Physics 23 Practice Final - 3 hours

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Monday, December 5

Write your answers in a blue book. Calculators and one page of notes allowed. No textbooks or other material allowed. Please make your work neat, clear, and easy to follow. It is hard to grade sloppy work accurately. Generally, make a clear diagram, and label quantities. Make it clear what you think is known, and what is unknown and to be solved for. Except for extremely simple problems, derive symbolic answers, and then plug in numbers (if necessary) after a symbolic answer is available. Use Gaussian centimeters-grams-seconds units for the electrostatic problems. **Put a box around your final answer... otherwise we may be confused about which answer you really mean, and you could lose credit.**

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1. Professor Snape has two boxes of gas. Each has volume $0.025\,\mathrm{m}^3$ and both are initally at room temperature, $T = 300\,\mathrm{K}$, and atmospheric pressure (10^5 Pascals). One box has one mole of air (molecular mass $0.029\,\mathrm{kg/mole}$) and one box has a mole of helium (atomic mass $0.004\,\mathrm{kg/mole}$). Call the speed of sound in air v_A and the initial speed of sound in helium as v_{Hi}. Snake asks both Potter and Malfoy to change the conditions of the 1 mole of helium so that its speed of sound equals that of the air. Potter leaves the temperature of helium unchanged, and makes the box a factor of $(v_{Hi}/v_A)^2$ smaller, to increase the density of the helium, and measures a final speed of sound in helium of v_{HP}. Then the helium is returned to its initial condition. Malfoy also hopes to increase the density, but leaves the volume of the helium unchanged, and makes the absolute temperature of the gas a factor of $(v_{Hi}/v_A)^2$ smaller, and measures a final speed of sound v_{HM}. Numerically evaluate v_A, v_{Hi}, v_{HP}, and v_{HM}. Which student gets the problem right? The ideal gas constant $R = 8.3\,\mathrm{Joules/K/mole}$.

2. A pipe is closed at one end, and open at the other, and is in air where the speed of sound is $v = 350\,\mathrm{m/s}$. The first overtone in the pipe plays at the musical note A_4, with a frequency of $440\,\mathrm{Hz}$. What is the length of the pipe?

3. A uniform (volume) charge density ρ occupies a spherical volume of radius a.

   (a) Describe the electric field (magnitude and direction) for all radii r.

   (b) How much energy does it take to move a charge q from $r = a$ to $r = 0$?

4. A uniform surface charge density σ occupies a ring between the radius $r = a$ and $r = b$ in a plane. Find the electric field and the electric potential at $r = 0$, taking the electric potential to be 0 at infinity.

5. An infinite line of charge with linear charge density λ is parallel to, and a distance a above, a conducting plane that is infinite in extent, as shown in Fig. 1.

   (a) Find the force per unit length on the line charge.

   (b) Find the surface charge density on the surface of the conducting sheet, as a function of x and z.

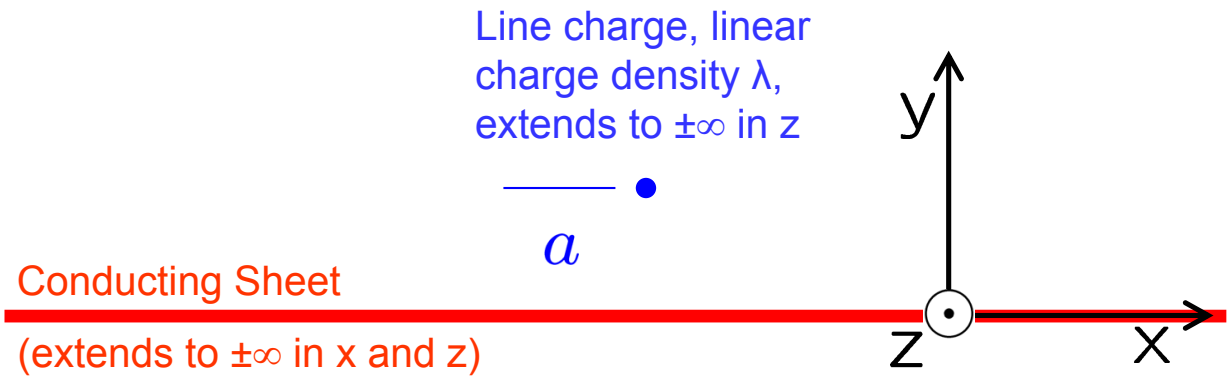

Figure 1: For use in Problem 5.

6. A person of mass m hangs at rest from a rope attached to a parallel plate capacitor, as shown in Fig. 2. The rope is attached to a square plate with sides of length L. The square plate is inside a piece of sheet metal bent into an upside-down U, with a distance $2s$ between the sides. The plate is in the center of the bent sheet metal, and the lower edge of the plate is just about to emerge from the bottom of the bent sheet metal. There is a charge Q on the outside U, and charge $-Q$ on the inner plate.

   (a) What minimum value charge Q is required?

   (b) Numerically evaluate Q in esu for $L = 1\,\mathrm{m} = 100\,\mathrm{cm}$, $s = 1\,\mathrm{cm}$, $m = 50\,\mathrm{kg} = 50,000\,\mathrm{g}$. Take the acceleration of gravity to be $g = 10\,\mathrm{m/s^2} = 1000\,\mathrm{cm/s^2}$.

   (c) Numerically evaluate the voltage difference between the U channel and the center plate.

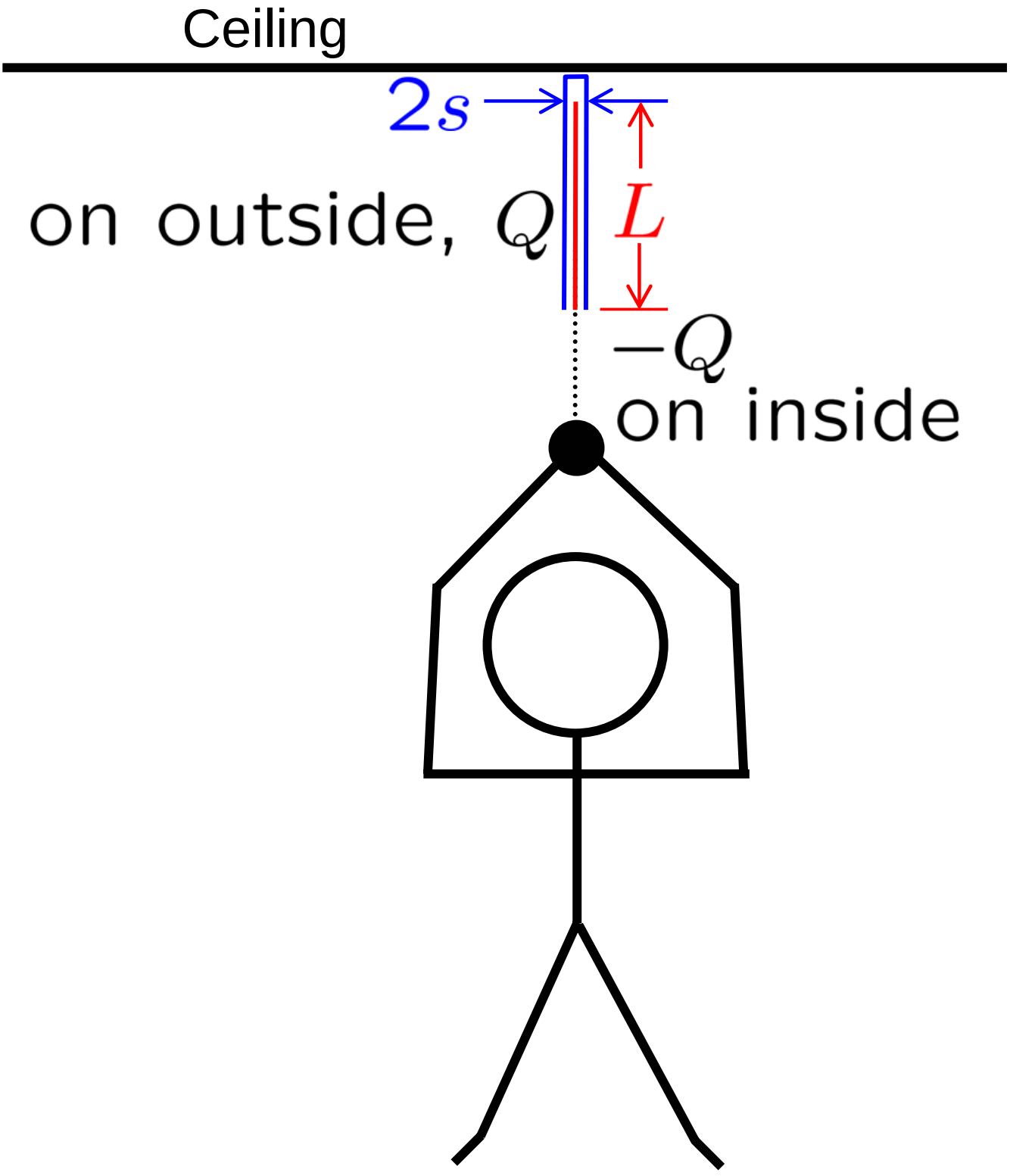

Figure 2: For use in Problem 6.