Study Guide for Midterm 1 for Calculus-Based Physics: Electricity and Magnetism

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Instructions: Work each problem before looking at the given answer. See if you first understand the problem *conceptually*, then work out the mathematics, then end with plugging in relevant data.

Memory Bank:

1. Coulomb Force: $\vec{F} = k\frac{q_1 q_2}{r^2}\hat{r}$
2. $k = 9 \times 10^9$ N C^{-2} m^2
3. $q_e = 1.6 \times 10^{-19}$ C
4. Mass of a proton: 1.67×10^{-27} kg
5. Electric field and charge: $\vec{F} = q\vec{E}$
6. Field of infinite wire of charge density λ: $\vec{E}(z) = \frac{2k\lambda}{z}\hat{z}$
7. Field of two oppositely charged infinite planes, with charge density σ: $\vec{E}(z) = \frac{\sigma}{\epsilon_0}\hat{z}$
8. $\epsilon_0 \approx 8.85 \times 10^{-12}$ F/m
9. Dipole moment: $\vec{p} = q\vec{d}$
10. Torque on dipole moment: $\vec{\tau} = \vec{p} \times \vec{E}$
11. Electric flux: $\Phi = \vec{E} \cdot \vec{A} = EA\cos\theta$
12. Gauss' law: $\Phi = Q_{enc}/\epsilon_0$
13. Potential energy and voltage: $U = q\Delta V$
14. Voltage of a point charge: $V(r) = k\frac{q}{r}$
15. Voltage and E-field: $\vec{E} = -\nabla V$, single-variable $\vec{E} = -\frac{dV}{dx}$
16. Constant E-field: $E = \frac{\Delta V}{\Delta x}$
17. E-field and voltage: $\Delta V = -\int \vec{E} \cdot d\vec{x}$
18. Capacitance: $Q = CV$
19. Parallel plate capacitor: $C = \frac{\epsilon_0 A}{d}$
20. Adding two capacitors in series: $C_{tot}^{-1} = C_1^{-1} + C_2^{-2}$
21. Adding two capacitors in parallel: $C_{tot} = C_1 + C_2$
22. Definition of current: $I(t) = \frac{dQ}{dt}$
23. Drift velocity: $v_d = \frac{I}{nAq}$
24. Ohm's law: $V = IR$
25. **Adding two resistors in series** $R_{tot} = R_1 + R_2$
26. **Adding two resistors in parallel** $R_{tot}^{-1} = R_1^{-1} + R_2^{-2}$

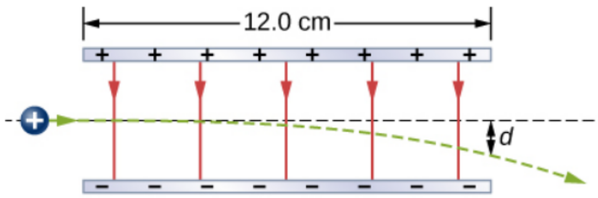

Figure 1: A constant E-field deflecting a positive charge q.

1. **Chapter 5, Electrostatics**

   (a) Protons in an atomic nucleus are typically 10^{-15} m apart. What is the electric force of repulsion between nuclear protons?

   Using $F = \frac{kq_e^2}{r^2}$, we find $F \approx 230$ N.

   (b) A charge $q_1 = 20\mu$C and a charge $q_2 = 10\mu$C are 1.0 m apart. What is the force on a positive test charge halfway between them, and in which direction is the force?

   The electric field points away from q_1 and has a magnitude of 3.6×10^5 N/C. Suppose the test charge has a charge q. The force is $F = qE$.

   (c) Suppose the "deflector" in Fig. 1 is $d = 12$ cm long. If a proton (mass given in Memory Bank) has an initial speed of $v = 1.5 \times 10^7$ m/s, and the field depicted is 4.0×10^5 N/C, by how much has it been deflected? (What is d?).

   Using kinematics and the fact that $F = qE$, $d = \frac{1}{2}\frac{qE}{m}\left(\frac{\Delta x}{v}\right)^2 \approx 1.15$ mm.

2. **Chapter 6, Gauss' Law**

   (a) Show that the field a distance z above an infinite line of charge with charge density λ (C/m) is $\vec{E}(z) = \frac{2k\lambda}{z}\hat{z}$. Use a Gaussian surface that has *cylindrical symmetry.*

   See Figure 6.29 of the text.

3. **Chapter 7, Voltage**

   (a) A lightning bolt strikes a tree, moving 20.0 C of charge through a potential difference of 10^8 Volts. What energy was dissipated?

   $U = 2 \times 10^9$ J, or 2 GJ.

   (b) Consult again Fig. 1. If the plates are 6 cm apart, and the field is still 4.0×10^5 N/C, what is the voltage difference between the plates?

   Using $E = \Delta V/\Delta x \rightarrow V = E\Delta x$, we find 24 kV.

4. **Chapter 8, Capacitance**

   (a) Find the charge stored when 5.0 V is applied to an 8.00 pF capacitor.

   Using $q = CV$, we find 40 pC.

   (b) Find the charge stored when 5.0 V is applied to two 8.00 pF capacitors *in parallel.*

   80 pC, from scaling.

   (c) Find the charge stored when 5.0 V is applied to two 8.00 pF capacitors *in series.*

   20 pC, from scaling.

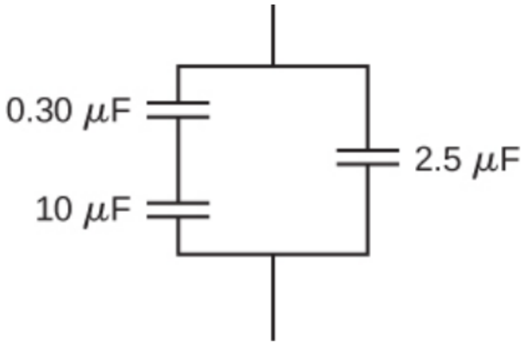

Figure 2: Three capacitors connected together.

(d) Find the total capacitance in the circuit diagram of Fig. 2.

The two capacitors on the left side are added in series, and that is added in parallel with the right-hand capacitor. The result is 2.8μF.

5. **Chapter 9, Current and Ohm's law**

(a) What current passes through a resistor with $R = 1$ kΩ, if the voltage applied is 12 V?

Using Ohm's Law, we find 12 mA.

(b) What current passes through two resistors with $R = 1$ kΩ, if the voltage applied is 12 V, and the resistors are connected *in series*? Draw a circuit diagram.

6 mA, from scaling, and the fact that the total resistance has doubled.

(c) What current passes through two resistors with $R = 1$ kΩ, if the voltage applied is 12 V, and the resistors are connected *in parallel*? Draw a circuit diagram.

24 mA, from scaling, and the fact that the total resistance has been halved relative to the first question.