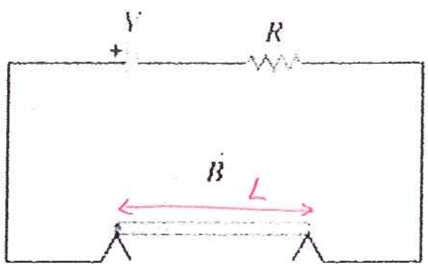
PHYS 102: General Physics - KOÇ UNIVERSITY
College of Sciences
Quiz ~~6~~ 7 Nov 25, 2016

Closed book. No calculators are to be used for this quiz.
Quiz duration: 10 minutes
Name: ID #: Signature:

Q. A metal bar with mass m rests on, but is not attached to, two metallic supports in a uniform magnetic field $\vec{B}$, as shown. A battery and a resistor R in series are connected to the supports. What is the highest voltage the battery can have without breaking the circuit at the supports?



The Magnetic Force is given by $F = ILB\sin\phi$ and $F_I = mg$ when the bar is just ready to leviate. when I becomes larger, $F_I > mg$ and $F_I - mg$ is the net force that accelerates the bar upward.

So $\longrightarrow$ $F_B = ILB = mg = F_g \Rightarrow I_{max} = \frac{mg}{LB}$

$\longrightarrow V_{max} = R I_{max} \Rightarrow \boxed{V_{max} = \frac{mgR}{LB}}$

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Q. A plastic circular disc laying in the xy-plane with its center at $(x, y) = (0, 0)$ has radius R and negligible thinkness. A positive charge q is distributed uniformly on it. The disk is rotating around the z-axis at angular speed ω as shown when a uniform magnetic field $\vec{B} = B\hat{j}$ is switched on.

(a) What is the direction of the magnetic torque vector acting on the disc?

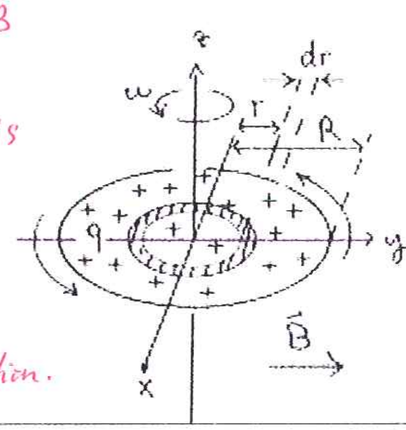
(b) Consider the circular portion of the disc with thickness dr at radius r. Find the magnitude of the torque about the axis in part (a) due to this infinitesimal current loop only, in terms of B, q, R, r, ω, and dr.

a) we know that $\vec{\tau} = \vec{\mu} \times \vec{B}$

$\hat{\mu}$ is in direction of $\hat{I}$ which is in $\hat{k}$ direction

So $\vec{\tau} = \hat{k} \times \hat{y} = -\hat{i}$ ✓

Torque is in negative x-direction.



$dA = 2\pi r dr$

$$\sigma = \frac{q}{\pi R^2} = \frac{dq}{\underbrace{2\pi r dr}_{dA}}$$

b) for $dr \rightarrow dI = \frac{dq}{T} = \sigma(2\pi r dr) \cdot \frac{\omega}{2\pi} = \sigma \omega r dr \rightarrow$ Current at "dr"

magnetic moment of the ring $\rightarrow d\mu = dI(\pi r^2) = \pi \sigma \omega r^3 dr$

So for Torque: $$d\vec{\tau} = d\vec{\mu} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 0 & d\mu \\ 0 & B & 0 \end{vmatrix} = (d\mu \cdot B)(-\hat{i}) = \sigma\pi B\omega r^3 dr(-\hat{i})$$

Extra: If problem asked for total Torque, we just integrate $d\tau$:

$$\vec{\tau} = \sigma\pi B\omega \int_0^R r^3 dr \,\hat{i} = -\frac{\pi}{4}\sigma B R^4 \omega \,\hat{i}$$

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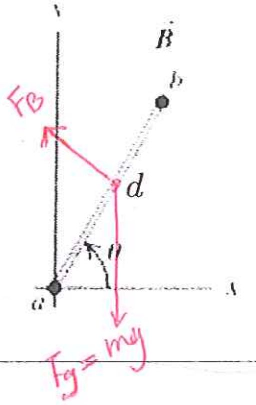
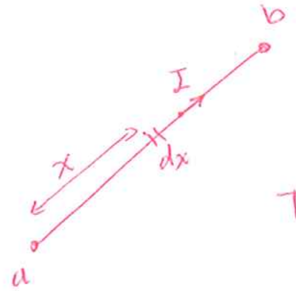
Q. A uniform bar with mass m and length d pivots without friction about an axis perpendicular to the bar at point a. The gravitational force on the bar acts in the $-y$ direction. The bar carries a current I in a uniform magnetic field $\vec{B}$ directed into the page and it is in rotational equilibrium (that is, under zero net torque) at an angle θ.

(a) Show the gravitational and magnetic forces acting on the bar by drawing arrows on the figure (assume that they act at the center of the bar).

(b) Show the direction of the current and express the condition for zero net torque in terms of B, I, d, m, and θ.



b)



$\Rightarrow \quad dF = IB\,d\ell = IB\,dx$

Torque around "a": $d\tau = x\,dF\sin\phi = \int_0^d x\,IB\,dx = \frac{1}{2}IBd^2$

For rotational equilibrium, the torques due to gravity and magnetic field must balance around "a":

$\tau = \vec{r} \times \vec{F} \Rightarrow \Sigma\tau = mg\,\frac{d}{2}\cos\theta - \frac{1}{2}IBd^2 = 0 \Rightarrow \underbrace{IdB = mg\cos\theta}_{\text{Condition for zero net torque}}$

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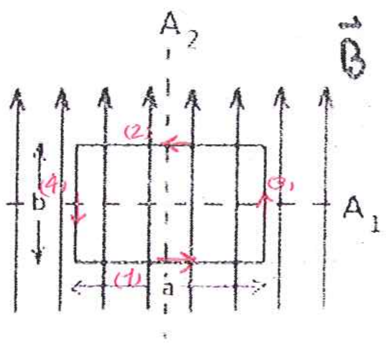
Q. A uniform rectangular coil of dimensions $a \times b$ is oriented with its plane parallel to a uniform magnetic field $\vec{B}$ shown by the arrows in the figure. A current i is suddenly started in the coil.

(a) About which axis will the coil start to rotate?

(b) Find the torque on the coil relative to the axis in part (a), just after the current is started.

$\vec{F} = I\,(\vec{\ell} \times \vec{B})$



a) We know that for (3) & (4) $\vec{\ell} \times \vec{B} = 0$ because they are in the same direction

for (1): $\vec{\ell} \times \vec{B}$ is prependicular to $A_1 - A_2$ plane outward $\odot$ $(\vec{F})$
for (2): $\vec{\ell} \times \vec{B}$ is prependicular to $A_1 - A_2$ plane inward $\otimes$ $(\vec{F})$

So it will rotate about $\underline{A_1}$ Axis.

b) $\tau = \vec{r} \times \vec{F} \longrightarrow \vec{F} = ILB \sin\overset{1}{\phi}$ $(\phi = 90^\circ)$

$\vec{\tau} = \left(\frac{b}{2} \cdot IaB\right)\hat{A}_1 + \left(\frac{b}{2} \cdot IaB\right)(-\hat{A}_1)$

$$\boxed{\vec{\tau} = baIB\,(-\hat{A}_1)}$$