Exam #: ________________________

Printed Name: ________________________

Signature: ________________________

PHYSICS DEPARTMENT

UNIVERSITY OF OREGON

Unified Graduate Examination

Part II

Electromagnetism

Friday, January 6, 2017, 13:30 to 16:10

The examination booklet is numbered in the upper right-hand corner of the cover page. Print and then sign your name in the spaces provided on the cover page. For identification purposes, be sure to submit this page together with your answers when the exam is finished.

There are four questions, each beginning on a new page. Read all four questions before attempting any answer. You may answer as many questions as you wish, however, only your top three scores will be used in the evaluation of your performance for a Ph.D. pass in this area, or your top two scores for a master's pass. (These scores will be added to your aggregate if taking the exam "under the old rules".)

Begin each answer on the same page as the question, but continue on additional blank pages if necessary. Write only on one side of each page. Each page should contain work related to only one problem. When you start a new problem, start a new page. Place both the exam number and the question number on all pages you wish to have graded. You are encouraged to use the constants on the following page, where appropriate, to help you solve the problems.

If you need to leave your seat, wait until everyone else is seated before approaching the proctor.

Calculators may be used only for arithmetic and will be provided. **Personal calculators are not allowed**. Dictionaries may be used if they have been approved by the proctor before the examination begins. **Electronic dictionaries are not allowed. No other papers or books may be used.**

When you have finished, come to the front of the room. For each problem, put the pages in order and staple them together. Then put all problems in numerical order and place them in the envelope provided. Finally, hand the envelope to the proctor.

Constants

Electron charge (e)	1.60×10^{-19} C
Electron rest mass (m_e)	9.11×10^{-31} kg ($0.511\,\mathrm{MeV/c^2}$)
Proton rest mass (m_p)	1.673×10^{-27} kg ($938\,\mathrm{MeV/c^2}$)
Neutron rest mass (m_n)	1.675×10^{-27} kg ($940\,\mathrm{MeV/c^2}$)
Atomic mass unit (AMU)	1.66×10^{-27} kg
Atomic weight of a hydrogen atom	1 AMU
Atomic weight of a nitrogen atom	14 AMU
Atomic weight of an oxygen atom	16 AMU
Planck's constant (h)	6.63×10^{-34} J·s
Bohr Magneton (μ_B)	9.27×10^{-28} J/G
Speed of light in vacuum (c)	3.00×10^{8} m/s
Boltzmann's constant (k_B)	1.38×10^{-23} J/K
Gravitational constant (G)	$6.67 \times 10^{-11}\mathrm{N \cdot m^2/kg^2}$
Permeability of free space (μ_0)	$4\pi \times 10^{-7}$ H/m
Permittivity of free space (ϵ_0)	8.85×10^{-12} F/m
Mass of earth (M_E)	5.98×10^{24} kg
Equatorial radius of earth (R_E)	6.38×10^{6} m
Mass of Sun (M_S)	1.99×10^{30} kg
Radius of Sun (R_S)	6.96×10^{8} m
Classical electron radius (r_0)	2.82×10^{-15} m
Density of water	1.0 kg/liter
Density of ice	0.917 kg/liter
Specific heat of water	4180 J/(kg K)
Specific heat of ice	2050 J/(kg K)
Heat of fusion of water	334 kJ/kg
Heat of vaporization of water	2260 kJ/kg
Specific heat of oxygen (c_V)	21.1 J/mole·K
Specific heat of oxygen (c_P)	29.4 J/mole·K
Gravitational acceleration on Earth (g)	$9.8\,\mathrm{m/s^2}$
1 atmosphere	1.01×10^{5} Pa

Problem 2.1

A Uranium nucleus can be modeled as a sphere with a uniform volume charge density, a total charge of $Q = 92e$, where e is the charge of an proton, and a radius $R = 7.71 \times 10^{-15}$ meters.

(a) [3 points] Use dimensional analysis to write down a formula for the electrostatic energy U of the nucleus in terms of Q, R, and a dimensionless, O(1) constant k. Do you expect k to be positive or negative?

(b) [2 points] Suppose the nucleus now undergoes nuclear fission, splitting into two equal spheres (each of which is a Palladium nucleus), each with the same charge density as the original uranium nucleus. After these two spheres have separated by a distance large compared to their individual radii, what is their total electrostatic energy (i.e., the total for *both* of them)? Is this higher or lower than the original energy, and by how much? That is, is energy released or absorbed in this process? Express your answer for this energy difference in terms of Q, R, and the unknown, O(1) constant k.

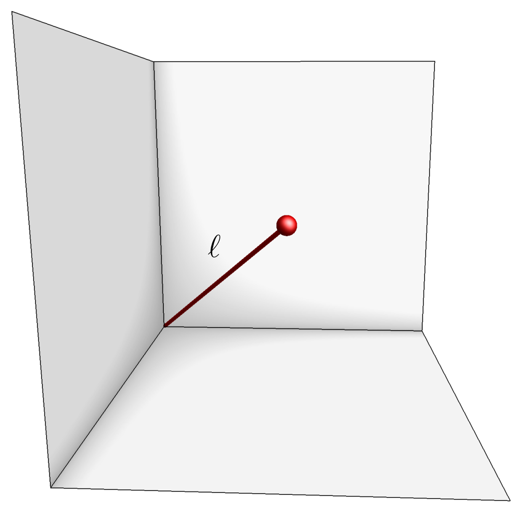
(c) [5 points] Calculate the dimensionless constant k from part (a) and evaluate the electrostatic energy of Uranium, and the energy released or absorbed as a result of the fission. Give a numerical answer in Joules or MeV.

Problem 2.2

Three semi-infinite conducting plane surfaces intersect at right-angles (edge of a semi-infinite box). A charge q is located at a distance ℓ on the diagonal that is equidistant from the surfaces as shown in the Figure.

(a) Calculate the magnitude, sign, and location of the image charge(s). (5 points)

(b) Evaluate the work needed to move q to infinity along the diagonal as shown in the Figure. (5 points)



Problem 2.3

In free space, a hollow non-conducting spherical shell of radius R rotates through its center about the $\hat{\mathbf{z}}$ axis with an angular velocity ω. Its surface has a static uniform charge density σ.

(a) (2 points) Determine the magnetic dipole moment, $\mathbf{m}_\ell$, of a constant current of magnitude j in a closed circular loop of radius r.

(b) (3 points) Determine the magnetic dipole moment, $\mathbf{m}$, of the sphere.

(c) (5 points) Find the magnetic field strength inside and outside the sphere along the $\mathbf{z}$ axis. You may leave your answer as an integral over the spherical coordinate θ. For $z \gg R$ find an exact expression for $\mathbf{B}$ along the $\mathbf{z}$ axis.

Problem 2.4

Consider an infinite block of a charge-neutral conductor obeying Ohm's Law with frequency-independent electrical conductivity σ. At time $t = 0$, a charge Q_0 is introduced in the form of a uniform charge density across a small sphere of radius R.

(a) **(8 points)** Obtain a differential equation governing the charge $Q(t)$ contained within this sphere with fixed R.

(b) **(2 points)** Calculate the time dependence of the charge, $Q(t)$, for $t \geq 0$.