Unit Exam III: Problem #1 (Fall '16)

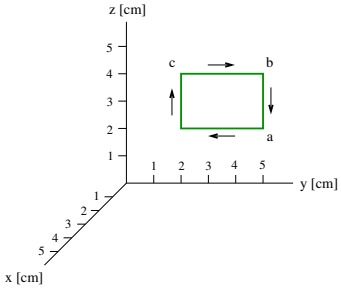
A current I is flowing around the conducting rectangular frame in the direction shown. The frame is located in a region of uniform magnetic field $\mathbf{B}$.

(a) Find the force $\mathbf{F}_{ab}$ (magnitude and direction) acting on side ab.

(b) Find the force $\mathbf{F}_{bc}$ (magnitude and direction) acting on side bc.

(c) Find the magnetic moment $\vec{\mu}$ (magnitude and direction) of the current loop.

(d) Find the torque $\vec{\tau}$ (magnitude and direction) acting on the frame.



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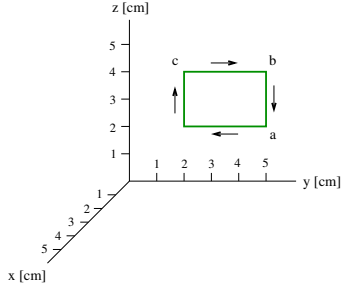

Solution for $I = 1.2\text{A}, \quad \mathbf{B} = 0.7\text{mT}\hat{\mathbf{k}}$:

(a) $\mathbf{F}_{ab} = (1.2\text{A})(-2\text{cm}\hat{\mathbf{k}}) \times (0.7\text{mT}\hat{\mathbf{k}}) = 0.$

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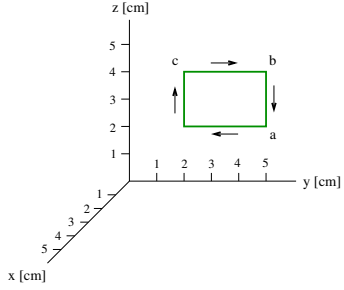

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(b) $\mathbf{F}_{bc} = (1.2\text{A})(3\text{cm}\hat{\mathbf{j}}) \times (0.7\text{mT}\hat{\mathbf{k}}) = 2.52 \times 10^{-5}\text{N}\hat{\mathbf{i}}.$

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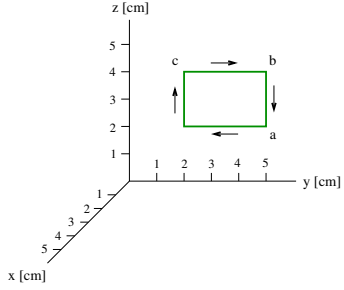

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(b) $\mathbf{F}_{bc} = (1.2\text{A})(3\text{cm}\hat{\mathbf{j}}) \times (0.7\text{mT}\hat{\mathbf{k}}) = 2.52 \times 10^{-5}\text{N}\hat{\mathbf{i}}.$

(c) $\vec{\mu} = (2\text{cm})(3\text{cm})(1.2\text{A})(-\hat{\mathbf{i}}) = -7.2 \times 10^{-4}\text{Am}^2\hat{\mathbf{i}}.$

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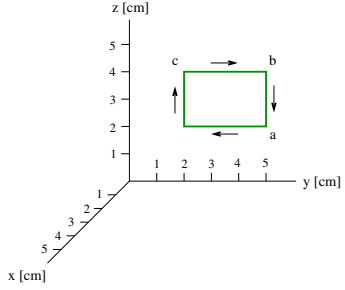

Solution for $I = 1.2\text{A}, \quad \mathbf{B} = 0.7\text{mT}\hat{\mathbf{k}}$:

(a) $\mathbf{F}_{ab} = (1.2\text{A})(-2\text{cm}\hat{\mathbf{k}}) \times (0.7\text{mT}\hat{\mathbf{k}}) = 0.$

(b) $\mathbf{F}_{bc} = (1.2\text{A})(3\text{cm}\hat{\mathbf{j}}) \times (0.7\text{mT}\hat{\mathbf{k}}) = 2.52 \times 10^{-5}\text{N}\hat{\mathbf{i}}.$

(c) $\vec{\mu} = (2\text{cm})(3\text{cm})(1.2\text{A})(-\hat{\mathbf{i}}) = -7.2 \times 10^{-4}\text{Am}^2\hat{\mathbf{i}}.$

(d) $\vec{\tau} = (-7.2 \times 10^{-4}\text{Am}^2\hat{\mathbf{i}}) \times (0.7\text{mT}\hat{\mathbf{k}}) = 5.04 \times 10^{-7}\text{Nm}\hat{\mathbf{j}}.$

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Solution for $I = 2.1\text{A}, \quad \mathbf{B} = 0.8\text{mT}\hat{\mathbf{j}}$

(a) $\mathbf{F}_{ab} = (2.1\text{A})(-2\text{cm}\hat{\mathbf{k}}) \times (0.8\text{mT}\hat{\mathbf{j}}) = 3.36 \times 10^{-5}\text{N}\hat{\mathbf{i}}.$

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Solution for $I = 2.1\text{A}, \quad \mathbf{B} = 0.8\text{mT}\hat{\mathbf{j}}$

(a) $\mathbf{F}_{ab} = (2.1\text{A})(-2\text{cm}\hat{\mathbf{k}}) \times (0.8\text{mT}\hat{\mathbf{j}}) = 3.36 \times 10^{-5}\text{N}\hat{\mathbf{i}}.$

(b) $\mathbf{F}_{bc} = (2.1\text{A})(3\text{cm}\hat{\mathbf{j}}) \times (0.8\text{mT}\hat{\mathbf{j}}) = 0.$

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Solution for $I = 2.1\text{A}, \quad \mathbf{B} = 0.8\text{mT}\hat{\mathbf{j}}$

(a) $\mathbf{F}_{ab} = (2.1\text{A})(-2\text{cm}\hat{\mathbf{k}}) \times (0.8\text{mT}\hat{\mathbf{j}}) = 3.36 \times 10^{-5}\text{N}\hat{\mathbf{i}}.$

(b) $\mathbf{F}_{bc} = (2.1\text{A})(3\text{cm}\hat{\mathbf{j}}) \times (0.8\text{mT}\hat{\mathbf{j}}) = 0.$

(c) $\vec{\mu} = (2\text{cm})(3\text{cm})(2.1\text{A})(-\hat{\mathbf{i}}) = -1.26 \times 10^{-3}\text{Am}^2\hat{\mathbf{i}}.$

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Solution for $I = 2.1\text{A}, \quad \mathbf{B} = 0.8\text{mT}\hat{\mathbf{j}}$

(a) $\mathbf{F}_{ab} = (2.1\text{A})(-2\text{cm}\hat{\mathbf{k}}) \times (0.8\text{mT}\hat{\mathbf{j}}) = 3.36 \times 10^{-5}\text{N}\hat{\mathbf{i}}.$

(b) $\mathbf{F}_{bc} = (2.1\text{A})(3\text{cm}\hat{\mathbf{j}}) \times (0.8\text{mT}\hat{\mathbf{j}}) = 0.$

(c) $\vec{\mu} = (2\text{cm})(3\text{cm})(2.1\text{A})(-\hat{\mathbf{i}}) = -1.26 \times 10^{-3}\text{Am}^2\hat{\mathbf{i}}.$

(d) $\vec{\tau} = (-1.26 \times 10^{-3}\text{Am}^2\hat{\mathbf{i}}) \times (0.8\text{mT}\hat{\mathbf{j}}) = -1.01 \times 10^{-6}\text{Nm}\hat{\mathbf{k}}.$