Last Name:________________First Name_________________NetID_______________
Discussion Section:________Discussion TA Name:______________________________

Instructions—
Turn off your cell phone and put it away.
Keep your calculator on your own desk. Calculators may not 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 a pen. Fill in completely (until there is no white space visible) the circle for each intended input – both on the identification side of your answer sheet and on the side on which you mark your answers. 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.

2. Print your last name in the **YOUR LAST NAME** boxes on your answer sheet and print the first letter of your first name in the **FIRST NAME INI** box. Mark (as described above) the corresponding circle below each of these letters.

3. 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**.

4. You may find the version of **this Exam Booklet at the top of page 2**. Mark the **version** circle in the **TEST FORM** box in the bottom right of your answer sheet. **DO THIS NOW!**

5. Do not write in or mark the circles in any of the other boxes (STUDENT NUMBER, DATE, SECTION, SCORES, SPECIAL CODE).

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 two Formula Sheets at the end.*

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 expulsion.**

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

Exam Grading Policy—

The exam is worth a total of 103 points, composed of two types of questions.

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

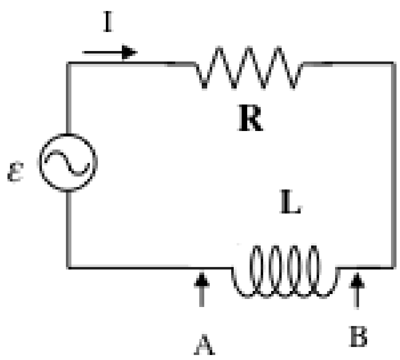
(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more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

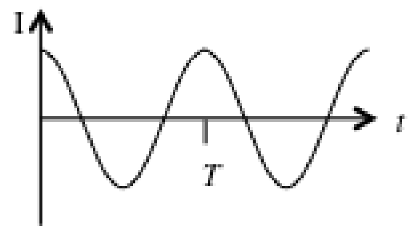
MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.

(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.

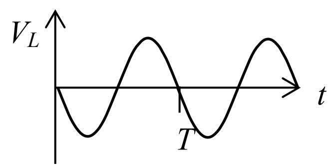
The following 2 questions are related and refer to the figure and graph below.

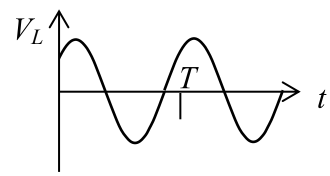
For the circuit shown at left below, the <u>current</u> is shown in the figure on the right as function of time. Assume R and L are ideal, and $R > 0, L > 0$.

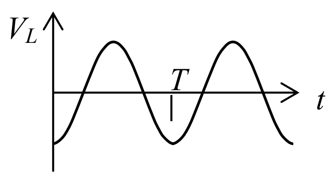




1) Which of the following graphs best describes the voltage across the inductor as a function of time, $V_L(t)$ (where $V_L = V_B - V_A$)?

a. 

b. 

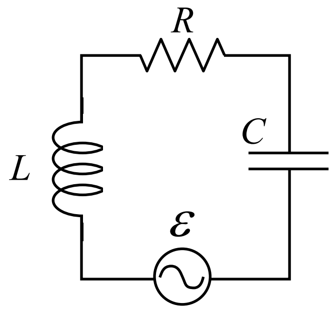
c. 

2) If the frequency of the generator increases (while holding ε_{max} constant), then the **maximum voltage** across the **resistor**

a. increases.
b. decreases.
c. stays the same.

The next two questions are related.

In the RLC circuit shown below, the generator voltage can be represented by $\mathcal{E}(t) = \mathcal{E}_{max} \sin(\omega t)$. The values of the capacitance C, resistance R, peak generator voltage $\mathcal{E}_{max}$, generator frequency ω, and phase angle ϕ by which the generator EMF <u>leads</u> the current are given in the figure.



$C = 20\ \mu\text{F}$
$R = 100\ \Omega$
$L = ?$
$\mathcal{E}_{max} = 24\ \text{V}$
$\omega = 5000$ rad/sec
$\phi = 45°$

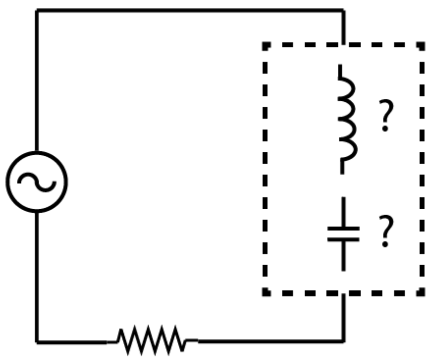
3) What is the inductance L?

a. 0.022 H
b. 0.0031 H
c. 0.036 H
d. 0.011 H
e. 0.05 H

4) We now change the frequency of the generator (ω) keeping all other properties of the circuit the same. How should we change the frequency to **increase** the maximum current through the circuit?

a. Increase ω.
b. Decrease ω.
c. Keep ω the same.

5) Mystery circuit! The circuit below is driven by an EMF $\mathcal{E}(t) = \mathcal{E}_{max}\sin(\omega t)$ at some frequency ω. You are told that the current, $I(t)$, through the circuit is **in phase** with the driving voltage, so $I(t) = I_{max}\sin(\omega t)$. You are also told that there is a resistor in **series** with either a capacitor, an inductor or both. Which is the case?

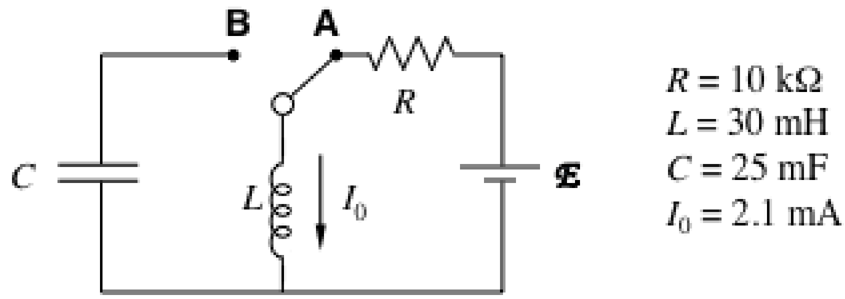


The resistor is in series with

a. either a capacitor OR an inductor.
b. both a capacitor and an inductor.
c. there is not enough information to determine.

The next two questions pertain to the following situation.

Consider the circuit shown below. The values of all circuit elements *except* for the battery voltage are known, and are given in the figure. A switch is hinged at the open circle and its top end can be connected to either contact **A** or contact **B** (indicated by the solid circles). This switch has been in position **A** for a very long time, and a steady current I_0 = 2.1 mA has been established through the inductor in the direction shown by the arrow.



6) What is the battery voltage $\mathcal{E}$?

a. $\mathcal{E} = 2$ V
b. $\mathcal{E} = 21$ V
c. Insufficient information is provided to determine this value.

7) <u>At time $t = 0$ seconds</u>, the switch is thrown to <u>position **B**</u>. Calculate the maximum voltage across the capacitor after the switch is thrown to position **B**.

a. $V_{C,\max} = 0.1$ mV
b. $V_{C,\max} = 1.6$ mV
c. $V_{C,\max} = 2.3$ mV
d. $V_{C,\max} = 4.4$ mV
e. $V_{C,\max} = 6.2$ mV

8) An astrophysicist is measuring spectra from the dust cloud around a comet approaching the Earth. What type of effect does she need to take into account due to the motion of the comet relative to the Earth?

a. The spectral lines are shifted towards shorter wavelengths.
b. The spectral lines are shifted towards longer wavelengths.
c. The spectral lines are not affected by the motion.

The next three questions pertain to the situation described below.

The electric field of an electromagnetic wave *in vacuum* has the following form:

$$E(y,t) = [(\hat{x}+\hat{z})/\sqrt{2}\,]E_0\, sin(k\,y - Wt)$$

where k is the wave number and ω is the angular frequency of the wave. Note $\hat{x}$, $\hat{y}$ and $\hat{z}$ are unit vectors in the +x, +y, and +z directions.

9) In what direction is this wave propagating?

a. $\hat{y}$ direction
b. $(\hat{x}+\hat{z})/\sqrt{2}$ direction
c. $(\hat{x}-\hat{z})/\sqrt{2}$ direction

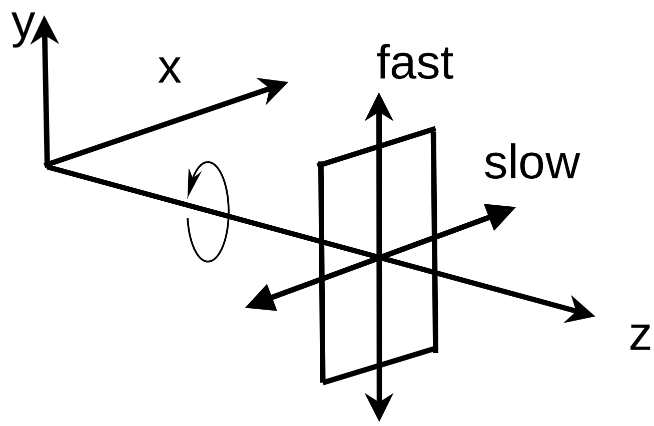
10) The corresponding **magnetic field** can be written: $B(y,t) = \hat{e}B_0\, sin(\kappa\, y - \omega\, t)$ where $\hat{e}$ is a unit vector. In terms of $\hat{x}$, $\hat{y}$ and $\hat{z}$, $\hat{e}$ can be written as:

a. $\hat{e} = \hat{x}$
b. $\hat{e} = (\hat{x}+\hat{y})/\sqrt{2}$
c. $\hat{e} = (\hat{x}-\hat{z})/\sqrt{2}$
d. $\hat{e} = (\hat{y}-\hat{z})/\sqrt{2}$
e. $\hat{e} = (-\hat{x}-\hat{y})/\sqrt{2}$

11) This electromagnetic wave is

a. linearly polarized.
b. circularly polarized.
c. unpolarized.

The next three questions pertain to the following situation:



Right circularly polarized light propagates in the positive z direction. The x-component of the electric field is given by $E_x = (100\ N/C)\ \sin(kz - \omega t)$

12) The x-component of the **magnetic** field is given by:

a. $B_x = -[(100\ N/C)/(3\times10^8\ m/s)]\sin(kz - \omega t)$
b. $B_x = -[(100\ N/C)/(3\times10^8\ m/s)]\cos(kz - \omega t)$
c. $B_x = 0$

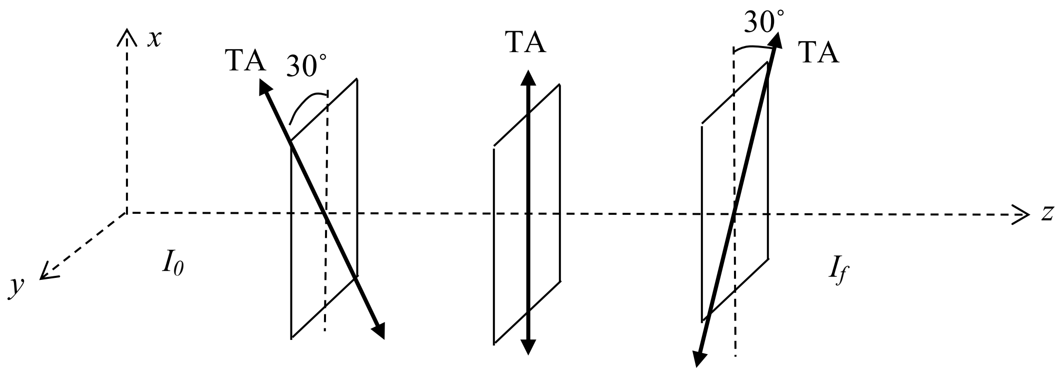
13) The intensity, I, of the wave is

a. 13.3 W/m^2
b. 18.8 W/m^2
c. 26.6 W/m^2
d. 37.5 W/m^2
e. 53.2 W/m^2

14) The light is now passed through a quarter wave plate as shown in the figure. When the light exits the quarter wave plate, it is

a. (right or left) circularly polarized.
b. linearly polarized.
c. unpolarized.

A beam of <u>unpolarized</u> light of intensity I_0 travels in the +*z*-direction and goes through an arrangement of three linear polarizers as shown in the figure below. The planes of all polarizers are parallel to the *xy* plane.



15) Find the ratio between the final intensity, I_f , and initial intensity, I_0.

a. $\frac{I_f}{I_0} = 0.16$

b. $\frac{I_f}{I_0} = 0.28$

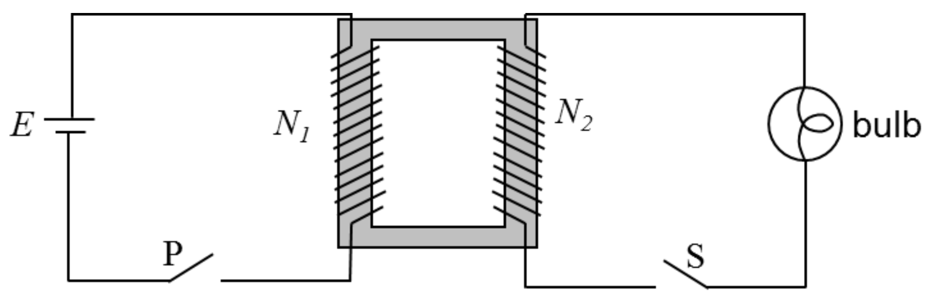
c. $\frac{I_f}{I_0} = 0.38$

d. $\frac{I_f}{I_0} = 0.42$

e. $\frac{I_f}{I_0} = 0.75$

The next two questions pertain to the situation described below.

The primary coil of a transformer has N_1 turns and is connected to a **battery**, which provides a **constant** voltage E. The secondary coil, with N_2 turns, is connected to a bulb. (Note: we assume the bulb will be visibly lit when the secondary coil gets the maximum *emf* allowed by this transformer).



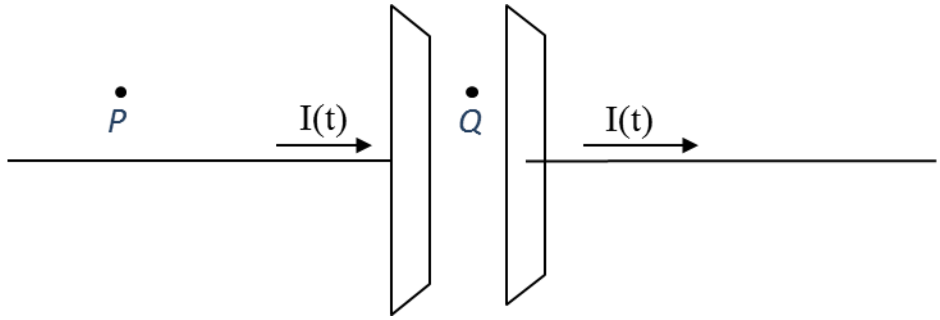
16) Consider the situation where switch S in the secondary circuit is open and switch P in the primary circuit has been closed for a long time. Switch S is now closed. Immediately after switch S closed, the bulb will:

a. Not be lit.
b. Be lit momentarily.
c. Be lit while both switches are closed.

17) Consider now the situation where switch P is open and switch S has been closed for a long time. Then switch P is suddenly closed. Immediately after this, the potential difference V_2 across the bulb is:

a. $V_2 = E\ N_1/ N_2$
b. $V_2 = E\ N_2/ N_1$
c. $V_2 = 0$
d. $V_2 = E\ (N_2/ N_1)^2$
e. $V_2 = E\ (N_2)^2 / N_1$

18) Assume that there is a parallel plate capacitor charging with time. The current is flowing in the wires as shown in the figure. Let $\boldsymbol{B_P}$ be the magnetic field at point P and let $\boldsymbol{B_Q}$ and $\boldsymbol{E_Q}$ be the magnetic and electric fields, respectively, at point Q, which lies in the region between the plates of the capacitor, as shown in the figure.



While the capacitor is charging:

a. $\boldsymbol{B_P} \neq 0$, $\boldsymbol{B_Q} \neq 0$, $\boldsymbol{E_Q} = 0$
b. $\boldsymbol{B_P} \neq 0$, $\boldsymbol{B_Q} = 0$, $\boldsymbol{E_Q} \neq 0$
c. $\boldsymbol{B_P} \neq 0$, $\boldsymbol{B_Q} \neq 0$, $\boldsymbol{E_Q} \neq 0$

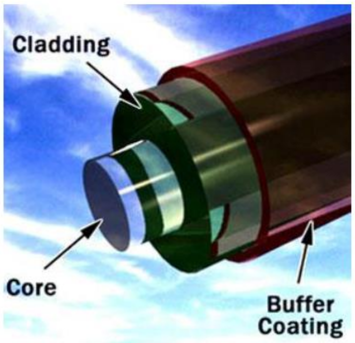
19) A newly designed analog radio is found to need unusually precise fine tuning of the frequency dial to pick up a certain frequency of a radio station. The customers would prefer a less sensitive dial. The engineer who is supposed to improve the radio should

a. increase the Q (quality factor) of the radio circuit.
b. decrease the Q of the radio circuit.
c. realize that Q has no effect on the sensitivity of the radio circuit.

20) Unpolarized light in air hits the surface of a diamond (n = 2.4) at some angle θ_i (measured from the vertical to the surface, as usual). The reflected light is completely horizontally polarized. What is θ_i?

a. 22.6˚
b. 67.4˚
c. 90.0˚

The next three questions pertain to the following situation:



An investment bank in Manhattan seeks to increase its competitive advantage for high speed trading through fast communication links between its computers at the Chicago Mercantile Exchange and its computer servers in New York City. A commercial provider offers optical fibers that run along public highways. The fiber core has an index of refraction of $n_{commercial}=1.5$. The cladding surrounding the core has an index of refraction of $n_{cladding}=1.2$. The total length of the fibers is $d_{commercial}=1290$ km. A newly hired engineering graduate from UIUC suggests for the company to use a new UIUC fiber core material with an index of refraction of $n_{UIUC}=1.4$. She proposes to lay a custom optical cable following a direct path from Manhattan to Chicago with length, $d_{UIUC}=1150$ km. Assume in this problem that the speed of light in vacuum is $c=300{,}000$ km/second.

21) The commercial optical cable and the UIUC cable use the same cladding material. Which of the following expressions correctly describes the relation between the critical angles for total internal reflection, $\theta_{commercial}$ and θ_{UIUC} in the two optical fiber cables (consider the reflection of light rays propagating inside the core and hitting the boundary between the core and the cladding)?

a. $\sin\theta_{commercial}/\sin\theta_{UIUC} = n_{UIUC}/n_{commercial}$
b. $\sin\theta_{commercial}/\sin\theta_{UIUC} = n_{commercial}/n_{UIUC}$
c. $n_{cladding} \times \sin\theta_{commercial}/\sin\theta_{UIUC} = n_{commercial}/n_{UIUC}$

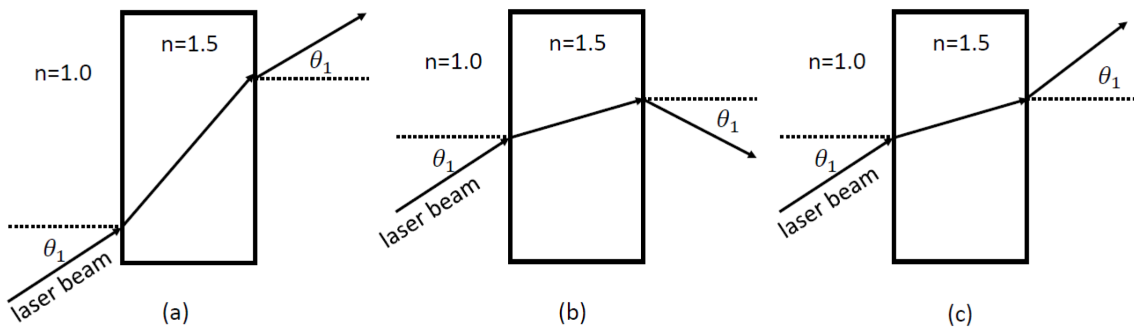
22) Assume both fibers use identical light sources at the input to the fibers for signal transmission (also assume the light source is diffuse and the beam diameter is larger than the core diameter). Which fiber core retains a larger fraction of light, leading to larger transmitted light signal amplitudes?

a. The commercial fiber core.
b. The UIUC fiber core.
c. The two fiber cores retain the same amount of light.

23) How large would be the difference in travel time between a light pulse sent from Manhattan to Chicago through the commercial optical fiber compared to a light pulse sent through the proposed UIUC fiber? (*1* millisecond = *0.001* seconds)

a. *0* milliseconds
b. *0.1* milliseconds
c. *1.1* milliseconds
d. *2.1* milliseconds
e. *3.1* milliseconds

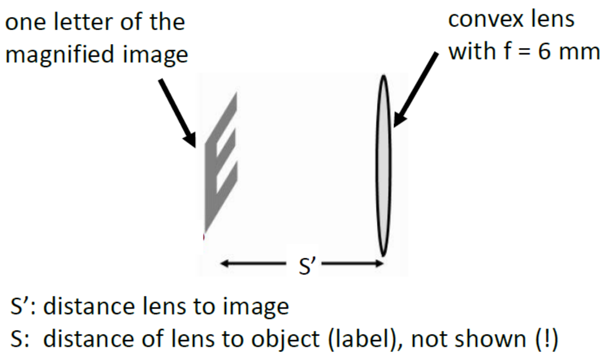
24) A laser beam propagates first through air, then through a glass block and exits back into air, as shown below:



Which graph shows the correct pathway for the laser beam?

a) graph (a)
b) graph (b)
c) graph (c)

The next two questions pertain to the following situation:



A convex lens is used to read the labels on surface mount elements on printed circuit boards. The lens has a focal length of *6* mm. The distance between the labels and the lens is *S* and the distance between the image and the lens *S'*.

25) The image viewed is not inverted and therefore

a) is a real image on the same side of the lens as the object.
b) is a virtual image on the opposite side from the object.
c) is a virtual image on the same side of the lens as the object.
d) is a real image on the opposite side from the object.
e) there is not enough information to determine.

26) If the image of the labels appears magnified by a factor 3, the distance between the lens and the labels must be

a) 4 mm.
b) 6 mm.
c) 8 mm.
d) 10 mm.
e) 12 mm.

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