Physics 227 - Final Exam

16 December 2003

Profs. Shapiro and Conway

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Your name sticker with **exam code**

Turn off and put away cell phones now!

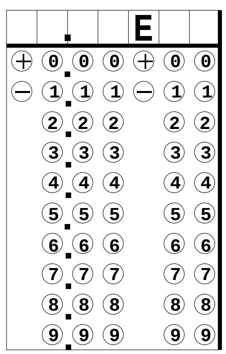
1. **THIS EXAM INCLUDES QUESTIONS WHICH REQUIRE A NUMERICAL ANSWER.**

The format on the machine-graded answer sheets requires that you express your answer is a very specific format. Several examples are shown below:

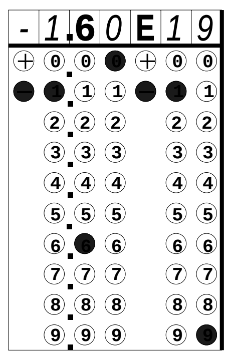
5.30 should be entered as **+5.30+00**

437 should be entered as **+4.37+02**

0.62458 should be entered as **+6.25−01**



Form for numerical answers.



The electron's charge entered.

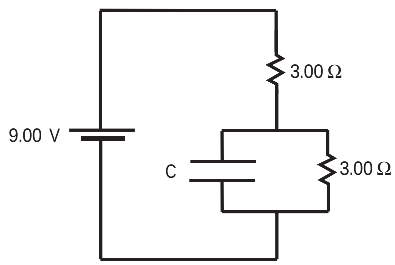
$-1.602176 \times 10^{-19}$ should be entered as **−1.60−19**. Note that all answers should be accurate to three **significant** digits. A sample fragment of the mark-sense form is shown.

NOTE THAT MULTIPLE CHOICE QUESTIONS START WITH THE NINTH QUESTION, BUT ITS NUMBER IS 16; ENTER THE ANSWERS ON THE MARK SENSE FORM ACCORDING TO THEIR PROBLEM NUMBERS, WHICH INCREASE HORIZONTALLY ACROSS THE FORM.

2. 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.
3. 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.
4. Under STUDENT # enter your 9-digit student ID.
5. Enter 227 under COURSE, and your section number (see label above) under SEC.
6. Under CODE enter the exam code given above.
7. During the exam, you may use pencils, a calculator, and one **handwritten** 8.5 x 11 inch sheet with formulas and notes, without attachments.
8. There are 32 questions on the exam. Several questions require you to enter a numerical answers as described above. **Be sure to fill in the circles as well as writing your answer in the boxes.** The remainder are multiple-choice. 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.
9. When you are asked to open the exam, make sure that your copy contains all 32 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.
10. Please SIGN the cover sheet under your name sticker and have your student ID ready to show to the proctor during the exam.

electromagnetic permittivity ϵ_0	8.854×10^{-12} C^2/N-m^2
electromagnetic constant $k_e \equiv \frac{1}{4\pi\epsilon_0}$	8.9875×10^9 N-m^2/C^2
magnitude of electron charge	1.602×10^{-19} C
electron mass	9.11×10^{-31} kg
proton mass	1.67×10^{-27} kg
magnetic permeability μ_0	$4\pi\times10^{-7}$ T-m/A
speed of light in vacuum	2.998×10^8 m/s

1. Calculate the charge on the capacitor, in coulombs, assuming C=9.00 μF.



2. A flat current loop has 20 turns, area 0.100 m^2, and the normal to the plane of the loop is oriented at 45° to ia uniform magnetic field of strength 1.20 T. If the loop carries 2 A current, find the torque on the loop (in N-m).

3. A toroidal magnet has 1000 turns, and carries a current of 1400 A. Calculate the magnitude of the magnetic field (in T) in the interior of the toroid, at a radius of 0.800 m from the axis of the toroid.

4. An electron moves with velocity $\vec{v}$=(48,000 m/s)$\hat{\imath}$ in a region where the electric field is (10 kV/m)$\hat{\jmath}$ and the magnetic field is (0.4 T)$\hat{k}$. Calculate the net force (in N) on the electron.

5. The maximum stored energy in the inductor in a series LC circuit is 0.25 J. If the capacitance is 42.0 μF, and the inductor is 2.6 mH, calculate the maximum charge on the capacitor (in C).

6. A series RLC circuit has a 2.30 Ω resistor, a 40.0 mH inductor and a 200 μF capacitor. It is driven by a 120 V (rms) 60 Hz voltage source. Calculate the average power dissipated by the resistor, in W.

7. A large solenoid is 5 m long and 3 m in diameter, and has a magnetic field of 2.20 T. Assuming the field is uniform, calculate the total energy of the magnetic field in the interior of the solenoid, in J.

8. A bright light sends out 50.0 kW of radiation equally in all directions. Calculate the amplitude of the electric field in the wave at a distance of 300 m from the antenna, in V/m.

16. A glass rod is placed on the x-axis extending from $x = 0.2$m to $x = 0.5$m. It has a charge distributed on it, **not uniformly**, so that the charge per unit length is x^{-2} μCm. The electric field at $x = 0$

a) points to the right with magnitude 2.25×10^5 N/C
b) points to the left with magnitude 9.45×10^4 N/C
c) points to the right with magnitude 2.70×10^4 N/C
d) points to the left with magnitude 3.51×10^5 N/C
e) points to the left with magnitude 1.69×10^6 N/C

17. A hollow metal sphere of inner radius $r_{in} = 1$ cm and outer radius $r_{out} = 2$ cm has a net charge of $+5$ μC. Furthermore, a –3 μC point charge is located at the center of the sphere. The charge on the outer surface of the sphere is:

a) +8-μC b) 0-μC c) –5-μC
d) +2-μC e) –3-μC

18. A charge of +Q and another of −Q are separated by a distance d and fixed in position. The work that must be done on an electron (charge = –e) to bring it from an infinite distance away to the point midway between these charges is $1/4\pi\epsilon_0$ times

a) –2eQ/d
b) Zero
c) –4eQ/d
d) +2eQ/d
e) +4eQ/d

19. A parallel plate capacitor is connected and remains connected to a battery. The space between the capacitor plates, which was initially empty (κ=1) is then filled with oil ($\kappa > 1$). Which is the correct statement?

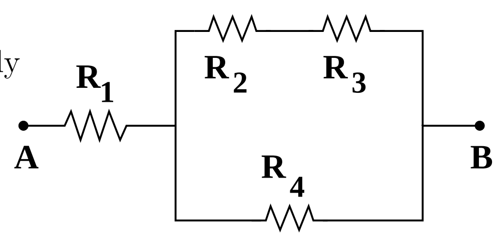
a) the charge on the plates remains the same
b) the potential difference across the plates increases
c) the potential difference across the plates decreases
d) the charge on the plates decreases
e) the charge on the plates increases

20. The current in a resistor decreases by 5A when the voltage across the resistor decreases from 10V to 7V. Find the resistance of the resistor.

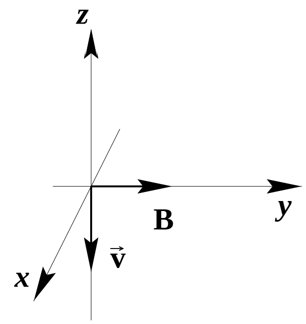
a) 0.6 Ω
b) $\frac{50}{7}$ Ω
c) 2.0 Ω
d) $\frac{7}{50}$ Ω
e) 1.4 Ω

21. All of the resistors in the figure are 100 Ω, and can withstand 25 W power dissipation. If the voltage V_{ab} between points a and b is increased, which resistor will burn out first?

a) R_1 and R_4, simultaneously
b) R_4
c) R_1
d) R_2 and R_3, simultaneously
e) R_2, R_3, and R_4, simultaneously



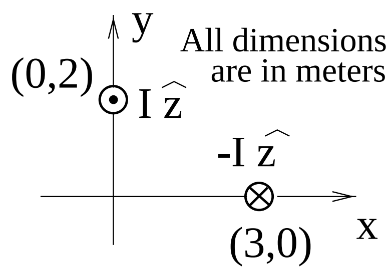
22. Consider an electron in a uniform magnetic field of magnitude 2.0 T in the $+y$ direction. When the velocity of the electron is 5.0×10^6 m/s in the $-z$ direction, the magnitude of the magnetic force on the electron is



a) 1.6×10^{-12} N
b) 0.8×10^{-12} N
c) 6.4×10^{-12} N
d) 3.2×10^{-12} N
e) none of the others

23. What is the field at the origin due to the two infinitely long wires shown. Each carries a current I in the direction indicated.

a) $\vec{B} = \frac{\mu_0}{2\pi} I[-\frac{1}{2}\hat{x} - \frac{1}{3}\hat{y}]$
b) $\vec{B} = \frac{\mu_0}{2\pi} I[-2\hat{x} - 3\hat{y}]$
c) $\vec{B} = \frac{\mu_0}{2\pi} I[\frac{1}{2}\hat{x} + \frac{1}{3}\hat{y}]$
d) $\vec{B} = \frac{\mu_0}{2\pi} I[2\hat{x} + 3\hat{y}]$
e) $\vec{B} = \frac{\mu_0}{2\pi} I[\frac{1}{2}\hat{x} - \frac{1}{3}\hat{y}]$



24. Wire of diameter 1 mm is wound around a plastic cylinder of diameter 1 cm and length 50 cm, uniformly in three layers, so that there are a total of 1500 turns, all continuous and in the same direction. The wire carries a current of 0.02 A. The magnetic field at the central point of the cylinder is

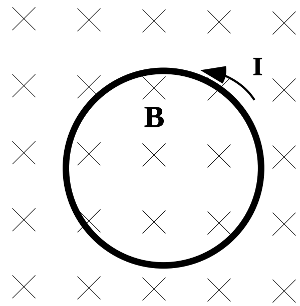
a) 38 μT
b) 75 μT
c) 1.2 mT
d) 0.92 mT
e) 2.5 μT

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

26. Wire in a circular loop of radius r lies in a plane perpendicular to a spatially uniform magnetic field directed into the page. Current is flowing in the loop as shown. We know that:

a) The magnitude of B is increasing with time.
b) The loop is moving with velocity $\frac{B}{2r}$ to the left.
c) The loop is moving with velocity $\frac{B}{2r}$ upwards.
d) The magnitude of B is constant in time.
e) The magnitude of B is decreasing with time.

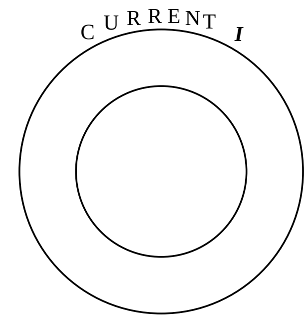


27. An electric generator consists of a loop of wire with area $0.1 \mathrm{m}^2$. It has 1000 turns and rotates at 60 rev/sec. The axis of rotation is perpendicular to a uniform magnetic field of 0.2 T. What is the maximum EMF produced in the loop?

a) (6.3×10^{-2}) V
b) (1×10^{3}) V
c) (7.5×10^{3}) V
d) 25 V
e) 333 V

28. Two concentric, circular loops of wire lie in the plane of the paper. The outer loop carries a current I. Pick the correct answer.

a. If I is clockwise and increasing, the induced current in the inner loop will be clockwise.
b. If I is clockwise and constant, the induced current in the inner loop will be counterclockwise.
c. If I is counterclockwise and decreasing, the induced current in the inner loop will be counterclockwise.



d. If I is clockwise and decreasing, the induced current in the inner loop will be zero.
e. If I is counterclockwise and constant, the induced current in the inner loop will be counterclockwise.

29. The current in a 90 mH inductor is given by $I = (t^2 - 6t)$ (with I in Amps and t in seconds). The emf produced by the inductor is zero when $t =$

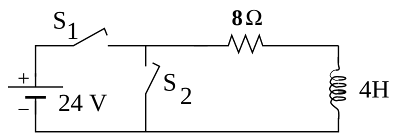
a) $-6s$ b) 6 s c) 3 s d) 2 s
e) 0 s

30. In an LC circuit the maximum current which flows is I_m and the maximum voltage drop across the capacitor is V_0. At the instant the voltage drop across the capacitor is $V_0/2$, what is the current flowing in the circuit?

a) $\frac{3}{8}I_m$ b) $\frac{1}{2}I_m$ c) $\frac{1}{4}I_m$ d) $\frac{\sqrt{3}}{2}I_m$
e) $\frac{3}{4}I_m$

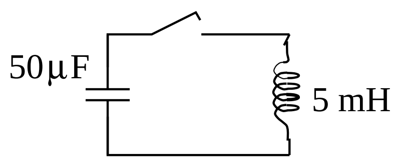
31. The circuit shown is in a state where switch S_1 is closed and S_2 is open for an effectively infinite length of time. How much energy is stored by the inductor in this steady state?

a) 24 J
b) 3 J
c) 6 J
d) 18 J
e) 36 J



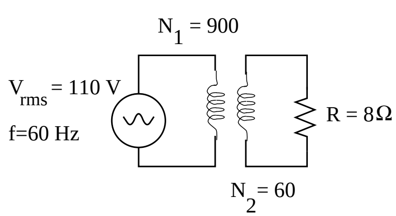
32. A 5 mH inductor an a 50 μF capacitor are connected as shown. Initially, the capacitor is charged to 50 V and the switch is open. What is the minimum time after the switch is closed that all of the energy in the circuit once again be stored in the capacitor? (Hint: This will occur when $|V_c|$ returns to its original value.)

a) (3.1×10^{-4}) s
b) (5.0×10^{-4}) s
c) (1.6×10^{-4}) s
d) (3.1×10^{-3}) s
e) (1.57×10^{-3}) s



33. A resistor of 8 Ω is connected to the 60 turn secondary winding of an ideal transformer. The primary has 900 turns and is connected to an AC EMF of 110 V (rms) and 60 Hz. What is the rms current in the resistor?

a) 13.75 A (rms)
b) 15 A (rms)
c) 206 A (rms)
d) 917 mA (rms)
e) 648 mA (rms)



34. A 0.2μF capacitor is connected across a 110 V (rms) 60-Hz voltage source. What is the rms current flowing through the capacitor?

a) 58.4 mA
b) 11.7 mA
c) 1.46 mA
d) 1.32 mA
e) 8.29 mA

35. A series RLC circuit has elements R=30 Ω, 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 resonant frequency. The maximum voltage across the capacitor is

a) 282 V
b) 100 V
c) 406 V
d) 200 V
e) 141 V

36. In an electromagnetic wave, at a given point in space,

a) the electric and magnetic fields are proportional to each other in magnitude, but are perpendicular to each other.
b) the electric field is constant while the magnetic field oscillates at the frequency of the wave.
c) the electric and magnetic fields oscillate in phase, with the electric field pointing in the direction of the propagation of the wave.
d) the electric field lags behind the magnetic field by 90°because it is the changing magnetic flux which produces the electric field.
e) the electric and magnetic fields oscillate out of phase so that the energy density at that point alternates between electric and magnetic, with the total constant.

37. What is the average energy per unit volume in a 5.0×10^{-3} W laser beam whose cross sectional area is $6 \times 10^{-4} \mathrm{m}^2$?

a) 2.5×10^9 J/m^3
b) 8.3 J/m^3
c) 900 J/m^3
d) 2.8×10^{-8} J/m^3
e) 5.6×10^{-8} J/m^3

38. Two astronauts, Neil and Sally, try the following experiment. A piece of paper that is perfectly reflecting on one side and perfectly absorbing on the other is at rest in a vacuum. Simultaneously, Neil shines a 20 W laser normal to the center of the reflecting side and Sally shines a different power laser normal to the center of the absorbing side. They observe the paper remains at rest and conclude that the power of Sally's laser is:

a) 10 W b) 40 W c) 80 W d) 5 W
e) 20 W

39. A circular mirror of diameter 3 cm is 0.5 m away from a 100 W laser with a 3 mm diameter beam that is normally incident upon it. What is the total force on the mirror due to the laser light?

a) 6.7×10^{-7} N
b) 6.0×10^{-10} N
c) 6.7×10^{-5} N
d) 3.3×10^{-7} N
e) 3.3×10^{-5} N