First Name: _____ *Last Name:* _____ *Section:* _____

April 25, 1997 Physics 208

Exam 3

Print your name and section clearly on all five pages. (If you do not know your section number, write your TA's name.) Show all work in the space immediately below each problem. Your final answer must be placed in the box provided. Problems will be graded on reasoning and intermediate steps as well as on the final answer. Be sure to include units wherever necessary, and the direction of vectors. Each problem is worth 25 points. In doing the problems, try to be neat. Check your answers to see that they have the correct dimensions (units) and are the right order of magnitudes. You are allowed one 8½ x 11" sheet of notes and no other references. The exam lasts exactly 50 minutes.

(Do not write below)

SCORE:

SOLUTIONS

Problem 1: _____

Problem 2: _____

Problem 3: _____

Problem 4: _____

TOTAL: _____

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1. An electromagnetic wave is produced by an electric charge that oscillates sinusoidally with a frequency of 10^{11} Hz and propagates through a medium with a permittivity of 1.5×10^{-11} F/m.

   a. What is the index of refraction of the medium? *(5 pts.)*

$$n = \sqrt{\epsilon/\epsilon_0} = \sqrt{\frac{1.5 \times 10^{-11}}{8.85 \times 10^{-12}}}$$

$$= 1.30$$

1.30

   b. What is the speed of the wave in the medium? *(5 pts.)*

$$v = \frac{c}{n} = \frac{3 \times 10^8}{1.30}$$

$$= 2.30 \times 10^8 \text{ m/s}$$

2.30×10^8 m/s

   c. What is the wavelength of the wave in the medium? *(5 pts.)*

$$\lambda = \frac{v}{f} = \frac{2.30 \times 10^8}{10^{11}}$$

$$= 2.30 \times 10^{-3} \text{ m}$$

2.30 mm

   d. If the wave intensity in the medium is 200 W/m^2, what is the rms electric field? *(5 pts.)*

$$I = \frac{1}{v \mu_0} E_{RMS}^2$$

$$E_{RMS} = \sqrt{v \mu_0 I} = \sqrt{2.30 \times 10^8 \times 4\pi \times 10^{-7} \times 200}$$

241 V/m

   e. What is the rms magnetic field for the above intensity? *(5 pts.)*

$$\frac{E}{B} = v$$

$$B_{RMS} = \frac{E_{RMS}}{v} = \frac{241}{2.30 \times 10^8}$$

$$= 1.05 \times 10^{-6}$$

1.05 μT

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2. A convex spherical mirror with radius of curvature $R = 20$ cm produces an upright image one-quarter as high as the object.

a. What is the position of the object? *(10 pts.)*

$$M = -\frac{s'}{s} = \frac{1}{4} \Rightarrow s' = -\frac{1}{4}s$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} = -\frac{2}{R}$$

$$\frac{1}{s} - \frac{4}{s} = -\frac{2}{R}$$

$$\frac{3}{s} = \frac{2}{R}$$

$$s = \frac{3R}{2} = \frac{3 \times 20}{2} = 30$$

IN FRONT OF MIRROR

30 cm

b. What is the position of the image? *(10 pts.)*

$$s' = -\frac{1}{4}s = -\frac{30}{4}$$

$$= -7.5 \text{ cm}$$

BEHIND MIRROR

7.5 cm

c. Is the image real or virtual? *(5 pts.)*

IMAGE IS BEHIND MIRROR

($s' < 0$) HENCE IMAGE IS

VIRTUAL

VIRTUAL

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3. An oil film ($n_1 = 1.45$) with thickness 280 nm floating on water ($n_2 = 1.33$) is illuminated by white light (400 – 700 nm) at normal incidence.

a. What (free-space) visible wavelength is dominantly reflected? *(10 pts.)*

$$\lambda = \frac{2nt}{N/2} \qquad N = 1, 3, 5, \cdots$$

$$= \frac{2 \times 1.45 \times 280 \times 2}{N} = \frac{1624}{N}$$

$$= 1624, 541, 325, \cdots$$

↑ VISIBLE

541 nm

b. What (free-space) visible wavelength is dominantly transmitted into the water? *(10 pts.)*

$$\lambda = \frac{2nt}{N} \qquad N = 1, 2, 3, \cdots$$

$$= \frac{2 \times 1.45 \times 280}{N} = \frac{812}{N}$$

$$= 812, 406, 271$$

↑ VISIBLE

406 nm

c. What color is the transmitted light? *(5 pts.)*

VIOLET (OR BLUE)

(SHORT WAVELENGTH END)

VIOLET

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4. A 50-kg astronaut takes a trip to Sirius, located 8 light years from Earth traveling at a constant speed of 2.4×10^8 m/s.

a. How much time is required for the trip according to an observer on Earth? *(5 pts.)*

$\frac{v}{c} = \frac{2.4 \times 10^8}{3 \times 10^8} = 0.8\,c$

$t = \frac{d}{v} = \frac{8}{0.8} = 10$ yrs

10 yrs

b. How much time is required for the trip according to the astronaut? *(5 pts.)*

$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = \frac{1}{\sqrt{1 - 0.64}} = \frac{1}{\sqrt{0.36}} = \frac{1}{0.6}$

$t_0 = t / \gamma = 0.6 \times 10 = 6$ yrs

6 yrs

c. What distance (in light years) does the astronaut measure between Earth and Sirius? *(5 pts.)*

$d = d_0 / \gamma = 0.6 \times 8$

$= 4.8$ lt-yr

4.8 lt-yr

d. What is the kinetic energy of the astronaut? *(5 pts.)*

$K = (\gamma - 1)\, mc^2 = (\frac{1}{0.6} - 1) \times 50 \times 9 \times 10^{16}$

$= 3 \times 10^{18}$ J

3×10^{18} J

e. How much mass would have to be consumed to accelerate the astronaut to her final speed? *(5 pts.)*

$\Delta m c^2 = K = (\gamma - 1)\, mc^2$

$\Delta m = (\gamma - 1)\, m = (\frac{1}{0.6} - 1) \times 50$

$= 33.3$ kg

33.3 kg