Early Booklet E.C.:	**+ 1**
Unit 4 Hwk. Pts.:	**/ 34**
Unit 4 Lab Pts.:	**/ 36**
Late, Incomplete, No Work, No Units **Fees**?	Y / N

Unit 4 – Magnetism

Essential Fundamentals of Magnetism

1. Magnetism is a fundamental force.
2. By convention, magnetic field lines are drawn from the north pole to the south pole.
3. On magnet A, the "north-seeking end" points towards the north pole of magnet B, but is the south pole of magnet A.
4. A magnetic field acts on a moving charge IF the charge moves across field lines.
5. When a conductor or magnet move with respect to each other, an electromotive force (emf), or voltage, is established
6. Transformers in AC circuits change voltage and current between coil proportionally to the number of coils in the primary and secondary.

Equation Sandbox

In Unit 4, some of the following equations will be used. Practice isolating variables to prepare for it

AP Equations

In-Class Equations

Magnetic Field near Wire
$B = \frac{\mu_0 I}{2\pi r}$
$I =$
$r =$

Magnetic Force on Moving Charge
$\vec{F}_M = q\vec{v} \times \vec{B}$
$q =$
$\vec{v} =$
$\vec{B} =$

EMF in Turning Loop
$\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t}$
$N =$
$\Delta\Phi_B =$
$\Delta t =$

Torque on Loop
$\tau = NIAB\sin\theta$
$N =$
$I =$
$A =$
$B =$

Magnetic Force on Wire
$\vec{F}_M = I\vec{\ell} \times \vec{B}$
$I =$
$\vec{\ell} =$
$\vec{B} =$

Solenoid Equation
$B = \frac{\mu_0 NI}{L}$
$N =$
$L =$
$I =$

Velocity Selector Eq.
$v = \frac{\Delta V}{Bd}$
$\Delta V =$
$B =$
$d =$

Back EMF Eq.
$\varepsilon_b = V - IR$
$V =$
$I =$
$R =$

EMF vs. Time
$\varepsilon = \varepsilon_0 \sin(2\pi ft)$
$f =$
$t =$
$\varepsilon_0 =$

Transformer Current
$I_s = \left(\frac{N_p}{N_s}\right) I_p$
$I_p =$
$N_p =$
$N_s =$

EMF in Moving Wire
$\varepsilon = B\ell v$
$B =$
$\ell =$
$v =$

Mag. Field Insidse Coil
$B = \frac{\mu_0 NI}{2r}$
$I =$
$r =$
$N =$

Max. EMF Equation
$\varepsilon_0 = NBA \bullet 2\pi f$
$B =$
$A =$
$f =$

Flux Definition
$\Phi_B = \vec{B} \bullet \vec{A}$
$\vec{B} =$
$\vec{A} =$

Transformer Voltage
$V_s = \left(\frac{N_s}{N_p}\right) V_p$
$V_p =$
$N_s =$
$N_p =$

Possible 4.1 Pts.: 4
Late, Incomplete, No work, No Units Fee: - 1 - 2
Final Score: / 4

4.1 Problems – Permanent Magnets, Poles, Magnetic Field Directions

Section 19.1 of your textbook.

1. Two identical bar magnets of negligible width are located in the *x*-*y* plane. Magnet #1 lies on the *x*-axis and its north end is at $x = +1.0$ cm, while its south end is at $x = +5.0$ cm. Magnet #2 lies on the *y*-axis and its north end is at $y = +1.0$ cm, while its south end is at $y = +5.0$ cm.

   A. In what direction would a compass point if it were located at the origin? (*Hint*: make a sketch of the two magnets and their individual fields at the origin.)

   B. Repeat part A for the situation where magnet #1 is reversed in polarity.

2. Two very narrow bar magnets are located in the *x*-*y* plane. Magnet #1 lies on the *x*-axis and its north end is at $x = +1.0$cm, while its south end is at $x = +5.0$ cm. Magnet #2 lies on the *y*-axis and its north end is at $y = +1.0$ cm, while its south end is at $y = +5.0$ cm. Magnet #2 produces a magnetic field that is only one-half the magnitude of magnet #1.

   A. In what direction would a compass point if it were located at the origin?

   B. Repeat part A for the situation where magnet #1 is reversed in polarity.

Possible 4.2 Pts.: 4	
Late, Incomplete, No work, No Units Fee: - 1 - 2	
Final Score:	/ 4

4.2 Problems – Magnetic Field Strength, Force
Section 19.2 of your textbook.

1. A positive charge moves horizontally to the right across this page and enters a magnetic field directed vertically downward in the plane of the page.
   A. What is the direction of the magnetic force on the charge: (1) into the page, (2) out of the page, (3) downward in the plane of the page, or (4) upward in the plane of the page? Explain.

   B. If the charge is 0.25 C, its speed is 2.0 E 2 m/s, and the force acting on it is 20.0 N, what is B?

2. A charge of 0.050 C moves vertically in a field of 0.080 T that is oriented 45˚ from the vertical. What speed must the charge have such that the force acting on it is 10 N?

3. A beam of protons is accelerated to a speed of 5.0×10^6 m/s in a particle accelerator and emerges horizontally from the accelerator into a uniform magnetic field. What magnetic field (give its direction and magnitude) oriented perpendicularly to the velocity of the proton would cancel the force of gravity and keep the beam moving exactly horizontally?

Possible 4.3 Pts.: 5
Late, Incomplete, No work, No Units Fee: - 1 - 2 -3
Final Score: / 5

4.3 Particles in Magnetic Fields, Current Carrying Wires

Section 19.3 – 19.5 of your textbook.

1. An ionized deuteron (a bound proton-neutron system with a net +*e* charge) passes through a velocity selector whose perpendicular magnetic and electric fields have magnitudes of 40 mT and 8.0 kV, respectively. If the plates are 1.0 meters apart, find the speed of the ion.

2. In a velocity selector, the uniform magnetic field of 1.5 T is produced by a large magnet. Two parallel plates with a separation of 1.5 cm produce the perpendicular electric field. What voltage should be applied across the plates so that:

   A. a singly charged ion traveling at 8 E 4 m/s will pass through undeflected

   B. a doubly charged ion traveling at the same speed will pass through undeflected.

3. A 2.0-m length of wire carries a current of 20 A in a uniform magnetic field of 50 mT whose direction is at an angle of 37˚ from the direction of the current. Find the force on the wire.

4. A wire carries a current of 10 A in the +*x*-direction in a uniform magnetic field of 0.40 T. Find the force per unit length and the direction of the force on the wire if the magnetic field is

(a) in the +*x*-direction

(b) in the +*y*-direction

(c) in the +z-direction

(d) in the –*y*-direction

(e) in the –*z*-direction

(f) at an angle of 45˚ above the +*x*-axis and in the *x*-*y* plane.

Possible 4.4 Pts.: 6
Late, Incomplete, No work, No Units Fee: - 1 - 2 -3
Final Score: / 6

4.4 Problems – Electromagnetism
Section 19.6 of your textbook.

1. The magnetic field at the center field at the center of a 50-turn coil of radius 15cm is 0.80 mT.
   A. Find the current in the coil.

   B. If you wanted to double the field strength while keeping the current and turn count the same, what would the coil area have to be?

2. A 2.5 cm solenoid has 150 loops, and carries a current of 1.3 A. What is the magnetic field strength in the middle of the coil?

3. A set of jumper cables used to start a car from another car's battery is connected to the terminals of both batteries. If 15 A of current exists in the cables during the starting procedure and the cables are parallel and 15 cm apart:
   A. do the wires repel or attract? Explain.

   B. What is the magnetic field strength that each wire produces at the location of the other?

   C. What is the force per unit length on the cables?

Possible 4.5 Pts.: 7
Late, Incomplete, No work, No Units Fee: - 1 - 2 -3
Final Score: / 7

4.5 Problems – Induced emf: Faraday's & Lenz's Laws

Section 20.1 of your textbook.

1. What should be the diameter of a circular wire loop if it is to have a magnetic field of 0.15 T oriented perpendicular to its area which produces a magnetic flux of 1.2×10^{-2} T · m^2?

2. A circular loop with an area of $0.015 m^2$ in in a uniform magnetic field of 0.30 T. What is the flux through the loop's plane if it is

   A. parallel to the field,

   B. at an angle of 37° to the field,

   C. perpendicular to the field?

3. The plane of a conductive loop with an area of 0.020 m^2 is perpendicular to a uniform magnetic field of 0.30 T. If the field drops to zero in 0.0045 s, what is the magnitude of the average emf induced in the loop?

4. An ideal solenoid with a current of 1.5 A has a radius of 3.0 cm and a turn density of 250 turns/m.

   A. What is the magnetic flux (due to its own field) through only one of its loops at its center?

   B. What current would be required to double the flux value in A?

Possible 4.6 Pts.: 8
Late, Incomplete, No work, No Units Fee: - 1 - 2 -3
Final Score: / 8

4.6 Problems – Electric Generators, Transformers

Section 20.2 & 20.3 of your textbook.

1. A student makes a simple ac generator by using a single square wire loop 10 cm on a side. The loop rotates at a frequency of 60 Hz in a magnetic field of 0.015 T.
   A. What is the maximum emf output?

   B. If she wanted to make the maximum output 2.5 volts by adding loops, how many should she use in total?

2. A simple ac generator consists of a coil of wire with 10 turns, each with an area of 50 cm^2. The coil rotates in a uniform magnetic field of 350 mT with a frequency of 60 Hz. Compute the maximum emf.

3. An ac generator operates at a rotational frequency of 60 Hz and produces a maximum emf of 100 V. Assume that its output at t = 0 is zero.
   A. What is the instantaneous emf at t = 1/240th of a second? At t = 1/120th of a second? How much time elapses between successive 0 volt outputs?

   B. What maximum emf would this generator produce if it were operated at 120 Hz instead?

4. An ideal transformer steps 8.0 V up to 2000 V, and the 4000 turn secondary coil carries 2.0 A.
   A. How many turns are in the primary coil?

   B. What's the current in the primary coil?

5. The primary coil of an ideal transformer has 720 turns, and the secondary has 180 turns. If the primary coil carries a current of 15 A at a voltage of 120 V, what are the voltage and output current of the secondary coil?

AP Physics 2	Unit 4.1 Lab - Magnetic Properties	
Reminder: Update Table of Contents		Correction Credit: Half

Lab Overview:

You and your team will explore some features that magnets possess.

Materials List:

- Two nails
- 25 cm thread
- Four small super magnets
- Small test tube
- 100 BBs
- Selection of different thin materials
- Caliper Measuring Tool

Magnet Properties Lab (4.1) Guide		
Table of Contents, Title/Date, Complete Synopsis, Two Purposes, Legible		/ 2
Mission 1: Magnetic Direction	Data table present	/ 1
	North-seeking end	/ 1
	Magnets vs. Twists	/ 2
M. 2: Force	Magnets vs. BBs	/ 2
Mission 3: Magnetic Permeabilty	3 Materials	/ 1
	Thickness Reported	/ 1
	Magnets vs. BBs	/ 2
Question 1: Thread twisting.		/ 2
Question 2: BB comparison.		/ 2
Question 3: Different materials		/ 2
Work Not Shown Fee:		-1 -2 -3
Late Lab Fee:		-4
Total:		/ 18

Mission 1: Magnetic Direction

The magnets are marked so one end is colored. Using the thread, nails, and ONE magnet, determine which end is north seeking and which is south seeking. You are essentially making a crude compass. Report which end is north-seeking in your Lab Book.

Twist the thread until the compass assembly flips around, counting how many turns it takes to do this. Record this number in a data table.

Next, put another magnet in your compass, and twist until it flips around. Repeat this with the third and fourth magnets, recording values in your data table for each additional magnet.

Mission 2: Magnetic Force

Put one magnet in a test tube, and determine how many BBs you can pick up. Record this in the same data table, and repeat this operation with two, then three, and finally 4 magnets.

Mission 3: Magnetic Permeability

Choose three of the different materials, and determine their different thicknesses with a caliper. Record this, as well as what sort of material it is in your data table. One at a time place one magnet on top of them, then put the bottom of the material against your BB collection, and record how many BBs are picked up.

Questions: **Rephrase and answer each in at least three complete sentences for full credit.**

1. In Mission 1, how did the number of twists of the thread change as you added more magnets to your crude compass? What could account for any differences?

2. How did the number of BBs picked up in Mission 2 change as more magnets were added? Was it a linear relation? What was noteworthy as you added more magnets to the tube?

3. In Mission 3, are there any relationships between materials vs. number of BBs picked up? Did any of the materials' results surprise you?

AP Physics 2	Unit 4.2 Lab - Electromagnets	
Reminder: Update Table of Contents		Correction Credit: Half

Lab Overview:

You and your team will build an electromagnet, and plot current vs. force on a graph.

Electromagnet Lab (4.2) Guide		
Table of Contents, Title/Date, Complete Synopsis, Two Purposes, Legible		/ 2
Mission 1: Data Table	Number of turns	/ 1
	Coil length	/ 1
	Average BB mass	/ 2
	Numeric data	/ 1
Analysis 1: Well-Labeled Graph		/ 3
Analysis 2: Slope Calculation		/ 2
Analysis 3: Expression of Force/Amp		/ 2
Question 1: Why find average mass?		/ 2
Question 2: Problems with lab?		/ 2
Work Not Shown Fee:		-1 -2 -3
Late Lab Fee:		-4
Total:		**/ 18**

Materials List:

Solderless Breadboard and Wires
Steel Nail
BB collection tray &100 BBs
2.0 m of Magnet Wire
Constant Current Supply
Electronic Balance

Mission 1: Electromagnet Strength

Record pertinent information in a well-organized, tidy data table as you perform the following:

Wind the magnet wire around your nail, counting how many turns you deposit, leaving a centimeter of exposed nail at the tip. The wire will have to overlap after you get halfway through. Measure the length of nail covered by the coil of wire.

Determine the average mass of one BB using a representative sample of BBs, showing your work somewhere in the Lab Book.

Hook your electromagnet up to your breadboard so that it is vertical, with the nail tip downward, then connect the power supply wires. Have the power supply set to 0-24 V, and set the meter button to read current (it should be pressed in – when it's out it measures voltage).

Slowly turn up the current through your electromagnet until it picks up one BB. Record this value, and keep turning the current, adding BBs every ½ A or so. GO NO HIGHER THAN 4.0 AMPERES! The wire will start getting warm at 4.0 A, and if too much current is used it will get hot. Adding BB's will require a bit of technique: sometimes jostling the glob of BBs will alter their configuration and cause them to fall.

Analysis: Answer these completely in your Lab Books

1. Make a well-labeled graph of current vs. BBs using a graphing program.
2. Determine an approximate slope of the line of your graph – it should be crudely linear.
3. Derive an expression of force per amp using the slope from Analysis 2.

Questions: Rephrase and answer each in at least three complete sentences for full credit.

1. What is the point of finding an average BB mass?
2. What problems did you encounter in this lab, and how could they be fixed

AP Physics 2	Unit 4 - Magnetism				
Application Problems, AP Test Preparation Questions					
Presentation Points:	/ 5	Late Fee:	-2	Completion (Booklet Check)	/ 5

Your grade on this problem set depends on the presentation you provide for your assigned problems, and whether **all** problems are complete when you submit your Booklet at the end of the Unit.

Application Problems

1. F=ILB How much current would it take for a 2.2 meter section of wire that weighed 1.5 g to hover in a 0.20 T magnetic field?

2. A transformer with primary voltage of 120 V has a turn ratio of 1:15.
   A. What is the secondary voltage of the system?

   B. If the circuit powered by the transformer has a resistance of 4.8 ohms, what are the input and output currents of the transformer?

AP Multiple Choice Questions

1. Which of the following is/are true concerning magnetic forces and fields?
   I) The magnetic field lines due to a current-carrying wire radiate away from the wire.
   II) The kinetic energy of a charged particle can be increased by a magnetic force.
   III) A charged particle can move through a magnetic field without feeling a magnetic force.

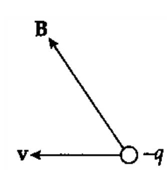
A. I only B. II and III only C. I and II only D. III only E. I and III only

2. The velocity of a particle of charge +4.0 E -9 C and mass 2 E -4 kg is perpendicular to a 0.1-tesla magnetic field. If the particle's speed is 3.0 E 4 m/s, what is the acceleration of the particle due to the magnetic force?

A. 0.0006 m/s^2 B. 0.006 m/s^2 C. 0.06 m/s^2 D. 0.6 m/s^2 E. None of these

3. In the figure, what is the direction of the magnetic force F_B?

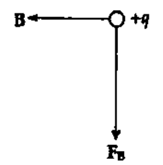
A. To the right
B. Downward, in the plane of the page
C. Upward, in the page's plane
D. Out of the plane of the page
E. Into the plane of the page



4. Due to the magnetic force, a positively charged particle executes uniform circular motion within a uniform magnetic field, B. If the charge is q and the radius of its path is r, which of the following expressions gives the magnitude of the particle's linear momentum?

A. qBr B. qB/r C. q/(Br) D. B/(qr) E. r/(qB)

5. In the figure, what must be the direction of the particle's velocity, v?

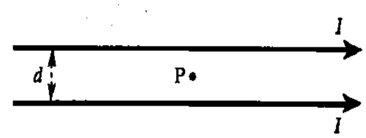


A. To the right B. Downward, in the plane of the page
C. Upward, in the plane of the page D. Out of the plane of the page
E. Into the plane of the page

6. A straight wire of length 2 m carries a 10-amp current. How strong is the magnetic field at a distance of 2 cm from the wire?

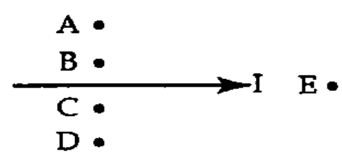
A. 1.0 E -6 T B. 1.0 E -5 T C. 2.0 E -5 T D. 1.0 E -4 T E. 2.0 E -4 T

7. In the figure, what is the magnetic field at the Point P, which is midway between the two wires?



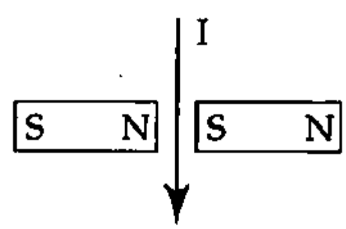
A. $2\mu_0 I/(\pi d)$, out of the page B. $2\mu_0 I/(\pi d)$, into the page
C. $\mu_0 I/(2\pi d)$, out of the page D. $\mu_0 I/(2\pi d)$, into the page
E. Zero

8. Here is a section of a wire with a current moving to the right. Where is the magnetic field strongest and pointing INTO the page?



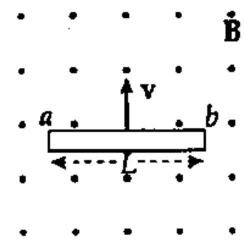
A. A B. B C. C D. D E. E

9. What is the direction of force acting on the current-carrying wire as shown?



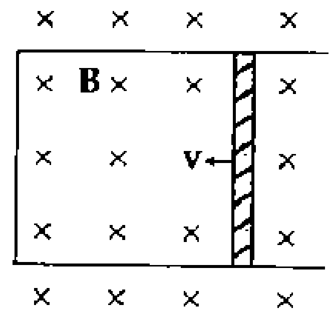
A. To the top of the page B. To the bottom of the page
C. Into the page D. Out of the page
E. To the right of the page

10. A metal rod of length L is pulled upward with constant velocity **v** through a uniform magnetic field **B** that points out of the plane of the page. What is the potential difference between points a and b?



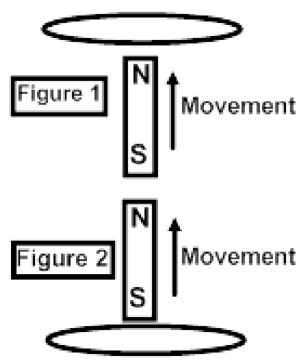
A. 0 B. 1/2vBL, with point a at the higher potential
C. 1/2vBL, with point b at the higher potential
D. vBL, with point a at the higher potential
E. vBL, with point b at the higher potential

11. A conducting rod of length 0.2m and resistance 10 ohms between its endpoints slides without friction along a U-shaped conductor in a uniform magnetic field B of magnitude 0.5 T perpendicular to the plane of the conductor, as shown in the diagram below. If the rod is moving with velocity **v** = 3 m/s to the left, what is the magnitude and direction of the current induced in the rod?



	Current	Direction
A.	0.03 A	down
B.	0.03 A	up
C.	0.3 A	down
D.	3 A	up
E.	3 A	down

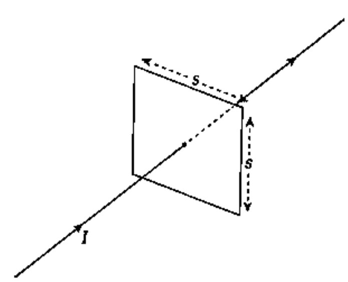
12. In figure 1, a permanent bar magnet is below a loop of wire. It is pulled upward with a constant velocity through the loop of wire as shown in figure 2. Which of the following best describes the direction(s) of the current induced in the loop (looking down on the loop from above)?



A. Always clockwise B. Always counterclockwise
C. First clockwise, then counterclockwise
D. First counterclockwise, then clockwise E. No current will be induced in the loop

13. A square loop of wire (side length = s) surrounds a long, straight wire such that the wire passes through the center of the square. If the current in the wire is I, determine the current induced in the square loop.

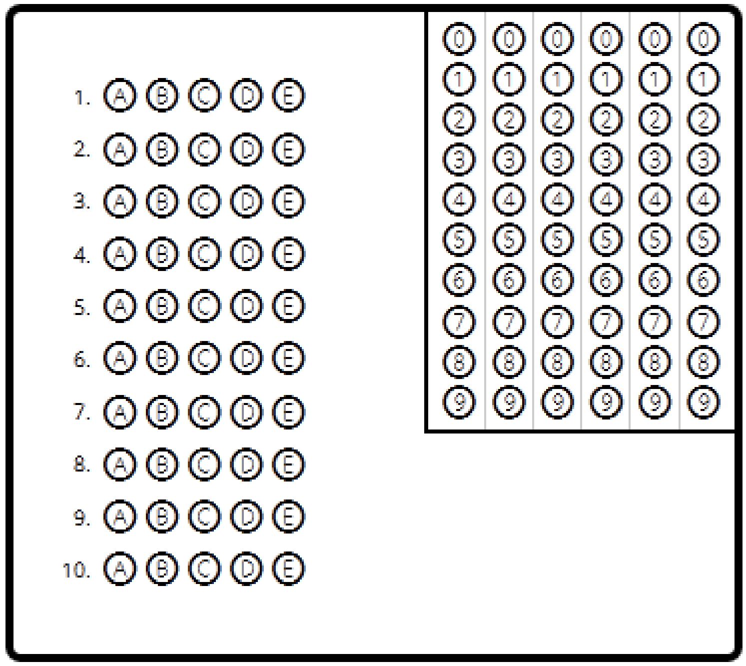
A. $\frac{2\mu 0 Is}{\pi(1+\sqrt{2})}$ B. $\frac{\mu 0 Is}{\pi\sqrt{2}}$ C. $\frac{\mu 0 Is}{\pi}$ D. $\frac{\mu 0 Is\sqrt{2}}{\pi}$ E. 0



AP Physics 2		Unit 4 Review - Magnetism					
Points:	/ 20	Late or Incomplete Fee:	-2 -4 -6	Correction Credit:		Final Score:	

Solve these problems here, THEN enter your responses in the bubble sheet provided.

Each question is worth two points.



1. A proton is projected with a velocity of 7.0 E 3 m/s into a magnetic field of 0.60 T perpendicular to the motion of the proton. What is the force that acts on the proton?

A. 13 E -16 N B. 6.7 E -16 N C. 3.4 E -16 N D. 0 N E. 4.2 E -16 N

2. A wire carrying a 2-A current is placed at an angle of 60° with the respect to a magnetic field of strength 0.2 T. If the length of the wire is 0.6 m what is the magnitude of the magnetic force acting on the wire?

A. 0.6 N B. 0.4 N C. 1.0 N D. 0.2 N E. 0.8 N

3. The magnetic field due to the current in a long, straight wire is 8.0 μT at a distance of 4.0 cm from the center of the wire. What is the current in the wire?

A. 3.2 A B. 0.20 A C. 1.6 A D. 0.40 A E. 0.80 A

4. What is the magnetic field at the center of a circular loop of wire of radius 4.0 cm when a current of 2.0 A flows in the wire?

A. 3.1 E -5 T B. 3.1 E -6 T C. 0 T D. 1.3 E -6 T E. 1.3 E -5 T

5. A solenoid 20. cm long is wound with 5000. turns of wire. What magnetic field is produced at the center of the solenoid when a current of 10. A flows?

A. 1.6 T B. 0.31 T C. 0.84 T D. 1.4 T E. 0.67 T

6. The flux through a coil changes from 5.0 E -5 Wb to 4.0 E -5 Wb in 0.1 s. What emf is induced in this coil?

A. 5 E -4 V B. 1 E -4 V C. 3 E -4 V D. 7 E -4 V E. 4 E -4 V

7. The cross-sectional area of an adjustable single loop is reduced from 1.0 m^2 to 0.25 m^2 in 0.10 s. What is the average emf that is induced in this coil if it is in a region where B = 2.0 T upward, and the coil's plane is perpendicular to B?

A. 15 V B. 12 V C. 0 V D. 21 V E. 18 V

8. An ac generator has 80 rectangular loops on its armature. Each loop is 12 cm long and 8.0 cm wide. The armature rotates at 1200 rpm about an axis parallel to the long side. If the loop rotates in a uniform magnetic field of 0.30 T, which is perpendicular to the axis of rotation, what will be the maximum output voltage of this generator?

A. 29 V B. 35 V C. 27 V D. 33 V E. 20 V

9. The primary coil of a transformer has 100 turns and its secondary coil has 400 turns. If the ac voltage applied to the primary coil is 120 V, what voltage is present in its secondary coil?

A. 30 V B. 100 V C. 70 V D. 480 V E. 400 V

10. A transformer consists of a 500-turn primary coil and a 2000-turn secondary coil. If the current in the secondary is 3.0 A, what is the current in the primary?

A. 1.3 A B. 0.75 A C. 48 A D. 24 A E. 12 A