PHY132 H1F
Test 1 Answers.
Harlow
Fall 2009

Possibly useful constants, conversions and equations:
The speed of sound in air (unless otherwise specified): $v = 343$ m/s

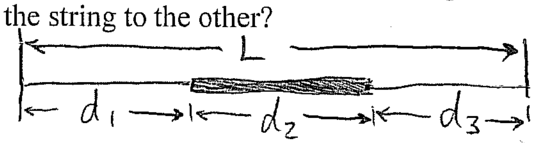
Quadratic equation: If $ax^2 + bx + c = 0$, then $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Planck's constant: $h = 6.63 \times 10^{-34}$ J s
1 nm = 10^{-9} m
2π radians = 360°
$\pi = 3.14159$

MULTIPLE CHOICE (10 points total)

#5 on Version 2

1. Consider a string of total length L, made up of three segments of equal length. The mass per unit length of the first segment is μ, that of the second is 4μ, and that of the third is μ. The third segment is tied to a wall, and the string is stretched by a force of magnitude T_s applied to the first segment; T_s is much greater than the total weight of the string. How long will it take a transverse wave to propagate from one end of the string to the other?



A. $2L\sqrt{\dfrac{\mu}{T_s}}$

B. $\dfrac{L}{3}\sqrt{\dfrac{\mu}{T_s}}\left(\dfrac{3}{2}+\sqrt{2}\right)$

C. $L\sqrt{\dfrac{\mu}{T_s}}\left(2+\sqrt{2}\right)$

(D.) $\dfrac{4L}{3}\sqrt{\dfrac{\mu}{T_s}}$

E. $\dfrac{L}{3}\sqrt{\dfrac{\mu}{T_s}}\left(1+\sqrt{\dfrac{3}{2}}\right)$

$d_1 = d_2 = d_3 = L/3$

$V_1 = V_3 = \sqrt{\dfrac{T_s}{\mu}}$, $V_2 = \sqrt{\dfrac{T_s}{4\mu}}$

$V_2 = V_1/2$

$V = \dfrac{d}{t} \Rightarrow t = d/V$

$t_{total} = t_1 + t_2 + t_3 = \dfrac{d_1}{V_1} + \dfrac{d_2}{V_2} + \dfrac{d_3}{V_3}$

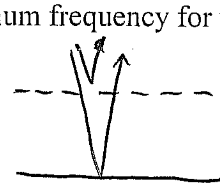
$t_{total} = \dfrac{L}{3}\left(\dfrac{1}{V_1} + \dfrac{1}{V_1/2} + \dfrac{1}{V_1}\right) = \dfrac{L}{3}\sqrt{\dfrac{\mu}{T_s}}\left(1 + 2 + 1\right)$

$t_{total} = \dfrac{4L}{3}\sqrt{\dfrac{\mu}{T_s}}$

#4 on Version 2

2. A form of sound-proofing is a wire mesh which is held at a fixed distance from a flat wall. When sound 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 $d = 3.24$ cm, what is the minimum frequency for which the sound-proofing will work properly? (3 sig figs.)

A. 26 Hz
B. 141 Hz
C. 1110 Hz
(D.) 2650 Hz
E. 10,600 Hz



path difference $\Delta r = 2d$
destructive interference for longest wavelength (lowest frequency):

$\Delta r = \dfrac{\lambda}{2}$ $\quad$ $V = \lambda f$

$\dfrac{\lambda}{2} = 2d$, $\lambda = 4d$

$f = \dfrac{V}{\lambda} = \dfrac{V}{4d} = \dfrac{343 \text{ m/s}}{4(0.0324 \text{ m})}$

$f = 2647$ Hz
$= 2650$ Hz to 3 sig. figs

3. A fish tank whose bottom is a mirror is filled with water to a depth, d. A small fish floats motionless, a distance y under the surface of the water. The index of refraction of the water is n. What is the apparent depth of the reflection of the fish in the bottom of the tank when viewed at normal incidence?

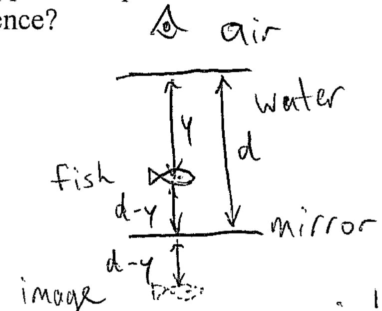
A. $\frac{2y-d}{n}$

B. $\frac{d-y}{n}$

(C.) $\frac{2d-y}{n}$

D. $\frac{y}{n}$

E. $\frac{d-y}{2n}$



- image in mirror is a distance $d + (d-y) = 2d - y$ below surface of water.
- This is object as viewed through water.
- Image distance is $s' = \frac{n_2}{n_1} s$, $n_1 = n$, $n_2 = 1$

$$s' = \frac{1}{n}(2d-y) = \frac{2d-y}{n}$$

#2 on Version 2

4. Sanjay has hyperopia. The near point of his left eye is 110 cm. What power lens will restore normal vision? [Neglect the small space between the lens and his eye.]

(A) +3.1 D

B. +3.3 D

C. –3.3 D

D. –3.1 D

E. +0.91 D

Require actual object to be 25 cm in front of lens. Image from this first lens should be 110 cm in front (to the left) of lens. This is virtual image, which becomes object of Sanjay's eye

#1 on Version 2

5. Each photon in a dental X-ray has an energy of 12 keV, or 1.9×10^{-15} J. How many microwave photons with a frequency of 2.45×10^9 Hz would have the same total energy as the energy of one dental X-ray photon?

A. 5.4×10^{23}

(B.) 1.2×10^9

C. 1.9×10^3

D. 5.4×10^{11}

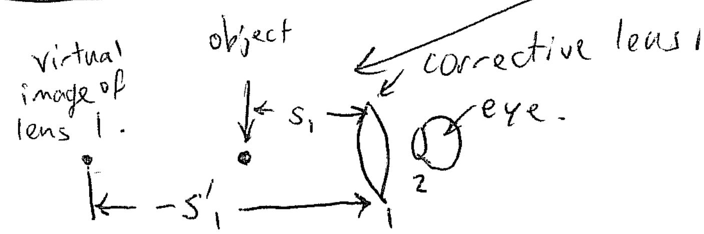
E. 9.7×10^3

$E_{ph} = hf$

$$\text{Number} = \frac{E_{total}}{E_{ph}} = \frac{E_{total}}{hf} = \frac{1.9\times10^{-15}\text{ J}}{(6.63\times10^{-34} \times 2.45\times10^9)}$$

$= 1.17\times10^9$

$= 1.2\times10^9$ to 2 sig figs.



$s_1 = 25$ cm.

$s_1' = -110$ cm.

$$\frac{1}{f_1} = \text{Power} = \frac{1}{s_1} + \frac{1}{s_1'} = \frac{1}{0.25\text{m}} + \frac{1}{-1.10}$$

Power $= +3.091\ m^{-1}$

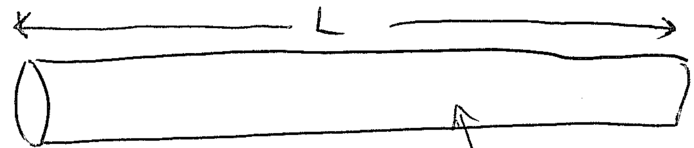
to 2 sig figs: +3.1 Diopters.

FREE-FORM IN TWO UNRELATED PARTS (8 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 (3 points)

A metal pipe, open at both ends, can create a standing wave in the second harmonic with a frequency of 483 Hz. What is the length of the pipe?



air, $v = 343$ m/s.

Second harmonic is $m = 2$.

$$f_2 = 2\,\frac{v}{2L} = \frac{v}{L}$$, solve for L:

$$L = \frac{v}{f_2} = \frac{343\ \text{m/s}}{483\ \text{Hz}} = 0.7101\ \text{m}$$

3 sig. figs: $L = 0.710$ m

Version 2, $f_2 = 583$ Hz,

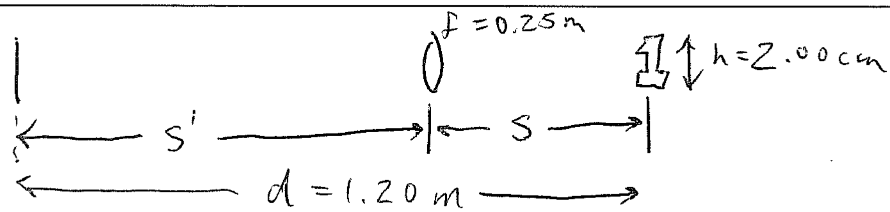
$L = 0.588$ m

Version 1

$L = 0.710$ m

PART B (5 points)

A 2.00 cm tall object and a viewing screen are held at a fixed distance of 1.20 m, and a focusing lens with diameter $D = 5$ cm and focal length $f = 0.250$ m is placed part-way between them. At what distance (or distances) must the lens be held away from the object in order to form a focused image on the viewing screen? What is the height of the image (or images)? [Please show solution within the box provided, and clearly draw a box around your final numerical answer or answers.]



$s + s' = d$, $\frac{1}{s'} + \frac{1}{s} = \frac{1}{f}$, solve for s.

$s' = d - s$

$\frac{1}{d-s} + \frac{1}{s} = \frac{1}{f}$ (× both sides by $(d-s)sf$)

$sf + f(d-s) = s(d-s)$

$\cancel{sf} + fd - \cancel{fs} = sd - s^2$

Quadratic equation with $a = 1$, $b = -d$, $c = fd$

$s^2 - ds + fd = 0$

Solution:

$$s = \frac{d \pm \sqrt{d^2 - 4fd}}{2} = \frac{d}{2} \pm \sqrt{\frac{d^2}{4} - fd}$$

$s = 0.6\ m \pm 0.2449\ m$

$s = 0.3551\ m$ or $0.8449\ m$ are both focused images.

Magnification: $m = \frac{-s'}{s} = -\frac{0.8449}{0.3551}$ or $\frac{-0.355}{0.8449}$

$= -2.38\times$ or $-0.420\times$

$h' = hm$, $h = 2.00$ cm

3 sig figs:

focus 1: $s = 0.355$ m, $h' = 4.76$ cm

focus 2: $s = 0.845$ m, $h' = 0.841$ cm