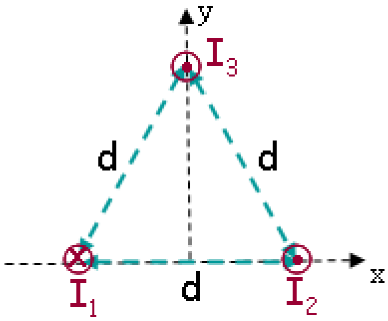
Three infinite straight wires are fixed in place and aligned parallel to the z-axis as shown. The wire at (x,y) = (-21 cm, 0) carries current I_1 = 3.8 A in the negative z-direction. The wire at (x,y) = (21 cm, 0) carries current I_2 = 0.8 A in the positive z-direction. The wire at (x,y) = (0, 36.4 cm) carries current I_3 = 5.5 A in the positive z-direction.



1) What is $B_x(0,0)$, the x-component of the magnetic field produced by these three wires at the origin?

$$B_x(0,0) = \frac{\mu_o I_3}{2\pi h}$$

The only x component contribution is from the I3 wire….

The constant u=1.25663706 × 10^{-6} m kg s^{-2} A^{-2}

Bx(0,0)=u (5.5 A)/2π .364 m=3.02x10^{-6} T

2) What is $B_y(0,0)$, the y-component of the magnetic field produced by these three wires at the origin?

In this case, the only contributes to the y component are from I1 and I2.

$$B_y(0,0) = -\frac{\mu_o}{2\pi \frac{d}{2}}(I_1 + I_2) = -\frac{\mu_o}{\pi d}(I_1 + I_2)$$

By(0,0)=-u(3.8+.8)A/π .21*2 m = -4.38 x 10^{-6}T

3) What is $F_x(1)$, the x-component of the force exerted on a one meter length of the wire carrying current I_1?

$$B_y(1) = -\frac{\mu_o I_3}{2\pi d}\sin(30^o) - \frac{\mu_o I_2}{2\pi d} \Rightarrow F_x(1) = -\frac{\mu_o I_1}{2\pi d}\left(I_3 \sin(30^o) + I_2\right)$$

Fx=-u 3.8A/(2π.21*2) (5.5 A sin(d30)+.8 A)=-6.42x10^{-6} N

4) What is $F_y(1)$, the y-component of the force exerted on a one meter length of the wire carrying current I_1?

$$B_x(1) = \frac{\mu_o I_3}{2\pi d}\cos(30^o) \Rightarrow F_y(1) = -\frac{\mu_o I_1 I_3}{2\pi d}\cos(30^o)$$

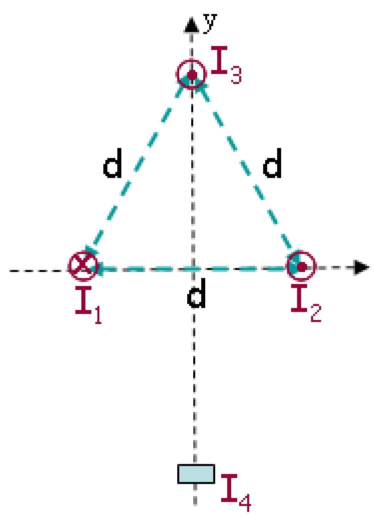
Fy=-u*3.8A*5.5Acos(30)/(2*π*2*.21m)=-8.61x10^{-6} N

5) What is $F_x(2)$, the x-component of the force exerted on a one meter length of the wire carrying current I_2?

$$B_y(2) = +\frac{\mu_o I_3}{2\pi d}\sin(30^o) - \frac{\mu_o I_1}{2\pi d} \Rightarrow F_x(2) = \frac{\mu_o I_2}{2\pi d}\left(I_1 - I_3 \sin(30^o)\right)$$

Fx=-u .8A/(2π.21*2) (3.8 A sin(d30)-5.5 A)=4x10^{-7}N

6)



Another wire is now added, also aligned with the z-axis at (x,y) = (0, -36.4 cm) as shown. This wire carries current I_4 A. Which of the following statements is true?

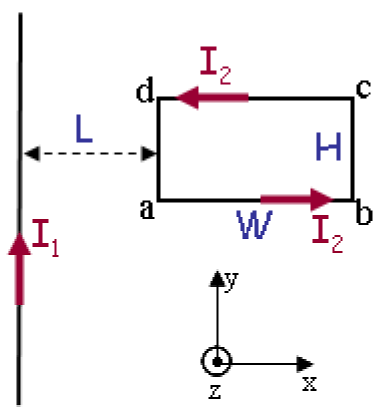
- If I_4 is directed along the positive z-axis, then it is possible to make the y-component of the magnetic field equal to zero at the origin.
- If I_4 is directed along the negative z-axis, then it is possible to make the y-component of the magnetic field equal to zero at the origin.
- If I_4 is directed along the positive z-axis, then it is possible to make the x-component of the magnetic field equal to zero at the origin.
- If I_4 is directed along the negative z-axis, then it is possible to make the x-component of the magnetic field equal to zero at the origin.

Right Answer:
3

Feedback:
Your answer is correct! If the current I_4 flows in the same direction as the current I_3, then the magnetic field it produces at the origin can cancel the field produced by the current I_3. The field produced by both these currents is in the x-direction.

Recall question 1, the only contribution to the x component of the magnetic field at the origin is due to I3. That means if you place another current at I4 think about how to make the magnetic field contributions be anti-parallel.

A rectangular loop of wire with sides H = 23 cm and W = 54 cm carries current I_2 = 0.239 A. An infinite straight wire, located a distance L = 35 cm from segment ad of the loop as shown, carries current I_1 = 0.662 A in the positive y-direction.



1) What is $F_{ad,x}$, the x-component of the force exerted by the infinite wire on segment ad of the loop?

Recall: F=ILxB

$$F_{ad,x} = I_2 H \frac{\mu_0 I_1}{2\pi L}$$

Fad,x=.239 A *.23 m *u*.662 A/(2π*.35 m)=2.07×10^{-8}N

2) What is $F_{bc,x}$, the x-component of the force exerted by the infinite wire on segment bc of the loop?

$$F_{bc,x} = -I_2 H \frac{\mu_o I_1}{2\pi(L+W)}$$

Note the sign is opposite from before, you'd expect that because the current is going in the opposite direction here.

Fbc,x=-.239 A *.23 m *u*.662 A/(2π*(.35 m+.54m)=-.81x10^{-9} N

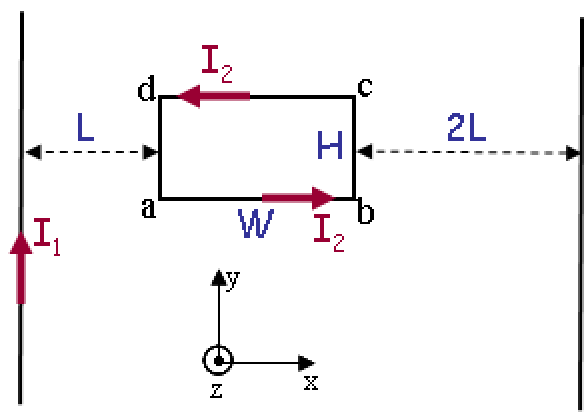
3) What is $F_{net,y}$, the y-component of the net force exerted by the infinite wire on the loop?

Think about the possible contributions to Fy from the top and bottom wire and the directions of the currents…

Fnet,y=0.

4)

Another infinite straight wire, aligned with the y-axis is now added at a distance 2L = 70 cm from segment bc of the loop as shown. A current, I_3, flows in this wire. The loop now experiences a net force of zero.



What is the direction of I_3?

- along the positive y-direction
- along the negative y-direction

Right Answer:
2

Feedback:
Your answer is correct! The current I_1 produces a net force on the loop in the positive x-direction. For the current I_3 to produce a net force on the loop that cancels the force from I_1, it must be directed in the negative y-direction to create a magnetic field in the region of the loop that is directed in the negative z-direction.

Here I thought about how the B field lines from each wire would add up, and under what conditions they would cancel.

4) What is the magnitude of I_3?

$$I_1\left(\frac{1}{L}-\frac{1}{L+W}\right)=I_3\left(\frac{1}{2L}-\frac{1}{2L+W}\right) \Longrightarrow I_3=I_1\left(\frac{2L(2L+W)}{L(L+W)}\right)=2I_1\frac{2L+W}{L+W}$$

The only forces to consider are the x components, (re problem 3). Set the forces due to each wire on the right and left vertical wire segments so that they are equal and opposite.

I3=2*.662 A *(2*.35m+.54 m)/(.35 m+.54 m)=1.844 A (in the neg y direction, the problem asked for magnitude)