Last Name:________________First Name_________________Network-ID__________

Discussion Section:________Discussion TA Name:______________________________

Turn off your cell phone and put it out of sight.
Keep your calculator on your own desk. Calculators cannot be shared.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the **center** of its circle.

2. You may find the version of **This Exam Booklet at the top of page 2**. Mark the version circle in the TEST FORM box near the middle of your answer sheet. **DO THIS NOW!**

3. Print your **NETWORK ID** in the designated spaces at the *right* side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

4. Print **YOUR LAST NAME** in the designated spaces at the *left* side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

5. Print your UIN# in the STUDENT NUMBER designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box.

6. Sign your name **(DO NOT PRINT)** on the **STUDENT SIGNATURE** *line*.

7. On the **SECTION** *line*, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

Before starting work, check to make sure that your test booklet is complete. You should have 14 ***numbered pages*** *plus three (3) Formula Sheets.*

Academic Integrity—**Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **116** points, composed of three types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

MC2: *multiple-choice-two-answer questions, each worth 2 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

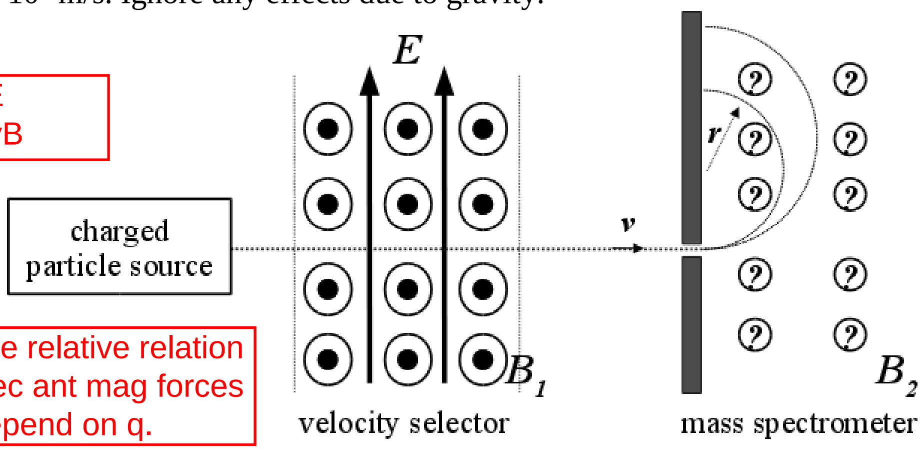
Some helpful information:

- A reminder about prefixes: p (pico) = 10^{-12}; n (nano) = 10^{-9}; μ (micro) = 10^{-6}; m (milli) = 10^{-3}; k (kilo) = 10^{+3}; M or Meg (mega) = 10^{+6}; G or Gig (giga) = 10^{+9}.

The next three questions pertain to the following situation:

A beam of particles is sent through a velocity selector in order to isolate charges of a particular speed to enter into a mass spectrometer (see below). In the region of the velocity selector, the electric field E = 2500 N/C upward and the magnetic field B_1 is of unknown magnitude out of the page. The speed of the selected charged particles is $v = 2.2 \times 10^8$ m/s. Ignore any effects due to gravity.

F_elec = qE
F_mag = qvB



Note that the relative relation between elec ant mag forces does not depend on q.

1. The velocity selector is set up to select positive charges *only*.

a. T
b. F

This is because B looks associated with E (prop to B) from the moving observer.

2. What is the magnitude of the magnetic field B_1 in the region of the velocity selector?

a. B_1 = 0.13 μT
b. B_1 = 11 μT
c. B_1 = 56 μT
d. B_1 = 84 μT
e. B_1 = 166 μT

```
Electric and magnetic forces balance
 -> E = vB or B = E/v = 2500/2.2x10^8
                      = 1136 x 10^{-8} T
```

3. The selected charged particles are then sent into a mass spectrometer to identify the composition of the stream from the source. The magnetic field B_2 = 5.5 μT in this region is oriented such that the charged particles deflect in semicircles as shown. For a certain particle in the beam, the mass is measured to be $m = 1.56 \times 10^{-24}$ kg for following a path of radius r = 7.5 mm. What is the charge q of the particle?

radial acceleration: a_c = v^2/r
eq of motion: mv^2/r = F

a. q = 41.8 nC
b. q = 96.2 nC
c. q = 8.3 nC
d. q = 0.368 nC
e. q = 25.0 nC

```
mv^2/r = qvB -> r = mv/qB so q = mv/rB.
m, v, r and B are known.
q = (1.56x10^{-24})x (2.2x10^8)/(0.0075)(5.5x10^{-6})
  = 83.2 x 10^{-24+8+6} = 83.2 x 10^{-10} C
```

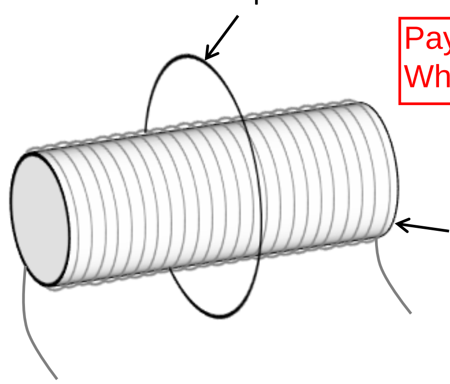
The next three questions pertain to the following situation:

A single circular loop of wire of radius r_{loop} = 5 cm is placed around a very long solenoid as shown in the figure. The solenoid has a radius r_{sol} = 1 cm, a length L = 40 cm, 10000 turns of wire, and is driven by a current I = 0.2 A.

normal to
the area
φ
B

¥Phi = BA cos ¥phi

Pay attention to the definition of ¥phi.
When A appears, the angle is wrt the normal



Bsol = ¥mu_0 n I

4. Calculate the flux Φ through the loop.

a. $\Phi = 1.2\times10^{-7}$ Wb
b. $\Phi = 2.0\times10^{-6}$ Wb
c. $\Phi = 6.7\times10^{-6}$ Wb
d. $\Phi = 5.5\times10^{-5}$ Wb
e. $\Phi = 9.5\times10^{-5}$ Wb

```
n = 10000/0.4, ¥phi = 0,
I = 0.2 A, A = ¥pi(0.01)^2.
Therefore,
¥Phi = 4¥pi x 10^{-7}x(10^4/0.4)x0.2x¥pi(0.01)^2
     = 0.00197 x 10^{-3}= 1.97 x 10^{-6}Wb
```

5. Which of the following will NOT change the flux Φ through the loop?

a. decreasing the current I in the solenoid
b. increasing the radius r_{loop} of the loop
c. tilting the loop relative to the solenoid

both are correct.

6. Calculate the energy U stored in the solenoid.

a. U = 2.0 mJ
b. U = 0.37 mJ
c. U = 12.8 mJ

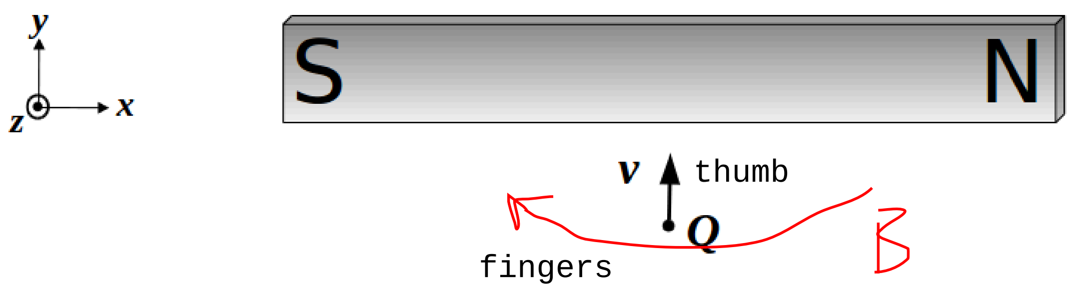
U = LI^2/2
L = N¥Phi/I

```
These formulas imply U = N¥Phi I/2.  N = 10000.
U = 10^4x1.97 x 10^{-6}x0.2/2 = 1.97 x 10^{4-6-1}
```

However, we skip this.

7. A proton is moving toward a bar magnet. What is the direction of the magnetic force on the proton if it travels in the $+y$ direction at the point designated Q in the figure? (The point Q is directly below the center of the bar magnet.)

B is from N to S.



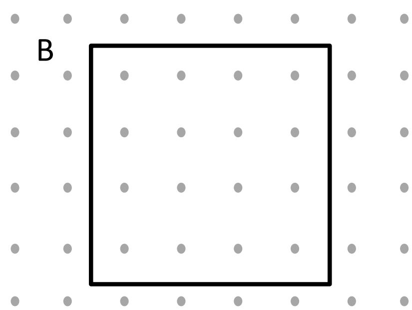
Hence, your palm up.

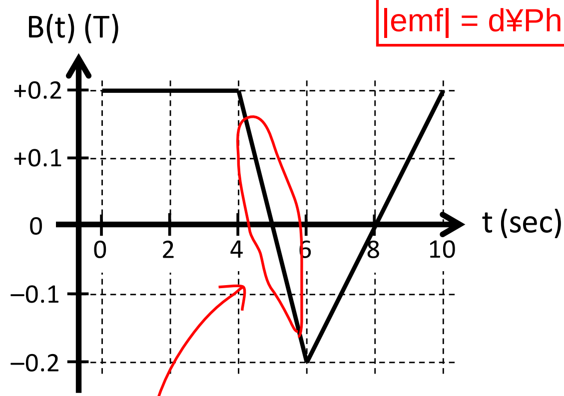
a. left
b. right
c. into the page
d. out of the page
e. There is no magnetic force on the proton.

The next two questions pertain to the following situation:

A loop of wire of area $A = 0.01$ m^2 lies in the plane of the page. The loop sits in a spatially uniform magnetic field B, which varies with time according to the graph below. A positive B corresponds to a magnetic field pointing out of the page; a negative B corresponds to a field pointing into the page.

Faraday
|emf| = d¥Phi/dt





8. At which of the following times is the induced emf ε in the loop maximum?

Largest flux changing rate -> largest emf

a. $t = 2$ s
b. $t = 5$ s
c. $t = 7$ s

9. Calculate the magnitude of the induced emf ε in the loop at time $t = 8$ s.

d¥Phi/dt = AdB/dt = 0.01x(0.4/4)=10^{-3} V

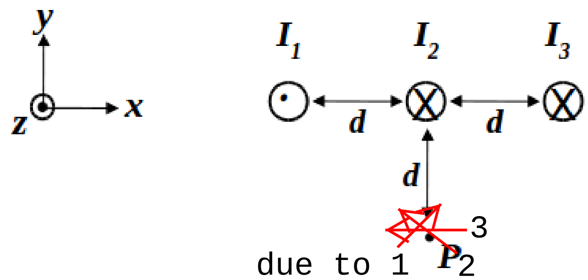
a. $\varepsilon = 0$ mV
b. $\varepsilon = 1.0$ mV
c. $\varepsilon = 6.67$ mV
d. $\varepsilon = 37.5$ mV
e. $\varepsilon = 62.5$ mV

The next three questions pertain to the following situation:

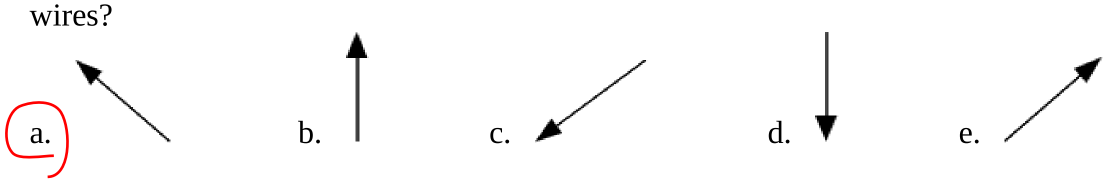
Three infinitely long current-carrying wires are placed in a horizontal line, with a distance d between each. The magnitudes of the currents in each of the wires are $I_1 = I_2 = I_3 = I$. Point $\boldsymbol{P}$ is located a distance d directly under wire 2.

B due to wire
|B| = ¥mu_0I/2¥pi r
right-hand screw

Sketch the B field



10. What is the general direction of the net magnetic field at point $\boldsymbol{P}$ due to the three wires?



11. What is the y-component of the magnetic field at point $\boldsymbol{P}$?

a. $B_y = +\dfrac{2\mu_0 I}{\pi d}$

b. $B_y = 0$

c. $B_y = +\dfrac{\mu_0 I}{2\pi d}$

d. $B_y = -\dfrac{2\mu_0 I}{\pi d}$

e. $B_y = +\dfrac{\mu_0 I}{\sqrt{2}\pi d}$

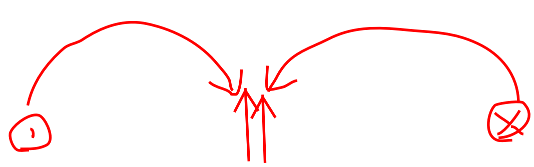
As can be seen from the figure the y-component is due to 1 and 3. This is the |B| due to 1 times 2 cos 45 deq =¥sqrt{2}:
B_y = (¥mu_0I/2¥pi r)¥sqrt{2}
where r = ¥sqrt{2}d

12. What is the magnitude of the net force on a length L of wire 2 due to the other two wires?

a. $F_{2,net} = \dfrac{\mu_0 I^2 L}{\pi d}$

b. $F_{2,net} = \dfrac{2\mu_0 I^3 L}{\pi d}$

c. $F_{2,net} = \dfrac{3\mu_0 I^2 L}{2\pi d}$



F = ILB
B = ¥mu_0I/(2¥pi x r)

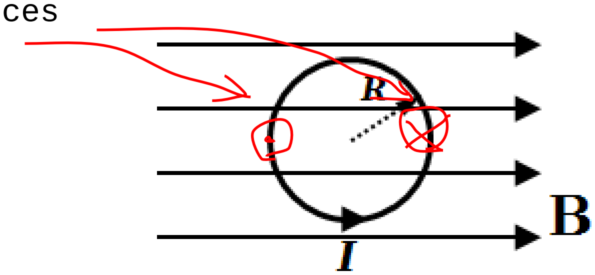
F = ¥mu_0I^2L/(2¥pi d) is due to one wire.

The next two questions pertain to the following situation:

A single wire loop is placed in a uniform magnetic field as shown in the diagram. The loop has radius R = 15 cm. The current in the loop is measured to be I = 3.33 A in the counterclockwise direction, as indicated in the figure. The net torque this loop experiences is measured to be $\tau = 5.25 \times 10^{-3}$ N·m.

¥tau = NIAB sin ¥phi

forces



The angle ¥phi is measured from the normal.
When A appears, the angle is measured from the normal.

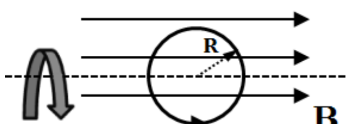
13. What is the magnitude of the magnetic field?

a. B = 66.7 mT
b. B = 22.3 mT
c. B = 97.2 mT
d. B = 343 mT
e. B = 5.6 mT

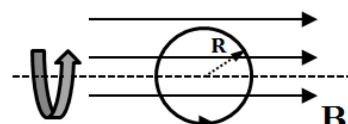
torque = 3.33 x (¥pi 0.15^2)x B =5.25x10^{-3}
(¥phi = 90 deg)
Hence,
B = 5.25x10^{-3}/3.33 x (¥pi 0.15^2)
= 22.3 x 10^{-3} T

14. Which picture below shows the direction of rotation at the moment the loop is allowed to rotate freely?

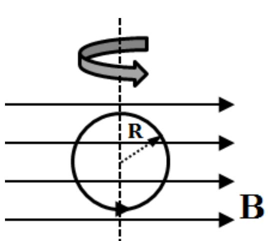
Notice that the force is max when B and I are perpendicular.



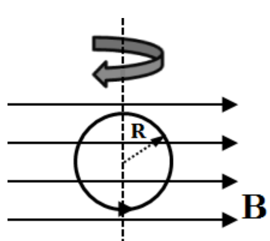
a.



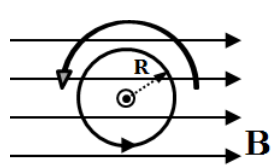
b.



c.



d.

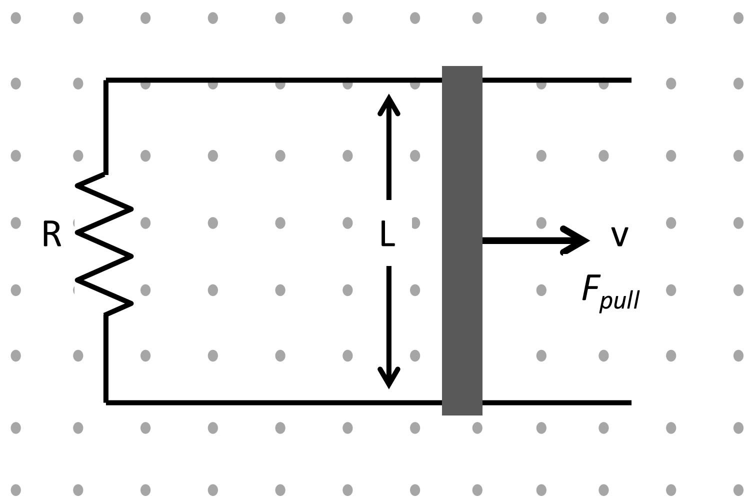


e.

See the above figure.

The next three questions pertain to the following situation:

A metal bar slides on a conducting track with width L = 5 cm and a resistor R = 2 Ω in a uniform magnetic field B = 0.1 T out of the page. The bar is pulled to the right with a force $F_{pull} = 2\times10^{-5}$ N, such that the bar slides in that direction at a ***constant speed*** v.



emf = d¥Phi/dt
¥Phi = BA cos¥phi

¥phi is measured from the normal direction.

15. Calculate the magnitude of the current I in the sliding bar.

a. I = 4 mA
b. I = 1.5 mA
c. I = 0.25 mA
d. I = 17.5 mA
e. I = 0 mA

```
`constant v' implies no net force:
The magnetic force on the bar is
     F = ILB = F_pull
     I = F_pull/LB = 2x10^{-5}/(0.05 x 0.1)
        = 400x10^{-5} = 4 mA.
```

16. What is the correct expression for the speed v of the sliding bar?

a. $v = \dfrac{LB}{F_{pull}R}$

b. $v = \dfrac{F_{pull}R}{LB}$

c. $v = \dfrac{F_{pull}R}{(LB)^2}$

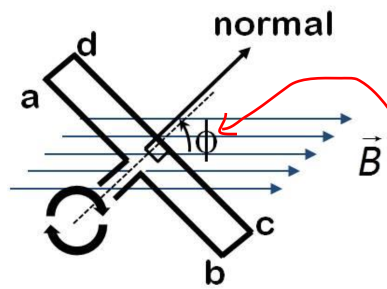
energy conservation or power balance
power required to pull the bar = power dissipated at R

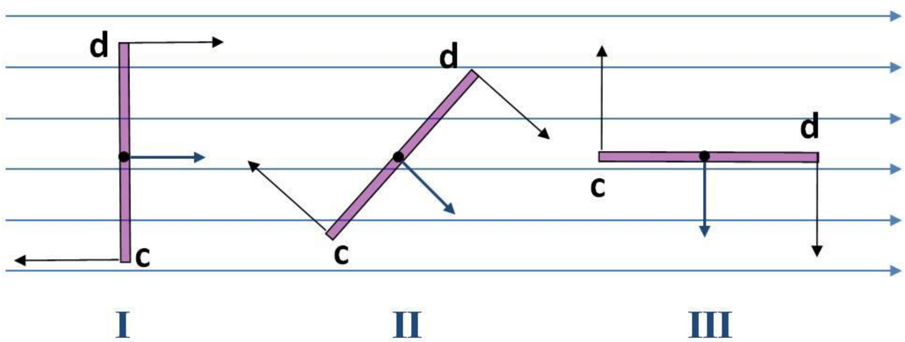
```
F_pull v = RI^2 = R(F_pull/LB)^2.
Therefore,
v = R F_pull/(LB)^2
```

17. A rectangular loop in a generator rotates at a constant angular frequency in uniform magnetic field as shown below. The bottom panel shows cross sectional views of the loop at three different moments. In which configuration is the magnitude of the induced current largest?

current max -> emf max

¥phi = AB cos ¥phi





a. I
b. II
c. III

Neither A nor B changes; ¥phi changes.
cos ¥phi changes most when ¥phy = 90 deg.

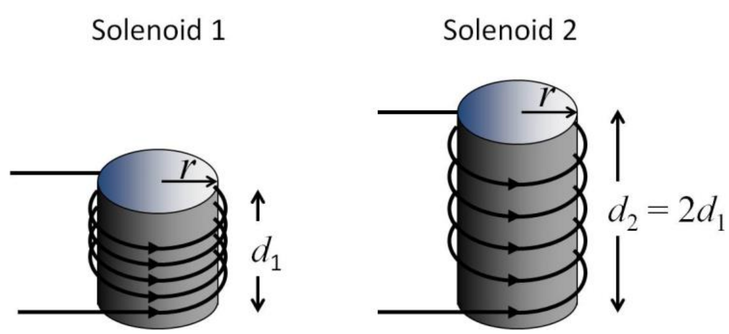
18. A power plant generates P = 0.5 GW of power, which is to be delivered to a nearby city through a transmission cable at a certain voltage. At which of the following voltages is the *least* power lost in the transmission cable?

P = I^2R

a. 12.5 kV
b. 5500 V
c. 110 V

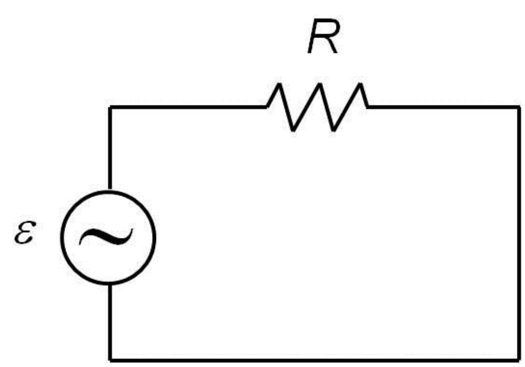
19. Consider two solenoids of the same radius r as shown. Solenoid 2 is twice as long as Solenoi [illegible] e $r << d_1, d_2$. If the *number of turns per unit length* for Solenoid 1 is twice as large as that for Solenoid 2, what is the relationship between their inductances, L_1 and L_2?

skipped



a. $L_2 = L_1/4$
b. $L_2 = L_1/2$
c. $L_2 = L_1$
d. $L_2 = 2L_1$
e. $L_2 = 4L_1$

20. A resistor R = 17 Ω is connected to a generator as shown. The generator voltage is given as $\varepsilon = \varepsilon_{max}\sin(277t)$ Volts.



You measure the *rms* (root mean square) current, I_{rms}, flowing through the resistor using an ammeter and obtain I_{rms} = 3.57 A. What is the maximum generator voltage, ε_{max}?

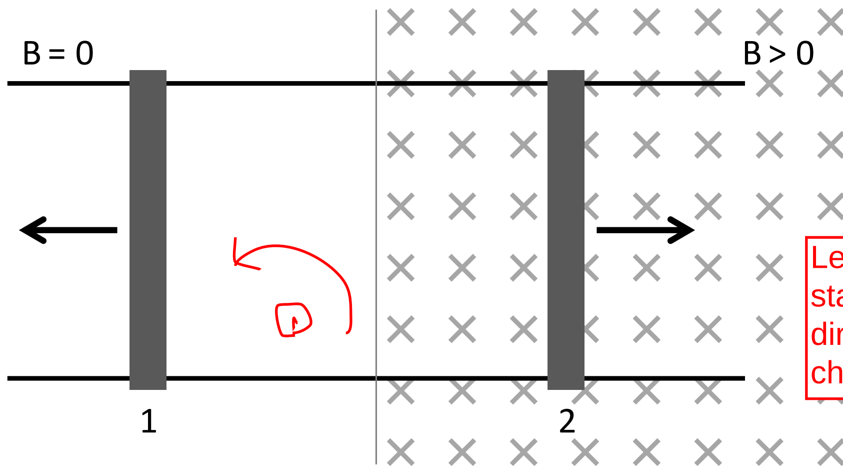
a. ε_{max} = 61 V
b. ε_{max} = 86 V
c. ε_{max} = 110 V

```
V_rms = R I_rms = 17 x 3.57 = 60.69
-> V_max = ¥sqrt{2}V_rms = 85.82 V.
```

The next two questions pertain to the following situation:

Consider a circuit consisting of *two* vertical metal bars labeled 1 and 2 that slide on two horizontal conducting rails, as shown in the figure. There is a uniform magnetic field *B* directed into the page ***over the right half of the circuit only***. (There is NO magnetic field over the left half.)

Initially both sliding bars 1 and 2 are at rest.



Lenz tells us the world is stable: change occurs in the direction to reduce any change.

21. The sliding bar 2 is now moved to the right. In what direction does the current flow around the circuit?

a. clockwise
b. counterclockwise
c. there is no current

The magnetic flux into the page increases. Lenz tells us that the `loop' wishes to decrease the magnetic flux into the page, so it creates B out of the page.

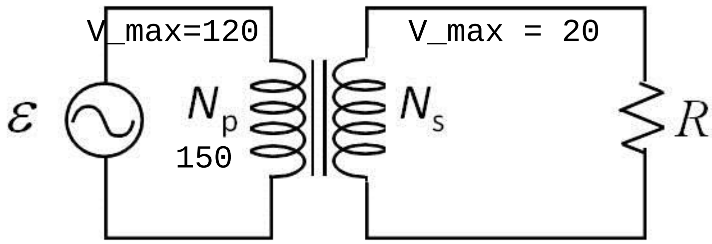
22. Now sliding bar 2 is at rest and sliding bar 1 is moved to the left. In what direction does the current flow around the circuit?

a. clockwise
b. counterclockwise
c. there is no current

There is no flux change.

The next three questions pertain to the following situation.

A transformer consists of a primary coil of N_p = 150 turns and a secondary coil of unknown turns N_s as shown. The generator voltage is given as $\varepsilon = 120\sin(120\pi t)$ Volts. The secondary coil is connected to a load of resistance R = 13 Ω.



23. Find N_s for which the maximum induced voltage in the secondary coil is 20 V.

V/N is constant

a. N_s = 900
b. N_s = 60
c. N_s = 25

Ns = Np(Vs/Vp)
= 150(20/120) = 25

24. What is the average power, P_{rms}, delivered to the load by this transformer, given a maximum induced voltage in the secondary coil of 20 V?

P = V_max^2/2R

power is preserved by a transformer

P = 20^2/26 = 15.38 W.

a. P_{rms} = 13.0 W
b. P_{rms} = 15.4 W
c. P_{rms} = 27.7 W
d. P_{rms} = 30.8 W
e. P_{rms} = 1108 W

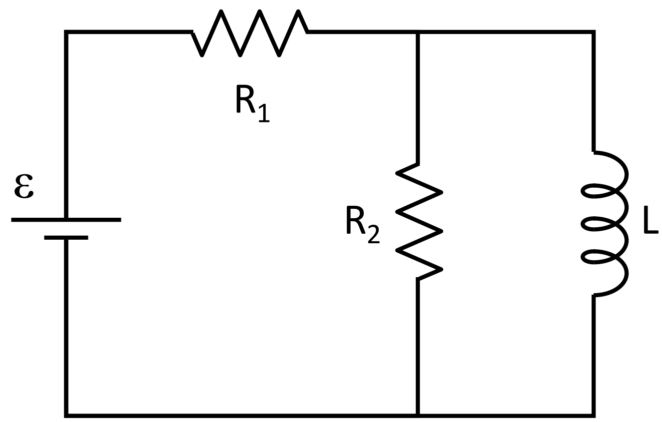
in the steady state.

25. If the generator is replaced with a 24 V battery, what is the maximum voltage, V_{max}, across the secondary coil of 300 turns?

a. V_{max} = 0 V
b. V_{max} = 12 V
c. V_{max} = 48 V

skipped

26. Two resistors and an inductor are connected to a battery as shown. ε = 12 V, R_1 = 9 Ω, R_2 = 15 Ω, and L = 350 mH.



After a long time, what is the current, I_L, flowing through the inductor?

a. I_L = 1.33 A
b. I_L = 0.81 A
c. I_L = 0.75 A
d. I_L = 0.52 A
e. I_L = 0 A

Check to make sure you bubbled in all your answers.
Did you bubble in your name, exam version and network-ID?