Gen. Phys. II Exam 3 - Chs. 24,25,26 - EM Waves, Ray Optics, Optical Instruments Apr. 1, 2019

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. Bonus points possible by correctly using prefixes like 2.0 mV, 7.8 MW, 1.6 kΩ, 3.4 μT, etc., in lieu of scientific notation like 2.0×10^{-3} V.

OpenStax Ch. 24 - Electromagnetic Waves

1. (3) Which type of electromagnetic (EM) waves has the highest speed in vacuum?

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

2. (3) An EM wave is traveling to the south with its 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.

3. (3) Some EM waves have frequencies from about 10 GHz to the highest practical LC resonance around 1 THz. These wave would be called

a. radio waves. b. microwaves. c. visible light. d. ultraviolet light. e. gamma rays.

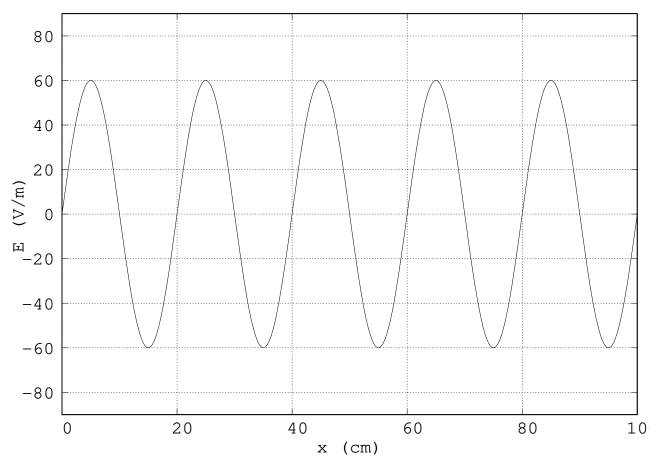
4. (2) **T F** The speed of light in matter is greater than in vacuum.

5. (2) **T F** Magnetic fields are generated by moving charges or by changing electric fields.

6. (2) **T F** Ampère experimentally verified the production and detection of EM waves using RLC circuits.

7. (12) The diagram shows a snapshot of the electric field $\mathbf{E}(x)$ in an EM wave travelling to the right in vacuum.

a) (6) How much time passes for the wave to travel a distance of one wavelength?



b) (6) How strong is the magnetic field $\mathbf{B}$ at a point where the electric field is maximum?

8. (7) WIBW TV channel 13 uses a broadcast frequency around 215 MHz. The RLC-circuit in a TV has a 420 pH (picohenry) inductor. What value of capacitance should be used in its RLC circuit for tuning in channel 13?

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9. (6) A cell phone emits EM waves isotropically with a total power of about 0.80 W when on a call. At 1.0 km from the phone, how strong is the intensity (W/m^2) of the EM waves from the phone?

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

1. (2) **T** **F** A convex mirror always forms an upright image of any real object.

2. (2) **T** **F** A concave mirror always forms a real image of any real object.

3. (2) **T** **F** The focal length of a converging lens is a negative number.

4. (2) **T** **F** The magnification of an image formed by a plane mirror is always +1.

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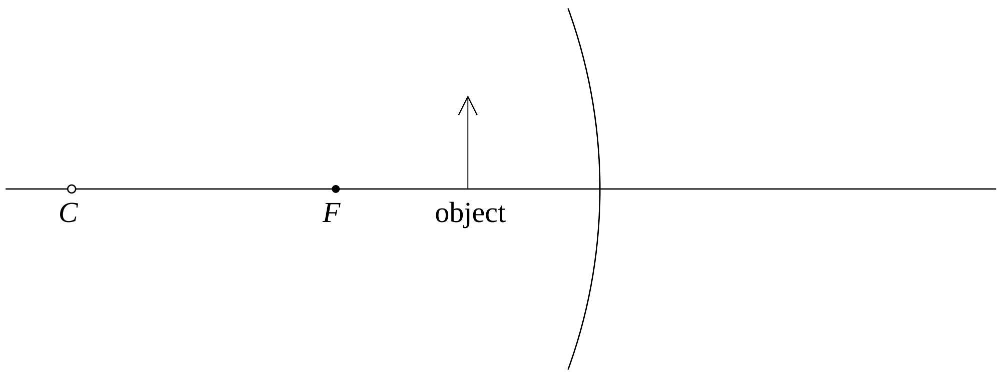
5. (10) For this mirror and object: a) (6) Using a straightedge, draw at least two rays to find the image.



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

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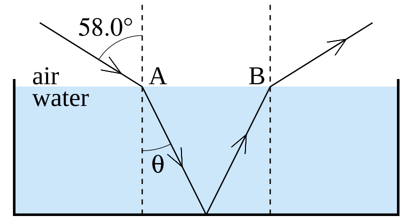
6. (8) You find a mirror in your attic. If you hold the mirror 42.0 cm from your face, the image of your face is perceived to be 84.0 cm behind the mirror.

a) (2) The image of your face will be a. real b. virtual.

b) (6) If your face is 25 cm long vertically, how long is its image in the mirror?

7. (10) A ray of light enters a pool filled with water ($n_w = 1.33$) that is 2.00 m deep and reflects off the bottom, as shown.



a) (5) Find the angle θ that the ray makes with the vertical under water.

b) (5) How large is the distance AB from where the ray enters to where it emerges from the water?

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8. (6) A 1.50 mm long seed is held 7.00 cm from a lens. A biologist looks through the lens and sees a virtual image of the seed 56.0 cm behind the lens. Calculate the focal length of the lens.

OpenStax Ch. 26 - Vision, Optical Instruments   Name____________________________________

1. (2) **T F** The lenses in your eyes have fixed focal lengths.

2. (2) **T F** The lenses in your eyes have positive focal lengths.

3. (2) **T F** In a farsighted eye, the image of a distant object falls on the retina.

4. (2) **T F** In a farsighted eye, the image of a nearby object falls in front of the retina.

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5. (6) What is the power (in diopters) of an eye's lens when viewing an object 45.0 cm away? Assume a lens-to-retina distance of 1.90 cm.

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6. (8) A patient's right eye can only focus clearly out to a distance of 42 cm. The vision is to be corrected with an appropriate contact lens.

a) (2) The vision of this eye is   a. nearsighted.   b. farsighted.

b) (6) What power contact lens is needed (in diopters) so that the eye can focus clearly on objects very far away?

7. (6) A patient's left eye requires the use of a contact lens whose power is +2.50 D (diopters) for reading books held 25 cm away from the eye. What is this eye's near point distance when not using the contact lens?

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8. (12) A geologist wants to examine a 0.80 mm long crystal in a rock, using her eye with a near point distance of 20.0 cm. She has a magnifying lens with a focal length of 5.00 cm.

a) (6) If she views the crystal with her naked eye, what is its approximate angular size in radians when held at the near point distance?

b) (6) If she views the crystal through the magnifying lens, so that its image is at infinity, what is its approximate angular size now? (Hint: Where is the crystal placed for that?)

 Ch. 24 = __________/40 Ch. 25 = __________/42 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)

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

Energy density, intensity, power:

$u = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$ (instantaneous energy density)
$I = \overline{u}c = \frac{1}{2}\epsilon_0 E_0^2 c$ (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)
$d_i > 0 \Rightarrow$ real, light side.
$m > 0 \Rightarrow$ upright.
$|m| > 1 \Rightarrow$ magnified.

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

Refraction, Lenses:

$n = c/v$ (index of refraction)
$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ (lens equation)
$d_i > 0 \Rightarrow$ real image, light (opp.) side.
$m > 0 \Rightarrow$ upright.
$|m| > 1 \Rightarrow$ 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)
$d_i < 0 \Rightarrow$ virtual image, dark (same) side.
$m < 0 \Rightarrow$ inverted.
$|m| < 1 \Rightarrow$ diminished.

OpenStax Chapter 26 Equations - Optical Instruments & Vision

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.

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

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

Vision correction

Far point FP = ∞. (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

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

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

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

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

Microscopes

$\theta = \frac{h_o}{\text{NP}}$ (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)

$M_e = \frac{\theta'}{\theta} = \frac{\text{NP}}{d_o'}$ (angular magnification due to eyepiece lens)

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

Telescopes

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