General Physics II **Exam 3 - Chs. 22–25 - EM Waves & Optics** **April 1, 2013**

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 wave is traveling west with electric field vector oscillating vertically up and down. Its magnetic field vector is oscillating

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

2. (3) Which of these types of EM waves has the longest wavelength in vacuum?

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

3. (3) **T F** Garage door openers use lower frequency EM waves than wireless internet technology.

4. (3) **T F** Microwave ovens use EM waves of about the same frequency as wireless internet technology.

5. (3) **T F** The main absorber of ultraviolet light in Earth's atmosphere is methane (CH_4).

6. (12) A TV dish antenna receives EM waves of frequency 2.55 GHz from a satellite 36000 km away.

b) (6) What is the distance between successive wave crests of the electric field vector of the waves?

a) (6) How much time in milliseconds does the signal require to travel from the satellite to the dish antenna?

7. (12) A light source emits EM waves of 4.00 W total power uniformly in all directions. Assume the waves have a single frequency (monochromatic).

a) (6) What is the intensity of the waves at 2.00 m from the light source?

b) (6) What is the electric field amplitude E_0 produced at 2.00 m from the light source?

8. (4) Electromagnetic waves of frequency f travel from vacuum into glass. Inside the glass,

a. the frequency stays the same but the speed increases.
b. the frequency stays the same but the speed decreases.
c. the frequency increases but the speed stays the same.
d. the frequency decreases but the speed stays the same.

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9. (4) Electromagnetic waves of wavelength λ travel from vacuum into glass. Inside the glass,

a. the wavelength stays the same and the speed increases.
b. the wavelength stays the same and the speed decreases.
c. the wavelength increases and the speed increases.
d. the wavelength decreases and the speed decreases.

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10. (16) You want to have a bathroom mirror that will create an upright image of your face magnified $2.5\times$ when you are 50.0 cm in front of it.

a) (6) Where will the image of your face be? Is it in front of or behind the mirror, and at what distance?

b) (2) Circle the correct image type: a. real b. virtual

c) (8) What kind of mirror is it? a. concave b. convex c. planar Find its focal length.

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11. (18) A 0.250-cm long diamond is placed 3.00 cm in front of a lens. Its image is formed 30.0 cm from the lens on the same side as the diamond.

a) (2) Circle the image type: a. real b. virtual.

b) (2) Circle the image orientation: a. upright b. inverted.

c) (6) What is the focal length of the lens?

d) (2) Which type of lens is it? a. converging. b. diverging. c. flat on both sides.

e) (6) How long is the image of the diamond?

12. (2) **T** **F** The image of a real object formed by a convex mirror is always virtual.

13. (2) **T** **F** The focal length of a plane mirror is infinite.

14. (2) **T** **F** Any converging lens has a negative focal length.

15. (2) **T** **F** When the image distance d_i is negative, the image is virtual.

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16. (12) A diver shines a flashlight upward from the bottom of a 3.00 m deep pool so that the light beam makes an angle of 10.0° to the vertical (the index of refraction of water is 1.33).

a) (6) At what angle to the vertical does the light leave the water?

b) (6) For a person outside the pool, at what depth is the image of the flashlight?

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17. (8) A person's right eye is only able to focus clearly on objects at least 2.50 m from the eye and farther.

a) (2) This eye is a. nearsighted. b. farsighted. c. normal.

b) (6) What type of eyeglass lens placed 2.00 cm in front of the eye will allow the eye to focus clearly on objects as close as 25 cm? State your answer by giving the power of the lens in diopters.

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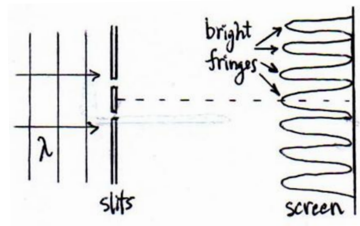
18. (12) A magnifying glass has a 5.00 cm focal length. It is used to view some print 4.40 cm from the lens.

a) (6) Where is the image of the print? Be specific: draw a sketch showing the lens, object, and image.

b) (6) How large is the angular magnification, assuming your near point distance is 25 cm?

19. (12) Two narrow slits are separated by 0.250 mm and illuminated with green light of wavelength 555 nm. The light passes through the slits and shines on a screen 2.00 m behind the slits.



a) (6) If the zeroth order bright fringe falls on the screen at angle $\theta = 0$ radians (straight in front of the slits), at what angle (in radians) does the first order bright fringe appear?

b) (6) How far apart are neighboring bright fringes on the screen?

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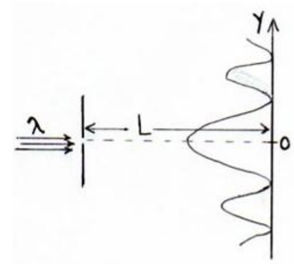
20. (12) Monochromatic light shines through a slit 4.50×10^{-3} mm wide, making a diffraction pattern on a distant screen. The angle between the first dark fringes on either side of the central maximum is 12.0° (dark fringe to dark fringe).



a) (6) What is the wavelength of the light?

b) (6) If red light at wavelength 685 nm is passed through the same slit, What is the angular width of its central maximum (dark fringe to dark fringe)?

Score = ___________/145.

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)

$\epsilon_0 = 1/4\pi k = 8.854$ pF/m (permittivity of space)

$e = 1.602 \times 10^{-19}$ C (proton charge)

$\mu_0 = 4\pi \times 10^{-7}$ T·m/A (permeability of space)

$m_e = 9.11 \times 10^{-31}$ kg (electron mass)

$m_p = 1.67 \times 10^{-27}$ kg (proton mass)

$c = 3.00 \times 10^8$ m/s (speed of light)

$c = 2.99792458 \times 10^8$ m/s (exact value in vacuum)

Units

$N_A = 6.02 \times 10^{23}$/mole (Avogadro's #)

1 u = 1 g/N_A = 1.6605×10^{-27} kg (mass unit)

1.0 eV = 1.602×10^{-19} J (electron-volt)

1 V = 1 J/C = 1 volt = 1 joule/coulomb

1 F = 1 C/V = 1 farad = 1 C^2/J

1 H = 1 V·s/A = 1 henry = 1 J/A^2

1 A = 1 C/s = 1 ampere = 1 coulomb/second

1 Ω = 1 V/A = 1 ohm = 1 J·s/C^2

1 T = 1 N/A·m = 1 tesla = 1 newton/ampere·meter

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.

$|m| > 1 \Rightarrow$ magnified.

$|m| < 1 \Rightarrow$ 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.

$|m| > 1 \Rightarrow$ magnified.

$|m| < 1 \Rightarrow$ 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)

$d = 1/(\text{lines per meter})$.

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)