Physics 208 Final Exam   Name___________________________________

You are graded on your work, with partial credit. See the last pages of the exam for formula sheets.
Please be clear and well-organized, so that we can easily follow each step of your work.

Your score on this exam will be multiplied by 8/7 (so that the maximum grade before any bonus points is changed from 175 to 200). This final exam grade will then be counted in the way specified in the syllabus/course outline.

1. Fun with the electric field

A solid metal sphere with radius 0.600 m carries a net charge of -0.400 nC, with 1 nC $= 10^{-9}$ C.

(a) (10) Determine the electric field at a point 0.100 m outside the surface of the sphere. (Give the magnitude and direction of the field, with the direction being toward sphere, away from sphere, or parallel to sphere.)

(b) (10) Determine the electric field at a point inside the sphere which is 0.100 m below the surface.

2. Fun with interference and diffraction.

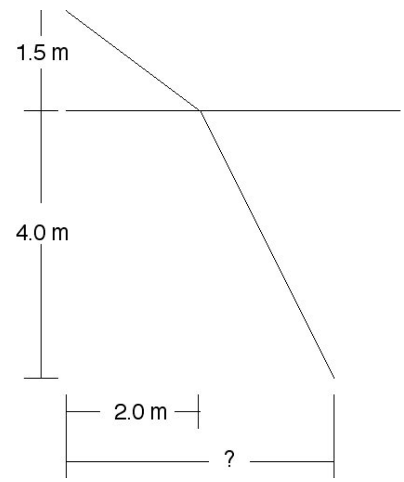
(a) (15) Your job is to design a reflective coating for a window. This means that you are to **specify the thickness of a film**, which will be deposited on the glass of the window, such that **the film will maximize constructive interference** for visible light with an **average wavelength (in vacuum) of 550 nm**. The index of refraction is **1.50 for the glass** and **2.00 for the film**. But your colleagues tell you that they cannot produce a reliable film that is too thin, and that **the thickness must be greater than 100 nm**. Calculate the required thickness of the film.

(b) (10) If you can read the bottom row of your doctor's eye chart, your eye has a resolving power of one arcminute, equal to 1/60 degree. If this resolving power is diffraction-limited, to what effective diameter of your eye's optical system does this correspond? (Again assume that the wavelength is 550 nm.)

3. Fun with refraction

You have a relaxing swim at a pool party, but as you prepare to leave you notice that your keys are missing. It is dark, so you borrow a powerful flashlight, and luckily spot your keys on the bottom of the pool. The beam from the flashlight shines directly on the keys when the flashlight is held 1.5 m above the water surface, and is directed at a point on the surface which is a horizontal distance of 2.0 m from the edge. (Note: The index of refraction of water is 1.33.)

(a) (8) Calculate the angle of incidence (the angle between the incident beam and the normal to the air/water interface) as the beam enters the water.

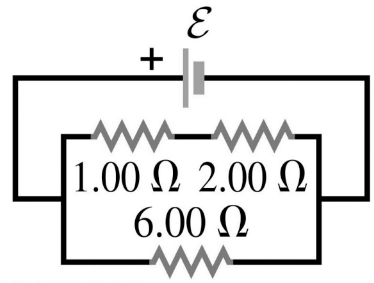


(b) (8) Calculate the angle of refraction (the angle between the refracted beam in the water and the normal to the air/water interface).

(c) (9) If the water is 4.0 m deep, how far are the keys from the edge of the pool?

4. Fun with resistors

(a) (5) See the drawing: Calculate the equivalent resistance for the 1.00 Ω and 2.00 Ω resistors.



(b) (5) Calculate the equivalent resistance for all 3 resistors.

(c) (5) The battery has an emf of 6.0 V and negligible internal resistance. Calculate the current through the battery.

(d) (5) Calculate the current through the 1.00 Ω resistor.

5. Fun with LC oscillations (Recall the analogy with a simple harmonic oscillator in mechanics: Charge corresponds to displacement, and current corresponds to velocity.)

(a) (4) A capacitor with capacitance 3.0×10^{-5} F is charged by connecting it to a 6.0 V battery. What is the initial charge on this capacitor?

(b) (4) How much energy is initially stored in the capacitor?

(c) (4) With the charge constant, this capacitor is disconnected from the battery and connected across an inductor with an inductance of 3.0 H. What is the angular frequency ω of the electrical oscillations in this simple LC circuit?

(d) (4) What is the charge on the capacitor 0.023 s after the connection to the inductor is made? (Note: Be careful.)

(e) (4) At the same time as in part (d), what is the current through the inductor?

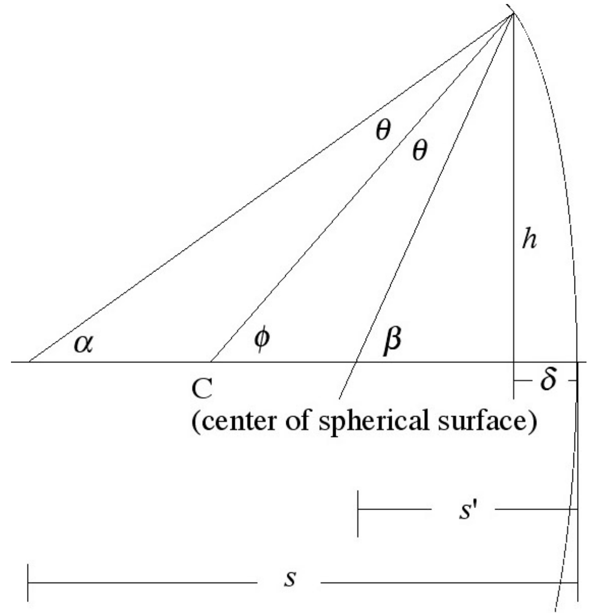
(f) (4) At the same time as in part (d), what is the energy stored in the capacitor?

(g) (4) At the same time as in part (d), what is the energy stored in the inductor?

(h) (2) Do your answers to (f) and (g), when compared with the answer to (b), satisfy conservation of energy?

6. Fun with geometric optics

(a) (4) In the drawing, for a concave spherical mirror with radius of curvature R, write an equation that relates the angles α, θ, and ϕ.



(b) (4) Now write an equation that relates the angles β, θ, and ϕ.

(c) (4) Next **obtain** an **approximate** equation that relates α, h, and s. (Recall that you are graded on your work, so you are supposed to clearly show each step.)

(d) (4) Similarly obtain an approximate equation that relates β, h, and s'.

(e) (4) Finally, obtain an approximate equation that relates ϕ, h, and R.

(f) (4) Use your results in parts (a)-(e) to obtain the fundamental equation of geometric optics that relates the object distance, the image distance, and the focal length f.

(g) (6) Now draw your own picture of a concave spherical mirror (just like the one above, but appropriately simplified so that all the angles etc. are not labeled), and **draw in clearly, neatly, and carefully any 3 of the principal rays** for a point object that is offset from the optic axis. **Be sure to label the focal point F and center of curvature C clearly.** (If you wish, you might show this as the top point on an extended object whose bottom is on the optic axis.)

7. Fun with Poynting's vector

A cylindrical conductor with a circular cross section has a radius a and a resistivity ρ, and it carries a constant current I.

(a) (5) Determine the magnitude of the electric field $\vec{E}$ at a point just inside the wire at a distance a from the axis.

(b) (5) Determine the magnitude of the magnetic field $\vec{B}$ at the same point.

(c) (5) Determine the magnitude of the Poynting vector $\vec{S}$ at this same point.

(d) (5) Use the result of part (c) to determine the rate of flow of energy into the volume occupied by a length ℓ of the conductor. (Hint: Integrate S over the surface of this volume.)

(e) (5) Compare your result to the rate at which thermal energy is generated in this volume.

8. (10 points extra credit) **Fun with applied physics**

Using ideas from Physics 208, clearly describe an important application, in real technology, of each of the following ideas.

(a) (2) Energy storage in a capacitor

(b) (2) Faraday's law

(c) (2) Oscillations of an LC circuit

(d) (2) Convex mirror

(e) (2) Converging lens for correcting vision (Hint: At some age you will need these.)

Merry Christmas and Happy Holidays!