Physics 2135 Exam 3

Nov. 14, 2017

Exam Total

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Name: Key

Rec. Sect:______________

Five multiple choice questions, 8 points each. Choose the **best or most nearly correct** answer. For questions 6-9, solutions must begin with a correct OSE. You must show work to receive full credit for your answers. **Calculators are NOT allowed.**

(8) C 1. An electromagnetic wave is traveling in the positive x-direction. At a certain position the magnetic field can be written as $\vec{B} = -B\hat{k}$. What is the direction of the electric field at that point?

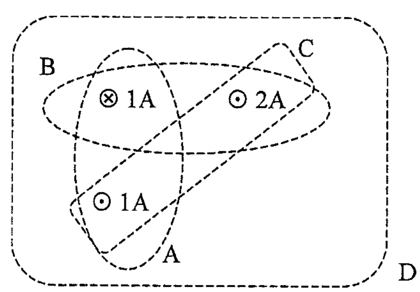
A. $\hat{k}$ B. $-\hat{i}$
C. $-\hat{j}$ D. $\hat{j}$

(8) C 2. Which of the following is **NOT** true about plane electromagnetic waves?

A. The wave propagates in a direction given by $\vec{E} \times \vec{B}$
B. The electric and magnetic fields are always perpendicular to each other
C. The waves require a medium in order to propagate
D. The ratio of the magnitudes of the magnetic and electric fields is a constant

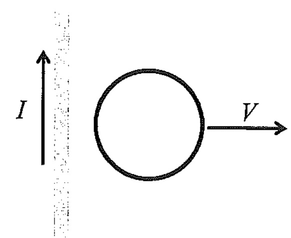
(8) C 3. The wires shown carry the current indicated either into or out of the page. For which path is the magnitude of $\oint \vec{B} \cdot d\vec{l}$ greatest?

A. B.
C. D.



(8) A 4. 4. A conducting loop is moving with speed V away from a long wire carrying a constant current I as shown. The direction of the induced current in the loop is

A. clockwise B. out of the page
C. there is no induced current D. counterclockwise



(8) Any 5. Which of the following will occur first?

A. Light sabers developed B. Photon torpedoes developed
C. Superluminal travel D. Total cell phone coverage in the Ozarks

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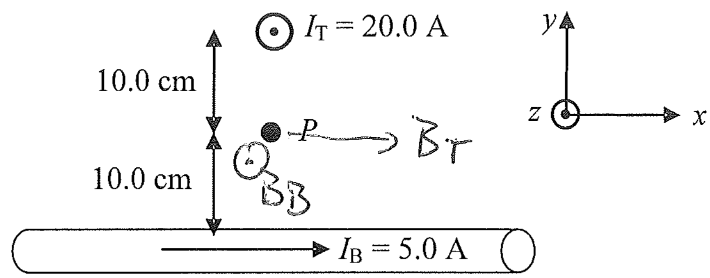
(40) 6. Two long wires are oriented so that they are perpendicular to one another as shown. At their closest point they are 20.0 cm apart. The top wire carries a current $I_T = 20.0$ A out of the page (in the positive z-direction). The bottom wire carries a current $I_B = 5.0$ A to the right (in the positive x-direction). What is the magnetic field at point P midway between the two wires? Substitute numerical values for all quantities and simplify your solution as much as possible. Express your answer in ***unit vector notation*** using the coordinate system given.



Long straight wire: $B = \dfrac{\mu_0 I}{2\pi r}$

Using RHR $\vec{B}_T$ in $\hat{i}$-direction
$\vec{B}_B$ in $\hat{k}$-direction

$$B_T = \frac{\mu_0 I_T}{2\pi r_T} = \frac{\mu_0 (20)}{2\pi (.1)} = \frac{(2\times10^{-7})(20)}{.1}$$

$$= 4\times10^{-5}\ T$$

$$B_B = \frac{\mu_0 I_B}{2\pi r_B} = \frac{\mu_0 (5)}{2\pi (.1)} = \frac{(2\times10^{-7})(5)}{.1} = 1\times10^{-5}\ T$$

Hence $\vec{B} = \vec{B}_T + \vec{B}_B = (4\times10^{-5}\,\hat{i} + 1\times10^{-5}\,\hat{k})\ T$

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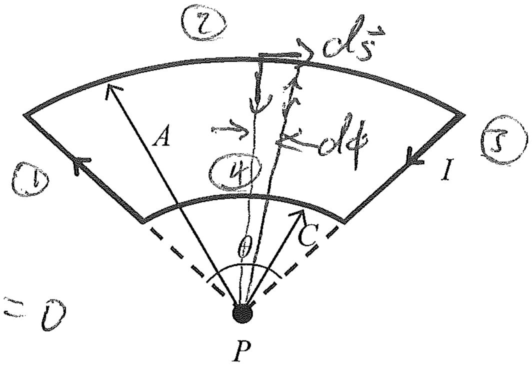
(40) 7. In the circuit shown, the curved segments of the wire are arcs of circles of radius A and C with a common center P. The straight segments are along radii. The wire carries current I in the direction indicated. Find the ***magnitude*** and ***direction*** of the magnetic field $\vec{B}$ at point P. Express your answer in terms of I, A, C, and θ.



Divide into 4 segments

for ① $d\vec{s}$ and $\hat{r}$ in opposite directions so

$$d\vec{s} \times \hat{r} = 0 \Rightarrow B_{①} = 0$$

for ③ $d\vec{s}$ and $\hat{r}$ in same direction so $d\vec{s} \times \hat{r} = 0$

$$\Rightarrow B_{③} = 0$$

for ② $d\vec{s}$ and $\hat{r}$ are $\perp$ so $|d\vec{s} \times \hat{r}| = ds$; direction is into page

$$dB_{②} = \frac{\mu_0 I}{4\pi} \frac{|d\vec{s} \times \hat{r}|}{r^2} = \frac{\mu_0 I \, ds}{4\pi A^2}$$

$$ds = A\, d\phi$$

$$dB_{②} = \frac{\mu_0 I \, d\phi}{4\pi A} \Rightarrow B_{②} = \int dB_{②} = \frac{\mu_0 I}{4\pi A} \int_0^\theta d\phi = \frac{\mu_0 I}{4\pi A} \theta$$

Similarly $B_{④} = \frac{\mu_0 I}{4\pi C} \theta$; direction is out of page.

Define $+\hat{k}$ as out-of-page

$$\vec{B} = \frac{\mu_0 I}{4\pi} \theta \left[\frac{1}{C} - \frac{1}{A}\right] \hat{k}$$

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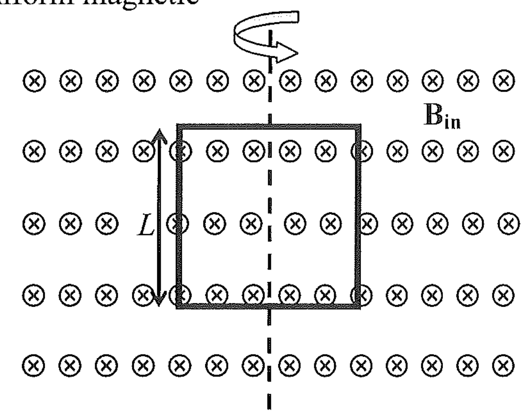
8. A square conducting coil with sides of length L contains N turns of wire and has a total resistance of R. The coil is rotated with angular speed ω about a vertical axis through its center (see figure) in a region of uniform magnetic field B_{in} directed into the plane of the paper.



(20) a) The coil is initially oriented so that its plane coincides with that of the paper. Calculate the induced emf in the coil as a function of time. Leave your answer in terms of L.

for 1 turn $\Phi_B = \vec{B}\cdot\vec{A} = BA\cos\theta$

$= BA\cos\omega t$

$= BL^2\cos\omega t$

$$|\mathcal{E}| = N\left|\frac{d\Phi_B}{dt}\right| = NBL^2\left|\frac{d(\cos\omega t)}{dt}\right| = NBL^2\omega\sin\omega t$$

(10) b) The maximum current induced in the coil is found to be I_{max}. Use this information to determine the length of the sides of the square L.

$I_{max} = \frac{\mathcal{E}_{max}}{R}$; from (a) $\mathcal{E}_{max} = NBL^2\omega$

$I_{max} = \frac{NBL^2\omega}{R} \Rightarrow L^2 = \frac{I_{max}R}{NB\omega}$

$L = \sqrt{\frac{I_{max}R}{NB\omega}}$

(10) c) When the induced emf is a maximum what is the magnitude of the torque exerted on the coil by the magnetic field?

$\mathcal{E}_{max}$ when $\sin\omega t = \sin\theta = 1 \Rightarrow \theta = \frac{\pi}{2}$

$\vec{\tau} = \vec{\mu}\times\vec{B} = NI\vec{A}\times\vec{B} \Rightarrow |\vec{\tau}| = NIAB\sin\theta$

when $\theta = \frac{\pi}{2}$ $|\vec{\tau}| = NIAB = NI_{max}L^2B$

or $|\vec{\tau}| = NI_{max}B\left(\frac{I_{max}R}{NB\omega}\right) = \frac{I_{max}^2R}{\omega}$

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9. A small square mirror with sides of length L faces a light source that emits a single wavelength of light. The light source is a distance D from the mirror and it radiates uniformly in all directions. At the mirror the electric field amplitude of the light is E_0.

(10) a) Determine the amplitude of the magnetic field of the light at the mirror, ***and*** the intensity of the light at the mirror.

$$B_0 = \frac{E_0}{c}$$

$$I = \frac{1}{2} c \varepsilon_0 E_0^2 = \frac{E_0^2}{2\mu_0 c} = \frac{c B_0^2}{2\mu_0}$$

any of these ok

(15) b) What is the average force exerted on the mirror by the light? You can assume that the mirror's surface is perpendicular to the incident light, and that the intensity of the light is uniform over the mirror's surface.

$$\langle P_{rad} \rangle = \frac{2I}{c} = \frac{F}{area} \Rightarrow F = \frac{2I(area)}{c}$$

$$F = \frac{2I}{c} L^2 \quad \text{and from above}$$

$$F = \varepsilon_0 E_0^2 L^2$$

(15) c) Determine the total power output of the light source assuming that it radiates uniformly in all directions.

$$I = \frac{P}{area} \Rightarrow P = I(area) = I(4\pi D^2)$$

$$P = \frac{1}{2} c \varepsilon_0 E_0^2 (4\pi D^2)$$

$$P = 2\pi c \varepsilon_0 D^2 E_0^2$$

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