General Physics II **Exam 3 - Chs. 22–25 - EM Waves & Optics** **October 24, 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 due north with electric field vector oscillating east-west. Its magnetic field vector is oscillating

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

2. (3) An EM wave travels due north. At a point in space where the electric field instantaneously has the strength E, the magnetic field strength is

a. 0. b. E/c c. c/E d. Ec e. $E+c$

3. (3) Which type of EM waves travels the fastest in vacuum?

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

4. (3) Which type of EM waves has the shortest wavelength in vacuum?

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

5. (3) Which is true about the electric and magnetic fields in an electromagnetic wave?

a. $\vec{B}$ is parallel to $\vec{E}$ and synchronized with $\vec{E}$.
b. $\vec{B}$ is perpendicular to $\vec{E}$ and synchronized with $\vec{E}$.
c. $\vec{B}$ is parallel to $\vec{E}$ but out of phase with $\vec{E}$.
d. $\vec{B}$ is perpendicular to $\vec{E}$ but out of phase with $\vec{E}$.

6. (12) 450 MHz radio waves travel out from a transmitter to a receiver 2400 km away.

a) (6) What time is required for the waves to travel from transmitter to receiver?

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

7. (12) A TV transmitter emits EM waves with a total power of 25 MW isotropically at 640 MHz.

a) (6) Calculate the average intensity I of the waves at 50.0 km from the transmitter.

b) (6) Calculate the electric field amplitude E_0 of the waves 50.0 km from the transmitter.

8. (16) An object placed 48 cm in front of a mirror is to have an upright image magnified by 3.0 $\times$.

a) (6) Find the location of the image. (2) Is it in front of or behind the mirror?

b) (6) Find the focal length of the mirror. (2) What kind of mirror is it?

---

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

10. (2) **T F** The image of a real object formed by a plane mirror always has magnification=+1.

11. (2) **T F** A diverging lens must have a positive focal length.

12. (2) **T F** When a lens makes a real image of a real object, the image is always inverted.

---

13. (6) In a certain glass prism, blue light ($\lambda \approx 400$ nm) refracts more strongly than red light ($\lambda \approx 700$ nm).

a) (2) **T F** The index of refraction is greater for blue light than for red light in this glass.

b) (2) **T F** Red light travels faster than blue light in this glass.

c) (2) **T F** Both these colors of light travel slower in the glass than they would in vacuum.

---

14. (18) A 3.50-cm long grasshopper is placed 12.0 cm in front of a lens. Its image is formed 48.0 cm beyond the lens on the other side.

a) (2) **T F** The image is a real image.

b) (2) **T F** The image is 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 grasshopper?

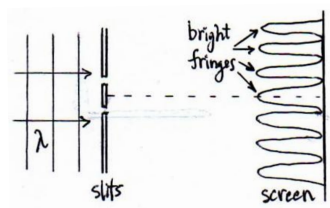
15. (8) A person's right eye is corrected to have the normal far point of infinity (∞) by using a contact lens of power -0.24 D.

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

b) (6) What is the eye's far point without the lens in place?

---

16. (12) A double slit has separation $d = 0.080$ mm. Monochromatic light of unknown wavelength passes through the slits. The first order bright fringes appear at $\theta = \pm 0.0075$ radian on both sides of the central maximum.

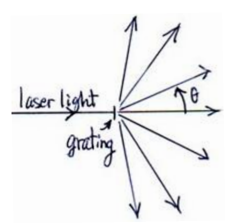


a) (6) What is the wavelength of the light?

b) (6) About how far apart are neighboring bright fringes on a screen placed 4.0 m behind the slits?

---

17. (12) A diffraction grating has 7800 lines per centimeter. 532 nm wavelength light shines perpendicularly through it and then makes bright fringes on a screen.



a) (6) How many bright fringes will be cast onto the screen?

b) (6) At what angle to the centerline do the highest order bright fringes appear?

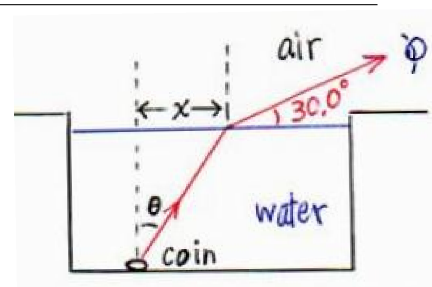
18. (12) A camera has a telefoto-lens with maximum f-ratio of f/5.6 and focal length of +400. mm. It is used to snap a photo of a 8.00 m high tree that is 150. m away.

a) (6) What is the maximum usable diameter over which the lens can collect light? (Hint: Use the f-ratio.)

b) (6) How large is the image of the tree on the film?

---

19. (20) There is a coin at the bottom of a 2.50-meter-deep water-filled pool ($n = 1.33$). Standing at the edge of the pool, you observe the coin by looking along a line that makes an angle of 30.0° with the surface of the water.



a) (4) On the diagram, extend any rays needed, to show where the image of the coin will appear.

b) (8) Use Snell's Law to determine the underwater refraction angle θ shown in the diagram.

c) (8 bonus pts) Do some trig to determine the depth of the coin's image. Finding the distance x might help.

Score = ___________/151.

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.
$|m| > 0 \Rightarrow$ 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)

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

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)