Phys122

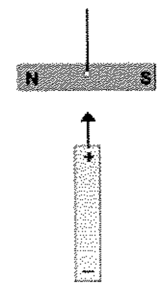
HW 7: Due Thursday, April 6, 2006

Chapter 19

Problems: 2, 10, 26, 30, 60

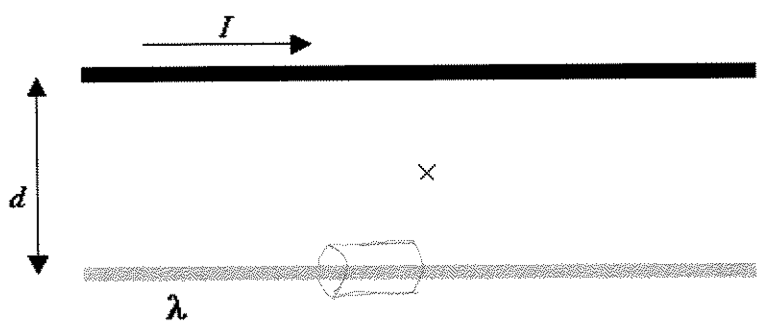
Magnets and charge

A bar magnet is hung from a string through its center as shown in the figure. A charged rod is slowly brought up slowly into the position shown. In what direction will the magnet tend to rotate? Suppose the charged rod were replaced by a bar magnet with the north pole on top. In what direction will the magnet tend to rotate? Is there a difference between what happens to the hanging magnet in the two situations? Explain why you either do or do not think so.



Comparing electric and magnetic forces

In the picture below are shown a long wire carrying a current *I* to the right and a long amber rod with a charge density (charge/unit length) of λ. Assume *I* and λ are both positive.



$\oint E \cdot da = Q_{enc}/\varepsilon_0$

$E(2\pi r)L = \lambda L/\varepsilon_0$

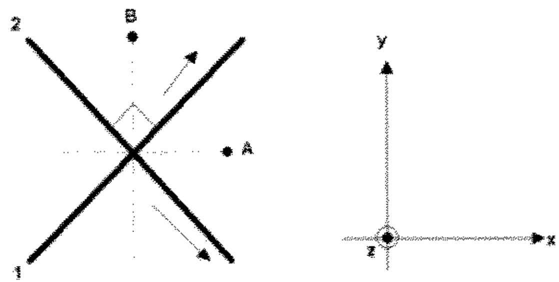
$E = \frac{\lambda}{2\pi\varepsilon_0}\left(\frac{1}{r}\right)$

A. The two are separated by a distance *d*. The point marked x is half-way between them. On the diagram, draw arrows to represent the following. **(Be sure to label your arrows clearly so we can tell which one is which.)**
   i. the direction of the magnetic field at the point marked x.
   ii. the direction of the electric field at the point marked x
   iii. the direction of the electric force that a charge *q* placed at x would feel
   iv. the direction of the magnetic force that a charge *q* placed at x would feel if it were moving to the right.

B. The current, *I*, is +10 A, the charge density, λ, is -1 nC/m (=10^{-9} C/m) (note that it is negative), and the distance between the wires is 40 cm. At the instant shown, a proton with charge $q = 1.6 \times 10^{-19}$ C is moving into the page with a speed $v = 10^6$ m/s. Ignoring gravity, what is the magnitude and direction of the net force it feels at that time?

Magnetic forces

In the figure at the left below are shown parts of two long current carrying wires labeled 1 and 2. The wires lie in the same plane and cross at right angles at the point indicated. When it carries a current, each wire carries the same amount of current in the direction shown. At the right is shown a set of coordinate directions for describing the direction of vectors.



For each of the vectors labeled (a)-(c) below indicate the direction of the vector by specifying its direction using the coordinate system shown. For example, you might specify "the +x direction" or "the -z direction" or "in the x-y plane at 45° between the +x and +y directions." If the magnitude of the vector requested is zero, write "0".

a. The direction of the force on a positively charged ion at the point B moving in the +y direction if only wire 1 carries current. +x direction
b. The direction of the force on a positively charged ion at the point B moving in the -z direction if both wires carry current. 0
c. The direction of the force on a positively charged ion at the point A moving in the +x direction if only wire 2 carries current. -y

For the next two parts of the problem, select which answer is correct if both wires carry current.

d. The magnetic force on wire 1 will
   i. push it in the -z direction
   ii. push it in the +z direction
   iii. tend to rotate it clockwise about the joining point
   iv. tend to rotate it counter-clockwise about the joining point
   v. none of the above.
e. The magnetic force on wire 2 will
   i. push it in the -z direction
   ii. push it in the +z direction
   iii. tend to rotate it clockwise about the joining point
   iv. tend to rotate it counter-clockwise about the joining point
   v. none of the above.

Tutorial Problem

In lab recently you studied magnets and the forces they put on each other.

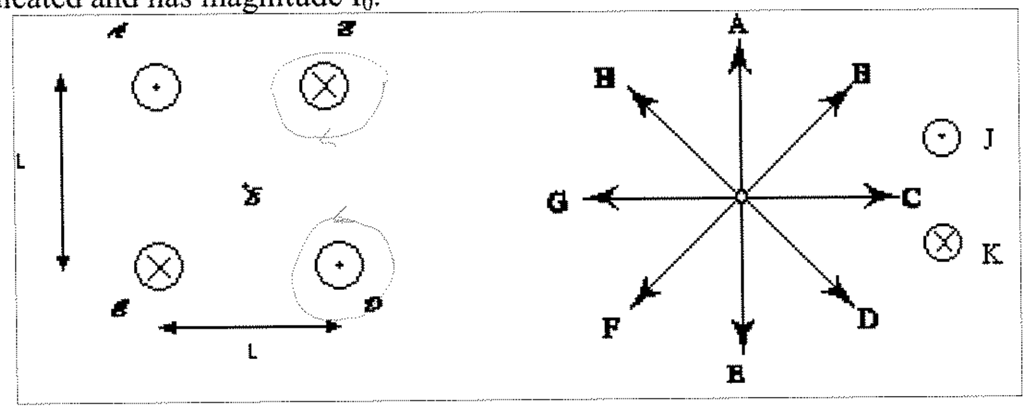
Below is a statement and drawing from Leah explaining her model of a magnet.

> *"A magnet has two ends, called a north pole and a south pole. The north pole is positively charged, and the south pole is negatively charged. Throughout the magnet there are atoms with positive and negative charge, but in the north pole there are more positives than negatives, and in the south pole there are more negatives than positives. It's almost like a positive charged piece of tape attached to a negative charged piece of tape except it stays charged a lot longer."*

1. Explain at least three things you could do to test Leah's model using equipment available in the lab room. Include in your answer all the possible results and whether they agree with her model, disagree with her model, or do neither.

2. What experiences do you have from everyday life that could bear on Leah's model? Explain if they agree or disagree with this model.

3. The figure at the left below shows a cross section of four long parallel wires (labeled A through D) taken in a plane perpendicular to the wires. One or more of the wires may be carrying a current. If a wire carries a current it is in the direction indicated and has magnitude I_0.



For each of the four vector quantities (i) through (iv) give the direction of the quantity. To indicate the direction, use one of the letters associated with a directional arrow on the "compass" figure at the right below. If the magnitude of the quantity is zero, write "0". If it is non-zero, but in none of the indicated directions, write "Other".

For each answer, give a brief explanation of how you got it.

a. Only wires B and D are carrying current. The direction of the force on wire D is ____.

b. Only wires B and D are carrying current. The direction of the force felt by an electron traveling in the C direction (on the compass) is ____.

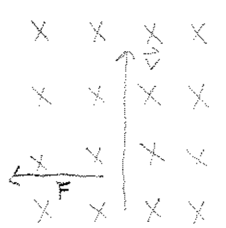
c. Only wires B and D are carrying current. The direction of the force felt by an electron traveling in the A direction (on the compass) is ____.

d. All four wires are carrying current. The direction of the net force felt by wire A is ____.

HWK 7

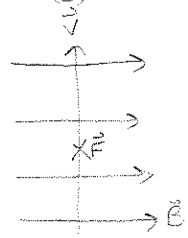
2) a)

(a)



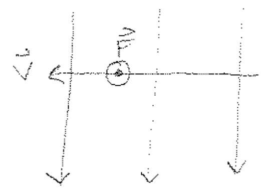
left

(b)



into page

(c)



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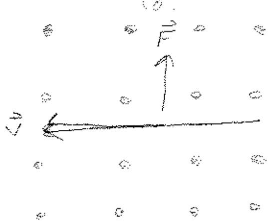
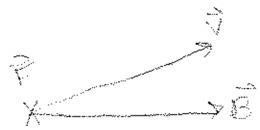
(d)



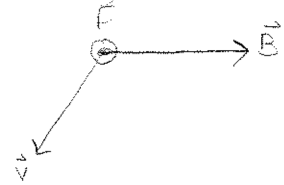
up

(e)



into page

(f)



out of page

b) $F = qvB\sin\theta$ so if q is negative F goes in opposite direction

(a) right (b) out of page (c) into page (d) down (e) out of page (f) into page

10) force on arm = force on all Na^+ ions

$F_1 = qvB\sin\theta = (1.6\times10^{-19}C)(0.851\,m/s)(0.254T)\sin(51.0°)$

$F_1 = 2.69\times10^{-20}\,N$

for $N = (100cm^3)(3.0\times10^{20}\,Na^+\,ions/cm^3) = 3.0\times10^{22}\,Na^+$ ions

$\boxed{F_N = NF_1 = 807N}$

26)

resistance of loop $= \rho \frac{\ell}{A_c} = (1.70\times10^{-8}\,\Omega\cdot m)\frac{(8m)}{(1.00\times10^{-4}m^2)}$

$R = 0.00136\,\Omega = 1.36\times10^{-3}\,\Omega$

using $V=IR \Rightarrow I = V/R = (0.100V)/(1.36\times10^{-3}\,\Omega) = 73.5A$

$\tau = BIA_\ell \sin\theta$

maximum torque is when $\sin\theta = 1$

$\Rightarrow \tau = (0.400T)(73.5A)(4m^2) = \boxed{117 N\cdot m}$

30) $r = mv/qB$

as in problem 29: $v = E/B = (950 V/m)/(0.930T)$

$\Rightarrow v = 1022\, m/s$

$r = \frac{(2.18\times10^{-26}kg)(1022 m/s)}{(1.6\times10^{-19}C)(0.930T)} = \boxed{1.49\times10^{-4}m}$

60) $B = k/h^3$ distance from plane to top of disk $= \frac{1.0mm}{2} = 0.5mm$

$B(h=0.5mm) = k/(0.5mm)^3 = (5\times10^{-2}T)$ at top of disk

$\Rightarrow k = (0.5mm)^3(5\times10^{-2}T) = 6.25\times10^{-12}\,T\cdot m^3$

when $B = 5.0\times10^{-5}T$:

$B = \frac{k}{h^3} \Rightarrow 5.0\times10^{-5}T = \frac{(6.25\times10^{-12}\,T\cdot m^3)}{h^3}$

$\Rightarrow h^3 = \frac{6.25\times10^{-12}\,T\cdot m^3}{5.0\times10^{-5}T} = 1.25\times10^{-7}m^3$

$\Rightarrow h = 0.005m \Rightarrow x = h - 0.5mm = \boxed{4.5mm}$

Magnets & charge

If the polarized rod is brought in slowly enough that it generates no magnetic field then it will have **no effect** on the (presumably) neutral bar magnet. However, even if a field is generated by the polarized rod, it will tend to roll the magnet up the string, which gravity will prevent, so **no effect**

If the rod is replaced by a bar magnet with the N pole up the top magnet will **rotate clockwise** until its S pole points down.

There is a difference between the two because the poles of a magnet don't behave as if they are charged.

Comparing electric and magnetic forces

A. i: into the page

ii: up

iii: up (if $q>0$) or down (if $q<0$)

iv: up (if $q>0$) or down (if $q<0$)

B. $F_{mag} = qvB\sin\Theta$

since both $\vec{v}$ and $\vec{B}$ go into the page, $\Theta = 0$ and $\sin\Theta = 0$

$\Rightarrow$ **$F_{mag} = 0$**

$F_{electric} = qE$

if we draw a Gaussian cylinder around the charged rod and use $EA = Q_{enclosed}/\varepsilon_0$ there is no $\vec{E}$ field perpendicular to the ends of the cylinder

[illegible]

Comparing electric and magnetic forces
(continued...)

the charge enclosed is λL, where L is the length of the cylinder and r is its radius

so $EA = Q_{enc}/\varepsilon_0$

$\Rightarrow E(2\pi r)L = \lambda L/\varepsilon_0$

$\Rightarrow E = (\lambda/2\pi\varepsilon_0)(\frac{1}{r})$

$\Rightarrow F_{electric} = \frac{(1.6\times10^{-19}C)(-10^{-9}C/m)}{2\pi(8.85\times10^{-12}C^2/N\cdot m^2)} \frac{1}{(20\times10^{-2}m)}$

$|F_{electric}| = 1.44\times10^{-17}N$

and the direction is **down**

Magnetic Forces
B is perpendicular to both $\vec{v}$ and $\vec{B}$

a) $\vec{B}$ is in +z direction, $\vec{v}$ is in +y direction, so

F is in +x direction

b) $\vec{B}$ is in +z, $\vec{v}$ is in -z, so ($\theta = 180$)

F is 0

c) $\vec{B}$ is in +z, $\vec{v}$ is in +x, so

F is in -y direction

d) iii - current-carrying wires are attracted if their currents are parallel, repulsed their currents are anti-parallel

e) iv - it's attracted to wire 1

* sweep your right-hand fingers from $\vec{v}$ to $\vec{B}$, the direction your thumb points in is the direction of $\vec{F}$ for a positive charge

Tutorial Problem

1. A) Hold a charged object near a magnet and see if it is attracted or repulsed. Possible results:

   No interaction = disagree

   Interaction of either kind = neither b/c object may be interacting for reasons other than charge

   B) Hold it near a conductor and see if it is possible to induce a charge on the conductor as we did in tutorial. Possible results:

   No charge = disagree

   Charge = agree

   c) Try to pick up small pieces of paper with one end as we did in tutorial. Possible outcomes:

   Can't pick up paper = disagree

   Picks up paper = agree

2. • Lots of magnets are made of metal and most metals conduct so they lose charge easily = disagree
   • If an object is attracted to a magnet it is more attracted as it gets closer; the same is true of charged objects = agree

3. assume the particles discussed are located at point E

   a/i: E (anti-parallel wires repel one another)

   b/ii: O at the point E the magnetic fields from the two wires look like:

and the two arrows sum to ... pointing in the G direction

Tutorial Problem

(continued)

since $\vec{B}$ points in G direction and $\vec{v}$ is C direction,

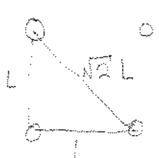
$F = qvB\sin\theta$ where $\theta = 180°$

$\Rightarrow F = 0$

c/iii: using right-hand rule from A to G and accounting for negative charge of the electron gives

K direction

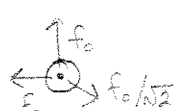
d/iv: wire A is repelled by wires B & C and attracted by wire D; the forces per length due to wires B and C are



$F/\ell = (\mu_0 I_0^2/2\pi)\frac{1}{L}$

and that due to wire D is $F/\ell \cdot (\mu_0 I_0^2/2\pi)\frac{1}{(\sqrt{2}L)}$

so the free-body diagram is



where $f_0 = (\mu_0 I_0^2/2\pi L)$

the forces due to B & C sum as vectors:

$F_{BC} = \sqrt{f_0^2 + f_0^2} = \sqrt{2}\, f_0$

and are greater than $F_D = f_0/\sqrt{2}$

so the total pull is in the **H direction**