University of Wisconsin-Madison
Engineering Physics Department
Fall 2009 Qualifying Exams

Classical Physics

You must solve 4 out of the 6 problems.
Start each problem on a new page.

SHOW ALL YOUR WORK.
WRITE ONLY ON THE FRONT PAGES OF THE WORKSHEETS, <u>NOT</u> ON THE EXAM PAGES

Grading is based on both the final answer and work done in reaching your answer. All problems receive an equal number of points.

Clearly indicate which problems you want graded. If you do not indicate which problems are to be graded, the first four solutions you provide will be graded.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

$I_{disk} = \frac{1}{2}MR^2$ $I_{sphere} = \frac{2}{5}MR^2$ $I_{rod} = \frac{1}{12}ML^2$

$\mu_0 = 4\pi \times 10^{-7}$ H/m $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m

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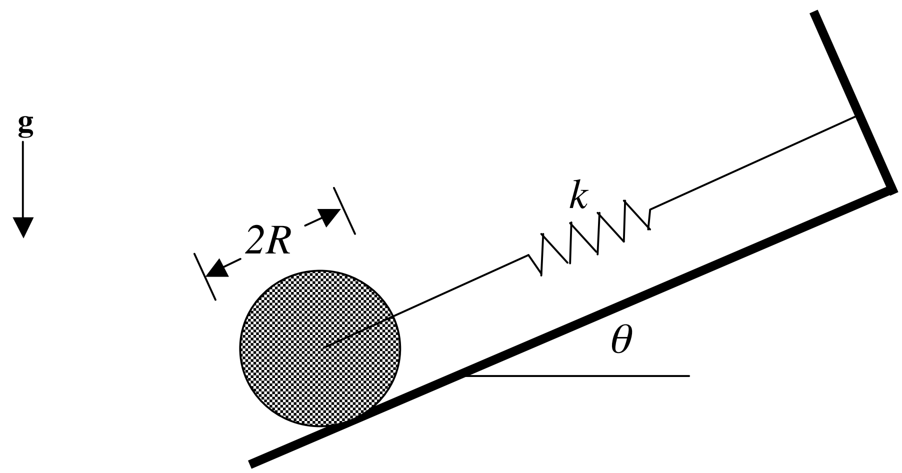
Problem 1. A uniform disk of mass m and radius R rests on a fixed incline, as shown below, and is supported by a spring of stiffness k. Determine the natural frequency of oscillations of this disk, assuming the disk does not slip.



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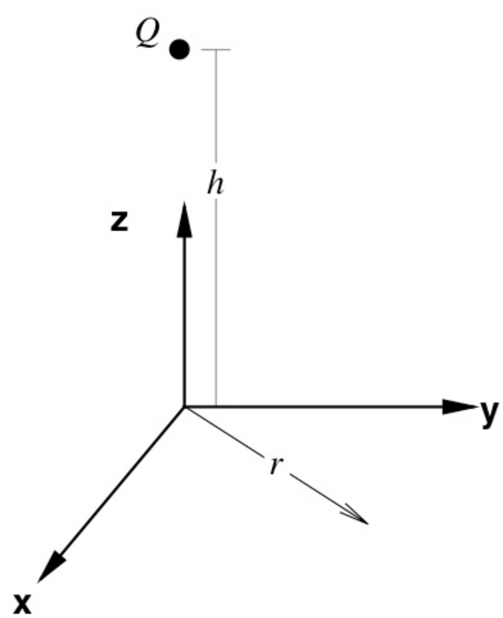
Problem 2. A small spherical conductor with electrical charge Q is located a distance h above an infinitely large, electrically grounded conducting plane. Determine the surface charge (charge per unit area) on the plane as a function of Q, h, and the distance r from the point on the surface below the charge.



In the sketch, the infinitely large conducting plane is located at z=0, and the point charge is directly above the origin.

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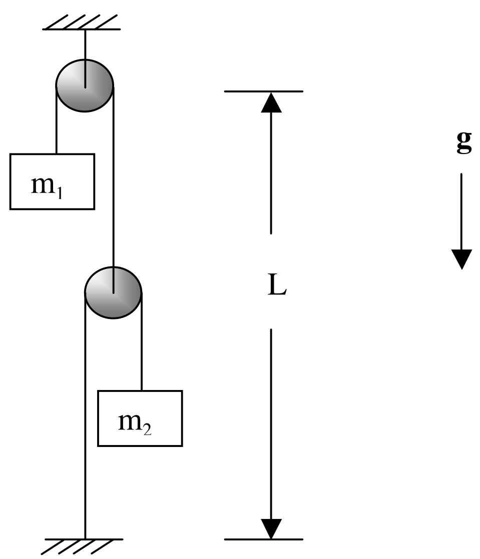
Problem 3. Consider the block-pulley system subject to gravity, as shown below. The strings are flexible and inextensible.

a) (6 points) Ignoring the masses of the strings and pulleys, determine the accelerations of the blocks.
b) (2 points) For what masses would this system be in equilibrium?
c) (2 points) Qualitatively discuss the consequences of including the masses of the strings and pulleys.



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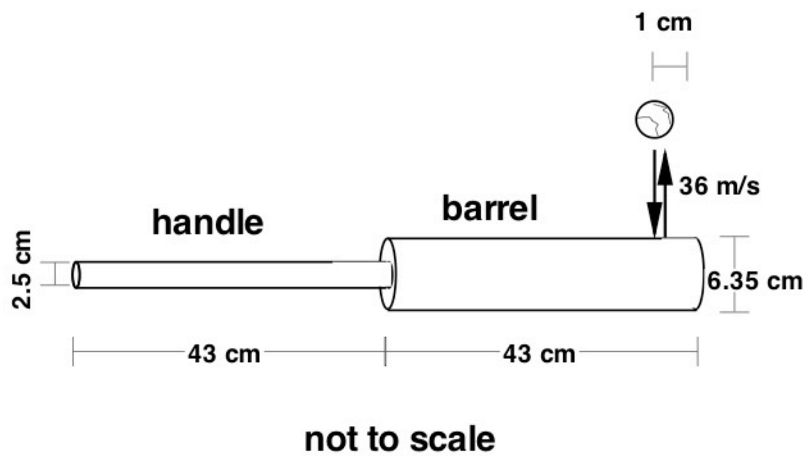
Problem 4. Find the *change* in the rate of rotation ($\Delta\omega$) of a 0.91 kg, 0.86 m baseball bat that has been released by a batter and contacts a baseball traveling at 36 m/s relative to the point of contact on the bat. All motion is co-planar. The bat can be modeled as a 0.025 m diameter cylinder (the handle) connected to a 0.0635 m diameter cylinder (the barrel), each of length 0.43 m. The baseball travels perpendicular to the axis of the bat immediately before and after contact, has the same relative speed before and after contact, and hits the bat 0.01 m from its end. A baseball's mass is 0.15 kg.



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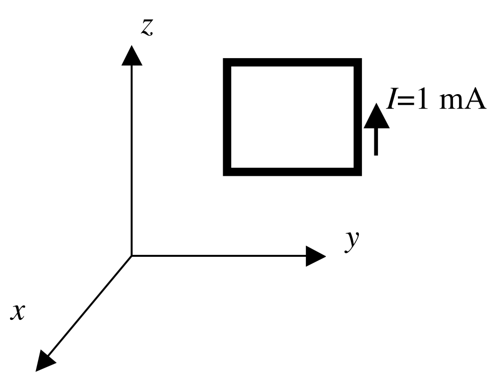
Problem 5. Consider a square current loop in the y-z plane. The corners of the loop are at (x,y,z)=(0,1,1), (x,y,z)=(0,2,1), (x,y,z)=(0,2,2), and (x,y,z)=(0,1,2), where positions are in meters. Find the direction and magnitude of the net force on this loop for the two cases given below, assuming there is a current of 1 mA flowing in the loop (in the direction shown below).

a. (4 points) There is a uniform magnetic field of $\mathbf{B} = B_x\hat{\mathbf{x}}$, where B_x=2 Tesla.
b. (6 points) There is a magnetic field resulting from an infinitely long wire carrying 1000 A of current and coinciding with the z-axis.



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Problem 6. A traveling wave propagates in a coaxial waveguide that is filled with a dielectric of relative permittivity 16. The radius of the inner conductor is a = 4 mm, and the radius of the outer conductor is b = 6 mm. The wave is a cylindrically symmetric mode, and the current in the inner conductor at some arbitrary position is $I_0 \sin(\omega t)$, where I_0 = 2 mA, and $\omega = 10^9$ rad/s.

What is the time-averaged power flowing through the waveguide?