This print-out should have 9 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

001 10.0 points
Two alpha particles (helium nuclei), each consisting of two protons and two neutrons, have an electrical potential energy of $6.25 \times 10^{-19}$ J.

Given: $k_e = 8.98755 \times 10^9$ N m$^2$/C$^2$, $q_p = 1.6021 \times 10^{-19}$ C, and $g = 9.8$ m/s$^2$.

What is the distance between these particles at this time?
Correct answer: $1.47639 \times 10^{-9}$ m.

Explanation:
Let:

$U_{electric} = 6.25 \times 10^{-19}$ J,
$k_e = 8.98755 \times 10^9$ N m$^2$/C$^2$,
$q_p = 1.6021 \times 10^{-19}$ C,
$q_0 = 2q_p = 3.2042 \times 10^{-19}$ C, and
$q_n = 0$ C.

$q_1 = q_2 = 2q_p + 2q_n$
$= 2(1.6021 \times 10^{-19} \text{ C}) + 2(0 \text{ C})$
$= 3.2042 \times 10^{-19}$ C

$U_{electric} = k_e \frac{q_1 q_2}{r}$
$r = k_e \frac{q_1 q_2}{U_{electric}}$
$= k_e \frac{q_1^2}{U_{electric}}$
$= (8.99 \times 10^9 \text{ N} \cdot \text{m}^2$/C$^2$)$
\times \frac{(3.2042 \times 10^{-19} \text{ C})^2}{6.25 \times 10^{-19}}$
$= 1.47639 \times 10^{-9}$ m.

002 10.0 points
The compressor on an air conditioner draws 99 A when it starts up. The start-up time is about 0.4 s.

How much charge passes a cross-sectional area of the circuit in this time?
Correct answer: 39.6 C.

Explanation:
Let: $I = 99$ A and $\Delta t = 0.4$ s.

Current is
$I = \frac{dQ}{dt} = \frac{\Delta Q}{\Delta t}$
$\Delta Q = I \Delta t = (99 \text{ A})(0.4 \text{ s})$
$= 39.6 \text{ C}$.

003 (part 1 of 2) 10.0 points
A capacitor has a capacitance of 2.3 pF.

a) What potential difference would be required to store 17 pC?
Correct answer: 7.3913 V.

Explanation:
Let: $C = 2.3 \text{ pF} = 2.3 \times 10^{-12}$ F and $Q = 17 \text{ pC} = 1.7 \times 10^{-11}$ C.

The capacitance is
$C = \frac{Q}{\Delta V}$
$\Delta V = \frac{Q}{C} = \frac{1.7 \times 10^{-11}}{2.3 \times 10^{-12} \text{ F}}$
$= 7.3913 \text{ V}$.

004 (part 2 of 2) 10.0 points
b) How much charge is stored when the potential difference is 2.2 V?
Correct answer: 5.06 pC.

Explanation:
Let: $\Delta V_2 = 2.2$ V.

The stored charge is
$Q = C \Delta V_2$
$= (2.3 \times 10^{-12} \text{ F})(2.2 \text{ V})$
$\times \left(\frac{1 \times 10^{12} \text{ pC}}{1 \text{ C}}\right)$
$= 5.06 \text{ pC}$. 

What is the radius of the smallest possible circular orbit that a proton with the kinetic energy equal to 1.3 MeV can have in a 1 T magnetic field?

The mass of a proton is $1.67 \times 10^{-27}$ kg and its charge is $1.609 \times 10^{-19}$ C.

Correct answer: 0.164273 m.

Explanation:

Let: $m = 1.67 \times 10^{-27}$ kg, $Q = 1.609 \times 10^{-19}$ C, $B = 1$ T, and $E = 1.3$ MeV.

The energy of a proton is $E = \frac{1}{2} m v^2$, so

$$v = \sqrt{\frac{2E}{m}} = \sqrt{\frac{2(1.3 \text{ MeV})(1.609 \times 10^{-19} \text{ J/eV})}{(1 \times 10^{-6} \text{ MeV/eV})(1.67 \times 10^{-27} \text{ kg})}} = 1.58273 \times 10^7 \text{ m/s}.$$ If the proton is shot into the magnetic field with a velocity at right angles to the direction of the field, we will get the smallest radius

$$r = \frac{m v}{B q} = \frac{(1.67 \times 10^{-27} \text{ kg})(1.58273 \times 10^7 \text{ m/s})}{(1 \text{ T})(1.609 \times 10^{-19} \text{ C})} = 0.164273 \text{ m}.$$ 

Let: $L = 9$ m, $r = 2.8085 \text{ mm} = 0.0028085$ m, and $\rho_{20} = 1.7 \times 10^{-8}$ Ω · m.

The area is $A = \pi r^2$ and the resistance is

$$R = \rho_{20} \frac{L}{A} = \rho_{20} \frac{L}{\pi r^2} = (1.7 \times 10^{-8} \text{ Ω · m}) \times \frac{9 \text{ m}}{\pi (0.0028085 \text{ m})^2} = 0.00617437 \Omega.$$

A 9 m long piece of wire of density 8.34 g/m³ has a diameter of 5.617 mm. The resistivity of the wire is $1.7 \times 10^{-8}$ Ω · m at 20°C. The temperature coefficient for the wire is 0.0038 (°C)⁻¹.

Calculate the resistance of the wire at 20°C.

Correct answer: 0.00617437 Ω.

Explanation:

Let: $T_1 = 40°C$, $T_2 = 56°C$, $r = 2.8085 \text{ mm} = 0.0028085$ m, $\rho_{20} = 1.7 \times 10^{-8}$ Ω · m, $\alpha = 0.0038 (°C)^{-1}$, and $L = 9$ m.

$$A = \pi r^2,$$

and

$$\rho_1 = \rho_{20} \{1.0 + \alpha [T_1 - T_2]\} = (1.7 \times 10^{-8} \text{ Ω · m}) \times \{1.0 + [0.0038 (°C)^{-1}] \times [(40°C) - (20°C)]\} = 1.8292 \times 10^{-8} \text{ Ω · m}.$$ 

$$R_1 = \frac{\rho_1 L}{A} = \frac{\rho_1 L}{\pi r^2} = (1.8292 \times 10^{-8} \text{ Ω · m}) \times \frac{9 \text{ m}}{\pi (0.0028085 \text{ m})^2} = 0.00664362 \Omega.$$
\[
\rho_2 = \rho_{20} \{1.0 + \alpha [T_2 - T_{20}]\} \\
= (1.7 \times 10^{-8} \, \Omega \cdot m) \\
\times \{1.0 + [0.0038 \, ^\circ C^{-1}] \\
\times [(56{^\circ}C) - (20{^\circ}C)]\} \\
= 1.93256 \times 10^{-8} \, \Omega \cdot m.
\]

\[
R_2 = \rho_2 \frac{L}{A} = \rho_2 \frac{L}{\pi r^2} \\
= (1.93256 \times 10^{-8} \, \Omega \cdot m) \\
\times \frac{9 \, m}{\pi (0.0028085 \, m)^2} \\
= 0.00701902 \, \Omega.
\]

So the difference in the resistance is
\[
\Delta R = |R_2 - R_1| \\
= |0.00701902 \, \Omega - 0.00664362 \, \Omega| \\
= 0.000375402 \, \Omega.
\]

**Explanation:**

Let : \( I = 11 \, A \), \( n = 6 \times 10^{28} \, \text{electrons/m}^3 \), \( q_e = 1.60218 \times 10^{-19} \, \text{C} \), and \( A = 4 \, \text{cm}^2 = 0.0004 \, \text{m}^2 \).

The current in a conductor is given by
\[
I = n q v_d A,
\]
where \( n \) is the number of charge carriers per unit volume, \( q \) is the charge per carrier, \( v_d \) is the drift velocity of the carriers and \( A \) is the cross section of the conduction.

Solving for \( v_d \), we have
\[
v_d = \frac{I}{n q A} \\
= \frac{11 \, A}{6 \times 10^{28} \, \text{electrons/m}^3 \times 1.60218 \times 10^{-19} \, \text{C}} \\
\times \frac{1}{0.0004 \, \text{m}^2 \times \frac{1000 \, \text{mm}}{1 \, \text{m}}} \\
= 0.00286069 \, \text{mm/s}.
\]

**008 10.0 points**

A 14 pF capacitor is connected across a 55 V source.

What charge is stored on it?

Correct answer: \( 7.7 \times 10^{-10} \, \text{C} \).

**Explanation:**

Let : \( C = 14 \, \text{pF} = 1.4 \times 10^{-11} \, \text{F} \) and \( V = 55 \, \text{V} \).

The capacitance is
\[
C = \frac{q}{V} \\
q = CV \\
= (1.4 \times 10^{-11} \, \text{F})(55 \, \text{V}) \\
= 7.7 \times 10^{-10} \, \text{C}
\]

**009 10.0 points**

A conductor with cross-sectional area 4 cm\(^2\) carries a current of 11 A.

If the concentration of free electrons in the conductor is \( 6 \times 10^{28} \, \text{electrons/m}^3 \), what is the drift velocity of the electrons?

Correct answer: \( 0.00286069 \, \text{mm/s} \).