Problem 1.

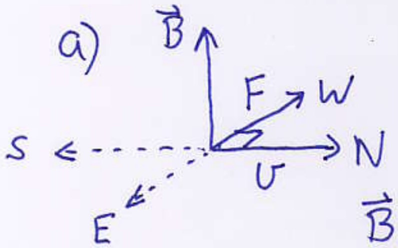
Consider an electron travelling at 4.0×10^2 m/s in a magnetic field. It experiences the greatest force if it is travelling northwards. The force in this case is directly west and of magnitude 3.2×10^{-19} N. Ignore the Earth's magnetic field, which is tiny in comparison.

a) What is the magnitude and direction of the magnetic field?

b) How would your answer change if it were a proton instead of an electron?

c) How much current would have to flow in a long, straight wire located 1 cm away from the electron in order to generate a magnetic field this strong?

a)



$\vec{F} = q\vec{v}\times\vec{B}$ Right Hand Rule: "North" × "up" = "East"

electron's charge = negative

$\therefore\ q\vec{v}\times\vec{B}$ = "West" if $\vec{B}$ is "up"

$\vec{B}$ $\boxed{\text{direction is vertical (upwards)}}$

greatest force $\therefore \sin\theta = 1 \quad (\theta = 90^\circ)$

$$F = qvB \qquad B = \frac{F}{qv} = \frac{(3.2\times10^{-19}\,N)}{(1.6\times10^{-19}\,C)(4\times10^{3}\,m/s)} = \boxed{5\times10^{-3}\,T}$$

b) magnitude of $\vec{B}$ unchanged, direction = $\boxed{\text{downwards}}$

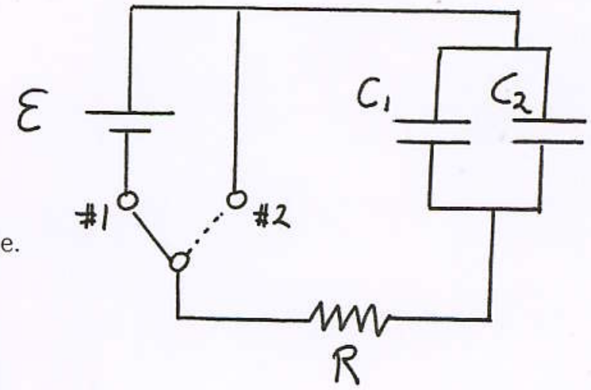
c)

$$B = \frac{\mu_0 I}{2\pi r} \quad \therefore \quad I = \frac{2\pi r B}{\mu_0} = \frac{2\pi\,(1\,cm)(5\times10^{-3}\,T)}{4\pi\times10^{-7}\,\frac{Tm}{A}}$$

$$= \boxed{250A}$$

large, but possible

Problem 2.



Consider the circuit shown, with $\mathcal{E} = 10$ V, $R = 100\ \Omega$, $C_1 = 200\ \mu$F and $C_2 = 100\ \mu$F.

a) The switch has been set to position #1 for a long time. What is the charge on capacitor C_1?

b) What is the current flowing through the resistor R?

c) Now the switch is switched to position #2, removing the battery from the circuit. How long will it take for the charge on C_1 to reach 25% of its initial value?

a) capacitor will be fully charged after "a long time" ∴ no current flowing ∴ no potential drop across R ∴ all battery voltage is across each of C_1 & C_2 ∴ $Q_1 = C_1 \mathcal{E}$

$$= (200\mu F)(10V) = \boxed{2\times10^{-3} C}$$

b) $\boxed{I_R = 0}$ (see above)

c) Discharging RC circuit

$C_{equivalent} = C_1 + C_2$ (in parallel) $= 300\mu F$

time constant $\tau = RC_{eq} = (100\Omega)(300\mu F) = 0.03 s$

$$Q = Q_0 e^{-t/\tau}$$

$$\therefore \frac{Q}{Q_0} = 0.25 = e^{-t/\tau}$$

$$\ln 0.25 = -t/\tau$$

$$t = -\tau \ln(0.25)$$

$$= -(0.03s)(-1.386) = 0.0416s \quad = \boxed{41.6\ ms}$$

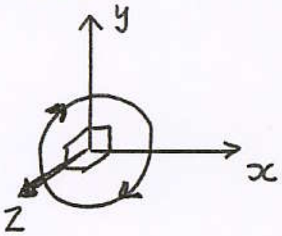
Problem 3.

A 19 loop circular coil, 16 cm in diameter, lies in the xy plane. The current in each loop of the coil is 7.6 A clockwise (when viewed from a point on the positive z axis), and there is a constant external magnetic field vector $\vec{\mathbf{B}} = (0.80\,\hat{\mathbf{i}} + 0.60\,\hat{\mathbf{j}} - 0.65\,\hat{\mathbf{k}})$ T.

a) What is the magnetic moment of the coil (magnitude and direction)?

b) Determine the torque on the coil due to the external magnetic field.

c) What is the the potential energy of the coil in the field?



a) $\mu = nIA = (19)(7.6\,A)\left(\pi\left(\frac{16\times10^{-2}m}{2}\right)^2\right)$

$= \boxed{2.90\ Am^2}$

Direction $= \boxed{-\hat{K}}$ (right hand rule)

↑ negative z direction ; into the page

b) $\vec{\tau} = \vec{\mu}\times\vec{B}$

$= (-2.90\,\hat{K}\,Am^2)\times(0.8\hat{i} + 0.6\hat{j} - 0.65\,\hat{K})T$

use: $\hat{K}\times\hat{K} = 0 \quad \hat{K}\times\hat{i} = \hat{j} \quad \hat{K}\times\hat{j} = -\hat{i}$

$\vec{\tau} = (-2.32\hat{j} + 1.74\hat{i})Nm$ $\boxed{\vec{\tau} = (1.74\hat{i} - 2.32\hat{j})Nm}$

units : $T = \frac{N}{Am}$ eg. $\vec{F} = I\vec{\ell}\times\vec{B}$

$\therefore (Am^2)(T) = Am^2\frac{N}{Am} = Nm$ [Correct unit for torque]

c) $U = -\vec{\mu}\cdot\vec{B} = -(-2.90\,\hat{K})\cdot(0.8\hat{i} + 0.6\hat{j} - 0.65\hat{K})\,TAm^2$

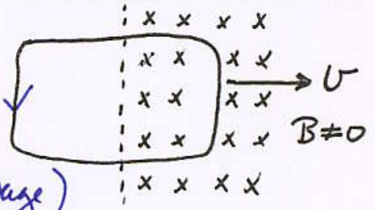
use: $\hat{K}\cdot\hat{i} = \hat{K}\cdot\hat{j} = 0$; $\hat{K}\cdot\hat{K} = 1$

$U = -1.88\ Nm = \boxed{-1.88\ J}$

4. Multiple Choice

a) A rectangular loop of wire is moved from a region with no magnetic field into a region which has a magnetic field pointing into the page, as shown. Which is the direction of the induced current in the coil?

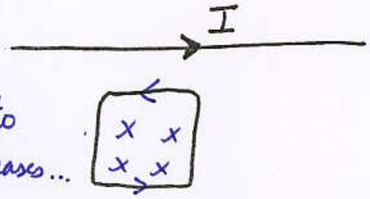
Lenz's law



- i) Clockwise
- [✓ ii) Counterclockwise]
- iii) There is no induced current in the wire

(increasing flux into page ∴ EMF to produce ϕ_B out of page)

b) A square coil of wire is located below a long straight wire. The current in the wire is flowing to the right and is increasing. What is the direction of the current induced in the coil?



- i) Clockwise
- [✓ ii) Counterclockwise]
- iii) There is no current

Lenz's law again; flux into page increasing as I increases...

c) In what direction is the net force on the coil?

- i) Up the page
- [✓ ii) Down the page]
- iii) Into the page
- iv) Out of the page
- v) To the right
- vi) To the left
- vii) There is no force

force on side of coil near wire largest opposite currents repel ∴ away from wire

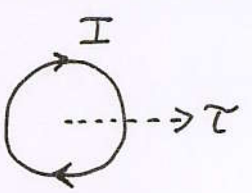
d) If instead the current in the wire is constant with time, but the coil is being pulled down (away from the wire), what would be the direction of the current induced in the coil?

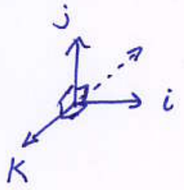
- [✓ i) Clockwise]
- ii) Counterclockwise
- iii) There is no current

flux into page decreasing (getting farther from wire ∴ EMF to produce flux into page

e) A coil is located in a magnetic field, and carries a clockwise current. The torque on the coil is determined to be to the right. In what direction is the magnetic field?

- i) To the left
- ii) To the right
- iii) Into the page
- iv) Out of the page
- [✓ v) Up the page]
- vi) Down the page
- vii) Toward Sadler Center





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

$\vec{\mu}$ = into page (right hand rule) = $-\hat{K}$

$\vec{\tau} = \hat{i}$

∴ $\vec{B}$ = up the page

since: $-\hat{K}\times\hat{j} = +\hat{i}$

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