PHYSICS-2112 Fall 2019 **Exam 3** **November 19, 2019**

Last Name (print)__________KEY____________ ***First*** Name (print)__________________________

Signature ________________________________ LSU ID 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.

Circle one:

C. Deibel	(Sec. 1; MWF 9:30 am)
M. Wilde	(Sec. 2; MWF 12:30 pm)
P. Sprunger	(Sec. 3; TTh 9:00 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 6 pages, including the cover sheet.

For the multiple choice questions, 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.

For the free-response problems, show all relevant work in the space provided. 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, you must indicate where your work is located. *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 **SI units**. 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 dimensionless.

You will have 60 minutes to complete this examination.

A

Question #1 (no points)

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

A. Sec. 1; MWF 9:30 am (Deibel)
B. Sec. 2; MWF 12:30 pm (Wilde)
C. Sec. 3; TTh 9:00 am (Sprunger)

Question #2 (no points)

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

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Question #3 (5 points)

The magnetic field of a light wave oscillates parallel to an x axis and is given by $B_x = B_m \sin(ky - \omega t)$. (i) In what direction does the light wave travel, and (ii) parallel to which axis does the associated electric field oscillate?

A. (i) +x direction (ii) x axis
B. (i) +y direction (ii) x axis
C. (i) – y direction (ii) x axis
D. (i) + y direction (ii) z axis
E. (i) – y direction (ii) z axis

$$B_x = B_m \sin(ky - \omega t)$$

y in argument means wave is traveling in y direction

Negative sign means wave is traveling in position direction

E and B components of wave must be perpendicular to each other AND direction of travel; therefore, E must be oscillating parallel to z axis

Question #4 (5 points)

The light intensity 10 m from a point source is 100 W/m^2. The intensity 1 m from the same source is:

A. 1 W/m^2
B. 10 W/m^2
C. 100 W/m^2
D. 1000 W/m^2
E. 10000 W/m^2

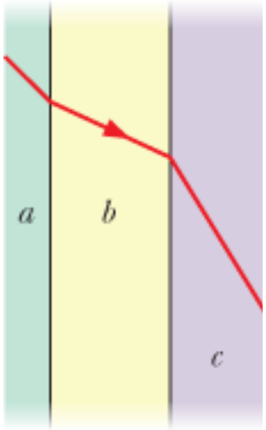
$I = \frac{P_s}{4\pi r^2}$ - This equation is true for both distances!

$$\frac{I_{1m}}{I_{10m}} = \frac{\frac{P_s}{4\pi(1m)^2}}{\frac{P_s}{4\pi(10m)^2}}$$

Therefore: $I_{1m} = 100\frac{W}{m^2}\frac{\frac{1}{(1m)^2}}{\frac{1}{(10m)^2}} = 10000\ W/m^2$

Question #5 (5 points)

In the figure, light travels from material *a* through material *b* and into material *c*. The refractions (but not the reflections) at the surfaces are shown. Rank the materials according to index of refraction, greatest first.



A. $a > b > c$
B. $a > c > b$
C. $b > a > c$
D. $b > c > a$
E. $c > a > b$

Light bends towards normal when going from *a* to *b* so $n_b > n_a$. Light bends away from normal in *c* compared to light in both *a* and *b*, so $n_c < n_a$. Therefore, $n_b > n_a > n_c$.

Question #6 (5 points)

The critical angle of cubic zirconia ***when submerged in water (n_{water} =1.33)*** is $\theta_c = 38°$. What is the index of refraction of cubic zirconia?

A. 2.37
B. 2.16
C. 1.33
D. 1.00
E. 0.46

Snells' Law: $n_{cz} \sin\theta_{cz} = n_{water} \sin\theta_{water}$

At critical angle, refracted angle is 90°, so

$$n_{cz} \sin 38° = 1.33 \sin 90°$$

$$n_{cz} = \frac{1.33}{\sin 38°} = 2.16$$

Question #7 (5 points)

An object *O* stands on the central axis of a concave/converging spherical mirror. The object distance is +20 cm and the distance between the focal point and the mirror is 40 cm (without proper sign). What is the lateral magnification of the image produced, *m*?

A. 1
B. 2
C. -2
D. 0.5
E. -0.5

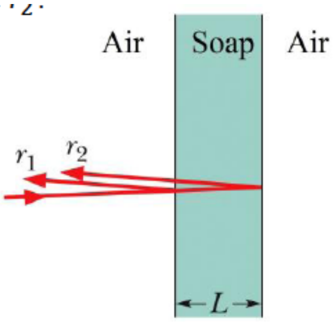
Concave/converging mirror means *f* is positive

$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f} \qquad \frac{1}{20cm} + \frac{1}{i} = \frac{1}{40cm} \Longrightarrow i = -40cm$$

$$m = -\frac{i}{p} = -\frac{-40cm}{20cm} = +2$$

Question #8 (5 points)

Light of wavelength 450 nm is incidence perpendicularly on a thin soap film (n = 1.40) that makes the wall of a soap bubble. (In the figure the rays are tilted for clarity). What ***minimum*** thickness *L* of the soap film will result in destructive interference of the reflected rays r_1 and r_2?



A. 482 nm
B. 675 nm
C. 321 nm
D. 80.4 nm
E. 161 nm

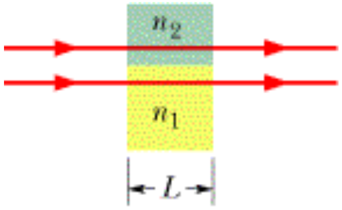
Since $n_{soap} > n_{air}$, there is only one λ/2 from the reflection of r_1.

$$2L + \frac{\lambda_n}{2} = \left(m + \frac{1}{2}\right)\lambda_n \quad \rightarrow \quad L = \frac{1}{2}\left(m + \frac{1}{2} - \frac{1}{2}\right)\frac{\lambda_{vac}}{n_{soap}}$$

so minimum *L* occurs when *m* =1 → $L = \frac{1}{2}(1)\frac{450\ nm}{1.4} = 161\ nm$

Question #9 (5 points)

Two waves of light traveling in air, both with a wavelength of 570 nm, are initially in phase. One wave travels through a plastic layer with thickness *L* = 2.81 µm and index of refraction n_1 = 1.32. The other wave travels through a layer of glass of the same thickness *L* with an index of refraction n_2 = 1.47. What is the phase difference between the two waves upon exiting the materials (in rad)?



A. 31 rad
B. 0.74 rad
C. 0.005 rad
D. 46 rad
E. 4.6 rad

$$\frac{\Delta\phi}{2\pi} = \frac{L}{\lambda}(n_1 - n_2)$$

$$\rightarrow \Delta\phi = 2\pi\frac{L}{\lambda}(n_1 - n_2) = 2\pi\frac{2.81\times10^{-6}m}{570\times10^{-9}m}(1.47 - 1.32) = 4.6\,rad$$

Question #10 (5 points)
When looking at a double slit interference pattern you move from the central bright fringe to the third order bright fringe. By how much does the path length traveled by light from the two slits (ΔL) change?

A. 0λ
B. 1λ
C. 2λ
D. 3λ
E. 4λ

$\Delta L = m\lambda$
For central bright fringe $m = 0$ and therefore $\Delta L = 0$
For third order fringe $m = 3$ and therefore $\Delta L = 3\lambda$
Therefore, change in path length between two situations is 3λ

Question #11 (5 points)
Monochromatic light of wavelength 594 nm is incident on a single slit of width $a = 0.0257$ mm. What is the ratio of the intensity at a point at $\theta = 0.0122$ ***radians*** from the central maximum to the to the intensity at the central maximum?

$$\frac{I}{I_m} = \frac{\sin\left(\frac{\pi d}{\lambda}\sin\theta\right)}{\frac{\pi d}{\lambda}\sin\theta} = \frac{\sin\left(\frac{\pi 0.0257\times 10^{-3} m}{594\times 10^{-9} m}\sin 0.0122 rad\right)}{\frac{\pi 0.0257\times 10^{-3} m}{594\times 10^{-9} m}\sin 0.0122 rad} = 0.361$$

A. 0.601
B. 0.361
C. 0.002
D. 1.000
E. 0.910

Question #12 (5 points)
The ability of a telescope to distinguish between (i.e. resolve) two objects can be increased by:

A. Decreasing the wavelength of light
B. Increasing the wavelength of light
C. Decreasing the lends diameter
D. Using a tripod
E. None of the above

Rayleigh's criterion tells us $\theta_R = 1.22\frac{\lambda}{d}$. Therefore, a smaller wavelength of light, i.e. a smaller λ, will give a smaller angle of resolution and one can then resolve objects that are closer together!

Problem #1 (28 points) - Show your work! (Circle your answers)

A dime is placed 8 cm in front of a converging lens with a focal length F_1 at 16 cm.

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

$$\frac{1}{p_1}+\frac{1}{i_1}=\frac{1}{f_1}$$

$$\frac{1}{+8\ cm}+\frac{1}{i_1}=\frac{1}{+16\ cm}$$

$$\boldsymbol{i_1=-16.0\ cm}$$

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

$$m_1=\frac{-i_1}{p_1}$$

$$m_1=\frac{-(-16.0\ cm)}{8\ cm}$$

$$\boldsymbol{m_1=+2}$$

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

The image is: REAL [✓ VIRTUAL]

Compared to the object, the image is: [✓ UPRIGHT] INVERTED

Compared to the object, the image is: [✓ LARGER] SMALLER

A second symmetrical, coaxial converging lens is placed 15 cm to the right of the first lens (when looking from above) with focal length F_2 at 7 cm.

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

$$\frac{1}{p_2}+\frac{1}{i_2}=\frac{1}{f_2}$$

$$\frac{1}{(16cm+15\ cm)}+\frac{1}{i_2}=\frac{1}{7\ cm}$$

$$\boldsymbol{i_2=+9.04\ cm}$$

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

$$m_2=\frac{-i_2}{p_2}$$

$$m_2=\frac{-(9.04\ cm)}{31\ cm}$$

$$m_2=-0.29$$

$$\boldsymbol{M=m_1m_2=-0.58}$$

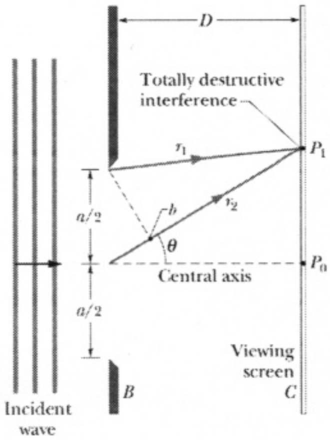
f) (6 points) Circle the correct answer for each of the following questions:

The final image with respect to the dime is: [✓ REAL] VIRTUAL

Compared to the dime, the image is: UPRIGHT [✓ INVERTED]

Compared to the dime, the image is: LARGER [✓ SMALLER]

Problem #2 (22 points) -- Show your work! (Circle your answers)



In the single-slit diffraction experiment of the figure, let the wavelength of the light be 530 nm, the slit width be 5.30 µm, and the viewing screen be at distance $D = 3.48$ m. Let a y-axis extend upward along the viewing screen, with its origin at the center of the diffraction pattern. Point P_1 is located at $y = 15.3$ cm. (Note that figure is not to scale.)

(a) (6 points) Give the order of the ***minimum*** in the diffraction pattern nearest to point P_1. Justify your answer.

First figure out angle θ for point P:

$\tan^{-1}\left(\frac{y}{D}\right) = \theta = \tan^{-1}\left(\frac{15.3 cm}{3.48 m}\right) = 0.0439$ rad $= 2.517°$

Now plug in to $a \sin\theta = m\lambda$ to get $m = \frac{a \sin\theta}{\lambda} = 0.439$

$\Rightarrow$ nearest minimum is $m=1$

(b) (5 points) What is the angle θ of this nearest **minimum**?

$(m=1)$

angle of nearest minimum is

$\theta = \sin^{-1}\left(\frac{m\lambda}{a}\right) = \sin^{-1}\left(\frac{1 \cdot 530 nm}{5.3 \mu m}\right) = 0.1002$ rad $= 5.74°$

(c) (6 points) Give the order of the **maximum** in the diffraction pattern nearest to point P_1 (recall that 0 is the central maximum). Justify your answer.

Since P_1 is @ $m = 0.439$ it lies between central maximum & 1st minimum, so answer is central maximum

(d) (5 points) What is the angle θ of this nearest **maximum**? Justify your answer.

for central maximum,

$\theta = 0$.