UNIVERSITY OF MARYLAND

Department of Physics

Physics 270 Fall 2008

Dr. Wallace, MWF 12:00, Room 1410 Physics

Sections: 0301 (W 1:00); 0302 (W 2:00); 0303 (Th 10:00)

Midterm Exam. II Friday November 7, 2008

Name (please print):

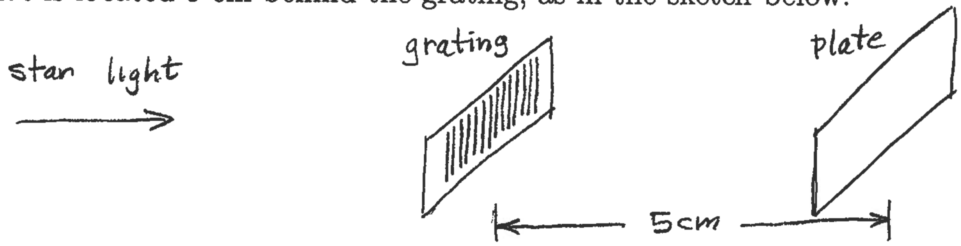
Circle section number above. Exams will be returned in sections.

Pledge: I pledge on my honor that I have not given or received any unauthorized assistance on this examination.

Signature:

Useful constants: $h = 6.63 \times 10^{-34}$ J s, $c = 3 \times 10^{8}$ m/s 1 eV $= 1.6 \times 10^{-19}$ J.

1.) A telescope receives light from distant stars. The light is analyzed by passing it through a diffraction grating with 2000 lines/cm and then collecting it on a photographic plate that is located 5 cm behind the grating, as in the sketch below.



a.) (10 pts.) If the light on the photographic plate makes bright lines that are 0.6 cm apart from each other, what is the wavelength of the light?

$\Delta y = .006\,m$

$d = \frac{1\,cm}{2000} = \frac{.01\,m}{2000} = 5\times10^{-6}\,m$

$\lambda = \frac{d\Delta y}{L} = \frac{(5\times10^{-6}\,m)(.006\,m)}{.05\,m} = 6\times10^{-7}\,m = 600\,nm$

2.) (10 pts.) An x-ray beam consists of photons that have energy equal to 15,000 eV. What is the wavelength of the photons?

$\lambda = \frac{h}{p}, \quad p = \frac{E}{c} \Rightarrow \lambda = \frac{hc}{E}$

$hc = \frac{(6.63\times10^{-34}\,Js)(3\times10^{8}\,m/s)}{1.6\times10^{-19}\,J/eV} = 1.24\times10^{-6}\,eV$

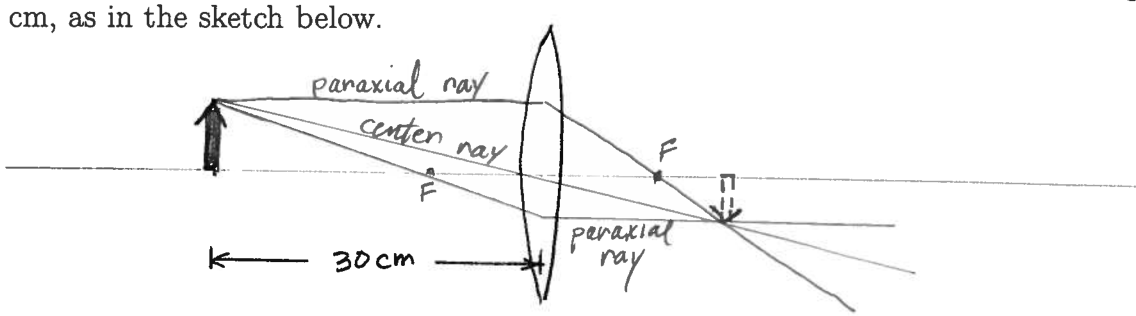
$\lambda = \frac{1.24\times10^{-6}\,eV\,m}{1.5\times10^{4}\,eV} = 0.829\times10^{-10}\,m = .0829\,nm$

3.) (10 pts.) An electron beam consists of electrons with mass 9.1×10^{-31} kg and energy 15,000 eV. Assume that the velocity of the electrons is much smaller than the speed of light, i.e., they are nonrelativistic. What is the wavelength of the electrons?

$p = mv = \sqrt{2mE} = \sqrt{2\cdot 9.1\times10^{-31}\,kg\; 1.5\times10^{4}\,eV\times\frac{1.6\times10^{-19}\,J}{eV}} = 6.61\times10^{-23}\,\frac{kg\,m}{s}$

$\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}\,Js}{6.61\times10^{-23}\,kg\frac{m}{s}} = 1.00\times10^{-11}\,m = 0.01\,nm$

4.) An object that is 2.4 cm high is placed 30 cm from a converging lens with a focal length of 10 cm, as in the sketch below.



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

$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = \frac{1}{10cm} - \frac{1}{30cm} = \frac{2}{30cm} = \frac{1}{15cm}$

$s' = 15\,cm$ — to the right of lens.

b.) (5 pts.) Is the image **upright** or **inverted.** Circle one.

c.) (5 pts.) What is the size of the image?

$$m = -\frac{s'}{s} = \frac{-15}{30} = -\frac{1}{2} \qquad h' = mh = -\frac{1}{2}(2.4\text{cm})$$

$$\therefore \quad |h'| = 1.2\text{cm}$$

d. (10 pts.) On the sketch above, draw the two principal rays that pass through the tip of the image.

5.) (10 pts.) Fission of uranium in a nuclear reactor converts about one part in 1200 (by mass) of the uranium to energy. If the reactor generates 1 GW of power, how much uranium must be converted to energy every year? (One year = 3.15×10^7 s.)

$$\left(\frac{M_u}{1200}\right) \times c^2 = P\cdot t = 1\times10^9 \frac{J}{s} \times 3.15\times10^7 s = 3.15\times10^{16} J$$

$$\frac{M_u}{1200} = \frac{3.15\times10^{16} J}{(3\times10^8 m/s)^2} = 0.35 \text{ kg}$$

$$M_u = 1200 \times .35k = 420 \text{ kg}$$

6.) A proton has mass 1.67×10^{-27} kg.

a.) (10 pts.) What is the proton's rest energy in MeV units?

$$m_p c^2 = (1.67\times10^{-27} kg)(3\times10^8 m/s)^2 \times \frac{1 eV}{1.6\times10^{-19} J} \times \frac{10^{-6} MeV}{eV}$$

$$= 939 \text{ MeV}$$

b.) (10 pts.) If the proton is accelerated to a speed u = 0.9 c, what is its **kinetic** energy in MeV units?

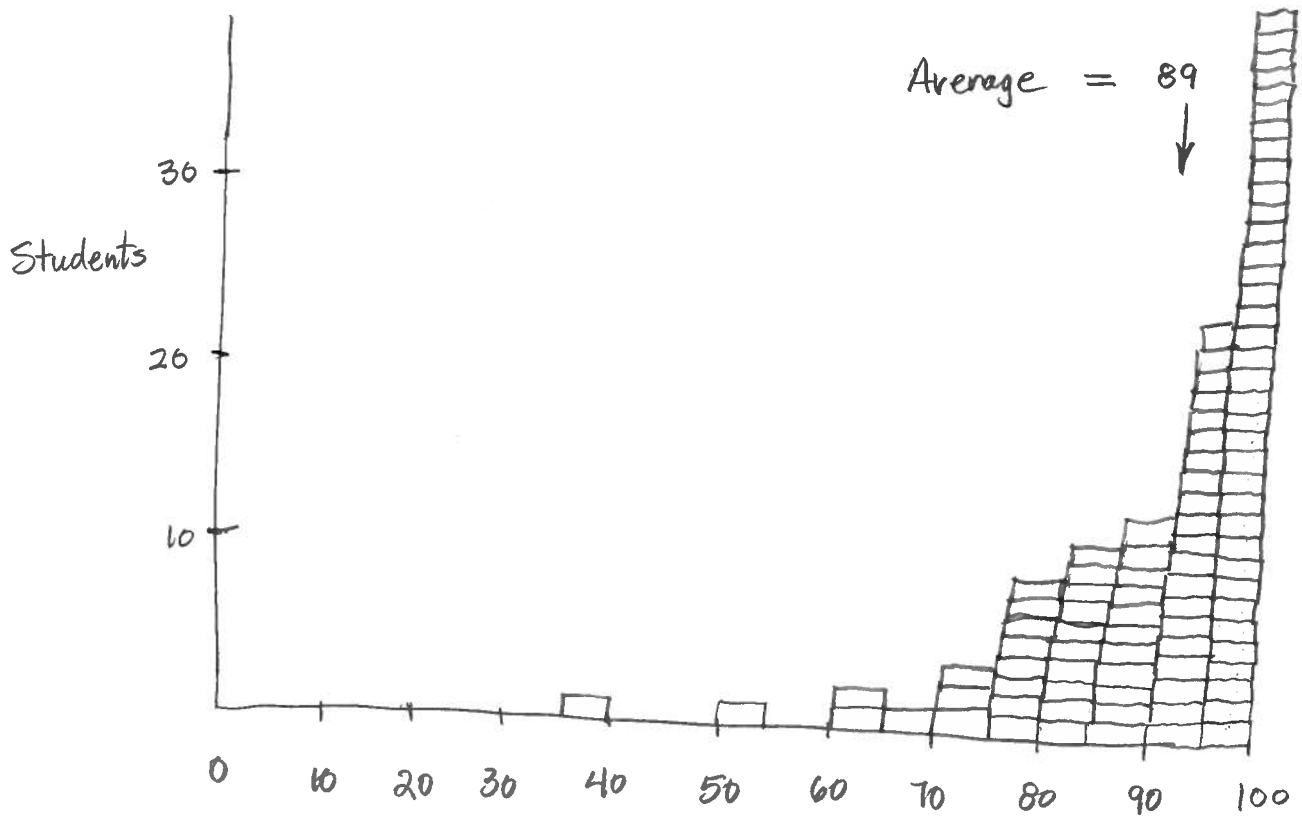
$$K = (\gamma - 1) m_p c^2 = (1.194)\, 939 \text{ MeV} = 1215 \text{ MeV}$$

$$\gamma = \frac{1}{\sqrt{1 - u^2/c^2}} = \frac{1}{\sqrt{1 - .81}} = 2.294$$

c. (10 pts.) If a proton that is moving at speed 0.9c approaches another proton that is moving at speed 0.9c in the opposite direction, what is the speed of one proton relative to the other?

$$u' = \frac{u - v}{1 - \frac{uv}{c^2}} \qquad -u = 0.9c \qquad v = 0.9c$$

$$u' = \frac{-1.8c}{1 + .81} = 0.994c = 2.98\times10^8 \text{ m/s}$$



Average = 89
Students
30
20
10
0
10
20
30
40
50
60
70
80
90
100