University of California, Santa Barbara
Department of Physics

PHYSICS 24	**FINAL EXAM**	**WINTER 2004**
A. N. Cleland	8-11 am	Tuesday, March 16, 2004

- **This exam is closed book, closed notes.**
- **Calculators are allowed**
- **Show all work clearly. Partial credit will be given if your thinking is clear.**

Write your name:

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Scoring:

Problem 1	__________	of 20
Problem 2	__________	of 20
Problem 3	__________	of 20
Problem 4	__________	of 20
Problem 5	__________	of 20
Problem 6	__________	of 20
Total	__________	of 120

Problem 1 (20 points). An accelerating charge radiates electromagnetic power, at a rate

$$\frac{dE}{dt} = \frac{q^2 a^2}{6\pi\varepsilon_0 c^3}$$

where q is the charge, a is the acceleration, $c = 3 \times 10^8$ m/s the speed of light and $\varepsilon_0 = 8.85 \times 10^{-12}$ C/m the permittivity of vacuum.

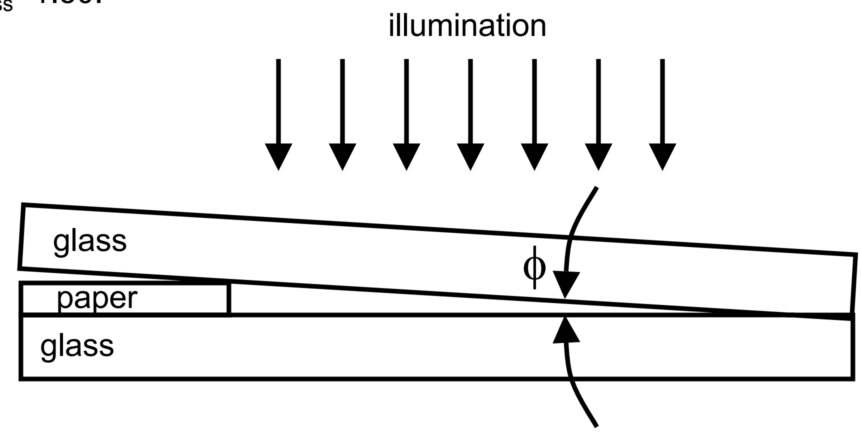
If an electron ($q = 1.6 \times 10^{-19}$ C, $m = 9.11 \times 10^{-31}$ kg) has a kinetic energy of 6.0 keV, and is traveling in an orbit with radius 0.5 m, what fraction of its energy does it radiate per second (assume constant speed)? Note that 1 eV = 1.602×10^{-19} J.

Problem 2 (20 points) An *L*-*C* circuit (no resistance) has its capacitor at maximum charge at time $t = 0$.

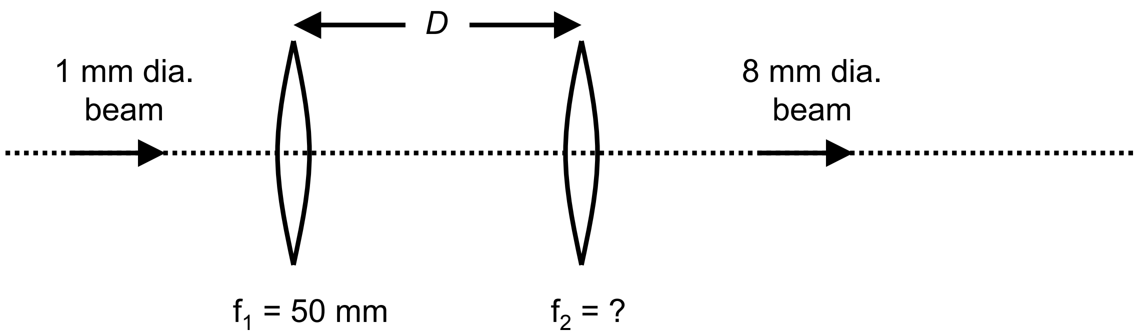
(a) If T is the period of oscillation of the circuit, find at the time at which the electric and magnetic energies will be *equal* in the circuit, in terms of T.

(b) How much longer after the time in (a) must you wait for the energies to again be equal? Again, give your answer in terms of T.

Problem 3 (20 points) Two plane glass slides are laid one on top of the other, with a thin piece of paper placed between them at one edge, so that a very small wedge of air is formed between them (see side view, below). The plates are illuminated at normal incidence with a monochromatic source of light with wavelength λ = 640 nm. You see 12 interference fringes per centimeter. Find the angle of the wedge ϕ. Note that n_{air} = 1.00, n_{glass}=1.50.



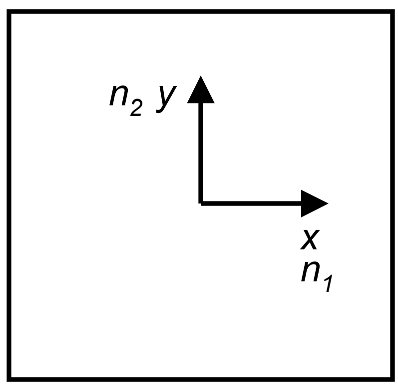
Problem 4 (20 points) A pair of converging lenses can be used to expand the diameter of a beam of light, for instance from a laser. A 1 mm diameter beam enters a converging lens with a focal length f_1= 50 mm, then passes through a second converging lens with a larger focal length f_2, emerging with a diameter of 8 mm. Find the focal length f_2 of the second lens, and the distance D of the second lens from the first.



Problem 5 (20 points) A **quarter wave plate** is an optical element that can transform circularly polarized light into linearly polarized light, and vice versa. One way to make a quarter wave plate is to use a slab of a *birefrigent* material, one which has a different index of refraction for the two linear polarizations of the electric field. For a slab with a thickness *d* into the page, the index of refraction for the electric field along *x* is n_1, while for that along *y* the index is n_2; assume $n_1 > n_2$. The slab will work as a quarter wave plate if the thickness *d* (into the page in the drawing) is such that light polarized along *x* emerges at the other side phase-shifted by $\pi/2$ (i.e. a quarter wavelength) compared to the light polarized along *y.*

(**a**) Find an expression for the smallest thickness *d* that will give this result, in terms of the indices of refraction and the vacuum wavelength of the light λ_0.

(**b**) For a plate made of material with $n_1 = 1.9$, $n_2 = 1.6$, and $\lambda_0 = 600$ nm, find *d*.



Problem 6 (20 points) A line of charge with linear charge density λ (coulombs per meter) is glued to the rim of a wheel of radius R, which is suspended horizontally and free to rotate about its vertical axis. A uniform magnetic field B_0 pointing upwards is present in the central area, filling a circle of radius a (and zero outside). The wheel is initially at rest, and then the magnetic field is turned off. What is the final angular momentum of the wheel? Note: It does not matter how fast the field is turned off! You may ignore the magnetic induction due to the rotation of the wheel itself.