Key

Multiple Choice (Problems 1-5) _______________ 15 pts
Fill The Blank (Problems 6-9) _______________ 8 pts
Problem 10 _______________ 8 pts
Problem 11 _______________ 12 pts
Problem 12 _______________ 12 pts
Problem 13 _______________ 6 pts
Problem 14 _______________ 14 pts
Problem 15 _______________ 13 pts
Problem 16 _______________ 12 pts
Bonus _______________ 18 pts
Total _______________

Mass of electron = $9.11 \times 10^{-31}$ kg
Charge on an electron = $1.6 \times 10^{-19}$ C
Permeability of free space = $4\pi \times 10^{-7}$ Tm/A
Permittivity of free space = $8.85 \times 10^{-12}$ $C^2/(N m^2)$
1. Two long parallel wires are placed side-by-side on a horizontal table. If the wires carry current in the same direction,
   A. both wires are lifted slightly
   B. the wires attract each other.
   C. the wires repel each other.
   D. one wire is lifted slightly as the other wire is forced against the table surface.

2. A horizontal rod (oriented in the east-west direction) is moved northward at constant velocity through a magnetic field that points straight down. Make a statement concerning the potential induced across the rod.
   A. The bottom surface of the rod is at higher potential than the top surface.
   B. The east end of the rod is at higher potential than the west end.
   C. The top surface of the rod is higher potential than the bottom surface.
   D. The west end of the rod is at higher potential than the east end.

3. A circular coil lies flat on a horizontal table. A bar magnet is held above its center with its north pole pointing downward, and released. As it approaches the coil, the falling magnet induces (when viewed from above)
   A. no current
   B. a counter clockwise current in the coil.
   C. a clockwise current in the coil.
   D. a current whose direction cannot be determined from the information provided.
4. Consider two current-carrying circular loops. Both are made from one strand of wire and both carry the same current, but one has twice the radius of the other. Compared to the magnetic moment of the smaller loop, the magnetic moment of the larger loop is 

\[ \mu = I A = I \pi r^2 \]

A. 4 times stronger  
B. 8 times stronger  
C. 2 times stronger  
D. 16 times stronger

\[ \frac{\mu_2}{\mu_1} = \left( \frac{r_2}{r_1} \right)^2 = (2)^2 \]

5. The force on a current carrying wire in a magnetic field is zero when

A. the current is at a 60 degree angle with respect to the field lines.
B. the current is parallel to the field lines.
C. the current is perpendicular to the field lines.
D. the current is at a 30 degree angle with respect to the field lines.

\[ F = I L B \sin \theta = 0 \]
\[ \Rightarrow \sin \theta = 0 \Rightarrow \theta = 0° \]

6. The unit of inductance is __Henry__

7. The unit of magnetic flux is __Weber or Tesla • meter²__

8. The unit of electromotive force is __Volt__

9. The unit of magnetic field is __Tesla or Gauss__
You are designing a generator with a maximum emf of 8.0 V. If the generator coil has 200 turns and a cross-sectional area of 0.030 m\(^2\), what would be the frequency in Hertz of the generator in a magnetic field of 0.0052 T?

\[
\varepsilon_{\text{max}} = \omega N B A
\]

But \(\omega = 2\pi f\)

\[
\Rightarrow \varepsilon_{\text{max}} = 2\pi f N B A
\]

\[
f = \frac{\varepsilon_{\text{max}}}{2\pi N B A}
\]

\[
f = \frac{8 \text{ V}}{2\pi \times (200 \text{ turns}) \times (0.0052 \text{T}) \times (0.030 \text{m}^2)}
\]

\[
f \approx 40.8 \text{ Hz}
\]
12 pts 11. A 150 W lamp is placed into a 120 Volt outlet.

4 pts A. What is the peak power delivered to the lamp?

\[
\text{Peak Power} = 2 \cdot P_{\text{Average}}
\]

\[
\text{Peak Power} = 2 (150 \text{W}) = 300 \text{W}
\]

4 pts B. What is the rms current?

\[
P_{\text{AV}} = I_{\text{Rms}} \cdot V_{\text{Rms}}
\]

\[
I_{\text{Rms}} = \frac{P_{\text{AV}}}{V_{\text{Rms}}} = \frac{150 \text{W}}{120 \text{V}}
\]

\[
I_{\text{Rms}} = 1.25 \text{A}
\]

4 pts C. What peak current?

\[
I_{\text{peak}} = \sqrt{2} \cdot I_{\text{rms}}
\]

\[
I_{\text{peak}} = \sqrt{2} \cdot (1.25 \text{A})
\]

\[
I_{\text{peak}} = 1.77 \text{A}
\]
12 points

12. A proton travels through a potential of 1.0 kV and then moves into a magnetic field of 0.040 T. What is the radius of the proton’s resulting orbit given that the mass of the proton is $1.67 \times 10^{-27}$ kg?

\[ E = qV \]

\[ E = (1 \text{e}) (1.0 \text{kV}) = 1.0 \text{ keV} = 1.6 \times 10^{-16} \text{ J} \]

\[ E = \frac{1}{2} m v^2 = \frac{p^2}{2m} \leftarrow \text{Either is good} \]

\[ p = \sqrt{2mE} \]

\[ p = \sqrt{2(1.67 \times 10^{-27} \text{kg})(1.6 \times 10^{-16} \text{J})} \]

\[ p \approx 7.31 \times 10^{-22} \text{ kg m/s} \]

\[ R = \frac{p}{Bq} \leftarrow \text{Either is good} \]

\[ R \approx \frac{7.31 \times 10^{-22} \text{ kg m/s}}{(0.040 \text{T})(1.6 \times 10^{-16} \text{C})} \]

\[ R \approx 0.114 \text{ m} \quad \text{or} \quad 11.4 \text{ cm} \]

\[ \text{suitable unit} \]
6 pts  13. A 3 meter long wire carrying 2.5 A is placed at an angle 30 degrees with respect to a magnetic field of 150 gauss. What is the force on the wire?

\[
B = (150 \text{ Gauss}) \left( \frac{1 \text{T}}{10,000 \text{ Gauss}} \right) \approx 0.015 \text{T} \quad \text{(1)}
\]

\[
F = I l B \sin \theta \quad \text{(3)}
\]

\[
F = (2.5 \text{ A}) (3 \text{ m}) (0.015 \text{ T}) \sin (30^\circ)
\]

\[
F \approx 0.0563 \text{ N} \quad \text{(1)} \text{ units} \quad \text{(4)}
\]

\[
+1 \#
\]
14 pts 14. A long solenoid with 250 turns has a radius of 2 cm and a length of 40 cm.

6 pts A. What is the magnetic field in the solenoid when a current of 2 A is applied to it?

\[ B = \frac{\mu_0 N I}{l} \]

\[ B = \left(4 \pi \times 10^{-7} \text{Tm/A}\right) (250 \text{ turns}) (2 \text{ A}) \]

\[ B = \frac{0.00157 \text{T}}{0.4 \text{ m}} \approx 0.003925 \text{T} \]

\[ B = 0.00157 \text{T} \text{ or } 0.003925 \text{T} \]

+2 for #
+1 for suitable unit if they put it in Gauss it is ok.

8 pts B. What is the solenoid's inductance?

\[ L = \frac{N \Phi_B}{I} \]

\[ \Phi_B = BA \]

A = \(\pi r^2 = \pi (0.02 \text{ m})^2 \approx 1.257 \times 10^{-4} \text{ m}^2\)

\[ L \approx \frac{(250 \text{ turns}) (1.57 \times 10^{-3}) (1.257 \times 10^{-4} \text{ m}^2)}{2 \text{ A}} \]

\[ L \approx 2.47 \times 10^{-5} \text{ H} \]

\[ L \approx 2.47 \times 10^{-5} \text{ H} \text{ or } 24.7 \mu \text{H} \]

Students can also use \[ L = \frac{\pi r^2 \mu_0 N^2}{l} \].
13 pts 15. A DC motor of internal resistance 6.0 Ω is connected to a 24 V power supply. The operating current is 1.2 A when the motor is operating at full speed.

5 pts A. What is the back emf when the motor is at full speed?

\[ V_R = I R \]  
\[ V_R = (1.2 A)(6 \Omega) \]  
\[ V_R = 7.2 V \]  
\[ \varepsilon = 24 V - 7.2 V \]  
\[ \varepsilon = [16.8 V] \]  

4 pts B. What is the back emf when the motor is operating at half speed?

\[ \varepsilon_{max} = \omega NBA \]  
\[ \frac{\varepsilon_H}{\varepsilon_F} = \frac{\omega_H}{\omega_F} = \frac{1}{2} \]  
\[ \varepsilon_H = \frac{1}{2} \varepsilon_F \]  
\[ \varepsilon_H = \frac{1}{2} (16.8 V) \]  
\[ \varepsilon_H = [8.4 V] \]
4 pts C. What is the motor's startup current (i.e. the current when the motor is initially turned on)?

\[ \Sigma \text{V} = 0 \]

\[ I = \frac{24\text{V}}{6\Omega} \]

\[ I = 4\text{A} \]

Units
16. When the current in a 10-H coil of one turn is equal to 2.5 A and is increasing at 40 A/S, find

4 pts  A) the magnetic flux through the coil.

\[ L = \frac{\phi_b}{I} \]

\[ \phi_b = LI \]

\[ \phi_b = (10 \text{ H})(2.5 \text{ A}) = 25 \text{ Wb} \] (units)

4 pts  B) the energy stored in the magnetic field.

\[ U = \frac{1}{2} LI^2 \]

\[ U = \frac{1}{2} (10 \text{ H})(2.5 \text{ A})^2 \]

\[ U = 31.3 \text{ J} \] (units)

4 pts  C) the induced emf in the coil.

\[ \mathcal{E} = L \frac{\Delta I}{\Delta t} \]

\[ \mathcal{E} = (10 \text{ H}) \left( \frac{40 \text{ A}}{5} \right) \]

\[ \mathcal{E} = 400 \text{ V} \] (units)
Bonus

Two long parallel wires carry currents of 25 A and 15 A in opposite directions and are separated by 0.30 m as shown. An electron located 0.90 m below the bottom wire is traveling parallel to the wires at a speed of 2.5 \times 10^5 \text{ m/s}.

10 pts  A. What is the magnetic field (magnitude and direction) at the electron’s location?

\[
B_1 = \frac{\mu_0 I_1}{2 \pi r_1} \quad (+) \\
B_1 = \left( \frac{4 \pi \times 10^{-7} \text{T m/A}}{2 \pi} \right) \left( \frac{25 \text{A}}{0.3 \text{m} + 0.9 \text{m}} \right) \quad (+) \text{ find } r_1
\]

\[
B_1 \approx 4.16 \times 10^{-6} \text{T} \approx 4.16 \mu \text{T} \quad (+)
\]

\[B_1 \text{ is into the page} \quad (+)
\]

\[
B_2 = \frac{\mu_0 I_2}{2 \pi r_2} \quad (+)
\]

\[
B_2 = \left( \frac{4 \pi \times 10^{-7} \text{T m/A}}{2 \pi} \right) \left( \frac{15 \text{A}}{0.9 \text{m}} \right) \quad (+) \text{ find } r_2
\]

\[
B_2 \approx 3.33 \times 10^{-6} \text{T} \approx 3.33 \mu \text{T} \quad (+)
\]

\[B_2 \text{ is out of the page} \quad (+)
\]

\[
B = B_1 - B = 8.33 \times 10^{-6} \text{T} \quad \text{or} \quad 0.833 \mu \text{T} \quad \text{into page} \quad (+)
\]
B. What is the magnetic force (magnitude & direction) the electron experiences?

\[ F = |q|v \times B \]

\[ F \approx (1.6 \times 10^{-19} \text{ C})(2.5 \times 10^5 \text{ m/s})(8.33 \times 10^{-7} \text{ T}) \]

\[ F \approx 3.33 \times 10^{-20} \text{ N} \]

By Right-Hand-Rule, the force is downward.