Gen. Phys. II Exam 3 - Chs. 24,25,26 - EM Waves, Ray Optics, Optical Instruments Mar. 29, 2021

Rec. Time **Name**

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 or answers.

OpenStax Ch. 24 - Electromagnetic Waves

1. (5) Which statements below are true about electromagnetic waves? Check all that apply.

a. They have parallel electric and magnetic fields.
b. They travel at a constant speed in vacuum, independent of the frequency.
c. The direction of propagation is perpendicular to the electric field.
d. They travel faster in glass than in vacuum.

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2. (5) 425 MHz electromagnetic waves carrying a TV signal are traveling due west from Topeka to Manhattan and have a vertical electric field. In what directions does the associated magnetic field oscillate?

a. north-south b. east-west c. vertically up and down d. no direction, because the magnetic field is zero.

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3. (5) A wide range of electromagnetic waves is passing through your body right now. Rank the following types of EM waves from highest to lowest frequency: visble light, AM radio, gamma-rays, ultraviolet light and infrared light.

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4. (5) A resonant circuit in a radio transmitter has an adjustable capacitor C and an adjustable inductor L. Initially the antenna it is connected to is emitting 5.00 MHz radio waves. What can be done to increase the frequency of the emitted waves? Check all that apply.

a. reduce C. b. reduce L. c. increase C. d. increase L.

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5. (5) A microwave tower is sending 236 MHz electromagnetic waves from Jenna's town to Denver, which is 668 km away. How long does it take for the signals to travel that far, in milliseconds?

6. (5) Electromagnetic waves emitted by a radio transmitter in the engineering building have a frequency of 2.26 kHz. How far do the waves travel (in km) during one period of the LC oscillator producing the waves? Tip: Make sure the distance is in km before submitting!

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7. (10) This is the question for which you must upload your work. Light is emitted isotropically from a light bulb and where it reaches you 3.72 m away the intensity is 515 μW/cm^2 (microwatts per square centimeter). What is the total power in the electromagnetic radiation from the light bulb, in watts?

OpenStax Ch. 25 - Ray Optics **Name**____

1. (6) An object is placed in front of a concave mirror, at a distance outside of the focal point (object distance $> f$).

The location of the image formed is	a. in front of	b. behind	c. to the side of	the mirror.
The type of image formed is	a. real	b. virtual.	c. latent.	
The orientation of the image formed is	a. inverted.	b. upright.	c. sideways.	

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2. (6) An object is placed in front of a convex mirror, at a distance less than the magnitude of the focal length (object distance $< |f|$).

The location of the image formed is	a. in front of	b. behind	c. to the side of	the mirror.
The type of image formed is	a. real	b. virtual.	c. latent.	
The orientation of the image formed is	a. inverted.	b. upright.	c. sideways.	

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3. (4) While looking at her face in a mirror, Cecilia sees her own image as upright and magnified. She concludes that (check all that are true)

a. the mirror is concave. b. the mirror is convex. c. the mirror is planar (flat).
d. she is closer to the mirror than one focal length. e. she is farther from the mirror than one focal length.

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4. (4) A lens is used to focus the rays of the sun onto a small point, to light a fire. Which type of edge-on profile could it have? Check all that apply.

a. convex on both sides b. convex on one side, planar on the other side
c. concave on both sides d. concave on one side, planar on the other side

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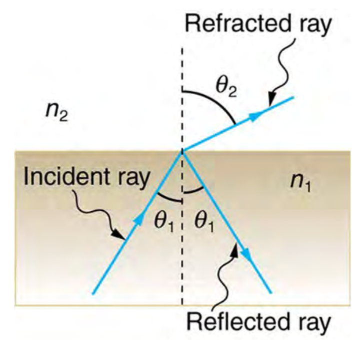
5. (4) You look at an object though some lens, and discover that the image you see is inverted and smaller than the object. What can you conclude? Check all that apply.

a. the image is virtual. b. the image is closer to the lens than the object is.
c. the image is real. d. the image is farther from the lens than the object is.

6. (6) The index of refraction of a flint glass is n=1.58. Light within the glass comes to its surface at an incident angle of 32.76 degrees. At what refraction angle to the normal does it emerge into the air on the outside, in degrees?



7. (10) This is the problem for which you must upload your work. A 9.4-mm high object is placed 70.2 mm in front of a (converging) camera lens whose focal length is +50.0 mm. After finding the location of the image formed, figure out the height of the image, h_i, in mm. Remember that if the image is inverted, the image height should be negative. Enter the result for h_i (in mm).

OpenStax Ch. 26 - Vision, Optical Instruments **Name**____________________________________

1. (5) Katie's left eye is so strongly farsighted that it can only focus clearly on things farther than 5.0 meters away. Which can you say about the eye's optics? Check all that apply.

a. the lens power is too weak. b. images of nearby objects fall behind or beyond the retina.
c. the lens power is too strong. d. images of nearby objects fall in front of the retina.

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2. (5) A patient's right eye at Holton Optometric Services is able to focus clearly on objects from 10.0 cm to 125 cm away, while objects outside this range are not in focus. What do you conclude about this eye? Check all that apply.

a. The eye is nearsighted. b. The lens power of the eye is too strong.
c. The eye is farsighted. d. The lens power of the eye is too weak. e. The eye has normal vision.

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3. (5) Doctor Robbins at Emporia Eye Vision takes a look at Jason's right eye and determines that it has a lens-to-retina distance of 2.00 cm while the lens power ranges from 52 diopters (relaxed) to 58 diopters (strained). What does Dr. Robbins say about the eye and the correction? Check all that apply.

a. The eye is nearsighted. b. A positive power corrective lens is needed to improve the vision.
c. The eye is farsighted. d. A negative power corrective lens is needed to improve the vision.
e. The eye has normal vision. f. No corrective lens is needed.

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4. (5) Steven goes to Holton Optometric Services and is told that his right eye is able to focus clearly on objects from 25 cm to more than 1.0 km away. What can you conclude about that eye? Check all that apply.

a. The eye is nearsighted. b. The lens power is too weak.
c. The eye is farsighted. d. The lens power is too strong. e. The eye has normal vision.

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5. (6) Regina's far point distance is 1.59 m, but she would like to be able to focus clearly on objects out to infinity, so she can distant birds and other animals. What is the power of the contact lens needed, in diopters, to correct her vision? Tips: Be sure to check signs and algebra. Draw a diagram to be sure.

6. (6) Students in the KSU biology lab are using a simple magnifying lens with a focal length of 2.0 mm to view an organism 0.082 mm long. Viewed through the magnifier with a relaxed eye, estimate the angular size of the organism as seen by the KSU biology students, in radians. Hint: Where is the organism placed with respect to the lens?

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7. (8) This is the problem for which you must show your work. You really need to draw a diagram if you want to get this correct!!

Samantha is an electronics technician whose near point without corrective lenses is 90.0 cm. She wants to use glasses placed 2.00 cm in front of her eyes so that she can focus clearly on objects as close as 16.0 cm from her eyes, viewed through the glasses. What power in diopters must the corrective lenses have? Be sure to check all signs!

 Ch. 24 = ___________/40 Ch. 25 = ___________/40 Ch. 26 = ___________/40

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

OpenStax Chapter 24 Equations - Electromagnetic Waves

Electromagnetic waves:

$|\vec{E}|/|\vec{B}| = c = 1/\sqrt{\epsilon_0\mu_0}$, (fields and speed)
$\omega = 2\pi f = \frac{1}{\sqrt{LC}}$ (LC oscillator frequency)

$f\lambda = c$, or $\lambda = cT$ (wave equation)
$x = ct$ (propagation in space)

Energy density, intensity, power:

$u = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$ (instantaneous energy density)
$I = \overline{u}c = \frac{1}{2}c\epsilon_0 E_0^2$ (EM waves intensity)

$\overline{u} = \frac{1}{2}\epsilon_0 E_0^2 = \frac{B_0^2}{2\mu_0}$ (average energy density)
$I = P/A = P/(4\pi r^2)$ (intensity definition)

Approximate wavelengths λ for types of EM waves:

0 (γ-rays) 30 pm (x-rays) 3 nm (uv) 400 nm (visible) 700 nm (ir) 300 μm (μ-waves) 3 cm (radio) ∞

$\longrightarrow$ $\longrightarrow$ $\longrightarrow$ increasing wavelength $\longrightarrow$ $\longrightarrow$ $\longrightarrow$

OpenStax Chapter 25 Equations - Geometrical Optics

Reflection, Mirrors:

$\theta_r = \theta_i$ (angle of reflection = angle of incidence)
$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ (mirror equation)
$d_i > 0 \implies$ real, light side.
$m > 0 \implies$ upright.
$|m| > 1 \implies$ magnified.

$f = r/2$ (focal length of spherical mirror)
$m = -d_i/d_o = h_i/h_o$ (linear magnification)
$d_i < 0 \implies$ virtual, dark side.
$m < 0 \implies$ inverted.
$|m| < 1 \implies$ diminished.

Refraction, Lenses:

$n = c/v$ (index of refraction)
$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ (lens equation)
$d_i > 0 \implies$ real image, light (opp.) side.
$m > 0 \implies$ upright.
$|m| > 1 \implies$ magnified.

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ (Snell's Law)
$m = -d_i/d_o = h_i/h_o$ (linear magnification)
$d_i < 0 \implies$ virtual image, dark (same) side.
$m < 0 \implies$ inverted.
$|m| < 1 \implies$ diminished.

Angles in radians

$\theta = s/r$ angle = arc length / radius = separation / distance away.

Lens power

$P = 1/f$ (power in diopters, when f is in meters).

Cameras

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

film exposure = exposure time / (f-number)^2.

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

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

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

$\theta = \frac{h_o}{\mathrm{NP}}$ (angular size at NP, via bare eye)

$\theta' = \frac{h_o}{d_o}$ (angular size at d_o, thru magnifier)

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

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

Microscopes

$\theta = \frac{h_o}{\mathrm{NP}}$ (angular size of object at NP, via bare eye)

$m_o = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$ (1^{st} image, linear magnification of objective lens)

$M_e = \frac{\theta'}{\theta} = \frac{\mathrm{NP}}{d'_o}$ (angular magnification due to eyepiece lens)

$M = \frac{\theta_{\mathrm{micro}}}{\theta} = m_o M_e$ (net angular magnification compared to bare eye)

Telescopes

$M = \frac{\theta'}{\theta} = -\frac{f_{\mathrm{obj}}}{f_{\mathrm{eye}}}$ (angular magnification compared to bare eye)