University of Wisconsin-Madison
Engineering Physics Department
Spring 2007 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. _____

Useful constants:

$\mu_0 = 4\pi \times 10^{-7}$ H/m $\qquad$ $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m

$c = 3 \times 10^8$ m/s $\qquad$ $g = 9.81\,\text{m/s}^2$

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Problem 1.

A ball of mass m is thrown at speed v_0 toward a cup that is mounted at the end of a bar of length $3L$. Another ball of mass $2m$ is mounted to the other end of the bar, and a pivot attaches the bar to a fixed structure as shown in the figure. Assume that the bar and the cup have negligible mass, and treat the balls as point masses.

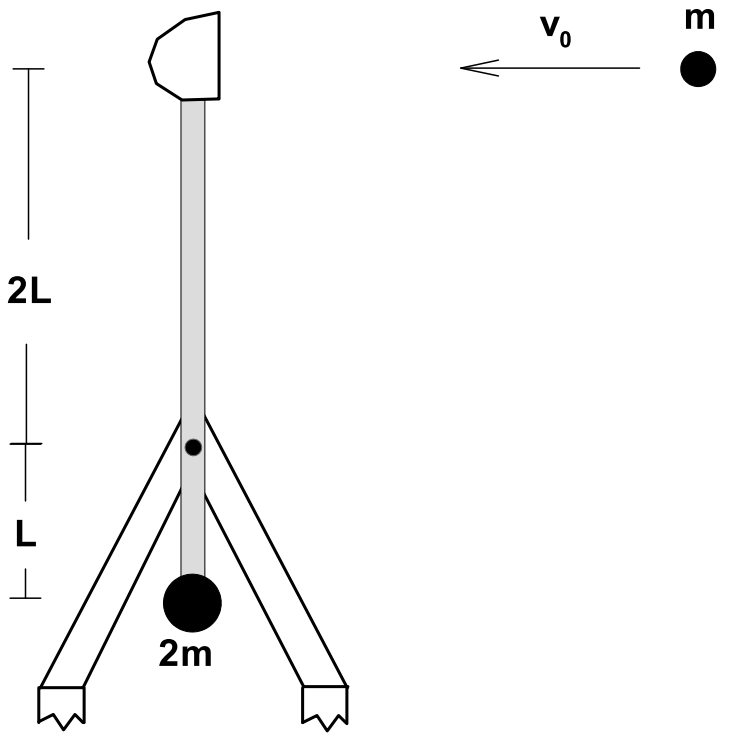

Diagram of initial state.

a) (5 points) In terms of m, L, and v_0, what is the angular velocity of the bar after the ball of mass m is caught in the cup?

b) (5 points) How large is the final kinetic energy relative to the initial kinetic energy?

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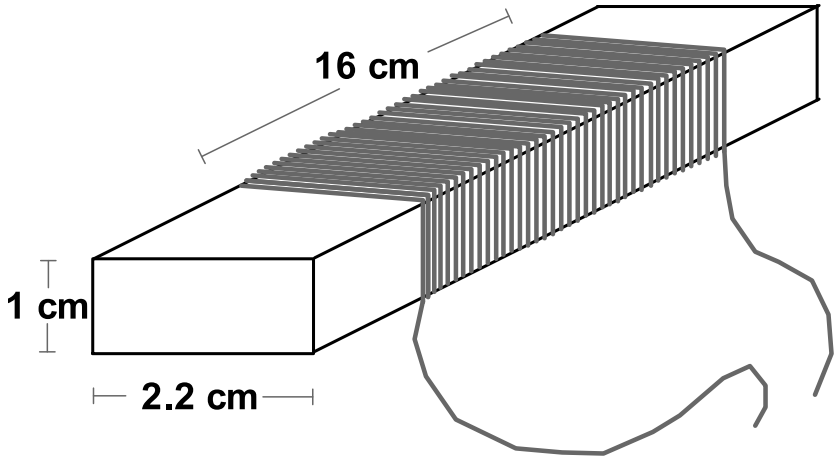
Problem 2.
A solenoid is made from an insulated wire wrapped tightly around a rectangular rod of insulating material such that there are 80 turns over 16 cm, as shown in the diagram below.



Wire wrapped around insulator.

a) (5 points) How much magnetic energy is stored in the solenoid when the leads are connected to a 10 A source of current?

b) (5 points) A second insulated wire (not shown in the diagram) is wrapped 32 times over 8 cm of the first wire. If its leads are connected to a 5 A source of current such that current in the second wire flows in the opposite direction around the rod (relative to the 10 A in the first wire), how much magnetic energy is stored in the system?

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Problem 3.
A model rocket has a total mass of 42 g, where 40 g of the mass is fuel. When the fuel is ignited, it is lost at a constant rate of 10 g/s.

a) (5 points) What minimum speed of escaping burned fuel is required to get the rocket moving vertically (against gravity) immediately after the fuel is ignited?

b) (5 points) Assuming that the rocket only moves vertically and that the exhaust velocity determined from part a) remains constant while the fuel is burning, determine the rocket's velocity as a function of time (before and after the rocket runs out of fuel).

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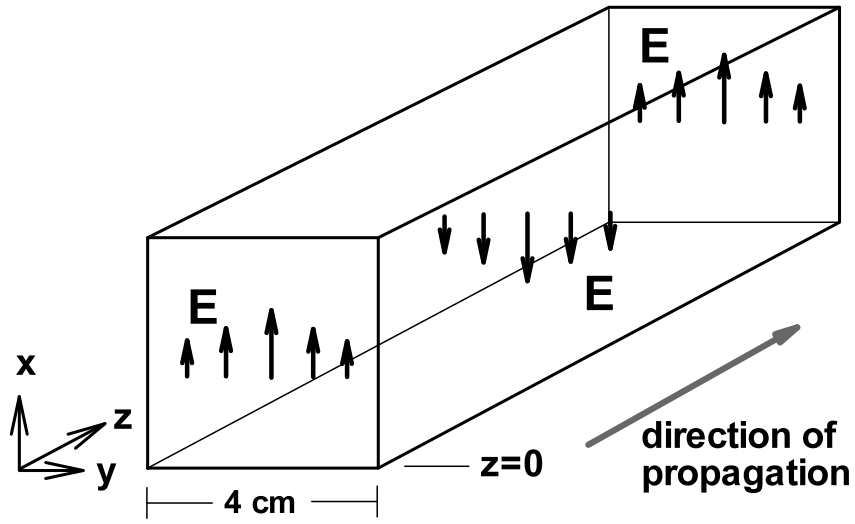
Problem 4.

An electromagnetic wave propagates inside a tube of square cross section that is 4 cm on a side. The electric field is in the *x*-direction only (one of the transverse directions) with ½ sine-wave variation in the *y*-direction, as shown in the schematic, and the wave propagates in the +*z*-direction. The tube is evacuated (no dielectric filling), and its walls are perfect conductors.



Wave electric field at an instant in time.

a) (7 points) Sketch the magnetic field distribution in the *y*-*z* plane over a full wavelength in *z* at the same instant in time shown in the sketch. Be sure to indicate the *z*=0 position in your sketch to show the phase relation to **E**. Also, **clearly mark the +*y* and +*z* directions**.

b) (3 points) If the frequency of the wave is 5.4 GHz ($f = 5.4\times10^{9}$ s^{-1}), what is the wavelength in the *z*-direction?

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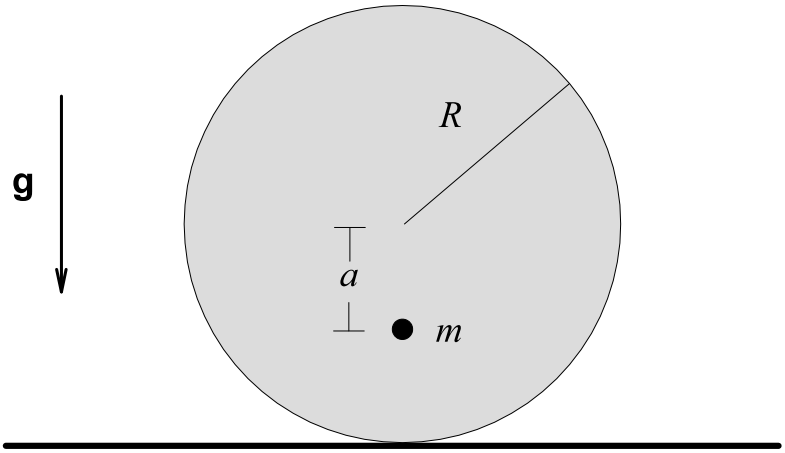
Problem 5.
A mass *m* is attached a distance *a* from the center of a disk of radius *R* that has negligible mass. The disk is free to roll without slip across a level surface.



Initial orientation of the disk.

a) (5 points) In terms of *a, g,* and *R*, what rate of angular rotation is needed to get the disk to make at least one complete rotation if it starts in the orientation shown in the figure?

b) (5 points) Find a relation for the angular frequency of small-amplitude oscillations about the state shown in the figure.

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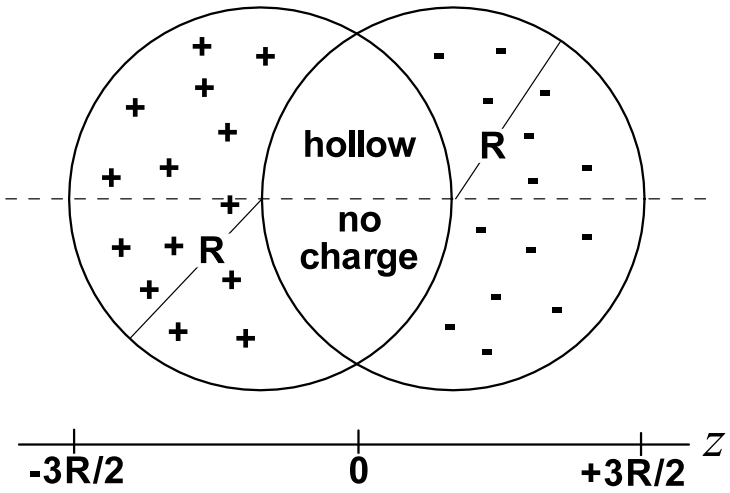
Problem 6.

Two rotationally symmetric shapes of charge are assembled as shown in the figure below. [Each shape is three-dimensional, like a sphere that is partially cut away.] The absolute value of the charge density in each shape is ρ, but the one located at $z<0$ is positively charged, and the one located at $z>0$ is negatively charged. Determine the magnitude and direction of the electric field in terms of ρ and R along the axis of symmetry for $-\frac{3}{2}R \le z \le +\frac{3}{2}R$.



The dashed line shows the axis of symmetry for the two charge distributions. Find **E** along the dashed line.