University of Maryland
Department of Physics

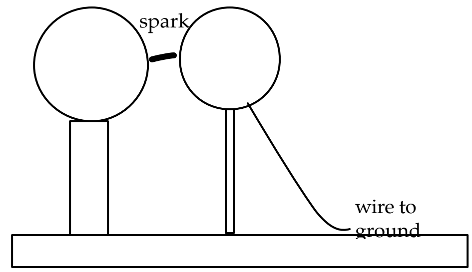
Spring 2002 — Laura Lising

Physics 122 — March 20, 2003

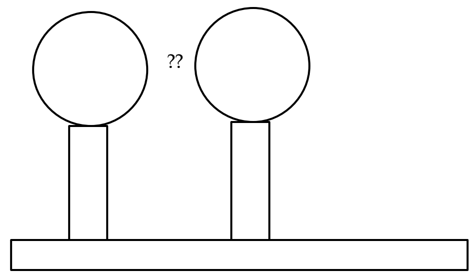
Exam #1 Make-up

Multiple choice questions.

1) (7 pts.) In one lecture demonstration I had the Van de Graaf generator and grounded metal sphere on the lecture table. If I put the two spheres close enough together, we could see a spark jump between them. That's what I've shown in the figure.



Suppose that instead of having a grounded metal sphere I used a second Van de Graaff generator, just like the first one. Then you'd expect I'd get



a) sparks that could be twice as long and intense.
b) more powerful sparks, but not necessarily twice as long and intense.
c) sparks about the same length and intensity.
d) sparks about half the length and intensity.
e) no sparks between the two Van de Graaf generators.

The two would be at the same voltage if I turn them on at the same time, because they'd get the same charge and it would be in the same arrangement. Without any potential (voltage) difference between them, there'd be no reason for current to flow. That is, they're both at the same electrical pressure.

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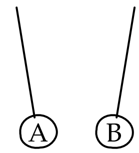
2) (7 pts.) Two identical metal balls are suspended from thin conducting wires. Ball A has a total charge +q and ball B has a total charge –q, and the electrostatic attraction pulls the balls toward each other, to the equilibrium position shown. If we were to add charge to ball A, to a total of +2q, we should expect



a) both balls would experience the same increase in electrostatic force

b) the electrostatic force on ball B would increase, but the electrostatic force on ball A would remain constant

c) both would have an increase in electrostatic force, but it would be greater for ball A

d) the electrostatic force on ball A would increase, but the electrostatic force on ball B would remain constant

e) both would have an increase in electrostatic force, but it would be greater for ball B

f) the electrostatic force on both balls would remain constant

The force on each of them is the same strength: $F = kq_1q_2/r^2$ doesn't depend on which charge is q_1 and which is q_2. (If it did, it would conflict with Newton's Third Law.)

3) (7 pts.) Same balls as in question two. This time, suppose we double the charge on both balls, so that A has a total charge +2q and B a total charge –2q. In the new equilibrium position, we would expect the electrostatic attraction to be

a) the same strength as when the charges were +q and –q

b) 2x as strong as when the charges were +q and –q

c) 4x as strong as when the charges were +q and –q

d) between 2x and 4x as strong as when the charges were +q and –q

e) more than 4x as strong as when the charges were +q and –q

The attraction is stronger because the charges are greater, so in the *new equilibrium position the charges will be closer together.* Double both charges → 4x the strength; move them closer together → increase the strength even more.

4) (7 pts.) A hollow sphere made out of electrically **insulating** material is electrically neutral (no excess charge). A small amount of negative charge is suddenly placed at one point P on the outside of this sphere. If we check on this excess negative charge a few seconds later we will find one of the following possibilities:

a) All of the excess charge remains right around P.

b) The excess charge has distributed itself evenly over the outside surface of the sphere.

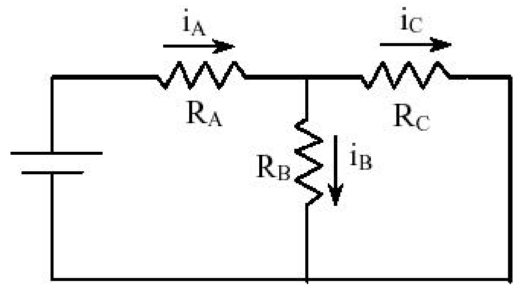
c) The excess charge is evenly distributed over the inside and outside surface.

d) Most of the charge is still at point P, but some will have spread over the outside surface.

e) There will be no excess charge left.

The charge is going to stay put because insulators do not allow charge to move around. Go on and off, yes, but not move around.

5) (7 pts.) In this circuit, R_A is identical to R_B, and their resistance is half of R_C: $R_A = R_B = 1/2\ R_C$. i_A is the current through resistor A, i_B the current through resistor B, and i_C through resistor C.



Which of the following must be true?

a) $i_A = i_B$, only
b) $i_A = i_C$, only
c) $i_A = i_B = i_C$
d) $i_A = i_B + i_C$
e) $i_A = i_B - i_C$
f) None of these.

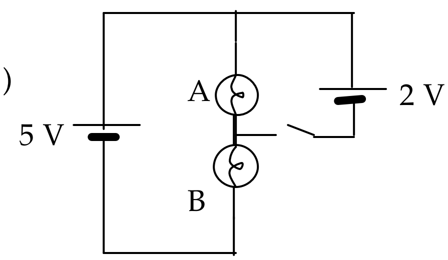
Current in to the junction at the top = current out of the junction. (I saw a lot of people choosing (a), perhaps because the resistances i_A and i_B go through are equal. But resistance and current are only related through voltage, and you don't yet know that the voltages are equal. In fact, if you stop and reason it through you know they must not be.)

6) (7 pts.) What is the relationship between i_B and i_C?

a) $i_B = 1/3\ i_C$
b) $i_B = 1/2\ i_C$
c) $i_B = i_C$
d) $i_B = 2i_C$
e) $i_B = 3i_C$
f) None of these.

$R_B = 1/2\ R_C$ means R_C is twice R_B. Resistor B has the same voltage across it as resistor C. Same V, half the R, so twice the current I. Resistor B is smaller and thus has the larger current.

7) (7 pts.) Here's more on this circuit. This time, suppose that there was only a single battery in the first loop and the batteries are no longer identical but as shown. When the switch is closed, what happens?

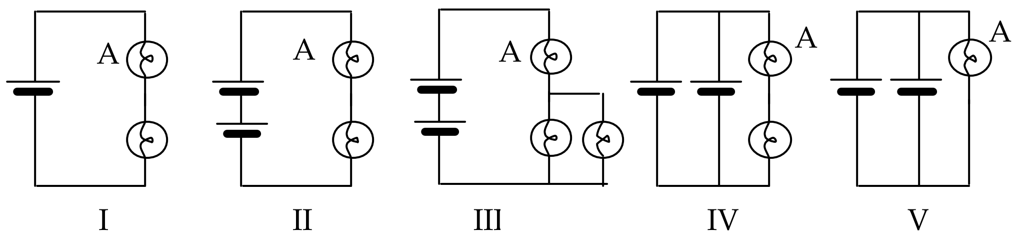


a) Nothing happens (both bulbs are the same as before.)
b) Bulb A gets brighter, and B gets dimmer.
c) Bulb B gets brighter and A gets dimmer.
d) Both bulbs get brighter
e) Bulb A goes out.

With the switch open, there's 2.5 V across bulb A and 2.5 V across Bulb B. Close the switch, and there's 2 V across A because the 2 V battery will make it be so and thus there needs to be 3 V across B to make the 5 V battery happy. The higher potential difference across B means more current flows through B and there's more power used; vice versa for A.

You might notice that this circuit has a reverse current flow through the 2 V battery, and some people could reasonably have decided that's not possible. So I gave full credit for answer A, nothing will change, which would be what would happen if current just couldn't flow backward through the 2 V battery.

8) (7 pts.) Which circuit below has the largest power consumption for bulb A?

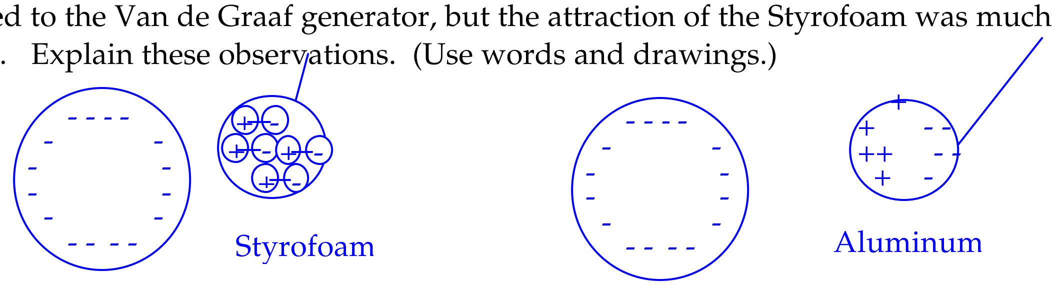


) I b) II c) III d) IV e) V

In this problem, the bulbs are identical, so I'm basically asking in which circuit is bulb A brightest since brightest means most current and for constant resistance $P= I^2R$. We know that the bulbs in I and IV should be equally bright. Adding a second battery in parallel doesn't change the voltage across the bulbs and thus can't change the current through them. The current is twice as high in II and V as in I and IV because there is twice the voltage drop across A. But in III it's even higher. Compare II and III. II has the same voltage drop across both bulbs, but in III, the two parallel bulbs will have less voltage drop across them than A will (because they are equivalent to a smaller bulb is one way to think of it. Or just because you know they will only have half the current as through A so the voltage drop must be less) Anyway, so the parallel bulbs have less voltage drop and A in III has more, so it will be brighter and consume more power.

Short answer questions, with explanations. For these, you do need to explain.

9) (15 pts.) In class we saw that both a Styrofoam ball and a roll of aluminum foil were attracted to the Van de Graaf generator, but the attraction of the Styrofoam was much weaker. Explain these observations. (Use words and drawings.)



The aluminum attracts to the generator because it's positive charges are attracted and it's negatives repelled, so since they can move freely in a conductor, the charge distributes itself as shown. This separation of charge creates a net force despite the fact that the foil is still electrically neutral because the positives are closer to the generator and thus their attractive force is greater than the repulsive that the farther negative charges feel.

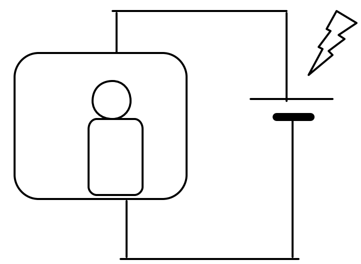
The Styrofoam does not allow charge to separate as much. Charge cannot move around, but the dipoles can orient themselves as shown. Since the charges are separated the net force as above can still arise, but it is not as strong because the charges cannot get as far apart from each other.

[To get full credit you needed to explain why charge separates and why this leads to a force.]

(10 pts.) One piece of advice you often hear about safety during a lightening storm is to go inside a car, because then you're surrounded by metal.

Someone might question that advice: Metal is a conductor, which allows electricity to flow, so the lightening could go right through it and get you!

However, another person might argue that you could think of the lightening as a battery (a voltage source) and draw a picture like this



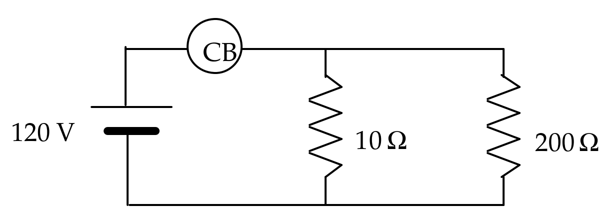
Thinking about our model, do you think the advice is good advice and if so, how do you respond to the first person's concern?

It is good advice! But not because the tires are insulators! *Air* is also a great insulator, but when there's that much voltage (thousands and thousands of volts), air breaks down and conducts – the tires couldn't prevent the air around them from conducting, so it doesn't matter whether they insulate or not.

You're safe because you're surrounded by metal, and metal conducts current easily. There's no reason for the current to go through you, when it has the easy route of the metal to take around you (even if you are touching the metal! It doesn't rely on their being all these good insulators around, although that helps.) That answer was worth full credit, but there's a bit more to it than that: You're in the middle of the metal, and the charge wants to stay to the outside. If you talked only about that and were clear and consistent, I gave you full credit, too.

So if you are in a car in a lightning storm (spelled lightning, not lightening as I had in the question!), stay in the car!
Again, lots of reasonable ideas got partial credit…

10) (25 pts.) This diagram could show, schematically, the wiring for a toaster and a light bulb connected to the same household circuit, and both turned on. (For those of you who know about alternating current, we're pretending it's direct current and not alternating.)



The "CB" is the circuit breaker, which is like an ammeter with a switch it can open when the current gets too high: It measures the current and, if the current goes above a certain value, the circuit breaker opens the switch and breaks the connection. In this case, suppose it's a 20 Amp circuit breaker, so it will break the connection if the current goes above 20 Amps.

a) Which resistor do you expect would depict the toaster and which the light bulb and why?

b) Find the current through the circuit breaker.

V/R for the 10 Ω resistor is 120 V/10 Ω = 12 Amps.

V/R for the 200 Ω resistor is 120 V/200 Ω = 0.6 Amps.

(Notice that the 10Ω resistor has more current going through it.)

So the total is 12.6 Amps – that's the current through the circuit breaker.

c) How much power is the toaster using?

P = VI = (120 V) (12 Amps) = 1440 Watts.

If you thought the toaster was 200 Ω resistor: P = VI = (120 V) (0.6 Amps) = 72 Watts. I didn't take points off for this again.

d) If we plugged an 800 Watt rice cooker into the same outlet, would the circuit breaker break the connection?

P = VI = 800 Watts, so I = 800 W/120 V = 6.7 Amps.

Now the total current is 12.6 Amps + 6.7 Amps = 19.3 Amps – so the circuit breaker just made it – the amperage is below 20, and the connection won't break.