Midterm 1 for Calculus-Based Physics: Electricity and Magnetism

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March 6, 2019

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** $R_{tot}^{-1} = R_1^{-1} + R_2^{-2}$

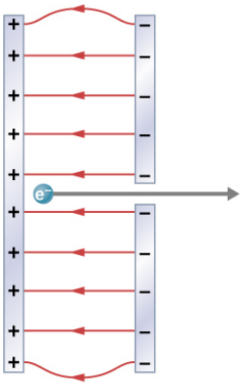

Figure 1: A device accelerating a **positively charged** particle to the right.

1. **Chapter 5, Electrostatics**

   (a) Two electrons approach each other in space. What is the electric force of repulsion between them when they are separated by 10^{-14} m?

   (b) A charge q_1 is located at (-2,0) in a 2D coordinate system, and a charge q_2 is located at (4,0). If $2q_1 = q_2$, find the value of the electric field at (0,0).

   (c) In Fig. 1, assume a proton is being accelerated to the right. (a) If the electric field is $E = 2000$ N/C to the right, what is the force on the proton? (b) Using Newton's Second Law, show that the acceleration is $a = (q/m)E$. (c) Recall that an object that is accelerating travels a distance d in a time t according to $d = \frac{1}{2}at^2$. How far has the proton travelled in 1 μs?

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

   (a) Derive (a) the electric field of a point charge using Gauss' Law. (b) Derive the electric field versus r of a solid sphere of constant charge density ρ_0 and radius R, for $r > R$. (c) Do the results from (a) and (b) resemble each other? How?

3. **Chapter 7, Voltage**

   (a) An arch of electricity sends 2.0 C of charge through a potential of 10^5 Volts. What energy was dissipated?

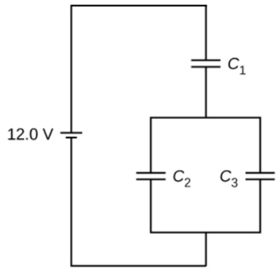

Figure 2: A circuit of capacitors.

(b) Consult again Fig. 1. (a) If the plates are 100 cm apart, and the field is still 2000 N/C, what is the voltage difference between the plates? (b) Draw the voltage as a function of distance between the plates.

4. **Chapter 8, Capacitance**

(a) Find the charge stored when 5.0 V is applied to an 50.0 pF capacitor.

(b) Find the charge stored when 5.0 V is applied to two 50.0 pF capacitors *in parallel*.

(c) Consult Fig. 2. If $C_1 = 50.0$ pF, $C_2 = 25.0$ pF, and $C_3 = 5.0$ pF, and $V = 12.0$ Volts, what is the total charge?

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

(a) Suppose the charge collected in a capacitor is measured to follow the function $Q(t) = -Q_0 \exp(-t/\tau)$. What is the current flowing into the capacitor?

(b) Suppose two resistors $R_1 = 1\text{k}\Omega$ and $R_2 = 10\text{k}\Omega$ are connected *in parallel* to a 5.0 V battery. What is the current that flows from the battery?