Exam Total

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PHYS 2135 Exam III
April 23, 2019

Name: ____________________ Section: _________

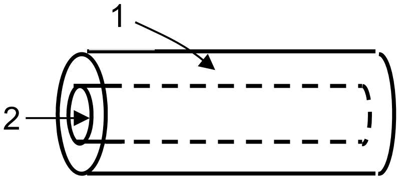
For questions 1-5, select the best answer. For problems 6-10, solutions must begin with an Official Starting Equation, when appropriate. Work must be shown to receive credit. Calculators are not allowed.

(8) ___**B**___ **1.** Two long, straight, parallel wires carry identical currents in opposite directions. The force between the two wires is

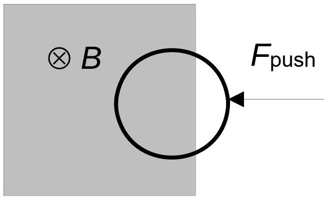
[A]	attractive	[B]	repulsive
[C]	zero	[D]	indeterminate

(8) ___**C**___ **2.** Two solenoids, wound in the same direction, are coaxial as shown. Solenoid 1, outer, has 1000 turns/meter and twice the radius of solenoid 2, inner, which has 2000 turns/meter. What direction and ratio of currents, I_1/I_2 will result in zero magnetic field near the axis of solenoid 2?

[A] $I_1/I_2=2$, currents in same direction
[B] $I_1/I_2=1/2$, currents in same direction
[C] $I_1/I_2=2$, currents in opposite direction
[D] $I_1/I_2=1/2$, currents in opposite direction



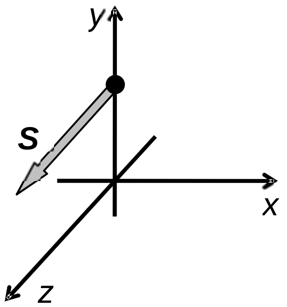
(8) ___**B**___ **3.** A circular conducting loop is pushed into a region of uniform magnetic field, directed into the page as shown in the diagram. In which direction will the induced current flow?



[A] ↻ [B] ↺ [C] ⊙ [D] ⊗

(8) ___**D**___ **4.** The figure to the right shows the direction of propagation (Poynting vector) of an electromagnetic wave at a certain point in space and a certain instant in time. If the magnetic field direction at this point and time is in the positive *y* direction, what is the direction of the electric field at this point and time?

[A] negative *z*	[B] positive *z*
[C] negative *x*	[D] positive *x* .



(8) ________ **5** (Free). Electric and magnetic fields

[A] are hard to plow.
[B] provide a good foundation for power lines.
[C] flourish in sunlight.
[D] need water to grow currants.

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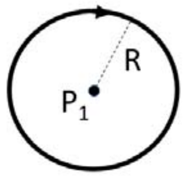
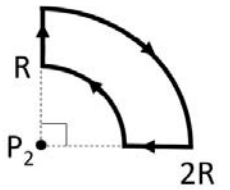
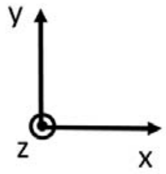
6. Two thin wires are shaped as in the figure (a) and (b) below. They each carry a steady current I in the direction indicated by the arrows.



(a)



(b)



(15) (a) Calculate the magnitude and direction of the magnetic field at the center P_1 of the loop of radius R as a function of μ_0, I, and R. You must show the steps of your derivation and explain the result to get credit.

$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{s} \times \hat{r}}{r^2}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi}\int_0^{2\pi}\frac{Rd\phi(-\hat{\phi}) \times (-\hat{r})}{R^2}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi R}\int_0^{2\pi} d\phi\,(-\hat{k})$$

$$\vec{B} = \frac{-2\pi\mu_0 I}{4\pi R}\hat{k}$$

$$\vec{B} = -\frac{\mu_0 I}{2R}\hat{k}$$

(25) (b) Calculate the magnitude and direction of the magnetic field at the point P_2 as a function of μ_0, I, and R. You must show the steps of your derivation and explain the result to get credit. The inner arc has a radius R and the outer arc has a radius 2R.

For the two straight segments, $d\vec{s} \parallel \hat{r}$. Thus, they do not contribute to $\vec{B}$.

For the inner arc:

$$\vec{B}_I = \frac{\mu_0 I}{4\pi}\int_0^{\pi/2}\frac{Rd\phi\hat{\phi}\times(-\hat{r})}{R^2}$$

$$\vec{B}_I = \frac{\mu_0 I}{4\pi R}\left(\frac{\pi}{2}\right)\hat{k}$$

For the outer arc:

$$\vec{B}_O = \frac{\mu_0 I}{4\pi}\int_0^{\pi/2}\frac{2Rd\phi(-\hat{\phi})\times(-\hat{r})}{(2R)^2}$$

$$\vec{B}_O = \frac{-\mu_0 I}{8\pi R}\left(\frac{\pi}{2}\right)\hat{k}$$

$$\vec{B} = \left(\frac{\mu_0 I}{8R} - \frac{\mu_0 I}{16R}\right)\hat{k}$$

$$\vec{B} = \frac{\mu_0 I}{16R}\hat{k}$$

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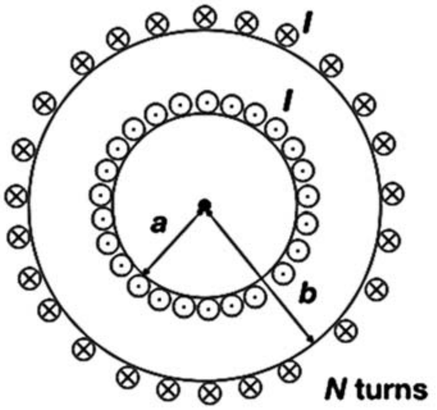
7. Consider an ideal toroidal solenoid with N turns, each carrying a current I directed as shown in the figure. Applying Ampere's law, find the direction and magnitude of the magnetic field in the following regions:



(10) (a) *r > b.*

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enc}}$$

There is no enclosed current. $\vec{B} = 0$.

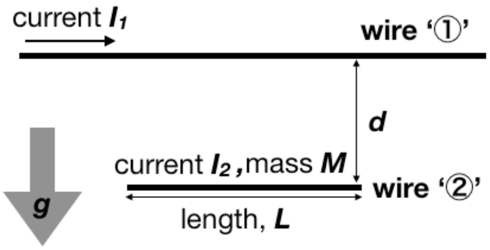
(10) (b) *a < r < b.*

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enc}}$$

$$B(2\pi r) = \mu_0 NI$$

$$B = \frac{\mu_0 NI}{2\pi r}$$ *Counter-Clockwise (By the right hand rule)*

8. As shown in the figure, a long straight wire, labeled ①, carries a current I_1 and is fixed in position. Wire ②, of length L and mass M, carries a current I_2 and is placed a distance d from wire ①.



(10) (a) **Applying Ampere's law**, find the direction and magnitude of the magnetic field produced **at** wire ② **by** wire ①.

Direction: (circle one) up (↑) down (↓) [✓ into page (⊗)] out of page (⊙)

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enc}}$$

$$B(2\pi d) = \mu_0 I_1$$

$$B = \frac{\mu_0 I_1}{2\pi d}$$

(10) (b) Wire ② does not fall, but stays at the same vertical position. Under this condition, find the direction of the current in wire ②. Also, express the distance d in terms of I_1, I_2, L, M, and constants. Note that gravity is NOT ignorable.

Direction: (circle one) [✓ left to right (→)] right to left (←)

$$F_g = F_B$$

$$Mg = \left|I_2\vec{L}_2 \times \vec{B}_1\right| = I_2 L\left(\frac{\mu_0 I_1}{2\pi d}\right)$$

$$d = \frac{\mu_0 I_1 I_2 L}{2\pi M g}$$

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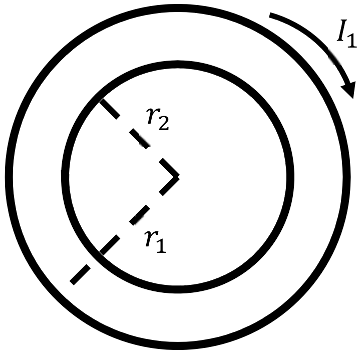
9. The current in a long solenoid is given by $I_1 = I_0 e^{-\alpha t}$ and is clockwise as illustrated in the figure. The solenoid has N_1 windings, length L_1, radius r_1 and resistance R_1. A single circular wire loop of radius $r_2 < r_1$ and resistance R_2 is placed at the center of the solenoid as shown in the figures. (I_0 and α are both positive quantities.

End View

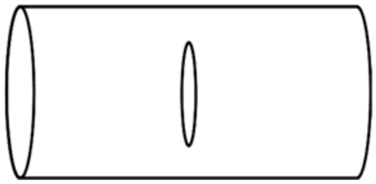


(10) (a) In what direction is the induced current in the loop for $t > 0$? [Circle the correct answer.]

[✓ [A] Clockwise]
[B] Counter-clockwise

(20) (b) Determine the induced emf $\mathcal{E}$ in the loop for $t > 0$.

Side View



$$B_1 = \mu_0 n_1 I_1$$
$$B_1 = \mu_0 \left(\frac{N_1}{L_1}\right) I_0 e^{-\alpha t}$$
$$\mathcal{E} = -\frac{d}{dt}\,\phi_B$$
$$\mathcal{E} = -\frac{d}{dt}\left[\mu_0 \left(\frac{N_1}{L_1}\right) I_0 e^{-\alpha t} (\pi r_2^2)\right]$$
$$\mathcal{E} = \frac{\mu_0 N_1 I_0 \alpha \pi r_2^2}{L_1} e^{-\alpha t}$$

(10) (c) Determine the current I_2 in the loop for $t > 0$.

$$I_2 = \frac{\mathcal{E}}{R_2}$$
$$I_2 = \frac{\mu_0 N_1 I_0 \alpha \pi r_2^2}{L_1 R_2} e^{-\alpha t}$$

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10. A satellite located a distance H above the surface of the earth emits a radio signal of frequency f uniformly in all directions. The signal with intensity I_0 is received by a totally absorbing square antenna with side length L on the surface of the earth that is perpendicular to the incoming signal. All answers should be expressed in terms of H, f, I_0, L, and fundamental constants.

(10) (a) What is the power of the signal generated by the satellite?

$$I = \frac{P}{A}$$
$$P = 4\pi H^2 I_0$$

(10) (b) What is the maximum electric field at the location of the antenna?

$$I = c\langle u\rangle = c\left(\frac{1}{2}\epsilon_0 E_{\text{max}}^2\right)$$
$$\sqrt{\frac{2I_0}{c\epsilon_0}} = E_{\text{max}}$$

(10) (c) What is the average energy density delivered to the antenna by the electric field?

$$\langle u_E\rangle = \frac{1}{2}\langle u\rangle = \frac{1}{2}\left(\frac{I_0}{c}\right)$$

(10) (d) What force does the radiation exert on the antenna?

$$\frac{F}{A} = \langle P_{\text{rad}}\rangle = \frac{I}{c}$$
$$F = \frac{I_0 L^2}{c}$$

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