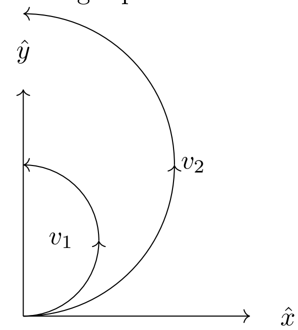
Make sure to fill out the grading sheet completely including your **name, exam flavor and UIN**. You are allowed to write and work on this exam copy, but your answers must be bubbled in on the grading sheet to receive credit. Your bubbled responses are the only responses that will be considered for the grade.

Physics 207 Exam 3 – **Flavor 1**

Problem 1 (4 points) Two electrons enter a region of uniform magnetic field shown below. This figure will be used for problems 1 and 2. Which of the following represents the relationship between the speeds of the electrons?

(A) $v_1 > v_2$
(B) $v_1 = v_2$
(C) $v_1 < v_2$



Problem 2 (4 points) What is the direction of the magnetic field in the previous problem?

(A) $+\hat{x}$
(B) $+\hat{y}$
(C) $+\hat{z}$
(D) $-\hat{x}$
(E) $-\hat{y}$
(F) $-\hat{z}$

Problem 3 (7 points) A proton enters a region of space with a uniform magnetic field $\vec{B} = B\hat{\imath}$. At the instant it enters the field, it experiences a magnetic force $\vec{F} = -F\hat{k}$. What could you conclude about an initial velocity of the proton? Note that B and F are both positive constants in this problem.

(A) $v_x = \frac{F}{qB}$, $v_y = 0$, Nothing can be concluded about v_z

(B) $v_x = 0$, $v_y = \frac{F}{qB}$, Nothing can be concluded about v_z

(C) $v_x = \frac{F}{qB}$, Nothing can be concluded about v_y, $v_z = 0$

(D) $v_x = 0$, Nothing can be concluded about v_y, $v_z = \frac{F}{qB}$

(E) Nothing can be concluded about v_x, $v_y = \frac{F}{qB}$, $v_z = 0$

(F) Nothing can be concluded about v_x, $v_y = 0$, $v_z = \frac{F}{qB}$

Problem 4 (7 points) If $I_2 = 2I_1$ in the figure below, what is the magnitude and direction of the magnetic field at the center of the circle? Consider only the circular parts of the wires.

(A) $B = \dfrac{\mu I_1}{4R}$ into the page

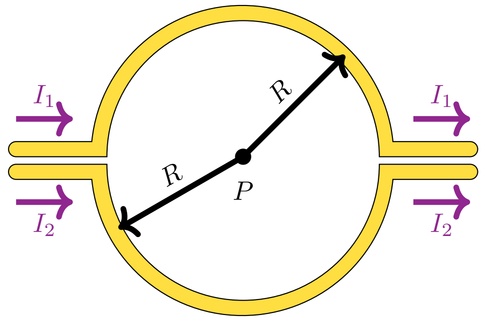
(B) $B = \dfrac{\mu I_1}{2R}$ into the page

(C) $B = \dfrac{\mu I_1}{R}$ into the page

(D) $B = \dfrac{\mu I_1}{4R}$ out of the page

(E) $B = \dfrac{\mu I_1}{2R}$ out of the page

(F) $B = \dfrac{\mu I_1}{R}$ out of the page



Problem 5 (8 points) Two long parallel wires separated by a distance d are carrying the currents $4I$ and I in the same direction as it shows in the figure. At value of x is the total magnetic field exactly zero?

(A) $x = -\dfrac{4d}{3}$

(B) $x = -\dfrac{4d}{5}$

(C) $x = -\dfrac{3d}{4}$

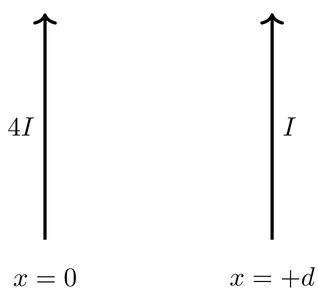
(D) $x = -\dfrac{3d}{5}$

(E) $x = +\dfrac{3d}{5}$

(F) $x = +\dfrac{3d}{4}$

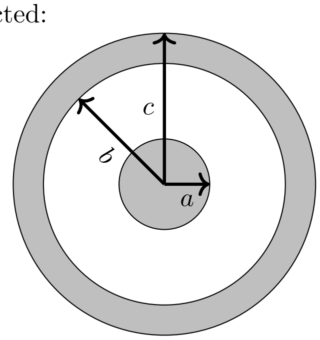
(G) $x = +\dfrac{4d}{5}$

(H) $x = +\dfrac{4d}{3}$



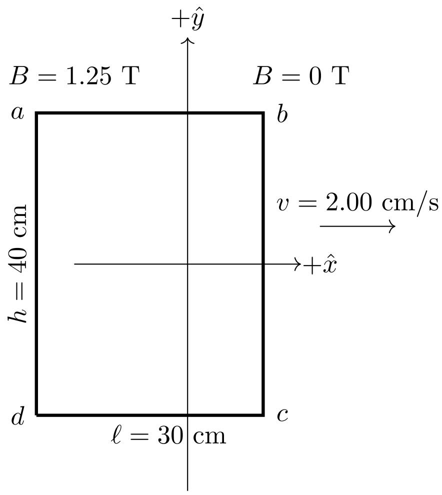
Problem 6 (4 points) A long solid cylindrical conductor with a radius a carries a current I into the page from the perspective shown below. It is surrounded by a concentric tube with inner radius b and outer radius c carrying the current I in the opposite direction. The magnetic field in the outer tube ($b < r < c$) is directed:

(A) Radially outward from the central axis
(B) Radially inward toward the central axis
(C) Clockwise from this perspective
(D) Counterclockwise from this perspective
(E) The magnetic field is zero in that region



Problem 7 (7 points) This figure and prompt is used for problems 7-9. A uniform magnetic field $B = 1.25$ T directed into the page is set in the region $x < 0$ while $B = 0$ in the region $x > 0$. A rectangular loop with a resistance $R = 1.00\ \Omega$ and with the vertical and horizontal dimensions of 40 cm and 30 cm is crossing the border between these two regions at the velocity 2.00 cm/s as shown in the figure.

What is the magnitude of the induced current in the loop.



(A) 150 mA
(B) 30 mA
(C) 15 mA
(D) 10 mA
(E) 7.5 mA
(F) 3 mA

Problem 8 (3 points) What direction is the induced current in the loop?

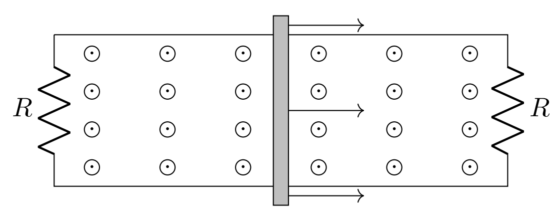
(A) Clockwise
(B) Counterclockwise

Problem 9 (3 points) Which side of the loop is the emf induced?

(A) Side ab (top)
(B) Side bc (right)
(C) Side cd (bottom)
(D) Side da (left)

Problem 10 (5 points) Find directions of the currents in the left & right resistor due to a slider moving with a velocity v to the right.

(A) Both currents are up
(B) Both currents are down
(C) Up through the left resistor and down through the right resistor
(D) Down through the left resistor and up through the right resistor
(E) Both currents are zero



Problem 11 (8 points) A proton enters a velocity selector with speed v_0 in the positive x-direction and propagates through the device without deflection. The electric field in the device is $\vec{E} = 1.8 \times 10^4 \hat{\jmath}$ and the magnetic field is $\vec{B} = 0.60\hat{k}$. When the proton leaves the selector it enters a mass spectrometer with a magnetic field $\vec{B} = 2.3\hat{k}$. What is the radius of the proton's path in the mass spectrometer? Assume all vectors have SI units.

(A) 8.8×10^{-5} m
(B) 7.2×10^{-5} m
(C) 6.5×10^{-4} m
(D) 5.2×10^{-4} m
(E) 4.9×10^{-5} m
(F) 3.6×10^{-5} m
(G) 2.7×10^{-4} m
(H) 1.4×10^{-4} m

Problem 12 (3 points) Using the velocity selector from the previous problem, if the proton was traveling with speed $1.1v_0$, what direction would it be deflected?

(A) $+\hat{\imath}$
(B) $+\hat{\jmath}$
(C) $+\hat{k}$
(D) $-\hat{\imath}$
(E) $-\hat{\jmath}$
(F) $-\hat{k}$
(G) It would not be deflected

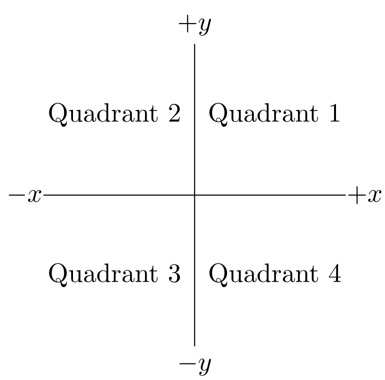
Problem 13 (7 points) A rectangular coil of wire with dimensions 2.0 cm by 3.0 cm and 75 turns carries a current of 4.0 A. The loop is placed in a uniform magnetic field of 0.30 T such that the plane of the loop makes an angle of 30 degrees with the magnetic field direction. What is the net torque acting on the loop?

(A) 1.6×10^{-2} Nm
(B) 2.7×10^{-2} Nm
(C) 3.9×10^{-2} Nm
(D) 4.7×10^{-2} Nm
(E) 6.2×10^{-2} Nm
(F) 8.2×10^{-2} Nm

Problem 14 (9 points) An infinitely long straight wire lies along the y-axis and carries a current of 13 A in the $+\hat{\jmath}$-direction. At a particular moment in time, an electron is at the position $(x, y) = (5, -7)$ and is traveling with velocity $\vec{v} = 520\hat{\jmath}$. What is the magnitude of the force the wire exerts on the electron? Assume all values and vectors are in base SI units.

(A) 2.5×10^{-23} N
(B) 3.1×10^{-23} N
(C) 4.3×10^{-23} N
(D) 6.2×10^{-23} N
(E) 8.7×10^{-23} N
(F) 9.6×10^{-23} N

Problem 15 (4 points) In the previous problem, what is the direction of the force the ***electron*** exerts on the ***wire***?



(A) $+x$
(B) Quadrant 1
(C) $+y$
(D) Quadrant 2
(E) $-x$
(F) Quadrant 3
(G) $-y$
(H) Quadrant 4

Problem 16 (9 points) There exists an object with a charge $q = 30.0$ mC that has a velocity vector $\vec{v} = 200\hat{\imath}$. There also exists and electric field $\vec{E} = -200\hat{\jmath} - 300\hat{k}$ and a magnetic field $\vec{B} = 3.00\hat{\jmath} - 4.00\hat{k}$. What is the magnitude of the net force acting on the object? (Assume the mass is very small so gravity can be ignored.)

(A) 857 N
(B) 671 N
(C) 73.1 N
(D) 40.8 N
(E) 30.0 N
(F) 20.1 N
(G) 10.8 N
(H) 2.43 N

Problem 17 (8 points) An object has a charge $q = 4.00$ C and a mass $m = 3.00$ μg. It is moving in a circular path with radius $r = 6.00$ m with a constant speed of $v = 250$ m/s. What is the magnetic field created by this object at the center of its circular path?

(A) 4.89×10^{-4} T
(B) 3.13×10^{-5} T
(C) 1.67×10^{-5} T
(D) 7.18×10^{-6} T
(E) 2.78×10^{-6} T

Useful Constants:
Acceleration due to gravity: $g = 9.80$ m/s^2
Basic unit of charge: $e = 1.6 \times 10^{-19}$ C
Mass of electron: $m_e = 9.11 \times 10^{-31}$ kg
Mass of proton/neutron: $m_p = 1.67 \times 10^{-27}$ kg
Coulomb constant: $k = 8.99 \times 10^9$ Nm^2/C^2
Permittivity of free space: $\epsilon_0 = 1/(4\pi k) = 8.85 \times 10^{-12}$ C^2/Nm^2
Permeability of free space: $\mu_0 = 4\pi \times 10^{-7}$ Tm/A
Speed of light in a vacuum: $c = 3 \times 10^8$ m/s
Planck's Constant: $h = 6.626 \times 10^{-34}$ Js
eV to joule conversion: 1 eV = 1.6×10^{-19} J
kilowatt-hour to joule conversion: 1 kW·hr=3.6×10^6 J
Atomic Mass Unit: 1 u = 1.66054×10^{-27} kg = 931.5 MeV/c^2

Vector Concepts:
Unit Vector: $\hat{r} = \frac{\vec{r}}{r}$
Gradient: $\vec{\nabla} = \frac{\partial}{\partial x}\hat{x} + \frac{\partial}{\partial y}\hat{y} + \frac{\partial}{\partial z}\hat{z}$
Dot Product: $\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}| \cos\theta$
Dot Product: $\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$
Cross Product:

$$\begin{aligned} |\vec{A} \times \vec{B}| =& |\vec{A}||\vec{B}| \sin\theta \\ \vec{A} \times \vec{B} =& (A_y B_z - A_z B_y)\hat{x} - (A_x B_z - A_z B_x)\hat{y} \\ &+ (A_x B_y - A_y B_x)\hat{z} \end{aligned}$$

Sample Indefinite Integrals:

$$\int \frac{dx}{\sqrt{x^2 \pm a^2}} = \ln(x + \sqrt{x^2 \pm a^2}) + c$$

$$\int \frac{xdx}{(x^2 + a^2)^{3/2}} = -\frac{1}{\sqrt{x^2 + a^2}} + c$$

$$\int \frac{dx}{(x^2 + a^2)^{3/2}} = \frac{x}{a^2\sqrt{x^2 + a^2}} + c$$

$$\int x^n dx = \frac{x^{n+1}}{n+1} + c(n \neq -1)$$

$$\int \frac{dx}{x} = \ln(x) + c$$

$$\int \frac{dx}{x^2 + a^2} = \frac{1}{a} \arctan\frac{x}{a} + c$$

$$\int \frac{dx}{\sqrt{a^2 - x^2}} = \arcsin\frac{x}{a} + c$$

SI Prefixes:
T=$\times 10^{12}$, G=$\times 10^9$, M=$\times 10^6$, k=$\times 10^3$
c=$\times 10^{-2}$, m=$\times 10^{-3}$
μ=$\times 10^{-6}$, n=$\times 10^{-9}$, p=$\times 10^{-12}$, f=$\times 10^{-15}$

Useful integral relationships:
Spherical: $\mathrm{d}V = 4\pi r^2 \mathrm{d}r$
Cylindrical (with constant r): $dV = \pi r^2 \mathrm{d}z$
Cylindrical (with constant z): $dV = z 2\pi r \mathrm{d}r$
Cylindrical (with constant r): $dA = 2\pi r \mathrm{d}z$
Cylindrical (with constant z): $dA = 2\pi r \mathrm{d}r$

Geometry:
Surface Area of a Sphere: $A = 4\pi r^2$
Volume of a Sphere: $V = \frac{4}{3}\pi r^3$
Area of curved region of a cylinder: $A = 2\pi r h$
Volume of a cylinder: $V = \pi r^2 h$

Physics 1 Concepts:
Work: $W = \int \vec{F} \cdot d\vec{\ell}$
Potential Energy of conservative force:
$W_{cons} = -\Delta U$
Kinetic Energy: $K = \frac{1}{2}mv^2$
Momentum: $\vec{p} = m\vec{v}$

Chapter 21:

Coulomb's Law [N]: $\vec{F} = \frac{kq_1q_2}{r^2}\hat{r}$

Force due to an electric field [N]: $\vec{F} = q\vec{E}$

E Field due to a pt. charge [N/C]: $\vec{E} = \frac{kq}{r^2}\hat{r}$

E Field due to a continuous charge dist. [N/C]:
$\vec{E} = \int \frac{kdq}{r^2}\hat{r}$

Electric dipole moment [Cm]: $\vec{p} = q\vec{d}$

Torque on an electric dipole [Nm]: $\vec{\tau} = \vec{p} \times \vec{E}$

Electric pot. energy stored in electric dipole [J]:
$U = -\vec{p} \cdot \vec{E}$

Chapter 22:

Electric Flux [Vm or Nm^2/C]: $\Phi_E = \int \vec{E} \cdot d\vec{A}$

Electric Flux when E and θ are const. on the surface: $\Phi_E = EA\cos\theta$

Gauss's Law (vacuum): $\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{encl}}}{\epsilon_0}$

Chapter 23: The below equations generally but not always assume that $V(\infty) = 0$ and/or $U(\infty) = 0$.

Elec. pot. energy between 2 pt charges [J]:
$U = \frac{kq_1q_2}{r}$

Elec. pot. difference btw. two locations [V or J/C]:
$\Delta V = \frac{\Delta U}{q}$ (or often) $V = \frac{U}{q}$

Electric potential due to a point charge [V]:
$V = \frac{kq}{r}$

Electric potential due to a charge dist. [V]:
$V = \int \frac{kdq}{r}$

Relating $\vec{E}$ and V: $\vec{E} = -\vec{\nabla}V$

$\Delta V = V_b - V_a = -\int_a^b \vec{E} \cdot d\vec{\ell}$

Chapter 24:

Capacitance [F]: $Q = CV$

Capacitance for Parallel Plates [F]: $C = \frac{\kappa\epsilon_0 A}{d}$

Energy stored in a capacitor [J]: $U = \frac{1}{2}CV^2$

E field energy density [J/m^3]: $u_E = \frac{1}{2}\kappa\epsilon_0 E^2$

Definition of Dielectric Constant: $C = \kappa C_0$

Eff. Cap. (series) [F]: $\frac{1}{C_{eff}} = \sum_i \frac{1}{C_i}$

Eff. Cap. (parallel) [F]: $C_{eff} = \sum_i C_i$

Chapters 25 and 26:

Electric Current [A]: $I = \frac{dq}{dt}$

I from current density [A]: $I = \int \vec{j} \cdot d\vec{A}$

j of uniform current [A/m^2]: $|\vec{j}| = \frac{I}{A}$

j for charges in motion [A/m^2]: $\vec{j} = nq\vec{v}_d$

Ohm's Law: $\vec{E} = \rho\vec{j}$

Ohm's Law: $\Delta V = IR$ (or often just) $V = IR$

Resistivity and conductivity: $\rho = \frac{1}{\sigma}$

Resistance of a wire [Ω]: $R = \frac{\rho\ell}{A}$

Resistance of an object [Ω]: $R = \int \frac{\rho(x)dx}{A(x)}$

Power in a circuit element [W]:
$P = I\Delta V$ (or often) $P = IV$

Eff. Res. (series) [Ω]: $R_{eff} = \sum_i R_i$

Eff. Res. (parallel) [Ω]: $\frac{1}{R_{eff}} = \sum_i \frac{1}{R_i}$

Time constant for an RC-circuit [s]: $\tau = RC$

Charge on a charging capacitor [C]:
$q(t) = q_{\max}(1 - e^{-t/\tau})$

Charge on a discharging capacitor [C]:
$q(t) = q_0 e^{-t/\tau}$

Current in an RC-circuit [A]: $I(t) = I_0 e^{-t/\tau}$

Chapter 27:

Mag. Force on a moving q [N]: $\vec{F} = q\vec{v} \times \vec{B}$

Mag. Force on a current-carrying conductor [N]:

$\vec{F} = I \int d\vec{\ell} \times \vec{B}$

R of q's path in a B field [m]: $R = \dfrac{mv}{|q|B}$

Magnetic Dipole Moment [Am^2]: $\vec{\mu} = I\vec{A}$

Torque on current loops [Nm]: $\vec{\tau} = N\vec{\mu} \times \vec{B}$

Mag. pot. energy in a magnetic dipole [J]:

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

Chapter 28:

Biot-Savart Law (2 forms):

B made by a moving charge [T]: $\vec{B} = \dfrac{\mu_0}{4\pi} \dfrac{q\vec{v} \times \hat{r}}{r^2}$

B made by any current [T]: $\vec{B} = \int \dfrac{\mu_0}{4\pi} \dfrac{I d\vec{\ell} \times \hat{r}}{r^2}$

B made by a long straight wire in a vacuum [T]:

$B = \dfrac{\mu_0 I}{2\pi r}$

B made by N loops, w/ radius R, on the axis,

z from the center (vacuum) [T]: $B = \dfrac{N\mu_0 I R^2}{2(z^2 + R^2)^{3/2}}$

B made inside a solenoid: $B = \mu_0 K_m \dfrac{N}{\ell} I$

Chapter 29:

Magnetic Flux [Wb]: $\Phi_B = \int \vec{B} \cdot d\vec{A}$

Magnetic Flux when B and θ are const.

on the surface: $\Phi_B = BA\cos\theta$

Faraday's Law [V]: $\mathcal{E} = -N\dfrac{d\Phi_B}{dt}$

Motional emf [V]: $\mathcal{E} = \int (\vec{v} \times \vec{B}) \cdot d\vec{\ell}$

Induced E Fields: $\oint \vec{E} \cdot d\vec{\ell} = -\dfrac{d\Phi_B}{dt}$

Displacement current [A]: $i_d = \epsilon_0 \dfrac{d\Phi_E}{dt}$

General Ampere's Law: $\oint \vec{B} \cdot d\vec{\ell} = \mu_0(I_{\text{encl}} + i_d)$