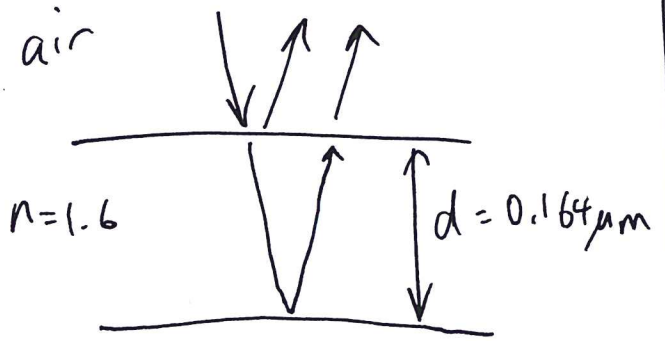
Practice Problem Set 10

Please go to https://q.utoronto.ca, go to the PHY152 course Home Page, click on Course Materials, and scroll down to Past Final Exams.

1. Final Exam 2018, Question 3. [This was the **most difficult** question on the 2018 exam; the class average for this particular question was 38%.]

> 3. [6 points] Light is incident normally from air onto a liquid film that is on a glass plate. The liquid film is 0.164 μm thick, and the liquid has an index of refraction of 1.60. The glass has index of refraction n = 1.50. Calculate the longest visible wavelength (as measured in air, in appropriate units) of the light for which there will be totally destructive interference between the rays reflected from the top and bottom surfaces of the film. Note any assumptions you made in your calculation.



air - liquid interface, n increases
$\Rightarrow$ π phase change.

liquid - glass interface,
n decreases
$\Rightarrow$ 0 phase change.

From aid sheet: constructive interference:

$$2nd = (m + \tfrac{1}{2})\lambda$$

∴ destructive interference is when:

$$2nd = m\lambda$$

$n = 1.6$ index in film. $m = 1$ for longest λ.

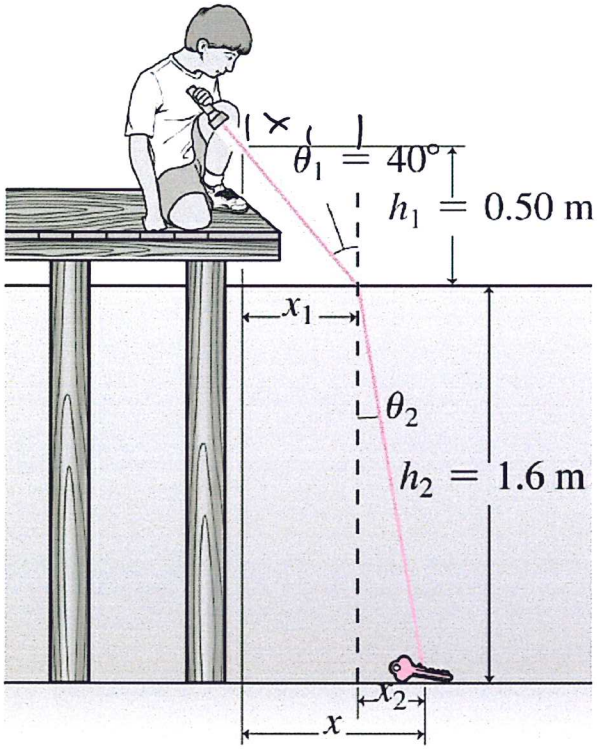
$$\lambda = 2nd = 2(1.6)(0.164\ \mu m)$$

$$\boxed{\lambda = 0.525\ \mu m}$$

$= 525$ nm, green light

2. Final Exam 2018, Question 9. [This was the **easiest** question on the 2018 exam; the class average for this particular question was 93%.]

9. [6 points] It is night and you have dropped your car keys off the end of a dock into water that is 1.6 m deep. A flashlight held directly above the dock edge and 0.5 m above the surface of the water illuminates the keys when it is aimed at 40° to the vertical (as shown in the figure below). What is the horizontal distance *x* from the edge of the dock to the keys?



Snell's Law

$n_1 \sin\theta_1 = n_2 \sin\theta_2$.

n_2 = water = 1.33

$\theta_2 = \sin^{-1}\left(\frac{n_1}{n_2}\sin\theta_1\right)$

$= \sin^{-1}\left(\frac{1}{1.33}\sin 40°\right)$

$\theta_2 = 28.901°$

Geometry: $\tan\theta_1 = \frac{x_1}{h_1} \Rightarrow x_1 = h_1 \tan\theta_1$

$\tan\theta_2 = \frac{x_2}{h_2} \Rightarrow x_2 = h_2 \tan\theta_2$

$x = x_1 + x_2$

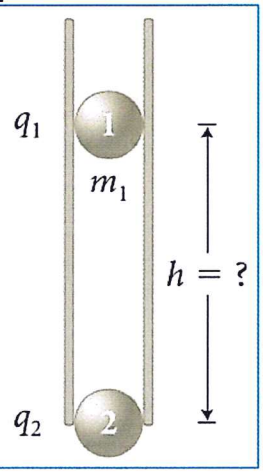
$= h_1 \tan\theta_1 + h_2 \tan\theta_2 = 0.5(\tan 40°) + 1.6 \tan(28.9$

$x = 0.41955 + 0.8833$

$x = 1.3$ m

3. Final Exam 2017, Question 13. [This was the **most difficult** question on the 2017 exam; the class average for this particular question was 52%.]

13. [14 points total] A small sphere 1 carrying charge q_1 and having inertia m_1 is constrained to moving inside a narrow vertical tube (see figure to the right). Fixed at the bottom is a small sphere 2 carrying charge q_2.
    a. [4 points] Determine the equilibrium height h for sphere 1, ignoring friction.
    b. [6 points] When sphere 1 is displaced vertically from this equilibrium position by a small amount (Δy), derive an expression for all forces acting on sphere 1 in the y-direction. [Hint: You will want to consider what happens when $\Delta y/h \ll 1$.]
    c. [4 points] If sphere 1 is released from position Δy, it moves in simple harmonic motion. Determine the angular frequency of the oscillations of sphere 1.



(a) fbd for 1: $\uparrow \frac{kq_1q_2}{h^2}$, $\downarrow m_1 g$

Equilibrium:

$$m_1 g = \frac{kq_1q_2}{h^2}$$

$$\boxed{h = \sqrt{\frac{kq_1q_2}{m_1 g}}}$$

(b) $\uparrow \Delta y$.

$$F_y = \frac{kq_1q_2}{(h+\Delta y)^2} - m_1 g$$

$$F_y = \frac{kq_1q_2}{h^2}\left(1 + \frac{\Delta y}{h}\right)^{-2} - m_1 g$$

Note eq: condition:

$$\boxed{F_y = \frac{kq_1q_2}{h^2}\left[\left(1 + \frac{\Delta y}{h}\right)^{-2} - 1\right]}$$

Aid sheet:

$(1+x)^n = 1 + nx$ for $x \ll 1$ $\Rightarrow$

$$F_y \approx \frac{kq_1q_2}{h^2}\left[1 - \frac{2\Delta y}{h} - 1\right]$$

3. cont

$$F_y \approx -2\frac{k q_1 q_2}{h^2}\frac{\Delta y}{h}$$

(b) $$F_y \approx -\frac{2 k q_1 q_2}{h^3}\Delta y$$

when $\frac{\Delta y}{h} \ll 1$

(c). $$F_y = m_1 \Delta\ddot{y}$$

$$m_1(\Delta\ddot{y}) = -\frac{2 k q_1 q_2}{h^3}\Delta y$$

$$\Delta\ddot{y} = -\left[\frac{2 k q_1 q_2}{m_1 h^3}\right]\Delta y$$

$$= \omega^2$$

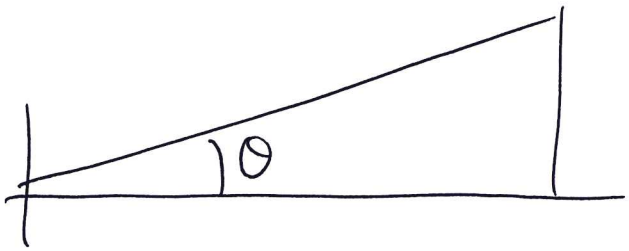
$$\omega = \sqrt{\frac{2 k q_1 q_2}{m_1 h^3}} = \sqrt{\frac{2 m_1 g}{m_1 h}}$$

$$\omega = \sqrt{\frac{2g}{h}}$$

Wow!! Physics is so beautiful!

4. Final Exam 2017, Question 2. [This was the **easiest** question on the 2018 exam; the class average for this particular question was 85%.]

2. [4 points] A He-Ne laser, which produces light of wavelength 632.8 nm, is used to calibrate a diffraction grating. If the first-order maximum occurs at 20.5° from the central spot, what is the distance between the slits of the grating?
   a. 0.905 μm
   b. 1.81 μm
   c. 2.20 μm
   d. 3.62 μm
   e. 4.52 μm



$d \sin\theta = m\lambda \qquad m = 1$

$$d = \frac{\lambda}{\sin\theta} = \frac{632.8 \text{ nm}}{\sin 20.5}$$

$$d = 1806.9 \text{ nm}$$

$$= 1.81 \ \mu\text{m}$$