PHY 101 Practice Exam III

Monday, November 27, 2:15-3:35PM

Please be sure to show your work where it is requested. If no work is shown where it is requested, you will not receive any points. Partial credit will be given where appropriate, so *show me your physics thoughts.* Don't forget to include units with your quantitative answers.

Please answer the following multiple choice questions. Circle only one answer per question.

(1) Electric potential, measured in Volts, is the ratio of electric energy to amount of electric
A. voltage.
B. charge.
C. current.
D. resistance.

(2) The unit F, the farad, is equal to which of the following?
A. Volt/meter
B. Volt/Coulomb
C. $Volt^2$/Coulomb
D. Coulomb/Volt

(3) How does the resistance of a piece of conducting wire change if both its length and diameter are tripled?
A. Remains the same
B. half as much
C. third as much
D. three times as much

$R = \rho \frac{L}{A}$

3b The magnetism of the Earth acts approximately as if it originates from a huge bar magnet within the Earth. Which of the following statements are true?
A. the north magnetic pole of the Earth is located at the Earth's North Pole
B. the south magnetic pole of the Earth is located at the Earth's South Pole
C. the Earth's North Pole is magnetically a south pole
D. the Earth's magnetic field is vertical at the equator

(4) A parallel plate capacitor is attached to a battery that supplies it a constant potential difference. While the battery is still attached, the parallel plates are separated a little more. Which statement describes what happens?
A. Both the electric field and the charge on the plates decrease.
B. The electric field increases and the charge on the plates decreases.
C. The electric field remains constant and the charge on the plates increases.
D. The electric field remains constant and the charge on the plate decreases.

$C = \varepsilon_0 \frac{A}{d}$ $E = \frac{Q}{\varepsilon_0 A}$ $\frac{\Delta V}{d} = E$

(5) A straight wire is carrying a current downward. Observed from above (i.e., looking downward towards the wire), the magnetic field lines are
A. forming counter-clockwise circles.
B. radially outward.
C. radially inward.
D. forming clockwise circles.

(6) Three 9 Ω (Ohm) resistors are connected together. What is the least resistance that can be attained with these resistors?
A. 1 Ω
B. 2 Ω
C. 3 Ω
D. 9 Ω

in parallel

(7) A tiny charged pellet of mass m is suspended at rest by the electric field between two horizontal, oppositely charged parallel plates. The lower plate has a positive charge and the upper plate has a negative change. Which statement below is *not* true?
A. The electric field between the plates points vertically upward.
B. The magnitude of the electric force on the pellet is equal to mg.
C. The pellet is negatively charged.
D. If the magnitude of charge on the plates is increased, the pellet begins to move upward.

(8) If the area of the plates of a parallel plate capacitor is tripled and the plate separation is halved, by what factor does the capacitance change?
A. it triples
B. it doubles
C. it increases by a factor of 6
D. it increases 1.5 times

$C = \varepsilon_0 \frac{A}{d}$

(9) A bird can safely land on a bare high voltage power line because
A. Its feet are good insulators, and therefore it is protected.
B. Its internal resistance is very high, so very little current will flow.
C. The line cannot deliver enough current to harm it.
D. If both feet are touching the bare wire, they are at the same potential, therefore no current can flow between the feet and through the birds body.

(10) An ampere, A, is equivalent to a
A. V/m.
B. V C.
C. C/s.
D. C s.

(11) Consider three 2 μF capacitors in parallel with each other and connected to a battery. What is the equivalent capacitance of the circuit?
A. 2 μF
B. 6 μF
C. 2/3 μF
D. 12 μF

$2 + 2 + 2\ \mu F = 6\ \mu F$

(12) The magnetic field lines inside a bar magnet go in what direction?
A. from north pole to south pole
B. from south pole to north pole
C. from side to side
D. There are no magnetic field lines inside a bar magnet.

Now respond to the following short answer questions. Please answer THREE out of FOUR for questions (13)-(16). CLEARLY indicate which ones you would like to be graded on the front sheet of the exam.

(13) A positive charge is initially at rest in an electric field and is free to move. Does the charge start to move toward a position of higher or lower potential? Is there an analogy with gravity here? What happens to a negative charge in the same situation?

Charges move from higher to lower potential and yes there is an analogy with gravity of objects falling from a higher to lower gravitational potential ($\frac{U_g}{m}$) The negative charge moves from lower potential to a higher one

(14) A capacitor stores not only charge but energy. How can one quantify this energy in terms of charge and the potential difference across the capacitor? Also, recall the demo for discharging the energy in the capacitor. Describe the demo.

Energy stored in a capacitor $= \frac{1}{2} Q\Delta V$

The capacitor is charged and so energy is stored. Once the "circuit" is closed by providing a conducting pathway between the two plates, the capacitor becomes discharged in a short burst

(15) Describe the rules used to analyze circuits. What conservation laws do they come from?

Loop rule: $\sum_{loop} \Delta V_i = 0$ → conservation of energy

Junction rule: $\sum I_{i,in} = \sum I_{i,out}$ → conservation of charge

(16) Describe the two right hand rules used to find the direction of a magnetic field generated by a wire that does not form a loop and by a wire that does form a loop. How does the latter inform how the magnetic field of a solenoid is determined? A solenoid is a coil of wire (N loops of wire stacked together). Take the right hand for both and place it as if you are going to shake someone's hand

long straight wire) thumb direction of current, other 4 fingers curling shows direction of B

solenoid) curl 4 finger (except thumb) in the direction of the current and the direction the thumb points gives the direction of B

Now answer TWO of the following THREE quantitative questions (17)-(19). Please clearly indicate which ones you would like to be graded on the front sheet of the exam. You are welcome to approximate g as 10 m/s^2, ϵ_0 as 9×10^{-12} $C^2/(N\,m^2)$, the mass of the electron as 9×10^{-31} kg, and the charge of the electron as -2×10^{-19} C to obtain numbers. See how close you come to reaching a number without the use of a calculator.

(17) A beam of moving electrons generates a magnetic field. If the beam strength is quantified by 3×10^{10} electrons passing a point along the beam every 2 μs, what is the magnetic field strength at a distance of 3 cm from the beam center?

Use $I = \frac{\Delta q}{\Delta t}$ with $\Delta q = N q_e$ and $B = \frac{\mu_0 I}{2\pi r}$.

$$B = \frac{\mu_0}{2\pi r}\left(\frac{N q_e}{\Delta t}\right)$$

$\mu_0 = 4\pi \times 10^{-7} \frac{Tm}{A}$

$r = .03\ m = 3 \times 10^{-2}\ m$

$\Delta t = 2 \times 10^{-6}\ s$

$N = 3 \times 10^{10}$

$q_e = -2 \times 10^{-19}\ C$ — we will only look at magnitude or strength so we need not keep track of the sign

$$B = \frac{(4\pi \times 10^{-7} \frac{Tm}{A})}{2\pi\,(3 \times 10^{-2}\ m)} \frac{(3 \times 10^{10})(2 \times 10^{-19}\ C)}{2 \times 10^{-6}\ s} = 2 \times 10^{-8}\ T$$

(18) An alpha particle (charge $+2|q_e|$) moves through a potential difference of $\Delta V = 0.5$ kV. Its initial kinetic energy is 4×10^{-16} J. What is its final kinetic energy?

$$K_i + U_{E,i} = K_f + U_{E,f}$$

$$K_i + U_{E,i} - U_{E,f} = K_f$$

$$K_i - \Delta U_E = K_f$$

$$K_i - 2|q_e|\Delta V = K_f$$

$K_i = 4 \times 10^{-16}\ J$

$\Delta U_E = q\Delta V$ — charge of alpha particle

$$4 \times 10^{-16}\ J - 2(2 \times 10^{-19}\ C)(5 \times 10^{2})\ V$$

$$4 \times 10^{-16}\ J - 20 \times 10^{-17}\ J = (4 \times 10^{-16} - 2 \times 10^{-16})\ J = 2 \times 10^{-16}\ J$$

(19) In the movie *The Matrix*, humans are used to generate electricity. Estimate the total amount of stored electrical energy in the brain's 10^{11} nerve cells. Assume each nerve cell can be treated as a parallel plate capacitor with positive charges just outside the cell membrane and negative charges just inside the cell membrane. Each nerve cell membrane has a surface area of 1×10^{-7} m^2, a thickness of 9 nm, and a potential difference across the membrane of 70 mV.

For one nerve cell as a capacitor:

$$E_{one} = \frac{1}{2} Q(\Delta V) = \frac{1}{2} C(\Delta V)^2 = \frac{1}{2}\frac{\varepsilon_0 A}{d}(\Delta V)^2 \quad (Q = C(\Delta V))$$

$$E_{one} = \frac{\frac{1}{2}(9 \times 10^{-12} \frac{C^2}{Nm^2})(1 \times 10^{-7}\ m^2)(7 \times 10^{-2})^2}{9 \times 10^{-9}\ m}$$

$A = 1 \times 10^{-7}\ m^2$

$d = 9 \times 10^{-9}\ m$

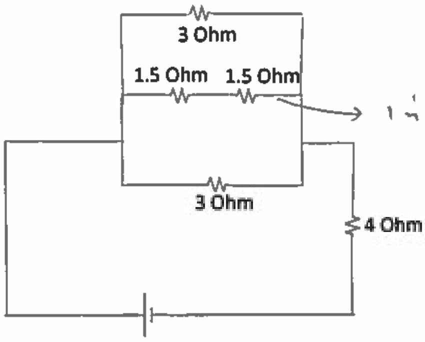
$\varepsilon_0 = 9 \times 10^{-12} \frac{C^2}{Nm^2}$

$\Delta V = 70 \times 10^{-3}\ V$

$$E_{one} = \frac{49}{2} \times 10^{-12+7-4+9}\ J = \frac{49}{2} \times 10^{0}\ J$$

$$E_{all} = 10^{11}(49/2)\ J = \frac{49}{2} \times 10^{11}\ J$$

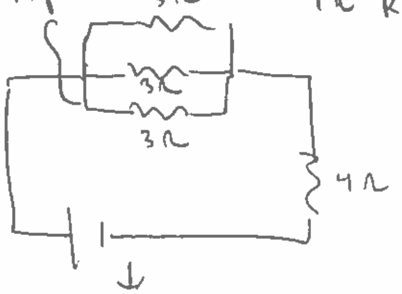
Please answer the final question (20).
(20) Consider the circuit diagram below.

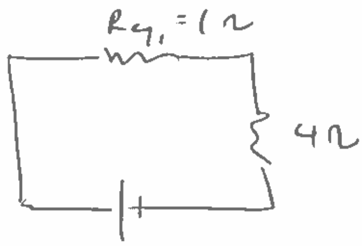


→ in series

$$\frac{1}{R_{eq_1}} = \frac{1}{3\Omega} + \frac{1}{3\Omega} + \frac{1}{3\Omega} = \frac{1}{1\Omega} = \frac{1}{R}$$

in parallel





(a) Find the equivalent resistance for the circuit.

(b) If the battery is a 10 V battery, what is the current in the circuit?

$$I = \frac{\Delta V}{R} = \frac{10\,V}{5\Omega} = 2\,A$$

(c) With this 10 V battery, what is the current through the 4 Ohm (Ω) resistor?

Since the current through the 4Ω resistor is the same as the total current in the circuit $I_{\text{through } 4\Omega} = 2A$.