Study Guide for Final Exam for Algebra-Based Physics-2: Electricity, Magnetism, and Modern Physics (PHYS135B-01)

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1. **Electric charge and electric fields**

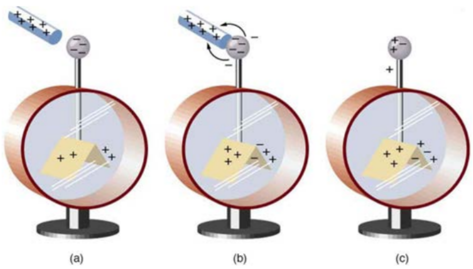

Figure 1: Touching charge to an electroscope. A glass rod with a positive net charge is moved near the ball. Initially, the electroscope is electrically neutral.

(a) Which of the following is true of the electroscope in part (a) of Fig. 1?
- A: The net charge in the gold leaves plus the ball is positive.
- B: The net charge in the gold leaves plus the ball is negative.
- C: The net charge in the gold leaves plus the ball is zero.
- D: The net charge in the gold leaves plus the ball is equal and opposite to that of the rod.

(b) Which of the following is true of the electroscope in part (b) of Fig. 1?
- A: Touching the positive rod to the ball causes current to flow.
- B: Touching the positive rod to the ball leaves the electroscope with a positive charge.
- C: Touching the positive rod to the ball increases the net charge of the rod.
- D: A and B

(c) Which of the following is true of the electroscope in part (c) of Fig. 1?
- A: Charge redistributes evenly, and the leaves remain apart.
- B: Charge redistributes evenly, and the leaves close.
- C: Charge redistributes non-uniformly and so the leaves remain apart.
- D: Charge redistributes non-uniformly and so the leaves close.

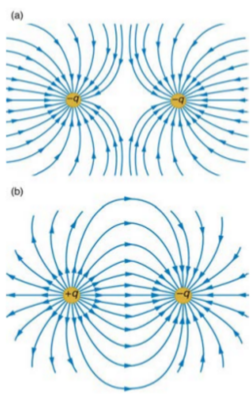

Figure 2: (Top) The electric field of two positive charges. (Bottom) The electric field of a dipole.

(d) A test charge $+q$ in between the charges in Fig. 2 (a) will:

- A: Move to the left
- B: Move to the right
- C: Remain stationary
- D: Move down

(e) A test charge $+q$ in between the charges in Fig. 2 (b) will:

- A: Move to the left
- B: Move to the right
- C: Remain stationary
- D: Move down

(f) If a uniform external electric field points up in Fig. 2 (a), the charges will

- A: Move to the left
- B: Move to the right
- C: Remain stationary
- D: Move up

(g) If a uniform external electric field points up in Fig. 2 (b), the dipole will

- A: Rotate clockwise
- B: Rotate counter-clockwise
- C: Remain stationary
- D: Move down

2. **Electric potential and electric fields**

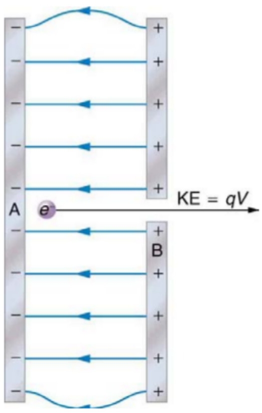

Figure 3: An electron is accelerated through a potential V.

(a) Suppose the voltage in Fig. 3 is 1 kV. The final energy of the electron is

- A: 1 Joule
- B: 1 eV
- C: 1 keV
- D: 10 Joules

(b) Suppose the voltage in Fig. 3 is doubled. The final velocity

- A: Increases by a factor of 2
- B: Increases by a factor of $\sqrt{2}$
- C: Increases by a factor of 4
- D: Decreases by a factor of 2

(c) Recall that the relationship between the voltage, electric field, and separation in a capacitor is $V = Ed$. What is the electric field inside a capacitor with separation 0.1 mm, and is charged at 12 V?

- A: 1.2 V/m
- B: 1.2 mV/m
- C: 120 kV/m
- D: 120 V/m

(d) Draw a graph of the voltage versus separation for the capacitor in the previous problem. Label which side of the graph corresponds to positive charge and which side corresponds to negative charge. Label the axes with approprate units.

(e) Recall that the definition of capacitance is $Q = CV$, for a charge Q and voltage V. How much charge is stored on the capacitor in the previous two problems ($V = 12$ V), if the capacitance is 1μF?

(f) The capacitance of a parallel plate capacitor is $C = \epsilon_0 A/d$, where A is the area of the plates, d is the separation between the plates, and $\epsilon_0 = 8.85 \times 10^{-12}$ N^{-1} C^2 m^{-2}. What is the capacitance of a capacitor with an area of 4 mm^2 and a separation of 1 mm?

(g) If two such capacitors are connected *in parallel*, what is the total capacitance? What is the total capacitance if they are connected *in series*?

3. **Electric current, resistance, and Ohm's law**

(a) Recall that Ohm's law states that $V = iR$, and that resistors in series add, while resistors in parallel add in reciprocal. Find the total current from the battery in the circuit drawn in Fig. 4.

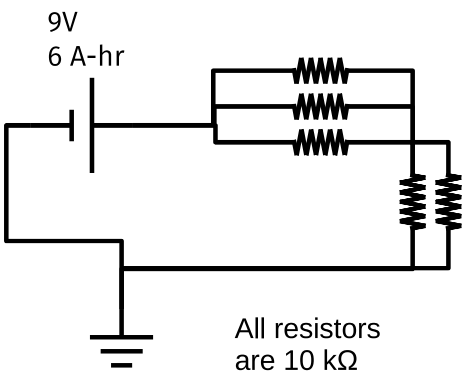

Figure 4: A DC circuit with a battery voltage of 9V and five identical resistors.

(b) How long before the charge in the battery is drained in the circuit in Fig. 4?

(c) How are the four stages of the voltage pulse in Fig. 5 created in the human body?

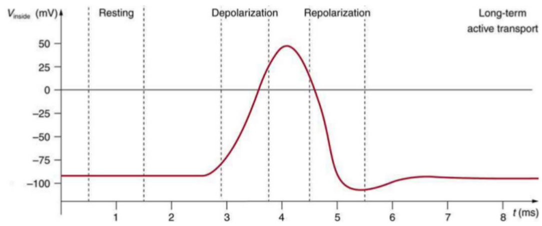

Figure 5: The voltage versus time of a nerve action pulse.

4. **Magnetism**

(a) The toroidal magnetic field in the tokamak fusion reactor in Fig. 6 is created by the external current. The plasma is hot ionized gas, and the *poloidal* magnetic field is created by it. In which direction is the plasma flowing, and which law of physics creates the poloidal field as a result?

- A: Counter-clockwise, Faraday's Law
- B: Counter-clockwise, Ampère's Law
- C: Clockwise, Faraday's Law
- D: Clockwise, Ampère's Law

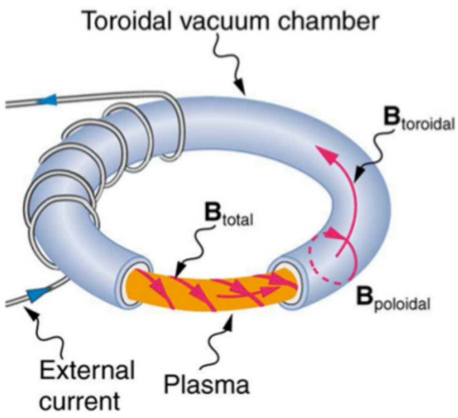

Figure 6: The basic premise of a tokamak, containing plasma for fusion reactions.

(b) Describe the motion of positively charged particles in the tokamak if they experience the toroidal magnetic field as a uniform field directed around the circle.

(c) The velocity of a fluid flowing through the line in Fig. 7 is being measured using the Hall effect. If the magnetic field is 10 gauss (10^{-3} T), the line has $l = 1$ cm, and $\epsilon = 10$ mV, what is the velocity of the fluid?

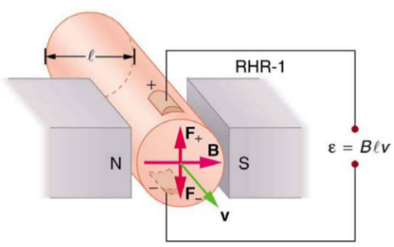

Figure 7: A hall voltage measurement of the velocity of a fluid.

5. **Electromagnetic waves**

(a) Recall that $c = f\lambda$. Using the speed of light ($c = 3.0 \times 10^8$ m/s), convert each of the following frequencies to their corresponding wavelengths:

- 10 MHz
- 100 MHz
- 1 GHz

(b) Recall that $c = f\lambda$ is modified to $c/n = f\lambda$ when an electromagnetic wave is traveling in a dielectric material, where n is the index of refraction. Suppose we record a radio wave traveling through a block of a substance that is 10 m long, and the wave travels for 67 ns from the start to the end of the block. What is the index of refraction n?

(c) If the frequency is 1 GHz, what is the wavelength *while the wave is inside the material*? (It's not the value for air).