University of Wisconsin-Madison
Engineering Physics Department
Spring 2006 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. _____

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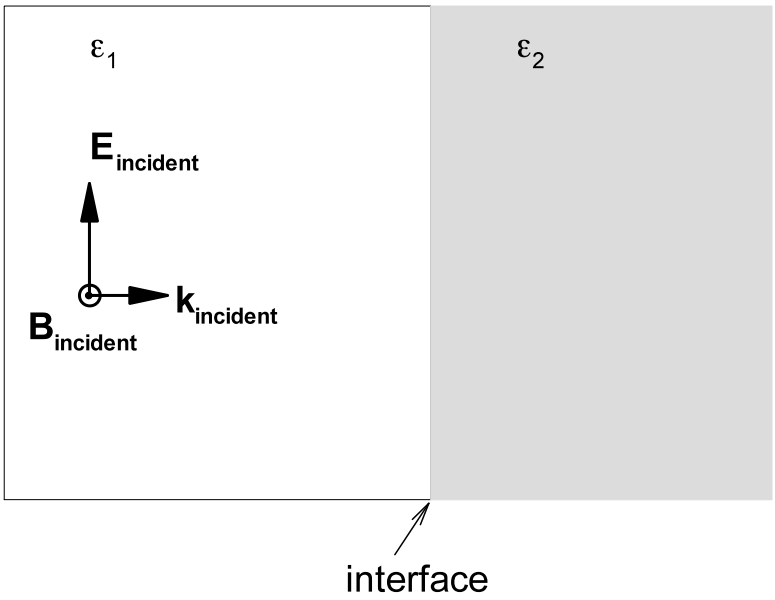
Problem 1.

A plane electromagnetic wave is launched through a linear dielectric medium with dielectric constant ε_1. The wave travels directly toward an interface with a second dielectric medium that has a dielectric constant of $\varepsilon_2 = 2\ \varepsilon_1$. Some of the wave is transmitted through the interface, and some of the wave is reflected.



a) What is the wavelength of the transmitted wave relative to the wavelength of the incident wave?

b) What is the magnitude of the electric field of the transmitted wave relative to that of the incident wave. At the interface, is the transmitted **E** in phase or out of phase with the incident **E**?

c) What is the magnitude of the electric field of the reflected wave relative to that of the incident wave. At the interface, is the reflected **E** in phase or out of phase with the incident **E**?

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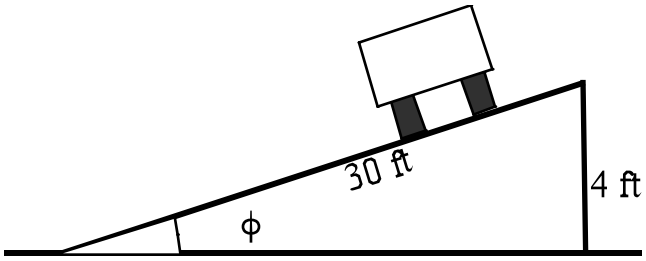
Problem 2.

The outside curve of a highway forms an arc whose radius is 150 ft. If the roadbed is 30- ft wide and its outer edge is 4 ft higher than the inner edge, for what speed is it ideally banked such that the car maintains is position on the road without relying on friction?



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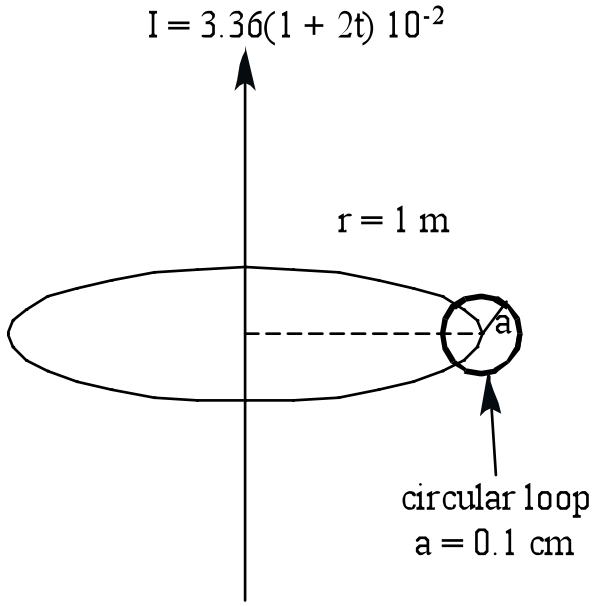
Problem 3.

The current I in a long straight wire is increasing at a steady rate such that $I(t) = 3.36(1 + 2\,t) \times 10^{-2}$ A for t in seconds. A small circular loop of wire with radius $a = 0.1$ cm is positioned with its center located a distance $r = 100$ cm from the wire. The wire lies within the plane defined by the circular loop (see figure). If the resistance of the loop is $R = 8.99 \times 10^{-4}\ \Omega$, what is the induced current i_{loop} flowing in the loop and in which direction does it flow?



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Problem 4.

Assume a tunnel is drilled through the earth along a diameter. Assume no resistance from air in the tunnel or at the earth's surface. Also, assume the earth is of uniform density.

(a) If a stone were dropped into the tunnel at one end, how long would it take for the stone to return to its original position?
(b) Compare your answer in (a) to the period of an earth satellite in orbit at a minimum radius (i.e., at the earth's surface).

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Problem 5.

A metal sphere of radius r_1 = 5 cm has an initial charge of 10^{-6} C. Another metal sphere of radius r_2 = 15 cm has an initial charge of 10^{-5} C. If the two spheres are brought together to touch each other, what charge will remain on each?

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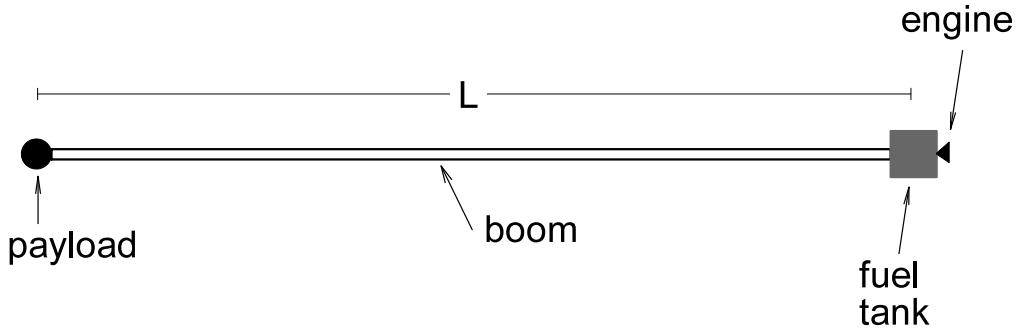
Problem 6.

A deep-space probe consists of a fuel tank, the rocket engine, a long boom, and a payload as shown in the figure below. The sizes of the payload, fuel tank, and rocket engine and the cross-section diameter of the boom are all very small relative to the length (L) of the boom. The probe is launched from a station in space away from any significant gravitational forces. The total initial mass is M_0 ; the initial fuel mass is $M_f=M_0/2$; the mass of the boom and the mass of the payload are $M_b=M_p=M_0/4$. (The mass of the engine itself is negligible.) The exhaust velocity from the rocket engine is $V_{ex}=1000L$ per second, and the rate of mass flow is constant and empties the tank in one year.



(not drawn to scale)

a) What is the change in speed of the probe in units of L per second over the year when the engine is firing?

b) Just before the tank empties, a bolt slips and the engine becomes misaligned with the boom by 1/100 radian. What is the angular acceleration of the probe after the bolt slips?

NOTE: the moment of inertia of the boom about its long axis is $I_b = \dfrac{M_b L^2}{12}$