University of Wisconsin-Madison
Engineering Physics Department
Spring 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. _____

$I_{disk} = \frac{1}{2}MR^2$ $\qquad$ $I_{sphere} = \frac{2}{5}MR^2$

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

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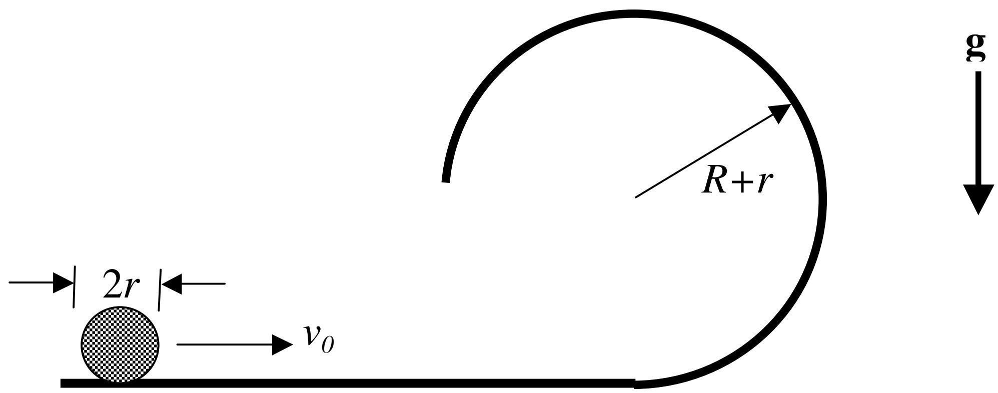
Problem 1. The sphere pictured below has mass m and radius r. The sphere has initial velocity v_0, directed toward a loop of radius $R+r$ that is oriented in a vertical plane. What minimum value of v_0 is required to ensure that the sphere rolls completely around the loop without leaving the track? Assume that the sphere rolls without slipping.



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Problem 2. A capacitor is fabricated from a conducting rod with a 2 mm diameter inserted into a conducting tube of inner diameter 14 mm. The rod and the tube are 40 cm in length. Dielectric material fills the gap between the rod and tube and holds the rod along the geometric center of the tube. Over 30 cm of the length, the permittivity of the dielectric material is $\varepsilon_1 = 2\times10^{-11}$ F/m, and over the remaining 10 cm, the permittivity is $\varepsilon_2 = 1\times10^{-10}$ F/m.

How much energy (in Joules) is stored in the capacitor when the rod is charged to $+2\times10^{-5}$ C, and the tube is charged to -2×10^{-5} C?

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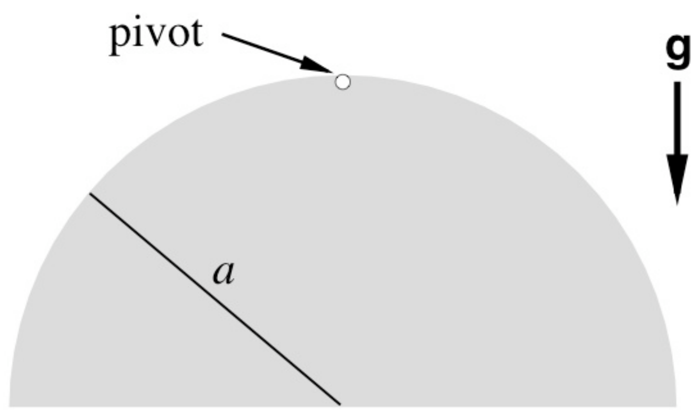
Problem 3. A circular disk of radius a and uniform mass density is cut in half and mounted on a frictionless pivot to create a pendulum, as shown in the figure. Determine the oscillation frequency of small-angle oscillations in terms of g and a.



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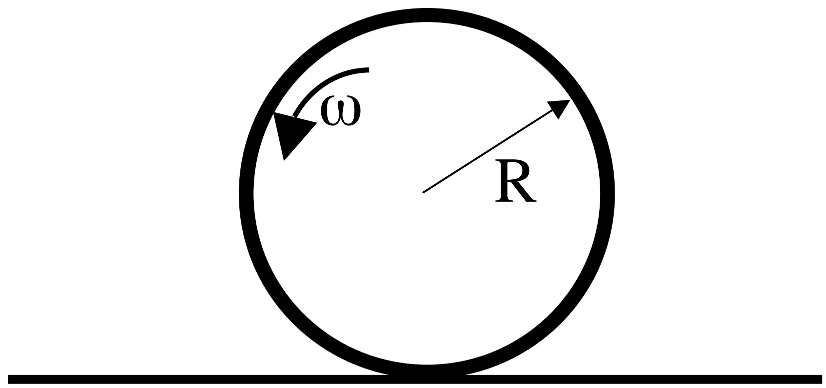
Problem 4. A thin hoop of radius R and mass m is given an initial angular velocity ω and then placed on a surface. The friction coefficient between the hoop and the surface is μ. Determine the distance traveled by the hoop before it stops slipping.



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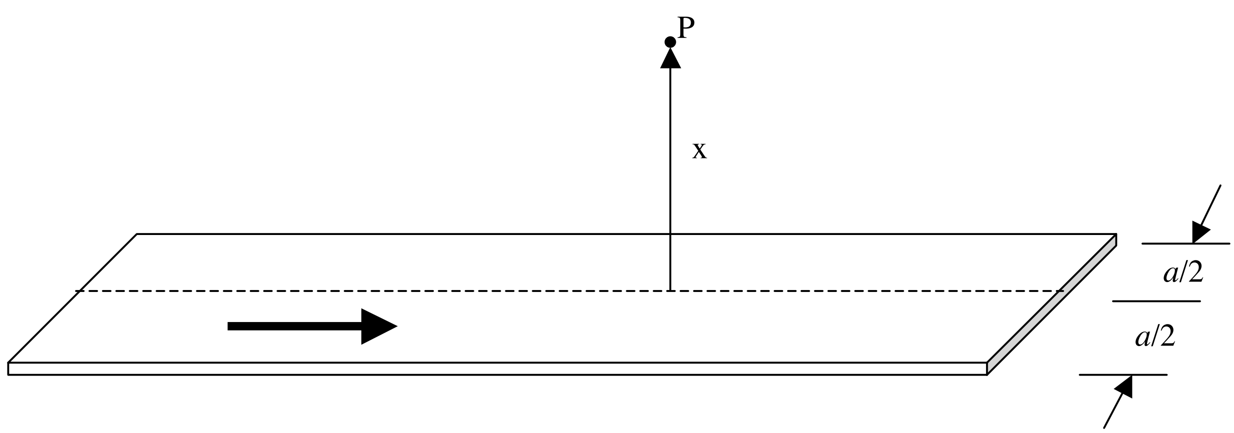
Problem 5.

a. (8 points) Determine the direction and magnitude of the magnetic field at point P, a distance x above the center of an infinitely long, thin current sheet of width a, as shown in the figure below. The current I in the sheet is evenly distributed within the volume.
b. (2 points) Use this solution to determine the magnetic field a distance x above an infinitely wide, thin current sheet, keeping the current density (I/a) constant.



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Problem 6. Two circular loops of wire lie in the same plane and are centered at the same point. The larger loop has radius a, and the smaller loop has a radius b, and $b << a$. An AC source of current is connected to the larger loop, and the current in this wire as a function of time is

$$I_L(t) = I_a \sin(2\pi f\, t),$$

where f is the frequency. The smaller loop is connected to a voltmeter. As a function of time and the constants f, I_a, a, and b, what is the voltage, $V(t)$, on the voltmeter ? State any approximations made in your computation.

[Note the current and voltage sign conventions shown in the schematic, and assume that the leads to the current source and voltmeter are shielded.]