University of Wisconsin-Madison
Engineering Physics Department
Spring 2010 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, NOT 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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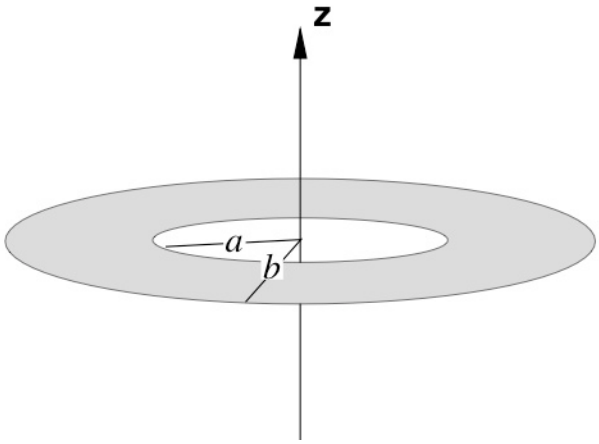
Problem 1.

Positive electrical charges are spread uniformly over a thin annular disk with inner radius a and outer radius b. The total charge on the disk is Q.



a. (2 points) Along the geometric axis (z) of the disk, what is the direction of the electric field **vector** over $-\infty < z < +\infty$? [Use z=0 for the location of the disk.]

b. (8 points) What is the magnitude of the electric field along the geometric axis?

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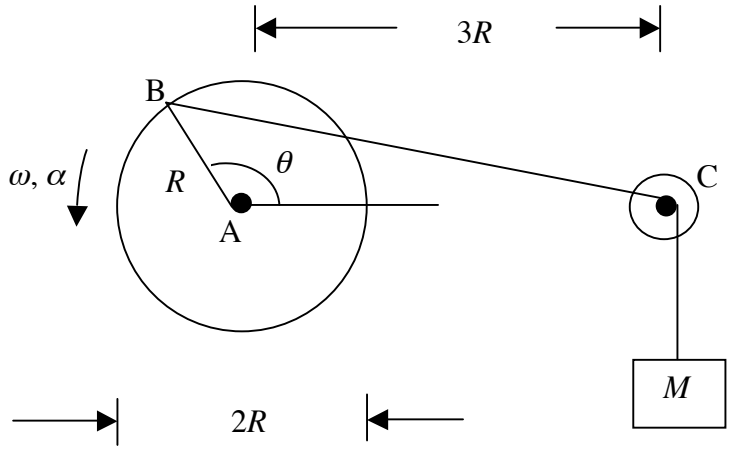
Problem 2.

A disk of radius R is pinned at point A. It is rotating counter-clockwise with a known, time-dependent angular velocity ω and angular acceleration α. A block of mass M is attached to the disk at point B by a rope which passes over a massless pulley at point C. The rope remains taught due to the force of gravity on the block. The centers of the disk and pulley are at the same height and are separated by a distance $3R$.



1. (3 points) What is the velocity of the block as a function of θ, ω, and α?
2. (3 points) What is the acceleration of the block as a function of θ, ω, and α?
3. (2 points) What are the velocity and acceleration of the block when $\theta=\pi/2$?
4. (2 points) What are the velocity and acceleration of the block when $\theta=\pi$?

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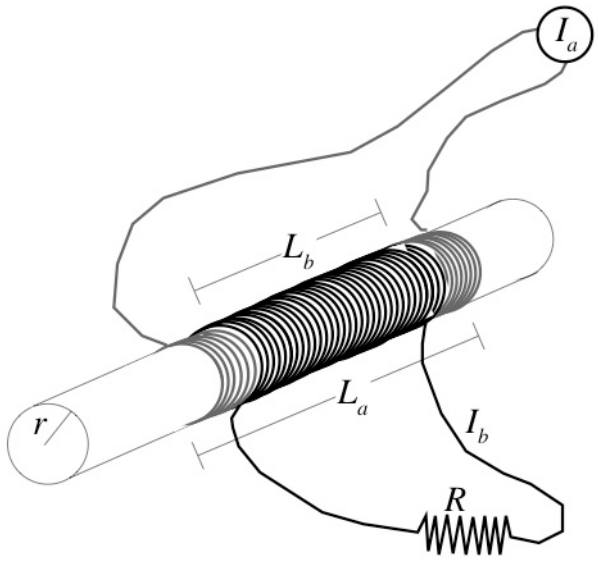
Problem 3.

A transformer is constructed by wrapping one wire (the primary) around an insulating rod of radius r with N_a' turns per unit length over a length L_a of the rod. A second wire (the secondary) is wrapped with N_b' turns per unit length on top of the primary over a length L_b, where $r<<L_b<L_a$. The secondary is connected to a resistor of resistance R Ohms. The resistance of the secondary wire and the inductance of the leads are negligible.



Find an expression for the current in the secondary circuit (I_b) as a function of time when the current in the primary (I_a) is

$$I_a(t) = \begin{cases} 0, & t \le 0 \\ At, & t > 0 \end{cases}$$

where A is a constant.

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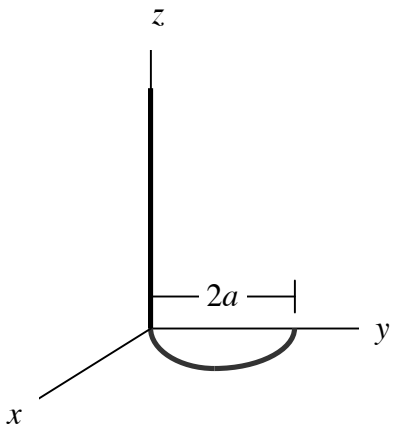
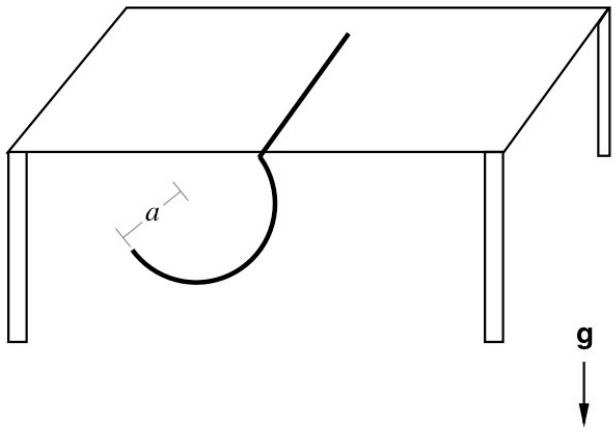
Problem 4.

One end of a rigid wire of uniform mass density is bent into a semi-circular arc of radius a. The rest of the wire extends in the direction that is normal to the plane of the arc. The figure on the left shows the geometry of the wire with the arc in the x-y plane and the rest of the wire extending in the z-direction. The wire is placed on a flat surface with the arc hanging off the surface, as shown on the right.





a. (5 points) Find an expression for the angle between a line that passes through the two ends of the arc and the vertical direction when the wire is at rest.

b. (5 points) Find the angular frequency of small oscillations about the equilibrium position from part a.

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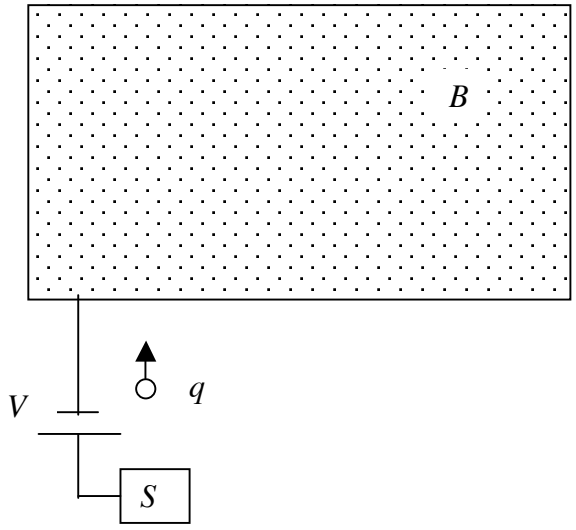
Problem 5.

An ion of mass M and charge q is produced at rest in source S. The ion is accelerated by a potential difference V and enters a region of uniform magnetic field B, which is perpendicular to the page.



1. (3 points) Briefly describe how this setup can be used as a mass spectrometer. That is, how can it be used to measure the mass of the ion?
2. (5 points) Derive a relationship for the ion mass in terms of the system parameters and any measured parameters that you require.
3. (2 points) Quantify this result by calculating what the spectrometer would measure for the case of a singly-charged chlorine ion (with a mass number of 35) if V=7300 Volts and B=0.5 T.

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Problem 6.

The ball shown below has mass M and is traveling towards the center of the rod with velocity V. The rod has length L, mass $6M$, and is pinned at the top. Determine the angular velocity of the rod just after impact if the coefficient of restitution is 0.5.