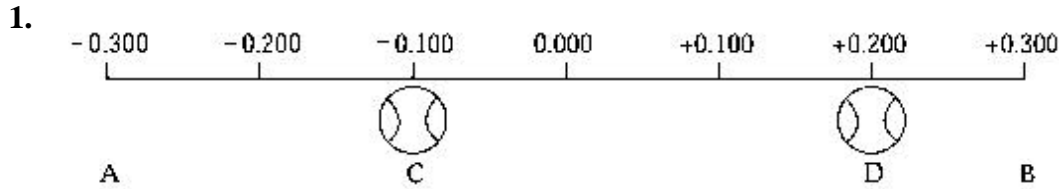


**Multiple choice questions [70 points]**

Answer all of the following questions. Read each question carefully. **Fill the correct bubble on your scantron sheet.** All questions are worth the same amount of points. Each question has exactly one correct answer.

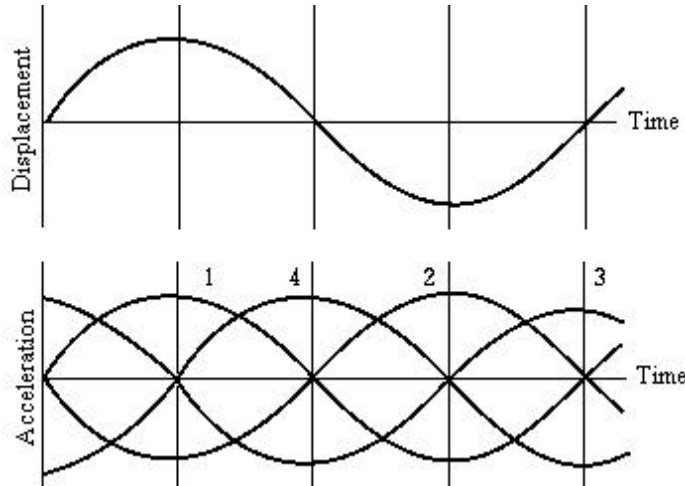


A ball moves with simple harmonic motion between points A and B (distances are in meters). The magnitude of the acceleration of the ball at point C is  $5.00 \text{ m/s}^2$ . What is the magnitude of the acceleration of the ball at point D?

(Hint: recall that for harmonic motion  $\ddot{x} + \omega^2 x = 0$ )

- A.  $1.25 \text{ m/s}^2$
  - B.  $2.50 \text{ m/s}^2$
  - C.  $5.00 \text{ m/s}^2$
  - D.  $7.50 \text{ m/s}^2$
  - E.  $10.0 \text{ m/s}^2$
- E.** At C,  $5 + \omega^2(-0.1) = 0 \Rightarrow \omega^2 = \sqrt{50} \text{ rad/s}$   
 At D,  $\ddot{x} = -0.2 \times 50 = 10 \text{ m/s}^2$

2.



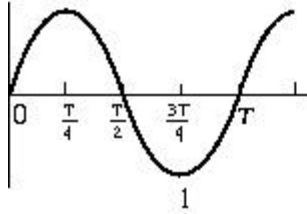
The top graph represents the variation of displacement with time for a particle executing simple harmonic motion. Which curve in the bottom graph represents the variation of acceleration with time for the same particle?

- A. 1
- B. 2**  
 $x \propto \sin(\omega t) \Rightarrow \ddot{x} \propto -\sin(\omega t)$
- C. 3
- D. 4
- E. None of these is correct

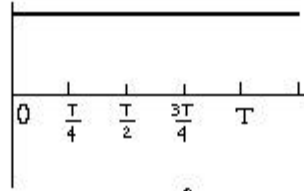
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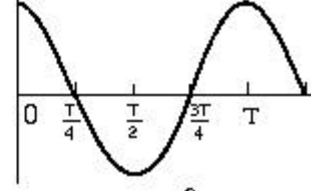
3.



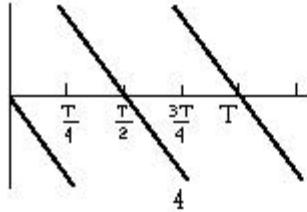
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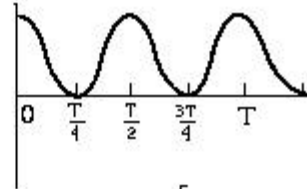
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5

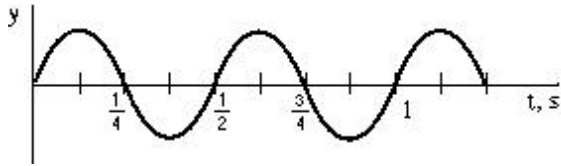
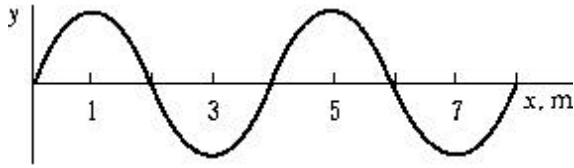
The kinetic energy of a body executing simple harmonic motion is plotted against time expressed in terms of the period  $T$ . At  $t = 0$ , the displacement is zero. Which of the graphs most closely represents these conditions?

- A. 1
- B. 2
- C. 3
- D. 4
- E. 5**

$$x = A \sin \omega t \Rightarrow KE \propto \cos^2(\omega t)$$

4. Sound travels at 340 m/s in air and 1500 m/s in water. A sound of 256 Hz is made under water. In the air,
- A.** the frequency remains the same but the wavelength is shorter. Recall the tutorial on reflection and transmission.
  - B. the frequency is higher but the wavelength stays the same.
  - C. the frequency is lower but the wavelength is longer.
  - D. the frequency is lower and the wavelength is shorter.
  - E. both the frequency and the wavelength remain the same.

5.



A wave is traveling with a speed  $v$  along the  $x$  axis in the positive direction. The upper graph shows the displacement  $y$  versus the distance  $x$  for a given instant of time. The lower graph shows the displacement  $y$  versus the time  $t$  for any given point  $x$ . From the information in the graphs, what is the wave speed  $v$ ?

- 8.0 m/s  
**A.**  $v = \frac{\lambda}{T} = \frac{4\text{m}}{0.5\text{s}}$   
**B.** 4.0 m/s  
**C.** 6.0 m/s  
**D.** There is not enough information to solve the problem.  
**E.** None of these is correct.

6. We can hear sounds that are produced around a corner but cannot see light that is produced around a corner because
- A.** light travels only in straight lines whereas sound can travel in a curved path.  
**B.** sound has more energy than light.  
**C.** sound has shorter wavelengths than light.  
**D.** sound has longer wavelengths than light.  
**E.** None of these is correct.

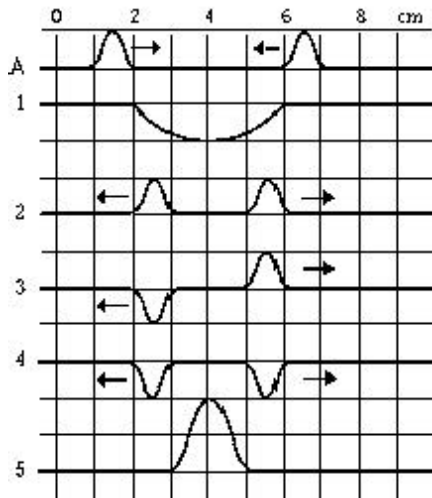
7. A passenger car traveling due east at 53.6 m/s passes a truck traveling due east at 13.4 m/s. After the car passes, the horn on the truck is blown at a frequency of 350 Hz. The speed of sound in air is 335 m/s. The frequency heard by the driver of the car is

- A. 290 Hz
- 306 Hz

**B**  $f = \frac{c - v_{car}}{c - v_{truck}} f_0 = \frac{335 - 53.6}{335 - 13.4} \times 350$

- C. 314 Hz
- D. 400 Hz
- E. 434 Hz

8.

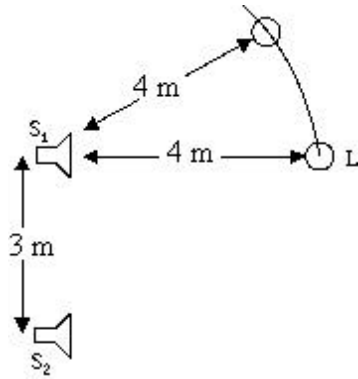


Sketch A shows two identical pulses traveling in opposite directions along a string, each with a velocity of 1.0 cm/s. After 4.0 s, the string will look like which of the other sketches?

- A. 1
- 2
- B** Move each pulse by 4 squares in its direction of motion and apply the principle of superposition.
- C. 3
- D. 4
- E. 5

Name: \_\_\_\_\_ Total Points: \_\_\_\_\_  
(Last) (First)

9.



Two loudspeakers  $S_1$  and  $S_2$ , 3.0 m apart, emit the same single-frequency tone in phase at the speakers. A listener directly in front of speaker  $S_1$  notices that the intensity is a minimum when she is 4.0 m from that speaker (see figure). The listener now walks around speaker  $S_1$  in an arc of a circle, staying 4.0 m from that speaker but increasing her distance from the other speaker. How far is she from speaker  $S_2$  when she notices the first maximum in the sound intensity?

Hint:

at the minimum,  $\Delta D_{\min} = (2k+1)\lambda/2$  for some integer  $k$ .

at the next maximum,  $\Delta D_{\max} = \Delta D_{\min} + \lambda/2$ .

Try the different cases below and see if you can find an integer  $k$  given the two equations above.

- A. 4.5 m
- B. 5 m
- C. 5.5 m
- 6 m

At the minimum  $\Delta D_{\min} = 5\text{m} - 4\text{m} = 1\text{m} = (2k+1)\lambda/2$  ( $k$  is an integer)

The next maximum must be such that  $\Delta D_{\max} = \Delta D_{\min} + \lambda/2$  (since at a max, the path difference is a multiple of the wavelength)

Also  $\Delta D_{\max} = d_2 - 4\text{m}$  where  $d_2$  is the distance to  $S_2$

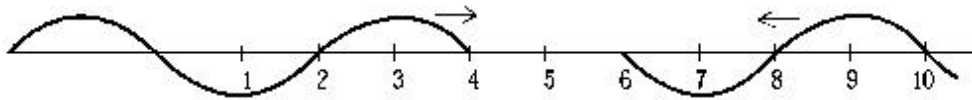
**D.**  $d_2$  must be greater than 5m since the listener walks away from  $S_2$ .  
 If  $d_2 = 5.5\text{m}$ ,  $\lambda = 1\text{m}$ . It is not possible since there is no  $k$  such that  $1 = (2k+1)/2$

If  $d_2 = 6.5\text{m}$ ,  $\lambda = 3\text{m}$ . It is not possible since there is no  $k$  such that  $1 = (2k+1)3/2$

If  $d_2 = 6\text{m}$ ,  $\lambda = 2\text{m}$ . Take  $k=0$ , so that  $1 = (2k+1)2/2$

- E. 6.5 m

10.



The two progressive waves are moving with equal velocities and wavelengths but in opposite directions in the string. Which of the following gives all of the points that will be nodes in the resultant standing wave?

- A. 2, 4, 6, 8, and 10
- B. 2, 6, and 10
- C. 1, 5, and 9
- D. 3 and 7
- 1, 3, 5, 7, and 9

**E.** Draw each wave at several later times and apply the principle of superposition. At any of the points 1, 3, 5, 7 and 9, if there is a crest from one wave there is a trough from the other wave.

11. The third harmonic of a tube closed at one end is 735 Hz. If the speed of sound in air is 335 m/s, what is the length of the tube?

- A. 11.6 cm
- B. 22.9 cm
- 34.2 cm

**C.** In a tube closed at one end:  $L = n\lambda/4$  with  $n=1,3,5,\dots$

$$3^{\text{rd}} \text{ harmonic: } L = \frac{3}{4} \times \lambda = 0.75 \times \frac{335}{735}$$

- D. 45.7 cm
- E. 57.3 cm

12. An electromagnetic wave of intensity  $100 \text{ W/m}^2$  is incident normally on a square white card whose sides are  $25 \text{ cm}$ . If the card reflects all of the radiation incident on it, the approximate force exerted by the wave on this card is

A.  $64 \text{ nN}$

B.  $16 \text{ nN}$

$42 \text{ nN}$

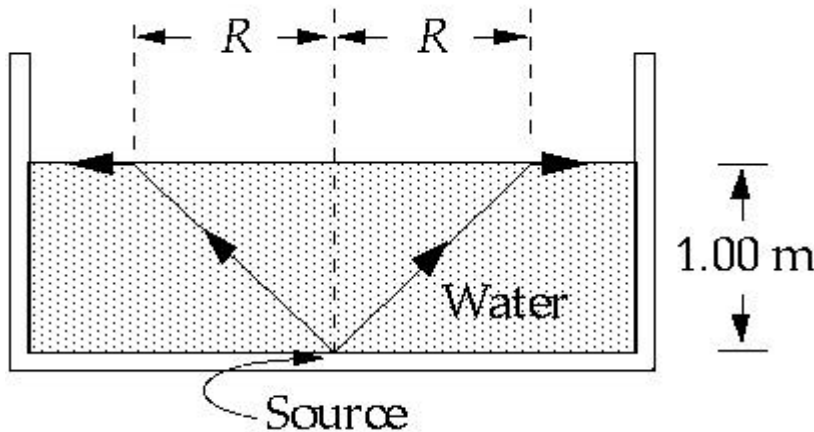
**C.** 
$$p = \frac{2I}{c} = \frac{2 \times 100}{3 \times 10^8} = 6.67 \times 10^{-7} \text{ Pa}$$

$$F = pA = 6.67 \times 10^{-7} \times (0.25)^2 = 41.7 \times 10^{-9} \text{ N}$$

D.  $10 \text{ nN}$

E. None of these is correct.

13.



You place a point source of light at the bottom of a pool of water  $1.00 \text{ m}$  deep. The source emits rays upward in all directions. You notice that a circle of light is formed by the rays that are refracted into the air and that the rays outside of this circle are reflected back into the water. The index of refraction of water is  $1.33$ . The radius  $R$  of the circle at the surface of the water is approximately

A.  $0.75 \text{ m}$

B.  $1.00 \text{ m}$

$1.14 \text{ m}$

**C.**  $n \sin q = 1 \Rightarrow q = 48.8^\circ$

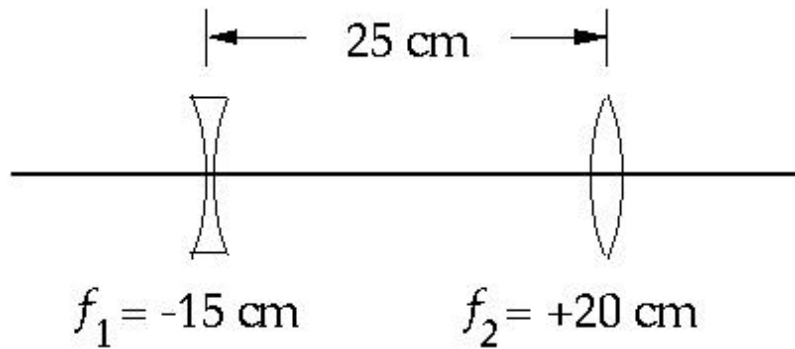
$$R = 1.00 \text{ m} \times \tan q = 1.14 \text{ m}$$

D.  $1.33 \text{ m}$

E. infinite



15.



A negative (=divergent) lens with a focal length of  $-15 \text{ cm}$  is  $25 \text{ cm}$  from a positive (=convergent) lens with a focal length of  $+20 \text{ cm}$  on the same axis. Parallel light from the left is incident on the negative lens. The image formed by the positive lens is

real and  $40 \text{ cm}$  from the positive lens.

The negative lens creates a virtual image  $15 \text{ cm}$  to its left.

$$\frac{1}{\infty} + \frac{1}{s'} = -\frac{1}{15} \Rightarrow s' = -15 \text{ cm}$$

**A.** The virtual image becomes the real object for the positive lens. It is located  $25+15=40\text{cm}$  to the left of the positive lens.

$$\frac{1}{40} + \frac{1}{s'} = \frac{1}{20} \Rightarrow s' = 40 \text{ cm}$$

Overall the object at infinity gives a real inverted image  $40 \text{ cm}$  to the right of the positive lens.

- B** virtual and  $20 \text{ cm}$  from the positive lens.
- C.** real and  $20 \text{ cm}$  from the positive lens.
- D.** real and  $13 \text{ cm}$  from the positive lens.
- E.** None of these is correct.

16. The rhinestones in costume jewelry are glass with index of refraction 1.50. To make them more reflective, they are often coated with a layer of silicon monoxide of index of refraction 2.00. What is the minimum coating thickness needed to ensure that light of wavelength 560nm and of perpendicular incidence will be reflected from the two surfaces of the coating with fully constructive interference?

$$7.00 \times 10^{-8} \text{ m}$$

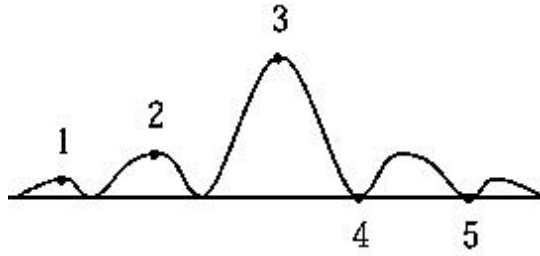
There is a  $\pi$  phase shift for the reflection at the air SiO boundary ( $n_{\text{air}} < n_{\text{SiO}}$ ). There is no phase shift for the reflection at the SiO-glass boundary ( $n_{\text{SiO}} > n_{\text{glass}}$ ).

- A.** There is constructive interference between 2 rays reflected at the 2 boundaries if

$$2n_{\text{SiO}}t = (2k + 1)\frac{\lambda}{2} \Rightarrow t_{\text{min}} = \frac{\lambda}{4n_{\text{SiO}}} = \frac{560 \times 10^{-9}}{8}$$

- B.**  $14.00 \times 10^{-8} \text{ m}$   
**C.**  $5.00 \times 10^{-8} \text{ m}$   
**D.**  $3.00 \times 10^{-8} \text{ m}$   
**E.**  $18.00 \times 10^{-8} \text{ m}$

17.



The diffraction pattern of a single slit is shown in the figure. The point at which the path difference of the extreme rays (i.e. coming from the left and right sides of the slit) is two wavelengths is

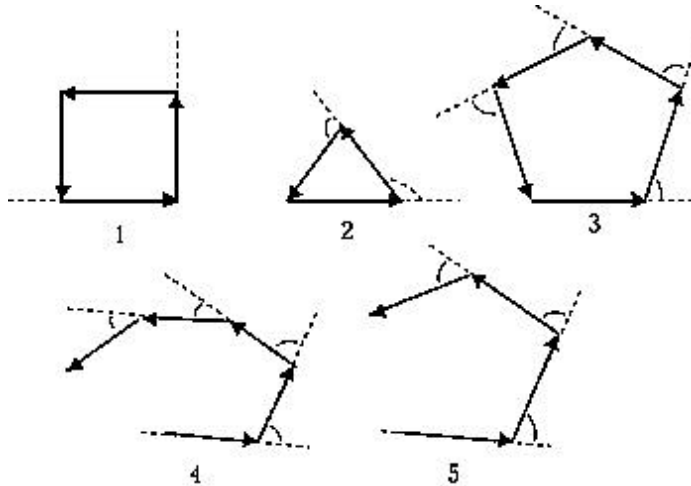
- A. 1
- B. 2
- C. 3
- D. 4
- 5

**E.** Diffraction minima are given by

$$\Delta D = m\lambda, m=1,2,3,\dots$$

The second minimum is such that  $m=2$

18.



Which of the phasor diagrams shows the first minimum for five equally spaced in-phase sources?

- A. 1
  - B. 2
  - C. 3
  - C.** There are five slits. There must be 5 phasors. At a minimum, the sum of the phasors is 0.
  - D. 4
  - E. 5
19. As the width of the slit producing a single-slit diffraction pattern is slowly and steadily reduced (always remaining larger than the wavelength of the light), the diffraction pattern
- slowly and steadily gets wider.
  - A.** Since  $a \sin \theta = m\lambda$  for the minima, as  $a$  is decreased,  $\theta$  increases. The pattern is getting wider on the screen.
  - B slowly and steadily gets brighter.
  - C. does not change because the wavelength of the light does not change.
  - D. slowly and steadily gets narrower.
  - E. None of these is correct.





### PROBLEM [30 points]

In conventional television, signals are broadcast from towers to home receivers. Even when a receiver is not in direct view of a tower because of a hill or building, it can still intercept a signal if the signal diffracts enough around the obstacle, into the obstacle's "shadow region." Current television signals have a wavelength of about 50 cm, but future digital television, signals that are to be transmitted from towers will have a wavelength of about 10 mm.

- 1). [10 pts] Will this change in wavelength increase or decrease the diffraction of the signals into the shadow regions of obstacles? Explain.

Diffraction is more predominant as the ratio  $\lambda/a$  increases where  $\lambda$  is the wavelength of the wave and  $a$  is a characteristic size of the obstacles. For example, for a rectangular slit of width  $a$ , the first diffraction minimum is at  $\sin \mathbf{q} = \frac{\lambda}{a}$ . The diffraction of the slit is more important if  $\theta$  is large that is if  $\lambda/a$  is large.

Since digital TV has a smaller wavelength than traditional TV, diffraction will be less in the shadow regions of obstacles.

- 2). [20 pts] Assume that the signal passes through an opening of 5.0 m width between two adjacent buildings. What is the angular spread of the central diffraction maximum (out to the first minima)  
a. [10 points] for a wavelength of 50 cm? (Show your work.)

$$\sin \mathbf{q} = \frac{\lambda}{a} = \frac{0.5}{5} \Rightarrow \mathbf{q} = 5.7^\circ$$

The angular spread is  $2\theta=11.5^\circ$

Name: \_\_\_\_\_ Total Points: \_\_\_\_\_

[10 points] for a wavelength  $\lambda$

$$\sin \theta = \frac{\lambda}{a} = \frac{0.01}{5} \Rightarrow \theta = 0.11^\circ$$

The angular spread is  $2\theta = 0.23^\circ$