Study Guide for PHYS135B Module 2, Spring 2021

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March 21, 2021

Instructions: Work each problem *before* checking your answer with the key (to follow on Moodle).

1 Memory Bank

1. $V = (4/3)\pi r^3$ ... The volume of a sphere.
2. $m = \rho V$ ... The relationship between mass m, density ρ, and volume V.
3. $\vec{F} = k\frac{q_1 q_2}{r^2}\hat{r}$ ... Coulomb Force
4. $k = 9 \times 10^9$ N C^{-2} m^2 ... Remember $k = 1/(4\pi\epsilon_0)$.
5. $q_e = 1.6 \times 10^{-19}$ C ... Charge of an electron/proton
6. Atomic mass: the number of grams per mole of a substance
7. $N_A = 6.03 \times 10^{23}$ ... Avagadro's number
8. $\vec{F} = q\vec{E}$ ... Electric field and charge
9. $\vec{E}(z) = \frac{\sigma}{\epsilon_0}\hat{z}$ ... Electric field of two oppositely charge planes each with charge density σ
10. $\epsilon_0 \approx 8.85 \times 10^{-12}$ F/m
11. $U = q\Delta V$ ... Potential energy and voltage
12. 1 eV: an electron-Volt is the amount of energy one electron gains through 1 V.
13. $V(r) = k\frac{q}{r}$ ... Voltage of a point charge
14. $\vec{E} = -\frac{\Delta V}{\Delta x}$ ... E-field is the slope or change in voltage with respect to distance
15. $V(x) = -Ex + V_0$ ... Voltage is linear between two charge planes
16. $Q = C\Delta V$ ... Definition of capacitance
17. $C = \frac{\epsilon_0 A}{d}$ ... Capacitance of a parallel plate capacitor
18. $C_{tot}^{-1} = C_1^{-1} + C_2^{-2}$ ... Adding two capacitors *in series.*
19. $C_{tot} = C_1 + C_2$ ... Adding two capacitors *in parallel.*
20. $i(t) = \Delta Q/\Delta t$ ... Definition of current.
21. $v_d = i/(nqA)$ ... Charge drift velocity in a current i in a conductor with number density n and area A.
22. $R_{tot}^{-1} = R_1^{-1} + R_2^{-1}$ ... Adding two capacitors *in parallel.*
23. $R_{tot} = R_1 + R_2$ ... Adding two capacitors *in series.*
24. $\Delta V = IR_{\rm tot}$ ... Ohm's Law
25. $P = IV$ ... Relationship between power, current, and voltage.
26. $V_{\rm C}(t) = \epsilon_1 (1 - \exp(-t/\tau))$ ... voltage across the capacitor in an RC series circuit. The time constant is $\tau = RC$.
27. $i(t) = \frac{\epsilon_1}{R}\exp(-t/\tau)$ ... Current in an RC series circuit.
28. $i_{\rm in} = i_{\rm out}$ ... Kirchhoff's junction rule.
29. $\epsilon_1 + \epsilon_2 + \epsilon_3 + ... = 0$ ... Kirchhoff's loop rule.

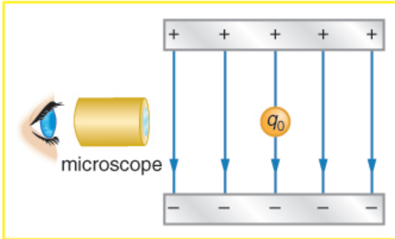

Figure 1: The classic Millikan oil drop experiment was a measurement of the charge of an electron.

2 Electric Charge and Electric Fields

1. (a) Two charges exert $F_C = 5.00$ N of force on each other. What will F_C be if the distance between them triples? (b) If one charge is 1 nC, and the other is 2 nC, what is the distance between them if $F_C = 5.00$ N?

2. The classic Millikan oil drop experiment was the first to measure accurately the electron charge. Oil drops were suspended against the gravitational force by a vertical electric field. (See Fig. 1.) The drops have radius 1.0μm, and a density of 920 kg/m^3. (a) Find the weight of the drop. (b) If the drop has a single excess electron, find the electric field strength needed to balance its weight.

3. Suppose two positive, identical charges are located a distance d apart. (a) Sketch the electric field below. (b) Sketch the electric field if instead one of the charges is negative.

3 Potential Energy and Voltage

1. What is the electric field across an 10.00 nm thick human nerve cell membrane if (a) the voltage across it is 50 mV? You may assume a uniform electric field. (b) Suppose this cell membrane is part of a nerve cell. How much energy would an electron gain if dropped through the 50 mV voltage and accelerated across the cell freely? Express your anser in electron-Volts (eV).

2. **Think back to the PhET simulations of parallel lines of charge.** Suppose a parallel plate capacitor is formed from a positive plate and a negative plate of charge. The plates' areas A are the same, and the plates' charges ($\pm Q$), and charge densities ($\pm Q/A = \pm\sigma$) are the same as well. (a) Write the expression for the electric field between the plates. (b) Suppose $Q = 1$ nC, and $A = 10$ mm^2. What is the value of the electric field between the plates? (c) Suppose 0 volts corresponds to the location of the negative plate. Draw the voltage as a function of distance between the plates. (d) What is the voltage near the positive plate, if the plates are are separated by a distance $d = 1$ mm?

4 Capacitors

1. What is the capacitance of the capacitor in the previous problem?

2. (a) Consider the same capacitor again, and suppose a second identical capacitor is connected *in parallel* with it. What is the total capacitance? (b) How much charge would the pair of capacitors store if the voltage across them was 5 volts?

3. How much energy in Joules would this charge have if it was all put to work?

5 Current, Resistance, and DC Circuits

1. Three identical resistors R are connected *in parallel*, and powered by an adjustable voltage source. The voltage and *total current* measurements are shown below. Determine the value of R.

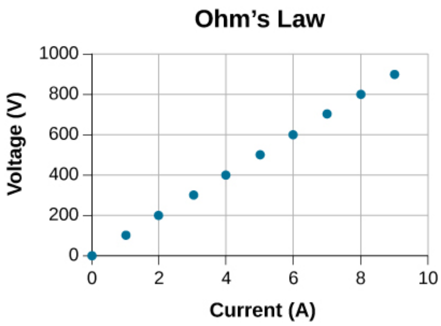

Figure 2: A graph of voltage versus current.

2. (a) Using the PHeT tool for DC circuit construction, design a circuit in which a battery with *fixed voltage* lights a bulb, but the bulb brightness can be dimmed or brightened. *Hint: use other components in series with the bulb.* Draw your design below. (b) Now make a parallel circuit in which two bulbs can be brightened or dimmed independently, and use switches to turn them on or off independently. Draw your design below.