Exam #: ______________________

Printed Name: ______________________

Signature: ______________________

PHYSICS DEPARTMENT

UNIVERSITY OF OREGON

Ph.D. Qualifying Examination, PART II

Thursday, September 20, 2001, 1:00 p.m. to 5:00 p.m.

The examination papers are numbered in the upper right-hand corner of each page. Print and then sign your name in the spaces provided on this page. For identification purposes, be sure to submit this page together with your answers when the exam is finished. Be sure to place both the exam number and the question number on any additional pages you wish to have graded.

There are six equally weighted questions, each beginning on a new page. Read all six questions before attempting any answers.

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. If you need extra space for another problem, start a new page.

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

Calculators may be used only for arithmetic. **Calculators with stored equations or text are not allowed**. Dictionaries may be used if they have been approved by the proctor before the examination begins. **No other papers or books may be used.**

When you have finished, come to the front of the room and hand your examination paper to the proctor; first put all problems in numerical order and staple them together.

Please make sure you follow all instructions carefully. If you fail to follow instructions, or to hand your exam paper in on time, an appropriate number of points may be subtracted from your final score.

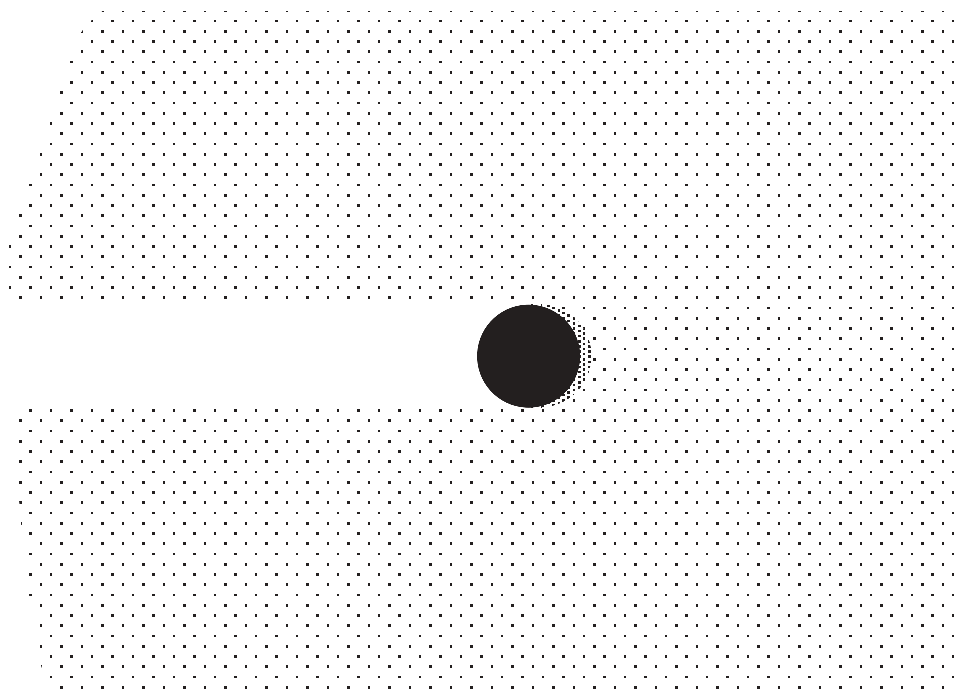
Constants

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 ($940\,\mathrm{MeV/c^2}$)
W^+ rest mass (m_W)	$80.4\,\mathrm{GeV/c^2}$
Planck's constant (h)	6.63×10^{-34} J$\cdot$ s
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
Density of iron at low temperature (ρ_{Fe})	$7.88 \times 10^3\,\mathrm{kg/m^3}$
Classical electron radius (r_0)	2.82×10^{-15} m
Gravitational acceleration on Earth (g)	$9.8\,\mathrm{m/s^2}$
Atomic mass unit	1.7×10^{-27} kg
Specific heat of oxygen (c_V)	21.1 J/mole$\cdot$ K
Specific heat of oxygen (c_P)	29.4 J/mole$\cdot$ K

Integrals

$$\int_{-\infty}^{\infty} dx\, x^{2n}\, e^{-ax^2} = \frac{1 \times 3 \times 5 \times \cdots \times (2n-1)}{2^n\, a^n} \sqrt{\frac{\pi}{a}}$$

$$\int_0^{\infty} \frac{dx}{x}\, x^n\, e^{-x} = \Gamma(n)$$



Problem 1

The Voyager spacecraft by now has left the solar system and is traveling through interstellar space in the direction of the constellation Taurus. Let the cross-sectional area of the spacecraft be A. At time $t = 0$, the spacecraft has mass m_0, is at position $x = 0$, and is moving with a velocity v_0 in the $\hat{x}$ direction. At $t = 0$ the spacecraft enters a stationary interstellar dust cloud of uniform mass density ρ. Suppose that the dust sticks to the surface of the spacecraft, thus causing the mass of the spacecraft to gradually increase. The cross-sectional area A of the spacecraft remains the same. Find the velocity and the position of the spacecraft for times $t > 0$.

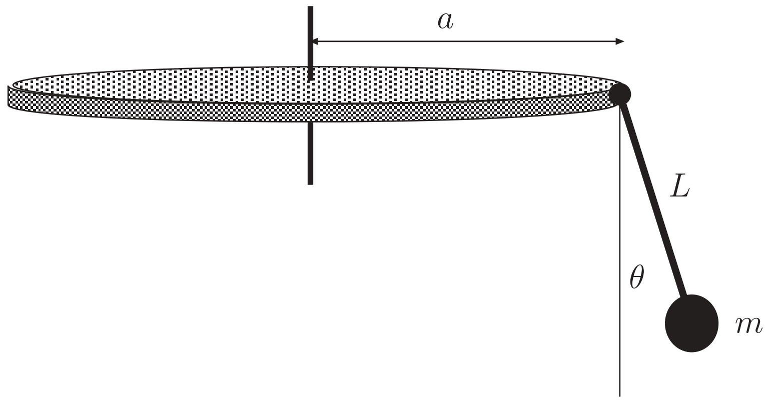
Problem 2

Weather patterns on the surface of the earth are influenced by the Coriolis force, which is a pseudo-force that arises when we consider the motion of the atmosphere in a reference frame that rotates with the earth.

a) Find the relation between the time derivative of a vector in a frame of reference rotating with angular velocity Ω and the time derivative of the vector in an inertial frame having the same origin as the rotating frame.

b) Derive an expression for the Coriolis acceleration.

c) In Salem (45^o North), what is the acceleration due to the Coriolis force on a wind with velocity 50 m/s towards the east? Do storms in the Northern Hemisphere centered on a region of low pressure circulate clockwise or counterclockwise? Why?



Problem 3

A mass m hangs on a massless rod of length L that is suspended from the edge of a horizontal disk of radius a. The rod is attached to the disk by a pivot, so that the angle θ of the rod relative to the downward direction can change. The mass is constrained to move in the plane containing the axis of the disk and the pivot. The disk rotates about its axis at a fixed angular velocity Ω.

a) Find the equation of motion that gives $d^2\theta/dt^2$ in terms of $d\theta/dt$, θ, Ω, m, a, L and the acceleration of gravity g.

b) Find an equation for the angle θ_0 of the rod when the system is in equilibrium ($\theta = \theta_0 =$ constant). Your equation should relate θ_0 to Ω, m, a, L and g.

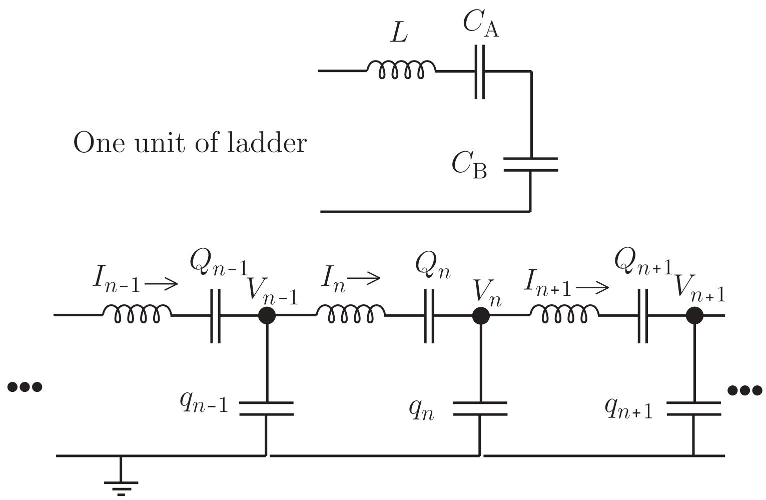
c) Derive an expression for the frequency ω of small oscillations of the rod about its equilibrium position. Your expression should give ω as a function of θ_0, Ω, m, a, L and g.

Problem 4

It is well known that dispersion and absorption in a dielectric material are closely related to the real and imaginary part of the complex dielectric susceptibility $\chi = (\epsilon/\epsilon_0) - 1$. Consider a monochromatic plane wave propagating in a homogeneous and isotropic dielectric material. For simplicity, assume that the electric field is polarized along the x-axis and propagates along the z-axis with frequency ω. Assume that the magnetic permeability of the material is the same as that of the vacuum, $\mu = \mu_0$.

a) From Maxwell's equations, determine the form of the solution for the plane wave in terms of χ.

b) Using the form of the solution, define the phase velocity and attenuation coefficient of the wave. If $|\chi| \ll 1$, how are the phase velocity and attenuation coefficient related to the real and imaginary parts of χ?



Problem 5

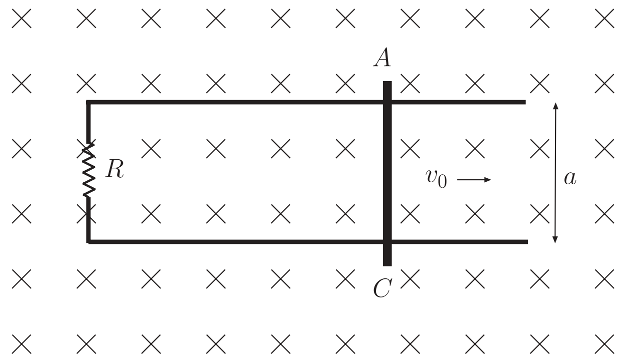
Consider the infinite ladder circuit shown above. The component values L, C_A, C_B are the same in each segment of the ladder. Label the ladder segments $\cdots, n-1, n, n+1, \cdots$. Potentials, currents, and charges for the nth segment are V_n, I_n, Q_n and q_n as shown.

a) Derive equations relating V_n, I_n, Q_n and their time derivatives to the corresponding quantities in neighboring segments. Use these relations to produce an equation of motion for d^2I_n/dt^2 in terms of dI_{n-1}/dt, dI_n/dt, dI_{n+1}/dt, I_{n-1}, I_n, I_{n+1} and the component values L, C_A, C_B.

b) Assume a solution for $I_n(t)$ of the form

$$I_n(t) = a \sin(\kappa n) \cos(\omega t + \phi). \tag{1}$$

Find the frequency ω that corresponds to a given value of κ.



Problem 6

A conducting bar AC of mass m can slide without friction on conducting rails separated by a distance a, as shown above. A resistor R joins the rails , as indicated. There is a uniform, constant magnetic field B directed into the page throughout the region of interest. We assume that the resistance of the rails and the bar is negligible and that the self-inductance of the circuit is negligible. At time $t = 0$ the bar has velocity $v(0) = v_0$ to the right.

a) Determine the magnitude and direction of the current in the resistor at $t = 0$

b) Determine the bar's velocity $v(t)$ for $t > 0$.

Now eliminate the resistor R and replace it with a coil with self-inductance L. At time $t = 0$ the bar has velocity $v(0) = v_0$ to the right and the current is $I(0) = 0$.

c) Determine the bar's velocity $v(t)$ for $t > 0$.