SP 212 and SP 212E Final Exam

Name__________________   Alpha  _____________
Instructor_________________  Section # ___________

Tuesday, 11 May 2004
0755 - 1055

INSTRUCTIONS, ETC.

1. Do not open or turn over the exam until told to do so.

2. Please fill in the top of this sheet now.

3. Your instructor is not permitted to answer any questions during the exam or to assist you in interpreting any of the questions on the exam.

4. There is no penalty for guessing.

5. The exam contains a few problems that deal with the same scenario. The answers do not depend upon one another i.e. There is no "double jeopardy."

6. During the exam you may use a calculator, a writing instrument, instructor-supplied scratch paper and one 8.5x11 inch equation sheet.

7. During the exam, you are permitted to write on the exam.

8. While working the exam, please mark your answers on the exam by circling the letter corresponding to the best answer.

9. After finishing the exam or at 1050, whichever is first, please obtain a SCANTRON answer sheet from your instructor. Important instructions for filling out the SCANTRON answer sheet will be found on the exam after the last question. Fill out the answer sheet completely then turn in the exam, the answer sheet, scratch paper and your gouge sheet by 1055. The materials that you turn in represent your work on the exam and all of the materials are subject to evaluation.

Prefixes:  mega (M) = 10^6  kilo (k) = 10^3  centi (c) = 10^{-2}  milli (m) = 10^{-3}
micro (μ) = 10^{-6}  nano (n) = 10^{-9}  pico (p) = 10^{-12}

Constants:  ε₀ = 8.85 × 10^{-12} C^2/ N·m^2  μ₀ = 4π × 10^{-7} T·m/A

  c = 3.0 × 10^8 m/s
1. An electroscope consists of neutral (uncharged) conducting material in contact with two gold leaves at the bottom (which are also conducting). A positively charged conducting rod is brought close to, but is not allowed to touch the electroscope. What type of charge is on each of the gold leaves?

A. One is negative, one is positive.
B. Both are negative.
C. Both are positive.
D. There is no charge on the leaves because the net charge in a conductor is 0.
E. There is no charge on the leaves because there is no contact with the conducting rod.

2. Three point charges are located at the corners of an equilateral triangle. $Q_2$ is at the origin and $Q_3$ is along the $x$-axis. The net force on $Q_1$ due to the other two charges is closest to

A. $(0 \ i -1.2 \ j) \ N$.
B. $(0.6 \ i - 1.0 \ j) \ N$.
C. $(0 \ i -1.4 \ j) \ N$.
D. $(0.6 \ i + 1.0 \ j) \ N$.
E. $(-1.4 \ i + 0 \ j) \ N$.

3. An electron with a velocity of $v = 5.0 \times 10^5 \ i \ m/s$ enters a tunnel that contains a uniform electric field $E = 20.0 \ N/C \ j$. Which curve best describes the path of the electron after it enters the tunnel?
4. A ring of radius $a = 0.35 \text{ m}$ has a charge of $Q = +14.0 \times 10^{-6} \text{ C}$ uniformly distributed on its surface. The center of the ring is at the origin. The electric field at point P on the axis of the ring, a distance $x = 1.50 \text{ m}$ from its center is closest to

A. $8.9 \times 10^4 \textbf{i} \text{ N/C}$
B. $1.1 \times 10^4 \textbf{j} \text{ N/C}$
C. $5.2 \times 10^4 \textbf{i} \text{ N/C}$
D. $2.7 \times 10^4 \textbf{i} \text{ N/C}$
E. $(2.7 \times 10^4 \textbf{i} + 2.7 \times 10^4 \textbf{j}) \text{ N/C}$

5. Two point charges are located on the $x$-axis with the $+2.0 \mu \text{C}$ charge at the origin. The total electric field at point P is closest to

A. $7.5 \times 10^7 \textbf{i} \text{ N/C}$
B. $1.5 \times 10^7 \textbf{j} \text{ N/C}$
C. $-7.5 \times 10^7 \textbf{i} \text{ N/C}$
D. $-1.5 \times 10^7 \textbf{i} \text{ N/C}$
E. $1.5 \times 10^7 \textbf{i} \text{ N/C}$

6. For the dipole shown below, what is the magnitude of the maximum torque on the dipole when it is placed in a uniform electric field of strength $5.4 \times 10^4 \text{ N/C}$?

A. $2.2 \times 10^{-10} \text{ N} \cdot \text{m}$
B. $8.6 \times 10^{-10} \text{ N} \cdot \text{m}$
C. $17.2 \times 10^{-10} \text{ N} \cdot \text{m}$
D. $1.1 \times 10^{-10} \text{ N} \cdot \text{m}$
E. $4.3 \times 10^{-10} \text{ N} \cdot \text{m}$
7. A hollow, spherical conductor, carrying a net charge of \( Q = +4.2 \ \mu\text{C} \), has a +2.0 mC charge in its interior. The shell has an outer radius of \( r_2 = 0.060 \ \text{m} \) and an inner radius of \( r_1 = 0.040 \ \text{m} \). What is the magnitude of the electric field at point P which is a distance of 0.045 m from the center?

A. 8.9 x 10^9 N/C  
B. 0  
C. 1.1 x 10^{10} N/C  
D. 5.0 x 10^9 N/C  
E. 2.0 x 10^3 N/C

8. The dashed circle represents the cross section of a spherical Gaussian surface. There are charges of +7.0 C and -2.0 C inside the Gaussian surface and +4.0 C and -5.0 C outside the surface as shown. The net (total) electric flux through the Gaussian surface is closest to

A. -4.5 x 10^{11} \text{ V} \cdot \text{m}.  
B. 5.6 x 10^{11} \text{ V} \cdot \text{m}.  
C. 4.5 x 10^{11} \text{ V} \cdot \text{m}.  
D. -5.6 x 10^{11} \text{ V} \cdot \text{m}.  
E. 0.

9. Plate 1 is positively charged and plate 2 is negatively charged. An electron is moved from plate 1 to plate 2. As the electron moves from plate 1 to plate 2, the electron

A. gains potential energy and moves to a lower potential.  
B. gains potential energy and moves to a higher potential.  
C. loses potential energy and moves to a lower potential.  
D. loses potential energy and moves to a higher potential.  
E. gains potential energy and the potential does not change.
10. The electric field in some region of space is given by \( \mathbf{E} = (4.0x^2 + 7.0x^3) \mathbf{i} \) N/m. Point A is located at the origin and point B is located at \( x = 2.0 \) m. What is the potential difference between points A and B i.e what is \( V_A - V_B \)?

A. 72 V
B. 100 V
C. 41 V
D. 39 V
E. 55 V

11. Three point charges are located as shown below. Based on the usual reference that the electric potential for a point charge is zero at infinity, the electric potential at the origin is closest to

A. +3.2 V.
B. +43 V.
C. +120 V.
D. +24 V.
E. +30 V.

12. Three point charges are initially infinitely far apart. When the charges are infinitely far apart, their electrostatic potential energy is defined to be zero. The particles are brought together to form the configuration shown in the diagram. The total electrostatic potential energy of the configuration of charges shown is closest to

A. -0.40 J.
B. 0.16 J.
C. 0.32 J.
D. 0.21 J.
E. -0.16 J.
13. An electron is at the center of the dark spot in each of the following diagrams. Based on the usual reference that the electric potential for a point charge is zero at infinity, which of the diagrams best describes the electric field lines and equipotential surfaces caused by the electron?

![Diagram of electric field lines and equipotential surfaces]

14. In the circuit shown, the charge on the 2.0 \( \mu \)F capacitor is closest to

A. 120 \( \mu \)C.
B. 160 \( \mu \)C.
C. 360 \( \mu \)C.
D. 240 \( \mu \)C.
E. 80 \( \mu \)C.

![Circuit diagram]

15. A parallel-plate capacitor is fully charged by a 1.5 V battery. The distance between the plates is 1.0 \( \times \) 10\(^{-3}\) m and a dielectric of dielectric constant \( K = 2.0 \) completely fills the space between the plates. If the capacitor stores 9.7 \( \times \) 10\(^{-4}\) J of energy, the area of the plates is closest to

A. 9.9 \( \times \) 10\(^{5}\) m\(^2\).
B. 3.2 \( \times \) 10\(^{4}\) m\(^2\).
C. 1.9 \( \times \) 10\(^{4}\) m\(^2\).
D. 4.9 \( \times \) 10\(^{4}\) m\(^2\).
E. 5.1 \( \times \) 10\(^{5}\) m\(^2\).
16. A hair dryer has an average power of 1000 W when connected to an ac line where \( V_{\text{rms}} = 120 \text{ V} \). What is the peak value of the current?

A. 5.89 A  
B. 16.7 A  
C. 8.33 A  
D. 11.8 A  
E. 12.2 A  

17. The equivalent resistance between points a and b of the following resistor network is closest to

A. 2.7 \( \Omega \)  
B. 14 \( \Omega \)  
C. 30 \( \Omega \)  
D. 7.7 \( \Omega \)  
E. 10 \( \Omega \)  

18. For the given circuit, the current through the 3.0 \( \Omega \) resistor is closest to

A. 0.67 A  
B. 4.0 A  
C. 2.4 A  
D. 0.80 A  
E. 1.3 A  

A-6
19. For the given circuit and given directions of the currents $I_1$, $I_2$ and $I_3$, the values of $I_1$ and $I_2$ are closest to

A. $I_1 = 0.59 \text{ A}$ and $I_2 = 0.70 \text{ A}$.
B. $I_1 = 0.50 \text{ A}$ and $I_2 = 0.61 \text{ A}$.
C. $I_1 = -0.68 \text{ A}$ and $I_2 = -0.84 \text{ A}$.
D. $I_1 = -0.41 \text{ A}$ and $I_2 = -0.30 \text{ A}$.
E. $I_1 = 0.41 \text{ A}$ and $I_2 = 0.52 \text{ A}$.

Questions 20 and 21 deal with the $RC$ circuit shown below. The capacitor is initially uncharged.

20. At time $t = 0$, the switch is placed in position $a$. The time at which the capacitor reaches 70\% of its maximum charge is closest to

A. 0.023 s.
B. 1.02 s.
C. 0.051 s.
D. 1.07 s.
E. 0.072 s.

21. Once the capacitor is fully charged, the switch is placed in position $b$. At $t = 0.020 \text{ s}$ after the switch is placed in position $b$, the magnitude of the voltage across the RESISTOR is closest to

A. 0.
B. 8.6 V.
C. 6.2 V.
D. 12.0 V.
E. 3.4 V.
22. At some instant a -0.010 C point charge with a velocity of $v = 1.50 \times 10^3 \text{i m/s}$ is at a position where there is a magnetic field $B = 0.125 \text{k T}$ and an electric field $E = 200 \text{i N/C}$. What is the total force on the particle?

A. (-2.0 i + 1.9 j) N
B. (1.9 i + 3.8 j) N
C. (2.0 i - 1.9 j) N
D. (-1.9 i – 3.8 j) N
E. (-2.0 i - 1.9 j) N

23. Consider a region of space where there is an electric field of magnitude 2.5 V/m that is increasing at a rate of 20.0 V/m·s. (For example, this could take place inside a parallel plate capacitor after a battery is connected.) If the radius of the region of space is 0.30 m and the electric field is perpendicular to this region, what is the magnitude of the displacement current in this region?

A. 1.6 x 10^{-11} A
B. 5.0 x 10^{-11} A
C. 1.5 x 10^{-12} A
D. 2.3 x 10^{-12} A
E. 1.6 x 10^{-12} A

24. The following two situations are separate. On the left, a square loop of wire is penetrated by a magnetic field out of the page that is increasing in strength. On the right, the north pole of a magnet is moving away from a coil of wire. The row that correctly gives the direction of the induced current through each resistor is

<table>
<thead>
<tr>
<th>Resistor 1</th>
<th>Resistor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>→</td>
</tr>
<tr>
<td>B</td>
<td>→</td>
</tr>
<tr>
<td>C</td>
<td>←</td>
</tr>
<tr>
<td>D</td>
<td>←</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
</tr>
</tbody>
</table>

The magnet is moving away from the loop.
The next two problems deal with two infinitely long, parallel, current-carrying wires with currents directed out of the page as shown. The wires are perpendicular to the plane of the page and are separated by a distance of 0.80 m.

$$I_1 = 20.0 \, \text{A}$$
$$I_2 = 30.0 \, \text{A}$$

25. The magnetic field at a point midway between the wires is closest to

A. $2.0 \times 10^{-5} \, \text{T}$ to the LEFT.
B. $5.0 \times 10^{-6} \, \text{T}$ UP.
C. $2.0 \times 10^{-5} \, \text{T}$ DOWN.
D. $2.4 \times 10^{-6} \, \text{T}$ to the LEFT.
E. $5.0 \times 10^{-6} \, \text{T}$ DOWN.

26. The force on a 2.5 m length of wire 1 due to wire 2 is closest to

A. $3.8 \times 10^{-4} \, \text{N}$ to the RIGHT.
B. $1.2 \times 10^{-4} \, \text{N}$ to the LEFT.
C. $4.7 \times 10^{-4} \, \text{N}$ to the RIGHT.
D. $1.8 \times 10^{-4} \, \text{N}$ to the LEFT.
E. $7.5 \times 10^{-4} \, \text{N}$ to the RIGHT.

27. A U-shaped conductor of width $l = 0.064 \, \text{m}$ is connected by a conducting bar as shown. A uniform magnetic field of magnitude 0.15 T exists everywhere in the region and is directed out of the page. If the bar is moved to the right at a constant speed of 2.0 m/s, what is the magnitude and direction of the induced current through the bar if the resistance of the circuit is 2.0 $\Omega$?

A. 9.6 mA UP
B. 19.6 mA DOWN
C. 14 mA UP
D. 14 mA DOWN
E. 9.6 mA DOWN
28. A solenoid of length 0.125 m and 255 loops carries a current of 0.55 A. What is the magnitude of the magnetic field inside the solenoid?

A. 1.8 x 10^{-3} T
B. 1.1 x 10^{-3} T
C. 1.6 x 10^{-4} T
D. 1.4 x 10^{-3} T
E. 2.4 x 10^{-4} T

29. The filament of a light bulb is made of a tungsten wire 7.5 x 10^{-3} m in length and 5.0 x 10^{-4} m in radius. When the bulb is not glowing, the filament is at room temperature, 20°C. When glowing, the filament reaches a temperature of 1750°C. Tungsten’s resistivity is \( \rho = 5.6 \times 10^{-8} \text{Ω} \cdot \text{m} \) and its temperature coefficient is \( \alpha = 0.0045 \text{ (°C)}^{-1} \) at 20.0°C. What is the resistance of the filament when glowing? (Assume that the wire has a circular cross section and that the dimensions of the wire do not change with temperature.)

A. 4.7 x 10^{-3} Ω
B. 3.8 x 10^{-3} Ω
C. 2.4 x 10^{-3} Ω
D. 7.0 x 10^{-3} Ω
E. 5.2 x 10^{-3} Ω

30. Which of the following statements is NOT true about a step-up transformer?

A. The input voltage must be less than the output voltage.
B. The output power must be no greater than the input power.
C. The input current cannot be direct current (dc).
D. The output current must be less than the input current.
E. The number of turns in the primary must be greater than the number of turns in the secondary.
31. A generator consists of a circular coil of wire rotating in a uniform magnetic field of strength 1.4 T. The coil has a radius of 0.25 m and there are 95 turns of wire. Determine how fast the coil must rotate in order to produce a 110 V peak emf.

A. 0.97 Hz
B. 1.2 Hz
C. 0.67 Hz
D. 6.9 Hz
E. 3.4 Hz

32. The segment of wire shown carries a current of 1.5 A. The curved portion is a section of a circle with the center at point C. If \( r = 0.055 \) m, the magnitude of the magnetic field at point C due to the curved portion of the segment of wire is closest to

A. 8.6 \( \mu \)T.
B. 2.2 \( \mu \)T.
C. 4.3 \( \mu \)T.
D. 17 \( \mu \)T.
E. 6.1 \( \mu \)T.

33. The mutual inductance between a long insulated coil wrapped around a solenoid is 4.0 \( \times 10^{-4} \) H. If the current in the solenoid drops at a constant rate from 15.0 A to zero in 0.076 s, the magnitude of the emf induced in the coil is closest to

A. 4.6 \( \times 10^{-4} \) V.
B. 7.9 \( \times 10^{-2} \) V.
C. 2.0 \( \times 10^{-6} \) V.
D. 46 V.
E. 2.0 V.
34. For the given $LR$ circuit, the current reaches 35% of its maximum value $4.8 \times 10^{-3}$ s after closing the switch. The time constant of the $LR$ circuit is closest to

A. 0.73 s.
B. 1.4 s.
C. 0.092 s.
D. 0.046 s.
E. 0.011 s.

35. The given $LC$ circuit is observed to oscillate with a frequency of 1500 kHz. When the current is 0.24 A, the energy stored in the inductor is closest to

A. $3.4 \times 10^{-7}$ J.
B. $2.1 \times 10^{-6}$ J.
C. $1.6 \times 10^{-7}$ J.
D. $5.6 \times 10^{-6}$ J.
E. $4.2 \times 10^{-7}$ J.

36. For an electromagnetic wave in a vacuum, the electric field is given by

$$E_y = 30.0 \sin(5.33 \times 10^6 x - 1.60 \times 10^{15} t)$$

where 30.0 has units of V/m, $x$ has units of m and $t$ has units of s. The wavelength and intensity of the wave, respectively, are closest to

A. $1.2 \times 10^{-6}$ m and 1.2 W/m².
B. $2.5 \times 10^{-6}$ m and 2.4 W/m².
C. $1.2 \times 10^{-6}$ m and 2.4 W/m².
D. $2.5 \times 10^{-6}$ m and 1.2 W/m².
E. $2.5 \times 10^{-6}$ m and 2.4 W/m².
37. A hunter (A) plans to spear a fish in water for dinner, while a diver (B) intends to spear a hovering seagull. From the point of view of each human predator, which statement properly describes the best strategy for a successful hunt?

A. A should aim below the fish image; B should aim above the gull image.
B. A should aim above the fish image; B should aim below the gull image.
C. Both should aim above the image of their quarry.
D. Both should aim below the image of their quarry.
E. They should each shoot directly at the image of their quarry.

38. An upwardly directed laser beam focused to a small spot of area = 1.00 × 10^{-3} \, \text{m}^2 supports a small bead of glass in a vacuum chamber. If all of the light is absorbed by the bead and the bead’s weight is 1.08 \times 10^{-9} \, \text{N}, the intensity of the laser beam is closest to

A. 160 \, \text{W/m}^2.
B. 324 \, \text{W/m}^2.
C. 640 \, \text{W/m}^2.
D. 240 \, \text{W/m}^2.
E. 80 \, \text{W/m}^2.
39. A two-lens system is constructed as shown with an object placed on the axis 75.0 cm to the left of a positive 30.0 cm focal-length lens. If lens 2 has a focal length of -40.0 cm and is 120 cm to the right of lens 1, the final image is located

A. 25.5 cm to the right of lens 2.

B. 22.2 cm to the right of lens 2.

C. 25.5 cm to the left of lens 2.

D. 22.2 cm to the left of lens 2.

E. at infinity.

40. A +4.00 cm focal-length lens is made from flint glass with index of refraction 1.57 for use in a camera. If the front face of the lens is flat, the magnitude of the radius of curvature of rear face and the shape of the lens, respectively, are best represented by

A. 6.28 cm and 

B. 2.28 cm and 

C. 4.56 cm and 

D. 2.28 cm and 

E. 6.28 cm and 

41. A laser beam with a wavelength and frequency in air of 540 nm and $5.6 \times 10^{14}$ Hz enters a fluid with refractive index 1.3 at an angle of 40º with respect to the normal to the surface. The frequency and wavelength of the light in the fluid are closest to

A. $5.6 \times 10^{14}$ Hz and 415 nm.

B. $5.6 \times 10^{14}$ Hz and 700 nm.

C. $7.3 \times 10^{14}$ Hz and 540 nm.

D. $4.3 \times 10^{14}$ Hz and 540 nm.

E. $5.6 \times 10^{14}$ Hz and 347 nm.
The next two problems deal with an unpolarized laser beam \( (\lambda_{\text{air}} = 515 \text{ nm}) \) that strikes a water/diamond interface as shown in the diagram and produces a reflected beam that can be completely blocked by rotating a linear polarizer (LP). The refractive indices of water and diamond are 1.33 and 2.42, respectively.

42. Using the axes shown, the function that best represents the electric field of the reflected light is

A. \( E(x,t) = E_o \cos(kx - \omega t) \) i.
B. \( E(x,t) = E_o \cos(kx - \omega t) \) j.
C. \( E(x,t) = E_o \cos(kx - \omega t) \) k.
D. \( E(x,t) = E_o \sin(kx + \omega t) \) j.
E. \( E(x,t) = E_o \sin(kx + \omega t) \) k.

43. The angle of incidence (relative to the normal to the surface) for which the light reflected from the water-diamond surface is completely polarized is closest to

A. 57.6°.
B. 59.5°.
C. 61.2°.
D. 66.3°.
E. 64.1°.

44. A laser beam of wavelength 514 nm is incident on a diffraction grating with 400 lines per millimeter. The laser beam is normally incident on the grating and the zero order bright spot is normally incident on the screen. If a screen is placed 2.0 meters from the grating, the distance on the screen between the zero and third order bright spots is closest to

A. 0.72 m.
B. 1.6 m.
C. 1.0 m.
D. 0.41 m.
E. 0.23 m.
45. An astronomer wants to use an optical telescope to study a binary star system. The stars are $5.0 \times 10^{11}$ m apart and both stars are $2.0 \times 10^{17}$ m from the earth. Assuming that the average wavelength of visible light is 550 nm, the diameter of the circular aperture of the telescope used to resolve these two stars must be at least

A. 9.0 cm.
B. 18 cm.
C. 27 cm.
D. 36 cm.
E. 45 cm.

46. Which coating thickness will produce an antireflection coating on a glass lens if the glass has a refractive index of 1.50, the coating has a refractive index 1.65, and the wavelength in air of the normally incident light is 610.0 nm?

A. 305 nm
B. 203 nm
C. 92.0 nm
D. 185 nm
E. 277 nm

47. A laser in a tank of clear oil with refractive index 1.27 emits an unpolarized beam that strikes a mirrored sidewall of the tank at an incident angle of 35º with respect to the normal. This beam reflects to point B on the oil/air interface. The tank is sitting on a level surface and has vertical sides. Which statement best describes what happens to the light at point B?

A. The light is reflected and refracted with the refracted light bending away from the normal.
B. The light is reflected and refracted with the refracted light bending toward the normal.
C. The reflected light is completely polarized with $\mathbf{E}$ perpendicular to the page.
D. The reflected light is completely polarized with $\mathbf{E}$ in the plane of the page.
E. All of the light is reflected.
48. Bart stops in front of a large spherical Christmas ornament with a radius of 12.0 cm to admire the reflected image of his front tooth. If his tooth has a height of +1.0 cm and is 20.0 cm from the surface of the ornament, the image of his tooth can best be described as

A. real and inverted with a height of –0.43 cm.
B. virtual and upright with a height of +0.43 cm.
C. virtual and inverted with a height of –0.23 cm.
D. virtual and upright with a height of +0.23 cm.
E. real and upright with a height of +1.2 cm.

49. A dentist needs a small mirror that will produce an upright image 4.0 times as large as a tooth when the mirror is 3.0 cm from the tooth. Which of the following mirrors would be best for this application?

A. Concave with focal length magnitude 4.0 cm
B. Convex with focal length magnitude 4.0 cm
C. Concave with focal length magnitude 8.0 cm
D. Convex with focal length magnitude 1.3 cm
E. Convex with focal length magnitude 8.0 cm

50. Two different wavelengths of light are used to illuminate a pair of slits that are separated by 0.150 mm. The fourth and fifth order bright lines (fringes) in the interference pattern are observed to overlap on a distant screen. Which pair of wavelengths is most likely produced by the source?

A. 488 nm and 610 nm
B. 633 nm and 488 nm
C. 752 nm and 633 nm
D. 488 nm and 515 nm
E. 457 nm and 686 nm

Instructions for filling out the SCANTRON answer sheet

1. Please fill out the form completely, but only write or mark in the spaces provided.

2. Please fill in the bubbles completely as shown in the example on the form. If you make a mistake, either erase completely or obtain a new form.