PHY132H1F Term Test —version 1

Tuesday, October 12, 2010 Duration: 80 minutes

SOLUTIONS

Possibly helpful information for this test:

$\pi = 3.14159$ Speed of light in a vacuum is $c = 3.00 \times 10^8$ m/s

Planck's constant is $h = 6.63 \times 10^{-34}$ J s Mass of the electron $m_e = 9.11 \times 10^{-31}$ kg

The near point for a normal eye is 25 cm. The speed of sound in air is 343 m/s, unless told otherwise.

$g = 9.80$ m/s^2 is the acceleration due to gravity near the Earth's surface.

1 cm = 10^{-2} m 1 mm = 10^{-3} m 1 μm = 10^{-6} m 1 nm = 10^{-9} m

MULTIPLE CHOICE (16 points total)

1. The near point (the smallest distance at which an object can be seen clearly) and the far point (the largest distance at which an object can be seen clearly) are measured for six different people, and listed in the table below.

Farsighted means near point > 25 cm.

	near point (cm)	far point (cm)
Avishka	40	∞
Berenice	30	300
Chadwick	25	500
Danya	25	∞
Edouard	80	200
Francesca	50	∞

(only Chadwick and Danya are not farsighted).

Which of the following choices lists all the farsighted people, ranked by the power of the lens needed to correct their hyperopic vision? [They are ranked from largest to smallest power required.]

A. Berenice, Avishka, Francesca, Edouard
B. Danya, Avishka, Francesca
C. Edouard, Berenice, Chadwick
D. Edouard, Francesca, Avishka, Berenice
E. Francesca, Avishka, Danya

A converging lens is needed to correct hyperopia.

Following Example 24.4, the power is related to near point distance, x_{NP}, is:

$$P = \frac{1}{25\,\text{cm}} - \frac{1}{x_{NP}}$$

Avishka: $P = 1.5\ \text{m}^{-1}$

Berenice: $P = 0.7\ \text{m}^{-1}$

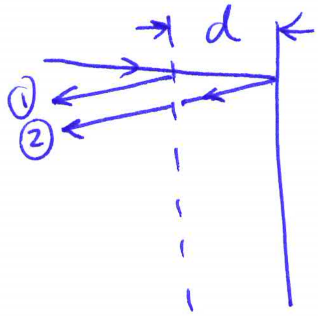
Edouard: $P = 2.8\ \text{m}^{-1}$

Francesca: $P = 2\ \text{m}^{-1}$

$E > F > A > B$

2. A form of sound-proofing is a fine wire mesh which is held at a fixed distance from a flat wall. When sounds waves are normally incident on the wall, they first encounter the mesh. About half of the sound intensity is reflected, and half is transmitted. The transmitted sound waves can then travel the distance, d, reflect off the wall, travel the distance d again, and then combine with the original reflected sound from the wire mesh. If the two sound waves are exactly out of phase at this point, they will destructively interfere, reducing the total reflected sound intensity. If $d = 2.54$ cm (one "inch"), what is the minimum frequency for which the sound-proofing will work properly?

A. 135 Hz
B. 141 Hz
C. 3380 Hz
D. 6750 Hz
E. 13,500 Hz



2 reflections: (2) has traveled $2d$ farther than (1).

From eq. 21.33:
Destructive interference occurs for:

$$\lambda = \frac{2d}{(m - \frac{1}{2})}$$

Maximum λ corresponds to minimum f $\therefore$ $m = 1$

$$\lambda = \frac{2d}{(1 - \frac{1}{2})} = 4d$$

For sound $v = \lambda f \Rightarrow f = \frac{v}{\lambda} = \frac{v}{4d} = \frac{343 \text{ m/s}}{4(0.0254 \text{ m})}$

$f = 3376.0$ Hz

or 3380 to 3 sig figs.

3. What is the speed of an electron with a de Broglie wavelength of 0.30×10^{-9} m?
A. 2.2×10^{-24} m/s
B. 6.6×10^{-16} m/s
C. 2.0×10^{3} m/s
D. 2.4×10^{6} m/s
E. 3.6×10^{6} m/s

Eq. 25.8: $\lambda = \frac{h}{p} = \frac{h}{mv}$

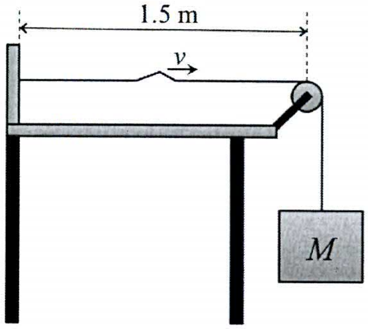
$\lambda m v = h$

$v = \frac{h}{\lambda m} = \frac{6.63 \times 10^{-34}}{(0.3 \times 10^{-9})(9.11 \times 10^{-31})}$

$v = 2.42 \times 10^{6}$ m/s

(less than 1% the speed of light, so relativistic effects are negligible.)

4. A 2.0 m long string with a mass of 4.0 grams is tied to a wall at one end, stretched horizontally to a pulley 1.5 m away from the wall, then tied to a hanging mass, M, as shown. When you pluck the string, sending a traveling pulse down the string, it travels at a speed v = 35 m/s. What is the mass, M?



A. 0.0071 kg
B. 0.25 kg
C. 0.33 kg
D. 2.5 kg
E. 3.3 kg

Tension in string $= T_s$

fbd for M:

$\uparrow T_s$

$\downarrow Mg$

$\Sigma F_y = 0 = T_s - Mg$

$\Rightarrow T_s = Mg$.

Mass density of string:

$$\mu_s = \frac{M_s}{L_s} = \frac{4\times10^{-3}\ \text{kg}}{2\ \text{m}} = 2\times10^{-3}\ \frac{\text{kg}}{\text{m}}.$$

Speed of transverse wave on a string

Eq. 20.1: $$V = \sqrt{\frac{T_s}{\mu_s}} = \sqrt{\frac{Mg}{\mu_s}}$$

$$v^2\mu_s = Mg$$

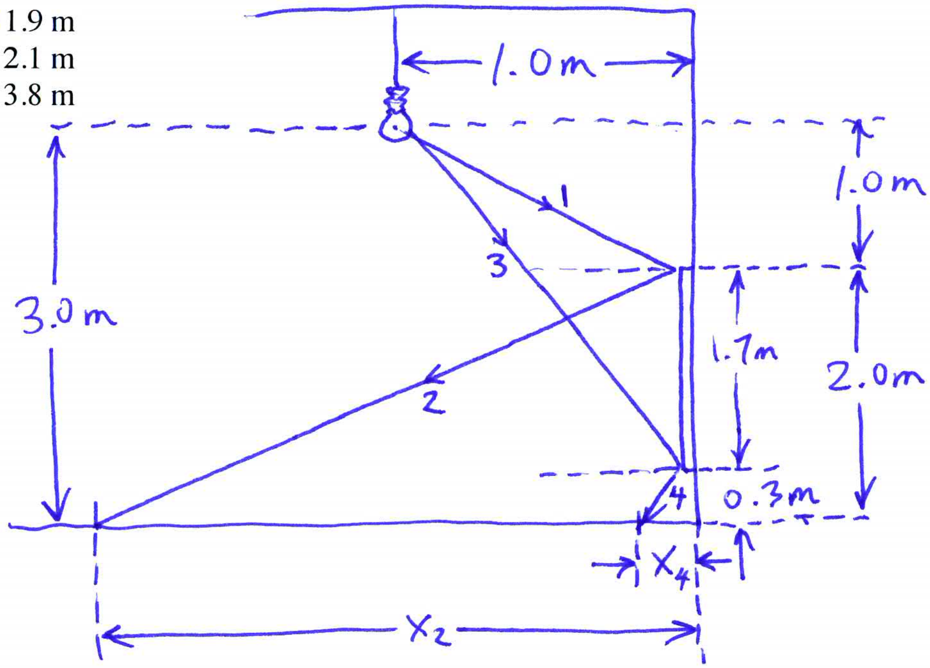
$$M = \frac{v^2\mu_s}{g} = \frac{(35)^2(2\times10^{-3})}{9.80}$$

$$M = 0.25\ \text{kg}.$$

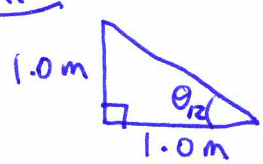
(If you take into account the string mass below the pulley, you get $M = 0.249$ kg $= 0.25$ kg to 2 sig figs).

5. A dressing mirror mounted on a vertical wall is 1.7 m tall. The bottom is 0.30 m above the floor. A bare light-bulb hangs on the ceiling a horizontal distance of 1.0 m away from the wall with the mirror. The light-bulb is 3.0 m above the floor. How long is the streak of reflected light across the floor, as measured perpendicularly away from the wall with the mirror?

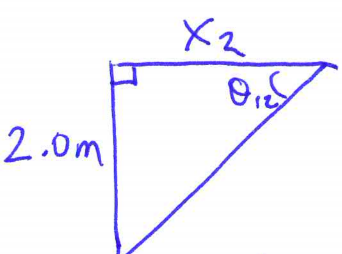
A. 0.11 m
B. 0.33 m
C. 1.9 m
D. 2.1 m
E. 3.8 m



Beam 1



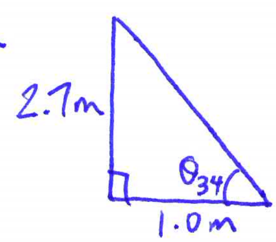
Beam 2 → same angle by law of reflection.



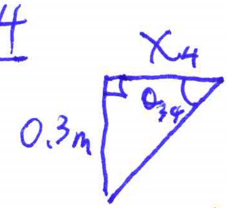
similar triangles ⇒ $\frac{1.0}{1.0} = \frac{x_2}{2.0}$

⇒ $\boxed{x_2 = 2.0\ \text{m}}$

Beam 3



Beam 4



similar triangles ⇒

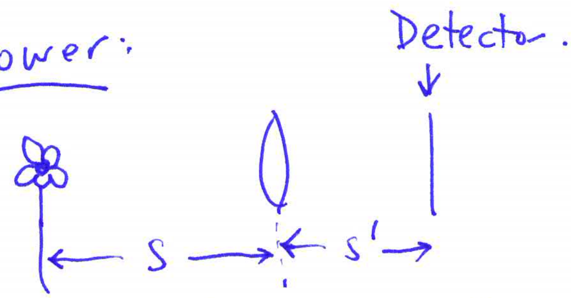
$\frac{1.0}{2.7} = \frac{X_4}{0.3}$ ⇒ $\boxed{X_4 = 0.11\ \text{m}}$

streak of light is $(X_2 - X_4)$ long

$= 2.0 - 0.11 = 1.89\text{m}$

6. The lens in your digital camera has a diameter of 2.5 mm, and according to the manufacturers specifications, its f-number is “F4.0”. The lens is held a certain distance away from the detector in order to produce a well-focused picture of a flower that is 15 cm away. You then turn to take a picture of a distant landscape. How far must the lens be moved, and in which direction, in order to obtain a well focused picture of the landscape?
   A. 0.71 mm closer to the detector
   B. 1.4 mm closer to the detector
   C. 11 mm closer to the detector
   D. 11 mm farther from the detector
   E. 20 mm farther from the detector

Flower:



$s = 15$ cm $\frac{f}{D} = 4.0 \Rightarrow f = 4.0(2.5m$

$f = 1.0$ cm

$$s' = \left(\frac{1}{f} - \frac{1}{s}\right)^{-1} = \left(\frac{1}{1} - \frac{1}{15}\right)^{-1}$$

$s' = 1.0714$ cm ← distance of lens from detector

Landscape

$s \to \infty \Rightarrow \frac{1}{s} = 0.$

$$s' = \left(\frac{1}{f} - \frac{1}{s}\right)^{-1} = \left(\frac{1}{f} - 0\right)^{-1} = f$$

$s' = 1.0$ cm. ← New position, closer to the detector by
$1.0714 - 1.0$
$= 0.0714$ cm,
or 0.714 mm

7. A typical 100 Watt incandescent light-bulb emits only 2.7 Watts of visible light. The average wavelength of this visible light is about 550 nm. Estimate the number of visible photons emitted by the light-bulb each second.
   A. 10^{19}
   B. 10^{21}
   C. 10^{23}
   D. 10^{25}
   E. 10^{27}

Eq. 25.4: $E_{ph} = hf = \frac{hc}{\lambda}$

$P = N E_{ph}$ where N = # of photons per second.

$$N = \frac{P}{E_{ph}} = \frac{P\lambda}{hc} = \frac{2.7(550\times10^{-9})}{6.63\times10^{-34}(3\times10^{8})}$$

$N = 7.5\times10^{18} \simeq 10^{19}$

8. A rectangular block of amber has a small insect embedded in it. The insect appears to be 7.0 mm below the flat surface of the amber. The index of refraction of amber is known to be 1.54. What is the insect's actual distance beneath the surface?

A. 2.8 mm
B. 4.5 mm
C. 7.0 mm
D. 11 mm
E. 18 mm

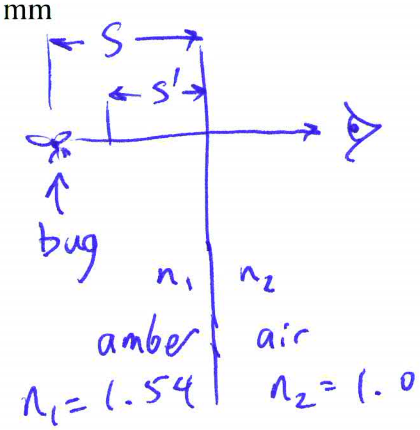
Eq. 23.13: $s' = \frac{n_2}{n_1} s$

$s' = 7.0\,mm$ = image distance,

$s = \frac{n_1}{n_2} s' = \frac{1.54(7.0\,mm)}{1.0}$

$s = 10.78\,mm$

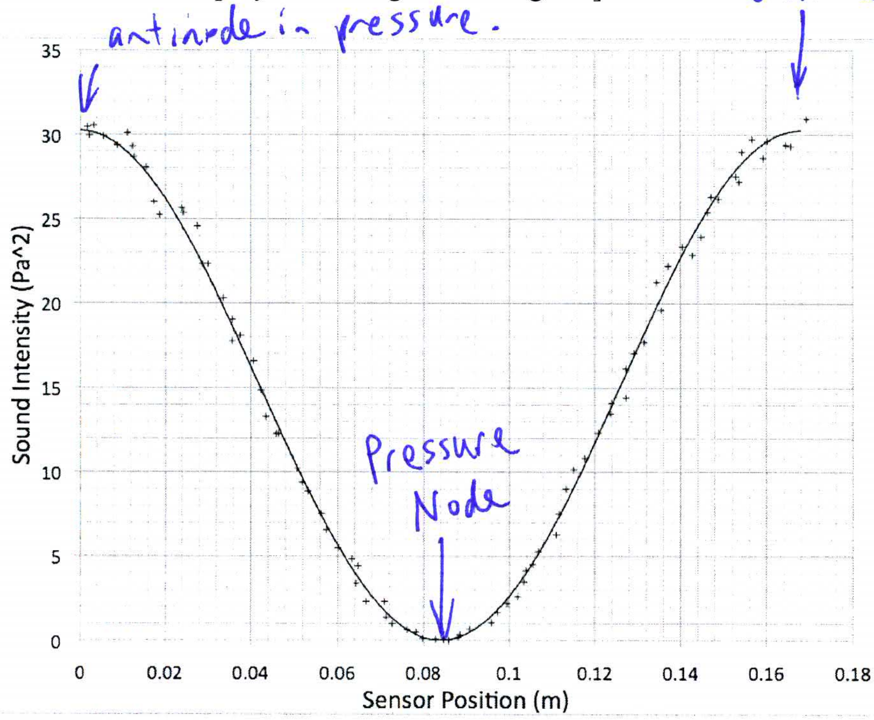
$\simeq 11\,mm$



PART A (~~6~~ 5 points)

In Practicals you set up standing sound waves in a tube filled with air. The frequency of the sound was set to 270 Hz. It was a "closed-closed" tube, which you measure to have a length of $L = 0.171$ m ± 0.002 m. You used a sound sensor which displayed the square of the pressure amplitude, called "Sound Intensity", versus sensor position. Estimate the *m*-number for the mode of the standing wave, the wavelength of the sound, and the error in this wavelength. [Please write your answers in the boxes provided. *m* should be displayed to 1 significant figure. Display the wavelength, λ, as *value* ± *error*, with the error displayed to 1 significant figure.]

antinode in pressure



ΔP^2

compare with Fig. 21.16 (a) → this is $m=1$ for pressure.

−2 for thinking $m=2$.

−1 for computing non-integer $m = 0.3$ using $v = 343$ m/s.

ΔP = pressure above ambient.

$m =$ 1 +3

Eq. 21.17: $\lambda = \frac{2L}{m} = 2L = 2(0.171 \pm 0.002)$

$\lambda = 0.342 \pm 0.004$

NOTE: The speed of sound is $v = \lambda f = 92 \pm 1$ m/s for this problem. That would mean the temperature in the tube is −392°C, which is completely impossible! I apologize for confusion this may have caused. The actual length of the tubes in Practicals was 0.63 m, not 0.17 m. That was a mistake in setting up the problem.

— J. Harlow,

$\lambda = 0.342 \pm 0.004$ m +2

PART B (~~6~~ 7 points)
Two trains approach one another on a long, straight track. The first train is traveling North at 36.0 m/s relative to the ground in still air. The frequency of the note emitted by the whistle on the first train is 462 Hz. A passenger is on the second train, which is moving at South a speed of 15.0 m/s relative to the ground. What is the frequency of the whistle as heard by the passenger on the second train?

$v_1 = +36$ m/s

source $f_0 = 462$ Hz

$v_2 = 15$ m/s

observer.

2 steps: ① . Source is moving toward observer, which will increase the frequency:

Eq. 20.39: $f_{1+} = \dfrac{f_0}{1 - v_s/v} = \dfrac{f_0}{1 - v_1/v}$ +2

② Observer is moving toward source, which will increase the frequency above f_{1+}: +2.

Eq. 20.40: $f_{2+} = (1 + v_o/v) f_{1+} = \dfrac{(1 + v_2/v) f_0}{(1 - v_1/v)}$ +2

$f_{2+} = \left(\dfrac{1 + 15/343}{1 - 36/343}\right) 462$ Hz

$= 538.75$ Hz. 3 sig figs.

+1

Note:
Misread "approach". 3rd word for "recede from" →

$f_{2-} = \dfrac{(1 - v_2/v) f_0}{(1 + v_1/v)}$

$= 399.8$ Hz

$f_{2-} = 400.$ Hz

to 3 sig figs

worth +6 if perfect

$\boxed{f = 539 \text{ Hz}}$

−1 for wrong/missing units.

−0.5 for wrong # of sig. figs.