Midterm 1 for Calculus-Based Physics: Electricity and Magnetism

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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: $C_{tot}^{-1} = C_1^{-1} + C_2^{-1}$
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. Power: $P = IV$
26. **Adding two resistors in series** $R_{tot} = R_1 + R_2$
27. **Adding two resistors in parallel** $R_{tot}^{-1} = R_1^{-1} + R_2^{-1}$

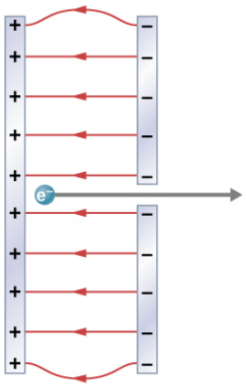

Figure 1: A device accelerating a **positively charged** particle to the right.

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^{-13} m?

   (b) A charge q_1 is located at (-2,-2) m in a 2D coordinate system, a charge q_2 is located at (-2,2) m, a charge q_3 is located at (2,2) m, and a charge q_4 is located at (2,-2) m. If $q_1 = q_2 = 20\mu$ C, and $q_3 = q_4 = 40\mu$ C, 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) Show that the electric field of an infinite line of charge with charge per unit length λ is $E = \lambda/(2\pi\epsilon_0 r)$, if the test charge is a distance r from the line.

3. **Chapter 7, Voltage**

   (a) An arch of electricity sends 10.0 C of charge through a potential of 10^4 Volts, and a second arch sends 1.0 C of charge through a potential of 10^5 Volts. What total energy was dissipated? (Add the two energies).

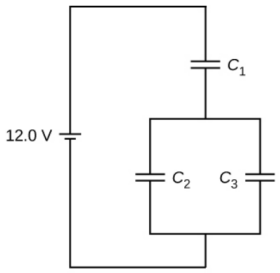

Figure 2: A circuit of capacitors.

(b) Consult again Fig. 1. (a) If the plates are 150 cm apart, and the field is still 2000 N/C, what is the voltage difference between the plates? (b) Draw $V(x)$, the voltage as a function of distance x between the plates.

(c) If a charge $q_1 = 10$ nC is fixed in place, and a charge of $q_2 = 0.1$ nC is placed a distance of 1 m from it, (a) what is the potential energy of q_2? (b) If q_2 has a mass of 10^{-6} kg, what speed will it reach if it is released?

4. **Chapter 8, Capacitance**

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

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

(c) Consult Fig. 2. If $C_1 = C_2 = C_3 = 0.1\ \mu$ F, and $V = 12.0$ Volts, what is the total charge stored?

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

(a) Suppose the charge collected in a capacitor is measured to follow the function $Q(t) = -Q_0 \exp(-t/\tau)$. (a) Using the definition of current, show that the current into the capacitor is $i(t) = (Q_0/\tau)\exp(-t/\tau)$. (b) If $\tau = RC$, with $R = 1000\Omega$, and $C = 1.0\mu$F, and $Q_0 = 1\mu$ C, what is the current when $t = 5$ ms?

(b) Suppose two resistors R_1 and R_2 are both 1000Ω, and are connected in parallel to a 5V battery. (a) What is the total current flowing from the battery? (b) What is the power being provided by the battery?