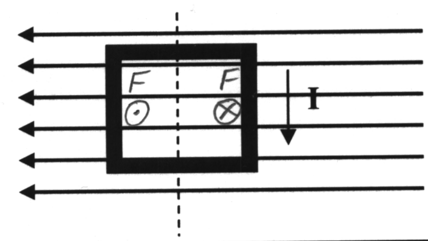
Magnetics – Set 2

Name: ____________________

Problems Solved __/ 6

Consider the current loop illustrated. Imagine viewing the loop from above, along the indicated axis. There will be a tendency for the loop to rotate: Looking down from above

a) clockwise
b) counterclockwise
c) not at all
d) none of the above

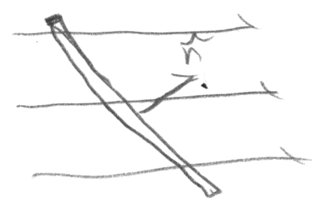


In the formula $\vec{F} = \vec{I}L \times \vec{B}$:

a) $\vec{F}$ must be perpendicular to $\vec{I}$ but not necessarily to $\vec{B}$
b) $\vec{F}$ must be perpendicular to $\vec{B}$ but not necessarily to $\vec{I}$
c) $\vec{I}$ must be perpendicular to $\vec{B}$ but not necessarily to $\vec{F}$
d) all three vectors must be mutually perpendicular
e) $\vec{F}$ must be perpendicular to both $\vec{I}$ and $\vec{B}$

The magnetic torque exerted on a flat current-carrying loop of wire by a uniform magnetic field $\vec{B}$ is:

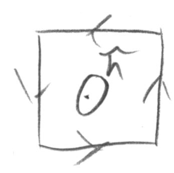
a) maximum when the plane of the loop is perpendicular to $\vec{B}$
b) maximum when the plane of the loop is parallel to $\vec{B}$
c) dependent on the shape of the loop for a fixed loop area
d) independent of the orientation of the loop
e) such as to rotate the loop around the magnetic field lines



You are facing a loop of wire which carries a clockwise current of 3.0 A and which surrounds an area of $5.8 \times 10^{-2} m^2$. The magnetic dipole moment of the loop is:

a) 3.0 A·m^2, into the page
b) 3.0 A·m^2, out of the page
c) 0.17 A·m^2, into the page
d) 0.17 A·m^2, out of the page
e) 0.17 A·m^2, left to right

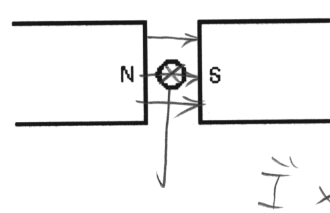
$\vec{\mu} = I\vec{A}$



$\mu = (3)(5.8 \times 10^{-2}) = .17\ A \cdot m^2$

The diagram shows a straight wire carrying a flow of electrons into the page. The wire is between the poles of a permanent magnet. The direction of the magnetic force exerted on the wire is:

a) ↑
b) ↓
c) ←
d) →
e) into the page



$\vec{I} \times \vec{B}$

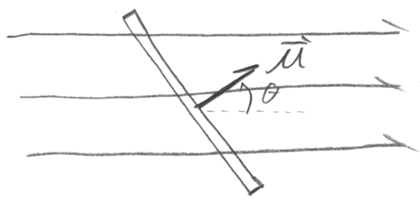
A circular coil of wire with 10 turns (coils) has a 0.23-m radius and carries a current of 2.6 A. It sits in an external magnetic field of 0.95 T.

a) The coil will experience a maximum torque when its magnetic moment is oriented at a particular angle relative to the external magnetic field direction. What is that relative angle? What is the value of maximum torque exerted on this loop by the field?

b) What angle must the loop's plane make with the external field if the torque is to be half its maximum value?

c) How much work is done <u>by the external field</u> if you rotate the loop with your hand from its orientation of zero torque (and minimum energy) to its orientation of maximum torque? Does the sign of your numerical answer make sense (i.e., should this work be positive or negative—compare with lifting a rock against gravity—does *gravity* do positive or negative work in that case)?

a)



$\vec{\tau} = \vec{\mu} \times \vec{B}, \quad \vec{\mu} = nI\vec{A}$

Cross product is maximized when $\vec{\mu} \perp \vec{B}, \theta = 90$

$|\vec{\tau}|_{max} = \mu B = nIAB = nI2\pi r B$

$|\vec{\tau}|_{max} = (10)(2.6A)(2)(\pi)(0.23)(0.95) = \boxed{35 N\cdot m}$

b) $|\vec{\tau}| = \mu B \sin\theta = \frac{1}{2}\mu B$ when $\sin\theta = \frac{1}{2}$

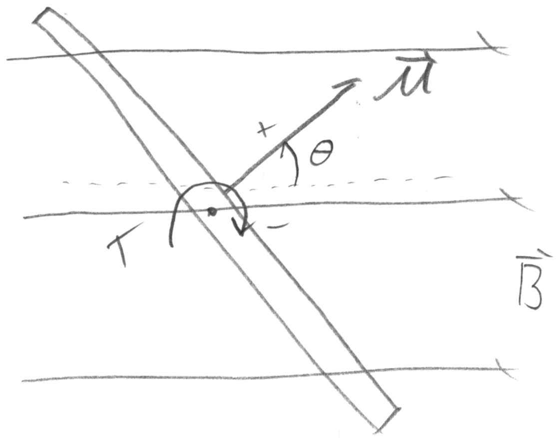
$\Rightarrow \theta = \sin^{-1}(\frac{1}{2})$

$\boxed{\theta = 30^{\circ}}$

continued ↓

Magnetics Set 2   c) continued

c)



Torque is negative

$$W = -\int_0^{\theta} T \, d\theta$$

$$\vec{T} = \vec{\mu} \times \vec{B}$$

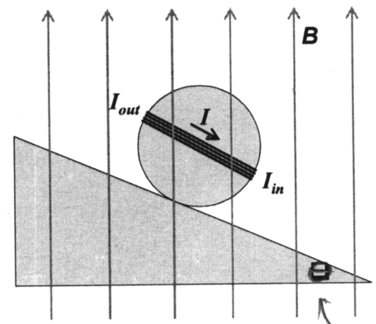
$$\Rightarrow T = \mu B \sin\theta$$

$$\Rightarrow W = -\int_0^{\pi/2} \mu B \sin\theta \, d\theta \Rightarrow W = -\mu B \left(-\cos\theta\right)\Big|_0^{\pi/2}$$

$$\Rightarrow \boxed{W = -\mu B}$$ $\Rightarrow$ negative work, positive potential

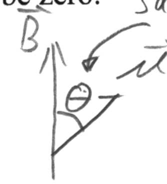
Name: ______________________

A non-conducting sphere has mass *m* and radius *R*. A compact coil of wire with *N* turns is wrapped tightly around it, with each turn concentric with the sphere. The sphere is placed on a plane with an angle of incline θ such that the coil is parallel to the inclined plane. A uniform magnetic field *B* passes through this entire region and points upward.



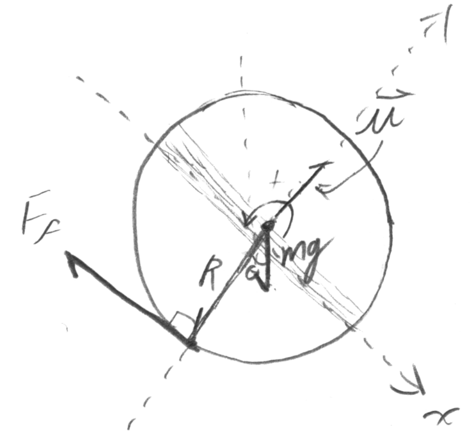
Find an expression for the current *I* passing through the coil that enables the sphere to rest in equilibrium on the inclined plane. Your answer should include only the given variables (and constants), and you should show that the result does not depend on θ.

Big hint: Draw a free-body diagram for the sphere. Label gravity acting at the center of mass and calculate its torque relative to the contact point with the incline. Then label the external field and the loop's magnetic moment. The net torque (clockwise vs. counterclockwise) must be zero.



Given
m
R
N
θ
B

Want
I



NSL

$$T_g + T_f + T_\mu = 0$$

$$0 - F_f R + \vec{\mu} \times \vec{B} = 0$$

$$\boxed{-F_f R + \mu B \sin\theta = 0}$$

Need translation version of NSL to eliminate F_f:

$$\vec{F} = m\vec{a}$$

$$-F_f + mg\sin\theta = 0 \Rightarrow \boxed{F_f = mg\sin\theta}$$

So: $-mgR\sin\theta + \mu B\sin\theta = 0$

continued ↓

2

Magnetics Set 2, P3 - continued

$$\Rightarrow \mu B \cancel{\sin\theta} = mgR\cancel{\sin\theta}, \quad \mu = NIA$$

$$= NI\pi R^2$$

$$\Rightarrow NI\pi R^{\cancel{2}} B = mg\cancel{R}$$

$$\Rightarrow \boxed{I = \frac{mg}{N\pi R B}}$$

Name: ______________________________

18) Wolfson, 2nd Ed., Chapter 26, Problem 55

Given

$N = 100$

$r = 1.5 cm$

$B = 0.12 T$

$I = 5.0 A$

want

μ

τ_{max}

a) $\mu = NIA$

$\Rightarrow \mu = NI\pi r^2$

$\Rightarrow \mu = (100)(5.0A)\pi(1.5 \times 10^{-2} m)^2$

$\boxed{\mu = 0.35\ Am^2}$

b) $\tau_{max} = \mu B$

$= (0.35)\cdot(0.12) = \boxed{0.042\ Nm}$

Name: ______________________________

19) Wolfson, 2nd Ed., Chapter 26, Problem 56

$$W = \int T\,d\theta$$

$$W = \int_0^{180} \mu B \sin\theta \, d\theta$$

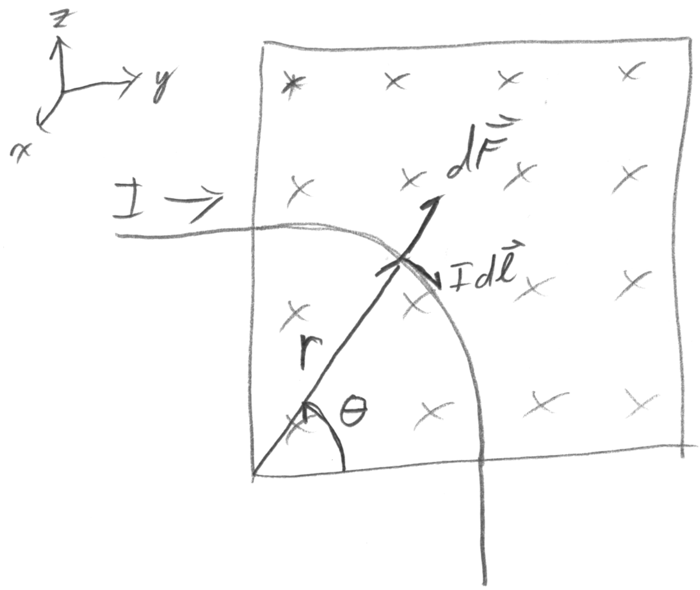
$$\Rightarrow W = \mu B(-\cos\theta\Big|_0^{180} = \boxed{2\mu B}$$

$$W = 2(1.4\times10^{-26})(9.4)$$

$$\boxed{= 2.65\times10^{-25}\,J}$$

Name: ______________________________

20) Wolfson, 2nd Ed., Chapter 26, Problem 57
Hint: You will need to find an expression for $d\vec{F}$ and integrate it along the curved path. Use polar coordinates and unit vectors.



Given
$I = 1.5A$
$B = 48mT$
$r = 21cm$

Want
F_{net}

$$d\vec{F} = Id\vec{l} \times \vec{B}$$

$$\Rightarrow d\vec{F} = IBdl\,\hat{r}, \quad dl = r\,d\theta, \quad \hat{r} = \cos\theta\,\hat{i} + \sin\theta\,\hat{j}$$

$$\Rightarrow d\vec{F} = IBr\,d\theta(\cos\theta\,\hat{i} + \sin\theta\,\hat{j})$$

$$\Rightarrow \vec{F}_{net} = IBr\left[\int_0^{\pi/2}\cos\theta\,d\theta\,\hat{i} + \int_0^{\pi/2}\sin\theta\,\hat{j}\right]$$

$$\Rightarrow \vec{F}_{net} = IBr\,\hat{i} + IBr\,\hat{j} \quad (\theta = 45^\circ)$$