Turn off your cell phone and put it out of sight.  
Keep your calculator on your own desk.  Calculators cannot 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 pen.  Darken each circle completely, but stay within the boundary.  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.  Be especially careful that your mark covers the center of its circle.

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

3. Print your NETWORK ID in the designated spaces at the right side of the answer sheet, starting in the left most column, then mark the corresponding circle below each character.  If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero.  If and only if there is a hyphen ".-" in your NetID, mark the hyphen circle at the bottom of the column.  When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

4. 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.

5. Print your UIN# in the STUDENT NUMBER designated spaces and mark the corresponding circles.  You need not write in or mark the circles in the SECTION box.

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 10 numbered pages plus three (3) Formula Sheets following these instructions.

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 dismissal from the University.

1 of 2 pages  
(26 problems)
This Exam Booklet is Version A. Mark the A circle in the TEST FORM box near the middle of your answer sheet. DO THIS NOW!

Exam Grading Policy—

The exam is worth a total of 128 points, composed of three 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.

MC2: multiple-choice-two-answer questions, each worth 2 points.
No partial credit.

(a) If you mark only one answer and it is the correct answer, you earn 2 points.
(b) If you mark the wrong answer or neither answer, you earn 0 points.

Some helpful information:
- A reminder about prefixes: p (pico) = 10^{-12}; n (nano) = 10^{-9}; µ (micro) = 10^{-6}; m (milli) = 10^{-3}; k (kilo) = 10^{-3}; M or Meg (mega) = 10^6; G or Gig (giga) = 10^9.
1) A parallel plate capacitor is connected to a 9 V battery, as shown below. At some time, the parallel plates are moved a small distance closer together.

What happens to the charge $Q \geq 0$ stored on the top capacitor plate? Note that the capacitor remains connected to the battery throughout.

a. $Q$ increases  
 b. $Q$ remains the same  
 c. $Q$ decreases 

2) The capacitor below is made of two parallel plates of area $A = 20 \text{ cm}^2$ separated by a distance $d = 3 \text{ mm}$. As shown below, two slabs of dielectric with dielectric constants $\kappa_1 = 2$ and $\kappa_2 = 4.5$ are placed between the two plates and take up exactly half the volume between the plates.

Calculate the capacitance $C$ of this capacitor.

a. $C = 50 \text{ pF}$  
 b. $C = 19 \text{ pF}$  
 c. $C = 67 \text{ pF}$  
 d. $C = 81 \text{ pF}$  
 e. $C = 11 \text{ pF}$
The next two questions pertain to the situation described below.

Consider the following network of resistors. All of the resistors have the same resistance $R$. The network is connected to a battery with emf $\varepsilon$, through which a current $I_b$ passes.

3) Calculate the equivalent resistance $R_{eq}$ of the network.
   
   a. $R_{eq} = R/3$
   b. $R_{eq} = R/2$
   c. $R_{eq} = 4R/3$
   d. $R_{eq} = R$
   e. $R_{eq} = 3R/8$

4) Calculate the current $I_4$ through resistor $R_4$ in terms of the battery current $I_b$.
   
   a. $I_4 = I_b / 3$
   b. $I_4 = 3I_b / 8$
   c. $I_4 = 4I_b / 3$
   d. $I_4 = I_b / 2$
   e. $I_4 = I_b$
The next three questions pertain to the situation described below.

The following circuit contains three capacitors $C_1 = 19 \mu F$, $C_2 = 1 \mu F$, and $C_3 = 7 \mu F$ connected to a battery with an unknown emf $\varepsilon$. The charge on capacitor $C_1$ is $Q_1 = 8 \mu C$.

5) How much energy is stored on capacitor $C_1$?

a. $E = 1.7 \times 10^6 J$

b. $E = 5.9 \times 10^6 J$

c. $E = 2.9 \times 10^6 J$

d. $E = 4.7 \times 10^7 J$

e. $E = 9.4 \times 10^7 J$

6) What is the charge $Q_2$ on capacitor $C_2$?

a. $Q_2 = 2.6 \mu C$

b. $Q_2 = 0.56 \mu C$

c. $Q_2 = 1 \mu C$

d. $Q_2 = 3.5 \mu C$

e. $Q_2 = 1.7 \mu C$

7) What is the equivalent capacitance $C_{eq}$ of the circuit?

a. $C_{eq} = 5.6 \mu F$

b. $C_{eq} = 9.6 \mu F$

c. $C_{eq} = 3 \mu F$

d. $C_{eq} = 15 \mu F$

e. $C_{eq} = 20 \mu F$
The next two questions pertain to the situation described below.

Consider the three resistors below made of identical material but of different dimensions.

8) If the same current $I$ passes through each resistor, which resistor dissipates the most power?

   a. $R_1$
   b. $R_2$
   c. $R_3$

9) If the same voltage $V$ is applied across each resistor, which resistor dissipates the most power?

   a. $R_1$
   b. $R_2$
   c. $R_3
10) In the following RC circuit with a switch S, two resistors $R_1$ and $R_2$ have the same resistance $R = 20 \, \Omega$, $C$ denotes a capacitor of capacitance $15 \, \mu F$, and $E$ denotes a 12 V battery.

Initially, switch S is open for a long time. After $t = 0$ switch S is closed. Choose the best figure from below describing the time-dependence of the current $I$ through $R_2$. Do not forget that the battery $E$ is still connected.

a. 3
b. 2
c. 1
The next two questions pertain to the situation described below.

In the following RC circuit with a switch S, two resistors $R_1$ and $R_2$ have the same resistance $R = 29 \, \Omega$, $C$ denotes a capacitor of capacitance $7 \, \mu F$, and $E$ denotes a $12 \, V$ battery.

11) Switch S has been closed for a long time. What is the current $I$ through $R_1$ immediately after S is opened? Pay attention to the direction of the current arrow in the figure.

   a. $I = +0.41 \, A$
   b. $I = -0.21 \, A$
   c. $I = +0.21 \, A$
   d. $I = 0 \, A$
   e. $I = -0.41 \, A$

12) What is the voltage $V_2$ across resistor $R_2$ at a time of 0.5 ms after switch S is opened?

   a. $V_2 = 3.2 \, V$
   b. $V_2 = 0.51 \, V$
   c. $V_2 = 1.8 \, V$
The next two questions pertain to the situation described below.

In the following figure, $E_1 = 12 \, V$, $E_2 = 4 \, V$, $R_1 = 7 \, \Omega$, $R_2 = 12 \, \Omega$, and $R_3 = 4 \, \Omega$. Initially, the switch S is open.

13) At junction P three currents $I_1$, $I_2$, and $I_3$ meet. Choose the correct relation among them from below.

a. $I_1 + I_2 + I_3 = 0$

b. $I_1 - I_2 - I_3 = 0$

c. $-I_1 + I_2 - I_3 = 0$

d. $I_1 - I_2 + I_3 = 0$

e. $I_1 + I_2 - I_3 = 0$

14) When the switch S is closed, what is the current $I_3$?

a. $I_3 = 0 \, A$

b. $I_3 = -0.57 \, A$

c. $I_3 = -0.75 \, A$

d. $I_3 = -0.33 \, A$

e. $I_3 = -0.7 \, A$
The next three questions pertain to the situation described below.

In the following figure, \( E_1 = 12 \, V \), \( E_3 = 7 \, V \), \( R_1 = R_2 = R_3 = R_4 = 3 \, \Omega \). \( E_2 \) is not known.

15) Choose the correct formula exhibiting Kirchhoff’s loop law from the following formulas.

a. \( I_2 R_2 + I_4 R_4 - I_3 R_3 - E_2 = 0 \)
b. \( I_2 R_2 - I_4 R_4 - I_3 R_3 + E_2 = 0 \)
c. \( I_2 R_2 + I_4 R_4 - I_3 R_3 + E_2 = 0 \)
d. \( I_2 R_2 + I_4 R_4 + I_3 R_3 - E_2 = 0 \)
e. \( I_2 R_2 + I_4 R_4 + I_3 R_3 + E_2 = 0 \)

16) What is the current \( I_4 \)? Pay attention to the direction of the current arrow in the figure.

a. \( I_4 = 0 \, A \)
b. \( I_4 = +1.2 \, A \)
c. \( I_4 = -2.3 \, A \)
d. \( I_4 = +2.3 \, A \)
e. \( I_4 = -1.2 \, A \)

17) The current \( I_2 \) is measured to be \(-1.5 \, A\). What is the current \( I_1 \)? Again, pay attention to the direction of the current arrow in the figure.

a. \( I_1 = +2.5 \, A \)
b. \( I_1 = -2.5 \, A \)
c. \( I_1 = -5.5 \, A \)
d. \( I_1 = +5.5 \, A \)
e. \( I_1 = 0 \, A \)
The next two questions pertain to the situation described below.

A current carrying loop of radius $r = 14 \text{ cm}$ is oriented horizontally, with its area parallel to the x-z-plane in the figure below, and a uniform magnetic field is applied that has no z-component. The x-component of the B field is $3 \text{ T}$ and its y-component is $4 \text{ T}$. The current $I = 7 \text{ A}$ is flowing into the (−z) direction at the rightmost point of the loop, as denoted in the figure that shows a side view of the loop. (The (−z)-direction points into the page).

18) What is the **magnitude** of the torque on the current loop?

a. $\tau = 1.7 \text{ N\cdot m}$
b. $\tau = 2500 \text{ N\cdot m}$
c. $\tau = 2.2 \text{ N\cdot m}$
d. $\tau = 1.3 \text{ N\cdot m}$
e. $\tau = 1800 \text{ N\cdot m}$

19) In which direction will the loop **start to turn** if left free?

a. Clockwise about an axis parallel to the z-axis
b. Counter-clockwise about an axis parallel to the z-axis
c. Around an axis that is **not** parallel to the z axis.
20) Four long straight wires carrying currents of equal magnitude \( I_1 = I_2 = I_3 = I_4 = I \) are parallel or antiparallel to each other such that their cross sections form the corners of a square, as shown in the figures. The figures indicate the directions of the current in each wire. In which case is the magnitude of the total magnetic field at the center of the square (O) the largest?
21) A charged particle travels counterclockwise with speed $v$ on a circle in the plane of the page, while a uniform magnetic field $B$ is applied in a perpendicular direction, pointing into the page (as shown below). The period $T$ is the amount of time the particle takes to travel around one complete circle. How would the period change if the speed of the particle was doubled?

- $T$ would increase by a factor of 4.
- $T$ would remain unchanged.
- $T$ would increase by a factor of 2.
- $T$ would decrease by a factor of 2.
- $T$ would decrease by a factor of 4.

22) Three long, parallel straight wires A, B and C carry a constant current of $I = 3 \, A$ each. The direction of the current of each wire is as indicated in the figure below. The length of the wires is $L = 1 \, m$ and the diameter is $D = 8 \, mm$. Wires A and B are stuck to each other but electrically insulated from each other. We call the combination of wires A and B a “double wire AB”. The distance from the center of C to the center of A is $r = 2 \, cm$.

What is the net force on the double wire AB due to wire C?

- $F = 1.5 \times 10^{-4} \, N$
- $F = 0 \, N$
- $F = 2.6 \times 10^{-5} \, N$
23) A particle of charge $-|q|$ moves in the positive x-direction with speed $v$. There is a uniform electric field $E$ of magnitude $|E|$ pointing in the positive y-direction and a uniform magnetic field $B$ pointing in the negative z-direction. What must be the magnitude of the magnetic field, $|B|$, such that the particle does not accelerate? (Hint: Pay careful attention to the given direction of $E$ and $B$).

![Diagram showing particle, electric field E in the y-direction, and magnetic field B in the negative z-direction.]

- a. $|B| = |E|
- b. The charge will accelerate for any magnetic field $B$ pointing in the negative z-direction.
- c. $|B| = |E|/v$

24) A negatively charged particle enters a uniform magnetic field from the south and is pushed to the east. In which direction does the magnetic field point?

![Diagram showing magnetic field lines pointing into the page to push the negatively charged particle to the east.]

- a. The magnetic field points into the page.
- b. The magnetic field points out of the page.
The next two questions pertain to the situation described below.

A negatively charged particle with charge $q = -3e$ enters a uniform magnetic field $B = 0.3 \, T$ pointing out of the page with a speed of $v = 10^6 \, m/s$ and sweeps out a half circle of radius $r = 5.9 \, cm$ before leaving the field.

25) What is the particle’s mass?

a. More information is required to determine the mass of the particle.

b. $m = 2.8 \times 10^{-20} \, kg$

c. $m = 8.5 \times 10^{-27} \, kg$

d. $m = 8.5 \times 10^{-21} \, kg$

e. $m = 2.8 \times 10^{-26} \, kg$

26) What is the speed $v$ of the particle upon exiting the region with the $B$ field?

a. $v = 10^5 \, m/s$

b. $v = 10^7 \, m/s$

c. $v = 10^4 \, m/s$

d. $v = 0 \, m/s$

e. $v = 10^6 \, m/s$
Physic 102 formula sheet (SP2015)

**Kinematics and mechanics**

\[ x = x_0 + v_0 t + \frac{1}{2} a t^2 \quad v = v_0 + at \quad v^2 = v_0^2 + 2a\Delta x \]

\[ F = ma \quad a_c = \frac{v^2}{r} \]

\[ E_{\text{tot}} = K + U \quad K = \frac{1}{2} m v^2 \quad p = mv \quad W_F = F d \cos \theta \]

**Electrostatics**

\[ F_{12} = k \frac{q_1 q_2}{r^2} \quad E = \frac{F}{q_0} \quad U_{12} = k \frac{q_1 q_2}{r} \quad V \equiv \frac{U}{q_0} \quad W_E = -\Delta U = -W_{\text{youn}} \]

Point charge \[ E = k \frac{q}{r} \quad V = k \frac{2}{r} \]

Electric dipole \[ p = q d \quad \tau_{\text{dip}} = p E \sin \theta \quad U_{\text{dip}} = -p E \cos \theta \]

**Resistance**

\[ R = \frac{V}{I} \quad I = \frac{\Delta q}{\Delta t} \quad \text{Physical resistance: } R = \rho \frac{L}{A} \]

\[ P = IV = I^2 R = \frac{V^2}{R} \quad R_S = R_1 + R_2 + \cdots \quad \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots \]

**Capacitance**

\[ C = \frac{Q}{V} \quad \text{Parallel plate capacitor: } C = \frac{k \varepsilon_0 A}{d} \quad E = \frac{Q}{\varepsilon_0 A} \quad V = Ed \]

\[ U_C = \frac{1}{2} Q V = \frac{1}{2} C V^2 = \frac{1}{2} Q^2 \quad C_P = C_1 + C_2 + \cdots \quad \frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots \]

**Circuits**

\[ \sum \Delta V = 0 \quad \sum \Delta I_{\text{in}} = \sum \Delta I_{\text{out}} \]

\[ q(t) = q_\infty (1 - e^{-t/\tau}) \quad q(t) = q_0 e^{-t/\tau} \quad I(t) = I_0 e^{-t/\tau} \quad \tau = RC \]

**Magnetism**

\[ F = q v B \sin \theta \quad r = \frac{mv}{qB} \quad F_{\text{wire}} = I L B \sin \theta \quad \tau_{\text{loop}} = N I A B \sin \varphi \]

Magentic dipole: \[ \mu = N I A \quad \tau_{\text{dip}} = \mu B \sin \varphi \quad U_{\text{dip}} = -\mu B \cos \varphi \]

\[ B_{\text{wire}} = \frac{\mu_0 I}{2\pi r} \quad B_{\text{sol}} = \mu_0 n I \]

**Electromagnetic induction**

\[ \mathcal{E} = -N \frac{\Delta \Phi}{\Delta t} \quad \Phi = BA \cos \varphi \]

\[ |\mathcal{E}_{\text{bar}}| = B L v \quad \mathcal{E}_{\text{gen}} = \mathcal{E}_{\text{max}} \sin \omega t = \omega N A B \sin \omega t \quad \omega = 2\pi f \]

\[ V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}} \quad I_{\text{rms}} = \frac{I_{\text{max}}}{\sqrt{2}} \quad V_P = \frac{I_S}{I_p} = \frac{N_p}{N_s} \]

**Electromagnetic waves**

\[ \lambda = \frac{c}{f} \quad E = c B \]

\[ u_E = \frac{1}{2} \varepsilon_0 E^2 \quad u_B = \frac{1}{2\mu_0} B^2 \quad \pi = \frac{1}{2} \varepsilon_0 E_{\text{rms}}^2 + \frac{1}{2\mu_0} B_{\text{rms}}^2 = \varepsilon_0 E_{\text{rms}}^2 = \frac{B_{\text{rms}}^2}{\mu_0} \quad S = I = \pi c = \frac{P}{A} \]

\[ f_0 = f_c \sqrt{\frac{1 + v_{\text{rel}}/c}{1 - v_{\text{rel}}/c}} \approx f_c \left(1 + \frac{v_{\text{rel}}}{c}\right) \quad I = I_0 \cos^2 \theta \]
Reflection and refraction
\[ \theta_t = \theta_i \]
\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]
\[ v = \frac{c}{n} \]
\[ \sin \theta_e = \frac{n_2}{n_1} \]
Compound microscope: \[ m_{obj} = \frac{L_{tube}}{f_{obj}} \]
\[ M_{eye} = \frac{d_{near}}{f_{eye}} \]
\[ M_{tot} = M_{eye} \cdot m_{obj} \]

Interference and diffraction
Double-slit interference: \[ d \sin \theta = m \lambda \]
Single-slit diffraction: \[ a \sin \theta = m \lambda \]
Circular aperture: \[ a \sin \theta \approx 1.22 \lambda \]

Quantum mechanics
\[ E = hf = \frac{hc}{\lambda} \]
Bohr atom: \[ 2\pi n_o = n \lambda \] \[ n = 1, 2, 3, \cdots \]
\[ r_n = \left( \frac{\hbar^2}{m_e e^2} \right) \frac{n^2 \pi^2}{Z} \approx (5.29 \times 10^{-11} \text{ m}) \frac{n^2 \pi^2}{Z} \]
\[ \frac{1}{\lambda} \approx (1.097 \times 10^7 \text{ m}^{-1}) Z^2 \left( \frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \]
Quantum atom: \[ L = \sqrt{\ell (\ell + 1)} \hbar \]
\[ L_Z = m_e \hbar \]
\[ S_z = m s h \]
Atomic magnetism: \[ \mu_{e,z} = -\frac{e}{2m_e} L_z \]
\[ \mu_{s,z} = -\frac{g e}{2m_e} S_z, g \approx 2 \]
\[ \mu_B = \frac{e \hbar}{2m_e} \approx 5.8 \times 10^{-5} \text{ eV/T} \]

Nuclear physics and radioactive decay
\[ A = Z + N \]
\[ r \approx (1.2 \times 10^{-15} \text{ m}) A^{1/3} \]
\[ E_0 = mc^2 \]
\[ m_{nucleus} = Z m_{proton} + N m_{neutron} - \frac{|E_{bind}|}{e^2} \]
\[ \frac{\Delta N}{\Delta t} = \lambda N \]
\[ N(t) = N_0 e^{-\lambda t} = N_02^{-t/T_{1/2}} \]
\[ T_{1/2} = \frac{\ln 2}{\lambda} \approx 0.693 \frac{1}{\lambda} \]

Constants and unit conversion
\[ g = 9.8 \text{ m/s}^2 \]
\[ e = 1.60 \times 10^{-19} \text{ C} \]
\[ \epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2 \]
\[ k \equiv \frac{1}{4\pi \epsilon_0} = 8.99 \times 10^9 \text{ Nm}^2/\text{C}^2 \]
\[ \mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m}/\text{A} \]
\[ c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = 3 \times 10^8 \text{ m/s} \]
\[ h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} \]
\[ \hbar = 1.240 \text{ eV} \cdot \text{nm} \]
\[ 1 \text{ eV} = 1.60 \times 10^{-19} \text{ J} \]
\[ m_{proton} = 1.673 \times 10^{-27} \text{ kg} = 938 \text{ MeV}/c^2 \]
\[ m_{electron} = 9.11 \times 10^{-31} \text{ kg} = 511 \text{ keV}/c^2 \]
\[ m_{neutron} = 1.675 \times 10^{-27} \text{ kg} = 939.5 \text{ MeV}/c^2 \]

SI Prefixes
<table>
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<th>Power</th>
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