

**Purdue University**  
**PHYS 221**  
**EXAM II – 11/9/04**

Please use a #2 pencil to fill in data for name and student ID on the computer sheet. Mark the correct answer for each problem on the same sheet. There will be no penalty for wrong answers. Please check to see that your exam has all 16 problems. All useful basic equations and constants are provided. Note that you will not need all of the equations and constants provided to do this exam.

1 When light goes from one medium to another medium with a different index of refraction, which of the following do (does) not change?

- a) the speed
- b) the wavelength
- Ⓒ the frequency
- d) the speed and the wavelength
- e) the frequency and the wavelength

Frequency remains the same.

2 What is the angular resolution of the eye at a wavelength of 500 nm for a pupil diameter of 2.8 mm?

- a)  $1.8 \times 10^{-4}$  rad
- b)  $2.2 \times 10^{-4}$  rad
- c)  $8.9 \times 10^{-5}$  rad
- d)  $4.5 \times 10^{-5}$  rad
- e)  $3.3 \times 10^{-5}$  rad

$$\lambda_0 = 500 \text{ nm} = 500 \times 10^{-9} \text{ m}$$

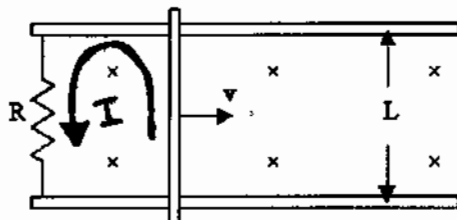
$$a = 2.8 \text{ mm} = 2.8 \times 10^{-3} \text{ m}$$

Following Rayleigh's Criterion we have

$$a \sin \theta = 1.22 \lambda_0$$

$$\theta = \sin^{-1} \left( \frac{1.22 \lambda_0}{a} \right) \leftarrow \text{in radians}$$

- 3 A conducting rod is sliding on metal rails with velocity  $v$ . A magnetic field  $B$  is into the paper, the separation of the rails is  $L$ , and the resistance of the circuit is  $R$ . In what direction in the diagram is the current flowing in the resistor?



- a) up  
 (b) down  
 c) up then down  
 d) down then up  
 e) insufficient information given

Since the magnetic flux into the page is increasing, an induced current would flow counter-clockwise. The current on the resistor then, would flow down.

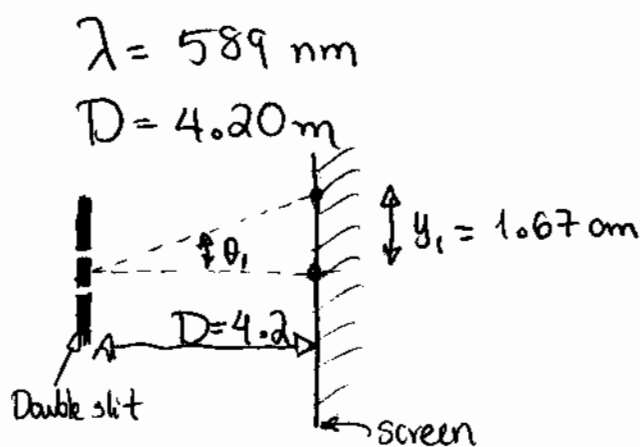
- 4 Laser light of 589 nm wavelength is shown through parallel slits forming a series of maxima on a screen 4.20 m away. If the distance between the central maximum and the first order maximum is 1.67 cm, what is the slit separation? (15 points)

- a)  $3.90 \times 10^{-3}$  cm  
 b)  $3.98 \times 10^{-3}$  m  
 c)  $9.98 \times 10^{-5}$  m  
 d)  $1.40 \times 10^{-3}$  m  
 (e)  $1.48 \times 10^{-4}$  m

$$d \sin \theta = m \lambda \quad m=1$$

$$d = \frac{(1)(\lambda)}{\sin \theta}$$

$$d = 1.48 \times 10^{-4} \text{ m}$$



$$\tan \theta_1 = \frac{1.67 \times 10^{-2} \text{ m}}{4.2 \text{ m}}$$

$$\theta_1 = 0.2278^\circ$$

- 5 A transformer has 200 turns on its primary and 12 turns on its secondary. If the input voltage is 2000 V, what is the output voltage?

a)  $3.3 \times 10^4 \text{ V}$

b) 240 V

c) 170 V

d) 120 V

e) 100 V

$$N_p = 200$$

$$N_s = 12$$

$$V_p = 2000 \text{ V}$$

$$V_s = ?$$

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

$$V_s = \frac{N_s}{N_p} V_p$$

$$V_s = \frac{12}{200} (2000 \text{ V}) = 120 \text{ V}$$

- 6 Which one of the following statements concerning the wavelength of an electromagnetic wave in a vacuum is true?

- a) The wavelength is independent of the speed of the wave for a fixed frequency.
- b) The wavelength is inversely proportional to the speed of the wave.
- c) The wavelength is the same for all types of electromagnetic waves.
- d) The wavelength is directly proportional to the frequency of the wave.
- e) The wavelength is inversely proportional to the frequency of the wave.

$$\lambda = \frac{c}{f}$$

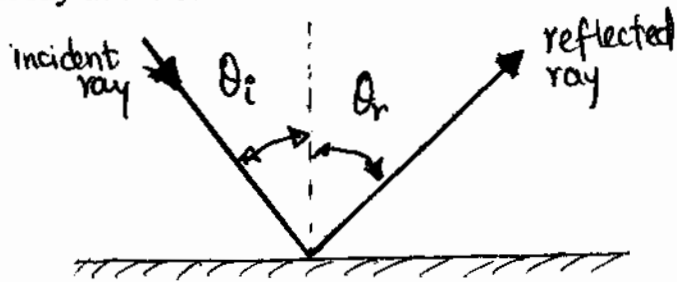
7 How long does it take for a radio signal to travel to a spacecraft  $1.5 \times 10^{11}$  m away?

- a) 5.0 s
- b) 50 s
- c) 500 s
- d) 5000 s
- e) 1000 s

$$\Delta t = \frac{\Delta x}{v} = \frac{1.5 \times 10^{11} \text{ m}}{3 \times 10^8 \text{ m/s}} = \boxed{500 \text{ s}}$$

8 A light ray reflects from a surface. If the angle of incidence is  $24^\circ$ , what is the angle between the reflected ray and the incident ray at the surface?

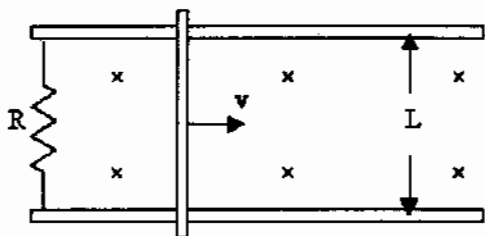
- a)  $24^\circ$
- b)  $12^\circ$
- c)  $66^\circ$
- d)  $48^\circ$
- e)  $102^\circ$



$$\theta_i = \theta_r = 24^\circ$$

the angle between the rays is equal to  $48^\circ$

- 9 A conducting rod slides at 4.0 m/s on metal rails separated by 2.0 m. If a current of 40 mA is generated in the circuit with resistance of  $0.36 \Omega$ , what is the magnetic field between the rails? (15 points)



- a) 0.028 T  
 b) 0.11 T  
 c) 14 mT  
 d) 3.6 mT

e) 1.8 mT

First we use Ohm's Law

$$V = IR = (40 \times 10^{-3} \text{ A})(0.36 \Omega)$$

$$V = 0.0144 \text{ V}$$

Then motional Emf.

$$\mathcal{E} = vLB \rightarrow B = \frac{\mathcal{E}}{vL} = \frac{0.0144 \text{ V}}{(4 \text{ m/s})(2 \text{ m})} = 1.8 \text{ mT}$$

- 10 Holograms appear three dimensional because

- a) they are in color.  
 b) they are transparent.  
 c) they consist of Young double slits.

d) they recreate wave fronts as if they came from the original source.

e) of their spectral response to refraction.

- 11 What electric field has the same energy density as a 1.0-T magnetic field?

- a) 1.0 V/m
- b)  $3.0 \times 10^8$  V/m**
- c)  $9.0 \times 10^{16}$  V/m
- d)  $1.1 \times 10^{-17}$  V/m
- e)  $3.3 \times 10^{-9}$  V/m

$$U_E = U_B$$
$$\frac{1}{2} \epsilon_0 E^2 = \frac{1}{2\mu_0} B^2$$

$$E^2 = \frac{B^2}{\epsilon_0 \mu_0}$$

$$E = \frac{1}{\sqrt{\epsilon_0 \mu_0}} B$$

$$E = c B = (3.0 \times 10^8 \text{ m/s})(1.0 \text{ T})$$

$$\boxed{E = 3.0 \times 10^8 \text{ N/C}}$$

- 12 Two waves will destructively interfere if:

- a) their phase difference is zero.
- b) their phase difference is  $\pi/2$  rad.
- c) their phase difference is  $\pm\pi/2$  rad.
- d) their phase difference is an even integral multiple of  $\pi$  rad.
- e) their phase difference is an odd integral multiple of  $\pi$  rad.**

- 13 What is the wavelength from a radio station having frequency 107.7 MHz?

- a) 2.79 m
- b) 27.9 m
- c) 32.3 m
- d) 323 m
- e) 108 m

$$\lambda f = c$$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{ m/s}}{107.7 \times 10^6 \text{ Hz}}$$

$$\lambda = 2.785 \text{ m}$$

- 14 Light has a wavelength of 340.0 nm and a frequency of  $5.403 \times 10^{14}$  Hz when traveling through a certain substance. What substance from Table 1 could this be? (Table 1 is on the last page of this exam.) (15 points)

- a) air
- b) benzene
- c) diamond
- d) carbon disulfide
- e) sodium chloride

$$v = \lambda f$$

$$= (340 \text{ nm})(5.403 \times 10^{14} \text{ Hz})$$

$$v = 1.837 \times 10^8 \text{ m/s}$$

$$n_{\text{substance}} = \frac{c}{v} = \frac{3 \times 10^8 \text{ m/s}}{1.837 \times 10^8 \text{ m/s}} = 1.633$$

which corresponds to  
carbon disulfide



- 15 An optical fiber having index of refraction 1.40 is clad with a material of index of refraction 1.25. What is the critical angle for this fiber? (15 points)

- a) 63.2°
- b) 26.8°
- c) 41.8°
- d) 73.0°
- e) 16.5°

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

$$\theta_c = \sin^{-1} \left( \frac{1.25}{1.40} \right)$$

$$\theta_c = 63.2^\circ$$

- 16 As you walk at 1.5 m/s toward a mirrored wall in a department store, how fast are you approaching your image?

- a) 1.5 m/s
- b) 3.0 m/s
- c) 6.0 m/s
- d) 0.75 m/s
- e) 0, the image stays at a constant distance



the approaching velocity is then 3 m/s

**Table 1**  
**Index of Refraction<sup>a</sup>**

Substance	Index of Refraction, $n$
<i>Solids at 20 °C</i>	
Diamond	2.419
Glass, crown	1.523
Ice (0 °C)	1.309
Sodium chloride	1.544
Quartz	
Crystalline	1.544
Fused	1.458
<i>Liquids at 20 °C</i>	
Benzene	1.501
Carbon disulfide	1.632
Carbon tetrachloride	1.461
Ethyl alcohol	1.362
Water	1.333
<i>Gases at 0 °C, 1 atm</i>	
Air	1.000 293
Carbon dioxide	1.000 45
Oxygen, O <sub>2</sub>	1.000 271
Hydrogen, H <sub>2</sub>	1.000 139

<sup>a</sup> Measured with light whose wavelength in a vacuum is 589 nm.