Physics 227 - Final Exam
19 December 2006
Profs. Coleman and Rabe

⟹ Your name sticker with **exam code** ⟹

Your signature ______________________

Turn off and put away cell phones now!

1. The exam will last from 4:00 pm to 7:00 PM. Use a #2 pencil to make entries on the answer sheet. Enter the following ID information now, before the exam starts.
2. In the section labelled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
3. Under STUDENT # enter your 9-digit student ID.
4. Enter 227 under COURSE, and your section number (see label above) under SEC.
5. Under CODE enter the exam code given above.
6. During the exam, you may use pencils, a calculator, and two **handwritten** 8.5 x 11 inch sheets with formulas and notes, without attachments.
7. There are 30 questions on the exam. For each multiple-choice question, mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess. **At the end of the exam, hand in the answer sheet and the cover page.** Retain this question paper for future reference and study.
8. When you are asked to open the exam, make sure that your copy contains all 30 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.
9. **Please SIGN the cover sheet under your name sticker and have your student ID ready to show to the proctor during the exam.**

Some possibly useful information:

$c =$ speed of light $= 3.00 \times 10^8$ m/s

$q_e = -e =$ charge on an electron $= -1.602 \times 10^{-19}$ Coulombs

$q_p = +e =$ charge on a proton $= +1.602 \times 10^{-19}$ Coulombs

$m_e =$ electron mass $= 9.11 \times 10^{-31}$ kg

$m_p =$ proton mass $= 1.67 \times 10^{-27}$ kg

$k_e = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}$

$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/(N \cdot m^2)}$

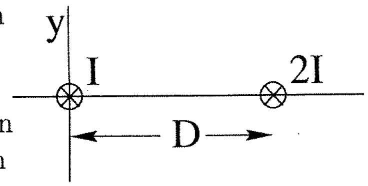
$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}$

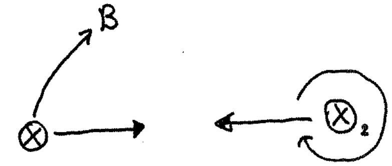
$g = 9.80\ \mathrm{m/s^2}$

1 mHz $= 10^{-3}$ Hz	1 kHz $= 10^{+3}$ Hz
1 MHz $= 10^{+6}$ Hz	1 GHz $= 10^{+9}$ Hz
1 mC $= 10^{-3}$ C	1 μC $= 10^{-6}$ C
1 nC $= 10^{-9}$ C	1 pC $= 10^{-12}$ C

1. At $x = 0$ a long straight wire carries current I <u>into</u> the plane of the paper. At $x = D$, another long straight wire carries current $2I$ <u>into</u> the plane of the paper. What is the direction of the force on the wire at the origin?

a. None of the other answers
b. towards the positive y-direction
c. out of the plane of the paper
d. towards the negative x-direction
e. towards the positive x-direction

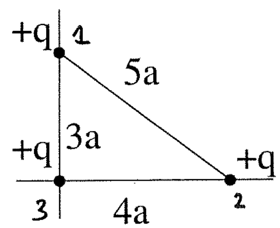




LIKE CURRENTS ATTRACT.

2. Three identical charges are initially at rest infinitely far apart. How much work is required to put the three charges together at rest as shown in the figure?

a) $0.78kq^2/a$
b) $0.20kq^2/a$
c) $0.45kq^2/a$
d) $1.6kq^2/a$
e) $2.4kq^2/a$



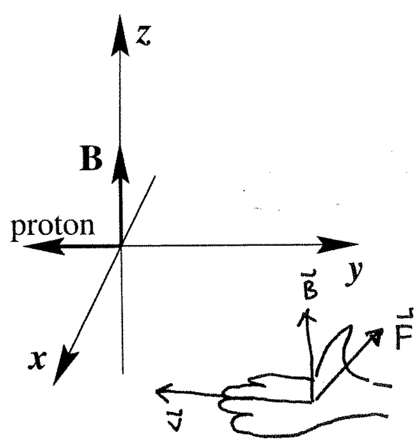
$$W = U = \sum_{i>j} \frac{k q_i q_j}{r_{ij}}$$

$$= \frac{k q_1 q_2}{r_{12}} + \frac{k q_2 q_3}{r_{23}} + \frac{k q_3 q_1}{r_{31}}$$

$$= \frac{kq^2}{a}\left(\frac{1}{5} + \frac{1}{4} + \frac{1}{3}\right) = \frac{47}{60}\frac{kq^2}{a} \quad a)$$

3. A proton is traveling in the negative y-direction. It enters a uniform magnetic field pointing in the positive z-direction. The force on the proton is in the

a) positive x-direction
b) positive y-direction
c) negative z-direction
d) none of the other answers
e) positive z-direction



$$\vec{F} = q\vec{v} \times \vec{B}$$
$$= q(-v\hat{j} \times B\hat{k})$$
$$= -qvB\,\hat{j} \times \hat{k}$$
$$= -qvB\,\hat{i}$$

Or by r.h. rule

4. A long solenoid has 15 turns per centimeter. What current must we put through its windings if we wish to achieve a magnetic field of 5.0×10^{-2} T in its interior?

a) 77 A
b) 12 A
c) 333 A
d) 27 A
e) 135 A

$$LB = \mu_0 N i$$

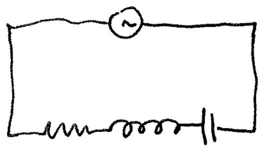
$$B = \frac{\mu_0 N i}{L}$$

$$i = \frac{B}{\mu_0 (N/L)} = \frac{5\times10^{-2}\,T}{4\pi\times10^{-7} \times 15\times10^{2}} = \frac{1}{12\pi}\times10^{3}\,A$$

$$= 27A$$

5. A series RLC circuit has elements $R = 30\Omega$, $L = 10^{-3}$ H, and $C = 10^{-7}$ F. the maximum current during the cycle is $I_m = 2$ A when the circuit is connected to an EMF oscillating at the angular frequency $\omega = 1.25 \times 10^5$/sec. The maximum EMF of the generator is

a) 76.5 V
b) 202.2 V
c) 154.2 V
d) 54.2 V
e) 108.2 V



$$V_m = I_m Z$$

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$= \sqrt{30^2 + (X_L - X_c)^2} = \sqrt{30^2 + 45^2} = 54\Omega$$

$$\left.\begin{array}{l} X_L = \omega L = 1.25\times10^5\times10^{-3} = 125\Omega \\ X_c = 1/(1.25\times10^5\times10^{-7}) = 80\Omega \end{array}\right\} X_L - X_c = 45$$

$$V_m = 2 \times 54 = \underline{108.2V}$$

6. A long straight wire of superconducting niobium, 2×10^{-3} m in **diameter**, carries a current of 1900 A. What is the strength of the magnetic field just outside the wire?

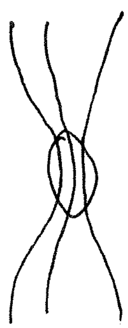
a) 2.4 T
b) 1.2 T
c) 0.19 T
d) 3.8 T
e) 0.38 T

$$2\pi r B = \mu_0 i \qquad B = \frac{\mu_0 i}{2\pi r} = \frac{\mu_0 i}{\pi d}$$

$$= \frac{4\pi\times10^{-7}\times1900}{\pi\times2\times10^{-3}} = \underline{0.38T}$$

7. Which of the following about magnetic materials is false?

a) A paramagnet develops an internal magnetization that points in the opposite direction to an applied field.
b) Superconductors are perfect diamagnets.
c) Ferromagnets develop a magnetization that persists, even in the absence of an applied field.
d) Paramagnets are attracted to regions of high field.
e) Diamagnets are repelled from regions of high field.



$U = -\frac{\chi B^2}{2}$. is lowered in regions of high field.

8. An electron moving in a plane perpendicular to a uniform magnetic field is observed to execute a circular orbit of radius 1 cm every 1 μs. What is the magnitude of the magnetic field?

a) 5 T
b) 3.31 T
c) (2.67×10^{-2}) T
d) (1.8×10^{-9}) T
e) (3.6×10^{-5}) T

$$\frac{mv^2}{R} = qvB \Rightarrow \omega = \frac{v}{R} = \left(\frac{qB}{m}\right)$$

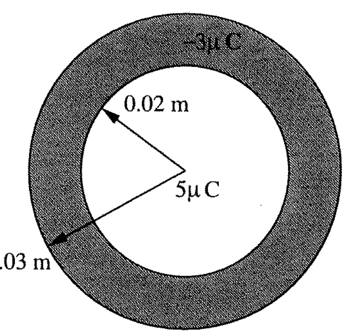
$$\omega = 2\pi f = \frac{2\pi}{T} = \frac{qB}{m}$$

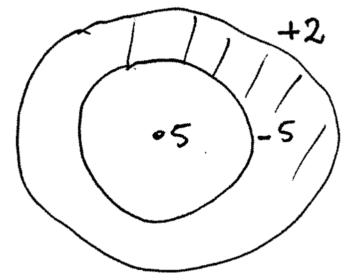
$$\Rightarrow B = \frac{2\pi m}{qT} = \frac{2\pi \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19} \times 10^{-6}}$$

$$= 3.6 \times 10^{-5}\ T$$

9. A point-charge of $+5\mu C$ is surrounded by a concentric hollow conducting sphere of inner radius 0.02m and outer radius 0.03m. The net charge on the conducting sphere is $-3\mu C$. What is the net charge on the inner surface of the hollow sphere?

a) $+3\mu C$
b) $-3\mu C$
c) $-5\mu C$
d) $+2\mu C$
e) $-2\mu C$

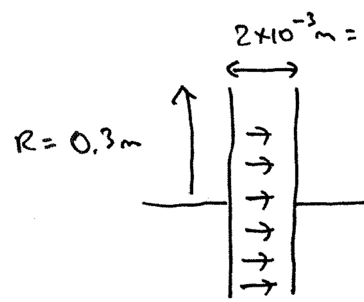




$q_{inner} = -5\mu C$

10. A parallel-plate capacitor consists of circular plates of radius 0.30 m separated by a distance of 2×10^{-3} m. The voltage applied to the capacitor is made to increase at a constant rate of 1.0×10^3 V/sec. Assume that the electric charge distributes itself uniformly over the plates. What is the magnitude of the magnetic field between the plates at a radius of 0.15 m?

a) 37.5×10^4 T
b) 8.3×10^{-16} T
c) 3.9×10^{-13} T
d) 8.3×10^{-13} T
e) 4.2×10^{-13} T



$$B(2\pi r) = \mu_0 \epsilon_0 \frac{dE}{dt} \cdot f$$

$$B = \frac{\mu_0 \epsilon_0}{2\pi r} \frac{dE}{dt} \cdot A$$

$$\frac{dE}{dt} = \left(\frac{dV}{dt}\right)\frac{1}{d} = \frac{10^3}{2 \times 10^{-3}} = 0.5 \times 10^6\ V/(ms)$$

$$B = \frac{\pi r^2}{2\pi r c^2} \frac{dE}{dt} = \frac{r}{2c^2} \frac{dE}{dt}$$

$$= \frac{0.15}{2(3 \times 10^8)^2} \times 0.5 \times 10^6 = 4.2 \times 10^{-13}\ T$$

11. An AC generator supplies 100 V to the primary coil of a transformer. The primary has 50 turns and the secondary has 500 turns. The secondary voltage is:

a) 1000 V b) 500 V c) 250 V d) 100 V e) 10 V

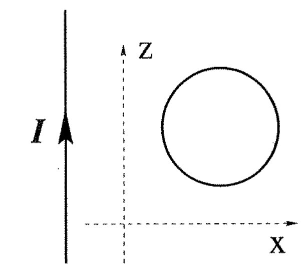
N_1 N_2

50 500

$\frac{N_2}{N_1} = \frac{V_2}{V_1}$ $V_2 = V_1\left(\frac{N_2}{N_1}\right)$

$= \underline{\underline{1000\,V}}$

12. A long straight wire carries a current I and is parallel to the z-axis, as shown. A loop of wire lying in the xz-plane is nearby. Which of the following is *false*?



a. If I is in the $+z$-direction and increasing in magnitude, a counterclockwise current is induced in the loop.

opposes change ✓

b. If I is in the $+z$-direction and decreasing in magnitude, a clockwise current is induced in the loop.

opposes change ✓

c. If I is an AC current, an AC current is induced in the loop.

TRUE.

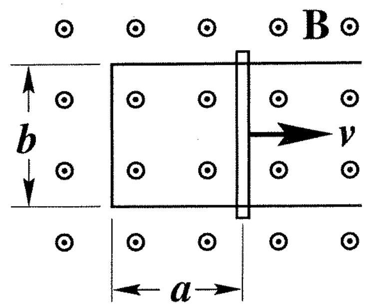
d. If I is constant in the $+z$-direction and the loop is moved in the $-z$-direction, a clockwise current is induced in the loop.

FALSE BECAUSE FLUX THROUGH LOOP IS CONSTANT

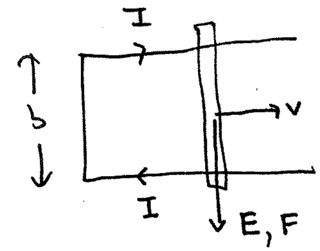
e. If I is constant in the $+z$-direction and the loop is moved in the $+x$-direction, a clockwise current is induced in the loop.

CURRENT OPPOSES REDUCING FLUX ✓

13. A metal rail with a sliding rod is in a uniform, constant magnetic field B directed out of the plane of the paper. The rod is sliding at speed v as shown. If the resistance of the assembly is R, what will be the induced current?



a) Zero
b) Bav/R clockwise
c) Bav/R counterclockwise
d) Bbv/R clockwise
e) Bbv/R counterclockwise



$\vec{F} = q\vec{v}\times\vec{B}$

$E = vB$

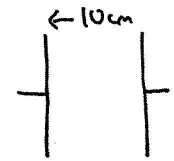
$V = \int E.dr = vBb$

$IR = vBa$

$I = \frac{vBb}{R}$ clockwise.

14. Two large parallel conducting plates are 10 cm apart and carry equal but opposite charges on their facing surfaces. An electron placed midway between the plates experiences a force of 3.2×10^{-17} N. The potential difference between the plates is

a) 2000 V
b) 200 V
c) 40 V
d) 20 V
e) 10 V



$F = eE$

$V = Ed = \frac{Fd}{e}$

$$V = \frac{3.2\times10^{-17}N \times 10^{-1}}{1.6\times10^{-19}} = 20V$$

15. A parallel-plate capacitor is charged by a battery, and then disconnected from it. If the plate separation is then doubled, what happens to the potential difference V between the plates and the energy U stored in the capacitor?

a) V gets doubled; U gets doubled
b) V gets doubled; U stays the same
c) V gets doubled; U gets halved
d) V gets halved; U gets halved
e) V gets halved; U stays the same

Constant charge. q

$C = \frac{\epsilon_0 A}{d}$ $\quad d \rightarrow 2d \quad C \rightarrow \frac{C}{2}$

$V_0 = \frac{q}{C} \rightarrow \frac{q}{C/2} = 2V_0$

$U = \frac{1}{2}qV_0 \rightarrow \frac{1}{2}q(2V_0)$ doubled

16. There is a current of 5 mA in a solenoid of inductance 0.60 mH. If the current is doubled, what will be the new inductance of the solenoid?

a) 0.30 mH
b) 0.42 mH
c) 0.60 mH
d) 0.85 mH
e) 1.20 mH

$I = 5mA$

$L = 0.6mH$

Inductance is independent of I

$$\left(L = \frac{N\Phi_B}{I} = \frac{NAB}{I} \; ; \quad B\ell = \mu_0 NI \Rightarrow B = \frac{\mu_0 NI}{\ell} \Rightarrow L = \frac{\mu_0 N^2 A}{\ell} \right)$$

17. A capacitor is connected to an AC source whose peak voltage is 12 V and whose angular frequency in 4000 rad/s. If the maximum current is 0.1 A, what is the capacitance?

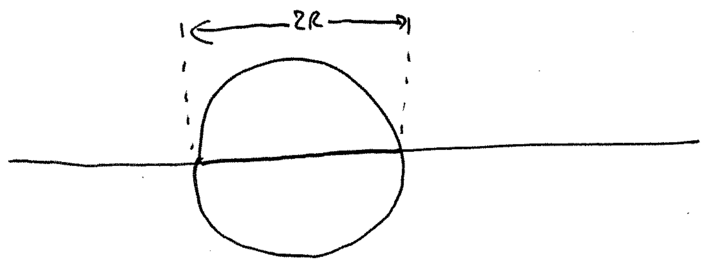
a) 2.1×10^{-6} F
b) 0.03 F
c) 3×10^{-4} F
d) 2.1×10^{-4} F
e) 8.3×10^{-3} F

$$V_{max} = I_{max} X_c = \frac{I_{max}}{\omega C} \Rightarrow C = \frac{I}{\omega V} = \frac{0.1}{4000 \times 12}$$

$$= 2.08 \times 10^{-6} \text{ F}$$

18. An infinitely long, straight string has a uniform linear charge density of λ expressed in C/m. A sphere of radius R has its center at a point on the string. What is the electric flux through the sphere?

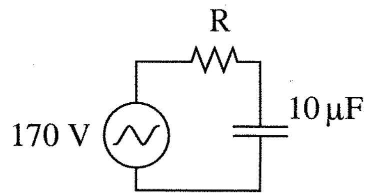
a) $\lambda R/2\pi\epsilon_0$
b) $\lambda/2\pi R\epsilon_0$
c) $\lambda R/2\epsilon_0$
d) λ/ϵ_0
e) $2\lambda R/\epsilon_0$



$$\Phi_E = \int \vec{E} \cdot d\vec{S} = \frac{Q_{enc}}{\epsilon_0} = \frac{1}{\epsilon_0} \lambda (2R) = \frac{2\lambda R}{\epsilon_0}$$

19. An RC circuit is driven by an AC voltage source $V = (170\text{V})\sin 377t$. If the capacitor is 10 μF, what must the resistor be, if the rms voltage across the resistor is to equal the rms voltage across the capacitor?

a) $R = 265\ \Omega$
b) $R = 3.77\ \text{m}\Omega$
c) $R = 45\ \text{k}\Omega$
d) $R = 37\ \text{M}\Omega$
e) $R = 10\ \Omega$



$V_{c\,max} = I_{max} X_c$

$V_{c\,rms} = I_{rms} X_c$

$V_{R\,rms} = I_{rms} R$

$V_{c\,rms} = V_{R\,rms} \Rightarrow X_c = R$

$\frac{1}{\omega C} = R = \frac{1}{377 \times 10 \times 10^{-6}} = 265\,\Omega$

20. An inductor carrying a current of 1mA is designed to store 1μJ of energy. What is its inductance?

a) 2 H b) 1 H c) 2 mH d) 1 mH
e) 2 μH

$U = \frac{1}{2} L I^2$ $L = \frac{2U}{I^2} = \frac{2 \times 10^{-6}}{(10^{-3})^2} = 2H$

21. The intensity of the electromagnetic radiation delivered by the Sun to the Earth's surface is 1000 W/m^2. What is the corresponding maximum value of the electric field?

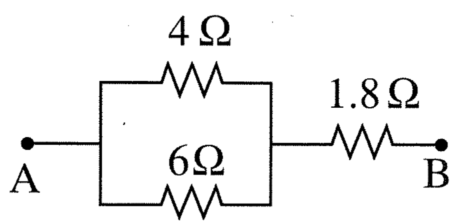
a) 7.5×10^5 V/m
b) 1.5×10^7 V/m
c) 31.6 V/m
d) 614 V/m
e) 868 V/m

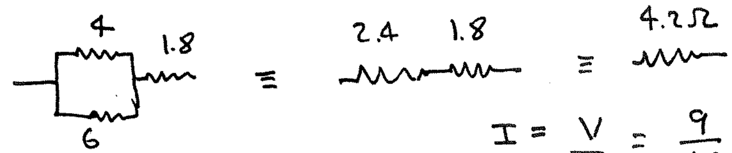
$S_{av} = \frac{\epsilon_0 c E_{max}^2}{2}$ $E_{max} = \sqrt{\frac{2S}{\epsilon_0 c}}$

$= \sqrt{\frac{2 \times 1000}{8.854 \times 10^{-12} \times 3 \times 10^8}} \approx 868\,\text{V/m}$

22. A potential difference of 9 Volts is applied between A and B in the figure shown. Then the current I in the 1.8 Ω resistor is, in amperes,

a) $4.0 \leq I < 6.0$
b) $2.0 \leq I < 2.5$
c) $I > 6.0$
d) $2.5 \leq I < 4.0$
e) $I < 2.0$





$\frac{1}{4} + \frac{1}{6} = \frac{10}{24} \Rightarrow R_{eq} = 2.4\,\Omega$

$I = \frac{V}{R} = \frac{9}{4.2} = 2.14$

b

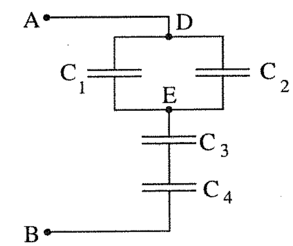
23. A light bulb consumes 50W of power and emits 5% of this as visible light. What is the intensity of the visible light a distance 2.0 m away?

a) 0.050 W/m^2 b) 1 W/m^2 c) 0.2 W/m^2
d) 0.15 W/m^2 e) 0.075 W/m^2

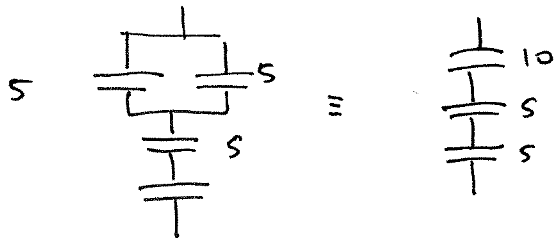
$P = f P_0 \qquad f = 0.05, \quad P = 50W$

$$S = \frac{P}{4\pi r^2} = \frac{0.05 \times 50}{4 \times \pi \times (2)^2} = 0.05\,W/m^2$$

24. Each capacitor shown has a value of 5 μF. What is the equivalent capacitance of this combination?



a) 0.5 μF
b) 2.0 μF
c) 20 μF
d) 15 μF
e) 5.0 μF



$$\left(\frac{1}{10} + \frac{1}{5} + \frac{1}{5}\right)^{-1} = \left(\frac{5}{10}\right)^{-1} = 2$$

$C = 2\mu F$

25. We desire to make an LC circuit that oscillates at f = 100 Hz using an inductance of 2.5 H. We also need a capacitance of:

a) 1 F b) 1 mF c) 1 μF d) 100 μF
e) 1 pF

$$2\pi f = \frac{1}{\sqrt{LC}} \Rightarrow C = \frac{1}{(2\pi f)^2 L} = \frac{1}{(2\pi(100))^2(2.5H)} = 10^{-6}F = 1\mu F$$

26. A thin copper wire of 0.20 mm diameter carries a current of 2 A. Copper has 8.4×10^{28} free electrons per m^3. What is the drift speed of the electrons?

a) 6.06×10^3 m/sec
b) 2.1×10^6 m/sec
c) 6.11×10^{-4} m/sec
d) 4.7×10^{-3} m/sec
e) 1.48×10^5 m/sec

$$j = \frac{I}{A} = nqv_d \Rightarrow v_d = \frac{I}{Anq} = \frac{2A}{(\pi \times (0.1 \times 10^{-3})^2)nq}$$

$$= \frac{2A}{(\pi(10^{-4})^2) \times 8.4 \times 10^{28} \times 1.6 \times 10^{-19}} = 4.7 \times 10^{-3} m/s.$$

27. The electric field for a plane EM wave is given by

$$\vec{E} = (1000)\cos([3.3 \times 10^5]x - 10^{14}t)\,\hat{y}$$

in S. I. units. For this wave

a) the magnetic field amplitude is 3×10^{11} T ✗
b) the wavelength is 3×10^{-6} m
c) the period is 6.3×10^{-14} s
d) the frequency is 10^{14} Hz
e) the magnetic field points in the $\hat{x}$ direction

$B = \frac{E}{c} = \frac{1000}{3\times10^8} = \frac{1}{3}\times10^{-5}$ T. ✗

$\frac{2\pi}{\lambda} = k \qquad \lambda = \frac{2\pi}{k} = \frac{2\pi}{3.3\times10^5} = 1.9\times10^{-5}$ m ✗

$\omega = 10^{14} = \frac{2\pi}{T} \qquad T = \frac{2\pi}{\omega} = \frac{2\pi}{10^{14}} = \underline{6.28\times10^{-14}\text{ s}}$ ✓

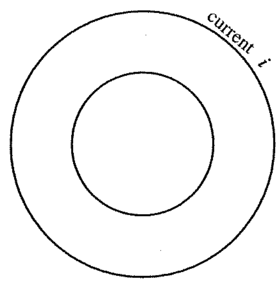
$f = \frac{10^{14}}{2\pi}$ ✗ $\qquad$ B points in the y direction ✗

28. Two concentric, circular loops of wire lie in the plane of the paper. The outer loop carries a current "i". Which of the following is true?

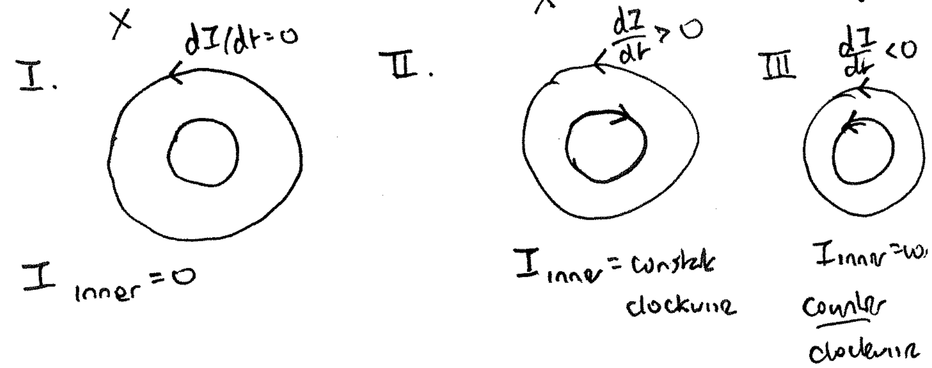
I: If i is counterclockwise and constant, the induced current in the inner loop will be nonzero and clockwise.

II: If i is counterclockwise and increasing, the induced current in the inner loop will be nonzero and counterclockwise.

III: If i is counterclockwise and decreasing, the induced current in the inner loop will be nonzero and counterclockwise.

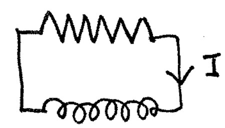


a) All three statements are true
b) II and III are true; I is false
c) Only III is true
d) I and III are true; II is false
e) Only I is true



29. A current of 2.0 amperes is running through an LR circuit containing a 1.0Ω resistor and a $10mH$ inductor. If the emf driving the current is suddenly switched off, how long does it take for the current to drop down to 0.5 A?

a) 13.9 ms $\quad$ b) 2.87 ms $\quad$ c) 1.40 ms $\quad$ d) 0.29 ms
e) 6.02 ms



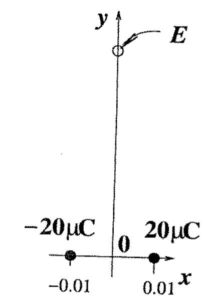
$IR + L\frac{dI}{dt} = 0$

$\frac{I}{\tau} + \frac{dI}{dt} = 0 \qquad \tau = L/R = 10\times10^{-3}/1 = 10^{-2}$ s

$I = I_0 e^{-t/\tau}$

$\ln(I/I_0) = -\frac{t}{\tau} \qquad t = \tau\ln\left(\frac{I_0}{I}\right) = 13.9\times10^{-3}$ s

30. A charge of $+20\mu C$ is placed on the x-axis at $x = 0.01$m, and a charge of $-20\mu C$ is placed on the x-axis at $x = -0.01$m. On the y-axis at $y = 1$m, the electric field is



a) pointing in the $+x$ direction
b) pointing in the $-x$ direction
c) pointing in the $+y$ direction
d) pointing in the $-y$ direction
e) zero

$\vec{E} = \vec{E}_1 + \vec{E}_2$

points in $-x$

direction