P114 University of Rochester NAME Soln key - SM
S. Manly Spring 2003

# Exam 3 (April 22, 2003)

***Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show all your work. Partial credit will be given.***

**Problem 1 (24 pts, 8 parts at 3 pts per part):**

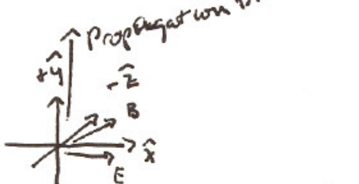
**Consider the electromagnetic plane wave consisting solely of the following electric and magnetic field components:**

$$\vec{E}(y,t) = (60\text{v/m})\sin[(1200\,\text{m}^{-1})y - (2.4\text{x}10^{11}\text{s}^{-1})t]\,\hat{x}$$

$$\vec{B}(y,t) = (2\text{x}10^{-7}\,\text{T})\text{Sin}[(1200\text{m}^{-1})y - (2.4\text{x}10^{11}\text{s}^{-1})t]\,(-\hat{z})$$

(a) **What is the maximum amplitude of the electric field strength for this wave?**

$60 \ \frac{V}{M}$




(b) **What the direction of propagation of this wave?**

direction $\sim \vec{E} \times \vec{B} \sim \hat{x} \times (-\hat{z}) \rightarrow +\hat{y}$ is Direction of Propagation

(c) **What type of polarization is exhibited by this wave and what is the direction of the polarization (for example, linear at so many degrees from the such and such axis or left-handed circular)?**

Linear Polarization along X axis direction

(d) **What is the frequency of this electromagnetic wave?**

$\sim A\sin(kx - \underbrace{\omega}_{2\pi\nu} t)$ $\quad 2.4\times10^{11}\,s^{-1} = 2\pi\nu$

$\nu = 3.8\times10^{10}\,Hz$

(e) **What is the wavelength of this electromagnetic wave?**

$k = \frac{2\pi}{\lambda} = 1200\,M^{-1} \qquad \lambda = 5.2\times10^{-3}\,M$

(f) **What is the velocity of this electromagnetic wave?**

$v = \lambda\nu = (5.2\times10^{-3}\,M)(3.8\times10^{10}\,s^{-1}) = 1.98\times10^{8}\,M/s$

(g) **What is the intensity of this electromagnetic wave?**

$I = \frac{1}{2}\frac{E_0 B_0}{\mu_0} = \frac{1}{2}\frac{(60\,V/m)(2\times10^{-7}\,T)}{4\pi\times10^{-7}\,N/A^2} = 4.8\,W/M^2$

(h) **What is the index of refraction of the medium through which this wave travels?**

$n = \frac{c}{v} = \frac{3\times10^{8}\,M/s}{1.98\times10^{8}\,M/s} = 1.51$

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|---|---|
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| 2) | /16 |
| 3) | /20 |
| 4) | /20 |
| 5) | /20 |
| tot | /100 |

**Problem 2 (16 pts):**

**Consider the Bohr model energy level diagram shown below. There is a series of spectral lines given by the transitions shown in the diagram.**

**(a) Circle the arrow corresponding to the transition in this series that gives light with the longest wavelength.**

$c = \nu\lambda$ longest $\lambda \Rightarrow$ lowest $E = h\nu$

**(b) For the transition indicated in part (a), compute the energy of the photon assuming the diagram is for $Be^{++}$ (Z=3).**

$\frac{mv^2}{R} = \frac{kZe^2}{R^2}$ $n\lambda = 2\pi r$ $n = 1,2,3\ldots$

$\lambda = \frac{h}{p}$ $n\frac{h}{mv} = 2\pi R$

$v = \frac{nh}{2\pi R m}$

$\frac{m}{R}\frac{n^2h^2}{(2\pi)^2R^2m^2} = \frac{kZe^2}{R^2}$

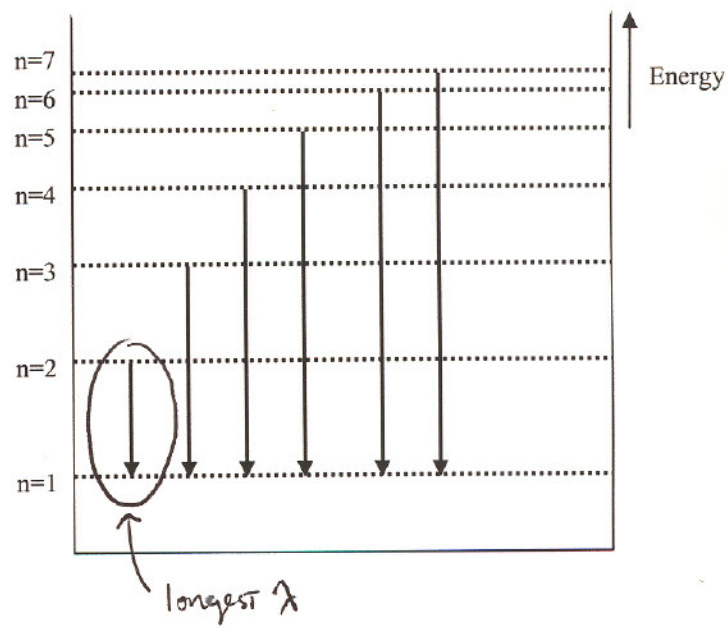
$R_n = \frac{n^2h^2}{(2\pi)^2 m k Z e^2}$

$E = \frac{1}{2}mv^2 - \frac{ke^2}{R} = -\frac{1}{2}\frac{kZe^2}{R}$

Sub in for $R_n$ and $v_n$

$E_n = \frac{-mk^2e^4Z^2}{2\hbar^2n^2} = -\frac{Z^2E_0}{n^2} = -\frac{Z^2(13.6\,eV)}{n^2}$

$E_\gamma = E_2 - E_1 = -3^2(13.6)\left(\frac{1}{4} - 1\right) = 91.8\ eV$




**Problem 3 (20 pts):**

**The years go by and you become a successful optometrist. One of your former old fart professors comes in for an examination. During the examination, as you have several sharp objects mere centimeters from his eyes, visions of the tortuous exams he put you through flash in your mind. But you take a deep breath and the urge to get even passes and you continue with the eye exam.**

**Your patient has a near point of 80 cm but needs to see clearly a computer screen 45 cm from his eyes.**

**What is the power (in diopters) and focal length of the lenses in the reading glasses suitable for allowing your dear old professor to see his computer?**

$\frac{1}{f(m)} =$ Power in diopters $= \frac{1}{i} + \frac{1}{o} = -\frac{1}{.8} + \frac{1}{.45} = 0.972$ Diopters

want to take object at .45 m
and put image at .8 m
image comes in with "−" because on
same side of lens as object

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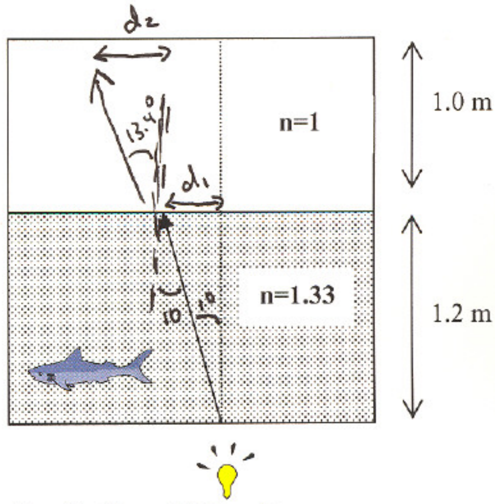
**Problem 4 (20 pts):**

(a) **There is a large fish tank in a public aquarium where a light shines through a very small window in the bottom of the tank. The ray of light enters the tank of water at an angle of 10 degrees with the vertical. Where does the spot of light hit the ceiling above the surface of the water (relative to the vertical line above the light source)? The depth of water and height of the ceiling above the surface of the water are provided on the sketch below.**




$\tan 10 = \frac{d_1}{1.2}$

~~$\sin 10 = \frac{\ }{hyp}$~~

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

$1.33 \sin 10 = 1 \sin\theta_2$

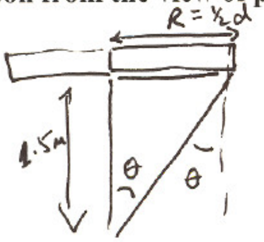
$\theta_2 = 13.4°$

$d_1 = \overbrace{1.2 \tan 10}^{.21}$ $\qquad d_2 = 1.0 \underbrace{\tan 13.4}_{.23}$

$d = d_1 + d_2 = .21 + .23 = .44\ m$

Spot of light hits ceiling 44 cm from vertical line directly above light source.

(b) **Suppose Saddam Hussein hid a small weapon of mass destruction in the middle of a pool of water in one of his presidential palaces. To help hide the weapon, he placed a water lily sculpture (think of it as being shaped like a circle) directly over the weapon. If the water were 1.5 m deep and you assume the weapon to be small, what is the minimum size of the water lily that should have been placed in the pool to hide the weapon from the view of passing investigators?**




$\theta$ corresponding to light that just hits edge of lilly

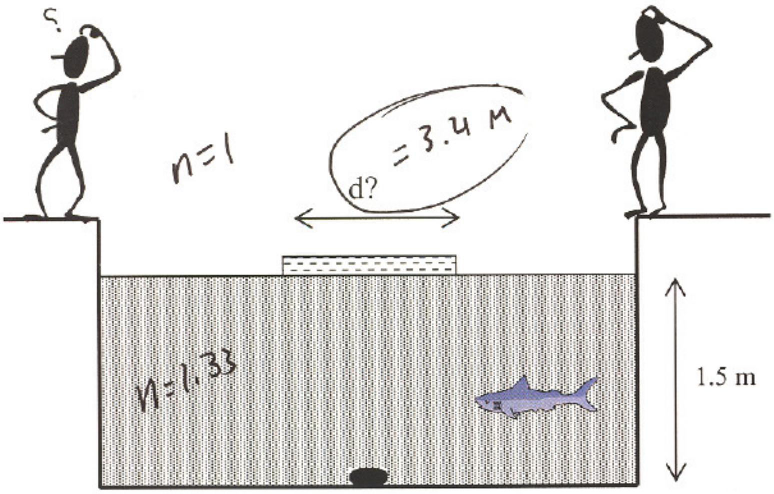
$\frac{\frac{1}{2}d}{1.5\ M} = \tan\theta$

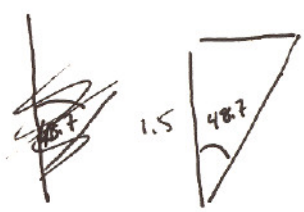
If $\theta_{critical} \leq \theta$ Then no light can be seen coming out of the water beyond the edge of the lily sculpture.

What is $\theta_c$?

$1.33 \sin\theta_c = (1.0) \sin 90°$

$\theta_c = 48.7°$




$\frac{1}{2}d = (1.5) \tan 48.7$

$d = 3.4\ M$

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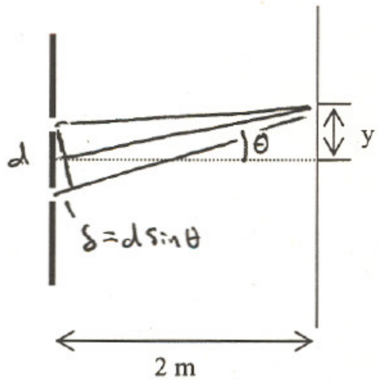
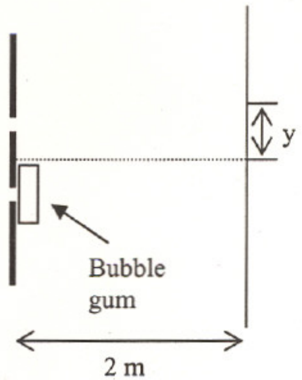
**Problem 5 (20 pts):**

**Biff Quanta, physicist extraordinaire, is making precise measurements of a two-slit interference pattern. Biff is bored because Biff knows exactly what he expects to see. The slits are separated by 1 mm and he illuminates them with laser light of wavelength 500 nm.**




For parts (a) and (b)




For part (c)

**(a) Assuming the slits are very narrow so they have a negligible effect on the interference pattern, what distance y will Biff measure on the screen between the central intensity maximum and the adjacent maximum?**

get Maxima at $d\sin\theta = m\lambda$

$m = 1,\ \lambda = 500\text{ nm}$

$d = .001\text{ m}$

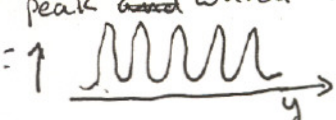
$\theta = 0.029^\circ$

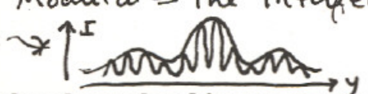

$\tan\theta = \frac{y}{2}$

$y = 1\text{ mm}$

**(b) Not that Biff is that type of guy, but hypothetically and qualitatively, what changes would take place in the pattern on the screen if Biff widened the individual slits?**

Initially the slits are very narrow which leads to a very wide ~~diff~~ central diffraction peak ~~and~~ which is thus NOT noticeable. As the slits are widened the central diffraction peak is Narrowed and Modulates the interference fringe pattern like so




**(c) Back to the narrow slits. Biff becomes quite excited when he makes his measurement because he gets an answer other than what he expects. Little does Biff realize that the week before his son, Crash Quanta, managed to deposit a very thin layer of bubble gum over one of the slits. If the bubble gum is 2 μm thick, what distance (y) on the screen did Biff actually measure between the central maximum and the adjacent maximum? (Assume a thin layer of bubbl…**

5(c) Badly Worded Problem Must be thrown out.