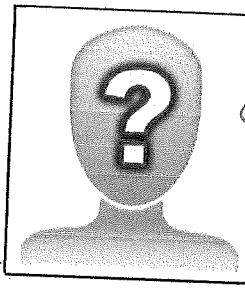
Physics 227 – Second Midterm Exam
Tuesday, April 10, 2018



CIZEWSKI

Physics 227, Section

RUID:

Code: 000

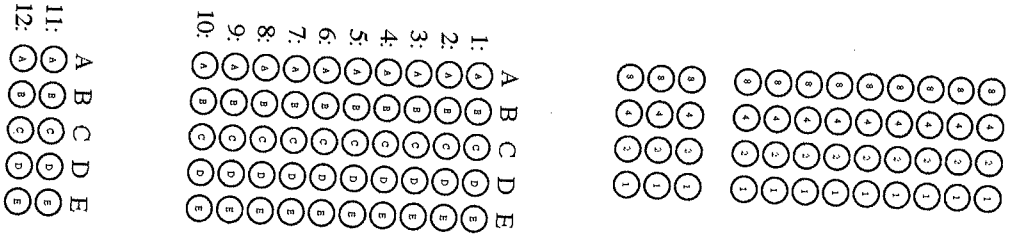
Your name with **exam code**

Your signature _____

Turn off and put away ALL electronic devices NOW. NO cell phones, NO smart watches, NO calculators.

1. The exam will last from 5:15 to 6:10 PM.
   Use a # 2 pencil to make entries in the circles at the bottom of the cover sheet.
2. Make sure your name and RU ID are correct on the cover page. **CAREFULLY detach the cover sheet (with your name, ID and the answer circles).**
3. During the exam, you may use pencils, NO calculator. and **ONE** $8\frac{1}{2}'' \times 11''$ sheet of paper with handwritten (both sides) equations and notes.
4. There are 12 multiple-choice questions on the exam. For each question, mark only ONE and only one answer on the answer sheet. There is no subtraction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess.

No marks except filled in answer circles below the line, please.



5. Before starting the exam, make sure that your copy contains all 12 questions and the information pages. Bring your exam to the proctor if this is not the case.

6. At the end of the exam, hand in **only the cover sheet**. Retain the question sheets for future reference and study.

7. During the exam, you are allowed one handwritten sheet of paper, 8.5 x 11 inches in size, handwritten on both sides. NO Calculators. NO Cell phones. NO smart watches.

8. The exam consists of 12 multiple-choice questions. For each multiple-choice question mark only **ONE** answer. 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.

9. If you have questions or problems during the exam, you may raise your hand and a proctor will assist you. We will provide the value of physical constants that are needed. It is your responsibility to know the relevant equations.

10. You are not allowed to help any other student, ask for help from anyone but a proctor, change your seat without permission from a proctor or use any electronic device. Doing so will result in a zero score for the exam.

11. **When you are done with the exam, show your student ID to a proctor, hand in only the cover sheet.**

Possibly useful constants:

$\epsilon_0 = 1/\mu_0 c^2 = 8.85 \times 10^{-12}$ C^2/N·m^2
$k = 1/4\pi\epsilon_0 = 8.99 \times 10^9$ N·m^2/C^2
c = speed of light $= 3.00 \times 10^8$ m/s
$-q_{electron} = q_{proton} = 1.602 \times 10^{-19}$ C
$m_{electron}$ = electron mass $= 9.11 \times 10^{-31}$ kg
m_{proton} = proton mass $= 1.67 \times 10^{-27}$ kg
$\mu_0 = 4\pi \times 10^{-7}$ T·m/A $= 12.57 \times 10^{-7}$ T·m/A
1 eV $= 1.602 \times 10^{-19}$ J.

Circumference of a circle $=2\pi r$; area of a circle is πr^2
Surface area of a sphere $= 4\pi r^2$; volume of a sphere $= \frac{4}{3}\pi r^3$
Surface area of a cylinder $= 2\pi rh + 2\pi r^2$; volume of cylinder $= \pi r^2 h$
$\sin(0°) = \cos(90°) = 0$
$\sin(90°) = \cos(0°) = 1$
$\sin(30°) = \cos(60°) = 1/2$
$\sin(60°) = \cos(30°) = \sqrt{3}/2$
$\sin(45°) = \cos(45°) = \sqrt{2}/2$
$\frac{d}{dx}x^n = nx^{n-1}$

$\int x^n dx = \frac{1}{n+1}x^{n+1}$ except when $n = -1$. For $n = -1$, $\int dx/x = \ln x$

$\frac{d}{dx}\sin(ax) = a\cos(ax)$

$\frac{d}{dx}\cos(ax) = -a\sin(ax)$

$\int \sin(ax)dx = -\cos(ax)/a$
$\int \cos(ax)dx = \sin(ax)/a$

Some metric prefixes:
f = femto $= 10^{-15}$
p = pico $= 10^{-12}$
n = nano $= 10^{-9}$
μ = micro $= 10^{-6}$
m = milli $= 10^{-3}$
k = kilo $= 10^3$
M = mega $= 10^6$
G = giga $= 10^9$

1. A rectangular block of metal has dimensions $d \times 2d \times 3d$ in the $x-y-z$ directions, respectively. It is made of a material with resistivity ρ. A potential difference V is applied between two opposite faces of the block. What is the maximum current density J in this rectangular block of metal?

a) $J = V/d$
b) $J = V/(\rho\, d)$
c) $J = V/(6d^3)$
d) $J = V/(\rho\, 6d^3)$
e) $J = V/\rho$

$E = \rho J = \frac{V}{d}$

$J = \frac{V}{\rho d}$

2. A constant current source sends a current I through a resistor R_1. A second resistor $R_2 << R_1$ is connected in parallel to the first resistor. What happens to the current I through the first resistor?

a) I increases.
b) I decreases, but not to 0.
c) I decreases to 0.
d) I stays the same.
e) Need to know voltage of the current source.

Resistors in parallel

$V_1 = I_1 R_1 = V_2 = I_2 R_2$

$\frac{R_2}{R_1} = \frac{I_1}{I_2}$ $R_2 << R_1$

$\Rightarrow I << I_2$

$\Rightarrow I_1$ decreases but not to zero

3. A proton (charge= $+e$, mass=M) and a deuteron (charge= $+e$, mass= $2M$) have the same kinetic energy. They enter a magnetic field and both move in circular paths. How are the radii of the paths related?

a) $r_d = r_p/\sqrt{2}$
b) $r_d = r_p$
c) $r_d = 2r_p$
d) $r_d = \sqrt{2} r_p$
e) $r_d = r_p/2$

$KE_p = KE_d \Rightarrow \frac{1}{2} M_p v_p^2 = \frac{1}{2}(2m) v_d^2$

$v_p^2 = 2 v_d^2 = \frac{v_p}{v_d} = \sqrt{2}$

$q v_p B = \frac{m v_p^2}{r_p} \Rightarrow r_p = \frac{m v_p}{qB}$

$q v_d B = 2m v_d^2 / r_d \Rightarrow r_d = 2m v_d / qB$

$\frac{r_d}{r_p} = \frac{2}{\sqrt{2}}$

$r_d = \sqrt{2}\, r_p$

4. An EMF source with a voltage V, a resistor with a resistance R and a capacitor with a capacitance C are connected in series. Initially a switch in this circuit is open. At time $t = 0$ the switch is closed and the capacitor starts to charge. Which of the following statements about the current I in the circuit and the charge Q on the capacitor is TRUE?

a) When $I = 0$, $Q = 0$. – never.
b) When $I = V/4R$, $Q = CV/4$. no
c) When $I = V/R$, $Q = CV$. no
d) When $I = V/4R$, $Q = 3CV/4$.
e) When $I = V/2R$, $Q = 2VC$.

capacitor charging

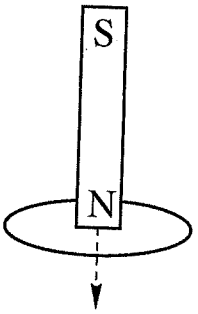
$Q = CV(1 - e^{-t/RC})$

$I = \frac{V}{R}(e^{-t/RC})$

When $I = \frac{V}{4R} \Rightarrow e^{-t/RC} = \left(\frac{V}{4R}\right)\left(\frac{R}{V}\right) = \frac{1}{4}$

$\Rightarrow Q = CV\left(1 - \frac{1}{4}\right) = \frac{3}{4} CV$.

5. A bar magnet with its north end down is dropped through a circular loop of wire from far above. Magnetic field lines exit the magnet through its north end and enter the magnet through its south end. Seen from above, the direction of the current induced in the loop will



a) first be counterclockwise and later clockwise.
b) be none of the other options.
c) always be counterclockwise.
d) always be clockwise.
e) first be clockwise and later counterclockwise.

initial $B_{induced}$ up ↑ $B_{induced}$ final $B_{induced}$ down ↓ I

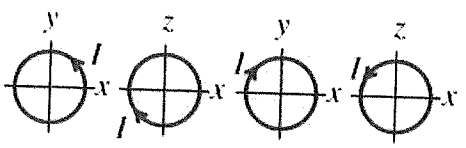
6. A solenoid is wound with 300 turns on a form 3 cm in diameter and 0.5 m long. The windings carry a current I. The current produces a magnetic field of magnitude $B = 3.0$ mT at the center of the solenoid. What is the current in the windings that produces this magnetic field? (Note: $\mu_0 = 4\pi \times 10^{-7}$ T·m/A) $B = \mu_0 n I = \mu_0 \left(\frac{N}{\ell}\right) I$

a) $I = 1/4\pi \times 10^2$ A
b) $I = 1/8\pi \times 10^2$ A
c) $I = 3/2\pi \times 10^2$ A
d) $I = 1/4\pi$ A
e) $I = 1/8\pi$ A

$$I = \frac{B\ell}{\mu_0 N} = \frac{(3.0\times10^{-3}\,T)(\frac{1}{2}\,m)}{(4\pi\times10^{-7}\,\frac{T\text{-}m}{A})(300)} = \frac{10^2}{8\pi}\ A.$$

7. The figure displays 4 identical circular coils with area A and N turns. They are free to rotate about a diameter that coincides with the x-axis. Current I is circulating in each coil. There is a uniform magnetic field $\vec{B}$ in the positive y-direction. Rank the potential energies U of each coil as oriented in the figure.

deduce $\vec{\mu}$ for each loop $U = -\vec{\mu} \cdot \vec{B}$



a) $U_A = U_C > U_B = U_D$
b) $U_A = U_C > U_D > U_B$
c) $U_B > U_A = U_C > U_D$
d) $U_A > U_B > U_C > U_D$
e) $U_D > U_A = U_C > U_B$

(a) ⊙ +z (b) ⊗ +y (c) ⊗ −z (d) ⊙ −y } $\vec{\mu}$

$U = -\vec{\mu} \cdot \vec{B}$

0 min 0 max

8. Which of the following is a correct statement in words of the following Maxwell equation?

displacement current

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 (I + \epsilon_0 \frac{d\phi_E}{dt})$$

circulation about closed loop

a) The circulation of magnetic field around a loop is proportional to the current + displacement current enclosed in the loop.

b) The magnetic flux through a loop is proportional to the current+ displacement current enclosed in the loop.

c) The circulation of electric field around a loop is proportional to the rate of change of magnetic flux through the loop.

d) Magnetic field lines never terminate due to the absence of magnetic monopoles.

e) The magnetic potential induced around a loop is proportional to the current enclosed by the loop.

9. The figure shows two long, parallel current-carrying wires. The wires carry equal currents I in the directions indicated and are located a distance d apart. What are the magnitude and direction of the magnetic field $\vec{B}$ at the point P that is located an equal distance d from each wire?

$B_{wire} = \frac{\mu_0 I}{2\pi d}$ tangent of circle at P

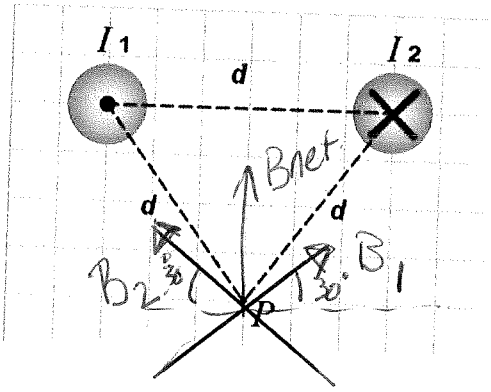
a) $\vec{B} = 2\mu_0 I/(2\pi d)$, upward

b) $\vec{B} = \mu_0 I/(2\pi d)$, downward

c) $\vec{B} = 2\mu_0 I/(2\pi d)$, to the right

d) $\vec{B} = 2\mu_0 I/(2\pi d)$, to the left

e) $\vec{B} = \mu_0 I/(2\pi d)$, upward



$B_{net} = 2\left(\frac{\mu_0 I}{2\pi d} \sin 30^\circ\right)$

$= \frac{\mu_0 I}{2\pi d}$ upward.

10. A source of emf is connected by wires to a resistor, and electrons flow in the circuit. The wire diameter is the same throughout the circuit. Which of the following statements is TRUE?

a) The potential energy of an electron before entering the source of emf is always less than the potential energy of an electron after leaving the source of emf. T

b) The potential energy of an electron before entering the source of emf is always greater than the potential energy of an electron after leaving the source of emf. F

c) The potential energy of an electron entering the source of emf is always the same as that of an electron leaving the source of emf. F

d) The drift speed of the electrons before entering the source of emf is faster than the drift speed of the electrons leaving the source of emf. F

e) The drift speed of the electrons before entering the source of emf is slower than the drift speed of the electrons leaving the source of emf. F

11. A particle with a positive charge moves in the $x - z$ plane as shown. the magnetic field $\vec{B}$ is in the positive z direction. What is the direction of the magnetic force $\vec{F}_B$?

$\vec{F} = q\vec{v} \times \vec{B} \Rightarrow$ negative y direction.

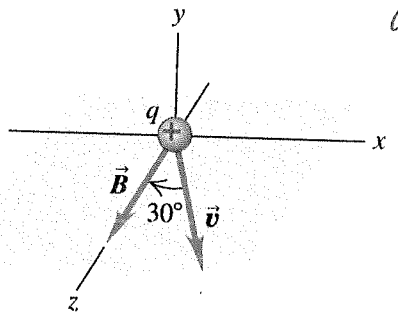
a) $\vec{F}_B$ is in the positive x direction.

b) $\vec{F}_B$ is in the positive y direction.

c) $\vec{F}_B$ is in the negative z direction.

d) $\vec{F}_B$ is in the negative y direction.

e) $\vec{F}_B$ is in the negative x direction.



12. A uniform magnetic field is applied perpendicular to the plane of a 100-turn circular coil with an area of 0.01 m^2 and a resistance of 1.0 Ω. If the magnetic field increases uniformly from 0.4 T to 1.4 T in 0.10 s, what is the magnitude of the emf ε induced in the coil?

a) $\varepsilon = 0.10$ V

b) $\varepsilon = 100$ V

c) $\varepsilon = 10$ V

d) $\varepsilon = 1.0$ V

e) $\varepsilon = 0.01$ V

$$\mathcal{E} = N \frac{\Delta B}{\Delta t} A$$

$$= (100)\frac{(1.4 - 0.4)}{0.10}(0.01) = 10\text{V}$$