Physics 116B – Exam #2 (Alternate) – Fall 2008

Only calculators and pens/pencils are allowed on your desk. No cell phones, music players, or additional scrap paper. You have 75 minutes to complete the exam.

Name ____________________________

Section (Circle): 3 Helms TR 8:10-9:25

1 Helms TR 11:00-12:15

If you are in Prof. Johns’s class, you’re in the wrong room!

I pledge my honor that I have neither given nor received aid on this work.

Signed ________________________________
MULTIPLE CHOICE. 3 points each. Choose the one alternative that best completes the statement or answers the question. Write your answer on the line next to each question. Partial credit will be given for work that is shown.

1) Alpha particles (charge = +2e, mass = 6.68 \times 10^{-27} \text{ kg}) are accelerated in a cyclotron to a final orbit radius of 0.90 m. The magnetic field in the cyclotron is 0.40 T. The period of circular motion of the alpha particles is closest to:

A) 0.50 \mu s  
B) 0.98 \mu s  
C) 0.33 \mu s  
D) 0.66 \mu s  
E) 0.80 \mu s

---

First figure out the velocity:

\[ F = ma \]

\[ q \times B = \frac{mv^2}{r} \]

\[ qB = \frac{mv}{r} \]

\[ v = \frac{qBr}{m} \]

Centripetal acceleration \( = \frac{v^2}{r} \)

Period is distance it travels in one trip divided by velocity.

\[ T = \frac{2\pi r}{v} = 2\pi r \left( \frac{m}{qB} \right) = \frac{2\pi m}{qB} = \frac{2\pi (6.68 \times 10^{-27} \text{ kg})}{(2 \times 1.6 \times 10^{-19} \text{ C})(0.40 \text{ T})} \]

\[ = 3.3 \times 10^{-7} \text{ s} \]

\[ = 0.33 \mu s \]
2) A rigid rectangular loop, which measures 0.30 m by 0.40 m, carries a current of 5.5 A, as shown. A uniform external magnetic field of magnitude 2.9 T in the negative x-direction is present. Segment CD is in the x-z plane and forms a 35° angle with the z-axis, as shown. In Fig. 27.7b, an external torque applied to the loop keeps it in static equilibrium. The magnitude of the external torque is closest to:

A) 1.3 N·m  B) 0.73 N·m  C) 1.6 N·m  D) 1.1 N·m  E) 1.4 N·m

\[ \mu = IA = (5.5 \, \text{A})(0.3 \, \text{m})(0.4 \, \text{m}) = 0.66 \, \text{A} \cdot \text{m}^2 \]

\[ \vec{\tau} = \vec{\mu} \times \vec{B} \]

torque on the loop

\[ \tau = \mu B \sin \Theta \]

\( \Theta \) is the angle between the normal vector of the loop and the magnetic field. Looking down

\[ \tau = (0.66 \, \text{A} \cdot \text{m}^2)(2.9 \, \text{T}) \sin 35° \]

\[ = 1.1 \, \text{N} \cdot \text{m} \]

The required external torque is equal and opposite to the magnetic torque.
3) A circular loop of radius 10 cm and three long straight wires carry currents of $I_1 = 60$ A, $I_2 = 10$ A, $I_3 = 60$ A, and $I_4 = 20$ A, respectively, as shown. Each straight wire is 20 cm from the center of the loop. In Fig. 28.1, the $y$-component of the resultant magnetic field at the center of the loop is closest to:

A) $+80 \mu T$  
B) $+50 \mu T$  
C) $-62 \mu T$  
D) $-50 \mu T$  
E) $-80 \mu T$

At the center, the field from $I_1$ is directed into the page. It has no $y$-component.

At the center, the field from $I_2$ is directed out of the page. It also has no $y$-component.

At the center, the field from $I_4$ is downward.

At the center, the field from $I_3$ is SE

\[ B_y = \frac{\mu_0}{2\pi r} (I_4 + I_3 \cos 45^\circ) \]

\[ r = 20\text{ cm} \]

\[ B_y = -62 \mu T \]
4) The heater element of a 120-V toaster is a 3.3-m length of nichrome wire, whose diameter is 0.80 mm. The resistivity of nichrome at the operating temperature of the toaster is $1.3 \times 10^{-6} \, \Omega \cdot m$. The nichrome wire is replaced by a 5.5-m length of tungsten wire. The power of the toaster, when operated at a voltage of 120 V, remains unchanged when the wire replacement is made. The resistivity of tungsten, at the operating temperature of the toaster, is $2.4 \times 10^{-7} \, \Omega \cdot m$. The diameter of the tungsten wire is closest to:

A) 0.34 mm  
B) 0.41 mm  
C) 0.28 mm  
D) 0.22 mm  
E) 0.15 mm

If the potential and the Power are the same, the resistance must also be the same:

$$R_1 = R_2$$

$$P_1 = P_2$$

$$\frac{\rho_1 L_1}{A_1} = \frac{\rho_2 L_2}{A_2}$$

$$A_1 = \pi r_1^2 = \pi d_1^2$$

$$A_2 = \frac{4 \pi r_2^2}{\pi d_2^2}$$

$$\rho_1 L_1 = \rho_2 L_2$$

$$\rho_1 = \rho_2 \frac{L_2}{L_1}$$

$$d_1 = \sqrt{\frac{\rho_1 L_1}{\rho_2 L_2}}$$

$$d_1 = \sqrt{\frac{1.3 \times 10^{-6}}{2.4 \times 10^{-7}}} \frac{(5.5 \text{ m})}{(3.3 \text{ m})}$$

$$d_1 = 0.44 \text{ mm}$$

5) An air capacitor is formed from two long conducting cylindrical shells that are coaxial, and have radii of 26 mm and 87 mm. The electric potential of the inner conductor with respect to the outer conductor is $-800 \, V$. The energy stored in the capacitor, in a one meter section of length is closest to:

A) 41 $\mu$J  
B) 21 $\mu$J  
C) 11 $\mu$J  
D) 5 $\mu$J  
E) 30 $\mu$J

$$C = \frac{2 \pi \varepsilon_0 L}{\ln(b/a)}$$

$$U = \frac{1}{2} CV^2 = \frac{V^2 \pi \varepsilon_0 L}{2 \ln(b/a)}$$

$$= \frac{(800 \, V)^2 \pi \varepsilon_0 (1 \text{ m})}{2 \ln(\frac{87 \text{ mm}}{26 \text{ mm}})} = 15 \mu \text{J}$$
6) In Fig. 27.1 is a velocity selector that can be used to measure the speed of a charged particle. A beam of particles is directed along the axis of the instrument. A parallel plate capacitor sets up an electric field \( E \), which is oriented perpendicular to a uniform magnetic field \( B \). If the plates are separated by 9 mm and the value of the magnetic field is 0.6 T, what voltage between the plates will allow particles of speed \( 5 \times 10^5 \) m/s to pass straight through without deflection?

A) 8500 V  B) 420 V  C) 2700 V  D) 860 V  E) 17,000 V

No net force means

\[
\vec{F}_E = \vec{F}_B \\
qE = qvB \\
E = vB
\]

For a uniform \( E \) field

\[
\vec{V} = \vec{E} dl \\
\vec{E} = \frac{\vec{V}}{d}
\]

\[
\frac{\vec{V}}{dl} = vB \\
V = vdlB = (5 \times 10^5 \text{ m/s}) \times 0.009 \text{ m} \times 0.6 \text{ T} = 2700 \text{ V}
\]
7) In Fig. 26.7, what is the power dissipated in the 2-Ω resistance in the circuit?

A) 6.67 W  
B) 8.0 W  
C) 3.56 W  
D) 5.33 W  
E) 2.67 W

First figure out total current.

\[ I_{\text{tot}} = \frac{V_{\text{tot}}}{R_{\text{tot}}} \]

Then find the drop across the 4Ω resistor.
\[ \Delta V = IR = (2A)(4\Omega) = 8V \]

The rest of the voltage is across the 1Ω and the 2Ω, so

\[ I_{\text{tot}} = \frac{12V}{6\Omega} = 2A \]

So the power in the 2Ω is
\[ P = 12\Omega \cdot (1.33A)^2 \cdot (2\Omega) = 3.56W \]

8) If you were to cut a small permanent bar magnet in half,

A) neither piece would be magnetic.
B) each piece would contain both north and south poles, but on a given piece the intensity of the north and south poles would not necessarily be equal.
C) one piece would be a magnetic north pole and the other piece would be a south pole.
D) each piece would in itself be a smaller bar magnet with both north and south poles.
E) None of these statements is true.

In a normal bar magnet, only D would be true. But for an oddball, B might be true too.
FREE RESPONSE. 16 points total. Write your final answer for each part in the box provided. Partial credit will only be given if you show your work and it is clear.

9) Consider the circuit below. All switches are initially open and there is no charge on any capacitor.

![Circuit Diagram]

(a) Switch $S_1$ is now closed and the other switches are left open. Calculate the charge on the $3 \mu F$ capacitor after a long time.

$$C_{eq} = \left(\frac{1}{3} + \frac{1}{4}\right)^{-1} = 1.71 \mu F$$

$$Q = CV = (1.71 \mu F)(12V) = 20.6 \mu C$$

(b) Switch $S_1$ is now opened and then switch $S_2$ is closed. (Switch $S_3$ remains open.) Calculate the charge on the $3 \mu F$ capacitor after a long time.

The circuit now looks like this

![Circuit Diagram]

Start with $Q$ from part (a) on the left side. Some charge will flow to the right side until the potential difference on both sides is the same.

$$Q_1 = Q_2 \frac{C_1}{C_2}$$

$$Q_1 = (Q - Q_1) \frac{C_1}{C_2}$$

$$Q_1 \left(1 + \frac{C_1}{C_2}\right) = Q \left(\frac{C_1}{C_2}\right)$$

$$Q_1 = \frac{Q (C_1/C_2)}{1 + C_1/C_2} = \frac{(20.6 \mu C) \frac{1.71}{3}}{1 + \frac{1.71}{3}} = 5.25 \mu C$$

$$Q = 5.25 \mu C$$
(c) Switch $S_2$ is now opened and then switch $S_3$ is closed. (Switch $S_1$ remains open.) Calculate the current in the resistor 1 ms after the switch is closed.

\[ I = \frac{Q_0}{RC} e^{-t/RC} \]

\[ I_{1ms} = \frac{15.35 \mu C}{(100 \Omega)(5 \mu F)} e^{-(1.001s)/(100 \Omega)(5 \mu F)} = 4.2 mA \]

(d) Calculate total energy dissipated in the resistor during the same time.

\[ E = 23 \mu J \]

"Hard way"

\[ P = I^2 R \]
\[ U = \int P \ dt \]
\[ = \int_0^{1ms} I^2 R dt \]
\[ = \frac{R Q_0^2}{2C} \left[ -e^{-2t/RC} \right]_0^{1ms} \]
\[ = \frac{Q_0^2}{2C} \left[ -2(1.001s)/(100 \Omega)(5 \mu F) \right] + 1) \]
\[ = 23 \mu J \]

"Easy way"

The change in the stored energy in the capacitor is equal to the energy dissipated in the resistor.

\[ Q_0 = 15.35 \mu C \]
\[ Q(1ms) = Q_0 e^{-(1.001s)/(100 \Omega)(5 \mu F)} \]
\[ = (15.35 \mu C) e^{-(1.001s)/(100 \Omega)(5 \mu F)} \]
\[ = 2 \mu C \]
\[ U = \frac{1}{2} Q^2 C \]
\[ \Delta U = \frac{1}{2C} (Q_0^2 - Q_f^2) \]
\[ = \frac{1}{2(5 \mu F)} (15.35 \mu C)^2 - (2 \mu C)^2 \]
\[ = 23 \mu J \]
Physics 116B – Exam #2 (Regular) – Fall 2008

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Signed ________________________________
MULTIPLE CHOICE. 3 points each. Choose the one alternative that best completes the statement or answers the question. Write your answer on the line next to each question. Partial credit will be given for work that is shown.

1) An air capacitor is formed from two long conducting cylindrical shells that are coaxial, and have radii of 16 mm and 120 mm. The electric potential of the inner conductor with respect to the outer conductor is –500 V. The energy stored in the capacitor, in a one meter section of length is closest to:

A) 9.7 μJ  
B) 2.5 μJ  
C) 6.9 μJ  
D) 2.5 μJ  
E) 4.9 μJ

\[ C = \frac{2\pi \varepsilon_0 L}{\ln \left( b/a \right)} \text{ for a cylindrical capacitor} \]

\[ U = \frac{1}{2} CV^2 = \frac{V^2 \pi \varepsilon_0 L}{\ln \left( b/a \right)} \]

\[ = \frac{(500\text{V})^2 \pi \varepsilon_0 (1\text{m})}{\ln \left( \frac{120}{16} \right)} = 3.45 \mu\text{J} \]

2) The heater element of a 120-V toaster is a 2.7-m length of nichrome wire, whose diameter is 0.50 mm. The resistivity of nichrome at the operating temperature of the toaster is \(1.3 \times 10^{-6} \Omega \cdot \text{m}\). The toaster is operated at a voltage of 120 V. The power drawn by the toaster is closest to:

A) 780 W  
B) 810 W  
C) 830 W  
D) 860 W  
E) 890 W

\[ P = \frac{V^2}{R} \]

\[ R = \rho \frac{L}{A} = \pi r^2 = \frac{\pi d^2}{4} \]

\[ P = \frac{V^2 A}{\rho L} = \frac{V^2 \pi d^2}{4 \rho L} = \frac{(120\text{V})^2 \pi (1.5 \times 10^{-3} \text{m})^2}{4(1.3 \times 10^{-6} \Omega \cdot \text{m})(2.7\text{m})} = 805 \text{W} \]
3) In Fig. 26.6, the current of the circuit in the 8-Ω resistor is 0.5A. What is the current in the 2-Ω resistor?

A) 2.25 A  B) 4.5 A  C) 6.4 A  D) 9.5 A  E) 0.75 A

\[ I_9 = 0.5A \] so

\[ I_{16} = 2.5A \]

\[ I_{top} = I_8 + I_{16} = 7.5A \]

\[ V_{top} = I_{top} R_{top} = (7.5A)(20Ω + (\frac{1}{16}+\frac{1}{8})^{-1}) = 19V \]

\[ V_{top} = V_{bottom} \]

\[ I_2 = \frac{V_{bottom}}{2Ω} = \frac{19V}{2Ω} = 9.5A \]
4) In Fig. 27.1 is a velocity selector that can be used to measure the speed of a charged particle. A beam of particles is directed along the axis of the instrument. A parallel plate capacitor sets up an electric field $E$, which is oriented perpendicular to a uniform magnetic field $B$. If the plates are separated by 3 mm and the value of the magnetic field is 0.8 T, what voltage between the plates will allow particles of speed $5 \times 10^5$ m/s to pass straight through without deflection?

A) 7500 V  B) 1200 V  C) 190 V  D) 3800 V  E) 380 V

No net force means $F_E = F_B$

$$qE = qvB$$

$$E = vB$$

For a uniform $E$-field

$$V = Ed$$

$$E = \frac{V}{d}$$

$$\frac{V}{d} = vB$$

$$V = dlvB = (1.003 m)(5 \times 10^5 m/s)(0.8T) = 1200 V$$
5) Alpha particles (charge = 2e, mass = 6.68 × 10⁻²⁷ kg) are accelerated in a cyclotron to a final orbit radius of 0.60 m. The magnetic field in the cyclotron is 0.10 T. The period of circular motion of the alpha particles is closest to:

(A) 3.3 µs  B) 3.9 µs  C) 3.2 µs  D) 2.0 µs  E) 2.6 µs

First figure out velocity

\[ F = ma \]
\[ qVB = \frac{mV²}{r} \]
\[ V = \frac{qVB}{m} \]

Period is distance it travels in one trip divided by velocity

\[ T = \frac{2\pi r}{V} = 2\pi \sqrt{\frac{m}{qVB}} = \frac{2\pi m}{qVB} = \frac{2\pi (6.68 \times 10^{-27} kg)}{(2)(1.6 \times 10^{-19} C)(0.1 T)} = 1.3 \mu s \]
6) A circular loop of radius 10 cm and three long straight wires carry currents of \( I_1 = 80\, \text{A} \), \( I_2 = 20\, \text{A} \), \( I_3 = 80\, \text{A} \), and \( I_4 = 40\, \text{A} \), respectively, as shown. Each straight wire is 20 cm from the center of the loop. In Fig. 28.1, the \( z \)-component of the resultant magnetic field at the center of the loop is closest to:

A) \(-230\, \mu\text{T}\)  \quad B) \(-480\, \mu\text{T}\)  \quad C) \(+60\, \mu\text{T}\)  \quad D) \(-60\, \mu\text{T}\)  \quad E) \(+480\, \mu\text{T}\)

The magnetic fields from \( I_3 \) and \( I_4 \) lie in the plane of the page. They have no \( z \)-component.

- \( I_1 \) has a field into the page.
- \( I_2 \) has a field out of the page.

\[ \mathbf{B}_{z} = \mathbf{B}_{1z} + \mathbf{B}_{2z} \]

\[ \mathbf{B}_{2z} = \frac{\mu_0 I_1}{2R_1} + \frac{\mu_0 I_2}{2\pi r_2} = \frac{\mu_0}{2} \left( \frac{80\, \text{A}}{0.1\, \text{m}} + \frac{20\, \text{A}}{\pi (0.2\, \text{m})} \right) = -480\, \mu\text{T} \]
7) A rigid rectangular loop, which measures 0.30 m by 0.40 m, carries a current of 5.5 A, as shown. A uniform external magnetic field of magnitude 2.9 T in the negative x-direction is present. Segment CD is in the x-z plane and forms a 35° angle with the z-axis, as shown. In Fig. 27.7b, an external torque applied to the loop keeps it in static equilibrium. The magnitude of the external torque is closest to:

A) 1.6 N·m  
B) 0.73 N·m  
C) 1.4 N·m  
D) 1.1 N·m  
E) 1.3 N·m

\[ \mu = I A = (5.5 \text{A})(0.4 \text{m})(0.3 \text{m}) = 0.66 \text{ Am}^2 \]

\[ \vec{T} = \mu \times \vec{B} \]

\[ T = \mu B \sin \theta \]

\[ T = (0.66 \text{Am}^2)(2.9 \text{T}) \sin 35^\circ \]

\[ = 1.1 \text{ Nm} \]
8) Two very long parallel wires are a distance \( d \) apart and carry equal currents in opposite directions. The locations where the net magnetic field due to these currents is equal to zero are:

A) The net field is not zero anywhere.
B) a distance \( d/2 \) to the left of the left wire and also a distance \( d/2 \) to the right of the right wire.
C) a distance \( d \) to the left of the left wire and also a distance \( d \) to the right of the right wire.
D) a distance \( d/\sqrt{2} \) to the left of the left wire and also a distance \( d/\sqrt{2} \) to the right of the right wire.
E) midway between the wires.

In between, the contributions from both wires add, so they can never cancel and give zero field.

On either side, the contributions are in opposite directions, so they do cancel partially.

However, since the currents are equal, and we are always closer to our wire, they cannot cancel completely and there will always be some field.
FREE RESPONSE. 16 points total. Write your final answer for each part in the box provided. Partial credit will only be given if you show your work and it is clear.

9) Consider the circuit below. All switches are initially open and there is no charge on any capacitor.

(a) Switch $S_1$ is now closed and the other switches are left open. Calculate the charge on the 3 $\mu$F capacitor after a long time.

$$Q_5 = C_5V = (3 \mu F)(12V) = 36 \mu C$$

We will want the charge on the other capacitor in a minute, so

$$Q_4 = C_4V = (4 \mu F)(12V) = 48 \mu C$$

The total stored charge is

$$Q = 36 \mu C + 48 \mu C = 84 \mu C$$

(b) Switch $S_1$ is now opened and then switch $S_2$ is closed. (Switch $S_3$ remains open.) Calculate the charge on the 3 $\mu$F capacitor after a long time.

Notice that the 3, 4, and 5 are now all in parallel.

$$\begin{align*}
3 & \quad 4 & \quad 5 \\
\downarrow & \quad \downarrow & \quad \downarrow \\
3 & \quad \frac{4}{5} & \quad 1
\end{align*}$$

This has an equivalent capacitance

$$C_{eq} = 3 + 4 + 5 = 12 \mu F$$

The charges will move around after we flip the switches, but the total is the same as before

$$V_{new} = \frac{Q}{C_{eq}} = \frac{84 \mu C}{12 \mu F} = 7V$$

Now there is 7V across each capacitor, so the charge on the 3, 5

$$Q = C_3V_{new} = (3 \mu F)(7V) = 21 \mu C$$

We will also use

$$Q_5 = C_5V_{new} = (5 \mu F)(7V) = 35 \mu C$$
(c) Switch \( S_2 \) is now opened and then switch \( S_3 \) is closed. (Switch \( S_1 \) remains open.) Calculate the current in the 100\( \Omega \) resistor 1 ms after the switch is closed.

\[
I(t) = \frac{Q_0}{RC} e^{-t/RC} = \frac{35\mu C}{0.75ms} e^{-\frac{1ms}{0.75ms}} = 12.3 mA
\]

\[
RC = (150\Omega)(5\mu F) = 0.75ms
\]

\[
1 = 12.3mA \quad (4)
\]

(d) Calculate total energy dissipated in the resistor during the same time.

"Hard Way"

\[
P = I^2R
\]

\[
U = \int P dt
\]

\[
= \frac{Q_0^2}{2C} \left[-e^{-2t/RC}\right]_{0}^{1ms}
\]

\[
= \frac{Q_0^2}{2C} (1 - e^{-2(1ms/0.75ms)})
\]

\[
= \frac{(35\mu C)^2}{2(5\mu F)} \left[-e^{-2(1ms/0.75ms)} + 1\right]
\]

\[
= 110\mu J
\]

"Easy Way"

\[
E = 90\mu J \quad (4)
\]

Change in stored energy in capacitor = energy dissipated in resistor

\[
Q_0 = 35\mu C
\]

\[
Q_f = Q_0 e^{-t/RC} = (35\mu C) e^{-1ms/0.75ms} = 9.2\mu C
\]

\[
U = \frac{1}{2} \frac{Q^2}{C}
\]

\[
\Delta U = \frac{1}{2C} (Q_0^2 - Q_f^2) = \frac{1}{2(5\mu F)} \left[(35\mu C)^2 - (9.2\mu C)^2\right]
\]

\[
= 110\mu J
\]
Physics 116B (Fall 08)

Exam 2

Regular

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Alternate

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