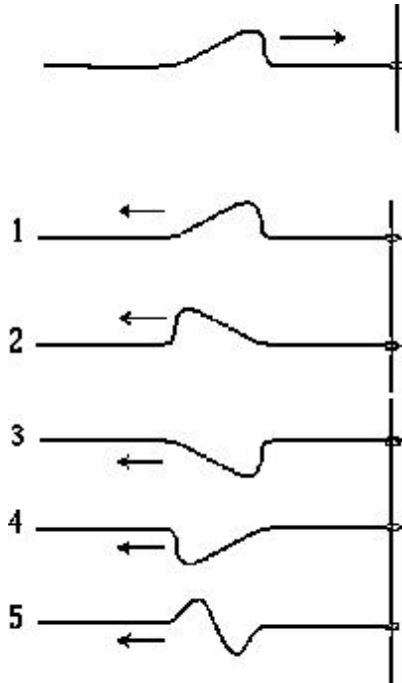


**Multiple choice questions [70 points]**

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.

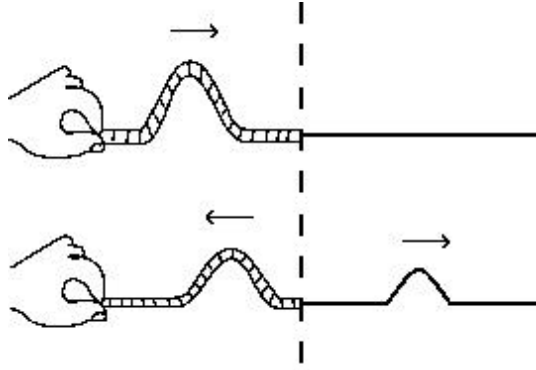
1. Sound travels at 340 m/s in the air and at 1500 m/s in water. A sound wave of wavelength  $\lambda$  and frequency  $f$  is generated under water. The sound wave is detected in the air above the water surface. The wavelength and frequency of the detected sound are  $\lambda'$  and  $f'$ . How do  $\lambda$  and  $\lambda'$ , and  $f$  and  $f'$  compare?
  - A.  $\lambda < \lambda'$  and  $f < f'$
  - B.  $\lambda = \lambda'$  and  $f = f'$
  - C.  $\lambda > \lambda'$  and  $f = f'$  The time interval between two wave fronts remains the same. The distance between two wave fronts decreases since the waves travel slower.
  - D.  $\lambda < \lambda'$  and  $f = f'$
  - E.  $\lambda > \lambda'$  and  $f > f'$
2. A traveling periodic wave passes a point of observation. At this point, the time between successive crests is 0.2s. What can you say about this wave?
  - A. The wavelength is 5 m
  - B. The frequency is 5 Hz ( $f = 1/T = 1/0.2 = 5$  Hz)
  - C. The velocity of propagation is 5 m/s
  - D. The wavelength is 0.2 m
  - E. The period is 0.4 s

3. A pulse moves in a string as indicated in the sketch. At the end of a string is a ring that can slide without friction on a post. On reflection, the pulse would most nearly be represented by



- A. 1  
**B. 2** (the ring acts as a free end)  
C. 3  
D. 4  
E. 5

4.



From the figure, you can conclude that

the medium to the left of the boundary is denser than the medium to the right. (The reflected wave travels slower than the transmitted wave.)

**A.**

Using  $v = \sqrt{\frac{T}{m}}$ , we conclude that  $\mu$  is greater for the medium on the left)

**B.**

the medium to the right of the boundary is denser than the medium to the left.

**C.**

the boundary acts as a fixed end.

**D.**

the wavelength of the transmitted wave is less than the wavelength of the reflected wave.

**E.**

there is a flaw in the drawing. Incident and reflected pulses should have the same height.

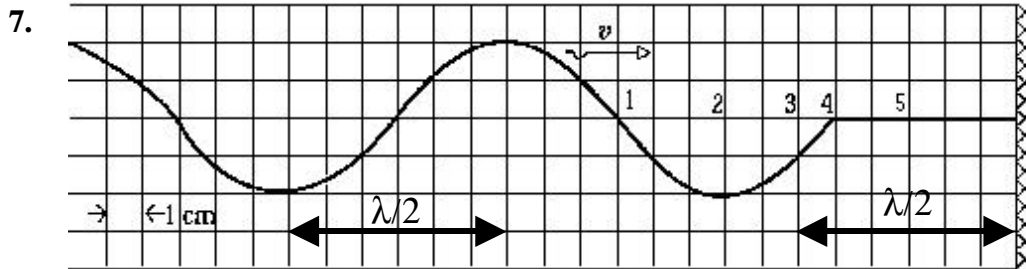
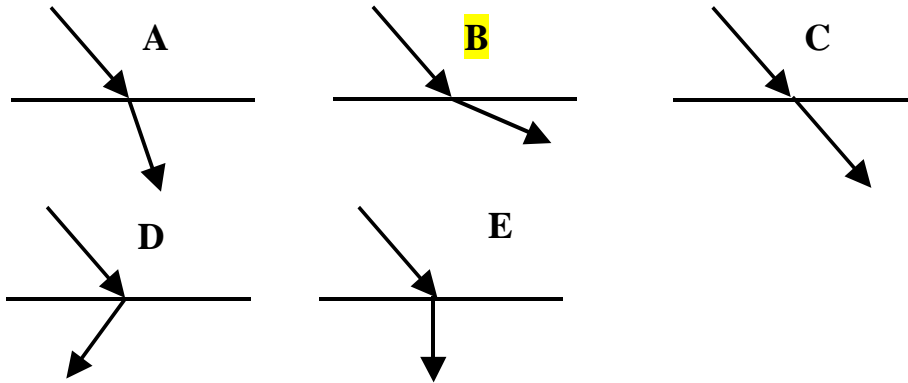
5. A jet engine emits a whine of frequency 3000 Hz. When the engine is moving directly away from the observer at half the speed of sound (speed of sound=340m/s), the observer hears a frequency of

**A. 1000 Hz****B. 1500 Hz**

**C. 2000 Hz**  $f' = f \left( \frac{v}{v+u} \right) = f \left( \frac{1}{1+\frac{u}{v}} \right) = 3000 \left( \frac{1}{1+0.5} \right) = 2000 \text{ Hz}$

**D. 4500 Hz****E. 6000 Hz**

6. Which ray diagram below would best represent water waves traveling from shallow to deep water? Recall that the deeper the water, the faster the water waves travel. The angle between the normal and the ray increases. Recall our "propagation and refraction of periodic waves" tutorial.

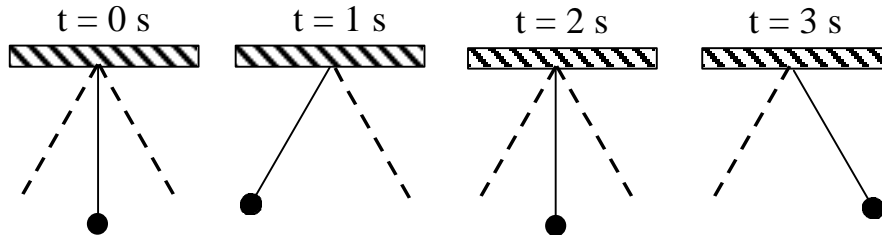


The figure shows a wave on a string approaching its fixed end at a wall. When the wave reaches the wall and is reflected, a standing wave is set up in the string. One will observe a node at position

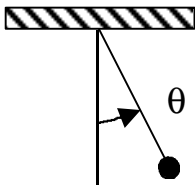
- A. 1  
 B. 2  
 C. 3 (Starting from the wall, nodes are located every  $\lambda/2$ )  
 D. 4  
 E. 5

Questions 8 through 14 all refer to the same problem.

The position of a simple pendulum is shown below at regular time intervals. The dotted lines indicate the maximum displacements of the pendulum from equilibrium.

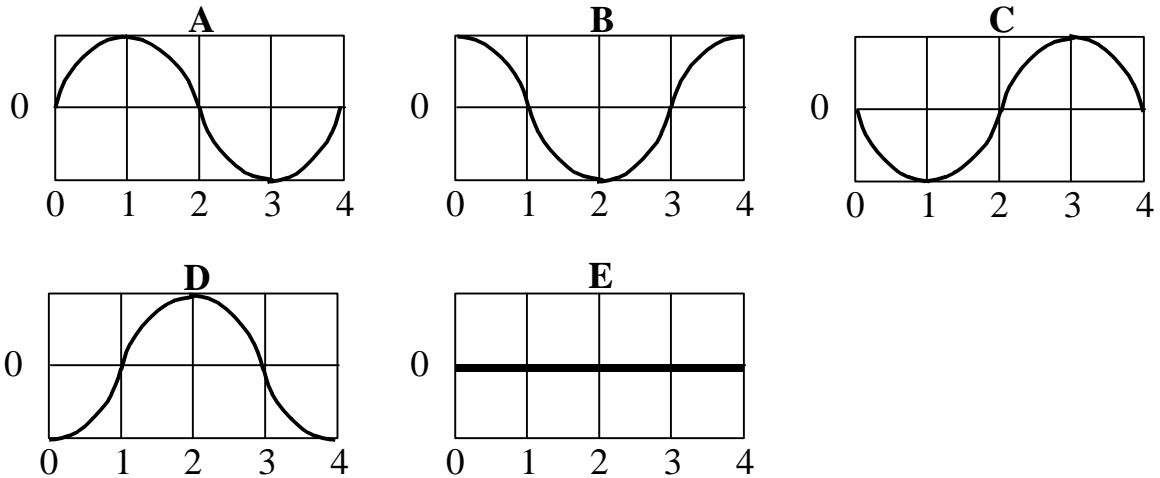


The angle  $\theta$  between the pendulum and the vertical is counted **positive** in the **counterclockwise** direction. Assume that the angle  $\theta$  is small.



8. What is the period of oscillation of the pendulum?
- A. 1 s
  - B. 2 s
  - C. 3 s
  - D. 4 s**
  - E. 5 s

Select from the following graphs for the next four questions





9. Which graph best represents the angle of the pendulum as a function of time (recall that angles are counted positive in the counterclockwise direction)?  
**C**: the angle is 0 at  $t=0$ s and is negative between 0s and 1s
10. Which graph best represents the angular velocity of the pendulum as a function of time  
**D**: take the derivative of the angle vs time graph (=C graph)
11. Which graph best represents the angular acceleration of the pendulum as a function of time?  
**A**: take the derivative of the angular velocity vs time graph (=D graph)
12. Which graph best represents the total mechanical energy of the pendulum as a function of time?  
**E**: the mechanical energy of a pendulum is constant. The value depends on the choice of a reference value for the potential energy. One can have 0J for the total mechanical energy.

13. At  $t = 2\text{s}$ , what is the direction of the linear acceleration of the pendulum?

A. 

B. 

C. 

**D.**  Draw a free body diagram when the pendulum is at its lowest position. It is made of the weight (down) and the tension (up). Without knowing the magnitude of the forces, we can only say that the net force is up or down. Thus, the acceleration and the change in velocity are either up or down. But the change in velocity at the lowest point must be directed up. Therefore, the acceleration is directed up.

E. undefined: the acceleration is 0

14. If the angle of the pendulum  $\theta$  as a function of time is written

$$q = q_{\max} \cos(\omega t + d)$$

what is a correct value for  $\delta$ ?

$\theta(t)$  is given by graph C, which has the equation

$$q = -q_{\max} \sin(\omega t) = q_{\max} \cos\left(\omega t + \frac{\pi}{2}\right) =$$

A. 0 rad

B.  $\pi/4$  rad

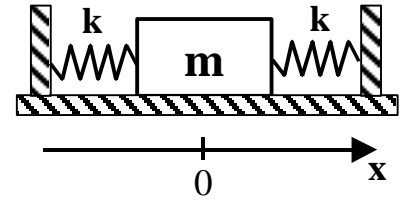
**C.**  $\pi/2$  rad

D.  $\pi$  rad

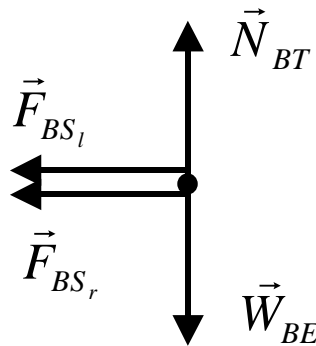
E.  $3\pi/2$  rad

**PROBLEM [30 points]**

Two identical springs of spring constant  $k$  are attached to a block of mass  $m$  and to fixed supports. In the equilibrium position shown in the figure, the block is at rest and the springs are unstretched. At  $t=0$ , the block is moved sideways.



- 1). [10 pts] Draw a free-body diagram for the block when it is at a **positive**  $x$  location. Carefully label all of the forces (the dot below represents the block).



B: block  
T: table  
S<sub>l</sub>: left spring  
S<sub>r</sub>: right spring  
E: Earth

- 2). [10 pts] Write the differential equation of motion for the block (derived from  $F=ma$ ).

Along the  $x$  axis directed to the right

$$-F_{BS_r} - F_{BS_l} = ma$$

$$-kx - kx = m \frac{d^2x}{dt^2}$$

$$\frac{d^2x}{dt^2} + 2\frac{k}{m}x = 0$$

- 3). [10 pts] What is the angular frequency of oscillation  $\omega$  ( $=2\pi f$ ) of the mass  $m$ ? The coefficient of  $x$  in the above equation is  $\omega^2$

$$\omega = \sqrt{\frac{2k}{m}}$$