

Name _____

Final Exam May 5, 2008

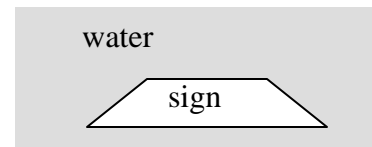
This test consists of five parts. Please note that in parts II through V, you can skip one question of those offered. Some possibly useful formulas appear below

<p style="text-align: center;"><u>Focal Length</u></p> $f = \frac{1}{2}R$ $\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right) \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$	<p style="text-align: center;"><u>2-Slit Interference</u></p> $\sin \theta_{\text{bright}} = \frac{m\lambda}{d}$ $I = I_{\text{max}} \cos^2 \left(\frac{\pi d \sin \theta}{\lambda} \right)$	<p style="text-align: center;"><u>Diffraction Grating</u></p> $mN > \lambda / \Delta\lambda$	<p style="text-align: center;"><u>Thin Film</u></p> $2t_{\text{Weak}} = \lambda m$
<p style="text-align: center;"><u>Magnification</u></p> $M \equiv h'/h = -q/p$ $m \equiv \theta/\theta_0$	<p style="text-align: center;"><u>Diffraction</u></p> $\sin \theta_{\text{dark}} = \frac{m\lambda}{d}$ $I = I_{\text{max}} \left[\frac{\sin(\pi a \sin \theta / \lambda)}{\pi a \sin \theta / \lambda} \right]^2$	<p style="text-align: center;"><u>X-Ray Scattering</u></p> $2d \cos \theta = m\lambda$	<p style="text-align: center;"><u>Brewster's Angle</u></p> $\tan \theta_p = n_2/n_1$
<p style="text-align: center;"><u>Telescope Magnification</u></p> $m = f_o/f_e$	<p style="text-align: center;"><u>Constants</u></p> $e = 1.602 \times 10^{-19} \text{ C}$ $\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$ $\mu_0 = 4\pi \times 10^{-7} \text{ T}\cdot\text{m}/\text{A}$	<p style="text-align: center;"><u>Relativity</u></p> $\gamma = \frac{1}{\sqrt{1-v^2/c^2}}$ $u' = \frac{u-v}{1-uv/c^2}$	<p style="text-align: center;"><u>Relativistic Doppler Effect</u></p> $f = f_0 \sqrt{\frac{1+v/c}{1-v/c}}$


Part I: Multiple Choice [20 points]


For each question, choose the best answer (2 points each)

- Suppose you have two nearly identical waves, but they differ by a phase. The two waves are then added together. For what phase difference will we get maximum destructive interference, so the waves tend to cancel out? Write the phase in radians.
 A) 0 B) $\frac{1}{2}\pi$ C) π D) 2π E) 4π
- If you placed a sign 1 m under water, so the surface of the sign is parallel to the surface of the water, and the water were perfectly smooth, the sign would appear
 A) Magnified in size, but neither closer nor farther than it actually is
 B) Magnified in size, and also farther away than it actually is
 C) Magnified in size, and also closer than it actually is
 D) Its usual size, but farther than it actually is
 E) Its usual size, but closer than it actually is



3. If an object without visual aids has an angular size of 1° , but with visual aids has an angular size of 2° , the angular magnification is $m =$
A) 4 B) 2 C) 1 D) $\frac{1}{2}$ E) $\frac{1}{4}$
4. When light goes through a diffraction grating, what sort of pattern does it make?
A) It comes out at a set of discrete angles that depend on wavelength
B) It makes a pattern of alternating dark and light regions
C) It makes a pattern with a bright band in the middle, and then several surrounding bands that are each half as wide as the central band
D) In the limit of many grating lines, the light goes straight through
E) If placed at the correct distance, the light will be focused to a point like a lens
5. One way to make EMF is with a battery. Another is to
A) Have a constant magnetic field through a stationary loop (only)
B) Have a constant magnetic field through a moving or rotating loop (only)
C) Have a changing magnetic field through a stationary loop (only)
D) B and C are both correct
E) A, B, and C are all correct
6. If you diffract light through a small hole, how will the diffraction pattern change if you make the hole smaller?
A) It will be smaller and brighter
B) It will be smaller and less bright
C) It will be smaller but the same brightness
D) It will be bigger and brighter
E) It will be bigger and less bright
7. Which of the following is not a consequence of special relativity?
A) Objects moving at high speed seem to get shorter
B) Clocks moving at high speed seem to run slower
C) The Doppler shift formula needs to be modified
D) Events that seem to be simultaneous according to one observer may not be simultaneous as viewed by another observer
E) Actually, all of these are consequences of special relativity
8. A converging lens in air is always
A) Convex on the front face
B) Concave on the front face
C) Convex on the back face
D) Thicker in the middle than on the edges
E) Thicker on the edges than in the middle

9. If you put polarized light into an optically active material, like sugar water, the polarization
- A) Will be completely blocked in one direction and mostly transmitted in the other direction
 - B) Will gradually rotate to be at a different angle
 - C) Will slowly become randomly polarized due to scattering
 - D) Will gradually reverse, so the electric field points the opposite direction
 - E) Will be irrelevant, since “polarization” is defined only in air
10. When light impinges on a boundary between regions at different indices of refraction at Brewster’s Angle, what happens?
- A) All of the light is reflected
 - B) All of the light is refracted
 - C) The light that is reflected will be completely polarized
 - D) The light that is refracted will be completely polarized
 - E) None of the above
11. In class, I dropped a small magnet down a copper tube. It fell, but very slowly. Why?
- A) According to Lenz’s law, the copper tube didn’t like changing magnetic flux, so it created currents that resulted in magnetic fields that resisted the motion of the magnet
 - B) Copper is a magnetic material, so the magnetic field of the magnet created a corresponding magnetic field in the copper, which the magnet was attracted to
 - C) The moving magnet created an electric field, which in turn attracted charges that held the magnet nearly in place
 - D) The moving magnet created electric fields, which caused charge to build up on the magnet, which deflected it sideways as it fell through the tube
 - E) Like Magneto from “X-men”, anything that has control of magnetism controls all metals, so it used its power to slow its fall
12. When working with a lens or a mirror, a real image is one that is
- A) In front in both cases
 - B) In back in both cases
 - C) In front for a lens, in back for a mirror
 - D) In back for a lens, in front for a mirror
 - E) None of the above
13. If a resistor with resistance $5\ \Omega$ had $30\ \text{V}$ across it, what would be the current through the resistor?
- A) $1/150\ \text{A}$ B) $1/6\ \text{A}$ C) $150\ \text{A}$ D) $6\ \text{A}$ E) None of the above
14. At right is the circuit symbol for a
- A) Battery B) Resistor C) Inductor D) Capacitor E) Switch
- 

15. Suppose the electric and magnetic field of an electromagnetic wave are as shown at right. In which direction is the wave traveling?
- A) Up B) Down C) Right D) Left E) Into the page
- 
16. Gauss's Law for electric fields says that the total electric flux out of a region of space is proportional to
- A) The total charge in that region
 B) The total current in that region
 C) The rate of change of magnetic flux
 D) The rate of change of current in that region
 E) The total electric potential on the surface of that region
17. Place the following three colors in correct order from longest to shortest wavelength
- A) Orange, Blue, Green
 B) Orange, Green, Blue
 C) Blue, Green, Orange
 D) Blue, Orange, Green
 E) Green, Blue, Orange
18. When you point X-rays at a crystalline arrangement of atoms, what pattern do you see reflected?
- A) You see bright reflections, but only at certain special angles
 B) You see bright reflections, except at certain special angles
 C) You see bright reflections in all directions
 D) You don't see reflections at all, but you do see spots caused by refraction
 E) X-rays are unaffected by crystals, so you don't see reflection or refraction effects
19. Basically, which of the following does a "step-up" transformer do to an AC source?
- A) It increases the voltage and increases the current
 B) It increases the voltage and decreases the current
 C) It decreases the voltage and increases the current
 D) It decreases the voltage and decreases the current
 E) A transformer has no effect on AC, it only affects DC
20. If a capacitor has capacitance C and potential difference ΔV , its charge Q is
- A) $\frac{1}{2}C(\Delta V)^2$ B) $(\Delta V)^2/2C$ C) $\Delta V/C$ D) $C/\Delta V$ E) $C\Delta V$

Part II: Short answer, old material: [20 points]

Choose **two** of the following three questions and give a short answer (2-3 sentences) (10 points each)

21. For each of the following five quantities, tell me the name of the metric unit and the appropriate symbol
a) Inductance b) Capacitance c) Current d) Resistance e) Frequency
22. Describe qualitatively the motion of a charged particle in a constant magnetic field
23. An inductor resists changes in what? Give any corresponding formulas.

Part III: Short answer, new material: [20 points]

Choose **two** of the following three questions and give a short answer (2-3 sentences) (10 points each)

24. Often, if you look closely at soap bubbles, you can see colorful patterns in the reflected light. What causes these colors?
25. For a telescope of fixed diameter, what ultimately limits how fine detail you can see on some distant astronomical object, using visible light? Give at least one formula.
26. Explain briefly what spherical aberration and chromatic aberration are.

Part IV: Calculation, old material: [60 points]

Choose **three** of the following four questions and perform the indicated calculations (20 points each)

27. The electrostatic potential in a certain region of space is given by

$$V(x, y, z) = 20(2z^2 - y^2 - x^2)$$

where V is in volts and (x, y, z) are the coordinates of a point in space, all in meters. A single proton of charge $e = 1.602 \times 10^{-19}$ C and mass $m = 1.673 \times 10^{-27}$ kg is at the position $(x, y, z) = (10 \text{ m}, 0, 0)$.

- (a) What is the potential energy of this proton at this position?
(b) What is the electric field at this position?
(c) What is the electric force on the proton, and its acceleration at this position?

28. In the circuit at right, there are 3 A flowing in from the top and out of the bottom of the circuit at all times.

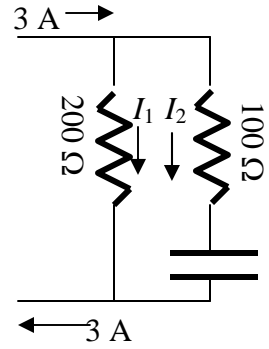
(a) Write an equation for I_1 and I_2 using Kirchoff's First law.

(b) Write an equation for I_1 and I_2 using Kirchoff's Second law.

Denote the voltage across the capacitor at any given time as ΔV , with the top at a higher voltage than the bottom

(c) If at $t = 0$, the capacitor has $\Delta V = 0$ on it, solve the equations you found in the previous two parts for the currents I_1 and I_2 .

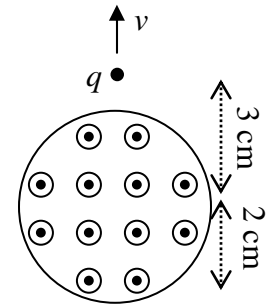
(d) After a long time, the capacitor reaches a steady state (no longer $\Delta V = 0$). What are the currents I_1 and I_2 at this time?



29. A cable of radius 2 cm has 100 A running through it. The current is distributed uniformly over the cross-sectional area of the cable, and as sketched at right, the current is moving directly out of the plane of the paper towards you.

(a) Find the magnitude and direction of the magnetic field 3 cm from the center of the cable, at the point charge q .

(b) A small charge of magnitude $q = -3 \mu\text{C}$ at a distance of 3 cm from the center is moving directly away from the cable at a velocity of $v = 100 \text{ m/s}$. Calculate the magnitude and direction of the force on the charge q .



30. A beam of light with frequency $f = 5.86 \times 10^{14} \text{ Hz}$ passes from air to glass at an angle of incidence of $\theta_i = 57.0^\circ$. Assume glass has an index of refraction of $n = 1.500$

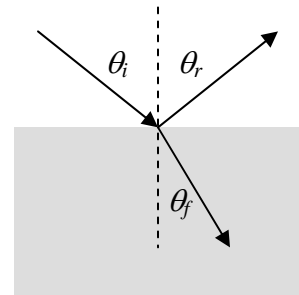
(a) At what angle θ_f does the light continue into the glass?

Some of the light reflects from the glass. What is the reflection angle θ_r ?

(b) For the incident light, what is the speed v and the wavelength λ ?

(c) For the transmitted light, what is the frequency f , the speed v , and the wavelength λ ? Also, what are these values for the reflected light?

(d) The critical angle for a glass/air transition can be shown to be 41.8° . Does this mean the light is totally reflected in this case?

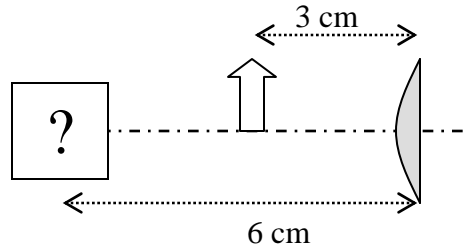


Part V: Calculation, new material: [60 points]

Choose **three** of the following four questions and perform the indicated calculations (20 points each)

31. Below is sketched a lens imaging system, consisting of a single plano-convex lens. It is discovered that when an object of height 2 cm is placed 3 cm in front of the lens, an image appears 6 cm in front of the lens.

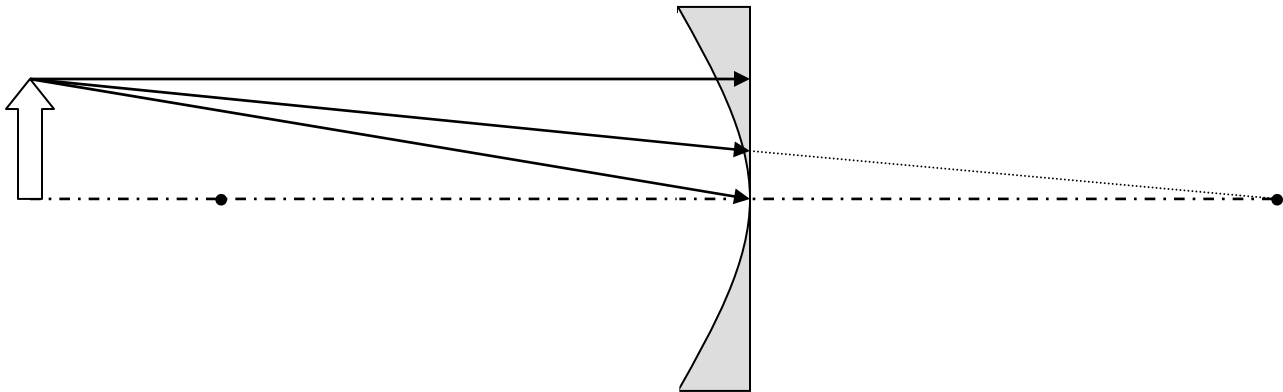
- (a) What is the magnification for this optical system?
How big will the image be? Will it be upright or inverted?
- (b) What is the focal length for this optical system?
- (c) If the lens is made from glass with an index of refraction of $n= 1.6$, what is the radius of curvature of the lens?



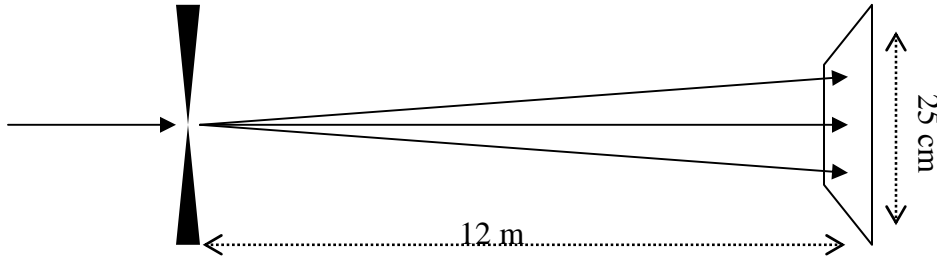
32. Below is sketched an imaging system consisting of a diverging lens. The two foci of the lens are marked. Also sketched in are three light rays: An upper one, initially parallel to the optic axis, a middle one, initially headed for the far focus of the lens, and the lower one, initially headed for the vertex of the lens. I recommend you work directly on this test.

- (a) Sketch the path of each of the light rays after they pass through the lens.
- (b) Using the paths just drawn, estimate the position of the image, and sketch it in.
- (c) Is the image real or virtual? Upright or inverted?

- (d) Estimate the magnification of the lens, including sign. _____



33. Light of wavelength $\lambda = 432 \text{ nm}$ passes through a slit 0.100 mm wide, and then travels a distance of 12.0 m before being projected onto a screen 25.0 cm in total width, such that the center of the pattern is directly at the center of the screen
- (a) Calculate all places on the screen where the diffraction pattern is completely dark. Give your answers as distances x from the center of the screen. You shouldn't give any answers larger than $x = 12.5 \text{ cm}$.
- (b) Calculate the ratio of the intensity at the edge of the screen (12.5 cm from the center) compared to the center



34. A rocket ship of length 150 m passes by us at a velocity of $v = 2.1 \times 10^8 \text{ m/s}$.
- (a) According to us, how long does the rocket ship look?
- (b) According to us, how long does it take from the time the front of the rocket ship passes us until the tail of the rocket ship passes us?
- (c) According to people on the rocket ship, how long does it take them to pass us?
- (d) Immediately after they have passed, we send them a radio signal, at velocity c , of course. According to them, how fast is the radio signal traveling?