Exam #: ________________________

Printed Name: ________________________

Signature: ________________________

PHYSICS DEPARTMENT

UNIVERSITY OF OREGON

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

PART I

Monday, March 30, 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	$1.7 \times 10^{-27}\,\mathrm{kg}$
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	$1.01 \times 10^{5}\ \mathrm{Pa}$

Stirling's Formula

$$\ln(x!) = x\ln(x) - x - \ln\left(\sqrt{2\pi x}\right) + \mathcal{O}(1/x)$$

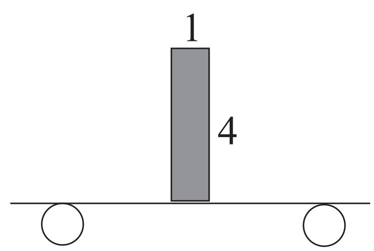
Integrals

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

$$\int_{0}^{\infty} dx\ e^{-cx} x^n = \frac{n!}{c^{n+1}}$$

Problem 1

A brick that is four times as high as it is thick is placed upright on the floor of a moving car (see figure). The car is moving at constant velocity, until suddenly the brakes are applied, giving a constant acceleration for the period considered in this problem. Assume the brick cannot slide.



(a) What is the smallest deceleration which will make the brick start to tip over?

(b) Will it tip over completely once it starts to tip?

(c) Will the brick tip forward or backward?

Problem 2

Consider a particle of mass m attached to a spring with restoring force $F_r = -kx$. Suppose the particle moves in a viscous medium which provides a damping force proportional to the particle's velocity: $F_v = -b\dot{x}$. Motion in this problem is restricted to one dimension.

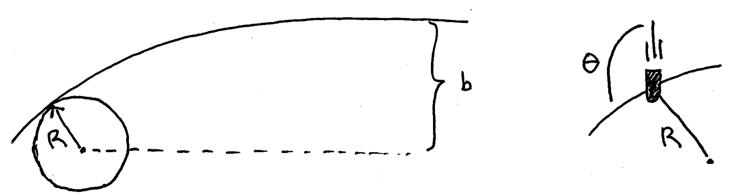
(a) Write the differential equation that describes the motion of the particle.

(b) Solve for the motion of the particle.

(c) Under what conditions (i.e., what values of the constants k, b, m) would the motion be oscillatory?

Problem 3

A satellite of mass m and negligible radius has initial speed v and moves from a long distance away towards a perfectly spherical planet of mass M and radius R. The impact parameter of the satellite is b.

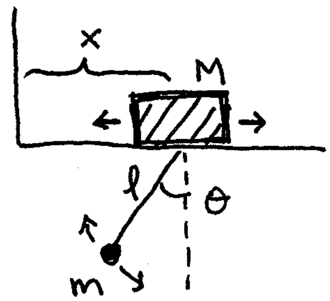


(a) What is the impact parameter b such that the satellite will just graze the planet?

(b) At the point of grazing, the satellite fires its engine for a brief time, and achieves a stable circular orbit. What was the change in speed? Did the satellite accelerate or decelerate? At what angle θ was the rocket engine fired (see figure)?

Problem 4

A simple pendulum of mass m and length l is attached to a block of mass M that is constrained to slide along a frictionless horizontal track. Gravity acts downward, perpendicular to the horizontal track.



(a) Write the Lagrangian for the system (assume $|\theta| < \pi/2$).

(b) Derive the equations of motion.

(c) Find the normal frequencies and modes for small oscillations of the pendulum and block.

Problem 5

A spherical nonconductor of radius R and dielectric constant of unity carries a total charge Q, with a volume charge density $\rho(r) = A/r$, where r is the distance from the center of the sphere and A is a constant.

(a) Determine the constant A.

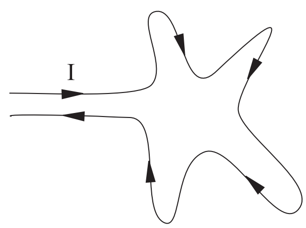
(b) Determine the electric potential $V(r)$ both inside and outsider the sphere. (Assume that $V = 0$ at infinity.)

(c) How much work would be required to assemble the charge distribution described?

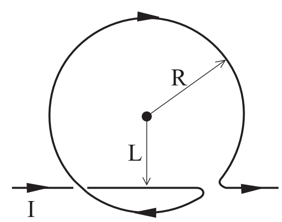
Problem 6

This problem concerns the magnetic field produced by a wire in two different shapes.

(a) Consider a flexible wire (*i.e.* one that can bend under the Lorentz force). When a current is passed through the wire shown below, will it tend to bunch up or form a circle?

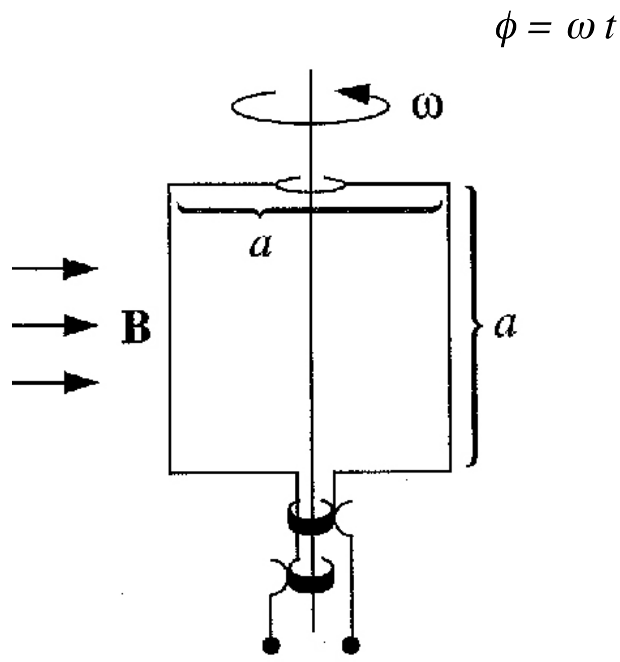


(b) Consider an inflexible wire (*i.e.* one that doesn't bend under the Lorentz force) in the shape shown below. The circular portion has a radius R with its center at a distance L from the infinitely long straight part. Find L such that the magnetic field at the center of the circular portion is zero.



Problem 7

A square loop of side a is mounted on a vertical shaft and rotated at angular velocity ω. A uniform magnetic field points to the right. An emf appears at the two circular contacts at the bottom of the diagram shown, and it oscillates in time.



(a) Suppose that we define the orientation of the square loop shown in the diagram to be $\phi = 0$. At what orientations will the emf reach its maximum magnitudes? At what orientations will it be zero?

(b) A 10 Ω resistor is now connected across the 2 terminals at the bottom. For a magnetic field strength of 1 Tesla, and a loop area, a^2, of 10 cm^2, determine how much work would be done to spin the loop at a rate of 10 revolutions/second for one minute (please express your answer in Joules).

Problem 8

A monochromatic plane electromagnetic wave impinges at normal incidence upon a planar surface, from vacuum into a dielectric medium of refractive index n.

(a) Compute the reflection coefficient for both the field amplitude and the field intensity of the incident wave.

(b) Determine the transmission coefficient for the field intensity. Is the sum of the intensity reflection and transmission coefficients equal the incident intensity? Explain why or why not.