Exam #: ________________________

Printed Name: ________________________

Signature: ________________________

PHYSICS DEPARTMENT

UNIVERSITY OF OREGON

Unified Graduate Examination

Part II

Electromagnetism

Friday, January 5, 2018, 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.

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 MeV/c^2)
Proton rest mass (m_p)	1.673×10^{-27} kg (938 MeV/c^2)
Neutron rest mass (m_n)	1.675×10^{-27} kg (940 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)	6.67×10^{-11} N·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 m/s^2
1 atmosphere	1.01×10^{5} Pa

Problem 2.1

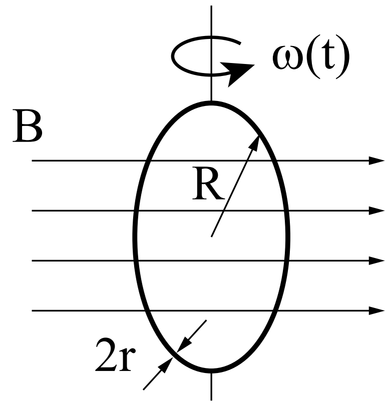
Consider a long thin wire with charge per unit length λ suspended at $z = d$ above an infinite conducting plane located at $z = 0$. Assume d is much larger than the radius R of the wire. The wire is parallel to the x axis.

(a) [6 points] Calculate the capacitance per unit length of the wire/plane system.

(b) [4 points] Calculate the surface charge density σ on the conducting plane as a function of y.

Problem 2.2

Consider a metallic ring of radius R, mass density ρ, and conductivity σ. The cross-sectional area of the ring is much smaller than the area of the ring, that is $\pi r^2 \ll \pi R^2$. A uniform **B**-field passes through the ring while the ring spins on its axis with an angular speed $\omega(t)$, as shown below.



a) (1 point) What is the resistance of the ring?

b) (2 points) If we define the ring angle $\theta = 0$ as the maximum in magnetic flux going through the ring, what is the magnetic flux as a function of θ?

c) (2 points) What is the time-dependent current in the ring as a function of $\theta(t)$?

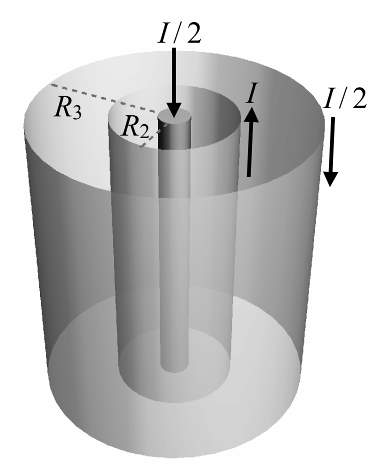
d) (2 points) Assuming the rate of energy dissipation over a rotation period through Joule heating is small compared to the total kinetic energy, what is the average power dissipated per rotation?

e) (3 points) If the ring starts with a rotation rate $\omega(0) = \omega_o$ and dissipates kinetic energy through slow Joule heating, what is the equation of motion for $\omega(t)$ and what is the time-scale for decay in $\omega(t)$?

2.3

A double coaxial system consists of a central cylindrical core surrounded by two concentric cylindrical shells of negligible thickness, see figure. All three components are perfectly conducting and infinitely long. The medium surrounding the conductors is air.

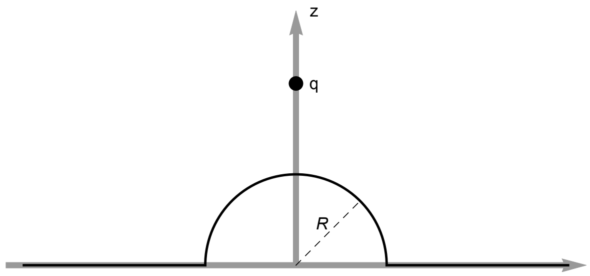
The radius of the inner wire core is R_1, the two shells have radii R_2 and R_3, respectively. The currents are distributed as shown, with the inner shell carrying I in the up direction and the core and outer shell each carrying return currents of $I/2$ downward. We assume that the current density in the inner core is uniform throughout the cross section.



Calculate the *total magnetic energy* per unit length, enclosed in the outermost radius R_3. Note that the core cannot be assumed to be infinitely thin.

2.4

A conducting surface grounded at infinity consists of a plane with a hemispherical bump of radius R (see the figure below).



A charge q sits a distance $r > R$ above the center of the hemispherical bump.

a) Calculate the steady state force on the charge. (7 pts)

(Hint: Use image charges. Note that you may need more than one image charge. You should verify that your image solution satisfies the correct boundary conditions.)

b) How much work must be done to move the charge q out to infinity? (3 pts)