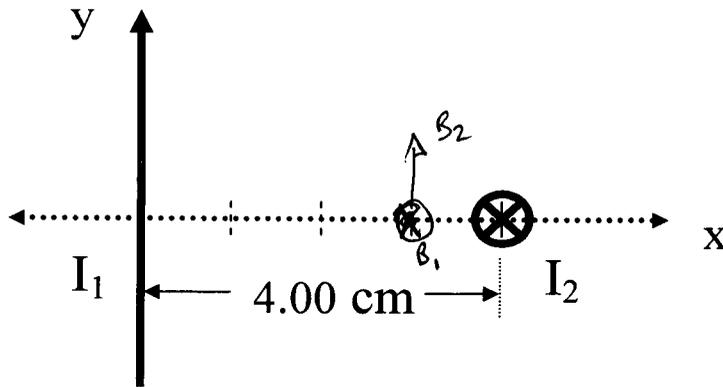


1. (10 points) Two very long parallel wires are oriented as show with current in the direction of the arrows. The current in the wire on the y axis is $I_1 = 9.00$ A upwards. The current in the wire at $x = 4.00$ cm is $I_2 = 4.00$ A in the direction shown.



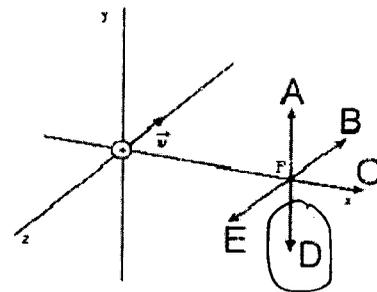
- a. (3) Draw the magnetic field vectors at the point (3.00 cm, 0).
- b. (7) What is the net magnetic field at this point? Your answer must be simplified, unambiguous and in a proper vector form. (10)

$$B_1 = \frac{\mu_0 I_1}{2\pi r_1} = 2 \times 10^{-7} \frac{N}{A^2} \frac{9A}{.03m} = 6 \times 10^{-5} T$$

$$B_2 = \frac{\mu_0 I_2}{2\pi r_2} = 2 \times 10^{-7} \frac{N}{A^2} \frac{4A}{.01m} = 8 \times 10^{-5} T$$

$$\vec{B} = \vec{B}_1 + \vec{B}_2 = -6 \times 10^{-5} T \hat{i} + 8 \times 10^{-5} T \hat{j}$$

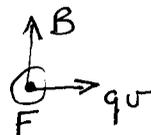
2. (2.5) A positively charged body is moving in the negative z direction as shown. What is the direction of the magnetic field due to the motion of this charged body at point P?



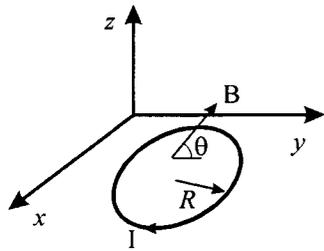
3. (2.5) If the magnetic field vector is directed toward the north and a positively charged particle is moving toward the east, what is the direction of the magnetic force on the particle?

- A. North
- B. South
- C. East
- D. West
- E. Down

D. Up



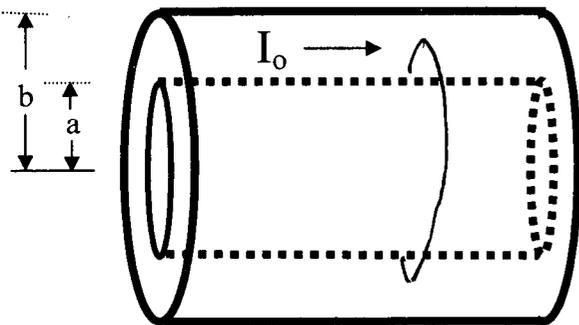
4. (2.5) A circular current loop lies in the xy plane and has radius $R = 10$ cm. The loop has 20 turns and carries a current $I = 4$ A as shown. The magnetic dipole of the loop is



$$\begin{aligned} \mu &= NIA \\ &= 20(4A)(\pi)(10\text{m})^2 \\ &= 2.51 \text{ A}\cdot\text{m}^2 \end{aligned}$$

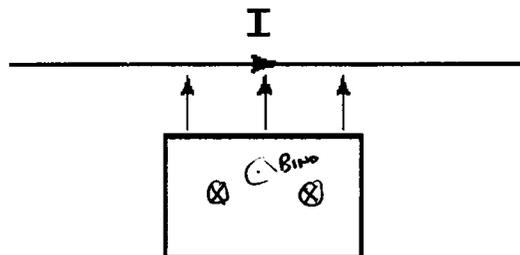
- A. $-2.51 \text{ A}\cdot\text{m} \hat{k}$
- B. $2.51 \text{ A}\cdot\text{m} \hat{k}$
- C. $-0.126 \text{ A}\cdot\text{m} \hat{k}$
- D. $0.126 \text{ A}\cdot\text{m} \hat{k}$
- E. $-0.628 \text{ A}\cdot\text{m} \hat{k}$

5. (10 points) A long straight cylindrical shell with an inner radius, a , and an outer radius, b , carries a uniform current I_0 to the right as shown for the segment below. Use Ampere's law to find the magnitude of the magnetic field at a distance r from the center axis of the shell when $a < r < b$. For any partial credit, be sure you start with Ampere's Law and clearly show the path around which you are integrating, specifying the dimensions of and current passing through that path.



$$\begin{aligned} \oint \vec{B} \cdot d\vec{Q} &= \mu_0 I_{ENCL} \\ B(2\pi r) &= \mu_0 \frac{(\pi r^2 - \pi a^2)(I_0)}{\pi b^2 - \pi a^2} \\ B &= \frac{\mu_0 I_0 (r^2 - a^2)}{2\pi r (b^2 - a^2)} \end{aligned}$$

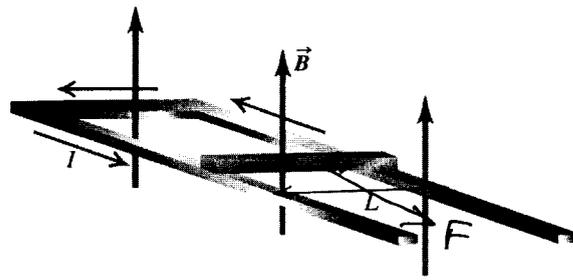
6 (2.5) A rectangular loop of wire is pushed toward a long straight current-carrying wire. The induced current in the loop is:



- A. clockwise
- B. counter-clockwise
- C. zero

7. A conducting bar of mass m and length L slides over horizontal rails that connected to a voltage source. The voltage source maintains a constant current I in the rails and bar, and a uniform, vertical magnetic field \vec{B} fills the region between the rails. This is known as a rail gun (and will be used on future Navy ships).

Let $B = 0.500 \text{ T}$, $I = 2000 \text{ A}$, $m = 25.0 \text{ kg}$, and $L = 50.0 \text{ cm}$. (20 points)



- a. (2) What is the direction of the magnetic force on the bar?

A: STOWN

- b. (4) Find the magnitude of the net force on the conducting bar. Ignore friction, air resistance, and electrical resistance.

$$|\vec{F}| = |\vec{I}L \times \vec{B}| = (2000\text{A})(.5\text{m})(.5\text{T}) = 500 \text{ N}$$

- c. (4) What is the acceleration of the bar?

$$a = \frac{F}{m} = \frac{500 \text{ N}}{25 \text{ kg}} = 20 \text{ m/s}^2$$

- d. (3) Derive an equation for the distance d that the bar must move along the rails from rest to attain a speed v .

$$v^2 = 2ad = 2\left(\frac{ILB}{m}\right)d$$

$$v = \sqrt{\frac{2ILBd}{m}} \quad d = \frac{m}{2ILB} v^2$$

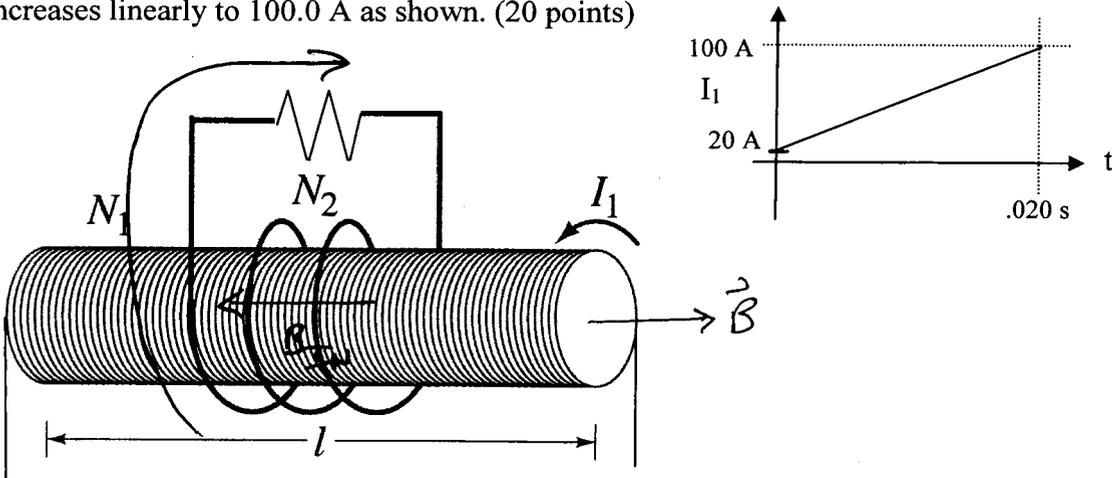
- e. (3) It has been suggested that rail guns based on this principle could accelerate payloads into earth orbit or beyond. Find the distance the bar must travel along the rails if it is to reach the escape speed for the earth (11.2 km/s).

$$d = \frac{11.2 \times 10^3 \text{ m/s}}{2(20 \text{ m/s}^2)} = 3.14 \times 10^6 \text{ m}$$

- f. (4) How much time would it take to reach this speed?

$$v = at, \quad t = \frac{11.2 \text{ km/s}}{20 \text{ m/s}^2} = 560 \text{ s}$$

8. An ideal solenoid has a cross-sectional area of 0.00500 m^2 . It is positioned in the center of a larger coil. Initially, current I_1 in the solenoid is 20.0 A , but in 0.0200 seconds, the current increases linearly to 100.0 A as shown. (20 points)



a. If the number of turns in the solenoid is $N_1 = 100.0$ and the length of the solenoid, $l = 5.00 \text{ cm}$, What is the initial magnetic field in the solenoid? Draw the direction of the magnetic field (5)

$$B_i = \mu_0 n I = \left(4\pi \times 10^{-7} \frac{\text{N}}{\text{A}^2}\right) \left(\frac{100}{.05 \text{ m}}\right) 20 \text{ A}$$

$$= 5.03 \times 10^{-2} \text{ T}$$

b. What is the rate of change of the magnetic field during these 0.0200 seconds.

$$B_f = 5(5.03 \times 10^{-2} \text{ T}) = 2.51 \times 10^{-1} \text{ T}$$

$$\frac{dB}{dt} = \frac{2.51 \times 10^{-1} \text{ T} - 5.03 \times 10^{-2} \text{ T}}{.02 \text{ s}} = 10.1 \frac{\text{T}}{\text{s}}$$

c. What voltage is induced in a larger **three-turn** ($N_2 = 3.00$) coil with cross section 0.0150 m^2 surrounding the smaller solenoid as shown? (5)

$$\mathcal{E} = \frac{d\Phi}{dt} = NA \frac{dB}{dt} = 3(10.1 \frac{\text{T}}{\text{s}})(.005 \text{ m}^2) = 0.15 \text{ V}$$

d. The larger coil is connected to a 5.00Ω resistor as shown (ignore the resistance of the coil of wire itself). What is the magnitude **and direction** of the current in the resistor while the magnetic field is changing? (5)

$$I = \frac{\mathcal{E}}{R} = \frac{.15 \text{ V}}{5 \Omega} = .030 \text{ A} \quad \text{LEFT} \rightarrow \text{RIGHT}$$