Mid-term Exam 1: PHYSICS 1C (Spring 2020)

Time: 2:00PM – 3:00PM, April 16, 2020, Instructor: Prof. Zhongbo Kang

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Student I.D. Number: 005129861

Exam Version: **A**

Note:

- Please make sure that you have ***read, signed and uploaded*** your "student verification form", without which your exam will not be graded.
- The exam time (in total 1 hour) is designed in such a way that ideally the actual time for answering the problems is 30 minutes, while the remaining 30 minutes are used to scan and upload your solution to gradescope.
- The exam is open book, and open notes. One page of physical equations is provided. You can use a calculator.
- Remember to write down each step of your calculations, for partial credits.

Score Sheet:

Problem 1 (8 points): ________________

Problem 2 (10 points): ________________

Problem 3 (7 points): ________________

Total (25 points): ________________

Formula Sheet

$\vec{F} = q\vec{v} \times \vec{B}$ (magnetic force on a moving charged particle)

$\Phi_B = \int B\cos\phi \, dA = \int B_\perp \, dA = \int \vec{B} \cdot d\vec{A}$ (magnetic flux through a surface)

$\oint \vec{B} \cdot d\vec{A} = 0$ (Gauss's law for magnetism)

$R = \dfrac{mv}{|q|B}$ (radius of a circular orbit in a magnetic field)

$\vec{F} = I\vec{l} \times \vec{B}$ (magnetic force on a straight wire segment)

$d\vec{F} = I\,d\vec{l} \times \vec{B}$ (magnetic force on an infinitesimal wire section)

$\tau = IBA\sin\phi$ (magnitude of magnetic torque on a current loop)

$\vec{\tau} = \vec{\mu} \times \vec{B}$ (vector magnetic torque on a current loop)

$U = -\vec{\mu} \cdot \vec{B} = -\mu B\cos\phi$ (potential energy for a magnetic dipole)

$\vec{B} = \dfrac{\mu_0}{4\pi} \dfrac{q\vec{v} \times \hat{r}}{r^2}$ (magnetic field due to a point charge with constant velocity)

$d\vec{B} = \dfrac{\mu_0}{4\pi} \dfrac{I\,d\vec{l} \times \hat{r}}{r^2}$ (magnetic field due to an infinitesimal current element)

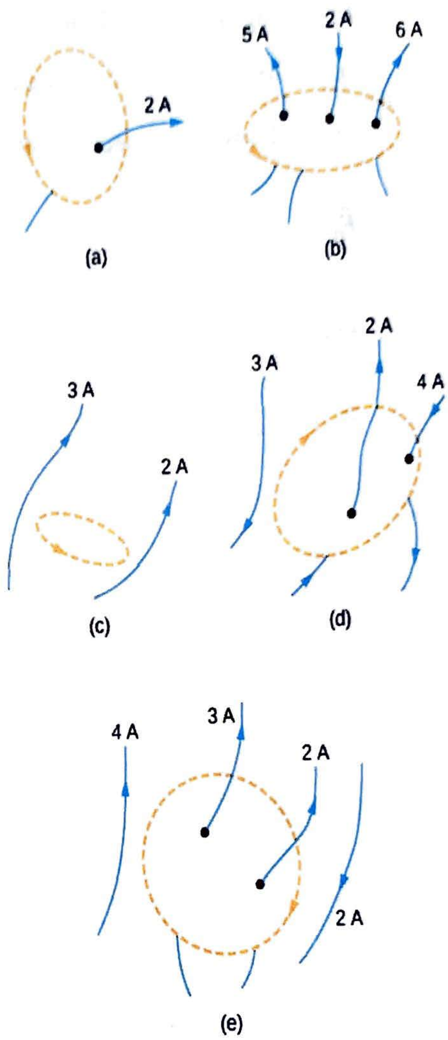
$B = \dfrac{\mu_0 I}{2\pi r}$ (magnetic field near a long, straight, current-carrying conductor)

$\dfrac{F}{L} = \dfrac{\mu_0 I I'}{2\pi r}$ (two long, parallel, current-carrying conductors) $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{encl}$ (Ampere's law)

Problem 1 (8 pts)

For the questions below, please give your final answers only.

a) (5 pts) Evaluate the line integrals $\oint \vec{B} \cdot d\vec{l}$ for each of the cases *a*, *b*, *c*, *d*, and *e* in the accompanying figure. Use $\mu_0 = 4\pi \times 10^{-7}$ T · m/A.



A: $8\pi \times 10^{-7}$ T·m

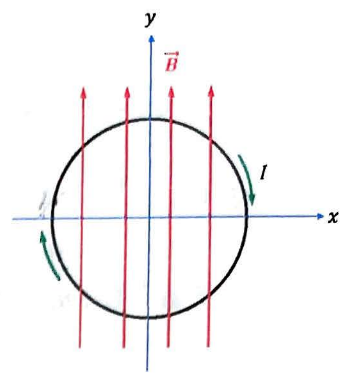
B: $36\pi \times 10^{-7}$ T·m

C: 0 T·m

D: $8\pi \times 10^{-7}$ T·m

E: $-20\pi \times 10^{-7}$ T·m

b) (3 pts) A circular current loop of radius R carrying a current I is placed in the xy-plane. A constant uniform magnetic field $\vec{B}$, cuts through the loop parallel to the y-axis. Please answer the following questions. Find the magnetic force on the upper half of the loop $\vec{F}_{up}$, the lower half of the loop $\vec{F}_{dn}$, and the net force on the loop $\vec{F}_{net}$. Specify both the magnitude and the direction.



$\vec{F}_{up}$: 2IRB N(out of the page)

$\vec{F}_{dn}$: −2IRB N(into the page)

$\vec{F}_{net}$: 0 N

Problem 2 (10 pts)

A proton ($q = 1.60 \times 10^{-19}$ C, $m = 1.67 \times 10^{-27}$ kg) enters a uniform magnetic field $\vec{B} = (0.630\ T)\hat{\imath}$ with a speed $\vec{v}$. Please answer the following questions

a) (3 pts) If the angle between $\vec{v}$ and $\vec{B}$ is 0°, what does the subsequent motion of the proton look like? If the angle is 90°, what would be the motion? If the angle is θ and $0 < \theta < 90°$, what would be the motion?

If the angle is 0°, the proton will go straight through in the direction it was moving.

If angle is 90°, the proton moves in a circle with its $R = \frac{mv}{|q| B}$

If the angle is $0 < \theta < 90°$, the proton moves in a helical path.

b) (5 pts) At what angle θ must the magnetic field be from the velocity so that the pitch of the resulting helical motion is equal to the radius of the helix? Does this angle depend on the magnitude of the charge q?

$\omega = \frac{v}{R}$ $\quad W = \frac{v}{mv}(|q|B)$ $\quad W = \frac{|q|B}{m}$ $\quad \frac{2\pi}{T} = \omega$

$T = \frac{2\pi}{\omega}$

$F = q|v||B|\sin\theta = \frac{mv^2}{R}$ $\quad T = \frac{2\pi m}{qB}$

pitch caused to parallel velocity

$\vec{v} = v_{\parallel} + v_{\perp}$

$= v\cos\theta + v\sin\theta$

$v_{\parallel}(T) = r$

$v_{\parallel}(T) = \frac{mv\sin\theta}{qB}$

$v\cos\theta\left(\frac{2\pi m}{qB}\right) = \frac{mv\sin\theta}{qB}$

$2\pi = \tan\theta$

$\theta = \tan^{-1}(2\pi)$

$\theta = 81°$

This angle does not depend on charge.

c) (2 pts) At $t = 0$, the proton has velocity components $v_x = 1.80 \times 10^5$ m/s, $v_y = 0$, and $v_z = 2.60 \times 10^5$ m/s. What is the magnitude and the direction of the magnetic force acting on the proton?

$F = |q| \, v \times B$

$v \times B = 10^5 (1.8\hat{i} + 2.6\hat{k}) \times 0.63\hat{i}$

$\hat{i} \times \hat{i} = 0 \quad \hat{k} \times \hat{i} = \hat{j}$

$= 1.638 \times 10^5$

$F = 1.6 \times 10^{-19} \times 1.638 \times 10^5$

$F = 2.62 \times 10^{-14} (\hat{j})$ N

Problem 3 (7 pts)

A solenoid with 25 turns per centimeter carries a current I. An electron moves within the solenoid in a circle that has a radius of 2.0 cm and is perpendicular to the axis of the solenoid. If the speed of the electron is 2.0 × 10^5 m/s, what is the current I?

$B = \mu_0 n I$ ✓ for solenoid. n → number of terms /m

$F = qvB$ = centripetal force. since the electron moves in a circle

$qvB = \frac{mv^2}{r}$

$B = \frac{mv}{qr} = \mu_0 n I$

$I = \frac{mv}{\mu_0 n q r}$

$I = 1.81 \times 10^{-2}$ A