Name*	Student Number								

*Please write your name – legibly! – as it appears in Blackboard.

Instructions

- Write your **name and student number** in the spaces provided above. Please write your name legibly, as it appears on Blackboard.
- Submit your answers to multiple-choice questions on a “blue" **Scantron (no. 4521)**.
- Refer to page 5 of this booklet for the **version number** of this test and enter the version number in the first column of the “special codes" area of your Scantron.
- As described in the syllabus, there are **penalties** for submitting a Scantron that requires manual processing, for any reason, including tears or wrinkles, an incorrect **student number** or a missing **test version** in the “special codes" area of the Scantron.
- This test has 13 questions on 11 pages, for a total of 0 points and 0 bonus points. **Be sure to answer all questions.**
- You may detach and keep (or discard) the **formula page** at the end of this booklet.

Multiple Choice

Conceptual Questions

1. (3 points) This question is based on (24.7.2-3) from the notes. At a particular instant, an electron moves toward the east in a uniform magnetic field that is directed straight downward. The magnetic force that acts on it is. . .

   A. zero.

   B. upward.

   C. toward the north.

   D. toward the south.

   E. downward.

2. (3 points) This question is based on (24.7.2-3) from the notes. Protons are positive particles. A proton has an initial velocity to the south but is observed to curve upward as the result of a magnetic field. This will happen if the magnetic field points. . .

   A. to the west.

   B. to the east.

   C. upward.

   D. downward.

   E. to the north.

3. (3 points) This question is based on (24.3.4) and (24.8.7) from the notes. Two long parallel wires are placed side-by-side on a horizontal table. It might help to sketch $\vec{B}$, I and $\vec{F}$ in *two* sketches, with a different wire as the source in each sketch. If the wires carry current in opposite directions. . .

   A. one wire is lifted slightly while the other wire is forced downward against the table's surface.

   B. both wires are lifted slightly.

   C. the wires pull toward each other.

   D. the wires push away from each other.

   E. the forces cancel.

4. (3 points) This question is based on (24.3.4-7) in the notes. Two long parallel wires placed side-by-side on a horizontal table carry identical current straight toward you. It might help to sketch the end-view of the wires, using "•" or "×" for the current. Then sketch the field for each wire. From your point of view, the net magnetic field at a point exactly between the two wires. . .

    A. points upward.

    B. points downward.

    C. points toward you.

    D. points away from you.

    E. is zero.

5. (3 points) This is based on (25.5.6-11) from the notes. A coil lies flat on a horizontal tabletop in a region where the magnetic field points straight down. The magnetic field disappears suddenly. It might help to make separate sketchs for the initial and final applied fields, looking down at the coil from above. Then make a third sketch for the induced field. When viewed from above, what is the direction of the induced current in this coil as the field disappears?

    A. counterclockwise

    B. clockwise

    C. clockwise initially, then counterclockwise before stopping

    D. counterclockwise initially, then clockwise before stopping

    E. There is no induced current in this coil.

6. (3 points) This is based on (25.8.15) from the notes. For an electromagnetic wave in free space, the electric and magnetic fields are. . .

    A. parallel to one another and perpendicular to the direction of wave propagation.

    B. parallel to one another and parallel to the direction of wave propagation.

    C. perpendicular to one another and perpendicular to the direction of wave propagation.

    D. perpendicular to one another and parallel to the direction of wave propagation.

    E. constantly changing orientation, compared to one another

Terminology Questions

7. (3 points) Fill in the blank with the *best* answer: magnets have two types of poles, called north and south poles, and thus are ______________.

   A. magnetic materials

   B. magnetic dipoles

   C. permanent magnets

   D. magnetic moments

   E. domains

8. (3 points) Fill in the blank with the *best* answer: positron-emission tomography (PET) requires the fluorine isotope, ^{18}F, which is created using a ______________ to fire energetic protons at ^{18}O atoms in water, replacing a neutron with a proton.

   A. compass

   B. solenoid

   C. torque

   D. electromagnet

   E. cyclotron

9. (3 points) Fill in the blank with the *best* answer: a transformer consists of two coils of wire wrapped on a single iron core; one coil, called the ______________ coil, is connected to an AC voltage.

   A. step-up

   B. step-down

   C. primary

   D. secondary

   E. voltage

10. (3 points) Fill in the blank with the *best* answer: one terminal of the electric supply is at a varying potential; we call this the ______________ side.

    A. hot

    B. neutral

    C. grounded

    D. leads

    E. lags

Spare Questions

Here is a chance to recover from mistakes. These spare questions can replace any two multiple-choice questions that were answered incorrectly, up to a maximum of ten correct answers.

11. (3 bonus points) This question is based on (26.5.6-7) from the notes. If the secondary coil of a transformer contains more loops than the primary coil, then, in the secondary coil...

    A. voltage increases and current increases

    B. voltage increases and current decreases

    C. voltage decreases and current increases

    D. voltage decreases and current decreases

    E. the answer depends on the load

12. (3 bonus points) This question is based on (26.1.4-6) and (26.2.8) in the notes. Which one of the following are correct expressions for the sinusoidal AC voltage? Pick just one answer.

    A. $v = V\cos(2\pi f t)$

    B. $v = V\cos(2\pi t/T)$

    C. $v = \sqrt{2}V_{\text{rms}}\cos(2\pi f t)$

    D. all of the above

    E. just two of the above.

Test Version

This is version 1 of the test. Enter this version number in the first column of the “special codes” area on your Scantron. Leave the other columns blank.

Induction: a Loop and a Nearby Wire

13. The long edge or a rectangular coil is parallel to a long wire. The coil is 3.00 m long and 0.500 m wide. The coil has 100 turns, a resistance of 10.0 Ω and the center of the coil is 12.0 m from the nearest point on the wire. The current in the wire decreases from 80.0 A to 60.0 A in a 1.25×10^{-3} s interval. The ultimate question is this: in terms of magnitude and direction, what is the induced current in the coil?

Prepare

Simplify

Make the following simplifications:

1. For computing flux, neglect the 0.500 m width of the coil, compared to the distance from the wire; treat the entire coil as 12.0 m from the wire, although some parts are slightly closer and other parts are slightly farther away.
2. In the "sketch" phase, draw just one loop of the coil *but* remember to account for all loops, in the "solve" phase.
3. Treat the coil as perfectly stationary.

(a) Based on the simplifications, for what directions of the current in the wire will the magnetic field of the earth have no affect on the induced emf in the coil? Put an "X" in all appropriate boxes: 13.(a)

□ north □ east □ south □ west	13.(a)

Define Symbols

(b) Which of the following symbols represent (explicitly) *given* values? In other words, for which symbols does the wording of the problem give a number? Put an "X" in the appropriate boxes: 13.(b)

- □ applied magnetic field: B_A
- □ induced magnetic field: B_I
- □ distance from wire to coil: d
- □ elapsed time: Δt
- □ current in the coil: I_C
- □ initial current in the wire: $(I_W)_i$
- □ final current in the wire: $(I_W)_f$
- □ length of rectangular coil: ℓ
- □ turns in the coil: N
- □ applied field orientation: θ_A
- □ induced field orientation: θ_I
- □ initial time: t_i
- □ final time: t_f
- □ resistance in the coil: R_C
- □ resistance in the wire: R_W
- □ width of rectangular coil: w

Diagram

A partial sketch is provided (Fig. 1). Consider some **key features** of the sketch:

1. The sketch is *not* to scale (the coil should be narrower and farther from the wire).
2. Only one loop of the coil is shown.
3. The dashed box is an aid to grading and has no physical significance.

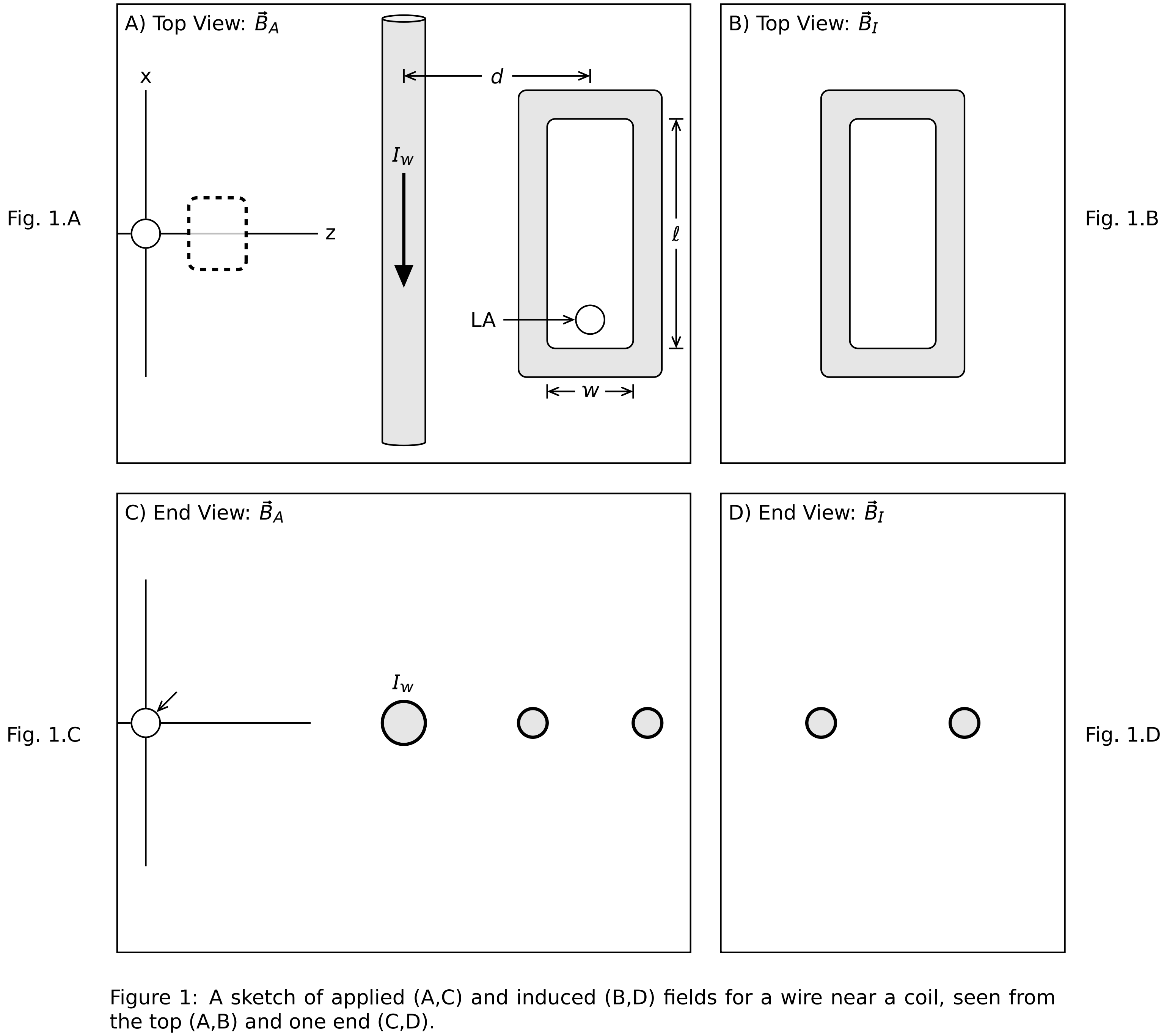

Figure 1: A sketch of applied (A,C) and induced (B,D) fields for a wire near a coil, seen from the top (A,B) and one end (C,D).

Applied Field, Top View: Fig. 1.A

(c) At the origin, use "•" or "×" to show the direction of the y-axis. 13.(c)

(d) The direction of I_W is shown. Near the center of the coil, use"•" or × to show one example of a field line. Inside the dashed line, use "•" or × to draw a second example. 13.(d)

(e) Choose a loop axis (LA) that makes θ_A as small as possible, using"•" or "×" to show the direction. 13.(e)

Applied Field, End View: Fig. 1.C

(f) Use either "•" or "×" to show I_W flowing out of the page. 13.(f)

(g) (3 points) Based on the direction of I_W, label the axes, using "•" or "×" for the third dimension.

(h) Sketch the applied field by drawing one field line that passes roughly through the center of the coil. Put an arrow on the line to show the direction of the field.

(i) Sketch and label and arrow for the loop axis. 13.(i)

Induced Current and Field, Top View: Fig. 1.B

(j) Inside the wire of the coil, draw an arrow labeled I_C to show the direction of the current. 13.(j)

(k) At the center of the coil, use "•" or "×" to show one example of a field line. 13.(k)

(l) Outside the coil, use "•" or "×" to draw one field line near the midpoint of each edge. 13.(l)

Induced Current and Field, End View: Fig. 1.D

(m) Sketch the induced current, using "•" or "×" at the center of each wire. 13.(m)

(n) Sketch one field line near each wire, using arrows to show the direction of the field. 13.(n)

Solve

(o) Using only symbols from part (b) write a formula for the total area of the coil, in the space provided. Be careful to account for the area of each loop. Also, write a formula for the initial applied field.

13.(o)-1	In symbols: $A =$	In symbols: $(B_A)_i =$	13.(o)-2

(p) As always, θ is the angle between a given field and the chosen loop axis. Based on part (e), write values for θ_A and $\cos\theta_A$ in the spaces provided. For simplicity, plug these values into subsequent formulæ.

13.(p)-1	In degrees: $\theta_A =$	In numbers: $\cos\theta_A =$	13.(p)-2

(q) Using parts (o) and (p), write down final flux and the *change* in flux.

13.(q)-1	In symbols: $\Phi_f =$	In symbols: $\Delta\Phi =$	13.(q)-2

(r) In the spaces provided, write a formula for $\mathcal{E}_C$ from Faraday's Law and a related formula for I_C from Ohm's Law.

13.(r)-1	In symbols, Faraday's Law: $\mathcal{E}_C =$	In symbols, Ohm's Law: $I_C =$	13.(r)-2

(s) There is a standard trick for dealing with absolute values. For this problem, which of the following is true? Put an "X" in the appropriate boxes:

☐ $(I_W)_f > (I_W)_i \implies \Delta\Phi > 0 \implies \left|\frac{\Delta\Phi}{\Delta t}\right| = \frac{\Delta\Phi}{\Delta t}$ since $\Delta\Phi$ and Δt are positive 13.(s)

☐ $(I_W)_f < (I_W)_i \implies \Delta\Phi < 0 \implies \left|\frac{\Delta\Phi}{\Delta t}\right| = -\frac{\Delta\Phi}{\Delta t}$ since $-\Delta\Phi$ and Δt are positive

(t) Combine parts (q), (s) and both equations from part (r) and solve for the current in the coil. Express the answer in terms of given symbols form part (b). Then plug in numbers.

13.(t)-1	In symbols: $I_C =$	In numbers: $I_C =$	13.(t)-2

Assess

Justify Simplifications

(u) For this part, ignore the first simplification. In other words, *do not* treat the long edges of the coil as equally distant from the wire 13.(u)

On the top view, for the induced field, sketch and label the force $\vec{F}_{WC}$, for the force by the wire on the coil. Draw separate vectors for each of the coil's long edges. In which direction does the next force point? Put an "X" in the appropriate box:

- ☐ along the positive x-axis
- ☐ along the negative x-axis
- ☐ along the positive y-axis
- ☐ along the negative y-axis
- ☐ along the positive z-axis
- ☐ along the negative z-axis

13.(u)

This shows that the third simplification is not really justified, unless there are other forces in the problem.

Rules of Thumb

(v) Are the directions of $\vec{F}_{WC}$ and $\vec{B}_W$ consistent? Explain. Write your assessment in the space provided.

13.(v)

(w) Are the directions of $\vec{F}_{WC}$ and I_C consistent? Explain. Write your assessment in the space provided.

13.(w)

Constants and Conversion Factors

$$\mu_0 = 1.26 \times 10^{-6}\,\mathrm{T \cdot m/A} \tag{1}$$

$$1\,\mathrm{nm} = 1 \times 10^{-9}\,\mathrm{m} \tag{2}$$

Formulæ

$$F = |q|vB\sin\alpha \tag{3}$$

$$F = ILB \tag{4}$$

$$\tau = (IA)B\sin\theta \tag{5}$$

$$B = \frac{\mu_0 I}{2\pi r} \tag{6}$$

$$B = \frac{\mu_0 N I}{L} \tag{7}$$

$$r = mv/|q|B \tag{8}$$

$$\Phi = AB\cos\theta \tag{9}$$

$$\mathcal{E} = \left|\frac{\Delta\Phi}{\Delta t}\right| \tag{10}$$

$$I = \frac{\mathcal{E}}{R} \tag{11}$$

$$v_{\mathrm{em}} = c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} \tag{12}$$

$$c = \lambda f \tag{13}$$

$$\frac{E_0}{B_0} = c \tag{14}$$

$$\mathcal{E} = vlB \tag{15}$$

$$E = hf \tag{16}$$

$$I = I_0 \cos^2\theta \tag{17}$$

$$\lambda_{\mathrm{peak}}\ (\text{in nm}) = \frac{2.9 \times 10^6\,\mathrm{nm \cdot K}}{T} \tag{18}$$

$$\mathcal{E} = \mathcal{E}_0 \cos(2\pi f t) \tag{19}$$

$$T = 1/f \tag{20}$$

$$V_R = I_R R \tag{21}$$

$$X_C = 1/(2\pi f C) \tag{22}$$

$$V_C = I_C X_C \tag{23}$$

$$X_L = 2\pi f L \tag{24}$$

$$V_L = I_L X_L \tag{25}$$

$$P_R = (I_{\mathrm{rms}})^2 R = \frac{(V_{\mathrm{rms}})^2}{R} = I_{\mathrm{rms}} V_{\mathrm{rms}} \tag{26}$$

$$I_{\mathrm{rms}} = I_R/\sqrt{2} \tag{27}$$

$$V_{\mathrm{rms}} = V_R/\sqrt{2} \tag{28}$$

$$(V_2)_{\mathrm{rms}} = \frac{N_2}{N_1}(V_1)_{\mathrm{rms}} \tag{29}$$

$$(I_2)_{\mathrm{rms}} = \frac{N_1}{N_2}(I_1)_{\mathrm{rms}} \tag{30}$$

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{31}$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \tag{32}$$

$$I_{\max} = \mathcal{E}_0/R \tag{33}$$

$$I = \frac{\mathcal{E}_0}{\sqrt{R^2 + (X_L - X_C)^2}} \tag{34}$$