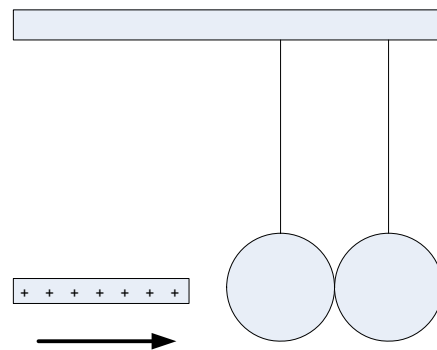

1. A lightweight metal ball hangs by a thread. When a plastic rod that has been rubbed with wool is held near, the ball moves toward the rod, touches the rod, then quickly flies away from the rod. The same thing happens when a glass rod that has been rubbed with silk is used instead. Construct a model for these situations and use it to explain the observations.

2. You put an empty soda can on a wooden tabletop. You rub one end of a plastic rod with wool and bring it close to the side of the can without touching it. You observe that the can rolls toward the rod. Rub one end of a glass rod with silk (to get an opposite charge) and repeat the experiment with the can. You observe the same phenomenon. No matter what charge is on the rod, the can is attracted to it. Use the models we developed in class to explain these observations. Repeat the experiment using a plastic bottle instead of the soda can. You observe that the bottle is attracted to both rods, but not as strongly. Construct a model for these situations and use it to explain the observations.

3. A 10.0cm aluminum sphere is charged with a Wimshurst generator so that it has +4 units of charge. A second otherwise identical sphere is charged so that it has -6 units of charge. The two spheres are brought into contact with each other. Construct a model for this situation and use it to predict step by step what will happen. Explain your reasoning, and draw diagrams showing what, if anything, the charges will do.

4. You've been given an unknown piece of material, roughly the size of a pencil. Design two experiments that could be used to determine whether the material is an insulator or a conductor. Construct a model for each of the experiments and use it to describe specifically what the outcome of each experiment will be if the material is an insulator or a conductor.

5. Two aluminum spheres hang by threads as shown. A glass rod that has been rubbed with silk (making the rod positively charged) is brought closer and closer. Construct a model for this situation and use it to predict **a)** what will happen when the rod is close (but not touching them) to the spheres, and **b)** what will happen when the rod is allowed to briefly touch the left sphere and then is moved far away from the spheres.



6. You are a photographer for an archaeological team working in an ancient tomb in Egypt. You need to set up a small floodlight down in one of the tunnels so you can take pictures of a wall full of amazing hieroglyphics that the team has just

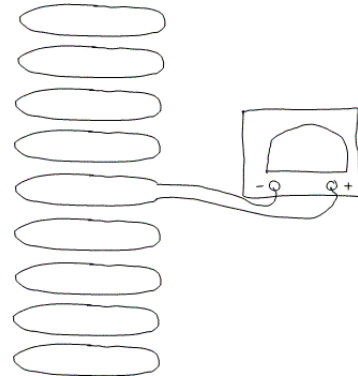
discovered. The problem is that the wall is $2000m$ from the entrance to the tomb, which is where the team's electric generator is. You know the specs for the generator and the floodlight: The generator produces a potential difference of $100V$ and the floodlight has a resistance of 100Ω . Normally you know this results in a current of roughly $1.00A$ through the floodlight and a power output of roughly $100W$. But, you've never had the floodlight anywhere near that far from the generator. You have enough wire to do it, but you know if the power output of the floodlight drops below $95.0W$ your pictures will come out too dark. You know the power cable for the floodlight uses 10 gauge copper wire (diameter $d = 2.59mm$, resistivity $\rho = 1.7 \times 10^{-8} \Omega \cdot m$). Construct a model for this situation (include a diagram) and use it to decide whether or not the floodlight will be bright enough so that good pictures of the newly discovered hieroglyphics can be taken.

7. You are given a spool of wire, wire cutters, a DC power supply, a galvanometer, a rectangular piece of unmagnetized iron, and an unmarked bar magnet. Design an experiment that will allow you to decide which end of the magnet is its north pole. Construct a model for the setup you come up with. Describe in detail how you will be able to tell which end of the magnet is its north pole based on the results of the experiment. Your experiment does not need to use all the equipment given to you.

8. A large number of circular wire loops are stacked on top of each other as shown. One of the loops in the middle of the stack is connected to a galvanometer. A bar magnet is dropped north pole first through the loops.



- Construct a model for this situation.
- Predict what the galvanometer will read as the magnet falls through the loops. Make your prediction in the form of a graph.
- As the magnet falls through the loops, you notice that it falls with an acceleration considerably less than $9.8m/s^2$. Explain this.



9. Imagine that you have used a Wimshurst machine to charge the plates of a parallel plate capacitor so that it has an approximately uniform electric field of magnitude $5.00 \times 10^4 \frac{N}{C}$ in the region between the centers of the plates. The plates of the capacitor are squares $5.00cm$ on a side and are separated by $2.00mm$. The

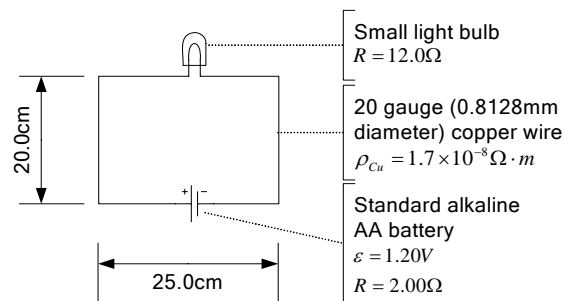
negative plate is heated at a spot near its middle. As a result a few electrons are freed from its surface and begin moving towards the positive plate.

- Construct a model of the situation. Use it to predict what the speed of the electrons will be the instant before they strike the positive plate. Use Newton's 2nd law as your process model.
- Change your model so that it uses the potential model for the electric interaction. Use this new model to make the prediction again, but use conservation of energy as your process model. (Hint: As a first step, find the potential difference between the two plates.) Do the two predictions agree?

10. In thinking about examples of where magnetism plays a role in everyday life you remember the magnets that some people use to attach notes to the door of their refrigerator. To investigate this, you find a bar magnet whose poles have been labeled. You move the magnet north pole first toward your metal refrigerator door. As the magnet gets closer you feel a stronger and stronger force pulling the magnet toward the door. Once they're touching you find that the force is strong enough that the magnet sticks straight out from the door without falling. You repeat this experiment but instead with the south pole closer to the door. The same thing happens. In addition, when you take an unmagnetized piece of iron (a magnetic material) and bring it close to the door no force is felt. Construct a model for this situation and use it to explain *in detail* why these things happened.

11. Nuclear fusion is being researched as an alternative future power source. In nuclear fusion a mixture of deuterium and tritium is exposed to extreme temperature and pressure. (Deuterium and tritium are isotopes of hydrogen, with 1 and 2 neutrons respectively. Hydrogen has none.) Under these conditions, a deuterium nucleus and a tritium nucleus can fuse into a single helium nucleus. This process releases a huge amount of energy. However, it is difficult to accomplish this because the deuterium and tritium nuclei repel each other due to their positive charge. But, if the two nuclei can be brought to within $10^{-15} m$ the fusion will occur. Construct a model for the situation and predict how much energy is required to bring the two nuclei close enough to fuse.

12. Consider the circuit shown. Construct 3 models for the situation by making 3 different sets of simplifications. One of your models should make the fewest simplifications possible.



- Carefully describe each of your 3 models.
- For each of your 3 models,

predict what the current in the circuit will be. Describe any additional assumptions that you made in making your prediction.

- c. Look at your 3 predictions. Of the simplifications you made while constructing your models, which ones were reasonable? Which ones were not?
 - d. For the simplifications that were not reasonable, what could be changed in the circuit so that the simplification would become reasonable? Come up with as many possibilities as you can.
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