General Physics II **Exam 3 - Chs. 22–25 - EM Waves & Optics** **October 20, 2016**

Name Rec. Instr. Rec. Time

For full credit, make your work clear. Show formulas used, essential steps, and results with correct units and significant figures. Points shown in parenthesis. For TF and MC, choose the *best* answer.

1. (3) An electromagnetic (EM) wave is traveling due east with its magnetic field vector oscillating north-south. Its electric field vector is oscillating

a. north-south. b. east-west. c. vertically up and down.

2. (3) Which type of EM waves has the lowest frequency in vacuum?

a. x-rays. b. infrared. c. red light. d. blue light. e. ultraviolet. f. AM radio. g. all tie.

3. (8) An EM wave is propagating in vacuum. The transmitter producing it has an oscillator operating at a frequency of 95.0 MHz.

a) (4) As the wave passes a fixed point in space, how much time elapses between two positive peaks of the electric field?

b) (4) If you could look at a snapshot of the waves, how far apart in space are two successive positive peaks of the electric field?

4. (12) A 580 kHz radio transmitter emits EM waves with a total power of 50.0 kW isotropically. A radio receives the signals at a distance of 1.00 $\times 10^2$ km from the transmitter.

a) (6) Determine the intensity of the waves received by the radio.

b) (6) How strong is the electric field amplitude that reaches the radio?

5. (10) A mirror makes an image at location d_i by the mirror equation, $1/d_o + 1/d_i = 1/f$, for an object at d_o.

a) (2) **T** **F** If d_i comes out positive, the image is on the same side of the mirror as the object.

b) (2) **T** **F** If d_i comes out positive, the image is upright.

c) (2) **T** **F** If d_i comes out negative, the image is behind the mirror.

d) (2) **T** **F** The focal length of a concave mirror is twice the radius of curvature.

e) (2) **T** **F** Only a concave mirror can make a magnified image.

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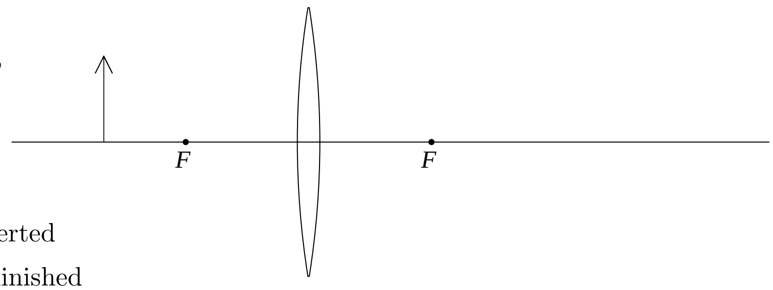
6. (10) For this lens and object,

a) (4) using a straightedge, draw at least two rays to find the image.



b) (2) Image type? a. real b. virtual

c) (2) Image orientation? a. upright b. inverted

d) (2) Image size? a. magnified b. diminished

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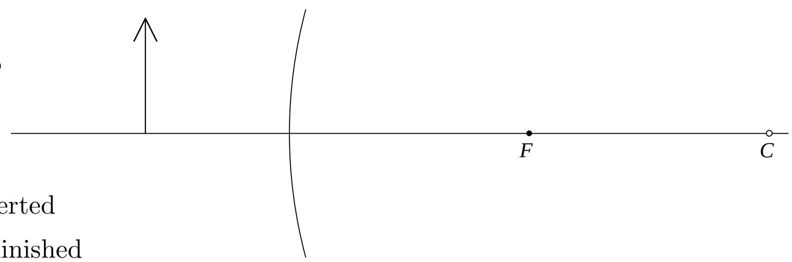
7. (10) For this mirror and object,

a) (4) using a straightedge, draw at least two rays to find the image.



b) (2) Image type? a. real b. virtual

c) (2) Image orientation? a. upright b. inverted

d) (2) Image size? a. magnified b. diminished

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8. (12) An object 3.6 cm high and 36.0 cm from a lens forms an image 0.80 cm high on the same side of the lens as the object.

a) (8) What is the focal length of the lens, with sign?

b) (2) The image is a. real. b. virtual.

c) (2) The lens is a. converging. b. diverging.

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9. (8) Standing 3.0 m in front of a mirror, you see your face right side up and magnified by 2.0×. Determine the focal length of the mirror, with sign.

10. (3) Light from a certain laser has a wavelength $\lambda = 589$ nm and speed c in vacuum. When the light passes into a piece of glass with index of refraction $n = 1.54$,

a. the wavelength and speed stay the same.
b. the wavelength and speed both increase.
c. the wavelength and speed both decrease.
d. the wavelength increases and the speed decreases.
e. the wavelength decreases and the speed increases.

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11. (12) In order to correct her vision, Suzy wears a contact lens whose power is +2.50 D on her right eye, allowing the eye to focus between 25 cm and infinity.

a) (2) The contact lens is used to correct a. nearsightedness. b. farsightedness.

b) (4) What is the focal length of the lens, in meters?

b) (6) Without that contact lens, what is the eye's near point distance?

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12. (12) A biologist uses a magnifying lens with focal length $f = 25.0$ mm directly in front of her eye to inspect an insect that is 1.80 mm long. Assume she has a normal near point of 25 cm and far point of infinity.

a) (4) How far from the lens should the insect be held so that its (virtual) image is at infinity?

b) (4) For the image at infinity, what is the angular magnification of the insect?

c) (4) What is the angular size of the insect's image viewed through the magnifying lens?

13. (10) A light ray in water (index of refraction = 1.33) travels at angle $\theta_w = 48°$ to the the vertical direction.

a) (6) At what angle to the vertical does the refracted light beam emerge in the air above the water?

b) (4) If instead the ray travels at $\theta_w = 55°$ in the water, explain in words what happens.

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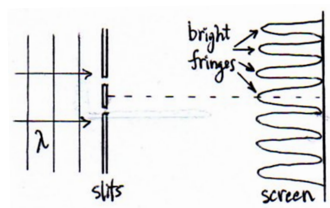
14. (8) Light of wavelength 656 nm from a laser falls on two very narrow slights separated by 45.0 μm. On a screen 3.00 m behind the slits, how far apart are the bright interference fringes?



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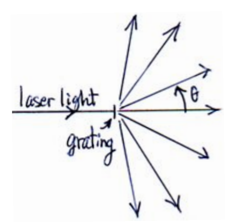
15. (12) A diffraction grating produces a first order maximum for blue light of wavelength 430 nm at an angle of 25° from the centerline, making bright fringes on a screen.

a) (6) How many lines per centimeter are on this grating?



b) (6) How many bright fringes will be cast on the screen?

Score = ____________/133.

Prefixes

a=10^{-18}, f=10^{-15}, p=10^{-12}, n=10^{-9}, $\mu = 10^{-6}$, m=10^{-3}, c=10^{-2}, k=10^{3}, M=10^{6}, G=10^{9}, T=10^{12}, P=10^{15}

Physical Constants

$k = 1/4\pi\epsilon_0 = 8.988$ GNm^2/C^2 (Coulomb's Law)
$e = 1.602 \times 10^{-19}$ C (proton charge)
$m_e = 9.11 \times 10^{-31}$ kg (electron mass)
$c = 3.00 \times 10^{8}$ m/s (speed of light)

$\epsilon_0 = 1/4\pi k = 8.854$ pF/m (permittivity of space)
$\mu_0 = 4\pi \times 10^{-7}$ T·m/A (permeability of space)
$m_p = 1.67 \times 10^{-27}$ kg (proton mass)
$c = 2.99792458 \times 10^{8}$ m/s (exact value in vacuum)

Units

$N_A = 6.02 \times 10^{23}$/mole (Avogadro's #)
1.0 eV = 1.602×10^{-19} J (electron-volt)
1 F = 1 C/V = 1 farad = 1 C^2/J
1 A = 1 C/s = 1 ampere = 1 coulomb/second
1 T = 1 N/A·m = 1 tesla = 1 newton/ampere·meter

1 u = 1 g/N_A = 1.6605×10^{-27} kg (mass unit)
1 V = 1 J/C = 1 volt = 1 joule/coulomb
1 H = 1 V·s/A = 1 henry = 1 J/A^2
1 Ω = 1 V/A = 1 ohm = 1 J·s/C^2
1 G = 10^{-4} T = 1 gauss = 10^{-4} tesla

Chapter 22 Equations

Electromagnetic waves:

$|\vec{E}|/|\vec{B}| = c = 1/\sqrt{\epsilon_0\mu_0}$, (fields)

$f\lambda = c$ (wave equation)

Energy density, intensity, power:

$u = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$ (instantaneous energy density)

$\overline{u} = \frac{1}{2}\epsilon_0 E_0^2 = \frac{B_0^2}{2\mu_0}$ (average energy density)

$I = \overline{u}c = \frac{1}{2}\epsilon_0 E_0^2 c$ (EM waves intensity)

$I = P/A = P/(4\pi r^2)$ (intensity definition)

Chapter 23 Equations

Reflection, Mirrors:

$\theta_r = \theta_i$ (angle of incidence = angle of reflection)

$f = r/2$ (focal length of spherical mirror)

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ (mirror equation)

$m = -d_i/d_o = h_i/h_o$ (linear magnification)

$d_i > 0 \Rightarrow$ real, light side.

$d_i < 0 \Rightarrow$ virtual, dark side.

$m > 0 \Rightarrow$ upright.

$m < 0 \Rightarrow$ inverted.

$|m| > 0 \Rightarrow$ magnified.

$|m| < 0 \Rightarrow$ diminished.

Refraction, Lenses:

$n = c/v$ (index of refraction)

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ (Snell's Law)

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ (lens equation)

$m = -d_i/d_o = h_i/h_o$ (linear magnification)

$d_i > 0 \Rightarrow$ real image, light (opp.) side.

$d_i < 0 \Rightarrow$ virtual image, dark (same) side.

$m > 0 \Rightarrow$ upright.

$m < 0 \Rightarrow$ inverted.

$|m| > 0 \Rightarrow$ magnified.

$|m| < 0 \Rightarrow$ diminished.

Chapter 24 Equations

Wave properties, interference:

$\lambda_n = \lambda_{\text{vacuum}}/n$ (wavelength in a medium)

$\Delta x = d\sin\theta$ (path difference in double slits)

$d\sin\theta = m\lambda$ (double slits bright fringes)

$d\sin\theta = (m+1/2)\lambda$ (double slits dark fringes)

Diffraction:

$D\sin\theta = m\lambda$ (single slit minima)

$y = L\tan\theta$ (position on a screen)

$d\sin\theta = m\lambda$ (diffraction grating maxima)

$d = 1/$(lines per meter).

Thin film interference:

$\Delta x =$ path ① - path ② (path difference)

reflect from higher $n \Rightarrow$ extra $\lambda/2$ path change.

$\Delta x = m\lambda$ (constructive interference)

$\Delta x = (m+1/2)\lambda$ (destructive interference)

Polarization:

$I = I_0\cos^2\theta$ (transmission thru polarizer)

$I = \frac{1}{2}I_0$ (transmission of unpolarized light)

Chapter 25 Equations

Cameras

$f/D =$ f-number, or lens aperture

film exposure = exposure time / f-number.

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ (lens equation)

$m = -d_i/d_o = h_i/h_o$ (image size and magnification)

Lens power

$P = 1/f$ (power in diopters).

Vision correction

Far point FP $= \infty$. (good vision)

Near point = NP $\leq$ 25 cm. (good vision)

Nearsighted. Use lens to get FP=∞.

Farsighted. Use lens to get NP=25 cm.

Simple magnifier

$\theta = \frac{h_0}{\text{NP}}$ (angular size viewed at NP.)

$\theta' = \frac{h_0}{d_0}$ (angular size viewed at any d_0.)

$M = \frac{\theta'}{\theta} = \frac{\text{NP}}{d_o}$ (ang. Mag. viewed at any d_0.)

$M = \frac{\theta'}{\theta} = \frac{\text{NP}}{f}$ (ang. Mag. viewed at $d_0 = f$.)

Telescopes

$M = \frac{\theta'}{\theta} = \frac{f_{\text{obj}}}{f_{\text{eye}}}$ (angular magnification)