BEFORE YOU BEGIN:

1. Fill in CORRECTLY your ID number in the Scantron, as well as which FORM of the test you have.
2. Write the course number (2306)
3. Write down your name on the test and scantron; fill in the appropriate ‘bubbles’
4. Assume MKS units unless specified otherwise.
5. Use these values:
   \( v_{\text{sound in air}} = 340 \text{ m/s} \)
   \( g = 9.8 \text{ m/s}^2 \)
   \( e=1.6\times10^{-19} \text{ C} \)
   \( k=9.0\times10^9 \text{ Nm}^2/\text{C}^2 \)
   \( \varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{Nm}^2) \)
   \( \mu_0 = 4\pi \times 10^{-7} \text{ Tm/A} \)

For problems where you are asked to rank items, items of different magnitudes should be separated by commas, while those of the same magnitude should have no comma between them. For example:

Rank the following numbers from highest to lowest
   A) 7
   B) 5
   C) 5
   D) 3
   Answer: A,BC,D

Honor Code

I have neither given nor received unauthorized assistance on this assignment.

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(sign here)
1. A long straight wire has current $I = 10$ A. A square loop of wire with edge 3 cm is placed 5 cm from the long wire (see figure). What is the magnitude of total magnetic flux through the square loop?

Hints:

$$B(r) = \frac{\mu_0 I}{2\pi r} \quad \int \frac{1}{x} \, dx = \ln(x)$$

1) $2.8 \times 10^8$ Wb
2) $9.4 \times 10^7$ Wb
3) $1.8 \times 10^7$ Wb
4) $9.2 \times 10^7$ Wb
5) $1.2 \times 10^8$ Wb

![Diagram of a long straight wire with a square loop of wire nearby.]

2. A square loop of wire with area $A = 20$ cm$^2$ is placed in a uniform vertical magnetic field $\vec{B} = 0.5 \hat{k}$ T. The loop rotates in the magnetic field, such that the surface normal vector $\hat{n}(t)$ of the loop is:

$$\hat{n}(t) = \cos(\omega t) \hat{k} + \sin(\omega t) \hat{i}$$

where $\omega = 10$ rad/s. What is the amplitude of the oscillating e.m.f. in the square loop?

![Diagram of a square loop of wire with a uniform vertical magnetic field.]
Three vertically oriented loops of wire are falling downwards with constant velocity (see figure). The loops enter a region of nonzero magnetic field below the dashed line. The magnetic field is zero above the dashed line.

Rank the loops from lowest to highest induced e.m.f. magnitude at the instant shown in the figure.

1) A,B,C
2) A,BC
3) C,B,A
4) ABC
5) AB,C

A 0.1 kg metal rod is falling downward while connected to a frictionless wire with negligible resistance. The rod itself has resistance $R = 0.1 \, \Omega$. The entire system is immersed in a magnetic field $B = 0.5 \, T$. (see figure). What is the terminal velocity of the rod?

Hint: balance the magnetic force by the gravitational force.
A bar magnet (north pole pointed downwards) falls through a circular loop (oriented horizontally). The induced magnetic field in the center of the loop due to current in the loop is:

1) directed upward always.
2) directed downward always.
3) directed upward then downward.
4) directed downward then upward.
5) zero.

A parallel plate capacitor is charged by a current I (see figure). This generates a time-dependent electric field within the capacitor.

By considering the integral \( \oint \vec{B} \cdot d\vec{l} \) around the dashed loop in the figure, what is the magnitude of the magnetic field \( \vec{B} \) at the radius \( r \)? Assume \( r > R \), where \( R \) is the radius of the capacitor.

1) \( \frac{\mu_0 I}{\pi R^2} \)
2) \( \frac{\mu_0 I}{2\pi R} \)
3) 0
4) \( \frac{\mu_0 R I}{\pi r^2} \)
5) \( \frac{\mu_0 I}{2\pi r} \)
A metallic disk with diameter 24 mm is placed in a solenoid. A sudden rising current \( I \) is sent through the solenoid to generate a rapidly growing magnetic field (see figure). This induces a current in the disk.

What best describes the force on the induced currents due to the magnetic field, i.e. from \( \mathbf{dI} \times \mathbf{B} \).

The figure shows four different sets of insulated wires that cross each other at right angles without actually making electrical contact. The magnitude of the current is the same in all the wires, and the directions of current flow are as indicated. For which (if any) configuration will the magnetic field at the center of the square formed by the wires be equal to zero?
The figure shows the cross-section of a hollow cylinder of inner radius \( a = 5.0 \text{ cm} \) and outer radius \( b = 7.0 \text{ cm} \). A uniform current density of \( 1.0 \text{ A/cm}^2 \) flows through the cylinder parallel to its axis. Calculate the magnitude of the magnetic field at a distance of \( d = 10 \text{ cm} \) from the axis of the cylinder.

![Diagram of a hollow cylinder]

1) \( 4.5 \times 10^{-4} \text{ T} \)  
2) \( 1.5 \times 10^{-4} \text{ T} \)  
3) \( 2.5 \times 10^{-4} \text{ T} \)  
4) \( 0.5 \times 10^{-4} \text{ T} \)  
5) 0.0 T

As shown in the figure, a rectangular current loop is carrying current \( I_1 = 2 \text{ A} \), in the direction shown, and is located near a long wire carrying a current \( I_w \). The long wire is parallel to the sides of the rectangle. The rectangle loop has length 0.80 m and its sides are 0.10 m and 0.70 m from the wire, as shown. We measure that the net force on the rectangular loop is \( 6.5 \times 10^{-6} \text{ N} \) and is directed towards the wire.

What is the magnitude of the current \( I_w \)?

![Diagram of a rectangular current loop]

1) 0.25 A  
2) 0.74 A  
3) 0.91 A  
4) 1.11 A  
5) 2.40 A
11 The figure shows, in cross section, several conductors that carry currents through the plane of the figure. The currents have the magnitudes \( I_1 = 4.0 \ A \), \( I_2 = 5.0 \ A \), and \( I_3 = 1.0 \ A \), and the directions shown. Four paths, labeled \( a \) through \( d \), are shown.

Rank the paths from greatest to smallest based on the value of \( \oint \vec{B} \cdot d\vec{l} \) around these paths in the counter-clockwise direction,

1) \( a, b, c, d \)
2) \( b, ad, c \)
3) \( d, c, a, b \)
4) \( c, a, bd \)
5) \( a, c, d, b \)

12 A 42 \( \mu \)C point charge moves on the \( x \)-axis in the positive direction with a speed of 190 m/s. A point \( P \) is on the \( y \)-axis at \( y = +40 \) mm. When the charge is at \( x = +40 \) mm, what is the magnitude of the magnetic field at point \( P \)?

1) 0.39 \( \mu \)T
2) 0.19 \( \mu \)T
3) 0.34 \( \mu \)T
4) 0.28 \( \mu \)T
5) 0.23 \( \mu \)T
A solenoid having $N$ turns and carrying a current of 2.000 A has a length of 34.00 cm. If the magnitude of the magnetic field generated at the center of the solenoid is 9.000 mT, what is the value of $N$?

1) 860.0  
2) 1218  
3) 2318  
4) 1591  
5) 3183

Two inductors are in parallel as shown, and are then in series with a resistor and a battery. What is the current in the resistor just after the switch is closed?

1) 0.2 mA  
2) 0 mA  
3) 6 mA  
4) 0.1 mA  
5) 2.5 mA
Four resistors, an uncharged capacitor and an inductor are wired as shown and with the values indicated. Rank the energy being stored in circuits A, B, C from the largest to the least, long after the switch is closed.

1) CB, A  
2) C, B, A  
3) B, C, A  
4) C, BA  
5) ABC

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Four resistors, an uncharged capacitor and an inductor are wired as shown and with the values indicated. Rank the power dissipated along paths A, B, C from the largest to the least, long after the switch is closed.

1) A, B, C  
2) C, A, B  
3) A, BC  
4) A, C, B  
5) ABC
17. What is the power going into the magnetic field of the inductor 2.0 \(\mu\)s after the switch is closed? Hint: first find the current at that time.

\[3.0 \text{ V} \quad 2.0 \Omega \quad 6.0 \mu\text{H}\]

1) \(0.213 \text{ W}\)
2) \(6.32 \text{ W}\)
3) \(4.43 \text{ W}\)
4) \(1.12 \text{ W}\)
5) \(0 \text{ W}\)

18. An L-C circuit containing a 70 mH inductor and a 2.0 nF capacitor oscillates with a maximum charge of 6.0 \(\mu\)C on the capacitor. What is the maximum current through the circuit? Hint: consider the energy stored in the circuit.

1) \(1.4 \text{ A}\)
2) \(2.3 \text{ A}\)
3) \(0.51 \text{ A}\)
4) \(0.13 \text{ A}\)
5) \(3.2 \text{ A}\)
A 87-mH solenoid inductor is wound on a form 0.80 m in length and 0.10 m in diameter. A coil is tightly wound around the solenoid at its center. The coil's resistance is 8.8 ohms. The mutual inductance of the coil and solenoid is 80 μH. At a given instant, the current in the solenoid is 660 mA, and is decreasing at the rate of 2.5 A/s. At the given instant, what is the magnitude of the induced current in the coil? ($\mu_0 = 4\pi \times 10^{-7} \text{T} \cdot \text{m/A}$)

1) 23 μA
2) 18 μA
3) 36 μA
4) 32 μA
5) 27 μA

How much energy is stored in a room 3.0 m by 4.0 m by 2.4 m due to the earth's magnetic field with a strength of $5.0 \times 10^{-5} \text{T}$? ($\mu_0 = 4\pi \times 10^{-7} \text{T} \cdot \text{m/A}$)

1) 570 mJ.
2) 10 mJ.
3) 100 mJ.
4) 570 mJ.
5) 29 mJ.