Do not turn this page until instructed

After that please remove this page. You can use it as scrap paper.
Questions 1-3. An α-particle with an electric charge of $3.2 \times 10^{-19}$ C and a mass of $6.6 \times 10^{-27}$ kg is moving along x-axis left to right. It enters a particle selector (a capacitor placed inside magnetic field) with electric field of $10^4$ V/m along y-axis pointing down and magnetic field of 5T along z-axis pointing into the page $\bigcirc$.

1. (2 points) The magnetic force on the α-particle is along
   a. x-axis  
   b. y-axis  
   c. z-axis  
   d. depends on the strength of the magnetic field

2. (6 points) What must be the speed of the α-particle for it to continue its motion along x-axis without deflection?

3. (4 points) What the magnitude of the magnetic force on the α-particle?

4. (3 points) An electron beam is coming at you between two magnetic poles as shown. In which direction will the beam deflect?
   a. $\uparrow$  
   b. $\downarrow$  
   c. $\leftarrow$  
   d. $\rightarrow$  
   e. out ($\bigcirc$)  
   f. in ($\bigcirc$)

5. (3 points) Charged particle beam deflects to the left when entering a region of uniform magnetic field, as shown. What is the charge of these particles?
   a. positive  
   b. negative  
   c. neutral  
   d. no way to tell
Questions 6-8 deal with the situation sketched at right. A coaxial cable consists of a solid inner conductor of radius $R_1=2\text{mm}$, surrounded by a concentric cylindrical tube of inner radius $R_2=4\text{mm}$ and outer radius $R_3=5\text{mm}$. The conductors carry equal and opposite currents $I_0=5\text{A}$ distributed uniformly across their cross sections.

6. (3 points) What is the direction of the magnetic field at $r=3\text{mm}$ to the left of the center?

   a. ↑   b. ↓   c. ←   d. →   e. out (☉)   f. in (☉)

7. (4 points) What is the magnitude of the magnetic field at $r=3\text{mm}$?

8. (6 points) What is the magnitude of the magnetic field at $r=4.5\text{mm}$?

Questions 9,10. Two long straight wires carry currents along the x-axis and y-axis respectively.

9. (3 points) In the 1st quadrant (upper right corner) the magnetic field is directed

   a. out of the page everywhere
   b. out of the page some places and into the page other places
   c. in the plane of the paper
   d. into the page everywhere

10. (6 points) If $I_x=5\text{A}$ and $I_y=7\text{A}$ what is the magnitude of the magnetic field at point (5cm; 7cm; 0cm)?
11. (3 points) Which one of the following actions will not increase the magnetic field of a solenoid?
   a. Use more current
   b. Increase the solenoid's diameter
   c. Add an iron core
   d. Add more turns of wire in the same length

12. (2 points) Two parallel wires carry currents in the same direction. Both currents and the distance between them are doubled. The force between wires
   a. remains the same
   b. doubles
   c. quadruples
   d. halves

Questions 13-17 deal with the situation sketched at right. A 20 cm long conducting rod is moving to the right with a speed of \( v = 2.5 \text{ m/s} \) on a U-shaped conductor in a uniform magnetic field \( B = 0.6 \text{ T} \) that points out of the paper. The resistance of the rod is \( 1.7 \Omega \). The resistance of the U-shaped conductor is \( 10.0 \Omega \) at the given instant.

13. (4 points) Calculate the induced emf.

14. (2 points) T F The magnetic flux through the circuit is decreasing.

15. (6 points) What is the current flowing in the circuit?

16. (2 points) What is the direction of the current?
   a. clockwise.
   b. counterclockwise.

17. (2 points) What is the direction of the electric field in the rod?
   a. up.
   b. down.
For
\[ \sum \text{ charge like } \eta \]
321

[\text{ electric field unifrom For }
0
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Physics122  Exam #3  November 30, 2005  12:10 to 1:10 pm

Constants and equations for exam 3. You may detach this page if you wish.

<table>
<thead>
<tr>
<th>Coulomb’s Law constant</th>
<th>k=8.99 x10^9 N m^2/C^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permittivity of free space</td>
<td>\varepsilon_0=8.85 x10^{12} C^2/N m^2</td>
</tr>
<tr>
<td>Charge of one electron</td>
<td>-e=-1.60 x10^{19} C</td>
</tr>
<tr>
<td>Magnetic permeability of free space</td>
<td>\mu_0=4\pi x10^7 T m/A</td>
</tr>
<tr>
<td>Speed of light in vacuum</td>
<td>c=3.00 x 10^8 m/s</td>
</tr>
</tbody>
</table>

\textbf{Coulomb’s law}

\[ F = k \frac{Q_1 Q_2}{r^2} \]

\textbf{Electric field}

\[ \vec{F} = q \vec{E} \text{ - definition of } \vec{E} \]
\[ E = k \frac{Q}{r^2} \text{ - point charge} \]
\[ E = V / d \text{ – capacitor, constant field} \]

\textbf{Electric Potential}

\[ PE = qV \text{ - potential energy of a charge in electric field} \]
\[ V = k \frac{Q}{r} \text{ - potential of a point charge} \]

\[ E_x = -\frac{\partial V}{\partial x}; \quad E_y = -\frac{\partial V}{\partial y}; \quad E_z = -\frac{\partial V}{\partial z}. \]

Work done by a electric force: \[ W=-(PE_{final}-PE_{initial}) \]
Work done by external force to move a charge \( q \) in electric field: \[ W=q(V_{final}-V_{initial}) \]

\textbf{System of charges}

\[ \vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 \ldots \text{ - sum of point-like charges} \]
\[ V = V_1 + V_2 + V_3 + \ldots \]
\[ V = k \int \frac{dQ}{r} \text{ - continuous distribution of charge} \]

\textbf{Electric Flux, Gauss’s Law}

For uniform field \( \Phi_E = \vec{E} \cdot \vec{A} \) - electric flux; \( \vec{A} \) – area vector, equal to area, pointing perpendicular to area

\[ \Phi_E = \int \vec{E} \cdot d\vec{A} \quad \Phi_E > 0 \text{ – outflux, } \Phi_E < 0 \text{ – influx, } \Phi_E = \frac{Q}{\varepsilon_0} \text{ – enclosed charge} \]

\textbf{Electric current}

Definition: \( I=\Delta Q/\Delta t \)
Power: \( P=IV \)
\[ V=IR \text{ – Ohms law} \]
In a resistor: \( P=I^2 R=V^2/R \)

\textbf{Resistors in DC circuits}

Series connection:
\[ R_{eq}=R_1+R_2+R_3 \]
\[ \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \]
\[ V=V_1+V_2+V_3 \]
\[ I=I_1=I_2=I_3 \]

Parallel connection:
\[ V=V_1=V_2=V_3 \]
\[ I=I_1+I_2+I_3 \]
Capacitor
\[ Q = CV \] – definition of capacitance
Energy stored:
\[ U = \frac{QV}{2} = \frac{CV^2}{2} = \frac{Q^2}{2C} \]
Parallel plates with dielectric K:
\[ C = K \varepsilon_0 \frac{A}{d} \]

Magnetic field
\[ B = \frac{\mu_0 I}{2\pi r} \] - magnetic field of a current; \( B = K_B \mu_0 I_n \) – magnetic field in solenoid, \( n = N/l \)
\[ F = Bl \sin \theta \]; \( F = qvB \sin \theta \); \( a = \gamma^2/r \) – centripetal acceleration
\[ \tau = rF \sin \theta \]; \( \mu = NAI \); \( \bar{r} = \bar{\mu} \times \bar{B} \)
\[ \int \bar{B}d\bar{l} = \mu_0 I_{enc} \] – Ampere’s law; \( \bar{d}\bar{B} = \frac{\mu_0 I}{4\pi} \frac{d\bar{l} \times \bar{r}}{r^2} \) - Biot-Savart law.

Induced emf
Magnetic flux: \( \Phi = BA \cos \theta \)
Faraday’s Law: \( E = -\frac{\partial}{\partial t} \Phi \)
Transformer:
\[ V_s / V_p = N_s / N_p \]
\[ V_s I_s = V_p I_p \]

AC circuits
Current:
\[ I(t) = I_0 \cos(2\pi ft) \]
Voltage:
\[ V(t) = V_0 \cos(2\pi ft + \phi) \]
RMS and peak:
\[ I_{rms} = I_0 / \sqrt{2} \]
\[ V_{rms} = V_0 / \sqrt{2} \]

Resistor R
\[ V = IR \]
\[ V_{rms} = I_{rms} R \]
\[ I, V \] – in phase: \( \phi = 0 \)

Capacitor
\[ dV / dt = I / C \]
\[ V_{rms} = I_{rms} X_C \]
\[ X_C = 1/(2\pi f C) \]
\[ V \text{ lags } I: \phi = -90^\circ \]

Inductor
\[ V = LdI / dt \]
\[ V_{rms} = I_{rms} X_L \]
\[ X_L = 2\pi f L \]
\[ V \text{ leads } I: \phi = 90^\circ \]

Impedance:
\[ Z = \sqrt{R^2 + (X_L - X_C)^2} \]
\[ V_{rms} = I_{rms} Z \]

Phase angle:
\[ \tan \phi = \frac{X_L - X_C}{R} \]
Power factor:
\[ \cos \phi \]
Power dissipated:
\[ P = I_{rms}^2 R \]

Resonance:
\[ X_L = X_C \]
\[ f_0 = \frac{1}{2\pi\sqrt{LC}} \]

EM waves
Displacement current:
\[ I_D = \varepsilon_0 A dE / dt \]
Wave:
\[ v = f\lambda \]
EM wave in vacuum:
\[ v = c \]

Trigonometry review
\[ \sin \theta = (opp)/(hyp), \cos \theta = (adj)/(hyp), \tan \theta = (opp)/(adj) \]
Pythagorean theorem:
\[ (hyp)^2 = (opp)^2 + (adj)^2 \]