SOLUTIONS

PHYSICS-2112 Spring 2018 **Exam 3** **April 10, 2018**

Last Name (print)________________________ First Name (print)________________________

Signature ________________________ LSUID No. ________________________

DEPARTMENTAL POLICY STATES THAT ANY AND ALL NONAPPROVED ELECTRONIC DEVICES MUST BE TURNED OFF AND IN YOUR BAG AT THE FRONT OF THE ROOM. NO STUDENT MAY LEAVE THE ROOM DURING THE EXAM FOR ANY REASON – ONCE A STUDENT EXITS THE ROOM HIS/HER EXAM IS OVER.

<u>Circle one:</u>

N. Zuniga-Hansen	(Sec. 2; MWF 11:30 am)
D. Mesa	(Sec. 3; MWF 1:30 pm)
C. Deibel	(Sec. 4; TTh 10:30 am)

Have your LSU ID ready when you turn in your paper.

You may only use an ordinary scientific or graphing calculator. *You may not use a cell phone, smart phone, or tablet application as your calculator.*

Examine your paper to be sure it is complete and legible. There should be 12 multiple choice questions and 2 free-response problems, totaling 100 points. There are 7 pages, including the cover sheet and a formula sheet, which is attached to this exam.

<u>For the multiple choice questions</u>, bubble in the correct answer on your scantron for each question. There is room on the exam for scratch work or calculations, but that work will not be checked or graded. Partial credit may be awarded on multiple choice questions, but this partial credit will be based on the answers that you have bubbled in on the scantron and NOT on your scratch work on the exam itself.

<u>For the free-response problems, show all relevant work in the space provided.</u> Without supporting work, even a correct answer will receive little or no credit. Partial credit will be awarded as warranted.

If your work for a problem is somewhere other than the space provided for that part of the problem, <u>you must indicate where your work is located</u>. *E.g.*, if you need more room for your solution, then you may write on the back of the page. Be sure to add a note to this effect; otherwise, anything on the back of the paper will be regarded as scratch work and will not be checked or graded.

Be sure that numerical answers appear with appropriate **<u>SI units</u>**. Points will be deducted for missing, incorrect, or "silly" units. If the final answer is, in fact, a dimensionless quantity, please write the numerical result followed by the word <u>dimensionless</u>.

You will have 55 minutes to complete this examination.

Question #1 (no points)

Bubble in the answer choice corresponding to your class section number.

a) Sec. 2; MWF 11:30 am
b) Sec. 3; MWF 1:30 pm
c) Sec. 4; TTh 10:30 am

Question #2 (no points)

Your version of the test is B. **Bubble in answer B** on your scantron.

Question #3 (5 points) Visible light has a frequency of about:

a) 5×10^{10} Hz
b) 5×10^{12} Hz
c) 5×10^{14} Hz
d) 5×10^{16} Hz
e) 5×10^{18} Hz

$\lambda_{vis} \approx 400\text{ nm} - 700\text{nm}$

$c = \lambda f$

$3 \times 10^8 \text{ m/s} = \lambda (500\text{nm})$

$\lambda = 6 \times 10^{14}\text{ Hz}$

Question #4 (5 points) The light intensity 10 m from a point source is 1000 W/m². The intensity 100 m from the same source is:

a) 1 W/m²
b) 10 W/m²
c) 100 W/m²
d) 1000 W/m²

$I = \frac{P}{4\pi r^2}$

$$\frac{1000\text{ W/m}^2}{I_2} = \frac{\frac{\cancel{P}}{\cancel{4\pi}(10\text{m})^2}}{\frac{\cancel{P}}{\cancel{4\pi}(100\text{m})^2}}$$

$I_2 = 1000\frac{\text{W}}{\text{m}^2}\left(\frac{10\text{m}}{100\text{m}}\right)^2$

$= 10\frac{\text{W}}{\text{m}^2}$

Question #5 (6 points) The critical angle of a diamond is about $\theta = 25°$ at an interface with air. What is the index of refraction of a diamond?

a) 2.37
b) 1.51
c) 0.42
d) 1.00

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

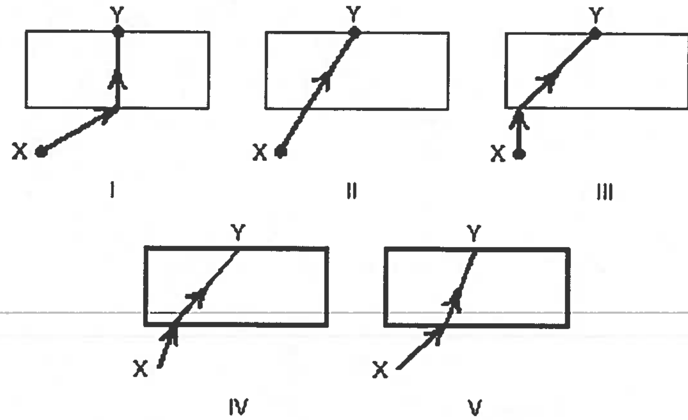
$n_{diamond} \sin\theta_c = n_{air} \sin 90°$

$n_{diamond} = \frac{1}{\sin\theta_c}$

$\theta_c = 25°$ so

$n_d = \frac{1}{\sin 25°} = 2.37$

Question #6 (5 points) Which diagram below illustrates the path of a light ray as it travels from a given point X in air ($n = 1$) to another given point Y in glass ($n > 1$)?



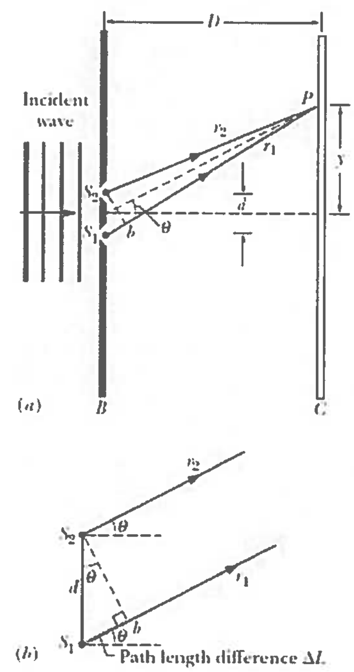
a) V
b) IV
c) III
d) II
e) I

$n_{glass} > 1$ so light bends closer to $0°$

Question #7 (5 points) When you stand in front of a plane mirror, your image is:

a) real, inverted, and the same size as you
b) real, erect, and the same size as you
c) real, erect, and smaller than you
d) virtual, erect, and smaller than you
e) virtual, erect, and the same size as you

Question #8 (5 points) The two rays of light of wavelength $\lambda = 600$ *nm* reach point P in the figure at angle $\theta = 0.26°$ with respect to the central axis. The slit separation is $d = 0.25$ mm. What is the path length difference between the two rays in terms of λ?



a) 1.0λ
b) 1.9λ
c) 3.5λ
d) 2.2λ

$\Delta L = d \sin\theta = m\lambda$

$0.25 \times 10^{-3}\,m \sin 0.26°$

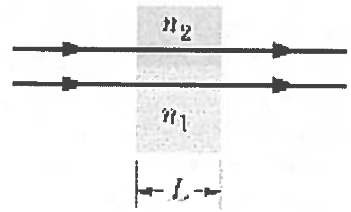
$= m\, 600 \times 10^{-9}\, m$

$m = 1.9$

so $\Delta L = m\lambda = 1.9\lambda$

Note: can use $\sin\theta \approx \theta$ if θ is in radians

Question #9 (6 points) In the figure, two waves of light in air, of wavelength *690 nm*, are initially in phase. One travels through a glass layer of index of refraction $n_1 = 1.52$ and thickness $L = 3.62\ \mu m$. The other travels through an equally thick plastic layer of index of refraction $n_2 = 1.35$, and the same thickness L. What is the phase difference between the two waves in rad?



$\lambda_n = \frac{\lambda}{n}$

a) 15 rad
b) 5.6 rad
c) 0.89 rad
d) 6.3 rad

$\Delta\phi = 2\pi \frac{L}{\lambda_{n_1}} - 2\pi \frac{L}{\lambda_{n_2}} = 2\pi \frac{L}{\lambda_{va}} [n_1 - n_2]$

$= 2\pi \frac{3.62\,\mu m}{0.69\,\mu m} [1.52 - 1.35] = 5.6$ rad

Question #10 (6 points) Light of wavelength 480 nm falls on a slit of width 3.5 µm. What is the relative intensity (that is, the value of I/I_m) of the diffraction pattern at an angle of 0.314 rad?

a) 2.4×10^{-4}
b) 1.0×10^{-1}
c) 1.7×10^{-3}
d) 1.0×10^{-2}

$$\frac{I}{I_m} = \left[\frac{\sin \frac{\pi a}{\lambda} \sin\theta}{\frac{\pi a}{\lambda} \sin\theta} \right]^2 = \left(\frac{\sin \frac{\pi\, 3.5\,\mu m}{0.48\,\mu m} \sin 0.314}{\frac{\pi\, 3.5\,\mu m}{0.48\,\mu m} \sin 0.314} \right)^2$$

$= (0.1)^2 = (1 \times 10^{-1})^2 = 1 \times 10^{-2}$

Question #11 (5 points) The ability of a telescope to distinguish two distant objects can be increased by:

a) increasing the wavelength of the light
b) using a tripod
c) decreasing the lens diameter
d) increasing the lens diameter
e) none of the above

$\theta_R = 1.22 \frac{\lambda}{d}$

So increasing d gives lower θ_R → two obj can be closer

Question #12 (6 points) 600-nm light is incident on a diffraction grating with a ruling separation of 1.7×10^{-6} m. The second order line occurs at a diffraction angle of:

a) 45°
b) 42°
c) 21°
d) 10°
e) 0°

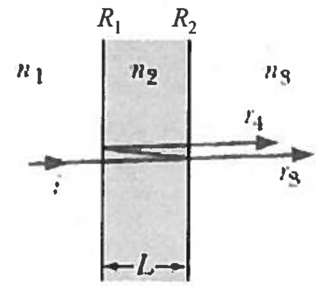
$d \sin\theta = m\lambda$

$1.7 \times 10^{-6}\,m \sin\theta = 2(600 \times 10^{-9}\,m)$

$\theta = 44.9°$

Problem 1 (18 points) – Show your work!

Light is incident perpendicularly on a thin layer (thickness L) of material 2 that lies between (thicker) materials 1 and 3 as shown in the figure (the rays are tilted only for clarity).



The indices of refraction and wavelength of the incident light are given in the table below.

n_1	n_2	n_3	λ
1.35	1.80	1.40	450 nm

(a) (4 points) What is the relative phase shift, in terms of number of wavelengths between rays 3 and 4 due to the reflections at the two interfaces R_1 and R_2 **only** (circle one)?

0λ $\frac{1}{4}\lambda$ $\frac{1}{2}\lambda$ 1λ 2λ

neither r_3 nor r_4 reflect off a surface with an $n > 1.80$

(b) (5 points) What should the third minimum thickness of the film be if, after the waves of rays r_3 and r_4 interfere, we see a bright spot?

$2L + \cancel{\text{"other"}} = m\lambda_{n_2}$ $\lambda_{n_2} = \frac{\lambda_{vac}}{n_2}$

0

$m = 3$ for 3^{rd} min. thickness so $2L = 3\frac{\lambda_{vac}}{n_2}$ $L = \frac{3}{2}\frac{450nm}{1.8} = 375nm.$

(c) (4 points) Using your answer to part (b), what is the geometrical path length difference, ΔL, between rays r_3 and r_4?

r_4 must traverse thickness L three times, while r_3 only traverses L once so

Δ pathlength $= 3L - L = 2L = 2(375nm) = 750nm$

(d) (5 points) What should the second minimum thickness of the film be if, after the waves of rays r_3 and r_4 interfere, we see a dark spot?

$2L + \cancel{\text{"other"}} = (m + \frac{1}{2})\frac{\lambda_{vac}}{n_2}$

0

$m = 0$ gives min thickness, so $m = 1$ gives 2^{nd} min. thickness

$2L = (1 + \frac{1}{2})\frac{\lambda_{vac}}{n_2}$ $L = \frac{\left(\frac{3}{2}\right)\frac{450nm}{1.8}}{2} = 187.5nm$

Problem 2 (28 points) – Show your work!

A seed is placed 6 cm in front of a converging lens with a focal length f_1 at 24 cm.

a) **(4 points)** Where is the image located (both the sign and the numerical value for the distance)?

$$\frac{1}{f} = \frac{1}{i} + \frac{1}{p}$$

for a converging lens f is positive

$$\frac{1}{24cm} = \frac{1}{i} + \frac{1}{6cm}$$

$i = -8cm$

b) **(4 points)** What is the magnification of the image (both the sign and the numerical value)?

$$m = -\frac{i}{p} = -\frac{-8cm}{6cm} = +1.33$$

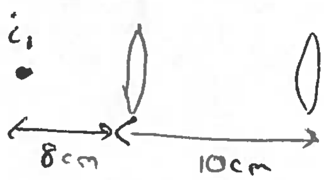
c) **(6 points)** Circle the correct answer for each of the following questions

(2 points) The image is:	REAL	VIRTUAL ← negative i
(2 points) Compared to the object, the image is:	UPRIGHT ← positive m	INVERTED
(2 points) Compared to the object, the image is:	LARGER ← $\|m\| > 1$	SMALLER

A second symmetrical, coaxial converging lens is placed <u>**10 cm**</u> to the right of the first lens (from above) with focal length f_2 **at 9.0 cm**

d) **(4 points)** Where does the system of two lenses produce an image of the seed (both the sign and the numerical value for the distance)?

Since i_1 from (a) is $-8cm$, image from 1st lens is 8cm in front of 1st lens



$p_2 = 8cm + 10cm = 18cm$

$$\frac{1}{f_2} = \frac{1}{i_2} + \frac{1}{p_2} \qquad \frac{1}{9cm} = \frac{1}{i_2} + \frac{1}{18cm}$$

$i_2 = 18cm$

e) **(4 points)** What is the overall magnification of the **two-lens system** (both the sign and the numerical value)?

$$m_2 = -\frac{i}{p} = -\frac{18cm}{18cm} = -1$$

$$m_{tot} = m_1 m_2 = (1.33)(-1) = -1.33$$

f) **(6 points)** Circle the correct answer for each of the following questions

(2 points) The image is:	positive i_2 → REAL	VIRTUAL
(2 points) Compared to the object, the image is:	UPRIGHT	INVERTED ← neg m_{tot}
(2 points) Compared to the object, the image is:	LARGER	SMALLER

$|m| > 1$