Physics 121 - Midterm I

Last Name	First Name	Student Number	Signature

Tutorial T.A. (circle one): Ricky Chu Firuz Demir Maysam Emadi Alireza Jojjati

Answer **ALL 10** questions. Show all your work and explain your reasoning for full credit. Neatness and clarity of presentation will be considered when assigning a grade. For multiple choice questions, circle one answer only. No aids other than the course calculator and the provided formula sheet may be used.

Light propagation & Simple harmonic waves

$$v_n = \frac{c}{n} = \lambda_n f$$
$$c = 2.998 \times 10^8 m/s$$
$$y(x,t) = A\sin[kx \pm \omega t + \phi_0]$$

Material	n
Air	1.00
Water	1.33
Oil	1.46
Glass	1.55
Diamond	2.41

Interference phenomena

$$\Delta\phi = 2\pi\frac{\Delta x}{\lambda} + \phi_0 = (m)2\pi$$
$$\Delta\phi = 2\pi\frac{\Delta x}{\lambda} + \phi_0 = (m+\frac{1}{2})2\pi$$
$$a\sin\theta_m = m\lambda \text{ (single slit)}$$
$$a\sin\theta_1 = 1.220\lambda \text{ (circular aperture)}$$
$$d\sin\theta_m = m\lambda \text{ (double-slit)}$$
$$d\sin\theta_m = \left(m+\frac{1}{2}\right)\lambda \text{ (double-slit)}$$
$$d\sin\theta_m = m\lambda \text{ (diffraction grating)}$$
$$2\theta_{\min} = 2\sin^{-1}\left(\frac{\lambda}{Nd}\right) \text{ (peak-width)}$$

Refraction, Lenses, etc.

$$n_1\sin\theta_1 = n_2\sin\theta_2$$
$$\sin\theta_c = \frac{n_2}{n_1}$$
$$\frac{1}{s}+\frac{1}{s'} = \frac{1}{f}$$
$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$
$$P = \frac{1}{f}$$
$$\frac{n_1}{s}+\frac{n_2}{s'} = \frac{n_2-n_1}{R}$$

Problem	1	2	3	4	5	6	7	8	9	10	**Total**
Maximum	1	4	6	5	6	3	3	6	3	3	**40**
Grade											

1. (1pts) Suppose a water wave is moving radially outward on the surface of the water from a point source. How should the power in a small segment of the wave front depend on the radial distance from the source?

   a) Decrease as $1/r$

   b) Decrease as $1/r^2$

   c) Independent of r

   d) Not given enough information

   Circumference $= 2\pi r$

2. (4 points) Basics of waves, please circle either True or False:

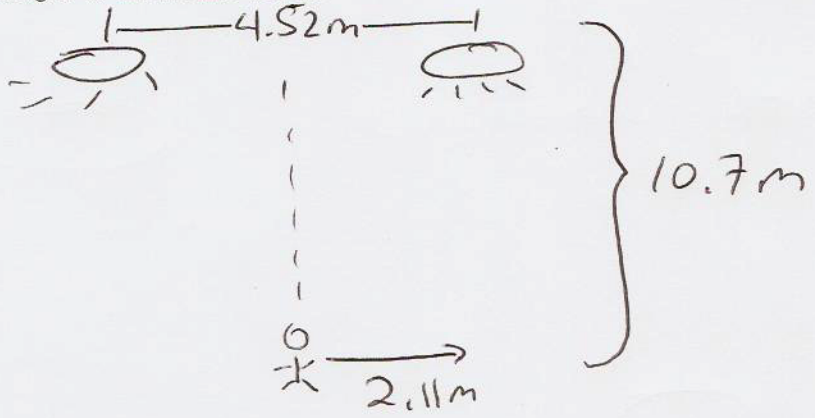
   (a) A wave pulse moves along a uniform string. The speed of the wave is constant but the speed of the particles of the string changes with time. **TRUE** **FALSE**

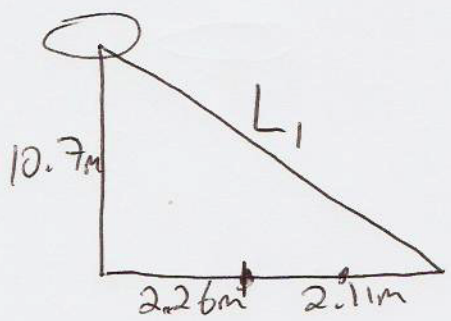
   (b) You are generating traveling waves on a stretched string by wiggling one end. If you suddenly begin to wiggle more rapidly, you will cause the waves to travel faster down the string. **TRUE** **FALSE**

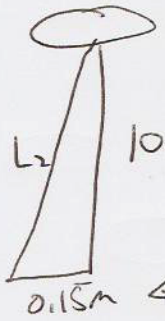
   (c) If you simultaneously send pulses of high-frequency X-rays and low-frequency radio waves from the earth to the moon, both waves will arrive at exactly the same time (assuming a vacuum between the earth and moon). **TRUE** **FALSE**

   (d) As light passes from air into glass, its wavelength decreases and its frequency increases so that its speed does not change. **TRUE** **FALSE**

3. (6 points) Two speakers mounted 4.52m apart on a wall emit identical sound waves. You are standing at the opposite wall of the room at a point directly between the two speakers. You walk 2.11m parallel to the wall, to a location where you first notice that the sound intensity is much less. If the wall along which you are walking is 10.7m from the wall with the speakers, what is the wavelength of the sound waves?







$2.26 - 2.11\,m = 0.15\,m$.

$L_1 = \sqrt{10.7^2 + 4.37^2}$

$L_1 = 11.56\,m$

$L_2 = \sqrt{0.15^2 + 10.7^2}$

$= 10.7\,m$

$\Delta L = L_1 - L_2 = 0.86\,m$

$\Delta\phi = 2\pi \frac{\Delta x}{\lambda} + \phi_0 = (m + 1/2)\,2\pi$

For $m = 0$:

$\Delta\phi = 2\pi \frac{\Delta L}{\lambda} = \frac{1}{2} \cdot 2\pi \Rightarrow \frac{\Delta L}{\lambda} = \frac{1}{2}$

$\boxed{\lambda = 2\Delta L = 2(0.86) = 1.72\,m}$

4. (5 points) Basics of gratings and slits, please circle TRUE or FALSE

   (a) Light passes through two small parallel slits and makes an interference pattern on a distant screen. If the two slits are now moved closer to each other, the bright finges will also move closer to each other. **TRUE** **FALSE**

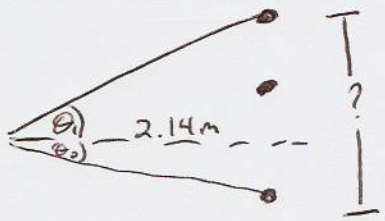
   (b) Visible light passes through a hole of diameter $150nm$ in a sheet of metal and falls on a distant screen. If the metal is heated, making the hole larger, the size of the central bright spot on the screen gets smaller. **TRUE** **FALSE**

   (c) A diffraction grating produces its first order bright spot an at angle of 40°. If you want to reduce this angle to 20° for the same wavelength of light, you must double the line density of the grating. **TRUE** **FALSE**

   (d) The intensity of the bright fringes in Young's double slit experiment is 4 times the intensity of the light expected from either one of the 2 slits. **TRUE** **FALSE**

   (e) When light passing through a diffraction grating falls on a distant screen, the interference bright spots are equally spaced along the screen. **TRUE** **FALSE**

5. (6 pts) A 2-slit arrangement with $60.3\mu m$ separation between the slits is illuminated with $482.0nm$ light. Assuming that a viewing screen is located $2.14m$ from the slits, find the distance from the first dark fringe on one side of the central maximum to the second dark fringe on the other side.

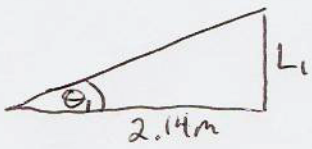


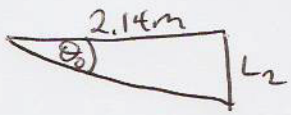
$d \sin\theta = (m+1/2)\lambda$ small angle $d\theta = (m+1/2)\lambda$

$\theta_0 = \frac{1/2\,\lambda}{d} = \frac{\frac{1}{2}(482\times10^{-9}m)}{(60.3\times10^{-6}m)}$

$\theta_0 = 4.0\times10^{-3}$ rad

$\theta_1 = \frac{3/2\,\lambda}{d} = 0.012$ rad.





$\tan\theta_1 = \frac{L_1}{2.14}$

$\theta_1 \approx L_1/2.14$

$L_1 = (2.14)(0.012)$

$L_1 = 0.026m$

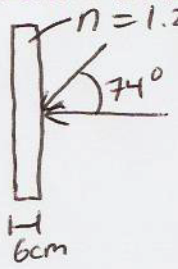
$\tan\theta_0 = \frac{L_2}{2.14}$

$L_2 = (2.14)(4\times10^{-3})$

$L_2 = 0.0086m$.

$\boxed{L_1 + L_2 = 0.035m}$

6. (3 pts) A ray of light incident normally on a glass plate 6.00cm thick and of refractive index $n = 1.29$. If the plate is turned through an angle of 74.0° about an axis perpendicular to the ray, what is the increase in the distance the ray travels in the glass? ($n_{air} = 1.00$)

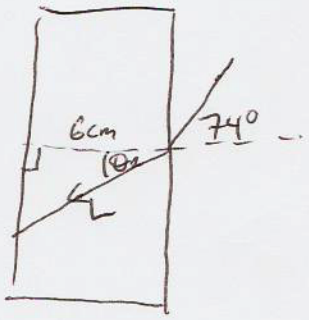


$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$(1)(\sin 74^\circ) = (1.29)\sin\theta_2$

$\theta_2 = 48.2^\circ$

Zoom



$\cos\theta_2 = \frac{6\text{cm}}{L}$

$L = \frac{6\text{cm}}{\cos\theta_2} = 9\text{cm}.$

$9\text{cm} - 6\text{cm} =$ **3cm extra**

7. (3 pts) The speed of light in a material is 0.50c. What is the critical angle of a light ray at the interface between the material and the vacuum?

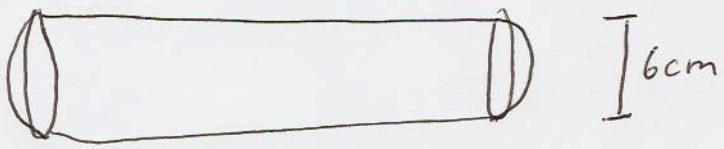
$n = \frac{c}{v_{medium}} = \frac{c}{0.5c} = 2$

$\sin\theta_c = \frac{n_2}{n_1}$

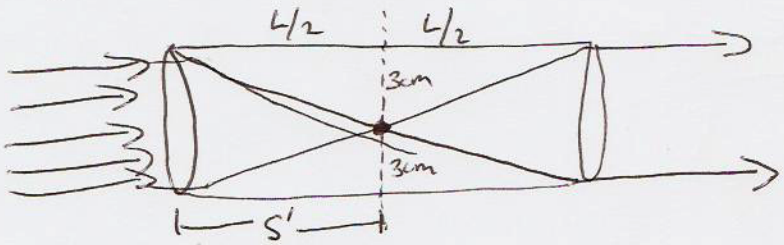
$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1}{2}\right)$

$\theta_c = 30^\circ$

8. (6pts) A beam of parallel light is directed through a glass rod parallel to its axis. The glass rod has a refractive index $n_g = 1.3$ and a diameter $D = 6cm$, and its ends are both polished to a radius of curvature $R = 4cm$. The parallel rays are brought to focus, diverge and strike the walls, where they are totally internally reflected. What is the minimum length the rod can have so that the rays entering the rod farthest from the optical axis emerge from the rod parallel?



Parallel rays entering the rod will be Focused at a point, s' From the surface. The out going rays will be parallel if they also pass through this point for the second surface:



$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}$$

$s \to \infty$

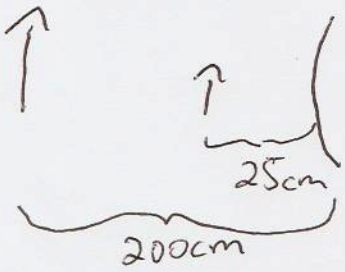
$$\frac{n_2}{s'} = \frac{n_2 - n_1}{R}$$

$$s' = \frac{n_2 R}{n_2 - n_1} = \frac{(1.3)(4cm)}{1.3 - 1} = 17.33cm.$$

Length is twice s':

$$\boxed{L = 34.7cm}$$

9. (3pts) A farsighted boy has a near point at 2.0m and requires eyeglasses to correct his vision. The eyeglasses should have lenses of the lowest power for which the near point becomes 25cm. What is the power (in diopters) that this boy needs?



$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$$\frac{1}{0.25m} + \frac{1}{(-2m)} = \frac{1}{f}$$

$$\frac{1}{f} = P = 3.5\,D$$

10. (3pts) Basics of the particle model of light. Circle TRUE or FALSE for each:

(a) The frequency of light is the number of photons per second that it carries. **TRUE** **FALSE**

(b) Photons all travel at the speed of light, so they must all have the same energy. **TRUE** **FALSE**

(c) A photon of violet light has more energy than a photon of green light. **TRUE** **FALSE**