First Name: SOLUTIONS *Last Name:* ___________________ *Section:* ________

April 28, 2000

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:

Problem 1: __________

Problem 2: __________

Problem 3: __________

Problem 4: __________

TOTAL: __________

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1. A thin converging lens with a focal length of 10 cm is placed directly next to a thin diverging lens with a focal length of -20 cm. An object of height 10 cm is placed 25 cm in front of the lenses.

a. Where is the image located? *(10 pts.)*

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{10} - \frac{1}{20} = \frac{1}{20} \Rightarrow f = +20\,\text{cm}$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

$$s' = \frac{1}{\frac{1}{f} - \frac{1}{s}} = \frac{1}{\frac{1}{20} - \frac{1}{25}} = \frac{1}{.05 - .04} = \frac{1}{.01}$$

$= 100\,\text{cm}$ behind the lens

100 cm

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

$$h' = -h s'/s = -10 \times 100/25$$

$$= -40\,\text{cm}$$

40 cm

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

$s' > 0 \Rightarrow$ real

$h' < 0 \Rightarrow$ inverted

real inverted

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2. Two slits a distance 1 mm apart are illuminated with coherent, monochromatic light and produce an interference pattern on a screen 10 m away. The distance between successive bright bands on the screen is 5 mm.

a. What is the wavelength of the light? *(9 pts.)*

$$\frac{\lambda}{d} = \frac{\Delta y}{L}$$

$$\lambda = \frac{d\Delta y}{L} = \frac{10^{-3} \times 5 \times 10^{-3}}{10}$$

$$= 5 \times 10^{-7}\ \text{m}$$

500 nm

b. How much energy (in electron volts) does each photon of light have? *(8 pts.)*

$$E = hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{5 \times 10^{-7}}$$

$$= 3.98 \times 10^{-19}\ \text{J}$$

$$= 2.49\ \text{eV}$$

2.49 eV

c. If the whole experiment is performed under water (n = 1.33), what would be the distance between successive bright bands? *(8 pts.)*

$$\Delta y_c = \frac{L\lambda}{d} \qquad \lambda = \lambda_o/n$$

$$= \frac{\Delta y_o}{n} = \frac{5}{1.33}$$

$$= 3.76\ \text{mm}$$

3.76 mm

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3. An astronaut, initially 20 years old, makes a journey to a point in the galaxy that is 10 light-years from the earth (as measured by a stationary observer on the earth) in a rocket ship that travels at a speed $v = 0.8c$ relative to the earth.

a. If the astronaut left the earth in the year 2080 and remained at her destination for one year, and then returned to the earth at the same speed, what year would it be when she returned? *(7 pts.)*

$$\Delta t_0 = \frac{L_0}{v} = \frac{10}{0.8} = 12.5 \text{ years}$$

$$\text{date} = 2080 + 12.5 + 1 + 12.5$$

$$= 2106$$

2106

b. How old would she be when she returned? *(6 pts.)*

$$\Delta t = \gamma \Delta t_0 \qquad \gamma = \frac{1}{\sqrt{1-.8^2}} = \frac{1}{0.6}$$

$$\Delta t_0 = \Delta t / \gamma = 0.6 \times 10 / 0.8 = 7.5 \text{ years}$$

$$\text{age} = 20 + 7.5 + 1 + 7.5 = 36$$

36

c. How many light years would the rocket ship's odometer have registered? *(6 pts.)*

$$L = L_0 / \gamma = 10 \times 0.6 = 6$$

$$2L = 12$$

12 lt yrs

d. What minimum fraction of the rocket ship's mass would have to be annihilated to achieve a velocity of $0.8c$? *(6 pts.)*

$$K = (\gamma - 1) m_f c^2 = (m_i - m_f) c^2$$

$$m_i = \gamma m_f$$

$$\frac{\Delta m}{m_i} = \frac{m_i - m_f}{m_i} = 1 - \frac{1}{\gamma}$$

$$= 1 - 0.6 = 0.4$$

40%

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4. A hydrogen atom decays from its first excited state to its ground state.

a. What is the energy of the photon emitted? *(5 pts.)*

$$\Delta E = 13.6\left(\frac{1}{1} - \frac{1}{4}\right) = 13.6 \times \frac{3}{4}$$

$$= 10.2$$

10.2 eV

b. What is the wavelength of the photon emitted? *(5 pts.)*

$$E = hf = hc/\lambda$$

$$\lambda = hc/E = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{10.2 \times 1.6 \times 10^{-19}}$$

$$= 1.2 \times 10^{-7}\ \text{m}$$

120 nm

c. If this photon is incident on a metal with a work function of 3 eV, what is the maximum kinetic energy (in eV) of the electron that is ejected from the metal? *(5 pts.)*

$$K_{max} = hf - \phi$$

$$= 10.2 - 3 = 7.2$$

7.2 eV

d. If the photon collides head-on with a free electron ($m_e = 9.1 \times 10^{-31}$ kg) initially at rest and the photon recoils backwards, how much energy (in eV) is imparted to the electron? *(5 pts.)*

$$\frac{2h}{\lambda} = mv \Rightarrow v = \frac{2h}{m\lambda}$$

$$K = \frac{1}{2}mv^2 = \frac{2h^2}{m\lambda^2}$$

$$= \frac{2 \times (6.63 \times 10^{-34}/1.2 \times 10^{-7})^2}{9.1 \times 10^{-31}} = 6.71 \times 10^{-23}\ \text{J} =$$

4.19×10^{-4} eV

e. What is the value of $\gamma - 1$ for the electron in part d above? *(5 pts.)*

$$K = (\gamma - 1)mc^2$$

$$\gamma - 1 = K/mc^2 = \frac{6.71 \times 10^{-23}}{9.1 \times 10^{-31} \times 9 \times 10^{16}}$$

$$= 8.19 \times 10^{-10}$$

8.19×10^{-10}