Gen. Phys. II Exam 3 - Chs. 24,25,26 - EM Waves, Ray Optics, Optical Instruments Mar. 26, 2018

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.

OpenStax Ch. 24 - Electromagnetic Waves

1. (3) Which type of electromagnetic (EM) waves has the highest frequency 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 vertically upward 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.

3. (3) The first physicist to confirm the generation and detection of EM waves by using LC oscillator circuits was

a. Alexander Bell. b. James Watt. c. André-Marie Ampère. d. Heinrich Hertz. e. Carl Friedrich Gauss.

4. (3) **T F** In vacuum, electromagnetic waves of higher frequencies travel faster than lower frequencies.

5. (3) **T F** EM waves in vacuum can be considered to be *transverse* waves.

6. (3) **T F** Earth's ozone layer is important in blocking dangerous infrared light from the sun.

7. (3) Which physical effect did James Clerk Maxwell add into the equations of electromagnetism that carry his name, based on theoretical reasoning?

a. changing magnetic fields produce electric fields. b. changing electric fields produce magnetic fields.
c. moving electric charges produce magnetic fields. d. moving electric charges experience magnetic forces.

8. (12) Some EM waves having a frequency of 580. kHz are travelling towards the east.

a) (6) At a fixed point in space, how much time elapses between the passing of two subsequent positive peaks of the magnetic field?

b) (6) How far apart along the east-west direction are neighboring positive peaks of the magnetic field?

9. (6) The LC-circuit in a radio transmitter uses a 5.00 pF capacitor together with a 1.00 μH inductor. What frequency radio waves would it transmit?

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10. (12) Your house sits 86 km from a 425 MHz TV transmitter emitting a total power of 125 kW. Assume that the radiation goes out isotropically from the antenna.

a) (6) How long does it take for the TV signal to go from the transmitter to your house?

b) (6) Measured at your house, how strong is the intensity of the EM waves from the transmitter?

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

1. (3) **T F** A concave mirror always forms an inverted image of any real object.
2. (3) **T F** A convex mirror always forms a virtual image of any real object.
3. (3) **T F** The focal length of a diverging lens is a positive number.
4. (3) **T F** A lens with a positive focal length is thicker at its center compared to its edge.

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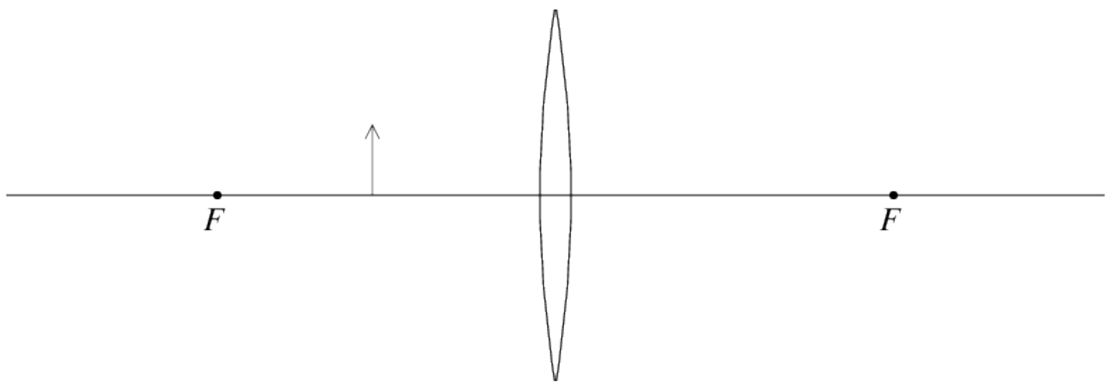
5. (12) For this lens and object: a) (8) Using a straightedge, draw at least two rays to find the image.



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

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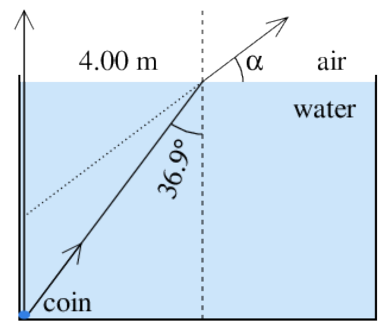
6. (12) Working for the cosmetics industry, you need to design a mirror to look at your own face magnified by $+4.0\times$ when held 16.0 cm away from it.

a) (3) The image of your face will be a. real b. virtual.

b) (9) Find the focal length and type (concave or convex) of mirror.

7. (8) A coin lies at the bottom corner of a pool filled with water ($n_w = 1.33$). One ray of light emerges from the center of the pool, 4.00 m from the edge, as shown in the diagram. Suppose you view the coin looking along this ray's line.



a) (8) Using Snell's Law of refraction, what angle α does the emerging ray make with the surface of the water?

b) (6-bonus) Viewed along that ray, how deep is the image of the coin?

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8. (6) A doctor examines a 2.0 mm wide mole with a 15.0 cm focal length magnifying lens held 14.0 cm from the mole. How far from the magnifying glass is the image of the mole?

OpenStax Ch. 26 - Vision, Optical Instruments   Name____

1. (3) **T F** In a nearsighted eye, the image of a distant object falls in front of the retina.

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

3. (3) **T F** The image of this exam on your retina is inverted.

4. (3) **T F** Accomodation in the eye takes place by changing the lens-to-retina distance.

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5. (6) What is the far point distance of an eye whose relaxed power is +52.85 D? Assume a 1.90 cm lens-to-retina distance.

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6. (8) A patient's right eye has a near point distance of 22 cm and a far point distance of 2.50 m. 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?

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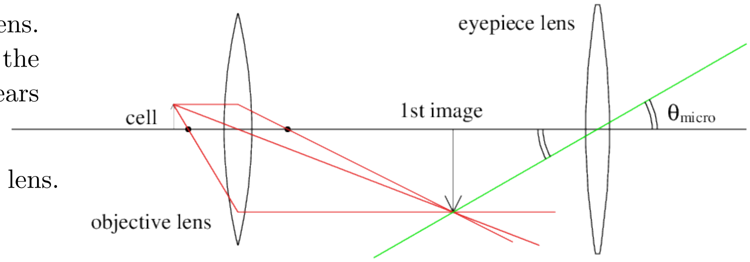
7. (8) In a LASIK vision correction procedure, the power of a patient's eye is increased by 3.20 D. (This is similar to placing a +3.20 D contact lens on the eye.) If the eye now has normal close vision, what was the eye's near point before the procedure?

8. (18) You have a compound microscope with a 4.00 mm focal length objective lens and a 2.00 cm focal length eyepiece lens. With a relaxed eye, you view a cell placed 4.10 mm from the objective lens. Viewed through the eyepiece, the cell appears to have angular size $\theta_{\text{micro}} = 0.080$ radians.



a) (6) Determine the linear magnification of the objective lens.

b) (6) Using θ_{micro}, determine the height of the 1^{st} image in mm.

b) (6) What is the actual size of the cell in μm?

Ch. 24 = ___________/51 Ch. 25 = ___________/50 Ch. 26 = ___________/52

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 - Electromagetic 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.

$|m| > 0 \Rightarrow$ 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.

$|m| < 0 \Rightarrow$ 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.

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 $= \infty$. (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

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