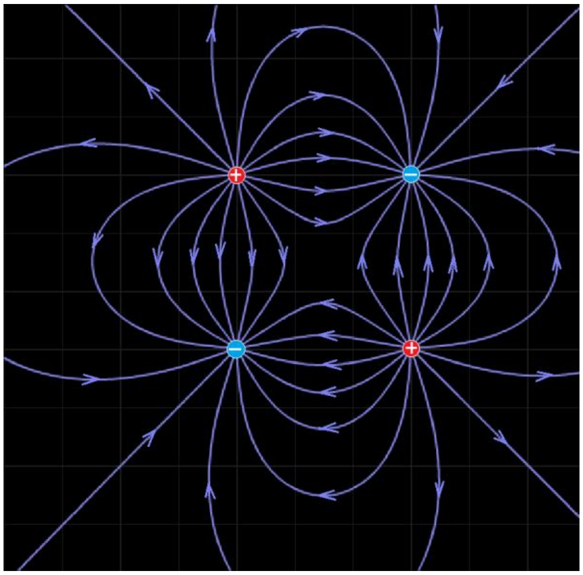
Answers – Physics C Electrostatics Assignment

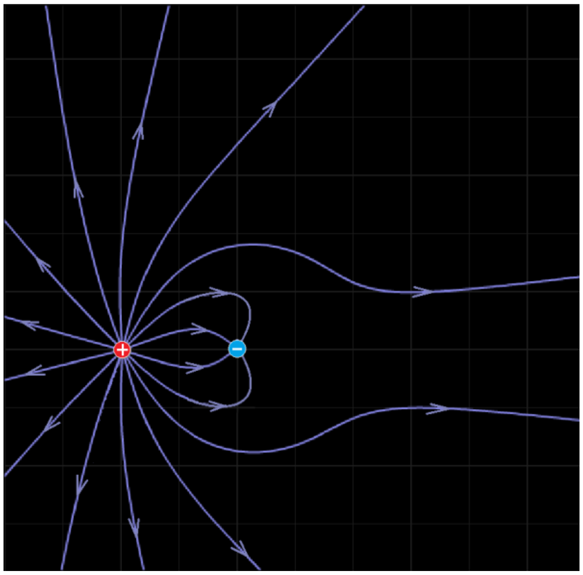
1. a. Electrons are transferred from the fur to the amber, which is an example of conduction.
   b. If the fur was originally neutral it must obtain a net positive charge by losing electrons.
2. a. Electrons are transferred from the glass to the silk, which is an example of conduction.
   b. If the silk was originally neutral it must obtain a net negative charge by gaining electrons.
3. a. Amber negative, glass positive, fur neutral (maybe)
   b. Amber becomes negative as before. The fur is then positive. The glass has a tendency to lose electrons, so it will do so when rubbed by the fur, which being positive should attract negative charges. The glass is then positive and the fur may end up being fairly neutral, but could be charged either way depending on how many electrons were transferred in each step.
4. a. The positively charged glass rod attracts all electrons within the pith ball and repels all protons within the pith ball. Electrons will "migrate" to the side of the ball closest to the glass rod, whereas protons are locked in place in the nuclei of the atoms. Because the electrons in the ball are then closer to the glass rod, the amount the rod attracts the electrons is greater than the amount the rod repels the protons. The pith ball becomes "polarized" by induction before contact occurs.
   b. Once the glass rod makes contact there is conduction of a certain number of electrons from the pith ball to the positively charged glass rod. This causes the pith ball to have a deficit of electrons and a net positive charge. Electrons moving into the glass rod cause its net positive charge to decrease, but if it still repels the pith ball, the net charge on the rod remains positive after contact and there is a net repulsion of the two positively charged objects.
5. a. The rubber and hair are similar materials to the amber and fur described in question 1. Therefore it is likely that the types of charge will be similar – the balloon becomes negative as the hair becomes positive.
   b. The neutral pieces of paper undergo charge by induction – electrons are repelled by the balloon and shift to the "far side" of the paper, making the overall repulsion less than the attraction of the protons in the paper.
6. a. Electrons within the rod are free to move through the metal and therefore move "down and out" of the rod, with some entering the ground and spreading into the earth. This "leaves behind" protons that are "locked in place" throughout the rod. The effect would be greatest at the tip of the rod, so it is positively charged.
   b. A lightning strike represents conduction of electrons. In this scenario, excessive electrons from the negatively charged cloud are attracted to the positive tip of the rod, and the tip of the rod is closer to the cloud than the immediate surroundings (which are also not likely to be as positively charged as the rod).
   c. The lightning rod would be just as effective if the cloud is positively charged. In this case electrons would move from the earth, through the ground, and toward the tip of the rod, creating an induced negative charge. If lightning occurs, then electrons from the rod would be transferred to the positively charged cloud.
7. a. 6.24×10^{12} more electrons
   b. 2.80×10^{-10} %
   c. 7.96×10^{-6} C/m^2
   d. Every electron repels every other electron and so the excess electrons will spread out until the net force on each is zero. This occurs with the electrons equally spaced and evenly distributed about the surface of the sphere, as far away from the center as possible.
   e. 4.65×10^{6} C

8. 2.4 × 10^{-6} N, repulsion
9. 0.29 m
10. 1.8 m/s^2 left, 9.8 m/s^2 down
    or 1$\underline{0}$ m/s^2, 260°
11. 0.98 μN, right; 1.6 μN, left;
    0.62 μN, right
12. $x = a\sqrt{n}$
13. a. 2.3 nC
    b. 1.6 nC, 3.2 nC
14. a. 29 billion electrons gained
    b. 30 billion electrons gained
    c. Only if the pith balls are compared to a third object can it be determined if the charge amounts are equal. Bring the glass rod to the same distance from each pith ball one at a time. If and only if each pith ball is repelled by the glass rod the same amount at the same distance then the charge amounts are equal.
15. $F = \dfrac{q^2\left(2\sqrt{2}-1\right)}{8\pi\varepsilon_0 a^2}$, toward center
16. a. 3.0 × 10^5 N/C, right
    b. 6.0 × 10^{-4} N, right
17. a. 4.8 × 10^{-13} N
    b. same amount, opp. direction
    c. 8.22 × 10^{-8} N
    d. Although the force from the electric field is less than the attraction of the proton, the electron is never at rest. To cause ionization is to change the "orbit" of the electron. The external field can do work on the electron and increase its "orbital energy", which can in principal lead to ionization. It is not as simple as "which force is bigger".
18. By the means described in the previous problem, the field is causing electrons to be "stripped" from molecules in the air. This results in conduction of electrons. A visible spark is seen when electrons are "captured" by positively ionized atoms, and these electrons lose energy in the form of emitted light.
19. a. 2.4 × 10^{-17} N, down
    b. 0.000000068 %
    c. Ignoring gravity on a subatomic particle in an electric field introduces a percent error in the net force on the particle. But this error is very nearly zero (even in this *weak* field) and the percent error would only *decrease* if the electric field is stronger.
20. a. 3.27 × 10^{-15} kg
    b. −6.36 × 10^{-19} C
    c. 4
21. 0.325 mm/s, down
22. a. 1.3 × 10^{17} m/s^2
    b. 7.3 × 10^7 m/s
    c. 7.2 × 10^{13} m/s^2, 1.7 × 10^6 m/s
23. a. $y = \dfrac{eEx^2}{2mv^2}$ b. $\tan q = \dfrac{eEx}{mv^2}$

24. a. 9.1°
    b. 48 kN/C
25. 3600 N/C, 900 N/C, 400 N/C
26. a. 21.6 kN/C, 180.0°
    b. 7.63 kN/C, 180.0°
    c. 2.02 kN/C, 0.0°
    d. 12.9 N/C, 0.0°
    (12.8 N/C using dipole approx.)
    e. 10.0 kN/C, 101.1°
27. a.
    b. 6.39 N/C, 180.0°
    (6.35 N/C not using approx.)
    c. 1.3×10^{-27} N, 90.0°
28. a. 1.0 kN/C, 180.0°
    b. x = 20.0 cm
    c. 91 N/C, 0.0° (at x = 34.0 cm)
    d. +6.0 nC explain or support!
29. $E = \dfrac{q\left(10\sqrt{5} - 2\right)}{5\sqrt{5}\pi\varepsilon_0 a^2}$
30. a.

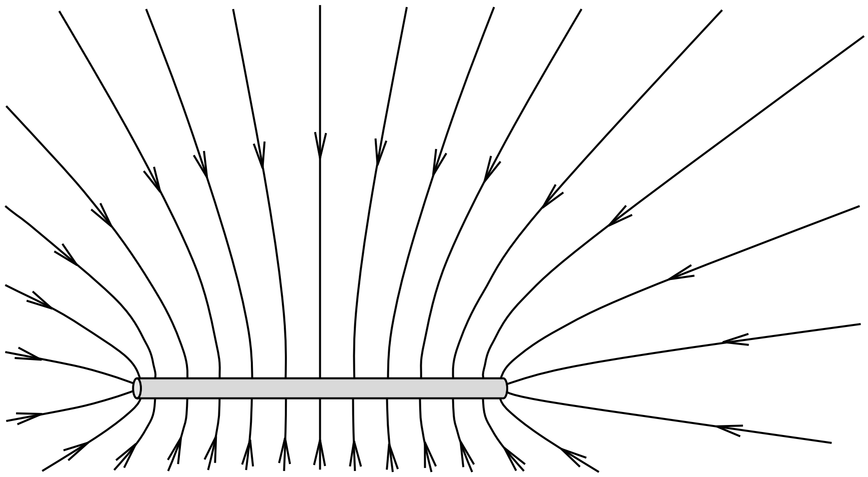


b.



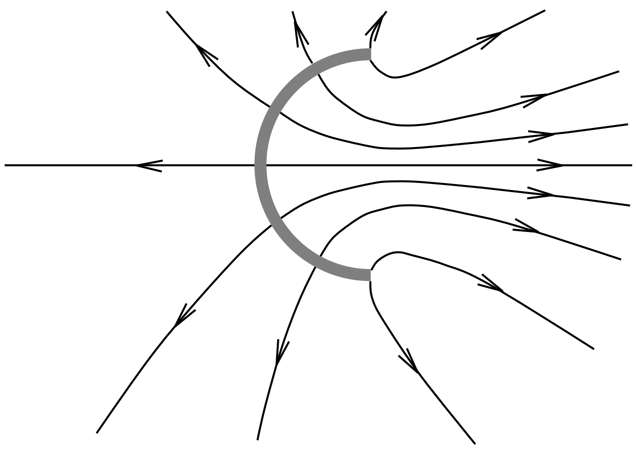
31. a. -2.5×10^{-7} C/m
    b. 5620 N/C, toward rod
    c. 1.12×10^{-5} N, toward rod
32. a. 4740 N/C, toward rod
    b. 447 kN/C, toward rod
33. a. 4990 N/C, toward rod
    b. 450 kN/C, toward rod
    c. 5.41%, 0.519% respectively
34. a. −56.5 kN/C
    b. 83.5 kN/C

35.



36. $E = \dfrac{Q}{2\pi^2 \varepsilon_0 R^2}$, down

37.



Note:
It is essentially impossible to show the electric field "correctly" in this scenario. Although the *direction* of the field is correct, the "density" of the lines implies the field strength is greatest at the arc's center, which is false!

38. a. 3.6×10^{-6} C/m^2
b. 2.0×10^5 N/C
39. a. 1.8×10^{-6} C/m^2
b. 2.0 × 105 N/C
40. a. The "inner" surface – *i.e.* the face of the plate closest to the other plate. Because the excess charge is free to move in a conductor it all migrates to one side due to the attraction of the oppositely charged plate nearby.
b. 7.00×10^{-7} C/m^2
c. 79 kN/C
d. Because the overall net charge of the two plates is zero, the net field of the two surfaces is essentially zero at a sufficient distance away from the center. Because the two surfaces are so close together, an object outside the plates is nearly the same distance from the positive plate as it is from the negative plate and hence the net force is close to zero.
41. 28 nC
42. $E = \dfrac{3\lambda}{4\pi\varepsilon_0 x}$, right