Exam #: ______________________

Printed Name: ______________________

Signature: ______________________

PHYSICS DEPARTMENT

UNIVERSITY OF OREGON

Master's Final Examination and Ph.D. Qualifying Examination

PART I

Tuesday, September 29, 2009, 9:00 a.m. to 1:00 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 eight equally weighted questions, each beginning on a new page. Read all eight 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. When you start a new 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 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, put all problems in numerical order and staple them together with this sheet on top. Then hand your examination paper to the proctor.

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)	$1.60 \times 10^{-19}\,\mathrm{C}$
Electron rest mass (m_e)	$9.11 \times 10^{-31}\,\mathrm{kg}$ ($0.511\,\mathrm{MeV/c^2}$)
Proton rest mass (m_p)	$1.673 \times 10^{-27}\,\mathrm{kg}$ ($938\,\mathrm{MeV/c^2}$)
Neutron rest mass (m_n)	$1.675 \times 10^{-27}\,\mathrm{kg}$ ($940\,\mathrm{MeV/c^2}$)
Atomic mass unit (AMU)	$1.7 \times 10^{-27}\,\mathrm{kg}$
Atomic weight of a nitrogen atom	14 AMU
Atomic weight of an oxygen atom	16 AMU
Planck's constant (h)	$6.63 \times 10^{-34}\,\mathrm{J{\cdot}s}$
Speed of light in vacuum (c)	$3.00 \times 10^{8}\,\mathrm{m/s}$
Boltzmann's constant (k_B)	$1.38 \times 10^{-23}\,\mathrm{J/K}$
Gravitational constant (G)	$6.67 \times 10^{-11}\mathrm{N{\cdot}m^2/kg^2}$
Permeability of free space (μ_0)	$4\pi \times 10^{-7}\,\mathrm{H/m}$
Permittivity of free space (ϵ_0)	$8.85 \times 10^{-12}\,\mathrm{F/m}$
Mass of earth (M_E)	$5.98 \times 10^{24}\,\mathrm{kg}$
Equatorial radius of earth (R_E)	$6.38 \times 10^{6}\,\mathrm{m}$
Radius of sun (R_S)	$6.96 \times 10^{8}\,\mathrm{m}$
Classical electron radius (r_0)	$2.82 \times 10^{-15}\,\mathrm{m}$
Specific heat of oxygen (c_V)	$21.1\,\mathrm{J/mole{\cdot}K}$
Specific heat of oxygen (c_P)	$29.4\,\mathrm{J/mole{\cdot}K}$
Specific heat of water ($0^o\,\mathrm{C} < T < 100^0\,\mathrm{C}$)	$4.18\ \mathrm{J/(g{\cdot}K)}$
Latent heat, ice $\rightarrow$ water	$334\,\mathrm{J/g}$
Latent heat, water $\rightarrow$ steam	$2257\,\mathrm{J/g}$
Gravitational acceleration on Earth (g)	$9.8\,\mathrm{m/s^2}$
1 atmosphere	$1.01 \times 10^{5}\ \mathrm{Pa}$

Pauli spin matrices

$$\sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \ , \ \sigma_y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \ , \ \sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \quad . \tag{1}$$

Hydrogen atom energy levels for a potential energy $V(r) = e^2/r$.

$$E_n = -\frac{me^4}{2\hbar^2}\,\frac{1}{n^2} \quad . \tag{2}$$

Integrals

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

$$\int_0^{\infty} dx\ e^{-cx} x^n = \frac{n!}{c^{n+1}}$$

Problem 1

A uniform ladder of total length L and mass m leans against a vertical wall at a point which is a distance h above the ground. The wall is frictionless, but the ground provides static friction that prevents the ladder from slipping.

(a) Draw a diagram, including all forces acting on the ladder. Specify the coordinate system that you will use to solve the problem.

(b) Find expressions for all forces exerted on the ladder by the ground and by the wall.

(c) What is the minimum coefficient of static friction between ladder and ground that is needed to keep it from slipping?

Problem 2

An object of mass m and total angular momentum L is in a circular orbit about the origin in a potential $V(r) = kr^2/2$.

(a) Determine the angular frequency of revolution $\dot{\theta}$ and the orbital radius for the motion.

(b) If the orbit is perturbed, the object will make small radial oscillations. Find the angular frequency ω of the oscillations and compare with $\dot{\theta}$.

(c) Describe and draw a picture of the orbit, exaggerating the small radial oscillations.

Problem 3

A uniform rod of mass M and length L is held at point O at one end and can swing freely about the vertical.

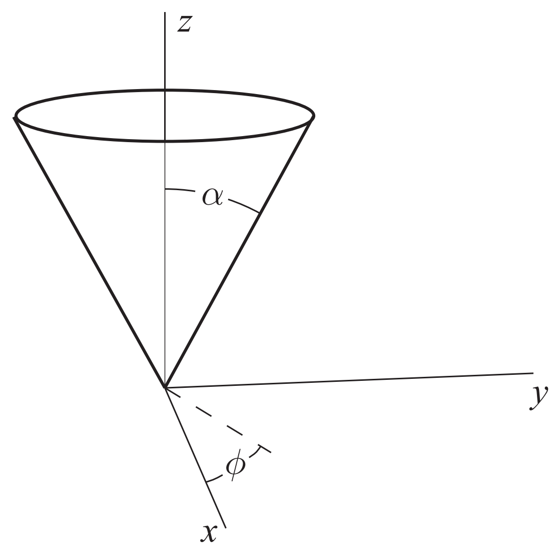
(a) Find the equation of motion for the angle θ for $\theta \ll 1$.

(b) If the rod is released from rest at an angle θ_0, find the resulting motion $\theta(t)$.

(c) Determine the period of the oscillations.

Problem 4

Consider a particle which is subject to gravity but constrained to move on the surface of a cone whose apex is at the origin ($x = y = z = 0$) and whose opening angle is 2α (see figure).



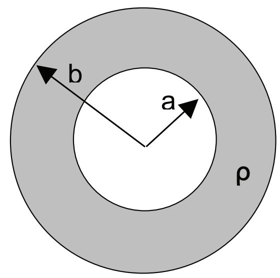
(a) Write the Lagrangian for the particle in cylindrical coordinates r, ϕ.

(b) Derive the equations of motion.

(c) Find two conserved quantities related to the motion of the particle.

Problem 5

Consider a resistive material bounded by two conducting concentric spheres of radii a and b that are maintained at a constant potential difference ΔV with the outer shell having the higher potential. The material between the spheres has resistivity ρ.



(a) Find the electric field inside of the resistive material in terms of the total current flowing between the spheres.

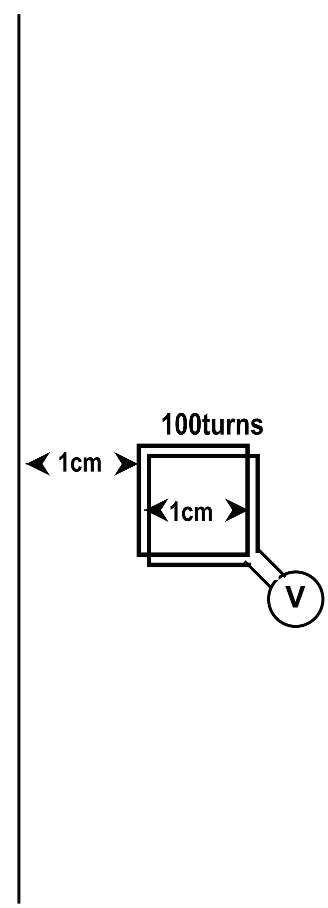
(b) What is the resistance of this arrangement?

Problem 6

A long wire with length $L \gg 1$ cm lies near a square wire loop of 100 turns, with a side length of one centimeter. The closest side of the loop is parallel to the wire and lies one centimeter away, as shown in the diagram.

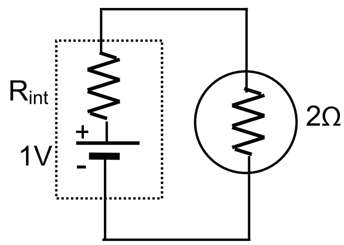
(a) Suppose there is current in the long wire that increases linearly in time: $I = At$ where A has the value of 10 A/s. What voltage will be induced in the loop and read by the voltmeter shown?

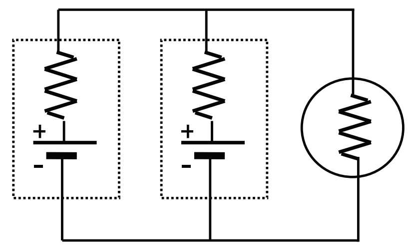
(b) Now suppose the voltmeter across the loop is replaced by a current source such that the current in the loop wire increases linearly in time: $I = At$ where A again has the value of 10 A/s. What will be the voltage between the ends of the long wire (which are now left open)?



Problem 7

A solar cell produces an emf of 1.0 V with no load connected to it. When a 2 Ω flashlight bulb is connected to the solar cell, a potential difference of 0.1 V is measured across the solar cell terminals.





(a) Determine the internal resistance, R_{int}, of the solar cell.

(b) If two identical solar cells like the ones in part (a) are arranged so they are connected in parallel to the 2 Ω light bulb, determine the power dissipated in the bulb.

(c) Determine the configuration of the two solar cells, parallel or series, that maximizes the power delivered to the bulb.

Problem 8

An electric field pulse in vacuum is described by the relation:

$$\boldsymbol{E}(x, y, z, t) = E_o \exp\left[-\left(\frac{ct - y}{1\text{ meter}}\right)^2\right]\hat{\boldsymbol{z}}$$

(a) Make a rough sketch of E_z versus y at $t = 0$ and $t = 10$ ns.

(b) Determine the $\boldsymbol{B}$ field associated with this electromagnetic pulse.

(c) If $E_0 = 10^4$ V/m, determine the total electromagnetic energy per unit area contained within this pulse (in J/m^2).