YTU Physics Department, 2016-2017 Spring Semester		Exam Date: 20 May 2017			Exam Time: 90 min.	
FIZ1002 Physics-2 Midterm-II		P1	P2	P3	P4	TOTAL
Name Surname						
Registration No						
Department						
Group No	Exam Hall	Signature of the Student				
Lecturer's Name Surname						

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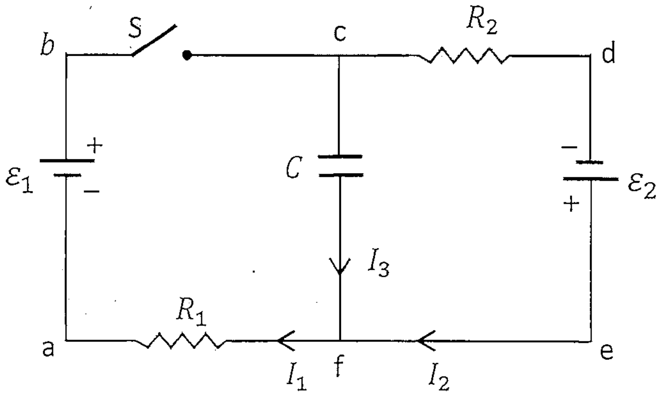
PROBLEM 1

The switch S in the circuit is initially open and the capacitor is uncharged. In here, $\varepsilon_1 = 1\,V$, $\varepsilon_2 = 3\,V$, $R_1 = 0.2\,\Omega$, $R_2 = 0.3\,\Omega$ and $C = 5\,\mu F$.



a) Find the **currents** running in the circuit and **the charge on the capacitor** after a long time while S is still open.

$I_1 = I_2 = I_3 = 0$ (3)

$Q_i = C\,\Delta V_C$ (1)

$Q_i = C.\mathcal{E}_2 = (5\mu F)(3V)$

$\boxed{Q_i = 15\mu C}$ (2)

b) Now the switch is closed. Find the **currents** and the **charge on the capacitor** after a long time after S is closed.

(1) $I_3 = 0$; $I_1 = I_2 = \dfrac{\mathcal{E}_1 + \mathcal{E}_2}{R_1 + R_2}$ (2)

$I_1 = I_2 = \dfrac{4}{0.5} = \dfrac{40}{5}$

$\boxed{I_1 = I_2 = 8A}$ (2)

Charge; Loop abcfa:

or Q/C

$\mathcal{E}_1 + \Delta V_C - I_1 R_1 = 0$ (3)

$\Delta V_C = I_1 R_1 - \mathcal{E}_1 = 8(0{,}2) - 1$

$\boxed{\Delta V_C = 0.6V}$

$Q_f = C.\Delta V_C = (5\mu F)(0{,}6)$

$\boxed{Q_f = 3\mu C}$ (3)

c) Find **powers supplied by the batteries** and **consumed across the resistors** after switch S is closed for a long time.

$P_{\mathcal{E}_1} = \mathcal{E}_1 I_1 = 1 \cdot 8 = 8W$ (2)

$P_{\mathcal{E}_2} = \mathcal{E}_2 I_2 = 3 \cdot 8 = 24W$ (2)

$P_\mathcal{E} = P_{\mathcal{E}_1} + P_{\mathcal{E}_2} \Rightarrow \boxed{P_\mathcal{E} = 32W}$

Supplied power

— o —

$P_{R_1} = I_1^2 R_1 = 8^2(0.2) = 12.8W$ (2)

$P_{R_2} = I_2^2 R_2 = 8^2 (0.3) = 19.2W$ (2)

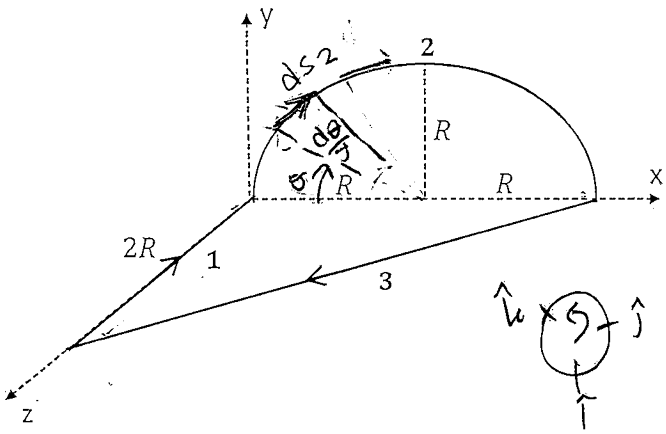
$P_R = P_{R_1} + P_{R_2} = 12.8 + 19.2$

$\boxed{P_R = 32W}$

Consumed power

PROBLEM 2

A closed loop carrying a constant current I is in a uniform magnetic field given by $\vec{B} = B_0(\hat{\imath}+\hat{\jmath})$ (T) as shown in figure ($\pi = 3$).



a) Find the magnetic forces acting on each wire.

Wire 1 : $\vec{F}_1 = I\vec{l}_1 \times \vec{B}$; $\vec{l}_1 = 2R(-\hat{k})$ 1

$\vec{F}_1 = 2IRB_0 (-\hat{k}) \times (\hat{\imath}+\hat{\jmath})$

$\boxed{\vec{F}_1 = 2IRB_0 (\hat{\imath}-\hat{\jmath})}$ 3

Wire 2 : $\vec{F}_2 = I\vec{l}_2 \times \vec{B}$; $\vec{l}_2 = 2R\hat{\imath}$ 2

$\vec{F}_2 = 2IRB_0 \, \hat{\imath} \times (\hat{\imath}+\hat{\jmath})$

$\boxed{\vec{F}_2 = 2IRB_0 \hat{k}}$ 3

Wire 3 : $\vec{F}_3 = I\vec{l}_3 \times \vec{B}$, $\vec{l}_3 = 2R(-\hat{\imath}+\hat{k})$ 2

$\vec{F}_3 = 2IRB_0 (-\hat{\imath}+\hat{k}) \times (\hat{\imath}+\hat{\jmath})$

$\vec{F}_3 = 2IRB_0 (-\hat{k}+\hat{\jmath}-\hat{\imath})$ 3

$\vec{F}_3 = 2IRB_0 (-\hat{\imath}+\hat{\jmath}-\hat{k})$

$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0$ //

Alternative method for wire 2 ;

$\vec{F}_2 = I\int d\vec{s}_2 \times \vec{B}$; $d\vec{s}_2 = R\,d\theta\,(\sin\theta\,\hat{\imath} + \cos\theta\,\hat{\jmath})$

$\vec{F}_2 = IRB_0 \int_0^{\pi} \underbrace{(\sin\theta\,\hat{\imath} + \cos\theta\,\hat{\jmath}) \times (\hat{\imath}+\hat{\jmath})}_{\hat{k},\ -\hat{k}} \, d\theta$

$\vec{F}_2 = IRB_0 \int_0^{\pi} (\sin\theta - \cos\theta)\, d\theta \ \hat{k}$

$\vec{F}_2 = IRB_0 \left(-\cos\theta - \sin\theta\right)\Big|_0^{\pi} (\hat{k})$

$\boxed{\vec{F}_2 = 2IRB_0 (\hat{k})}$

b) Find the magnetic dipole moment $\vec{\mu}$ of the loop.

$\vec{\mu} = \vec{\mu}_1 + \vec{\mu}_2$ 1

$\vec{\mu}_1 = I\vec{A}_1 \Rightarrow \vec{\mu}_1 = I\,\frac{\pi R^2}{2}(-\hat{k})$ 2

$\vec{\mu}_2 = I\vec{A}_2 \Rightarrow \vec{\mu}_2 = I\,\frac{4R^2}{2}(-\hat{\jmath})$ 2

$\vec{\mu} = \frac{3IR^2}{2}(-\hat{k}) + 2IR^2(-\hat{\jmath})$

$\boxed{\vec{\mu} = IR^2\left(-2\hat{\jmath} - \frac{3}{2}\hat{k}\right)}$ 2

c) Find the magnetic potential energy U of the loop.

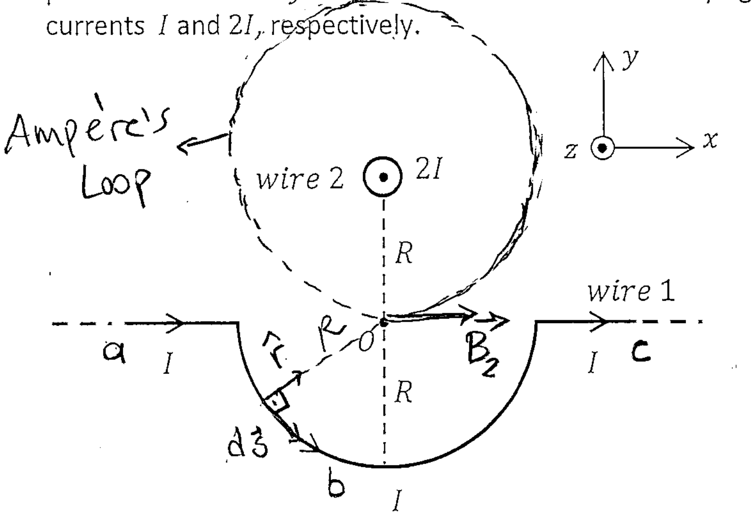
$U = -\vec{\mu} \cdot \vec{B}$ 2

$U = + IR^2 \underbrace{\left(2\hat{\jmath} + \frac{3}{2}\hat{k}\right) \cdot B_0 (\hat{\imath}+\hat{\jmath})}_{1}$

$\boxed{U = 2IB_0R^2}$ 2

PROBLEM 3

An infinitely long current wire (wire 1) is bent into a semicircle of radius R and two semi-infinitely long straight wires. Wire 1 is placed on xy-plane as shown in figure. Another infinitely long straight wire (wire 2) is placed parallel to z-axis at $y = R$. Wire 1 and wire 2 are carrying currents I and $2I$, respectively.



a) Find the **total magnetic field vector at point O** due to the wire 1 and wire 2.

Wire 1: Since $|d\vec{s} \times \hat{r}| = 0$ there is no contribution from segments a and c; $\boxed{B_a = B_c = 0}$ (2)

Segment b: Biot-Savart Law (1) or $B = \frac{\mu_0 I}{4\pi} \int \frac{ds \sin\theta}{r^2}$

$$B_b = \frac{\mu_0 I}{4\pi} \int \frac{|d\vec{s} \times \hat{r}|}{r^2} \quad ; \boxed{r = R} \quad (1)$$

$|d\vec{s} \times \vec{r}| = ds \quad \xrightarrow{\text{direction}} \odot \hat{k}$

$$B_b = \frac{\mu_0 I}{4\pi} \int \frac{ds}{R^2} \overset{(2)}{=} \frac{\mu_0 I}{4\pi R^2} \underbrace{\int ds}_{\pi R}$$

$$\boxed{\vec{B}_b = \frac{\mu_0 I}{4R} \hat{k}} \quad (1) \qquad B = \frac{\mu_0 I}{4R} \quad (2)$$

$$\vec{B}_1 = \vec{B}_a + \vec{B}_b + \vec{B}_c$$

$$\boxed{\vec{B}_1 = \frac{\mu_0 I}{4R} \hat{k}} \quad (2)$$

Wire 2; Ampère's Law

$$\oint \vec{B}_2 \cdot d\vec{s} = \mu_0 I_{in} \quad (2)$$

$$B_2 \, 2\pi R = \mu_0 \cdot 2I \quad (2)$$

$$\boxed{\vec{B}_2 = \frac{\mu_0 I}{\pi R} \hat{\imath}} \quad (2)$$

$$\vec{B}_o = \vec{B}_1 + \vec{B}_2$$

$$\boxed{\vec{B}_o = \frac{\mu_0 I}{R} \left(\frac{1}{\pi} \hat{\imath} + \frac{1}{4} \hat{k} \right)} \quad (3)$$

b) A charge $+q$ is passing through point O with a velocity of $\vec{v} = v_0 \hat{\jmath}$. Find **the magnetic force acting on the charge.**

$$\vec{F}_B = q \vec{v} \times \vec{B}_o \quad (2)$$

$$\vec{F}_B = \frac{q v_0 \mu_0 I}{R} \hat{\jmath} \times \left(\frac{1}{\pi} \hat{\imath} + \frac{1}{4} \hat{k} \right)$$

$-\hat{k}$ $\quad \hat{\imath}$

$$\boxed{\vec{F}_B = \frac{q v_0 \mu_0 I}{R} \left(\frac{1}{4} \hat{\imath} - \frac{1}{\pi} \hat{k} \right)} \quad (3)$$

PROBLEM 4

A circular conductive loop of radius r is placed in a uniform magnetic field $\vec{B} = B_0\hat{j}$ (figure 1). Loop rotates about z-axis with a constant angular speed ω (figure 2). ($\theta = \omega t$)

Figure 1

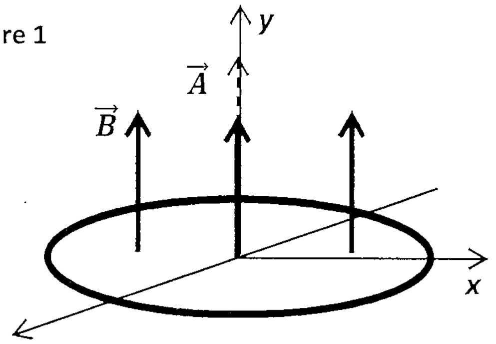
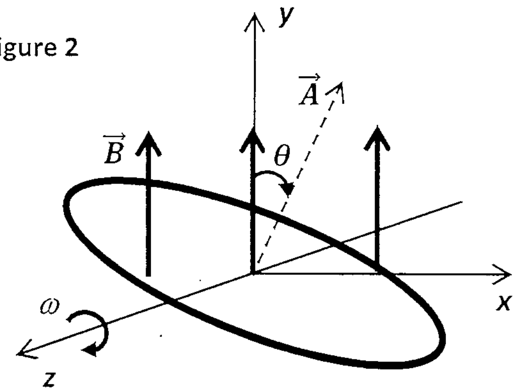


Figure 2



a) Find the **electromotive force induced in the loop** during the rotation.

$$\mathcal{E} = -\frac{d\Phi_B}{dt} \quad (2)$$

$$\Phi_B = B_0 A \cos\theta \ (4), \quad \theta = \omega t$$

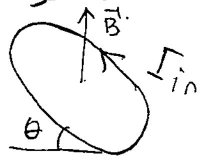
$$\Phi_B = B_0 A \cos\omega t$$

$$\mathcal{E} = -\frac{d}{dt}(B_0 A \cos\omega t) \quad (2)$$

$$\boxed{\mathcal{E} = +B_0 A \omega \sin\omega t} \quad (4)$$

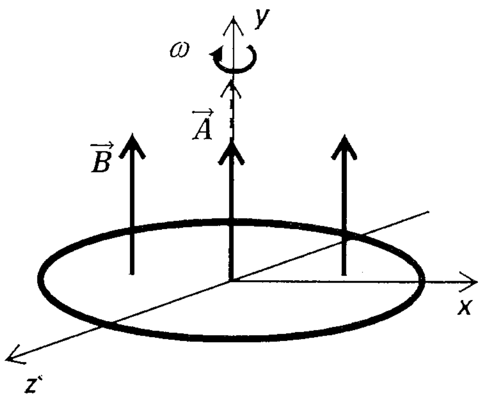
b) If the resistance of the loop is R, find the magnitude of the induced current. **Explain the direction of the induced current** when $0 < \theta < 90$ according to the Lenz Law.

Since magnetic flux decreases when $0<\theta<90$; induced current I_i must be counter clockwise in order to create magnetic field in the same direction (2)



$$I_i = \frac{|\mathcal{E}|}{R} \ (1) \Rightarrow \boxed{I_i = \frac{B_0 A \omega \sin\omega t}{R}} \ (3)$$

c) Find **the electromotive force induced in the loop** if it rotates about y-axis with a constant angular speed ω.



(2)

In this case; $\Phi_B = B_0 A \cos 0^\circ$ and constant all the time. Therefore;

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = 0 \quad (5)$$