Physics 2020-002 Name: KEY

Exam 1A – ~~6~~ 5 February 2017

Part A: Hard Multiple Choice (10 points total, 2 points each, Circle Best Answer).

1. An alpha particle ion with a charge of $+2e$ experiences a force of 2.67×10^{-12} N as it moves through an electric field. What is the strength of the electric field?

a) 1.67×10^{9} N/C b) 1.67×10^{23} N/C c) 3.83×10^{-6} N/C

(d) 8.33×10^{6} N/C e) 9.11×10^{-12} N/C

$E = F_e/q = \frac{2.67 \times 10^{-12} N}{2(1.602 \times 10^{-19} C)} = 8.33 \times 10^{6} N/C$

2. A particle produces a potential of 2.88×10^{-4} volts a distance of 0.222 m from the particle. What is the charge on this particle?

a) 1.60×10^{-19} C b) $362\,e$ c) $5.66\,e$

(d) 7.11×10^{-15} C e) 8.99×10^{-6} C

$V = \frac{k_e q}{r}, \quad q = \frac{Vr}{k_e} = \frac{(2.88 \times 10^{-4} V)(0.222 m)}{8.99 \times 10^{9} N m^2/C^2} = 7.11 \times 10^{-15} C$

3. A plate in a parallel-plate capacitor has a surface area of 2.45×10^{-4} m^2 and a plate separation of 1.88 mm. With an added dielectric, the capacitance of this capacitor is 5.40 pF. What is the dielectric constant of this dielectric?

a) 1.15×10^{-3} pF b) 1.15×10^{-12} (c) 4.68 d) 5.40 e) 120 pF

$C = \frac{\kappa \epsilon_0 A}{d}, \quad \kappa = \frac{Cd}{\epsilon_0 A} = \frac{(5.40 \times 10^{-12} F)(1.88 \times 10^{-3} m)}{(8.85 \times 10^{-12} C^2/N m^2)(2.45 \times 10^{-4} m^2)} = 4.68$

4. We experience a potential drop 24.4 V as a 332 mA current flows through a resistor. What is the resistance of the resistor?

a) 0.073 Ω b) 8.10 Ω c) 13.7 Ω (d) 73.5 Ω e) 81.0 kΩ

$R = \frac{\Delta V}{I} = \frac{24.4 V}{332 \times 10^{-3} A} = 73.5\ \Omega$

5. Copper has a resistivity of 1.70×10^{-8} Ω·m. How long would a length of copper wire have to be to achieve a resistance of 0.222 Ω if the diameter of this copper wire is 3.68 mm? (Assume the wire has a circular cross-section.)

a) 16.6 m b) 81.7 cm (c) 139 m d) 0.126 cm e) 0.680 m

$A = \frac{\pi D^2}{4} = \frac{\pi (3.68 \times 10^{-3} m)^2}{4} = 1.06 \times 10^{-5} m^2$

$R = \rho \frac{L}{A}, \quad L = \frac{RA}{\rho} = \frac{(0.222 \Omega)(1.06 \times 10^{-5} m^2)}{1.70 \times 10^{-8} \Omega m} = 139 m$

Part B: Easy Multiple Choice (10 points total, 1 point each, Circle Best Answer).

6. A thermometer that determines temperature as a result of the resistance measured in the thermometer is called a(n)

a) calorimeter b) ammeter c) barometer

d) electrocouple (e) none of these thermocouple

7. An electron ($q = -e$) lies on the origin of a Cartesian coordinate system. A helium nucleus ($q = +2e$) lies at -3.2 m on the y axis. A proton ($q = +e$) lies at +3.2 m on the y axis. Which direction will the electron move?

a) $+x$ b) $-x$ c) $+y$ (d) $-y$ e) none of these

8. Three capacitors are in series in a circuit, which of the following must be true?

a) Each capacitor must have the same capacitance.

b) The sum of the charges on each capacitor must equal the charge on the "equivalent" capacitor in the reduced circuit.

c) The sum of the capacitance on each capacitor must equal the capacitance of the "equivalent" capacitor in the reduced circuit.

(d) Each capacitor must have the same charge on it.

e) Each capacitor must experience the same potential drop as the voltage gain that the battery is supplying.

9. If an E-field in the Earth's atmosphere exceeds the dielectric strength of the atmosphere, which of the following will occur?

a) rain storm b) fog c) rainbow d) sunset (e) lightning

10. An electron that moves across a potential difference of one volt would require (or produce) how much energy?

a) 3.45×10^{-24} N·m b) 0.00 eV c) 6.78 N/C

(d) 1.602×10^{-19} J e) 13.6 eV

$= 1$ eV

11. The expression $\Delta V = IR$ is known as

a) Coulomb's law b) Ampere's law c) Gauss's law

d) Ohm's law e) Kepler's law

12. Which of the following would be a good example of a conductor?

a) copper b) rubber c) plastic d) glass e) flubber

13. Charge exchange between two isolated objects resulting from the generated electric field is called

a) induction b) advection c) accretion

d) convection e) conduction

14. When adding up parts to make a whole, such as adding components of a vector to determine the whole vector, this process is known as

a) Coulomb's Law

b) Gauss's Law

c) principle of superposition

d) principle of relativity

e) Faraday's Law of Induction

15. Which of the following physicists formulated the force law between two charges?

a) Gauss b) Coulomb c) Volta d) Galileo e) Newton

Part C: Problems (20 points total, 10 points each).

16. A gold wire of length 13.7 cm and diameter 0.188 mm is going to be used to construct a thermocouple. Gold has a temperature coefficient of resistivity of 3.40×10^{-3} °C^{-1}. (a) At 20.0°C, gold has a resistivity of 2.44×10^{-8} Ω·m, what is the resistance of this wire at this temperature? (b) After constructing our thermocouple, we place it into a liquid of unknown temperature and apply a voltage across the leads of the thermocouple of 0.224 V. If we measure a current of 0.884 A going through this thermocouple, what is the temperature of this liquid in °C? (**Show all work!**)

$\alpha = 3.40 \times 10^{-3}\ ^\circ C^{-1}$, $L = 13.7\ cm = 0.137\ m$, $D = 0.188\ mm = 0.188 \times 10^{-3}\ m$

(a) $T_0 = 20.0^\circ C$, $\rho_0 = 2.44 \times 10^{-8}\ \Omega m$

$A = \pi D^2/4 = \pi (0.188 \times 10^{-3}\ m)^2/4$

$= 2.78 \times 10^{-8}\ m^2$

$R_0 = \rho_0 L/A = \dfrac{(2.44 \times 10^{-8}\ \Omega m)(0.137\ m)}{2.78 \times 10^{-8}\ m^2}$

$= \boxed{0.120\ \Omega}$

(b) $T = ?$, $\Delta V = 0.224\ V$, $I = 0.884\ A$

$R = \dfrac{\Delta V}{I} = \dfrac{0.224\ V}{0.884\ A} = 0.253\ \Omega$

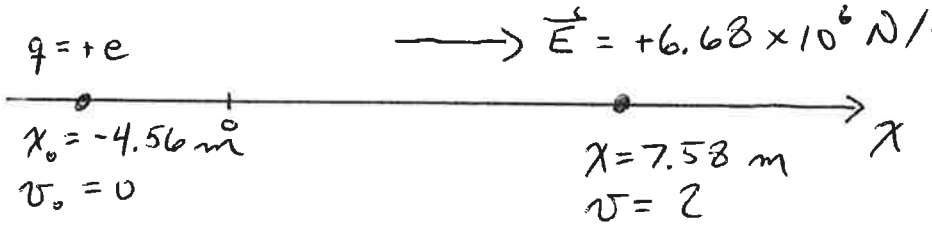
$R = R_0[1 + \alpha(T - T_0)]$, $1 + \alpha(T - T_0) = R/R_0$

$\alpha(T - T_0) = \dfrac{R}{R_0} - 1$, $T - T_0 = \dfrac{1}{\alpha}\left(\dfrac{R}{R_0} - 1\right)$

$T = T_0 + \dfrac{1}{\alpha}\left(\dfrac{R}{R_0} - 1\right) = 20.0^\circ C + \dfrac{1}{3.40 \times 10^{-3}\ ^\circ C^{-1}}\left(\dfrac{0.253\ \Omega}{0.120\ \Omega} - 1\right)$

$= 20.0^\circ C + 324.8^\circ C = \boxed{344.8^\circ C = 345^\circ C}$

17. A proton ($q = +e, m = m_p$) is released from rest at $x = -4.56$ m in a uniform electric field of $+6.68 \times 10^6$ N/C $\hat{x}$. (a) Calculate the change in potential energy when the proton moves along the x-axis to the $x = +7.58$ m position. (b) What will be the velocity of the proton at this position of +7.58 m? (c) What is the acceleration of this proton as it moves through the electric field? (**Physical constants given on Constants Sheet. Show all work!**)



(a) $\Delta V = -Ed$, $d = x - x_0 = 7.58\text{ m} - (-4.56\text{ m})$

$= 12.14$ m

$\Delta V = -(6.68 \times 10^6 \text{ N/C})(12.14\text{ m}) = -8.11 \times 10^7$ V

$\Delta PE = q\Delta V = e\Delta V = (1.602 \times 10^{-19}\text{ C})(-8.11 \times 10^7\text{ V})$

$= \boxed{-1.30 \times 10^{-11}\text{ J}}$

(b) $\Delta KE = -\Delta PE$, $\frac{1}{2}m_p v^2 - \frac{1}{2}m v_0^2 = -\Delta PE$ ($v_0 \to 0$)

$\frac{1}{2}m_p v^2 = -\Delta PE$, $v = \sqrt{\frac{2(-\Delta PE)}{m_p}}$

$v = \sqrt{\frac{2(+1.30 \times 10^{-11}\text{ J})}{1.672 \times 10^{-27}\text{ kg}}} = \boxed{1.25 \times 10^8\text{ m/s}}$

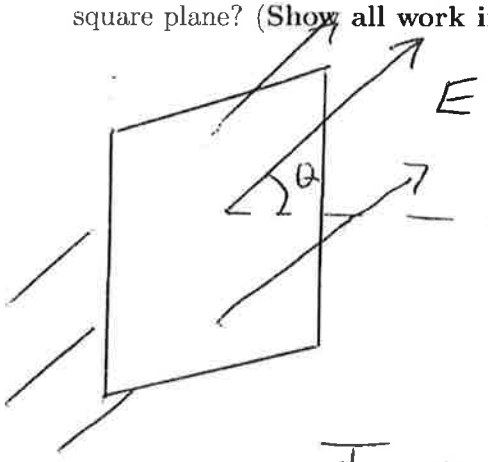
(c) $v^2 = v_0^2 + 2a(x - x_0) = 2ad$ ($v_0 \to 0$)

$a = \frac{v^2}{2d} = \frac{(1.25 \times 10^8\text{ m/s})^2}{2(12.14\text{ m})}$

$= \boxed{6.44 \times 10^{14}\text{ m/s}^2}$

Extra Credit Problem (5 points, do this only if you have time).

18. A square plane has electric field lines that cut through this plane at an angle of 46.8° with respect to the normal line producing an electric flux of 9.44×10^4 N·m^2/C. If the electric field is uniform at a strength of 3.56×10^4 N/C, what is the length of one of the sides of the square plane? (**Show all work including a diagram!**)



$\theta = 46.8°$

$\Phi_E = 9.44 \times 10^4 \text{ N m}^2/\text{C}$

$E = 3.56 \times 10^4 \text{ N/C}$

$\Phi_E = EA \cos\theta$

$A = \dfrac{\Phi_E}{E \cos\theta} = \dfrac{9.44 \times 10^4 \text{ N m}^2/\text{C}}{3.56 \times 10^4 \frac{\text{N}}{\text{C}} \cos 46.8°}$

$= 3.87 \text{ m}^2$

$L = \sqrt{A} = \sqrt{3.87 \text{ m}^2} = \boxed{1.97 \text{ m}}$