Exam #: ____________________

Printed Name: ________________

Signature:___________________

PHYSICS DEPARTMENT

UNIVERSITY OF OREGON

Master's Final Examination
and
Ph.D. Qualifying Examination, PART I

Monday, March 29, 2004, 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 twelve equally weighted questions, each beginning on a new page. Read all twelve 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 the 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

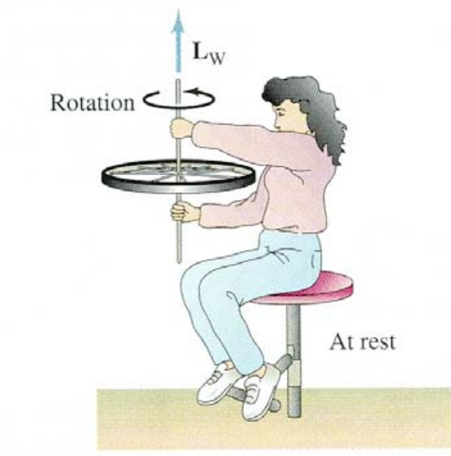
Electron charge (e)	1.60×10^{-19} C
Electron rest mass (m_e)	9.11×10^{-31} kg (0.511 MeV/c^2)
Proton rest mass (m_p)	1.673×10^{-27} kg (938 MeV/c^2)
Neutron rest mass (m_n)	1.675×10^{-27} kg (940 MeV/c^2)
W+ rest mass (m_W)	80.4 Gev/c^2
Planck's constant (h)	6.63×10^{-34} J·s
Speed of light in vacuum (c)	3.00×10^{8} m/s
Boltzmann's constant (k_B)	1.38×10^{-23} J/K
Gravitational constant (G)	6.67×10^{-11} Nm^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
Radius of sun (R_S)	6.96×10^{8} m
Temperature of surface of sun (T_S)	5.8×10^{3} K
Earth-sun distance (R_{ES})	1.5×10^{11} m
Density of iron at low temperature (ρ_{Fe})	7.88×10^{3} kg/m^3
Classical electron radius (r_0)	2.82×10^{-15} m
Gravitational acceleration on earth (g)	9.8 m/s^2
Atomic mass unit	$1.7 \mathrm{x} 10^{-27}$ kg
Specific heat of oxygen (C_V)	21.1 J/mole·K
Specific heat of oxygen (C_P)	29.4 J/mole·K
Avogadro's number	$6.02 \mathrm{x} 10^{23}$ atoms/mole
Gas constant (R)	8.31 J/mole·K

Stirling's formula:

$\ln(x!) \cong x\ln(x) - x - \ln(\sqrt{2\pi x})$ (the last term may often be neglected)

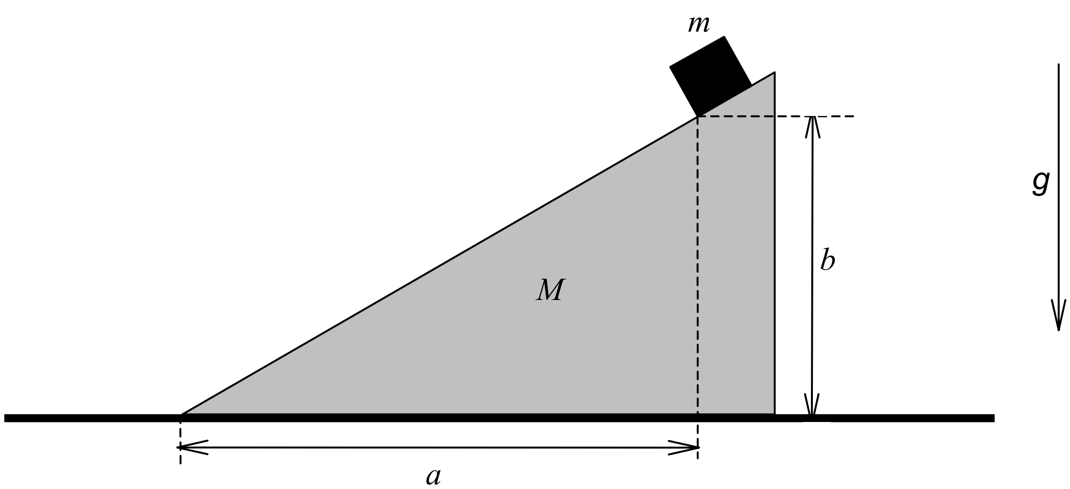
Problem 1

A student is sitting on the center of a stationary turntable, holding a rim-loaded bicycle wheel with its axis vertical. The moment of inertia of the wheel is 1 kg m^2 and its initial angular speed is 9 rad/s. The student now tilts the top of wheel's axis towards her head at an angle of 45°, taking 5 seconds to do so. Find the magnitude and direction of the applied torque. Assume friction is negligible everywhere, and neglect the effects of gravity.



Problem 2

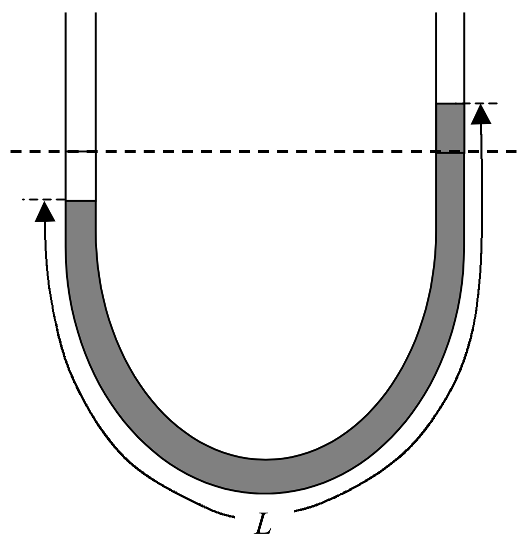
A small mass m with negligible dimensions is free to slide on a wedge-shaped block of mass M. The wedge is free to move in the horizontal plane. If mass m starts sliding from rest at a height b as shown, obtain the speed at which M will be moving when m reaches the bottom of the wedge. Assume all motions are frictionless. Gravity points downwards as shown.



Hint: Use conservation laws.

Problem 3

The figure below shows a U-tube of uniform cross-section open at both ends. The tube contains an incompressible fluid of density ρ , with a total column fluid length of L. Assume the fluid is free to flow in the tube with negligible friction. Show that if the fluid level is displaced from equilibrium as shown and then released, the fluid will oscillate in the tube. Determine the period of oscillation.

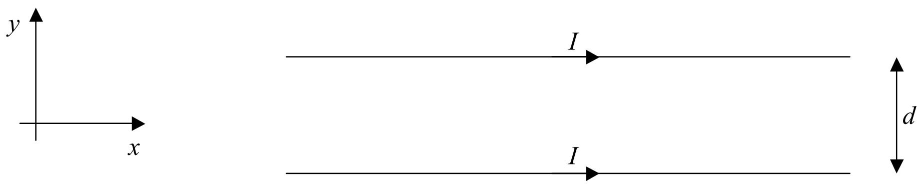


Problem 4

Find the potential inside and outside a thin spherical shell of radius R, which carries a uniform surface charge density σ.

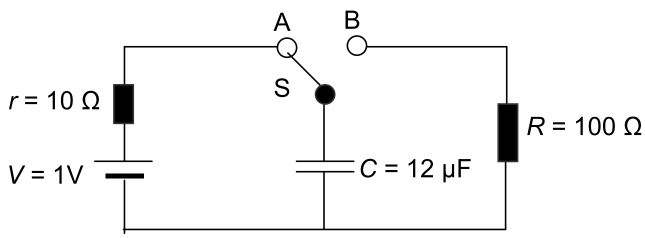
Problem 5

Consider two parallel, infinitely long wires a distance d apart, each carrying a current *I* in the positive x-direction.



Find the direction and the magnitude (per unit length) of the force experienced by each wire.

Problem 6



The capacitor C in the above circuit is charged using a battery by connecting switch S to contact A. At $t = 0$, the switch is thrown to contact B.

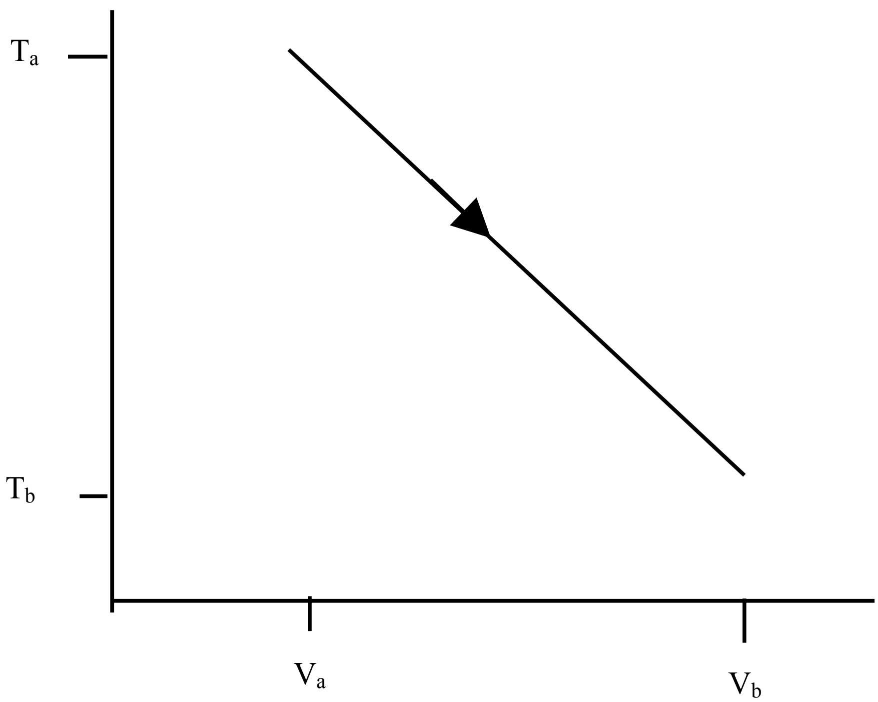
a) Find the magnitude of the current I through the resistor R as a function of time.

b) Draw a graph of $I(t)$ to scale.

Problem 7

An ideal gas in a container with a piston initially has volume V_a and temperature T_a. The piston is allowed to move quasi-statically (slowly, in quasi-equilibrium) so the volume increases to V_b. Heat flow from an "auxiliary system" is controlled in such a way that the T, V curve follows a straight line:

$$T(V) = T_a - \alpha\,(V - V_a), \text{ where } -\alpha \text{ is the slope of the line shown in the figure } (\alpha > 0).$$



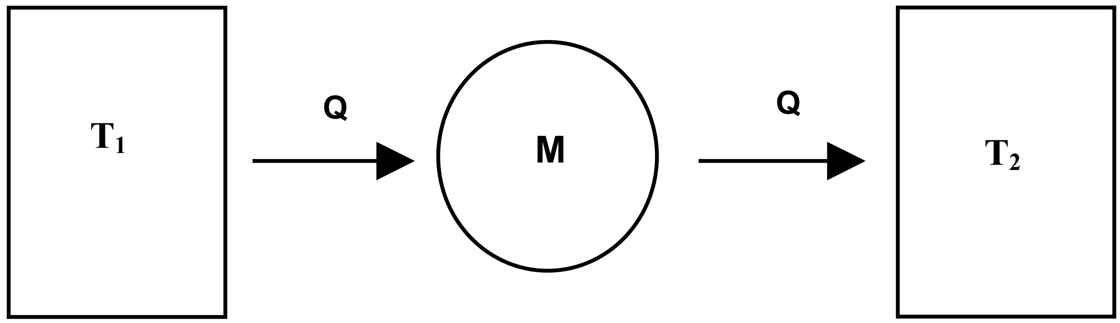
Recall that the heat capacity of an ideal gas is $C_V = (3/2)nR$ (where n is the number of moles). Find expressions for:

a) the total work done on the gas.

b) the total heat transferred to the gas.

Problem 8

A magic refrigerator is a machine M that transfers heat Q from a heat bath at temperature T_1 to a heat bath at temperature $T_2 > T_1$.



a) Show that this refrigerator violates a law of physics.

b) Modify the refrigerator and show that it can transfer heat from the cooler bath to the hotter bath without violating the above law of physics.

Problem 9

The speed of sound in a three-dimensional medium of density ρ is $\sqrt{\dfrac{B}{\rho}}$ where

$B = -V[\partial P/\partial V]_S$ is called the adiabatic bulk modulus. For an adiabatically compressed gas, $B = \gamma P$, where $\gamma = 1.4$ for diatomic gases such as air, and $\gamma = 1.67$ for monatomic gases. Obtain an expression for the speed of sound in an ideal gas of mass M per mole, and show that it depends on temperature rather than on density or pressure.

Problem 10

Group velocity v_g is not the same as the phase velocity v_p of an electron in wave mechanics.

Calculate the ratio v_p/v_g for a non-relativistic electron having kinetic energy 1 eV.

Problem 11

In a photoelectric experiment in which monochromatic light is incident on a sodium photo cathode, we find a stopping potential of 1.85 V for light of wavelength 3000 Å.

What is the work function of sodium, and what is the cut-off wavelength?

Problem 12

In outer space a beam of protons (mass 1.67×10^{-27} kg) is fired at a target 10^5 km away. If the velocity of the protons is 1000 m/s, what is the minimum achievable beam diameter at the target, taking into account the uncertainty principle?

(Hint: First express the expected deviation of the position of the protons at the target in terms of Δy and Δp_y of the protons when they leave the source.)