University of Wisconsin-Madison
Engineering Physics Department
Fall 2005 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. _____

The following relations may be useful:

sin(A+B)=sin(A)cos(B)+cos(A)sin(B)
cos(A+B)=cos(A)cos(B)-sin(A)sin(B)

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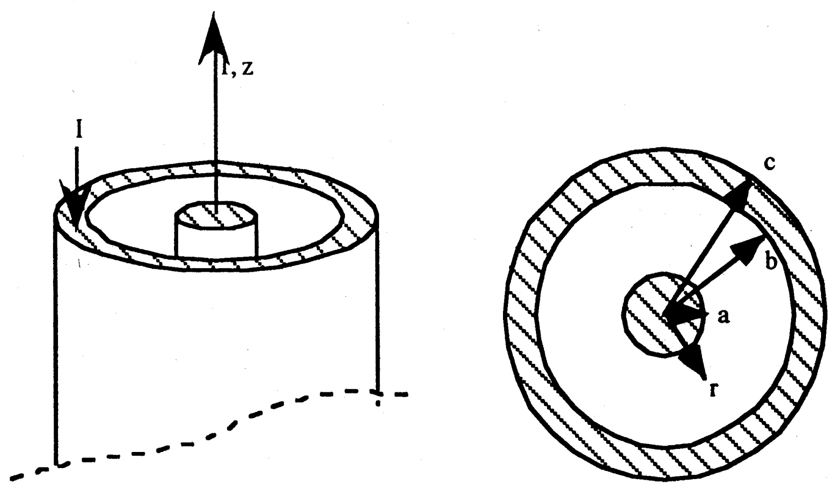
Problem 1.

Equal and opposite current flows in the infinite coaxial cylindrical conductors shown below. Assume the current is uniformly distributed in the conductors.

(a) Find expressions for the magnetic field as a function of radius in all regions of space.

(b) Assuming a very thin outer conductor, so that you can ignore the contributions from that region, find the self-inductance per unit length of the system.



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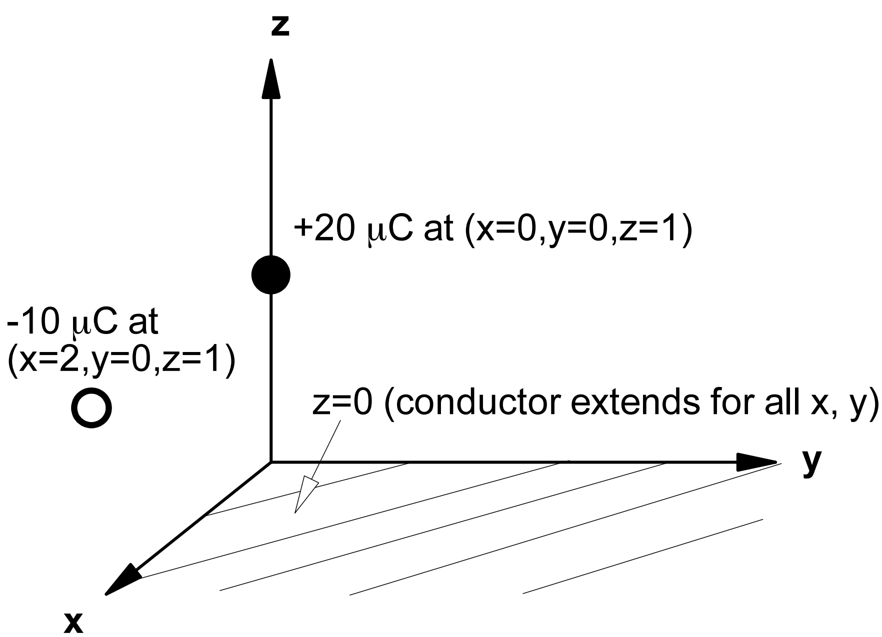
Problem 2.

An infinitely large conducting metal sheet is located at z=0 (extending in the x-y plane). A small sphere charged to +20 μC is located at (x=0, y=0, z=1 m). Another small sphere is charged to –10 μC and is located at (x=2 m, y=0, z=1 m). What is the magnitude and direction of the electric field at (x=1 m, y=1 m, z=2 m)? [ε_0=8.85×10^{-12} F/m]



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Problem 3.
A vertical magnetic field with peak amplitude of B_0=0.01 T varies sinusoidally in the x-direction, $\mathbf{B}(x) = -B_0\hat{\mathbf{y}}\cos(2\pi x)$ for x in meters, in some medium that we are able to probe with rectangular loops of wire. Consider the magnetic field to be uniform in the perpendicular (y- and z-) directions, and the wire loops are held in a plane that is parallel to the x-z plane with their sides aligned with the coordinates. A set of closely spaced lead wires connects the wire loops to a voltmeter.

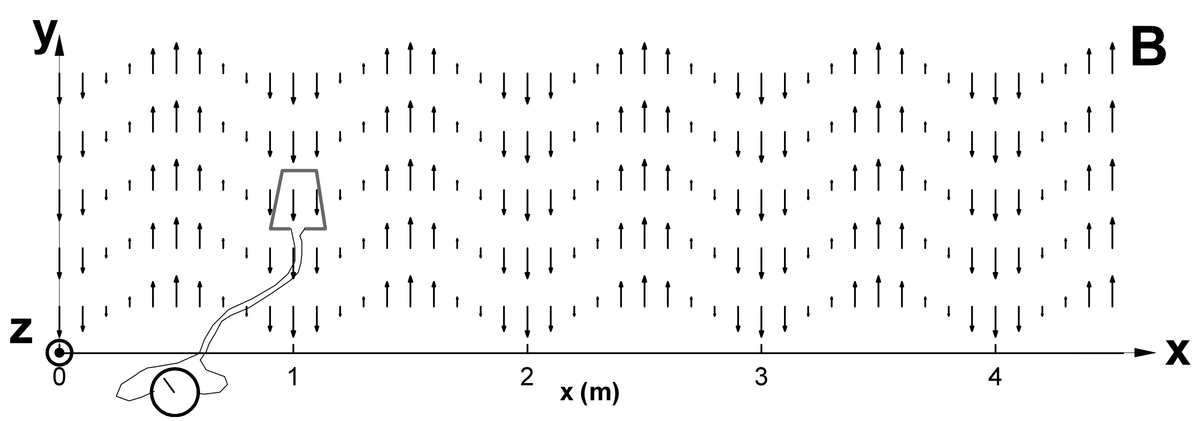

FIGURE: Vertical magnetic field passes through a square loop of wire (drawn in perspective) that is held parallel to the x-z plane.

a) What voltage signal is recorded (as a function of time) from a square loop that is 1 cm on a side moving at 10 m/s in the positive x-direction only, starting with its center at x=1 m?

b) What voltage signal is recorded (as a function of time) from a square loop that is 0.5 m on a side moving at 10 m/s in the positive x-direction only, starting with its center at x=1 m?

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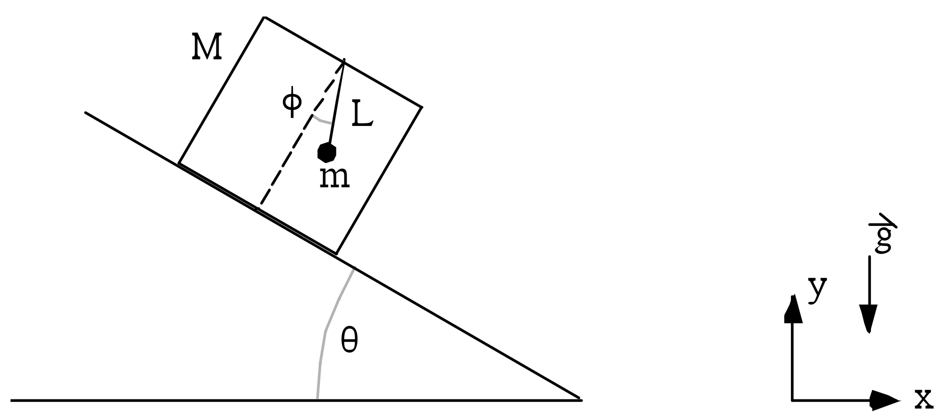
Problem 4.

A hollow box of mass M is sliding down a plane inclined at angle θ to the horizontal. The coefficient of friction between the box and the plane is μ. A pendulum bob of mass m is hung by a string of length L from the top of the box as shown in the figure.

Consider the situation where the angle ϕ between the string and the surface-normal is constant with respect to time while the box accelerates. Determine ϕ.



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Problem 5.

A solid sphere of mass M and radius R is thrown onto a surface with horizontal speed V_0. Initially, the sphere slides without rolling. The coefficient of kinetic friction between the sphere and the surface is μ. What will be its horizontal speed at the time when the sphere rolls without sliding?

(The moment of inertia for a sphere is $I = 2/5\ MR^2$)

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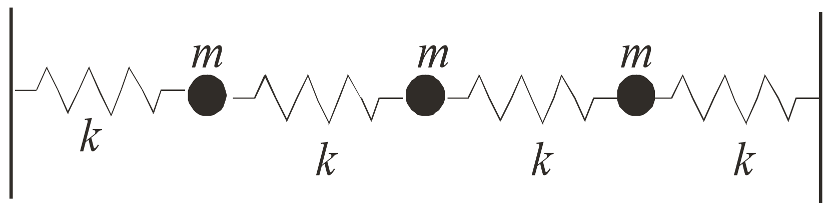
Problem 6.

Three masses (m=0.5 kg each) are connected to each other and to two walls by springs with the same spring constant (k) of 100 N/m, as shown in the figure.



One normal mode of oscillation for the system has an angular frequency of 20 rad/s ($\omega = \sqrt{2k/m}$).

a) What are the equations of motion for the three masses? [Consider 1D motion directed horizontally along the springs only.]

b) Find the angular frequencies of the other two modes of the system.

c) What is the eigenvector for the mode that oscillates at $\omega = \sqrt{2k/m}$?