-V_0}{bT}$

(d) $\frac{V_0-bT}{bT}$ (e) $\frac{bT+V_0}{bT}$

(2) Next, select the suitable value of $\frac{\text{The wavelength at the back of the ship}}{\text{The wavelength when the ship is stationary}}$ .

(a) $\frac{V_0}{bT}$ (b) 1 (c) $\frac{bT-V_0}{bT}$

(d) $\frac{V_0-bT}{bT}$ (e) $\frac{bT+V_0}{bT}$

-2007 5

5 An ambulance is running on an expressway at a speed of 60 km/h from east to west (from $A$ to $B$) as shown in Fig.7 with a siren of 880 Hz. Let the frequencies of the siren sound detected by an observer located at a point $O$ be $\nu_A$ and $\nu_B$ when the vehicle just passes point $A$ and point $B$ respectively. Point $C$ is just to the north of $O$ and $\overline{OC}=\overline{AC}=\overline{BC}=100\,\text{m}$. Here the sound velocity in calm air is 340 m/s.

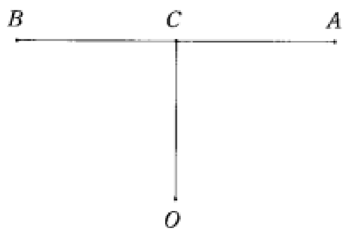



Fig. 7 Configuration

(1) In the case of calm weather (no wind), which is the approximate value of $\nu_A/\nu_B-1$?

(a) $-0.10$ (b) $-0.07$ (c) 0.0 (d) 0.07 (e) 0.10

(2) In the case of an east wind of 5 m/s (18 km/h), which is the approximate value of $\nu_A/\nu_B-1$?

(a) 0.0 (b) 0.03 (c) 0.07 (d) 0.10 (e) 0.13

(3) In the case of a north wind of 5 m/s (18 km/h), which is the approximate value of $\nu_A/\nu_B-1$?

(a) $-0.03$ (b) 0.0 (c) 0.03 (d) 0.07 (e) 0.10

-2008 1(4)

(4) When a train running at a speed of 72 km/h approaches a crossing signal, a passenger in the train hears the siren at 720Hz. What frequency does the passenger detect after the train passes the crossing signal? Take the speed of sound in air to be 340 m/s.

(a) 640Hz (b) 680Hz (c) 720Hz (d) 765Hz (e) 810Hz

-2009 5

5 An ambulance is running along a straight main road at a speed of $U$ (m/s) with a siren of frequency $\nu$ (Hz). It is assumed that a wind is blowing at speed $W$ (m/s) in the same direction as that of the ambulance. Let $\nu_+$ (Hz) and $\nu_-$ (Hz) be the frequency of the siren sound detected at the road side in the case of approach of the ambulance and its leaving respectively. Let $c$ (m/s) be the sound velocity in air. In the following three categories, choose the appropriate one in each.

(1) (a) always $c > U + W$. (b) always $c < U + W$. (c) neither (a) nor (b)

(2) (a) $\nu_+ - \nu = 0$, (b) $\nu_+ - \nu = \nu \frac{U}{c-U}$, (c) $\nu_+ - \nu = \nu \frac{U}{c+W-U}$,

(d) $\nu_+ - \nu = \nu \frac{U}{c-W-U}$, (e) $\nu_+ - \nu = \nu \frac{U}{c+U}$

(3) (a) $\nu_- - \nu = 0$, (b) $\nu_- - \nu = -\nu \frac{U}{c+U}$, (c) $\nu_- - \nu = -\nu \frac{U}{c-W+U}$,

(d) $\nu_- - \nu = -\nu \frac{U}{c+W+U}$, (e) $\nu_- - \nu = -\nu \frac{U}{c-U}$

-2012 5

5 An electric fan in room at 25 °C is producing a small sound in a swinging mode from its frame. The source of sound is assumed to be coming with the interaction of flow and the guarding frame wire. The emitted sound frequency is assumed to be independent of the swinging angle. Maximum instantaneous swinging angular velocity is assumed to be 1 rad/s, and sound velocity in stationary air at 25 °C is 344 m/s.

In case of 3 m/s of emitted wind speed and of 300 Hz of emitted fluid dynamic frequency, the detected sound frequency by a person just in front of the fan is

(1) (a) exactly constant with time,

(b) strongly varying ( more than 1 % ),

(c) weakly varying ( less than 1 % ).

The highest or constant detected frequency by the person is

(2) (a) more than 307 Hz,

(b) approximately 306 Hz,

(c) approximately 303 Hz,

(d) approximately 300 Hz,

(e) approximately 297 Hz.

The detected frequency by a person standing far away is

(3) (a) nearly constant with time,

(b) strongly varying ( more than 1 % ),

(c) weakly varying ( less than 1 % ).

-2013 5(2)(3)

The sound speed is approximately 340.2m/s at 288.15K.

**5** An ambulance is approaching crossroads with a constant speed of 60 km/h.

(2) The siren sound produced at the ambulance itself is assumed to be 440 Hz. Then the wavelength emitted forward at 288.15 K is approximately

(a) 0.71 m (b) 0.73 m (c) 0.77 m (d) 0.83 m

(3) The siren sound frequency detected by a person standing at the crossroads is approximately

(a) 419 Hz (b) 440 Hz (c) 462 Hz (d) 463 Hz (e) other

-2014 5

**5.** There are an observer A, a speaker B which emits sound waves of frequency $f$, a wall D which reflects sound waves, and an observer C who is in front of the wall D and always moves with the wall D, as shown in Fig. 5. The speed of sound is denoted as $V$. Find the answer to the following questions from the list of possible answers shown below and write the correct letter on the answer sheet.

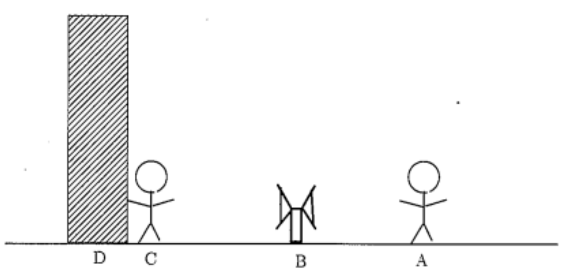



Fig. 5

**(1)** Observer A, the wall D, and observer C are at rest. The speaker B moves to the right with a speed of $v$. Find the frequency of the sound which observer A hears directly from the speaker B.

**(2)** Under the same conditions as indicated in question (1), find the frequency of the sound which observer A hears and which is reflected at the wall D.

**(3)** Under the same conditions as indicated in question (1), find the number of beats per second that observer A hears.

**(4)** Observer A and the speaker B are at rest. The wall D and observer C moves to the right with a constant speed $v$. Find the frequency that observer C hears.

**(5)** Under the same conditions as indicated in question (4), find the frequency of the sound which observer A hears and which is reflected at the wall D.

| | |
|---|---|
| (a) $f\frac{V+v}{V}$ | (b) $f\frac{V-v}{V}$ |
| (c) $f\frac{V}{V+v}$ | (d) $f\frac{V}{V-v}$ |
| (e) $f\frac{V+v}{V-v}$ | (f) $f\frac{V-v}{V+v}$ |
| (g) $f\frac{2Vv}{V^2-v^2}$ | (h) $f\frac{Vv}{V^2-v^2}$ |
| (i) $f\frac{V^2-v^2}{2Vv}$ | (j) $f\frac{V^2-v^2}{Vv}$ |
| (k) $f\frac{V^2+v^2}{V^2-v^2}$ | (l) $f\frac{V^2-v^2}{V^2+v^2}$ |

-2018 1(5)

**(5)** An observer is moving away at a constant speed of 5 m/s from a speaker which is emitting sound waves at a frequency of 660 Hz. The sound speed is 330 m/s. When the sound source S and the observation point O are located as shown in Fig. 1-4, what frequency of the sound will the observer hear?

| | | |
|---|---|---|
| (a) 650 Hz | (b) 652 Hz | (c) 654 Hz |
| (d) 660 Hz | (e) 666 Hz | (f) 668 Hz |

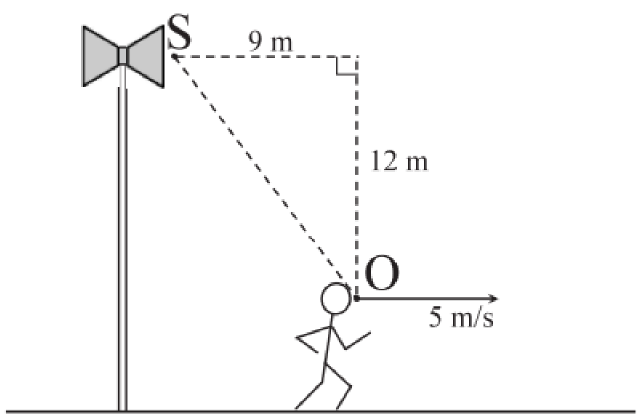



Fig. 1-4

-2020 5(2)-(4)

5. Two loudspeakers $S_1$ and $S_2$ are placed on a plane as shown in Fig. 5. The $x$ and $y$ axes are defined as shown in the figure, and an observer is located at the origin O of the $x-y$ plane. The speed of the sound is constant and denoted by $v$. The distances $\overline{OS_1}$ and $\overline{OS_2}$ are denoted by $d_1$ and $d_2$, respectively.

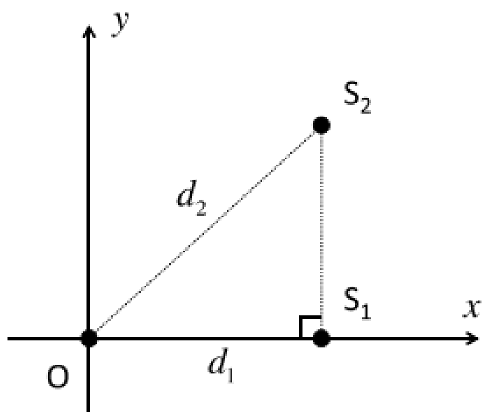



Fig. 5

Initially, both speakers are at rest and the $x$ coordinates of $S_1$ and $S_2$ are the same. They emit sound waves with the same frequency $f$ and the same amplitude. There is no phase difference between their sound waves.

Next, speaker $S_1$ starts to move at a constant speed $u$, which is much smaller than $v$, in the direction of the positive $x$ axis.

**(2)** Find the frequency of speaker $S_1$ heard by the observer.

(a) $\frac{v}{v+u}f$ (b) $\frac{u}{v+u}f$ (c) $\frac{v+u}{v}f$

(d) $\frac{u}{v}f$ (e) $f$ (f) $\frac{v-u}{v}f$

**(3)** A beat is heard by the observer due to the interference between the sound waves emitted by speakers $S_1$ and $S_2$. Find the period of the beat .

(a) $\frac{v+u}{vf}$ (b) $\frac{v}{uf}$ (c) $\frac{v+u}{uf}$

(d) $\frac{1}{f}$ (e) $\frac{v+u}{(v-u)f}$ (f) $\frac{v-u}{(v+u)f}$

Speaker $S_2$ starts to move as well at a constant speed $u$ in the direction parallel to the positive $x$ axis. A beat is heard by the observer at a different frequency.

**(4)** Find the frequency of the beat.

(a) $\frac{(d_2-d_1)\,vf}{d_2v+d_1u}$ (b) $\frac{(d_2-d_1)\,uf}{d_2v+d_1u}$ (c) $f$

(d) $\frac{(d_2-d_1)\,uvf}{(v+u)\,(d_2v+d_1u)}$ (e) $\frac{(v+u)\,f}{(d_2-d_1)\,uv}$ (f) $\frac{(d_2-d_1)\,vf}{(v+u)\,d_1}$