Name _____KEY______

Physics 161 Lab Time ________________

Exam 2 – Optics

March 3, 2011

- This is a closed book examination.
- You may use a 3x5 index card that you have made with any information on it that you would like. You must have your name, lab section and the date on your index card.
- There is extra scratch paper available.
- Please fill out the Scantron sheet completely
    - Include your test code.
    - Include your Dragon ID
    - Include your name
- Mark your exam and include explanations where needed. This will help you learn from your exam as well as provide any verification of your scantron sheet.
- Please make sure to fill out each "Problem Solving Sheet" completely
    - Include your test code
    - Include your Dragon ID
    - Include your name
    - Include your lab time
- Your explanation/work for the worked problems is worth ¾ of the points. You must use a separate "Problem Solving Sheet" for each problem.

A general reminder about problem solving:

1. Visualize - draw a picture
2. Pick a coordinate frame
3. Create a simplified picture – if appropriate
    a. Schematic with vectors and free body diagrams
    b. Energy level diagrams
    c. Wave pictures with multiple time frames (cartoon panels)
4. Write down what you know – create separate columns for different directions
5. Write down what you don't know and/or what you want to know
6. List mathematical relationships
7. Combine mathematical formulas, Simplify and Solve
8. Check your answer – Is it reasonable? Are the units correct?

- Show all work!

Assume the speed of light is $3\times10^8\frac{m}{s}$ unless otherwise specified.

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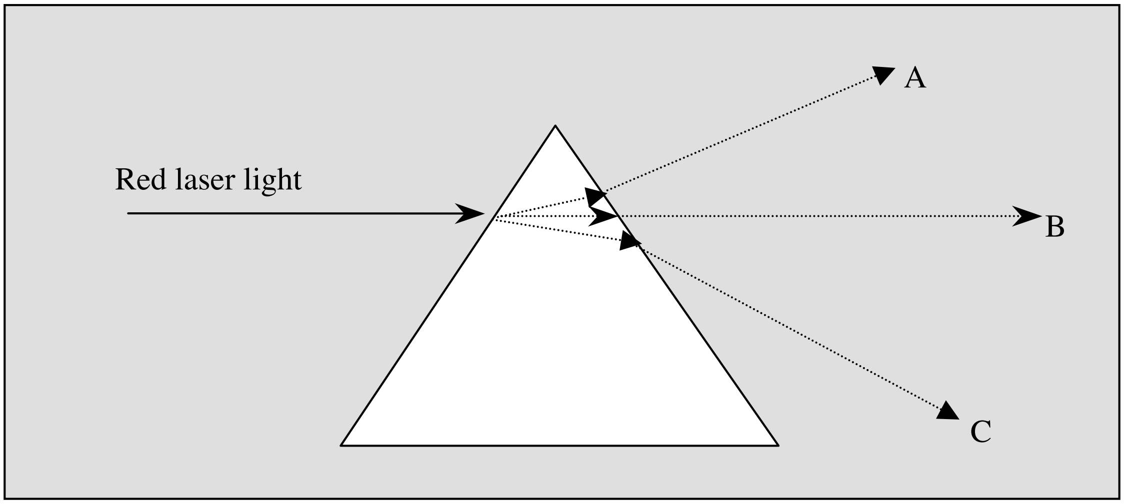
1. Suppose you are standing in front of a 0.25 m tall flat vertical mirror in which you can see some fraction of your body. What happens to that fraction when you step farther away from the mirror?

A. You see a smaller fraction of your body.
[✓ B.] You see the exact same fraction of your body.
C. You see the same fraction of your body but the image is shifted up.
D. You see the same fraction of your body but the image is shifted down.
E. You see a greater fraction of your body.

Angle of reflection equals angle of incidence. The angular image does not change.

You have a plastic (n=1.2) rectangle with a prism shape cut through it. Assume the index of refraction of air is n=1.0 and water is n=1.33. You have a red laser you can shine at the prism.



2. The plastic rectangle is placed in water. Which ray most closely shows the path the laser beam follows?

A. Ray A
B. Ray B
[✓ C.] Ray C
D. There is refraction but none of the rays closely resembles the correct path.
E. There is no refraction since the light is at the critical angle and it experiences total internal reflection.

Snell's Law – bends toward normal when going from n=1.2 to n=1.33

3. An object is placed far from the focal point of a negative lens. How does the image position change as the object is moved towards the lens?

[✓ A.] The image moves closer to the lens.
B. The image moves away from the lens.
C. The image switches from virtual to real.
D. The image switches from real to virtual.
E. The image position does not change.

Using the thin lens equation… when $s_o=\infty$ then $s_i=-f$; when $s_o=f$ then $s_i= -\frac{1}{2}f$; etc.

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4. What is the result of a red and green spotlight that overlap on a white wall?

A. The resulting color spot is magenta.
B. The resulting color spot is brown.
C. The resulting color spot is black.
[✓ D.] The resulting color spot is yellow.
E. The resulting color spot is white.

You will see both colors reflected you're your eyes so you need to add the colors. Additive colors are Red, Green and Blue.
R+G = Yellow; R+B=Magenta; G+B=Cyan

The next two questions deal with light having a wavelength in vacuum of 500 nm.

5. What is the wavelength of this light when the light enters glass (n=1.5).

A. $\lambda = 222$ nm
[✓ B.] $\lambda = 333$ nm
C. $\lambda = 500$ nm
D. $\lambda = 750$ nm
E. $\lambda = 1125$ nm

$c=\lambda f$ and $v=c/n$ so since the frequency does not change $v=(\lambda/n)f$ and the wavelength in the medium is λ/n

6. What is the frequency of this light when the light enters glass (n=1.5).

[✓ A.] $f = 600$ THz
B. $f = 400$ THz
C. $f = 267$ THz
D. $f = 167$ THz
E. $f = 900$ THz

$c=\lambda f$ so $c/\lambda = f$ and Tera = 10^{12}

7. What color light do you see if you are looking at white light which has passed through a magenta and cyan filter?

[✓ A.] You will see blue light.
B. You will see green light.
C. You will see red light.
D. You will see brown light.
E. You will see yellow light.

You will see only the light that can pas through both filters so you need to use subtractive colors: Yellow, Cyan and Magenta.
R+G = Yellow; R+B=Magenta; G+B=Cyan

8. You measure the wavelength and frequency of a red laser beam traveling in a piece of crown glass (n = 1.7). You measure $\lambda = 374$ nm and $f = 472$ THz. How fast is the beam of light traveling?

A. 3.00×10^8 m/s
B. 8.02×10^5 m/s
C. 6.36×10^5 m/s
D. 1.12×10^8 m/s
[✓ E.] 1.77×10^8 m/s

$v=\lambda f$ and $v=c/n$

9. You are researching coral and have a plastic magnifying glass (n=1.20) that you use to examine them in the air. You decide to examine the coral under water (n=1.33) with your magnifying lens. Can you get a magnified image of the coral under water?

[✓ A.] No. This does <u>not</u> work.
B. Maybe. This works so long as the object is closer than the focal distance.
C. Maybe. This works so long as the object is further than the focal distance.
D. Yes. This works for any object distance.

The magnifying glass is no longer a positive lens – it is a negative lens

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10. You measure the wavelength and frequency of a green laser beam traveling in an unknown material. You measure $\lambda = 423$ nm and $f = 545$ THz. What is the index of refraction of this material?
    - A. 1.817
    - B. 1.700
    - [✓ C.] 1.301
    - D. 1.288
    - E. 0.776

$v=\lambda f$ and $n=c/v$ so $c/\lambda f=n$

11. What is the critical angle for light traveling from leaded glass (n= 1.72) into water (n=1.33)?
    - A. 26.7 degrees
    - B. 35.5 degrees
    - C. 39.4 degrees
    - D. 48.8 degrees
    - [✓ E.] 50.6 degrees

$n_1\sin(\theta_1)= n_2\sin(\theta_2)$ where $n_1=1.72$, $\theta_1= \theta_c$, $n_2=1.33$ and $\theta_2=90$

12. An object is placed far from a positive lens. How does the image position change as the object is moved closer to the lens (but is still outside the focal length)?
    - A. The real image moves closer to the lens.
    - [✓ B.] The real image moves away from the lens.
    - C. The image switches from virtual to real.
    - D. The image switches from real to virtual.
    - E. The image position does not change.

$$\frac{1}{f}=\frac{1}{s_o}+\frac{1}{s_i}$$

13. An object is placed just outside the focal point of a positive lens. How does the image position change as the object is moved inside the focal point of the lens?
    - A. The real image moves closer to the lens.
    - B. The real image moves away from the lens.
    - C. The image switches from virtual to real.
    - [✓ D.] The image switches from real to virtual.
    - E. The image position does not change.

Ibid

14. A 3.0 cm tall object is placed 60 cm from a lens with a focal length of 20 cm. What is the size of the image?
    - [✓ A.] 1.5 cm
    - B. 2.0 cm
    - C. 3.0 cm
    - D. 4.5 cm
    - E. 9.0 cm

$m=-\frac{s_i}{s_o}$ The image distance is 30 cm so the magnification is -½

15. A 2.5 mm tall object that is placed 1.80 m from a lens forms a real image at 450 cm. What is the size of the image?
    - A. 1.0 mm
    - B. 2.5 mm
    - [✓ C.] 6.25 mm
    - D. 100 mm
    - E. 625 mm

Ibid

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16. A 5.0 cm tall object is placed 70 cm from a lens with a focal length of -30 cm. Where is the image formed?
    - [✓ A.] 21 cm from the lens on the same side as the object
    - B. 21 cm from the lens on the opposite side as the object
    - C. 53 cm from the lens on the same side as the object
    - D. 53 cm from the lens on the opposite side as the object
    - E. No image is formed

$$\frac{1}{-30cm}=\frac{1}{70cm}+\frac{1}{s_i}$$

17. A 1.6 m tall object is placed 4 m from the concave surface of a mirror with a 5 meter radius. Where is the image formed?
    - A. 1.54 meters from the lens on the same side as the object
    - B. 1.54 meters from the lens on the opposite side as the object
    - [✓ C.] 6.67 meters from the lens on the same side as the object
    - D. 6.67 meters from the lens on the opposite side as the object
    - E. 4.33 meters from the lens on the same side as the object

$$\frac{R}{2}=f \text{ so } \frac{2}{5m}=\frac{1}{4m}+\frac{1}{s_i}$$

18. A red laser, $\lambda = 632$ nm, is incident on a grating with 600 lines per mm. At what angle is the second maxima located?
    - [✓ A.] 49 degrees
    - B. 22 degrees
    - C. 43 degrees
    - D. 1.2 radians
    - E. There are no even maxima from a grating

For constructive interference the path length difference is and integer number of wavelengths so $n\lambda = d \sin(\theta)$ where d is 1mm per 600 lines so d=1.67μm (n=2)

19. A blue laser, $\lambda = 400$ nm, is incident on a narrow slit. A diffraction pattern is observed on a screen 5 meters away. The first minima is located 1 cm from the central maxima. How wide is the slit?
    - A. 100 μm
    - [✓ B.] 200 μm
    - C. 400 μm
    - D. 800 μm
    - E. 2000 μm

The relation for the first minima is given by $m\lambda = a \sin(\theta)$ where a is the slit width and m is the minima index. For small angles $\sin(\theta)$ is approximately the length to the minima divided by the distance to the screen so $m\lambda = a\, y / D$ and a = (1)(400nm)(5m)/(1cm)

20. A beam of white light traveling through air hits a glass block at an angle of 30 degrees from the normal. The beam bends to travel at an angle of 20 degrees from the normal when it enters the glass block. What is the index of refraction of the glass block?
    - A. 0.68
    - [✓ B.] 1.46
    - C. 1.97
    - D. 2.00
    - E. 2.88

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

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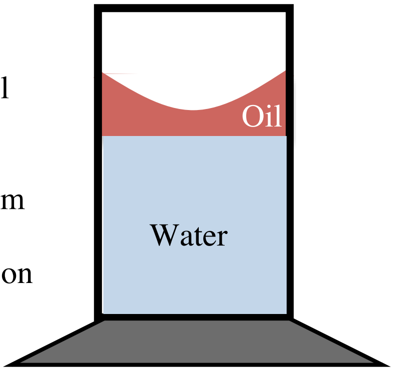
Do the next two problems using separate problem solving sheets. There are extra problems solving sheets available if you need one.



21. [10 PTS] Light of wavelength 632 nm in air is incident on a thin layer of oil (n=1.4) that is floating on water.
    A. What is the smallest thickness that would lead to constructive interference between the front and rear reflection of the light from the oil?
    B. What would you observe if the oil formed a parabolic meniscus on the surface of the water?

22. [10 PTS] You are standing next to Amy and she is just able to read a piece of paper 20 meters away. With your glasses on you can just read the paper when it is 10 meters away. With out your glasses you can just read the paper when it is 1 meter away.
    A. Draw a picture describing how your eye works (i.e. explain why you can't read the paper at the same distance as Amy is able to read it).
    B. What is your present prescription? (Assume your glasses sit 2 cm from your eye)
    C. What is your new prescription?