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

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1. **Electric charge and electric fields**

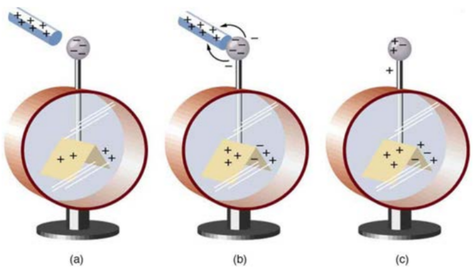

Figure 1: Touching charge to an electroscope. A glass rod with a positive net charge is moved near the ball. Initially, the electroscope is electrically neutral.

(a) In process (a)-(c) of Fig. 1, an electroscope gains a positive charge. The gold leaves each have a net positive charge and therefore remain apart. Suppose a charged particle like a cosmic ray passes between the leaves, and ionizes the air such that there is *temporarily* a negative charge in the air between the plates. What will happen?

- A: Nothing will happen. The leaves will remain apart.
- B: The angle between the leaves will decrease to a new value, and remain at that new value.
- C: The angle between the leaves will decrease to a new value temporarily, and spring back to the old value.

(b) Suppose one of the leaves in the electroscope in Fig. 1 is hit by a cosmic ray, and the cosmic ray *neutralizes it*. What will happen?

- A: Nothing will happen. The leaves will remain apart.
- B: The angle between the leaves will decrease to a new value, and remain at that new value.
- C: The angle between the leaves will decrease to a new value temporarily, and spring back to the old value.
- D: The angle between the leaves will decrease to zero.

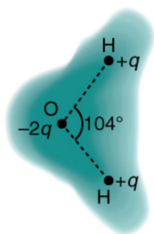

Figure 2: An illustration of the dipole moment of a water molecule.

(c) The charge distribution of a water molecule is modeled in Fig. 2. Recall that the electric *dipole moment* is $\vec{p} = q\vec{d}$, where d is a vector pointing from $-q$ to $+q$. There are two such vectors in the water molecule model in Fig. 2. In which direction does their sum point? This is the net dipole moment.

- A: Up
- B: Down
- C: Left
- D: Right

(d) If the molecule is in an electric field in the plane of the page and pointing up, what will happen?

- A: It will remain stationary.
- B: It will move up, but not spin.
- C: It will spin clockwise.
- D: It will spin counter-clockwise.

(e) If the molecule is in an electric field in the plane of the page and pointing down, what will happen?

- A: It will remain stationary.
- B: It will move down, but not spin.
- C: It will spin clockwise.
- D: It will spin counter-clockwise.

2. **Electric potential and electric fields**

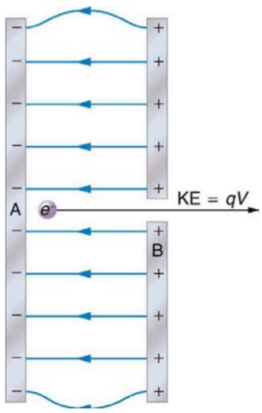

Figure 3: An electron is accelerated through a potential V.

(a) Suppose the voltage in Fig. 3 is 1 MV, and the particle has a charge equal to *three electrons*. The final energy of the particle is

- A: 1 keV
- B: 3 keV
- C: 1 MeV
- D: 3 MeV

(b) Suppose the charge of the particle in Fig. 3 is decreased by a factor of three. The final energy

- A: Increases by a factor of 3
- B: Increases by a factor of $\sqrt{3}$
- C: Decreases by a factor of 3
- D: Decreases by a factor of $\sqrt{3}$

(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 1 mm, and is charged at 3.3 V?

- A: 330 V/m
- B: 3.3 mV/m
- C: 33 V/m
- D: 3.3 kV/m

(d) Graph the voltage versus separation for the capacitor in the previous problem, and label the axes with approprate units. Indicate the x and y-intercepts and their corresponding numerical values.

(e) 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 2 mm^2 and a separation of 0.1 mm?

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.

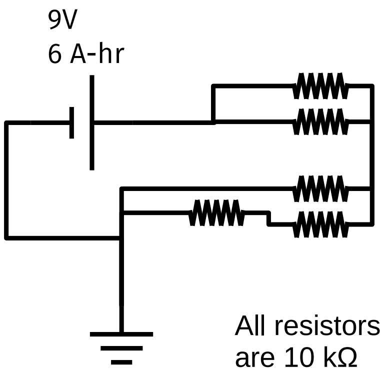

Figure 4: A DC circuit with a battery voltage of 9V and five identical resistors.

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

4. **Magnetism**

(a) The toroidal magnetic field in the tokamak fusion reactor in Fig. 5 is created by the external current. The plasma is hot ionized gas, and the *poloidal* magnetic field is created by it. If the direction of the current were reversed, in which direction would the toroidal magnetic field point?

- A: Counter-clockwise
- B: Clockwise
- C: Towards the center of the circle
- D: Away from the center of the circle

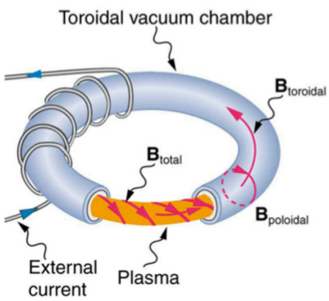

Figure 5: The basic premise of a tokamak, containing plasma for fusion reactions.

(b) A particular *proton* has a velocity component perpendicular to the toroidal field and parallel to the poloidal field. Describe its motion in words.

(c) A particular *electron* has a velocity component perpendicular to the toroidal field and parallel to the poloidal field. Describe its motion in words.

(d) The velocity of a fluid flowing through the line in Fig. 6 is being measured using the Hall effect. If the magnetic field is 10 gauss (10^{-3} T), the line has $l = 2$ cm, and $v = 20$ m/s, what is the Hall voltage?

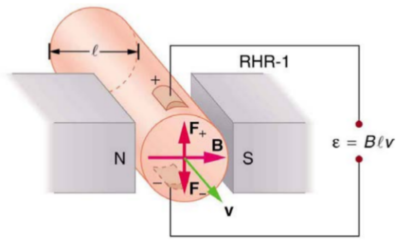

Figure 6: A hall voltage measurement of the velocity of a fluid.

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:

- 1 kHz
- 100 kHz
- 1 MHz

(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 1000 m long, and the wave travels for 7300 ns from the start to the end of the block. What is the index of refraction n?