Your name: ___________________ **TA name: _____________________**

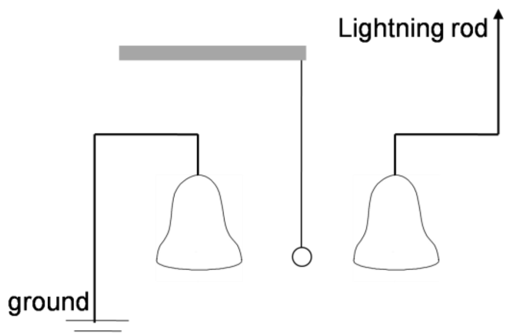
Section time:___________________

Written HW 1: Franklin's lightning bells
(due Friday, Sep 7, 2012 Friday at 2 PM)

Turn in this written homework in the appropriate slot in the brown Homework Cabinet at the entrance of the HelpRoom, Duane G2B90. Please STAPLE pages together, and **put your name and TA name at the top of every page!**

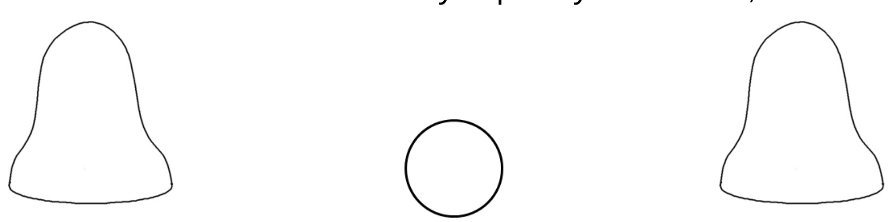
In this and all written homeworks, you will be graded on the clarity and completeness of your answer. ***No credit*** *will be given for an answer in a calculation without a derivation, even if the answer is correct. A calculation without units is also incorrect.*

Ben Franklin used the set-up of two metal bells, shown in the Figure, to warn him of approaching thunderstorms (it is another example of his dangerous experiments). The electrostatic device itself was first invented by the German scientist Andrew Gordon (Erfurt) about 1742, but it is most often referred to as Franklin's (lightning) bells. It was the first device that converted electrical energy into mechanical energy.



One of the two metal bells is electrically connected to the earth (ground) and the other is connected to a lightning rod. Between the two bells a metallic ball is suspended by an insulating thread. Please analyze this device by answering each of the questions below and on the other side of the page (parts 1-8)

1. Before a lightning bolt strikes, a great deal of charge must build up in the clouds in the form of excess electrons. As the charge builds up in a cloud the lightning rod transmits many of the excess electrons to the bell on the right. For ease let's assume that the electrons transmitted to the bell on the right all arrive at one time. Sketch in the diagram below the charge distribution (including induced charges) the instant after the electrons arrive. You may explain your answer, if needed.



(Problem continues on back!)

2. Roughly sketch *electric field lines* in the diagram. For this, please *redraw* the diagram with your charge distribution, this time adding the field lines.

3. Draw (roughly, no numbers, just schematically) the net electrostatic force vector on the metallic ball. *Explain* briefly but clearly your reasoning - how do you know the force is in this direction?

4. Let's get quantitative! A thunderstorm might deposit a charge of perhaps $Q_R = -0.3\ mC$ to the right bell. Assume that the two bells are point charges and the distance between them is $D = 100\ cm$. The metallic ball is initially positioned midway between the bells. Calculate the magnitude of the electric field at the midpoint between the two bells, due to (just) the charge Q_R alone. From now on assume that the bells are spheres.

5. (Assume the metallic ball is spherical with a diameter $d = 2.5\ cm$. *Let's also* assume it is made out of nickel, which has a density of roughly $9\ g/cm^3$.) After it first touches the right-hand bell, the little ball will pick up some charge, which will spread (pretty) uniformly over its entire surface. A reasonable number for the magnitude of this charge would be about 0.03 μC. Given these numbers, will the bell become discharged if the ball touches it once or twice? Why or why not?

6. After the ball has touched the right bell once, charged up, and has returned to the midpoint between the two bells, calculate the acceleration of the fully negatively charged metallic ball at this instant, due only to electrostatic forces (neglect gravity, and neglect the effects of the left-hand bell, which are smaller). In the calculation assume that both the bells as well as the ball are point charges. Does the number you get seem reasonable?

7. Explain qualitatively the mechanism that explains the tintinnabulation of Franklin's bells. Start with the initial stage, which you have analyzed under points 1-3. Use scientific terminology (polarization, like and opposite charges, attraction and repulsion etc.). Draw diagrams to support your explanation.

8. Given the numbers in the problem, why do you think was the set-up dangerous?