University of Wisconsin-Madison
Engineering Physics Department
Fall 2008 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 and formulae:

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

c = 3×10^8 m/s

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

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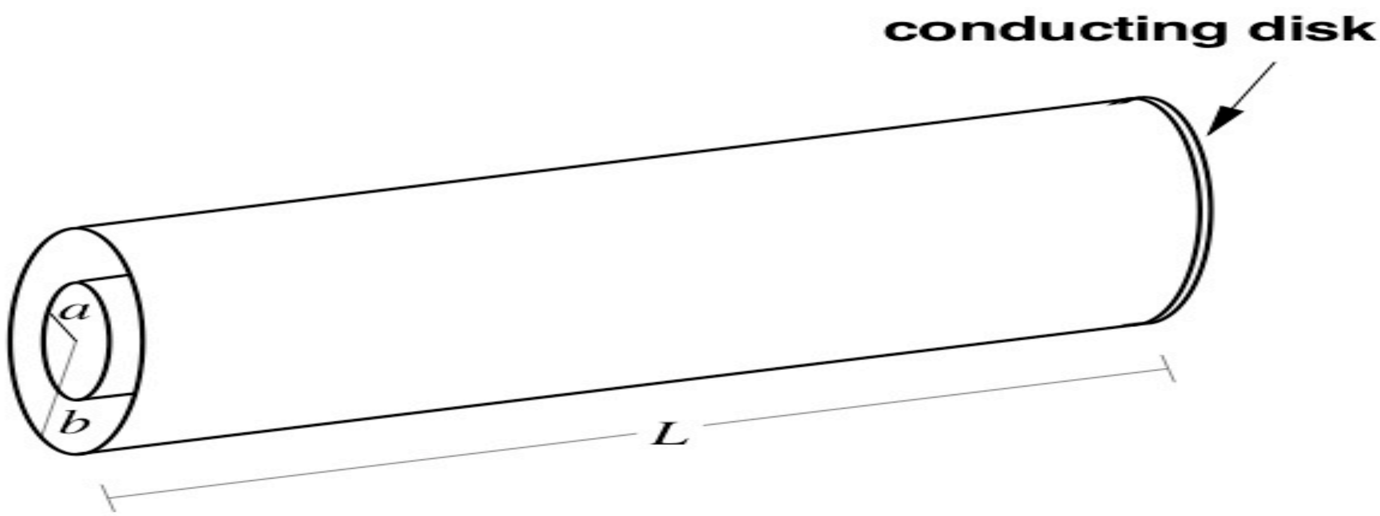
Problem 1. A solid circular cylindrical conducting rod of radius $a = 0.1$ m runs along the axis of a conducting circular cylindrical thin shell of radius $b = 0.2$ m, both having length L = 1.5 m, as shown in the figure. A flat metal disk electrically connects the rod to the shell at one end. Electrical leads to a 3 mF capacitor (not shown) are connected to the rod and to the cylinder at the open end of the coaxial configuration. Ignoring all resistance and any inductance that is external to the coaxial configuration, determine the oscillation frequency when charges move through this system.



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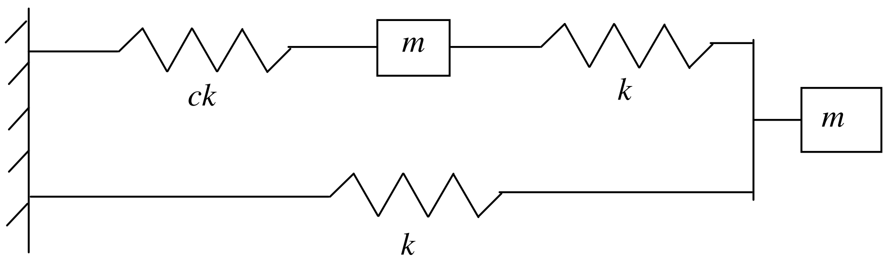
Problem 2. Consider the one-dimensional behavior (horizontal displacements only) of the spring-mass system illustrated. Here, k and ck are spring constants relative to unstretched and uncompressed lengths, c is a dimensionless constant permitted to be negative, and the two masses are identical.



(a) (5 points) Find the value of c so that the effective spring constant for the mass on the right is $+\infty$ in static conditions.

(b) (5 points) Show whether the structure can be dynamically stable for the c value determined in Part (a).

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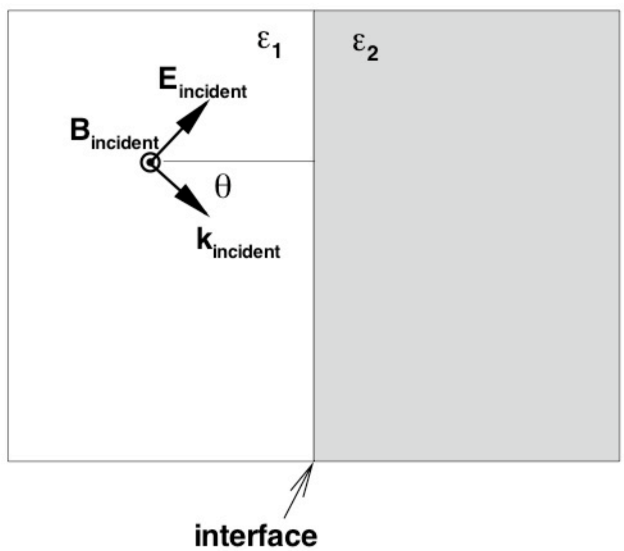
Problem 3. A plane electromagnetic wave travels through a linear dielectric medium whose dielectric constant is ε_1. There is a planar interface across which the dielectric constant changes to $\varepsilon_2 = \varepsilon_1/9$, and the direction of propagation is at an angle θ with respect to the interface-normal direction, as shown in the figure. The orientation of the wave fields with respect to the interface is also shown in the figure.



a. (4 points) Over what range of θ does the wave transmit across the interface?

b. (1 point) For values of θ for which the wave does **not** transmit across the interface, is the magnetic field of the reflected wave in phase or out-of-phase with the magnetic field of the incident wave along the interface?

c. (5 points) Give a qualitative physical explanation for how the answer to part b satisfies Maxwell's equations at the interface.

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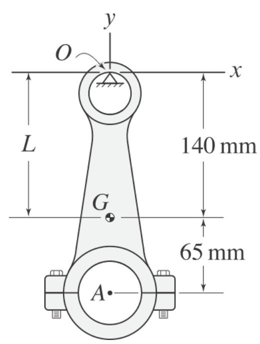
Problem 4. A connecting rod from a gasoline engine has mass m and center of gravity at point G. By supporting the connecting rod by a sharp edge at point O and allowing it to oscillate as a pendulum, the mass moment of inertia about the z axis through point O (*i.e.*, perpendicular to the figure) is given by Eq. (1)



$$I_O = \frac{T^2 mgL}{4\pi^2} \qquad (1)$$

where T is the time required for one full cycle of oscillation and L is the distance from point O to the center of gravity.

(a) (3 points) Explain what the mass moment of inertia quantifies or measures.

(b) (7 points) If the connecting rod has 15 kg mass, $T = 0.816$ s, and the center of gravity is located as shown, determine the mass moment of inertia about point A.

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Problem 5.

a) (8 points) Derive Eq. (1) from the preceding problem (Problem 4), and

b) (2 points) state all assumptions.

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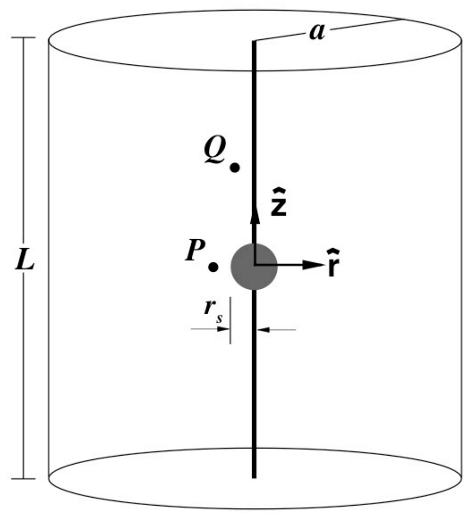
Problem 6. A conducting metal sphere of radius r_s=0.1 m is supported by conducting wires of radius 5×10^{-4} m that extend along the axis of a thin-walled hollow metal circular cylinder. The radius of the cylinder is a=1 m, and its length is L=6 m. Relative to ground, the wire and sphere are brought to an electrical potential of +10 V, and the cylinder is brought to —10 V.

Neglecting end effects, **ESTIMATE** the electrical potential at points P and Q shown in the figure and listed below, **AND** provide justification for your estimations. (The origin of the coordinates is at the center of the sphere, as shown.) NOTE: you need not derive the potential field from first principles.

a) (5 points) Point P is located at r=0.11 m, z=0 m.

b) (5 points) Point Q is located at $r = 5 \times 10^{-2}$ m, z=1 m.



Schematic of metal sphere supported inside a cylindrical conductor (not to scale)