

PHY132H1S

Term Test —version B

Tuesday, February 4, 2014 Duration: 80 minutes

Solutions

**Aids allowed:** A pocket calculator with no communication ability. A single aid-sheet prepared by the student, no larger than 8.5”x11”, written on both sides. A Hard-copy English translation dictionary. A ruler.

**Possibly helpful information for this test:**

$\pi = 3.14159$  is the ratio of the circumference to the diameter of a circle

The speed of sound in air may be assumed to be 343 m/s, unless otherwise stated.

Coulomb’s law constant is  $K = 8.99 \times 10^9 \text{ N m}^2/\text{C}^2$

Common Prefixes: k = “kilo-” =  $10^3$       c = “centi-” =  $10^{-2}$

$\mu$  = “micro-” =  $10^{-6}$

n = “nano-” =  $10^{-9}$

m = “milli-” =  $10^{-3}$

**Question 1**

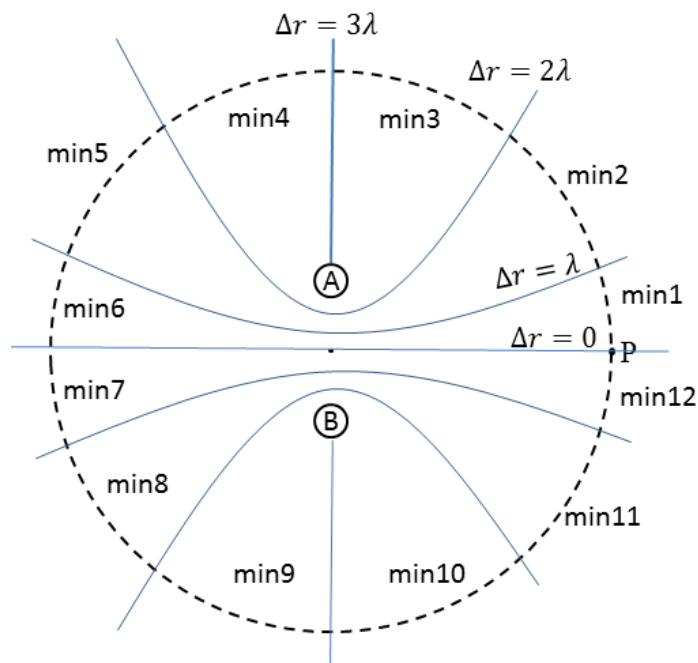
Two speakers, A and B, sit 1.5 m apart in the centre of a large field. They both emit a pure note, in phase, with a wavelength of 0.50 m. A large circle is traced out around them, centred on the point between the two speakers, with a radius of 3 m. If an observer begins at point P where the interference is maximum, and then walks counterclockwise around the circle one time, how many times will the observed sound intensity reach a minimum?

The distance between the speakers is  $3\lambda$ .

Compare with Figure 21.30 from the text.

Antinodal lines are drawn. I count 12 minima half-way between antinodal lines.

- (A) 10      (B) 12      (C) 6  
 (D) 15      (E) 8



### Question 2

Two positively charged particles  $q_1$  and  $q_2 = 2q_1$  lie on the  $x$ -axis.  $q_1$  is at  $x = 0$ , and  $q_2$  is at  $x = d$ , where  $d$  is a positive distance. At which of the following positions could a third charge be placed so as to experience little or no net force?

There are two source charges. We are looking for the spot where the electric field is zero. Since both charges are positive, the point along  $x$  where the electric field is zero must be between them:

$$0 < x < d.$$

Considering x-components:

$$E_1 = \frac{Kq_1}{x^2}$$

$$E_2 = -\frac{K2q_1}{(d-x)^2}$$

$$E_1 + E_2 = 0 = \frac{Kq_1}{x^2} - \frac{2Kq_1}{(d-x)^2}$$

Divide both sides by  $Kq_1$ , solve for  $x$ . I get a quadratic equation:

$$x^2 + 2dx - d^2 = 0$$

Solving that I get:

$$x = d(-1 \pm \sqrt{2})$$

choose the positive solution:

$$x = (\sqrt{2} - 1)d = 0.414d$$

- (A) **0.414 d**                      (B)  $d/2$                       (C)  $-d$                       (D)  $2.414 d$                       (E)  $d/3$

### Question 3

Ocean waves with a wavelength of 120 m are moving East at a speed of 16 m/s relative to the shore. A boat is traveling West with a speed of 4 m/s relative to the shore. What is the frequency of waves as observed by a person on the boat?

Relative speed is  $16 + 4 = 20$  m/s

$$v = \lambda f$$

$$f = v_{\text{rel}}/\lambda = 20/120 = 0.1667 \text{ s}^{-1} = 10 \text{ min}^{-1}$$

- (A) 6 waves per minute.                      **(B) 10 waves per minute.**                      (C) 0.1 waves per minute.  
(D) 11 waves per minute.                      (E) 2 waves per minute.

#### **Question 4**

An object with a height  $y_o$  is held a distance  $2f$  in front of a lens of positive focal length  $f$ . What is the height of the image,  $y_i$ ? [Positive values correspond to an erect image, negative values correspond to an inverted image.]

$$s=2f$$

$$s' = \left(\frac{1}{f} - \frac{1}{s}\right)^{-1} = \left(\frac{1}{f} - \frac{1}{2f}\right)^{-1} = \left(\frac{1}{2f}\right)^{-1} = 2f$$

$$m \equiv \frac{y_i}{y_o} = -\frac{s'}{s} = -1$$

- (A)  $-\frac{y_o}{2}$                       (B)  $-2y_o$                       (C)  $2y_o$                       (D)  $-y_o$

(E) No real image is formed in this case.

#### **Question 5**

A trumpet player stands on a rolling platform, which moves at a constant velocity towards a large stationary brick wall. He blows into the trumpet, producing a sound with constant frequency of  $f_0 = 256$  Hz, as measured when the trumpet and an observer are both at rest. The trumpet player hears the emitted sound as well as the echo of the sound which is reflected from the wall. He hears a beat frequency of  $f_{\text{beat}} = 3.0$  Hz. What is the speed of the trumpet player?

Source is moving toward wall, observer is moving toward wall, both with speed  $v_{os}$ .

Combine equations for approaching source and approaching observer.

$$f_+ = \frac{(1 + v_{os}/v)f_0}{1 - v_{os}/v}$$

$$f_{\text{beat}} = f_+ - f_0 = f_0 \left( \frac{(1 + v_{os}/v)}{1 - v_{os}/v} - 1 \right) = f_0 \left( \frac{1 + v_{os}/v - 1 + v_{os}/v}{1 - v_{os}/v} \right) = f_0 \left( \frac{2v_{os}/v}{1 - v_{os}/v} \right)$$

Solving for  $v_{os}$ :

$$v_{os} = v \frac{f_{\text{beat}}}{f_0(2 + f_{\text{beat}}/f_0)} = 344 \text{ m/s} \frac{3}{256(2 + 3/256)} = 2 \text{ m/s}$$

- (A) **2.0 m/s**                      (B) 4.0 m/s                      (C) 0.25 m/s                      (D) 343 m/s                      (E) 0.50 m/s

#### **Question 6**

After running a plastic comb through your hair several times you hold it near a metal can, which is lying on its side on a table. The can rolls toward the comb. Why does this happen?

- (A) The can has an overall negative electric charge.  
(B) The comb becomes polarized.  
(C) The can becomes magnetic.  
(D) This is very unlikely to happen, because in most cases the can should roll away from the comb.  
(E) **The can becomes polarized.**

**Question 7**

When one person shouts at a football game, the sound intensity level at the centre of the field is 60 dB. When all the people shout together, the intensity level increases to 100 dB. Assuming that each person generates the same sound intensity at the centre of the field, approximately how many people are at the game?

$$\beta = 10\log(I/I_0)$$

Intensity adds with numbers of people.  $I_2 = NI_1$ .

$$\beta_2 - \beta_1 = 10\log(I_2/I_1) = 10\log(N)$$

$$N = 10^{\frac{\beta_2 - \beta_1}{10}} = 10^{\frac{100 - 60}{10}} = 10^4 = 10,000$$

- (A) **10,000**                      (B) 20,000                      (C) 40                      (D) 40,000                      (E) 400

**Question 8**

Ramon has eyeglasses with the prescription  $-1.0$  D. What eye condition does Ramon have, and what is his far point without the glasses?

Negative prescription implies myopia.

Object is at infinity. Image is at focal point of lens, 1 m away. This is Ramon's far point.

- (A) Myopia, 10 m                      (B) Hyperopia, 1.0 m                      (C) **Myopia, 1.0 m**  
(D) Hyperopia, 0.25 m                      (E) Myopia, 2.0 cm

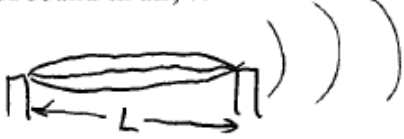
**FREE-FORM PART** (16 points total)

Clearly show your reasoning and work as some part marks may be awarded. Write your final answers in the boxes provided.

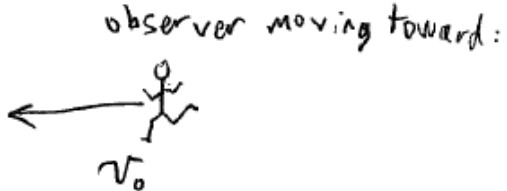
**PART A [8 points]**

The high "E-note" string on a guitar has a linear mass density of  $\mu$ . It is tightened between two fixed points a distance  $L$  apart to a tension of  $T$ . A performer on a stage plays this E-note at the same time as a fast spectator rushes toward the stage at high speed. What is the minimum speed the spectator must go so that the frequency he observes is above the human range of hearing,  $f_{max}$ ? Please express your answer in terms of numerical constants and any of the following:  $\mu$ ,  $L$ ,  $T$ ,  $f_{max}$  and the speed of sound in air,  $v$ .

speed of sound in air,  $v$ .



Source at rest.



observer moving toward:  
 $v_o$

Doppler:  $f_{obs} = f_{max} = f_o \left(1 + \frac{v_o}{v}\right)$

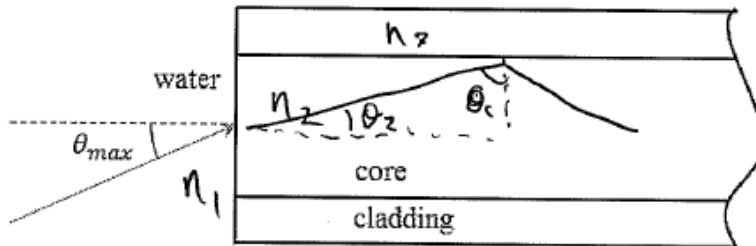
Assume fundamental frequency  $m=1$ :  $f_o = \frac{v}{2L}$  where  $v = \sqrt{\frac{T}{\mu}}$

$$f_o = \frac{1}{2L} \sqrt{\frac{T}{\mu}}$$
$$f_{max} = \frac{1}{2L} \sqrt{\frac{T}{\mu}} \left(1 + \frac{v_o}{v}\right)$$
$$2 f_{max} L \sqrt{\frac{\mu}{T}} = 1 + \frac{v_o}{v}$$
$$\frac{v_o}{v} = 2 L f_{max} \sqrt{\frac{\mu}{T}} - 1$$

$$v_{min} = v \left( 2 L f_{max} \sqrt{\frac{\mu}{T}} - 1 \right)$$

**PART B [8 points]**

Consider an optical fibre whose core has an index of refraction of  $n_{\text{core}} = 1.62$  and cladding has an index of refraction of  $n_{\text{cladding}} = 1.52$ . When immersed in water ( $n_{\text{water}} = 1.33$ ), what is the maximum angle  $\theta_{\text{max}}$  that a ray can be incident upon the centre of the tip of the fibre so that, when in the fibre and incident on the core/cladding interface, it will undergo total internal reflection?



$$n_1 = 1.33$$

$$n_2 = 1.62$$

$$n_3 = 1.52$$

Total internal reflection:  $\sin \theta_c = \frac{n_3}{n_2}$

Note from triangle  $\theta_2 + \theta_c + 90^\circ = 180^\circ$

$$\Rightarrow \theta_2 = 90 - \theta_c$$

$$\theta_c = 90 - \theta_2$$

$$\sin(90 - \theta_2) = \cos \theta_2 = \frac{n_3}{n_2}$$

Snell's Law at tip of fibre:

$$n_1 \sin \theta_{\text{max}} = n_2 \sin \theta_2$$

$$\theta_{\text{max}} = \sin^{-1} \left[ \frac{n_2}{n_1} \sin \left( \cos^{-1} \left( \frac{n_3}{n_2} \right) \right) \right]$$

$$= \sin^{-1} \left[ \frac{n_2}{n_1} \sin(20.2367^\circ) \right]$$

$$= \sin^{-1} [0.42132]$$

$$= 24.918$$

$$\theta_{\text{max}} = 24.9^\circ$$