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 bottom right on the face 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 15 **numbered pages** *plus three 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 bottom right on the face of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **106** 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.
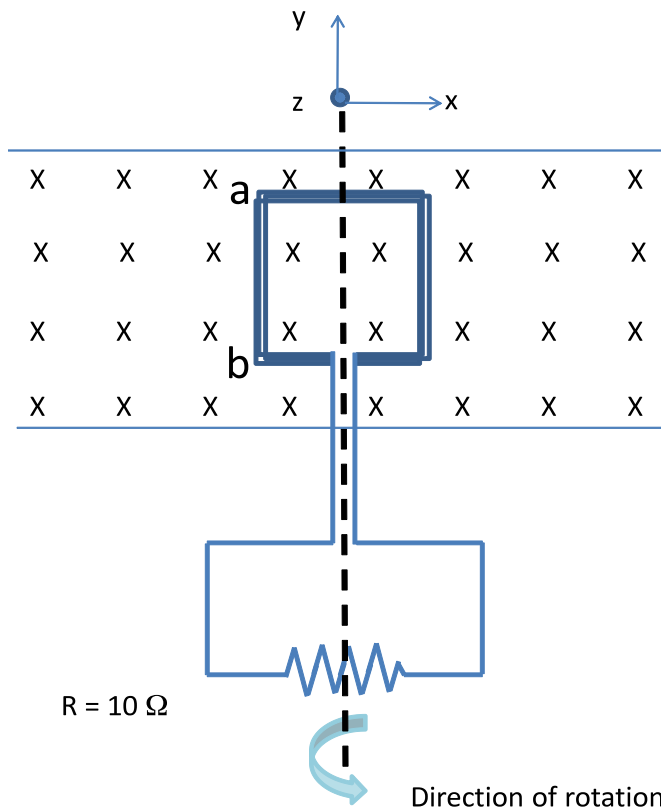(b) If you mark the wrong answer or neither answer, you earn **0** points.

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 coil consisting of 5 square turns connected in series rotates at 60 revolutions per second (ω = $2\pi60$ radians per second). The magnetic field B = 2 T points in the −z direction (into the page). At t = 0, the plane of the coil lies in the x-y plane; a side of the coil is labeled with points "a" and "b." The rotation is around the y axis, such that at t=0 side a-b is moving out of the page. The loops have an area of 100 cm² and no resistance of their own. A 10 Ω resistor is connected across the coils as shown.

Faraday's law
|emf| = N d¥Phi/dt

¥Phi = AB cos ¥phi
When A (area) appears ¥phi
is from the normal direction.

If the wires do not cut
magnetic vector
arrows, there is no
emf.

B = 2 T

Notice:
1 cm^2 = 10^{-4} m^2

R = 10 Ω

Direction of rotation

1. At t = 0

a. the current flows clockwise, directly from point b to point a.
b. the current flows counterclockwise, directly from point a to point b.
c. the current is zero.

```
¥phi = 0 at t=0.
emf = 5AB sin ¥phi = 0.
```

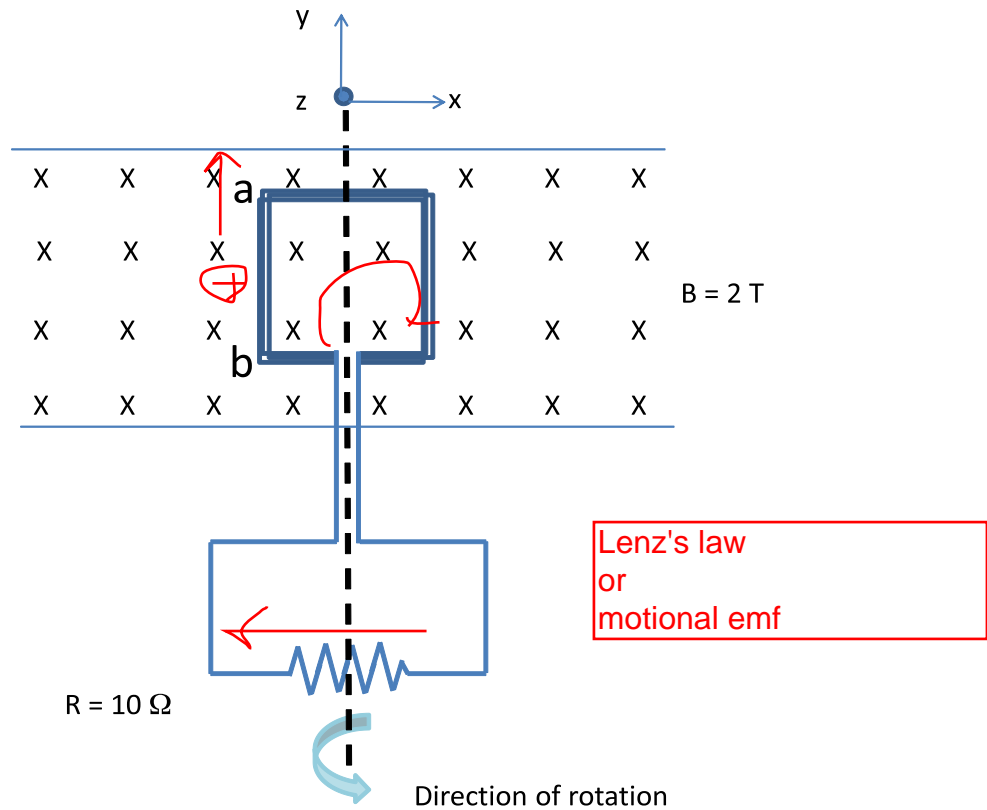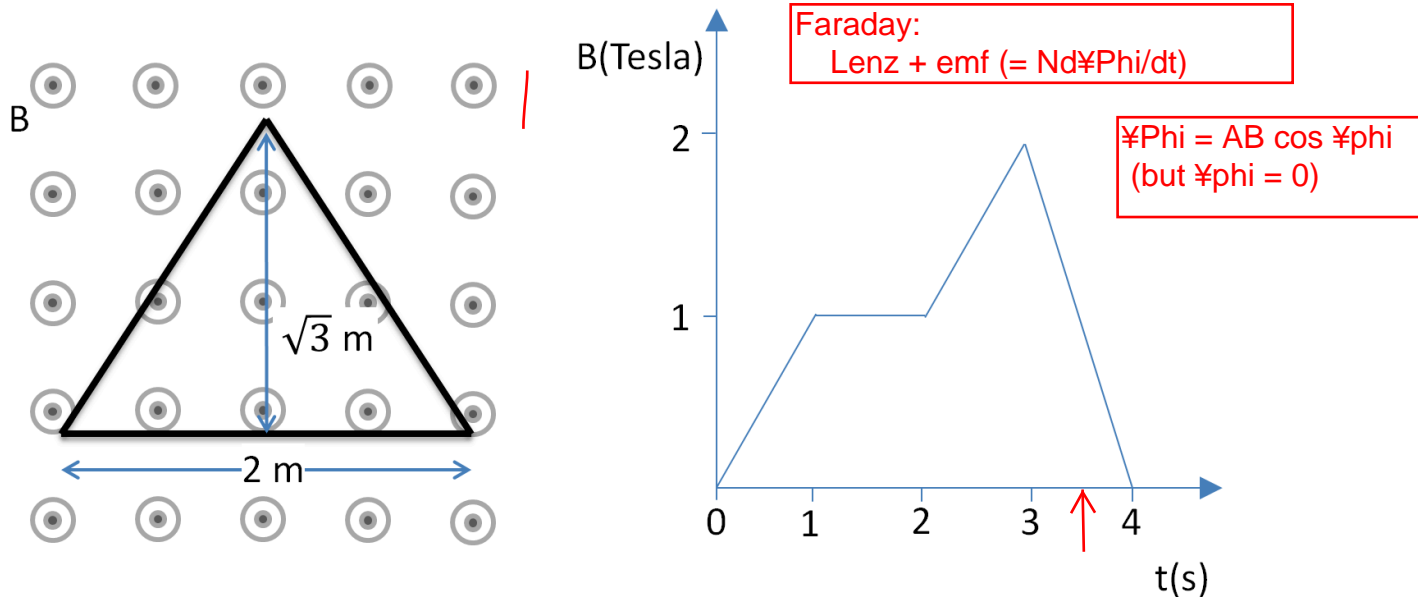2. The maximum value of the current is

a. 0 A
b. 1.00 A
c. 2.56 A
d. 100.53 A
e. 3.77 A

```
The max emf = NAB¥omega
            = 5 x (100 x 10^{-4}) x 2 x 120¥pi
            = 37.70 V
Since R = 10, so I = 37.70/10 = 3.77 A
```

The next question continues from the previous page.

y

z   →x

| X | X | X | a | X | | X | X | X | X |
| X | X | X | | X | | X | X | X | X |

B = 2 T

| X | X | X | X | | X | X | X | X |
| | | | b | | | | | |

| X | X | X | X | | X | X | X | X |

Lenz's law
or
motional emf

R = 10 Ω

Direction of rotation

3. Once the coil has rotated forward by 45°

a. the current flows clockwise, directly from point b to point a.
b. the current flows counterclockwise, directly from point a to point b.
c. the current is zero.

```
Motional emf
If you imagine a + charge on a-b, it moves
right (i.e., a current is to the right), so
it feels the force `upward' in the sheet of
the paper as noted by the arrow in the above
figure.
```

```
Mag flux our of the page
is diminishing, so the
loop wishes to make the
flux out of the page
-> Lenz + right-handed
      screw rule tells us
  an induced clockwise
   current.
```

The next two questions pertain to the following situation.

A triangular conducting coil lies in a uniform magnetic field B which varies in time as shown in the graph of B (Tesla) versus t (seconds). At t = 1 s, the magnetic field is pointing out of the page. The triangle has height h = $\sqrt{3}$ m, and the base of the triangle has length L = 2 m.

B

$\sqrt{3}$ m

2 m

B(Tesla)

2

1

0   1   2   3   4

t(s)

Faraday:
    Lenz + emf (= Nd¥Phi/dt)

¥Phi = AB cos ¥phi
(but ¥phi = 0)

Mag flux out of the page is
rapidly diminishing. Lenz
says B out of the page must
be created by
the loop.
-> counter-
clockwise

4. Which statement best represents the situation at t = 3.5 s?

a. The magnitude of the induced emf is 4.5 V, and the current flows counterclockwise.
b. The magnitude of the induced emf is 4.5 V, and the current flows clockwise.
c. The magnitude of the induced emf is 3.5 V, and the current flows counterclockwise.
d. The magnitude of the induced emf is 3.5 V, and the current flows clockwise.
e. There is no induced emf.

emf = A dB/dt
    = ¥sqrt{3}x 2 = 3.46 V

5. The current is zero

a. between t = 1s and t = 2s.
b. at t = 0.5 s.
c. at t = 3.5 s.

d¥Phi/dt = 0, where B is flat.

The next three questions pertain to the following situation.

An electromagnetic wave indicated below has wavelength $\lambda = 420$ nm.

y

E

X

Direction
of wave
travel

z

B
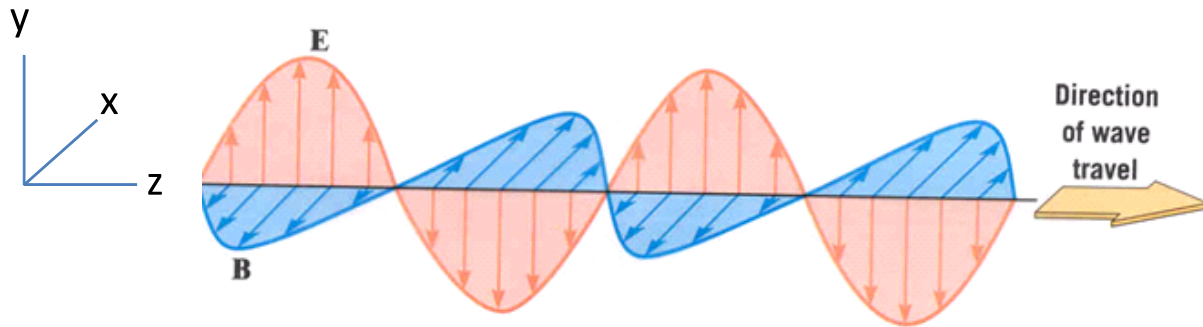
6. This wave is polarized along the

Propagation direction:
  E to B right-handed screw.

a. x axis.
b. y axis.
c. z axis.

7. The frequency of this wave is

f x ¥lambda = c

a) 7.14×10^{14} Hz
b. 2.13×10^{14} Hz
c. 4.76×10^{14} Hz

f = 3 x 10^8/(420 x 10^{-9}).
    = 0.007142 x 10^17 Hz.

This is a bad expression of
propagation of a wave.

8. The time it takes for a point on the wave to travel forward 2 m is

a. 2.30 ms
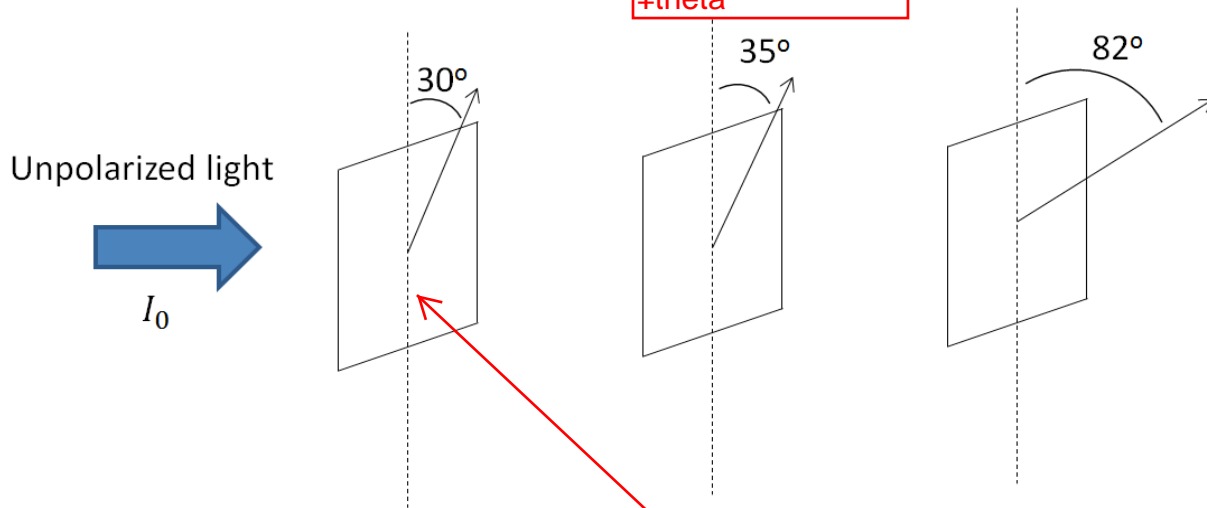b 6.67 ns
c. 1.75 ps

2/(3x10^8) = 0.667 x 10^{-8} s

The next two questions pertain to the following situation.

Unpolarized light with intensity I_0 is incident on a series of three polarizers, as shown in the picture below.

Unpolarize through linear polarizer
-> Intensity halved

$I = I_0 \cos^2$
¥theta

30°   35°   82°

Unpolarized light

I_0

9. The intensity after the first polarizer is

a. 0.75 I_0
b. 0.87 I_0
c. independent of the angle of the first polarizer.

relative angle 35 - 30

relative angle 82 - 35 = 47

10. The intensity of the light after the third polarizer is
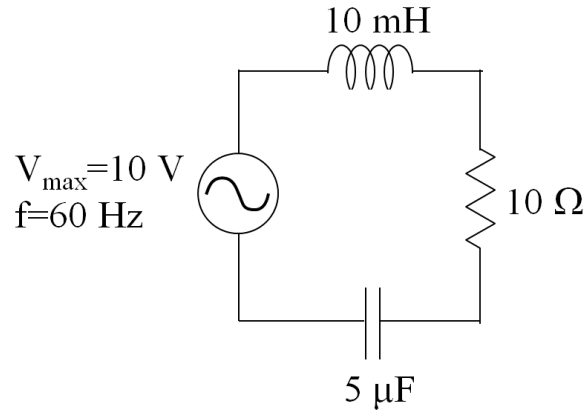
a. 0.05 I_0
b. 0.34 I_0
c. 0.23 I_0

```
I = (I_0/2) (cos 5 x cos 47)^2
  = (0.46158/2) I_0 = 0.2308 I_0
```

This contribute
the factor 1/2.

The next four questions pertain to the following situation:

A circuit consisting of a 10 Ω resistor, 10 mH inductor, and 5 μ[skipped]   series is being driven by an AC generator with V_{max}=10 V at f=60 Hz.

10 mH

V_{max}=10 V
f=60 Hz

10 Ω

5 μF

11. What is the impedance Z of this circuit?

a. 10 Ω
b. 50 Ω
c. 234 Ω
d. 265 Ω
e. 527 Ω

12. Which graph of the voltages across the capacitor and inductor shown below is most accurate? The voltage across the inductor is shown using a dashed line, and the voltage across the capacitor is shown using a solid line.

Vc

VL

1

Vc

VL

2

Vc

VL

3
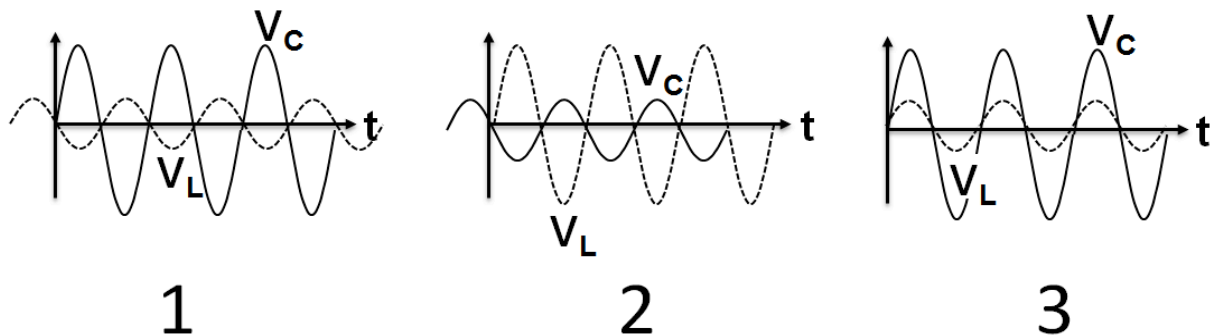
a. 1
b. 2
c. 3

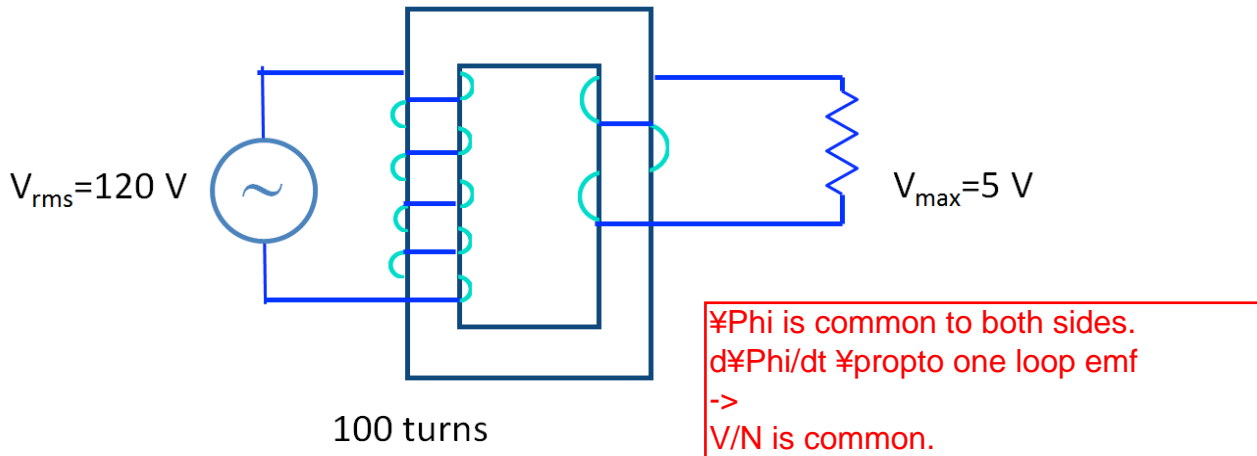***The next two questions continue from the previous p* skipped**
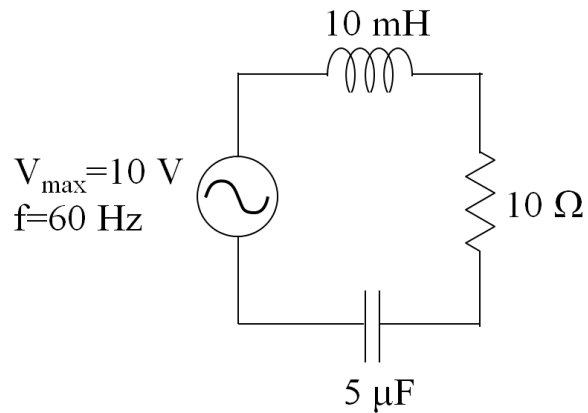
13. What is the resonant frequency of this circuit?

a. 1.4×10^{-3} Hz
b. 60 Hz
c. 320 Hz
d. 712 Hz
e. 956 Hz

14. The resistor will catch on fire if it dissipates more than 0.5 W of average power. What will happen to the resistor in this circuit if the circuit is driven on resonance?

a. The resistor will dissipate less than 0.5 W.
b. The resistor will not dissipate any power.
c. The resistor will dissipate more than 0.5 W and catch on fire.

15. There is a transformer inside the charger for your cell phone that is designed to reduce the voltage supplied by an electrical outlet. The outlets in your house provide V_{rms}=120 V AC power, while the charger requires V_{max}=5 V AC power. How many turns should there be on the secondary side of the charger if there are 100 primary turns?

V_{rms}=120 V $\sim$ V_{max}=5 V

¥Phi is common to both sides.
d¥Phi/dt ¥propto one loop emf
->
V/N is common.

100 turns

a. 3
b. 6
c. 1700

N_s = N_p V_s/N_p = 100(3.53/120) = about 3.

rms of V_s = 5/¥sqrt{2}

16. Your tibial plateau was fractured during a soccer game, and afterward you are having an MRI scan performed to check for damage to the menisci in your knee. The 1 T magnetic field inside the MRI machine is roughly uniform. You are lying very still when you realize that you forgot to take off your digital watch. There are 0.003 m long wires carrying 0.001 A of current perpendicular to the magnetic field inside your watch. What is the force on one of these wires?

a. 0.3×10^{-6} N
b. 3×10^{-5} N
c. 3×10^{-6} N

F = ILB cos¥theta

F = 10^{-3}x(3 x 10^{-3})x1 = 3 x 10^{-6} N

17. You are measuring the wavelength of the light emitted by a distant star. The star, which is moving away from you at 100,000 m/s, emits light with a 30.00 cm wavelength. What is the wavelength of the light that you measure?
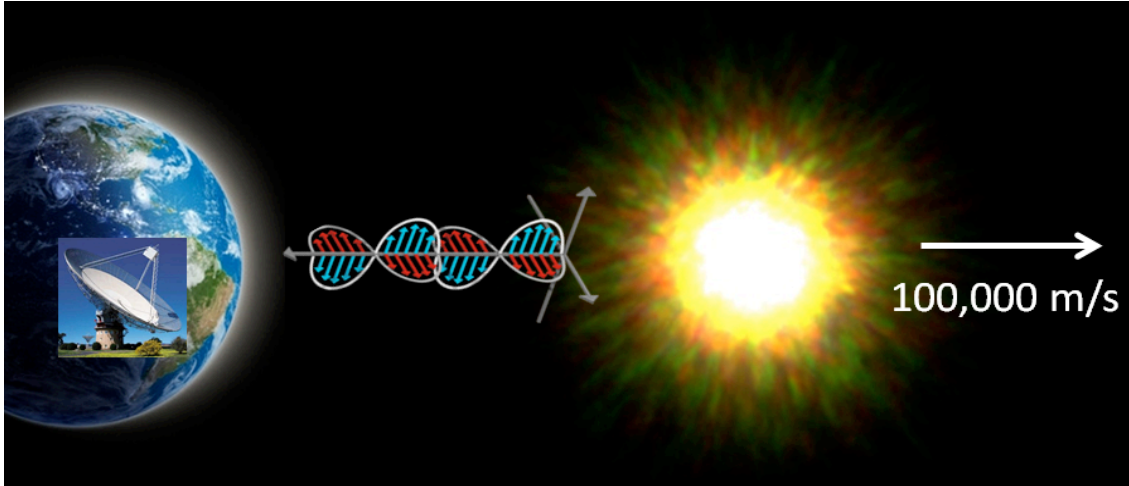
(approximate theory) of Doppler effect

a. 60.00 cm
b. 1.111×10^{-3} cm
c. 31.00 cm
d. 29.99 cm
e. 30.01 cm

The star is receding, so the light should be red-shifted.

    30 x (3x10^8 + 1x10^5)/3x10^8
    = 30 x (1 + 0.0003333) = 30.01 cm

The next two questions pertain to the following situation:

Two long straight wires are placed parallel to one another 9 cm apart, as shown in the figure. The current in wire 1 is oriented out of the page, and the current in wire 2 is oriented into the page. A point P is located 6 cm to the right of wire 2.

$I_1 = 2$ A $I_2 = 8$ A
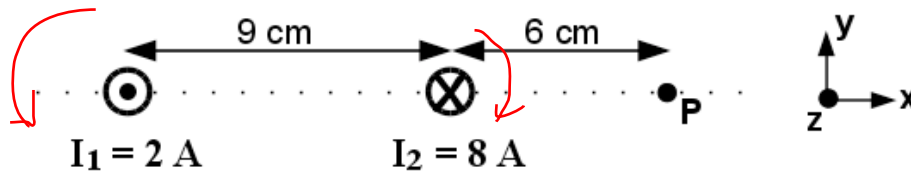
18. Calculate the net magnetic field in the y direction at the point P.

B due to wire
magnitude = $(\mu_0/2\pi)I/r$
direction: right-handed screw

a. $B_{net} = +1.04 \times 10^{-5}$ T
b. $B_{net} = +3.99 \times 10^{-5}$ T
c. $B_{net} = +6.72 \times 10^{-5}$ T
d. $B_{net} = -5.34 \times 10^{-5}$ T
e. $B_{net} = -2.40 \times 10^{-5}$ T

```
Two contributions are in the opposite direction and
I_2 wins, so the B field must be in the -y direction.

B = (¥mu_0/2¥pi)(8/0.06 - 2/0.15)
  = 2 x 10^{-7} x 120 = 240 x 10^{-7} T
```

19. The net magnetic field due to the two wires equals zero at a point in the region between the two wires.

```
They are all in the +y direction.
```

a. True
b. False

The next three questions pertain to the following situation:

A particle of mass 5 x 10^{-8} kg and charge q = +6 µC is moving with speed v_i = 3000 m/s when it enters a region with magnetic field B_{bottom}, which is perpendicular to the plane of the paper. The magnitude of B_{bottom} is not known. The particle follows a quarter-circle trajectory and enters another region with a different magnetic field B_{top}, which is also perpendicular to the plane of the paper. It again follows a quarter-circle trajectory. The magnitude of B_{top} is also not known. The radius of curvature for the motion in the top region is larger than that in the bottom region ($r_{top} > r_{bottom}$).
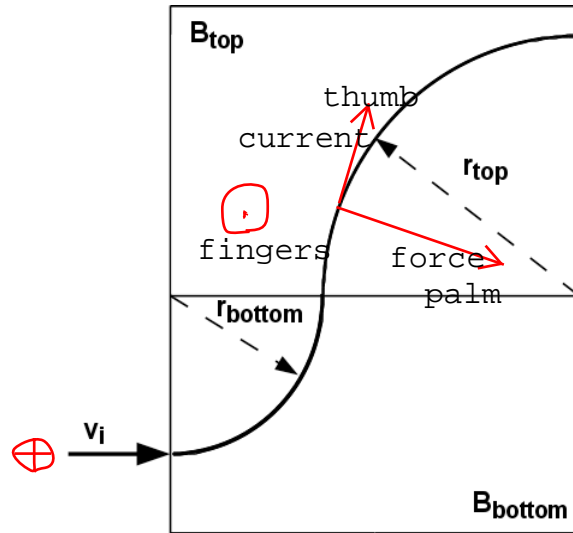
Magnetic force
F = qvB and RH rule

20. In which direction does B_{top} point?

mv^2/r = qvB
-> r = mv/qB

a. into the page
b. out of the page

21. Which is true regarding the relationship between B_{top} and B_{bottom}?

Since v is constant, r ¥propo 1/B

a. $B_{top} < B_{bottom}$
b. $B_{top} = B_{bottom}$
c. $B_{top} > B_{bottom}$

22. Calculate B_{top} if r_{top} = 1.35 m.

a. B_{top} = 4.9 T
b. B_{top} = 18.5 T
c. B_{top} = 68.4 T
d. B_{top} = 173 T
e. B_{top} = 557 T

B = mv/rq
  = 5x10^{-8} x 3x10^3/1.35x(6x10^{-6})
  = 1.85 x 10^{-8+3+6}= 18.5 T

The next two questions pertain to the following situation: | They are a bit hard problems. |

A square loop with sides of unknown length L is carrying a current I = 3 A. The loop is oriented in space at a 35° angle with respect to the horizontal. The current flows into the page at the top of the loop and out of the page at the bottom of the loop, as shown in the picture below. A magnetic field of magnitude B = 2.8 mT is applied in an unknown direction.

mag
dipole
moment

35°

torque

| magnetic dipole due to a loop |
| dipole magnitude   NIA |
| direction: right-handed screw |

| B for problem 24 |
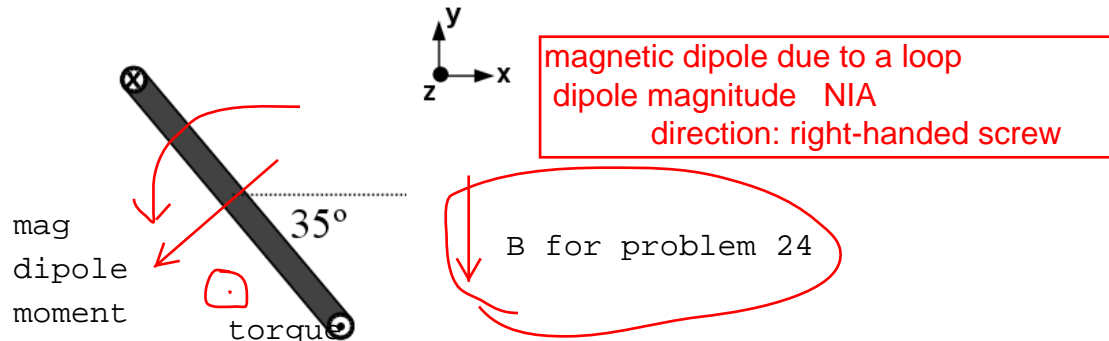
23. In which direction could the magnetic field be oriented for the torque due to the magnetic field to cause the loop to rotate in the counter-clockwise (CCW) direction as viewed in the picture above?

a. +x
b. +y
c. +z

| torque |
| magnitude = ¥mu B ¥sin ¥phi |
| direction: ¥mu to B right-handed screw |

torque vector coming out of the page
You can use the magnetic force on the top part of the loop

24. Presume the magnetic field is now directed downward, in the −y direction. The torque on the loop is measured to be τ = 6.4 x 10⁻⁶ N m. Calculate the length L of the sides of the square.

a. L = 0.381 m
b. L = 0.192 m
c. L = 0.633 m
d. L = 0.085 m
e. L = 0.037 m

mag dipole moment = L^2xI
torque = ¥mu B sin ¥phi
That is
  L^2 = torque/3B sin¥phi
      = 6.4x10^{-6}/(3x2.8x10^{-3} sin 35)
      = 1.328 x 10^{-3} = 0.0364^2

The next two questions pertain to the following situation:

A positively charged particle moving with speed v = 250 m/s enters a region of magnetic field of magnitude B = 300 T oriented out of the page, as shown in the figure. The magnetic force on the particle is measured to be 15×10^{-9} N.
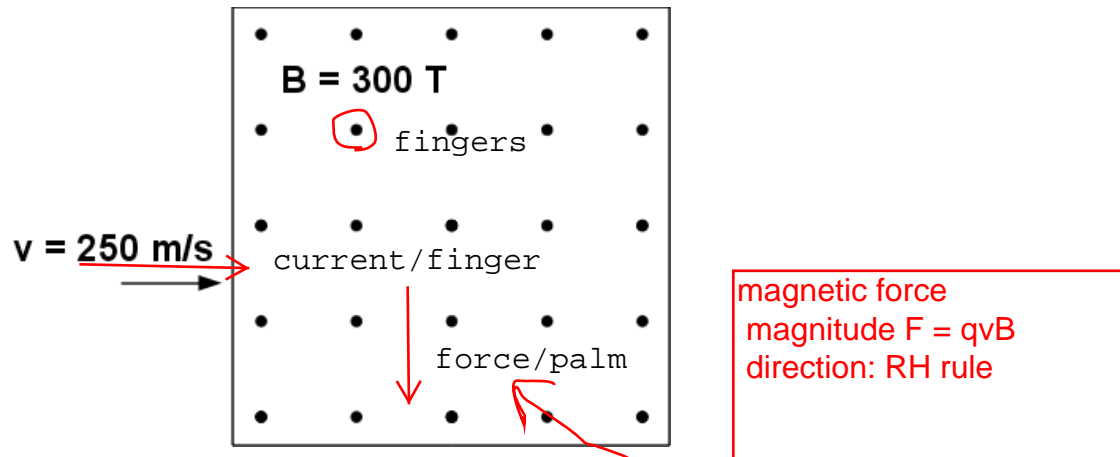
25. Calculate the charge Q of the particle.

a. $Q = 1 \times 10^{-13}$ C
b. $Q = 2 \times 10^{-13}$ C
c. $Q = 3 \times 10^{-13}$ C
d. $Q = 4 \times 10^{-13}$ C
e. $Q = 5 \times 10^{-13}$ C

```
Q = F/vB = 15x10^{-9}/(250x300)
  = 0.0002 x 10^{-9}
  = 2 x 10^{-4-9} C
```

26. An electric field is now applied in the same region as the magnetic field. In which direction must the electric field be oriented so that the charge travels a straight-line trajectory through the region of the two fields?

a. up
b. down
c. into the page
d. out of the page
e. right

```
The magnetic force is downward as in the figure above.

To kill this force, we need an electric force opposing
this: E field upward.
```

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