Exam Total

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PHYS 2135 Exam II
November 12, 2019

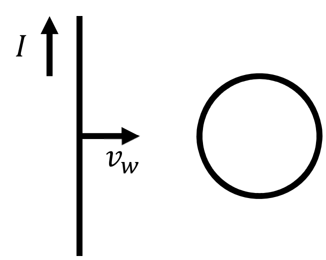
Name: ____________________ Section: _________

For questions 1-5, select the best answer. For problems 6-9, solutions must begin with an Official Starting Equation, when appropriate. Work for problems must be shown and answers provided in the given boxes. Calculators are not allowed.

(8) ___**A**___ **1.** Light from a laser in medium A is totally internally reflected off the surface of medium B even though medium B is clear. Select the correct statement about the speed of light in the two media.

[A] $v_A < v_B$
[B] $v_A = v_B$
[C] $v_A > v_B$
[D] The relative speeds in the two media cannot be determined.

(8) ___**B**___ **2.** A wire carrying a current upward is moved to the right near a stationary loop of wire, as illustrated. The current induced in the loop of wire is …

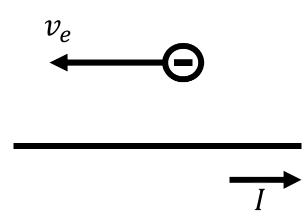


[A] clockwise.
[B] counter-clockwise.
[C] zero.
[D] downward.

(8) ___**F**___ **3.** An electromagnetic wave traveling in the $+y$ direction has an electric field in the $+x$ direction at a particular location and time. At the same location and time, the wave's magnetic field is in which direction?

[A] $\hat{\imath}$ [B] $\hat{\jmath}$ [C] $\hat{k}$
[D] $-\hat{\imath}$ [E] $-\hat{\jmath}$ [F] $-\hat{k}$

(8) ___**D**___ **4.** At a particular moment in time, an electron is moving parallel to a long straight wire carrying a current in the opposite direction, as illustrated. At the given moment of time, the force on the electron is in which direction?



[A] up [B] right [C] into page
[D] down [E] left [F] out of page

(8) _________ **5** (Free). Gauss, Ampere, Faraday and Maxwell would be a good name for which of the following?

[A] A law firm
[B] An electric company
[C] An ELO* tribute band
[D] A company that recycles gravitational lenses.

(*ELO was the Electric Light Orchestra)

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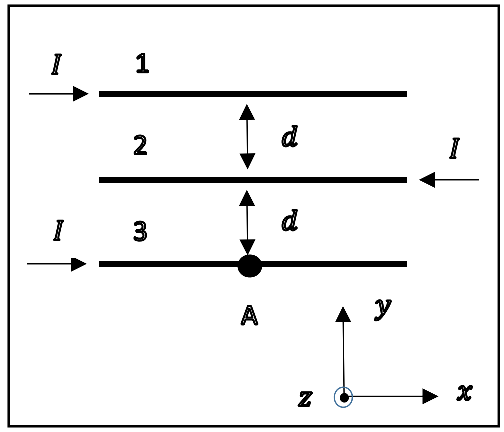
6. Three long parallel wires, all located within the $x-y$ plane, each carry a current I in the directions shown. The separation between adjacent wires is d. Point A is located at the midpoint of wire 3. [Express answers using given symbols and constants.]



(8) (a) What is the magnitude of the magnetic field generated by wire 1 at point A?

$$B = \frac{\mu_0 I}{2\pi(2d)}$$

$$\boxed{B = \frac{\mu_0 I}{4\pi d}}$$

(8) (b) What is the direction of the magnetic field from wire 1 at point A? Circle the correct direction.

$\hat{\imath}$ $-\hat{\imath}$ $\hat{\jmath}$ $-\hat{\jmath}$ $\hat{k}$ $-\hat{k}$

(8) (c) What is the magnitude of the magnetic field generated by wire 2 at point A?

$$\boxed{B = \frac{\mu_0 I}{2\pi d}}$$

(8) (d) What is the direction of the magnetic field from wire 2 at point A? Circle the correct direction.

$\hat{\imath}$ $-\hat{\imath}$ $\hat{\jmath}$ $-\hat{\jmath}$ $\hat{k}$ $-\hat{k}$

(8) (d) Compute the force per unit length on wire 3 from wires 1 and 2.

$$\vec{B} = \frac{-\mu_0 I}{4\pi d}\hat{k} + \frac{\mu_0 I}{2\pi d}\hat{k} = \frac{\mu_0 I}{4\pi d}\hat{k} \qquad \vec{L} = L\hat{\imath}$$

$$\vec{F} = I\vec{L} \times \vec{B} \qquad \frac{\vec{F}}{L} = I\frac{\mu_0 I}{4\pi d}(-\hat{\jmath})$$

$$\boxed{\frac{\vec{F}}{L} = \frac{-\mu_0 I^2}{4\pi d}\hat{\jmath}}$$

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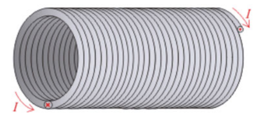
7. A thin, very long solenoid of diameter D and length $L >> D$ has a total of N turns of wire and carries a current I.



(10) (a) Calculate the magnitude of the magnetic field B_1 near the center of the solenoid. Express your answer using given symbols. You need to show derivation to get full credit.

$B_1 = \mu_0 \frac{N}{L} I$

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

$$\int_{\text{Left}} \vec{B} \cdot d\vec{s} + \int_{\text{Top}} \vec{B} \cdot d\vec{s} + \int_{\text{Right}} \vec{B} \cdot d\vec{s} + \int_{\text{Bottom}} \vec{B} \cdot d\vec{s} = \mu_0 NI$$

$\vec{B} \perp d\vec{s}$, 0 $\qquad$ $\vec{B} \perp d\vec{s}$, 0 $\qquad$ $B \approx 0$

$$BL = \mu_0 NI$$

(5) (b) The solenoid is stretched to twice its length while the total number of turns and the current are kept constant. What is the value of the magnetic field B_2 at the center of the solenoid after it has been stretched? Express your answer using B_1.

$B_2 = \frac{1}{2} B_1$

$$B_2 = \mu_0 \frac{N}{2L} I = \frac{1}{2} B_1$$

(10) (c) The original solenoid is now curved into the shape of a circle to form a toroidal solenoid. Calculate the magnitude of the magnetic field B_3 inside the toroid at a distance r from the center of the toroid. Express your answer using given symbols. You need to show derivation to get credit.

$B_3 = \frac{\mu_0 NI}{2\pi r}$

$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enc}}$ $\qquad$ $B(2\pi r) = \mu_0 NI$

(10) (d) Calculate the magnitude of the magnetic field B_4 outside the toroid. Express your answer using given symbols. You need to show derivation to get credit.

$B_4 = 0$

$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enc}} = 0$ $\qquad$ No net current through the surface.

(5) (e) Is the field inside the toroid uniform like in the solenoid? Circle the correct answer:

YES $\qquad$ NO

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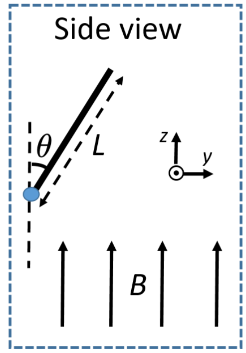
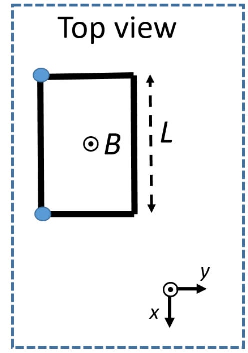
8. A square wire loop of side L is at an angle of θ (θ<90°) with respect to the vertical, as shown in the figure. The loop is in a spatially uniform magnetic field B pointing upward and has electrical resistance R. The magnetic field decreases with time as $B(t) = B_0 e^{-\alpha t}$ with $\alpha > 0$.





$$\vec{A} = A \sin\theta \, \hat{k} - A\cos\theta \, \hat{\jmath}$$

(8) (a) Calculate the magnitude of magnetic flux through the loop.

$$\boxed{\Phi_B = B_0 L^2 e^{-\alpha t} \sin\theta}$$

$$\Phi_B = \int \vec{B} \cdot d\vec{A} = \left(B_0 e^{-\alpha t} \hat{k}\right) \cdot \left[L^2\left(\sin\theta \, \hat{k} - \cos\theta \, \hat{\jmath}\right)\right]$$

(8) (b) Calculate the magnitude of the induced current in the loop

$$\boxed{I = \frac{B_0 \alpha L^2}{R} e^{-\alpha t} \sin\theta}$$

$$\mathcal{E} = -N \frac{d}{dt} \Phi_B$$

$$|\mathcal{E}| = \left|\frac{d}{dt}\left(B_0 L^2 e^{-\alpha t} \sin\theta\right| = \left|B_0 \, \alpha L^2 \, e^{-\alpha t} \ \ \sin\theta\right|$$

$$I = \frac{\mathcal{E}}{R}$$

(8) (c) What is the direction of the induced current in the loop as seen from the top (circle one)?

(i) $\odot$ (ii)  (iii) $\otimes$ (iv) 

(8) (d) Calculate the magnitude of the force on the right side of the loop.

$$\boxed{F = \frac{B_0^2 \alpha L^3}{R} e^{-2\alpha t} \sin\theta}$$

$$\vec{F} = I\vec{L} \times \vec{B}$$

$$\vec{F} = \left[\frac{B_0 \alpha L^2}{R} e^{-\alpha t} \sin\theta \, L(-\hat{\imath})\right] \times \left(B_0 e^{-\alpha t} \hat{k}\right)$$

(8) (e) In what direction (as seen from the side view) does the loop "want" to rotate in response to the magnetic force (circle one)? ~~Ignore gravity~~

(i) counter-clockwise (ii) clockwise

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9. The Sirius satellite orbits the Earth with its orbit radius 4 x 10^7 m (measured from the center of the Earth). The satellite transmits electromagnetic wave of 2 x 10^9 Hz. Assume the satellite transmits the radiation uniformly in all directions. The electromagnetic wave intensity received by a disk antenna on the Earth's surface is 2 x10^{-12} W/m^2 when the satellite is 3 x 10^7 m above it. The disk antenna has radius 2 m. (Your solution must begin with a starting equation. Use $\pi \approx 3$)

(value) (units)

da(10) (a) What is the wavelength of the Sirius satellite's radiation?

$\lambda = 0.15\,\mathrm{m}$

$$c = \lambda f$$

$$\lambda = \frac{c}{f} = \frac{3\times10^8\mathrm{m/s}}{2\times10^9\mathrm{Hz}} = 1.5\times10^{-1}\mathrm{m}$$

(10) (b) Calculate the total power output of the Sirius satellite.

$P = 2.16\times10^4\,\mathrm{W}$

$I = \frac{P}{A}$

$$P = IA = (2\times10^{-12}\mathrm{W/m^2})4\pi(3\times10^7\mathrm{m})^2$$

(10) (c) Calculate the amplitude of the electric and magnetic fields at the surface of the antenna. [Answer symbolically, using given symbols and constants.]

$E_m = \sqrt{\frac{2I}{c\epsilon_0}}$

$B_m = \sqrt{\frac{2I\mu_0}{c}}$

$I = c\langle u\rangle = \frac{1}{2}c\epsilon_0 E_m^2$ $\qquad$ $I = c\langle u\rangle = \frac{1}{2}c\frac{B_m^2}{\mu_0}$

(10) (d) Suppose the satellite's radiation is perpendicularly incident on disk antenna. If the radiation is completely absorbed by the antenna, what force does the radiation exert on the antenna?

$F = 8\times10^{-20}\,\mathrm{N}$

$\frac{I}{c} = \langle P_{\mathrm{rad}}\rangle = \frac{F}{A}$ $\qquad$ $F = \frac{I}{c}A = \frac{(2\times10^{-12}\mathrm{W/m^2})\pi(2\mathrm{m})^2}{3\times10^8\mathrm{m/s}}$

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