Selected Answers – Physics 2 Electrostatics Assignment

1. a. In order to become positive the glass must lose electrons. Because charge is conserved the silk must attain an equal and opposite negative charge that results from it gaining the electrons that the glass loses.
   b. The glass is an insulator and the positive charge is "trapped" at one end because electrons do not freely move through the glass and cannot move toward the positive end.
   c. Although the metal surface is a conductor, the charge on the glass would hardly change. Any part of the positive end that actually makes contact with the metal would gain electrons and become neutral, but other parts of that end would remain positive because glass is an insulator. The neutral end remains neutral.
2. a. In order for the spark to occur at the finger it must have traveled through the person's body, demonstrating it to be a conductor. If the body were an insulator the charge would remain on the feet!
   b. Before touching the knob electrons have spread out through the person's body – electrons spreading out from one another due to mutual repulsion. The hand is therefore somewhat negative. Electrons in the door knob are repelled by the negative hand and move through the conducting metal away from the hand – toward the knob on the opposite side of the door. This leaves the knob near the hand relatively positive, which attracts electrons. This may make the hand even more negative, which may make the knob more positive and so on until a spark occurs, transferring electrons from the hand to the knob.
3. a. There is an induced negative charge on the side of the ball nearest the rod and an induced positive charge on the side farthest from the rod. Because the negative side of the ball is closer to the rod there is more attraction than repulsion by the positive side.
   b. Once it touches the ball attains a net positive charge by conduction of electrons to the rod. Then like charges repel.
4. Electrons within the Earth are repelled by the negatively charged cloud, which induces a positively charged region of the ground below the cloud. Electrons within the cloud repel one another and are attracted to the induced positive charge of the ground.
5. a. 1.57×10^{-19} C, assuming quantization of charge $q = ne$ and values of $n = 2, 1, 1, 4, 3, 4$ respectively for the given values.
   b. The results are quite precise with only about 1% deviation, so only a small amount of random error is present. However there is clearly systematic error because the results are consistently less than expected and the mean charge quantum is 2% lower than the accepted value for e.
6. a. acting on negative sphere: 0.15 N, left; acting on positive sphere: 0.15 N, right
   b. Electrons in the negative sphere will shift to the left being attracted to the positive sphere and electrons in the positive sphere will shift to the left being repelled by the negative sphere. This induction makes the left side of the negative sphere more negative and it leaves the right side of the positive sphere more positive. This effectively decreases the distance between the charges and increases the attraction to an amount greater than 0.15 N.
   c. By conservation of charge there must be +1.4 μC of charge somewhere (so that the net amount produced is zero) – the base of the generator, the Earth, and the wire itself are likely locations of this "missing charge".

7. a. 71 N
b. 6.0×10^{-35} N
c. Adding two more gravitational forces of this size would triple the amount but would not come at all close to equaling the 71 N of repulsion. And that is assuming the three gravitational forces act in the same direction, which is not the case.
d. The strong nuclear force is an additional force acting on the particles and binds the nucleus together. The net strong nuclear force on each proton must be approximately 71 N!

8. a. 1.86×10^{-9} kg – a cube about 0.1 mm on each side, roughly the size of a period mark made by a pencil
b. 9.33×10^{16} atoms in each chunk – if only *one* of these atoms in each chunk loses or gains an electron then the electric force is as great as the gravitational force!

9. charges: 1.6×10^{-19} C (1 *e*) and 3.2×10^{-19} C (2 *e*) signs cannot be determined
masses: 5.0×10^{-27} kg (3.0 u) and 6.6×10^{-27} kg (4.0 u)
One possibility is a triton or hydrogen-3 nucleus (^{3}H) and an alpha particle or helium-4 nucleus (^{4}He). However, there is insufficient information to determine which mass goes with which charge so other scenarios exist if electrons are involved…

10. a. 5.1×10^{-5} N, 0.0° on middle charge
b. 2.9×10^{-5} N, 180.0° on left charge
(2.2×10^{-5} N, 180.0° on right charge)

11. a. 0
b. $d\sqrt{\frac{q_3}{q_1}}$
c. 2*F*, opposite the other two net forces

12. 1.1×10^{-5} N away from center of square

13. 0.286 m/s^2, 0.0°

14. a. 34$\underline{0}$ kN/C, 0.0°
b. 1.4 mN, 180.0°

15. a. 2.0×10^{5} N/C toward the sphere
b. 1.4×10^{-3} N
c. ±9.8 nC

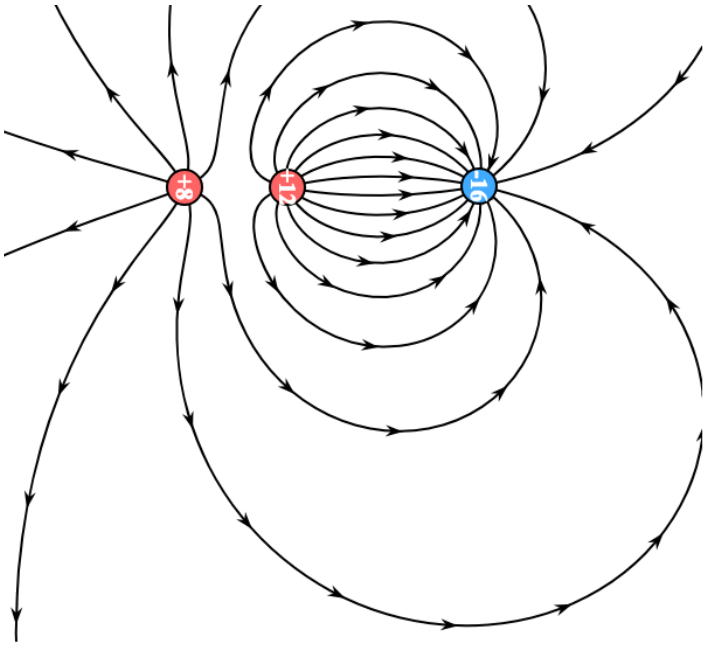
16. a. 4$\underline{0}$0 N/C, 270°
b. 1600 N/C, 0°
c. 4$\underline{0}$0 kN/C, 90°; 1600 kN/C, 180°

17. a. 7.5 μC
b. 5.3×10^{17} m/s^2

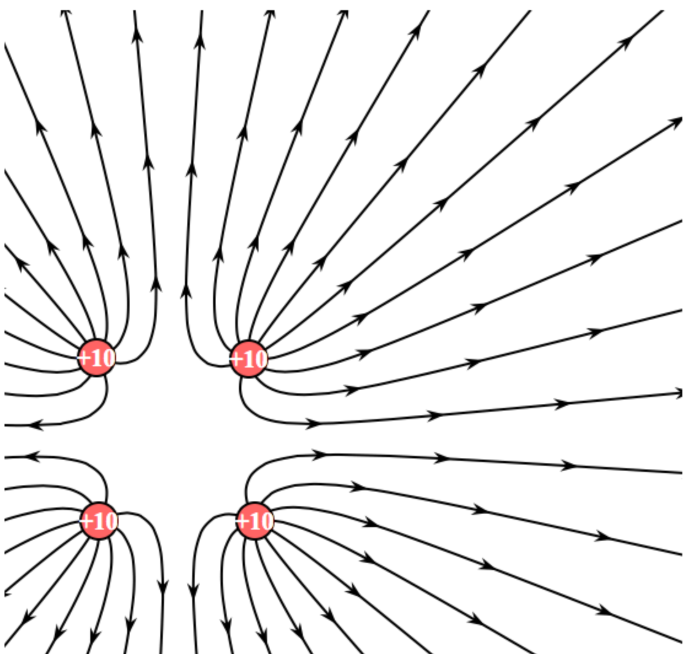
18. a. $Q = 4\pi\varepsilon_0 R^2 E$
b. 3.2, 10, 32

19. a. sketch of field
b. 64 kN/C toward the neg. sphere
c. 810 kN/C toward the neg. sphere

20. a.



b.



21. a. at the 60° vertex: $-\frac{8\sqrt{3}}{9}q$; at the 30° vertex: $-8q$

b. toward the hypotenuse at angle 30° relative to the long leg

22. a. $-4q$

b. $\vec{E} = \frac{3kq}{d^2}$, 30°

23. 2.4×10^{-19} J (or 1.5 eV)

24. a. 11 kC

b. 2900 mA h

25. a. 2.9 kV
    b. 5.3 MV
    c. By conservation of energy the electrons must gain a certain amount of kinetic energy governed by the voltage difference of the electrodes regardless of the distance. If the distance is increased the electric field is less, the acceleration is less, but the final speed should be the same. A more compact design has obvious advantages but there must be a sufficient distance between the plates to prevent a discharge of the electrons from one to the other.
26. a. 1400 N/C
    b. 360 V
27. a. −6.5 μC
    b. 450 V
28. a. −3.6 μJ
    b. 5×10^{-3} m/s slower due to electric field (7.663 m/s vs. 7.668 m/s)
29. a. 540 kN/C
    b. 570 V
    c. 1.1 mm
30. a. 35 kN/C
    b. 5.6×10^{-17} J
    c. 1.1×10^{7} m/s
31. a. 12°
    b. 6.4×10^{7} m/s
32. a. 630 kN/C pointing radially inward toward a point
    b. –6.3 μC This is comparable to a Van de Graaff sphere, so yes, doable!
    c. Normally it is assumed that celestial bodies have a net zero charge and the only force involved in orbital motion is gravity. However it is at least conceivable that a celestial object could have a net charge that would result in a force either supplementing or opposing gravity as the object orbits.
33. a. 240 V, 120 V; –240 kV, –120 kV
    b. field lines radially outward, isolines concentric circles;
    field lines radially inward, isolines concentric circles
    c. Electric field always points toward lower potential, very similar to the way that the force of gravity always points toward locations of less gravitational potential energy.
34. a. 27 kV, 140 kV
    b. 110 kV
    c. 3.1 m/s
35. a. At its release position the electric force upward is less than the gravitational force downward, therefore it accelerates downward and falls initially.
    b. Judging by values found in the previous problem, if it were to impact the sphere it would gain *more* electric potential energy than it *loses* gravitational potential energy (and would either have negative kinetic energy or require an additional force doing work).
    c. At some point the falling ball would gain exactly the same amount of electric energy as it loses gravitational energy. At that point its kinetic energy must be zero and the electric force is greater than the gravitational force. It therefore would accelerate upward and rise from that instantaneous point of rest.

36. $v=\sqrt{\dfrac{Qq}{2\pi\varepsilon_0 Rm}}$ If the objects are like charges then release the particle from the surface of the sphere and maximum speed is attained at infinite distance. If the objects are opposite charges than release the particle from an infinite distance and maximum speed is attained at the surface of the sphere.

37. a. $V=-\dfrac{kq}{d}$

b. $x=\dfrac{d}{5}, x=-\dfrac{d}{3}$

c. At infinite distance from the origin in any direction both field and potential would approach zero in value. However, in the vicinity of the charges there is nowhere else that *both* field *and* potential are zero. There is only one position in the vicinity where the field is zero and the potential there is not zero.

38. a. V = – 62.4916 MJ/kg, – 62.4035 MJ/kg

b. ΔV = +88.1 kJ/kg

c. ΔU = 8.81 MJ

d. ΔU = 8.82 MJ – not exactly correct because it is based on the assumption of a uniform gravitational field. In reality the value of g steadily decreases as altitude increases; because of this, *mgh* is an *over*estimate in this problem.