Physics 202  
Spring 1999  
Final Exam

FORM A

NAME:  
SS#:  
RECITATION SECTION/TA NAME:

- Answer ALL 25 questions.

- Make sure that you enter your FORM CODE and your SS# on the scan sheet. THIS IS ABSOLUTELY ESSENTIAL. You will NOT receive a grade for the exam if you forget!

- The exam has a time limit of 110 minutes.
- You may only consult your security blanket (a double sided standard sheet of paper)

- Useful constants:
  - Charge on electron = $1.6 \times 10^{-19}$ C
  - In Coulomb's Law, $k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9$ Nm$^2$/C$^2$
  - $\varepsilon_0 = 8.85 \times 10^{-12}$ C$^2$/Nm$^2$
  - $\mu_0 = 1.26 \times 10^{-6}$ H/m
1. The figure below shows a cylindrical Gaussian surface that surrounds a section of an infinitely long line of charge. The cylinder has a length $L$ and a radius $R$. The line of charge has a uniform linear charge density $\lambda$. What is the total flux through the surface of the Gaussian cylinder?

![Diagram of a cylindrical Gaussian surface]

(a) 0
(b) $2\pi RL\varepsilon_0$
(c) $(2\pi R^2 + 2\pi RL)(\lambda/\varepsilon_0)$
(d) $(2\pi R^2 + 2\pi RL)/\varepsilon_0$.

(e) $\lambda L/\varepsilon_0$ Gauss' Law tells us that flux = (charge enclosed/$\varepsilon_0$) (from sample test 1)

2. The figure below shows two uniformly charged arcs of radius $R$. The arc on the left has a net charge of $+Q$, whilst the arc on the right has a net charge of $+2Q$. If the magnitude of the electric field at the origin due to the arc on the left is $E$, what is the magnitude and direction of the electric field at the origin due to the arc on the right?

![Diagram of two uniformly charged arcs]

(a) $2E$, along the positive x-axis.
(b) $2E$ along the negative x-axis.
(c) $1.414E$ along the positive x-axis.
(d) $1.414E$ along the negative x-axis. Use superposition and do a vector sum. Vertical components cancel. Horizontal components add. -- see midterm 1
(e) $1.414E$ at an angle of $45^0$ to the x-axis, pointing downwards and to the left.
3. The figure below shows 3 point charges, each of magnitude Q, arranged at the corners of an equilateral triangle of side L. Two of the charges are positive and one of them is negative, as shown. The magnitude of the electric field due to any one of the charges at the geometric center C of the triangle is $E$. What is the magnitude of the TOTAL electric field at C?

(a) 0
(b) 0.5E
(c) 0.87 E
(d) 2E Use superposition again. The horizontal components from the +Q charges cancel. The vertical components are each 0.5E and add to the E from -Q. -- see midterm 1
(e) E

4. A solid spherical insulator of radius R carries a uniform charge density per unit volume. The electric field at the surface of the sphere has a magnitude of 12 N/C. What is the magnitude of the electric field at a distance R/2 from the center of the sphere?

(a) 0
(b) 8 N/C.
(c) 6 N/C. Use Gauss Law. Let total charge be Q. At R, $E = kQ/R^2 = 12$ N/C. At R/2, the charge enclosed is (1/8) total charge, so $E' = k(Q/8)/(R/2)^2 = kQ/(2R^2)$.
(d) 4 N/C.
(e) 3 N/C.
5. A conducting object carries an excess negative charge. You are given that the local charge density around some point P on the surface of the conductor = - 0.885 C/m² (note that it is negative). What can you conclude about the electric field outside the object, but very close to P?

(a) The magnitude of E is approximately $10^{11}$ N/C; it is perpendicular to the surface and points away from the surface.
(b) The field is perpendicular to the surface and points towards the surface, but we cannot estimate the magnitude without more detailed knowledge of the shape of the object.
(c) The magnitude of E is approximately $10^{11}$ N/C; it is tangential to the surface.
(d) The magnitude of E approximately $10^{11}$ N/C; it is perpendicular to the surface and points towards the surface. $E$ near the surface of a conductor = $\sigma/\varepsilon_0$.
(e) We cannot say anything about either the magnitude or the direction of E without more detailed knowledge of the shape of the object.

6. A total charge Q is distributed uniformly on a circle of radius R. How much external work is required to bring a charge of +1C from infinity to the center of the circle? (Assume as usual that the electric potential = 0 at infinity.)

(a) $\frac{Q}{4\pi \varepsilon_0 R^2}$.
(b) $\frac{Q}{4\pi \varepsilon_0 R}$. This is simply the defn of V...i.e. what is the electric potential at the center of the circle? All the charge is equidistant and potential is a scalar, hence the answer. See sample test 1.
(c) $\frac{Q}{8\pi \varepsilon_0 R}$.
(d) $\frac{Q}{(4\pi \varepsilon_0 R)(2\pi R)}$.
(e) Zero, since the force exerted on any charge at the center is 0 by symmetry.
7. A parallel plate capacitor is charged using a battery until the energy stored on the capacitor is 1 J. The battery is then disconnected. If the plates of the capacitor are pulled apart so that the distance between them is doubled, what happens to the energy stored on the capacitor?

(a) The energy stored is now 0.5 J.

(b) The energy stored is now 2 J. **Energy stored** = \( U = \frac{Q^2}{2C} \). \( Q \) is fixed, since battery is disconnected. \( C \) is halved. So, \( U \) doubles.

(c) The energy stored is still 1 J.

(d) The energy stored is now 4 J.

(e) The energy stored is now 8 J.

8. Two bulbs are connected in series to a 3 V battery. Bulb A lights up, while bulb B does not. What can you conclude?

(a) Bulb B has a broken filament.

(b) Bulb B has the lower resistance of the two bulbs. **The same current goes through the two bulbs. Bulb B does not light up because power dissipated** \( (I^2R) \) is too small. Demo in lecture + expt in prelab/lab.

(c) Bulb B has the higher resistance of the two bulbs.

(d) Electrons flow through bulb A but not through bulb B.

(e) If you switched the places of the two bulbs in the circuit, bulb B would now light up while bulb A would not.
9. You buy a set of Xmas lights in which 100 bulbs are connected in parallel with each other. The lights are connected across an ideal EMF source. Suppose 50 of the bulbs blow out. Which of the following statements is correct?

(a) The current through each of the remaining bulbs is unchanged. The EMF source is ideal. So, the voltage across each of the bulbs is fixed, no matter how many bulbs you put in parallel with each other. Demo in lecture + expt in lab

(b) The voltage across each of the remaining bulbs is halved.
(c) The current through each of the remaining bulbs is doubled.
(d) The current through each of the remaining bulbs is halved.
(e) The total current supplied by the EMF source is doubled.

10. A 10 µF, 20 µF and 60 µF capacitor are connected in series across a 9 V battery. What is the total charge stored on all three capacitors?

(a) 0.81 mC.
(b) 0.54 µC.
(c) 1 mC
(d) 54 µC Total C = 6µF. Hence, Q = CV.
(e) 8.1 mC
11. The figure below shows the path followed by two charged particles when they enter a region where a uniform magnetic field points into the plane of the page. The two particles have identical speeds when they enter this region and have the same mass. Which of the following statements is false?

(a) The charge on the two particles differs in sign.
(b) Particle 1 is positively charged.

(c) Particle 1 has charge of greater magnitude than particle 2. \( \frac{Mv^2}{r} = qvB \); so, \( r = \frac{(mv)}{(qB)} \). For a given \( v \), larger \( q \) \( \rightarrow \) smaller \( r \).
(d) The charge on the two particles differs in magnitude.
(e) The magnetic force on the two particles is always perpendicular to their instantaneous velocity.

12. The figure below shows 3 extremely long straight, parallel wires carrying currents into the page as indicated by the usual conventions. What is the direction of the force on the wire located at the origin? (As usual, \( \hat{i} \) and \( \hat{j} \) are unit vectors directed along +x and +y.)

(a) Parallel to \( (\hat{i} + \hat{j}) \). Use right hand rule + superposition for figuring out total B -- points along -i+j. Then figure out force from \( iLxB \).
(b) Parallel to \( (\hat{i} - \hat{j}) \).
(c) Parallel to \( (-\hat{i} + \hat{j}) \).
(d) Parallel to \( (-\hat{i} - \hat{j}) \).
(e) Parallel to \( \hat{i} \).
13. The figure below shows a rectangular loop of wire carrying current located near another very long straight wire also carrying a current. The straight wire is parallel to the long side of the rectangle. The arrows indicate the directions of the current. If the rectangular loop is released from rest, what will happen?

(a) It will begin to rotate about its long axis.
(b) It will begin to move towards the straight wire along a line perpendicular to it. **HW problem**
(c) It will move along a line parallel to the straight wire.
(d) It will move away from the straight wire along a line perpendicular to it.
(e) Since the net force on the loop is zero, it will stay at rest.

14. A cylindrical wire of cross-sectional radius R carries a uniform current density J. What is the magnetic field INSIDE the wire at a distance r from the cylinder axis?

(a) Zero -- it is always zero inside a conductor.
(b) \( \frac{\mu_0 J r^2}{R} \)
(c) \( \frac{\mu_0 J R^2}{2r} \)
(d) \( \frac{\mu_0 J r}{2} \) Use Ampere's Law: \( B(2\pi r) = \mu_0 \pi r^2 J \)
(e) \( \frac{\mu_0 J R}{2\pi} \)
15. The figure below shows a magnet and a loop of wire. The magnet moves with a constant speed towards the loop, as shown. Describe what happens (from the viewpoint of the magnet) in the loop of wire when the magnet approaches the loop.

(a) Nothing happens.
(b) A constant counter-clockwise current is induced.
(c) A constant clockwise current is induced.
(d) A time varying counter-clockwise current is induced. Use Faraday/Lenz law for direction of emf. Note however that the flux created by the magnet does not change at a constant rate even if the magnet is moving at constant speed. (Draw the field lines -- and recall your lab expt where the induced emf reached a peak as the magnet approached the coil and then became smaller.) So the emf magnitude changes with time.
(e) A time varying clockwise current is induced.

16. The figure below shows a loop of wire moving with constant velocity through a region of space where there exists a uniform magnetic field pointing OUT of the page. What is the direction of the induced current in the loop at positions A, B, C and D?

(a) A: no current; B: clockwise; C: no current; D: counter-clockwise. Faraday Law -- HW problem.
(b) A: clockwise; B: clockwise; C: counter-clockwise; D: counter-clockwise.
(c) A: no current; B: counter-clockwise; C: no current; D: clockwise.
(d) A: no current; B: clockwise; C: clockwise; D: counter-clockwise..
(e) A: counter-clockwise; B: counter-clockwise; C: no current; D: clockwise..
17. The switch in the circuit shown below is initially open. Then it is closed at $t = 0$.
Which of the following statements is **FALSE**?

(a) At $t = 5$ seconds, the energy dissipated by the resistor is negligible.
(b) At $t = 0.001$ seconds, the current in the circuit is negligible. At $t = 0.001$, $I \sim 9\text{mA}$ -- (i.e. finite) and then it drops to gradually zero. Concept: current in RC circuit immediately goes from 0 to finite value when $C$ starts charging.
(c) At $t = 5$ seconds, the potential difference across the capacitor is close to 9 V.
(d) At $t = 0.1$ seconds, the charge on the capacitor is about $5.7 \times 10^{-4}$ C.
(e) At $t = 0.001$ seconds, the charge on the capacitor is negligible.

18. The switch in the circuit shown below is initially open. Then, it is closed at $t = 0$.
Which of the following statements is **FALSE**?

(a) At $t = 5$ seconds, the energy dissipated by the resistor is negligible. **Time constant is 0.1 s.** At 5 s, current is pretty much 9A. Concept: after many time constants, the LR circuit looks just like a simple DC circuit.
(b) At $t = 0.001$ seconds, the current in the circuit is negligible.
(c) At $t = 5$ seconds, the potential difference across the inductor is negligible.
(d) At $t = 0.1$ seconds, the current in the circuit is about 5.67 A.
(e) At $t = 5$ seconds, the potential difference across the resistor is 9 V.
19. In the circuit shown below, the switch is initially open and the capacitor is charged to 1C. The switch is then closed at \( t = 0 \). When does the magnitude of the charge on the capacitor first return to its initial value?

(a) At \( t = 1 \) s.
(b) At \( t = 0.1 \) s
(c) At \( t = 0.32 \) s
(d) At \( t = 3.14 \) s Angular frequency of LC circuit = 1 rad/sec. So, period of oscillation is 6.28 s. C gets fully charged every half-period. HW problem.
(e) None of the above.

![Diagram of an LC circuit with a switch, capacitor, and inductor]

20. The current in a 0.5 H inductor is decreasing at a rate of 4 A/s. What is the magnitude and direction of the induced EMF?

(a) 2 V, in the direction of the existing current. \( \text{EMF} = L(\frac{di}{dt}) \). Since \( i \) is decreasing, induced EMF opposes the CHANGE i.e. is in the same direction as current.
(b) 8 V, in the direction of the existing current.
(c) 2 V, opposed to the direction of the existing current.
(d) 8 V, opposed to the direction of the existing current.
(e) 1 V, opposed to the direction of the existing current.
21. A student connects, one at a time, a resistor, a capacitor and an inductor across an ac source whose frequency can be varied. She measures both the current in the circuit and the voltage across the component under study while she varies the frequency of the driving EMF from 10 Hz to 1000 Hz. Which of the following observations is FALSE?

(a) When the resistor is in the circuit, the current amplitude is independent of frequency.
(b) When the capacitor is in the circuit, the current amplitude is larger at 10 Hz than at 1000 Hz. Reactance of a capacitor DECREASES as frequency INCREASES.
(c) When the inductor is in the circuit, the current amplitude is larger at 10 Hz than at 1000 Hz.
(d) When the capacitor is in the circuit, the current leads the driving EMF.
(e) When the resistor is in the circuit, the current and driving EMF are in phase.

22. Suppose you increase the inductance L in an oscillating LC circuit, with the maximum charge Q on the capacitor remaining fixed. Which of the following statements is TRUE?

(a) The current amplitude remains the same, but the maximum magnetic energy stored in the inductor increases.
(b) The current amplitude remains the same, but the maximum magnetic energy stored in the inductor decreases.
(c) The current amplitude increases, but the maximum magnetic energy stored in the inductor decreases.
(d) The current amplitude decreases, but the maximum magnetic energy stored in the inductor increases.
(e) The current amplitude decreases, but the maximum magnetic energy stored in the inductor remains the same. Q is fixed, so the total energy in the circuit remains fixed. Hence, the max magnetic energy stored remains fixed. However, this = (1/2)L(i_{max})^2. Since L increases, i_{max} must decrease. (HW problem).
23. When a series RLC circuit is in a condition of resonance, which of the following statements is **FALSE**?

(a) The inductive reactance equals the capacitative reactance.
(b) The phase constant of the circuit is zero.
(c) The current amplitude is at a maximum.
(d) The total circuit impedance is at a maximum. **At resonance** \( X_L = X_C \), so that \( Z = \sqrt{R^2 + (X_L - X_C)^2} \) is a minimum not maximum.
(e) The angular frequency of the driving EMF \( \omega = (LC)^{-1/2} \).

24. Which of the following statements is **INCORRECT**?

(a) In a region free of current, if the electric flux changes, a magnetic field is produced.
(b) A changing magnetic flux produces an electric field.
(c) An induced electric field created by a changing magnetic flux is always perpendicular to the magnetic field.
(d) The integral of the electric field over any closed surface is always equal to zero. **Gauss Law tells us this equals \( Q/\varepsilon_0 \). So, it's not necessarily zero.**
(e) The integral of the magnetic field over any closed surface is always equal to zero.

25. In a demonstration during the lecture, Professor Chan dropped a magnet through a copper tube held vertically. Why did the magnet fall much more slowly than when dropped outside the tube?

(a) An induced current was set up flowing around the cylindrical circumference of the tube.
(b) An induced current was set up flowing along the length of the tube.
(c) The copper tube was permanently magnetized.
(d) The earth's magnetic field was drawn into the tube and repelled the falling magnet.
(e) Professor Chan never did this demonstration.