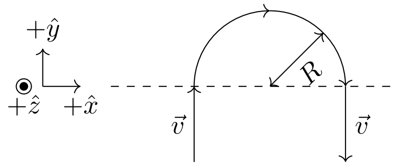
Make sure to fill out the grading sheet completely including your name, instructor, exam flavor and UIN. You are allowed to write, work on and keep this exam copy, but your answers must be bubbled in on the grading sheet to receive credit.

Physics 207 Exam 3 – Flavor 1

Problems 1-2: A beam of particles with charge $q = -3e$ and $M = 12m_p$ enters a region of space with a uniform magnetic field. The speed of the particles is $v = 3.15 \times 10^6$ m/s and the radius of their path when in the magnetic field is $R = 47.5$ cm. The picture to the right will show the trajectory of the particles and the coordinate system. The magnetic field exists only in the region of space above the dashed line.



Problem 1: (7 points) What is the magnitude of the magnetic field?
(A) 0.0231 T
(B) 0.0692 T
(C) 0.106 T
(D) 0.277 T
(E) 0.831 T
(F) 1.17 T

Problem 2: (3 points) What is the direction of the magnetic field?

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

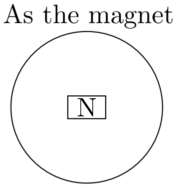
Problem 3: (9 points) What is the magnitude of the net force that acts on a particle with charge $q = 2$ C at the instant when it has a velocity vector $\vec{v} = -2000\hat{z}$ at a location in space with a magnetic field $\vec{B} = 0.55\hat{x} - 0.45\hat{z}$ and an electric field $\vec{E} = -400\hat{x} + 1400\hat{y}$? All vectors are given in SI units.

(A) 500 N
(B) 1000 N
(C) 2200 N
(D) 2910 N
(E) 3540 N
(F) 5060 N
(G) 5110 N
(H) 6800 N

Problem 4: (7 points) Niels Bohr created an early model of the atom where he predicted that the electron in the ground state of a Hydrogen atom moves with a speed of $c/137$ or 2.19×10^7 m/s with a circular radius of 5.29×10^{-11} m around the nucleus. Based on these predictions, what would be the magnitude of the magnetic field created by the electron at the center of its circular path?

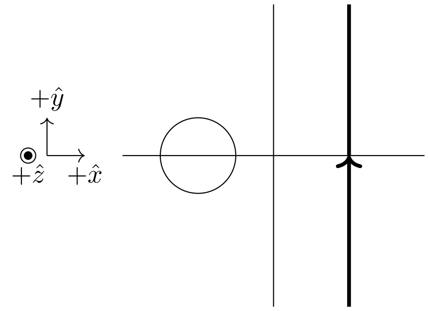
(A) 125 T
(B) 237 T
(C) 499 T
(D) 601 T
(E) 662 T

Problem 5: (3 points) You are looking down at a loop and there is a magnet below the loop with the north pole facing you. As the magnet falls away from you, which way does the induced current flow in the loop?



(A) Clockwise
(B) Counterclockwise
(C) The current will be zero.

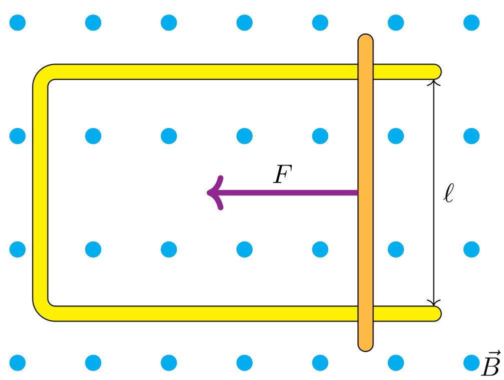
Problems 6-7: A long straight wire and a coil with N loops all exist in the xy-plane as shown below. The long straight wire carries $2500I$ in the $+y$-direction through the position $(0.6, 0)$. The coil of wire has a radius of 0.1 m, is centered at position $(-0.6, 0)$ and carries a magnitude of current, I. All answers below have been rounded to three significant figures.



Problem 6: (8 points) How many turns/loops does the coil have if the net magnetic field at the center of the coil is exactly zero?
(A) 66.3
(B) 133
(C) 398
(D) 796
(E) 2840
(F) 4770
(G) 5690
(H) 9550

Problem 7: (3 points) What direction is the current in the coil if the net magnetic field is exactly zero at the center of the coil?
(A) Clockwise
(B) Counterclockwise

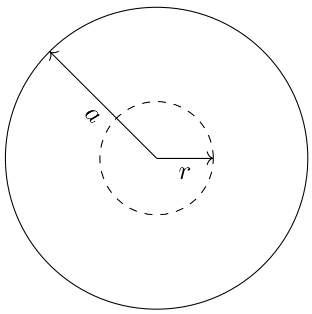
Problem 8: (8 points) A rectangular, conductive loop is created with width ℓ and a conducting bar with mass m. A uniform magnetic field $\vec{B}$ is directed perpendicular to the plane of the loop out of the plane of the figure. The bar is pushed with constant force F to the left. Assume that friction is negligible in this system, the resistance in the bar is R and the resistance of the rest of the loop is negligible. If the bar is in equilibrium, what is the constant speed with which it moves?



(A) $\dfrac{B\ell}{F}$
(B) $\dfrac{F}{B\ell}$
(C) $\dfrac{B\ell}{FR}$
(D) $\dfrac{FR}{B\ell}$
(E) $\dfrac{F\ell^2}{B^2R}$
(F) $\dfrac{FR^2}{B\ell}$
(G) $\dfrac{B^2\ell^2}{FR}$
(H) $\dfrac{FR}{B^2\ell^2}$

Problem 9: (3 points) Which end of the bar has the higher potential?
(A) Top
(B) Bottom
(C) The potential is the same at both ends.

Problem 10: (8 points) A long, straight, solid wire is carrying a uniform current I out of the page as in the figure below. The wire has a radius a. What is the magnetic field in the region of space where $r < a$?



(A) $\dfrac{\mu_0 I}{2\pi}\dfrac{1}{a}$

(B) $\dfrac{\mu_0 I}{\pi}\dfrac{1}{a^2}$

(C) $\dfrac{\mu_0 I}{2\pi}\dfrac{r}{a^2}$

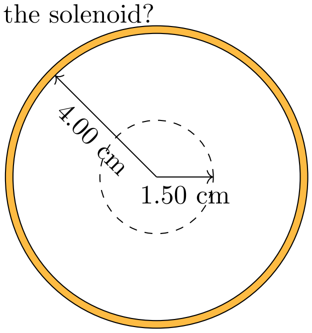
(D) $\dfrac{\mu_0 I}{2\pi}\dfrac{r^2}{a^3}$

(E) $\dfrac{\mu_0 I}{2\pi}\dfrac{1}{r}$

(F) $\dfrac{\mu_0 I}{\pi}\dfrac{1}{r^2}$

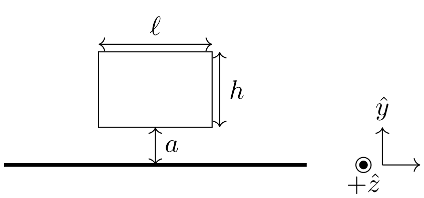
(G) $\dfrac{\mu_0 I}{2\pi}\dfrac{a}{r^2}$

Problem 11: (8 points) A long, thin solenoid has 200 turns per meter and radius 4.00 cm. The current in the solenoid is decreasing at a uniform rate of 30.0 A/s. What is the magnitude of the induced electric field at a point 1.50 cm from the axis of the solenoid?



(A) 8.67×10^{-2} N/C
(B) 7.54×10^{-3} N/C
(C) 1.51×10^{-4} N/C
(D) 4.02×10^{-4} N/C
(E) 2.12×10^{-5} N/C
(F) 5.65×10^{-5} N/C
(G) 3.84×10^{-6} N/C

Problem 12: (8 points) In the system below there is a wire carrying a current of the form $I(t) = I_0 \cos(\omega t)$. The rectangular loop has dimensions ℓ and h as shown. The closest part of the loop is a away from the wire. Both the wire and the loop are in the xy-plane. Which of the following integrals represents the flux as a function of time through the loop due to the wire?



(A) $\displaystyle\int_0^{\ell} \frac{\mu_0 I_0 \cos(\omega t)}{2\pi x} h\,dx$

(B) $\displaystyle\int_0^{\ell} \frac{\mu_0 I_0 \cos(\omega t)}{2\pi x} y\,dx$

(C) $\displaystyle\int_0^{h} \frac{\mu_0 I_0 \cos(\omega t)}{2\pi y} x\,dy$

(D) $\displaystyle\int_0^{h} \frac{\mu_0 I_0 \cos(\omega t)}{2\pi y} \ell\,dy$

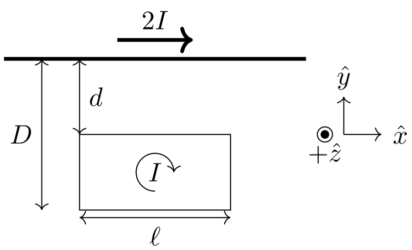
(E) $\displaystyle\int_a^{a+\ell} \frac{\mu_0 I_0 \cos(\omega t)}{2\pi x} h\,dx$

(F) $\displaystyle\int_a^{a+\ell} \frac{\mu_0 I_0 \cos(\omega t)}{2\pi x} y\,dx$

(G) $\displaystyle\int_a^{a+h} \frac{\mu_0 I_0 \cos(\omega t)}{2\pi y} \ell\,dy$

(H) $\displaystyle\int_a^{a+h} \frac{\mu_0 I_0 \cos(\omega t)}{2\pi y} x\,dy$

Problem 13: (8 points) A long, straight wire carries a current, $2I$ to the right as shown below. The loop carries a current I clockwise also as shown. What is the net magnetic force vector on the entire loop due to the long, straight wire?



(A) $\dfrac{\mu_0 I^2 (D-d)}{\pi}\left(\dfrac{1}{\ell}\right)\hat{y}$

(B) $\dfrac{\mu_0 I^2 (d-D)}{\pi}\left(\dfrac{1}{\ell}\right)\hat{y}$

(C) $\dfrac{\mu_0 I^2 \ell}{\pi}\left(\dfrac{1}{D}-\dfrac{1}{d}\right)\hat{y}$

(D) $\dfrac{\mu_0 I^2 \ell}{\pi}\left(\dfrac{1}{d}-\dfrac{1}{D}\right)\hat{y}$

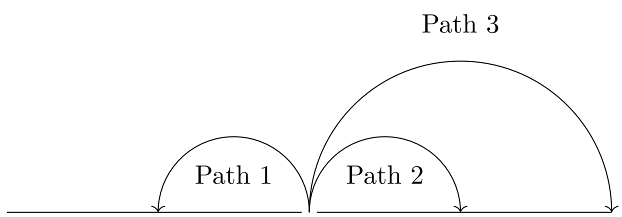
(E) $\dfrac{\mu_0 I^2 (D-d)}{\pi}\left(\dfrac{1}{\ell}\right)\hat{z}$

(F) $\dfrac{\mu_0 I^2 (d-D)}{\pi}\left(\dfrac{1}{\ell}\right)\hat{z}$

(G) $\dfrac{\mu_0 I^2 \ell}{\pi}\left(\dfrac{1}{D}-\dfrac{1}{d}\right)\hat{z}$

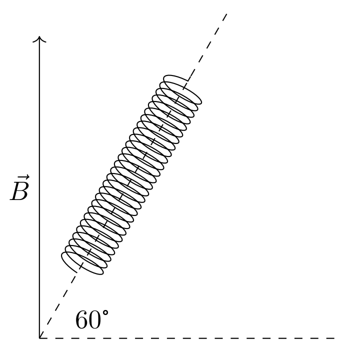
(H) $\dfrac{\mu_0 I^2 \ell}{\pi}\left(\dfrac{1}{d}-\dfrac{1}{D}\right)\hat{z}$

Problem 14: (6 points) A mass spectrometer and velocity selector are set up so that only particles of a speed v pass through the slit shown in the figure. The particles then follow paths like what are shown below. The three types of particles are positively charged hydrogen (H^+, $m = m_p$ and $q = +e$), negatively charged hydrogen (H^-, $m = m_p$ and $q = -e$) and doubly ionized helium (He^{2+}, $m = 4m_p$ and $q = +2e$). Which option below correctly pairs all three particles with the path numbers?



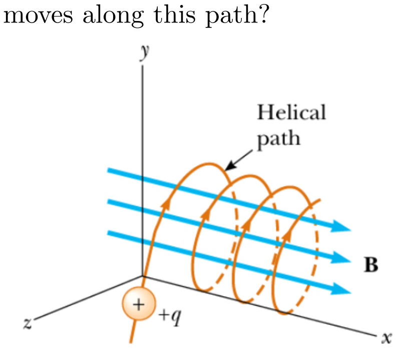
	Path 1	Path 2	Path 3
(A)	H^+	H^-	He^{2+}
(B)	H^+	He^{2+}	H^-
(C)	H^-	H^+	He^{2+}
(D)	H^-	He^{2+}	H^+
(E)	He^{2+}	H^+	H^-
(F)	He^{2+}	H^-	H^+

Problem 15: (8 points) A solenoid is 30.0 cm long, has a radius of 1.00 cm and has 400 turns. There is a magnetic field with a magnitude of 0.250 T that is pointing vertically as shown in the figure. The axis of the solenoid is 60 degrees away from the horizontal. If the solenoid feels a magnitude of torque equal to 0.0175 Nm, what is the current in the solenoid?



(A) 0.169 A
(B) 0.334 A
(C) 0.564 A
(D) 0.643 A
(E) 1.11 A
(F) 1.44 A
(G) 1.83 A
(H) 2.84 A

Problem 16: (3 points) A charged particle is moving in a helical path due to a magnetic field that is not perpendicular to the velocity of the particle. The charge is not under the influence of any other force. What happens to the speed of the particle as it moves along this path?



(A) The speed increases.
(B) The speed decreases.
(C) The speed stays constant.
(D) The speed oscillates between increasing and decreasing.
(E) It is impossible to tell.

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:

$$\int \frac{dx}{\sqrt{x^2 \pm a^2}} = \ln(x + \sqrt{x^2 \pm a^2}) + c$$
$$\int \frac{xdx}{(x^2 + a^2)^{3/2}} = -\frac{1}{\sqrt{x^2 + a^2}} + c$$
$$\int \frac{dx}{(x^2 + a^2)^{3/2}} = \frac{x}{a^2\sqrt{x^2 + a^2}} + c$$
$$\int x^n dx = \frac{x^{n+1}}{n+1} + c (n \neq -1)$$
$$\int \frac{dx}{x} = \ln(x) + c$$
$$\int \frac{dx}{x^2 + a^2} = \frac{1}{a}\arctan\frac{1}{x} + c$$
$$\int \frac{dx}{\sqrt{a^2 - x^2}} = \arcsin\frac{x}{a} + c$$

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: d$V = 4\pi r^2$dr
Cylindrical (constant over r): $dV = \pi r^2$dz
Cylindrical (constant over z): $dV = z 2\pi r$dr
Cylindrical (with constant r): $dA = 2\pi r$dz
Cylindrical (with constant z): $dA = 2\pi r$dr

Geometry:
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: $A = 2\pi rh$
Volume of a cylinder: $V = \pi r^2 h$

Physics 1 Concepts:
Work: $W = \int \vec{F} \cdot d\vec{\ell}$
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 an electric field [N]: $\vec{F} = q_0\vec{E}$

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

E Field Due to a cont. 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. ene. 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]:
$U = \frac{kqq_0}{r}$

Elec. pot. difference btw. two locations [V or J/C]:
$\Delta V = \frac{\Delta U}{q_0}$ (or often) $V = \frac{U}{q_0}$

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

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

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:
$E = \frac{E_0}{\kappa}$, $V = \frac{V_0}{\kappa}$, $C = \kappa C_0$

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. ene. 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]: $\vec{B} = \int \dfrac{\mu_0}{4\pi}\dfrac{Id\vec{\ell} \times \hat{r}}{r^2}$

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