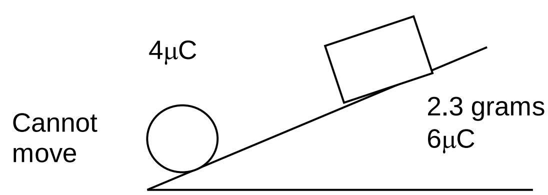
Unit #6: Review Sheet
Electrostatics, Electric Fields, Electric Potential

- Charges are one of two types – positive or negative.
- The smallest known charge to exist by itself is the charge on an electron (or proton) – 1.6×10^{-19} C
- The electric force is the force of either attraction or repulsion between two charges, or charged objects.
- Like charges repel one another; unlike charges attract one another.
- Coulomb's Law: Electric force = $F_e = kQ_1Q_2/r^2$
  - k = Coulomb's constant = 9.0×10^9 N-m^2/C^2
  - Q_1 = the size of one charge (in Coulombs)
  - Q_2 – the size of the second charge (in Coulombs)
  - r = the distance separating the two charges.
- While Coulomb's Law is straightforward, in order to find the electric force acting on a charged particle q, we must calculate the force between each individual charge and charge q and add these forces up as vectors.
- Such calculations are simplified by introducing a new term: the electric field.
- Electric field = F/q (units: N/C = V/m)
- Electric fields, just like forces, are vectors and must be treated as such.
- The magnitude of the electric field at a distance r from a point charge Q = kQ/r^2. The direction of the electric field is in the direction that the electric force would act on a small positive test charge.
- Electric fields are illustrated with electric field lines. Be sure to review what electric field lines are constructed, and the rules associated with them.

1. What force acts between two positively charged particles that are separated by a distance of 103 mm? The two charges are 3μC and 8μC. [20.36 N]

2. What is the charge on Particle 1 if it levitates over Particle 2 (3.2×10^{-8} C) at a height of 2 cm? The mass of Particle 1 is .82-grams. Assume the particles are on the surface of the Earth (g = 9.8 m/sec^2). [1.12×10^{-8} C]

3. At what distance from the 4×10^{-6} C charge is the 2.3-gram mass shown at right in equilibrium? The angle of the incline is 28 degrees. Assume a frictionless incline. [4.52 m]

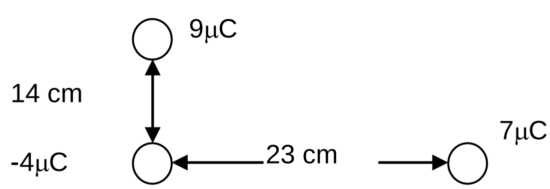


4. A mass with a charge of 4.6×10^{-7} C rests on a frictionless surface. A compressed spring exerts a force on the mass on the left side. Three centimeters to the right of the mass is a 7.5×10^{-7} C charge that can not move. How much is the spring compressed if the spring constant of the spring is 14 N/m? [24.6 cm]

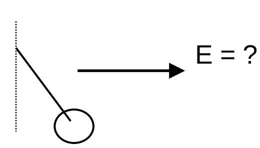
5. A 0.6-gram object with a charge of 8×10^{-7} C orbits a second object that has a charge of -5×10^{-8} C. The radius of the orbit is 13 mm. What is the orbital velocity of the object in orbit? [6.79 m/sec]

6. An 800-gram block with a charge of 6μC is placed 31 cm away from a charged object of –7μC (that can not move) on a horizontal frictional surface (μ = 0.3). What is the magnitude and direction of the acceleration of the mass? [1.98 m/sec^2, toward the charge]

7. What is the magnitude and direction of the net force acting on the 7μC charge? [4.5 N to the right, 64.7° below the horizontal]



8. What electric field must be present to suspend the 7-gram, 4×10^{-9} C charged ball at an angle of 35 degrees from the vertical? [1.2×10^7 N/C]

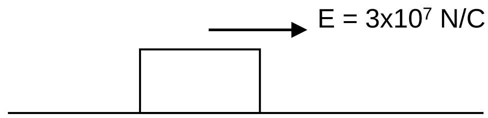


9. A 43-gram mass carries a charge of $9\mu C$. What vertical, upward-directed electric field is needed to lift it off the ground. Assume the mass is at the Earth's surface. [4.68×10^4 N/C]

10. A ball with a mass of 4500 grams and having a charge of $5\mu C$ is suspended from a string. If a vertically downward electric field of 6×10^7 N/C is turned on, what will the tension in the string be? [344.1 N]

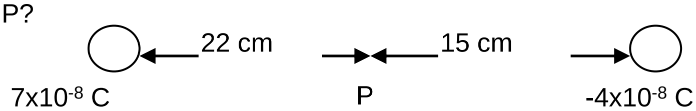
11. A 3.4×10^{-8} C charge feels a force of 2.6 N. What electric field is present? [7.65×10^7 N/C]

12. The 500-gram mass to the right has a charge of -7×10^{-8} C. If the coefficient of friction between the mass and the ground is $\mu = 0.2$, and an electric field is present as shown, what is the acceleration of the mass? [2.24 m/sec^2 to the left]



13. What is the magnitude and direction of the electric field generated by a $13\mu C$ charge located 8.9 cm away from the charge? [1.48×10^7 N/C, directed away from the charge]

14. What is the net electric field at point P? [2.90×10^4 N/C, directed to the right]



15. How much energy does a person carrying a package with a charge of $25\mu C$ require in order to be able to walk three meters head-on into an electric field with a strength of 7×10^7 N/C? [5250 J]

- The potential energy of charged particles depends upon their location relative to one or more "fixed" charges. Therefore, we seek to come up with a description of the space around the charged particles that will describe the potential energies a particle will have in this space.
- Electric potential = voltage = V = electrical potential energy of charge q / q. Here, q is the charge having the potential energy, not the charge(s) generating the potential itself.
- Units of V: J/C = 1 Volt
- We can describe the electric potential of a point in space.
- The electric potential for a point charge at a point a distance r from the point charge = kQ/r
- If you have multiple points, simply add up the V's from all of the points using negative signs to account for the sign on the charge.
- We also consider the difference in potential between two points. If an object's potential energy changes, work is done to (or by) the object. This amount of work (or change in potential energy) of a particle within an electric field can be related to the electric potential (V):
- $V_{ba} = V_b - V_a = W_{ba}/q = \Delta PE/q$. Here, we speak in terms of a charge moving from point a to point b.
- In a uniform electric field (e.g. between the plates of a charged capacitor), the electric field E is uniform throughout the space between the plates.
- For a uniform electric field, V = Ed where E is the field strength, and d is the distance between the plates.
- Positive charges "fall" (by themselves) from areas of high potential energy (high electric potentials) to low potential energies (low electric potentials). Negative charges will do the opposite. As the potential energy is reduced, energy transformation occurs. Often, electrical potential energy becomes kinetic energy.
- Equipotential surfaces are points in space within an electric field in which all points on the surface are at an equal electric potential. These surfaces are always at right angles to electric field lines.
- The work required to bring a positive charge q in from infinity to within a distance of r from a second positive charge Q equals kQq/r. This is the same amount of work required to take a negative charge q from a second positive charge Q a distance r away from Q to infinity.

16. An electron is released within a uniform electric field generated by two parallel plates. The plates are separated by 4 cm and the electric field as a strength of 28,000 N/C. After the electron has moved across the entire gap between the plates, what is the speed of the electron? (Hint: think work and energy). [1.98×10^7 m/sec]

17. What is the potential 3×10^{-11} m from an electron? [-48.0 V]

18. Points A and B are 1.7 m and 3.0 m respectively from a point charge of 4×10^{-6} C. Find V_A, V_B, and V_{BA}. [2.12×10^4 V, 1.2×10^4 V, $-.92\times10^4$ V]

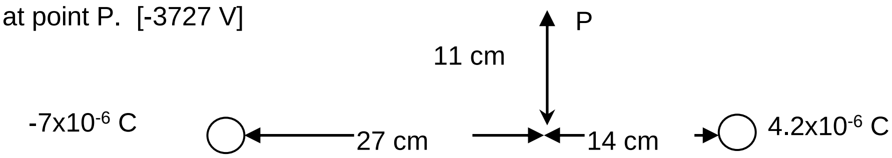
19. If an electron is released from infinity, how fast will it be traveling after falling to within 0.1×10^{-9} m of a proton? (Hint: How much work does it require to take the electron from r to infinity?) [2.25×10^6 m/sec]

20. Two plates are separated by 0.92 cm. If there is an electric field of 7×10^6 N/C between the plates, what is the potential between them? [6.44×10^4 V]

21. If an electron is released from a point in space and falls through a potential difference of 3.7×10^4 V, how much kinetic energy (in eV) will it gain? [37000 eV]

22. A 5μC charge is brought from infinity to a distance of .0003 cm from a 1.7×10^{-4} C charge. How much work was required in moving the 5μC charge? What is the final potential energy of the 5μC charge? What is the electric potential at the final position of the 5μC charge? [2.55×10^6 J, 2.55×10^6 J, 5.10×10^{12} V]

23. Find the potential at point P. [-3727 V]



24. A proton falls toward a negative plate at ½ the speed of light (1.5×10^8 m/sec). What is the potential between the plates? [1.17×10^8 V]

- Capacitors consist of parallel plates that store charge. Each plate is of area A, and the plates are separated by a distance d.
- When connected to a battery, the battery stores charge on the plates of the capacitor by removing electrons on one plate and storing them on the second.
- $Q = CV$ Q = the charge on each plate of the capacitor; V = the voltage across the charged capacitor.
- $C = \varepsilon_o(A/d)$ (for capacitors with a space filled with either air or a vacuum)
- $C = K\,\varepsilon_o(A/d)$ (for capacitors with a space filled with a dielectric; K = the dielectric constant for the material – a constant)
- ε_o = the permittivity of free space = a constant = 8.85×10^{-12} $C^2/(N\text{-}m^2)$
- The use of a dielectric increases the capacitance of a capacitor (and the energy stored in a capacitor) by increasing the quantity of charge that can be placed upon either plate of the capacitor.
- A capacitor stores energy. Energy can be thought to reside within the electric field between the two plates.
- The energy stored in a charged capacitor = $\frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}Q^2/C$

25. What is the capacitance of a capacitor that stores 4×10^{-3} C when 500 V is applied to it? [8μF]

26. What charge is deposited on a 40μF capacitor when 15 V is applied to it? [6×10^{-4} C]

27. 500 V will deposit 9×10^{-7} C when it is applied across a capacitor. What potential will be required to deposit 12×10^{-8} C on the same capacitor? [66.7 V]

28. How strong is the electric field between the plates of a 20-μF air-gap capacitor if they are 2.0 mm apart and each as a charge of 300 μC? [7500 V/m]

29. Dry air will break down if the electric field exceeds 3.0×10^6 V/m. What amount of charge can be placed on a capacitor if the area of each plate is 10 cm^2? [2.66×10^{-8} C]

30. A capacitor is made of two plates with an area of .01 m^2, separated by 2 cm. How much charge can be stored on this capacitor if it is connected to a 12-V battery and the capacitor has an air gap? How much charge can be stored if a mica dielectric is inserted within the same capacitor? [5.31×10^{-11} C; 3.72×10^{-10} C]