İzmir Kâtip Çelebi University
Department of Engineering Sciences
Phy102 Physics II
Final Examination
January 09, 2023 17:00 – 18:30
Good Luck!

NAME-SURNAME:

SIGNATURE:

ID:

DEPARTMENT:

INSTRUCTOR:

DURATION: 90 minutes

◇ **Answer all the questions.**
◇ **Write the solutions explicitly and clearly. Use the physical terminology.**
◇ **You are allowed to use Formulae Sheet.**
◇ **Calculator is allowed.**
◇ **You are not allowed to use any other electronic equipment in the exam.**
◇ **I declare hereby that I fulfilled the requirements for the attendance according to the University regulations and I accept that my examination will not be valid otherwise.**

Question	Grade	Out of
1A		15
1B		15
2		20
3		20
4		20
5		20
TOTAL		110

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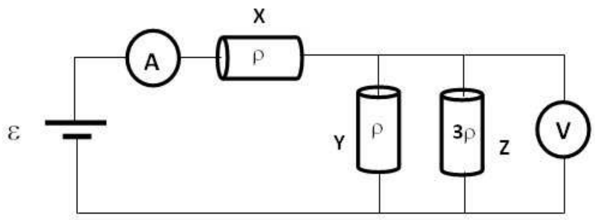
1. A) The circuit containing three cylindrical resistors, namely X, Y and Z, which obey Ohm's Law is shown in the figure below. The resistors which have length of L and cross-sectional area of A are connected to an ideal battery of emf ε. As shown an ammeter is connected in series while voltmeter is connected to ends of resistor Z. The resistors X and Y have a resistivity ρ and the resistor Z has a resistivity 3ρ.



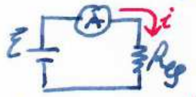
i Find the current i through the ammeter.

ii Find the reading of voltmeter.

Express your result in terms of given quantities and constants (ε, A, ρ, L). **(Hint:** Resistance is related to resistivity; $R = \rho\frac{L}{A}$)

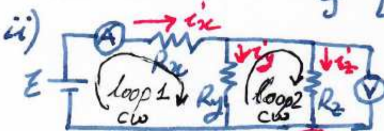
i) $\frac{1}{R_{yz}} = \frac{1}{R_y} + \frac{1}{R_z} \rightarrow R_{yz} = \frac{R_y R_z}{R_y+R_z} \Rightarrow R_{eq} = R_x + R_{yz} = R_x + \frac{R_y R_z}{R_y+R_z}$ (2) (2)

where $R_x = R_y = \rho\frac{L}{A}$ & $R_z = 3\rho\frac{L}{A} \Rightarrow R_{eq} = \rho\frac{L}{A} + \frac{\rho\frac{L}{A}\cdot 3\rho\frac{L}{A}}{\rho\frac{L}{A}+3\rho\frac{L}{A}} = \frac{7}{4}\rho\frac{L}{A}$ (2)



$\rightsquigarrow i = \frac{\varepsilon}{R_{eq}} = \boxed{\frac{4}{7}\frac{\varepsilon A}{\rho L}} = i_x \rightsquigarrow i_x = i_y + i_z$ (1)

ii)



(2)

Loop1: (2) $\varepsilon - i_x R_x - i_y R_y = 0 \rightsquigarrow i_y = \frac{\varepsilon - i_x R_x}{R_y}$

loop2: (2) $i_y R_y - i_z R_z = 0 \rightsquigarrow i_z = i_y \frac{R_y}{R_z}$

$\Rightarrow i_y = \frac{\varepsilon - i_x R_x}{R_y}$ & $i_z = \left(\frac{\varepsilon - i_x R_x}{R_y}\right)\frac{R_y}{R_z} = \frac{\varepsilon - i_x R_x}{R_z}$ (1)

$\Rightarrow V = i_z R_z = \left(\frac{\varepsilon - i_x R_x}{R_z}\right) R_z = \varepsilon - i_x R_x = \varepsilon - \left(\frac{4}{7}\frac{\varepsilon A}{\rho L}\right)\rho\frac{L}{A} = \varepsilon - \frac{4\varepsilon}{7}$

$\boxed{V = \frac{3\varepsilon}{7}}$ (1)

B) **What uniform magnetic field**, applied **perpendicular** to a beam of electrons moving at $1.30 \times 10^6\ m/s$, is required to make the electrons travel **in a circular arc** of radius of 0.35 m? **(Hint:** Centripetal Force; $F_c = m\frac{v^2}{R}$)

$v = 1.3 \times 10^6\ m/s$

$R = 0.35\,m$

$e = 1.602 \times 10^{-19}\,C$ $(\equiv |q|)$

$m_e = 9.109 \times 10^{-31}\,kg$

$B = ?$

$F_c = m\frac{v^2}{R}$ & $F_B = |q| v B \sin\theta$

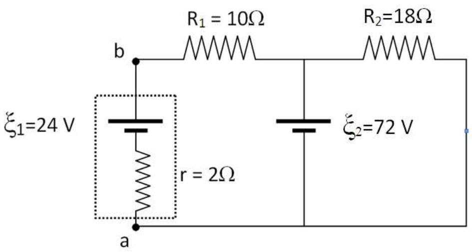
$|q| v B \sin 90° = m_e\, v^2/R$ 5

$\Rightarrow B = \frac{m_e v}{e R}$ 5

$= \frac{(9.109 \times 10^{-31}\,kg)(1.3 \times 10^6\,m/s)}{(1.602 \times 10^{-19}\,C)(0.35\,m)}$

$= \boxed{2.11 \times 10^{-5}\,T}$ 5

2. Consider circuit as shown in figure which consists of two batteries. One of the following batteries has an internal resistance r, while the other battery is an ideal battery.

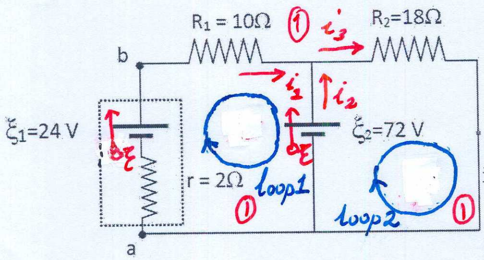


Calculate;

i Currents through each battery,

ii Total power dissipated by resistors.

iii Potential difference between points a and b, V_{ab},



i Currents through each battery,

ii Potential difference between points a and b, V_{ab},

iii Total power supplied by batteries,

iv Total power dissipated by resistors.

i) 1 loop 1: $-i_1 r + \mathcal{E}_1 - i_1 R_1 - \mathcal{E}_2 = 0 \Rightarrow -2i_1 + 24 - 10i_1 - 72 = 0$ 2

$-12 i_1 = 48$

$\boxed{i_1 = -4A}$ 1 opposite direction

2 loop2: $\mathcal{E}_2 - i_3 R_2 = 0 \Rightarrow 72 - 18 i_3 = 0$ 2 $\boxed{i_3 = 4A}$ 1

3 $i_1 + i_2 = i_3$ 1 $\Rightarrow -4A + i_2 = 4A \rightarrow \boxed{i_2 = 8A}$ 1

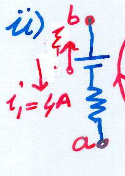
Three unknowns ($i_{1,2,3}$), three equations

$i_1 = -4A$: Through battery 1

$i_2 = 8A$: Through battery 2

$i_3 = 4A$: Through Resistor 3

ii)



$V_{ab} = V_b - V_a$ 2

$V_a + i_1 r + \xi_1 = V_b$

$V_b - V_a = 4A\,2\Omega + 24V$

$\boxed{= 32V}$ 1

iii) $P = i\mathcal{E}$

Battery 1: $P_1 = i_1 \xi_1 = (4A)(24V)$ $\boxed{= -96W}$ 1.5

Battery2: $P_2 = i_2 \xi_2 = (8A)(72V)$ $\boxed{= 576W}$ 1.5

$P_1 + P_2 \boxed{= 480W}$

iv) $P = i^2 R$

Resistor 1: $P_1' = i_1^2 R_1 = (4A)^2 (10\Omega) = 160W$ ← R_1 1

Resistor 2: $P_2' = i_3^2 R_2 = (4A)^2 (18\Omega) = 288W$ ← R_2 1

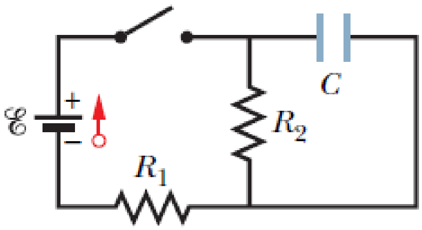
Internal Resistor r: $P_r' = i_1^2 r = (4A)^2 (2\Omega) = 32W$ ← r 1

$P_1 + P_2 = P_1' + P_2' + P_r'$

$480W = 480W$

3

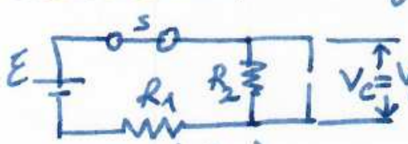
3. In Figure given below, $R_1 = 8.0 \times 10^3\ \Omega$, $R_2 = 10.0 \times 10^3\ \Omega$, $C = 6 \times 10^{-7}\ F$, and the ideal battery has emf $\epsilon = 12.0\ V$. First, the switch is closed a long time so that the steady state is reached. Then the switch is opened at time $t = 0$.

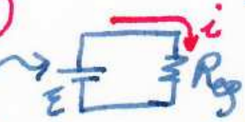


What is the current in resistor 2 at $t = 2.00 \times 10^{-3}\ s$?

$R_1 = 8\ k\Omega$
$R_2 = 10\ k\Omega$
$C = 0.6\ \mu F$
$\mathcal{E} = 12\ V$

initially, C acts as a connecting wire ①
after a long time, C acts as a broken wire ②
① Charging stage ② fully charged (2)
$\Rightarrow V_C = V_{R_2} = iR_2$





$i = \dfrac{\mathcal{E}}{R_1 + R_2}$ (2)

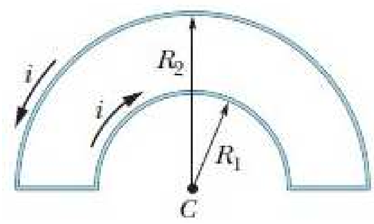
$\rightarrow V_{R_2} = \left(\dfrac{\mathcal{E}}{R_1+R_2}\right) R_2 = \dfrac{12V}{(8k\Omega + 10k\Omega)} 10k\Omega = \boxed{\dfrac{20}{3} V} (= V_C)$ when fully charged (3) (2)

③ switch is opened $\rightarrow t = 0$ & $V_C = V_0 = \frac{20}{3} V$ (2)
discharging through R_2, $V = V_0 \exp(-t/RC)$ (3)

$\rightarrow V = \left(\frac{20}{3} V\right) \exp\left(-\dfrac{2\,ms}{(10k\Omega)(0.6\mu F)}\right) = \left(\frac{20}{3} V\right) \exp\left(-\dfrac{2 \times 10^{-3} s}{10 \times 10^3 \Omega\ 0.6 \times 10^{-6} F}\right)$

$V(t = 2ms) = \boxed{4.78V}$ (2) $\rightarrow i_{R_2} = \dfrac{V}{R_2} = \dfrac{4.78V}{10k\Omega} = \boxed{4.77 \times 10^{-4} A}$ (1) (2) (1)

4. In Figure, two semicircular arcs have radii $R_2 = 2.6\ cm$ and $R_1 = 1.05\ cm$, carry current $i = 0.0937\ A$, and share the same center of curvature C.



What are the

i magnitude

ii direction (into or out of the page, why?)

of the net magnetic field at C?
Hint: Use Biot-Savart Law.

Biot-Savart law: $d\vec{B} = \frac{\mu_0}{4\pi} \frac{i\, d\vec{s} \times \hat{r}}{r^2}$ $\rightarrow$

$\hat{r} \perp d\vec{s}$

$dB = \frac{\mu_0}{4\pi} \frac{i\, ds \sin 90^\circ}{R^2} = \frac{\mu_0}{4\pi} \frac{i\, ds}{R^2}$ $\left\{ \begin{array}{l} \text{where} \\ ds = R\, d\phi \end{array} \right\}$ $\rightarrow B = \int dB$

$\rightarrow B = \frac{\mu_0}{4\pi} i \int_0^\phi \frac{R\, d\theta}{R^2} = \frac{\mu_0 i}{4\pi R} \phi$ $\left\{ \begin{array}{l} \text{where} \\ \phi \text{ is arc angle} \end{array} \right.$ (4)

$R_1 = 1.05 \times 10^{-2} m$
$R_2 = 2.6 \times 10^{-2} m$
$i = 0.0937\ A$
$\phi = 180^\circ \equiv \pi$

i) $B = B_1 + B_2 = \frac{\mu_0 i}{4\pi} \left(\frac{1}{R_1} - \frac{1}{R_2} \right) \pi$ (4)

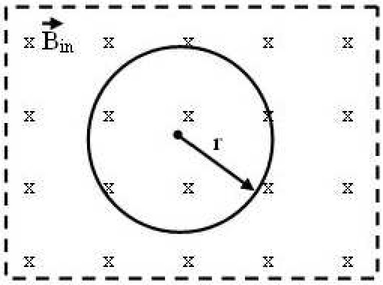
$\rightarrow B = \frac{(4\pi \times 10^{-7}\ Tm/A)\, 0.0937 A}{4\cancel{\pi}} \left(\frac{1}{1.05 \times 10^{-3} m} - \frac{1}{2.6 \times 10^{-3} m} \right) \cancel{\pi}$ (4)

$= \boxed{1.67 \times 10^{-6}\ T}$ (2)

ii) into the page (2) (4)

$\vec{B}_1$ (into the page) & $|\vec{B}_1| > |\vec{B}_2|$
C
$\vec{B}_2$ (out of the page)

5. In figure below, the magnetic flux through the circular loop of radius $r = 2.0\ m$ increases according to the relation $\Phi_B = 3t^2 + 3t$, where Φ_B is in Webers and t is in seconds.



i Find the magnitude of the induced emf, ξ in the circular loop at $t = 2.0\ s$.

ii What is the magnitude and direction of the induced current in the circular loop at $t = 2.0\ s$ if the loop has a total resistance of $R = 30\ \Omega$?

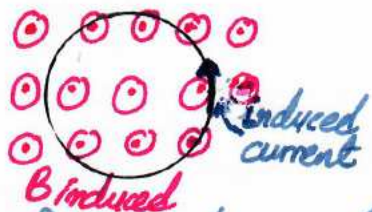
i) $\phi_B(t) = 3t^2 + 3t$: increasing flux ⇒ induced $\mathcal{E}$, i should oppose

$\underbrace{\mathcal{E}}_{\text{induced}} = -\underbrace{N}_{1} \frac{d\phi_B}{dt}$ 5 $\rightarrow |\mathcal{E}| = \frac{d}{dt}(3t^2+3t)\Big|_{t=2s} = 6t+3\Big|_{t=2s} = \boxed{15\ V}$ 3 5

ii) $i = \frac{\mathcal{E}}{R}$ 2 $= \frac{15\ V}{30\ \Omega} = \boxed{0.5A}$ 2

$\vec{B}_{applied}$ ⊗ ~ in to the page

$\vec{B}_{induced}$ ⊙ ← since it should oppose



by Right Hand Rule ~ direction of induced current is ccw 3

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DURATION: 90 minutes

◇ **Answer all the questions.**
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2		20
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4		20
5		20
TOTAL		110

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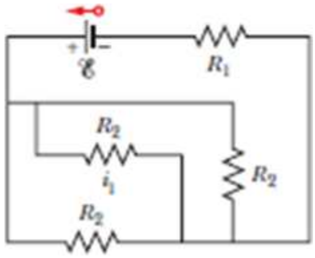
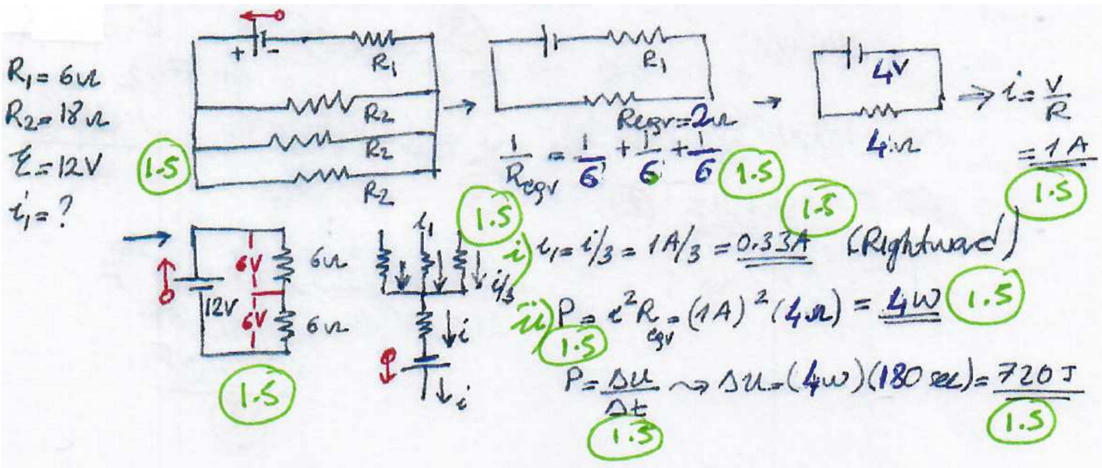
1. A) In Figure, $R_1 = 2.0\ \Omega$, $R_2 = 6.0\ \Omega$, and the ideal battery has emf $\varepsilon = 4.0\ V$.



i What are the size and direction (left or right) of current i_1?

ii How much energy is dissipated by all four resistors in 3.00 minutes?



B) A 15.0 $k\Omega$ resistor and a capacitor are connected in series and then a 12.0 V potential difference is suddenly applied across them. The potential difference across the capacitor rises to 5.0 V in 1.30 μs.

a) Calculate the time constant of the circuit.

b) Find the capacitance of the capacitor.

Charging capacitor: $q = C\mathcal{E}(1-e^{-t/RC})$ & $\tau = RC$ 2

$V(t) = \mathcal{E}(1-e^{-t/RC})$ 3

i) $V(t) = \mathcal{E}(1-e^{-t/RC}) \Rightarrow 5V = 12V\left(1-e^{-\frac{1.3\times10^{-6}s}{15\times10^{3}\Omega C}}\right)$, $15\times10^{3}\Omega C = \tau$ 3

$e^{-1.3\times10^{-6}s/\tau} = 1 - 5/12 \rightsquigarrow \ln e^{-1.3\times10^{-6}/\tau} = \ln 7/12$

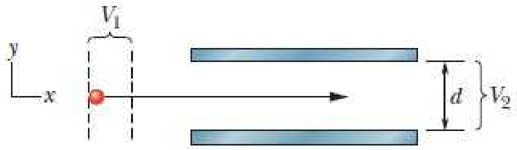
$\rightsquigarrow -1.3\times10^{-6}s/\tau = \ln 7/12 \rightsquigarrow \tau = \frac{-1.3\times10^{-6}s}{\ln 7/12} = \frac{-1.3\times10^{-6}s}{-0.54}$ 3

$\Rightarrow \tau = 2.41\,\mu s$ 2

ii) $\tau = RC \rightsquigarrow C = \frac{\tau}{R} = \frac{2.41\times10^{-6}s}{15\times10^{3}\Omega} = 1.61\times10^{-10}F$
$= 0.161\,nF$
$= 162\,pF$

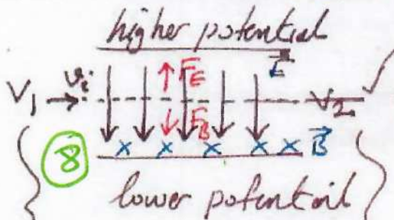
2

2. In Figure, an electron accelerated from rest through potential difference $V_1 = 1.00\ kV$ enters the gap between two parallel plates having separation $d = 10.0\ mm$ and potential difference $V_2 = 50\ V$. The lower plate is at the lower potential. Neglect fringing and assume that the electron's velocity vector is perpendicular to the electric field vector between the plates.



In unit-vector notation, what uniform magnetic field allows the electron to travel in a straight line in the gap?

$V_1 = 1\ kV$ & $d = 10\times10^{-3}\ m$, $V_2 = 50\ V$, $M_e = 9.11\times10^{-31}\ kg$



straight line $\Rightarrow |\vec F_B| = |\vec F_E|$ 2

$|q| v_i B = |q| E$

$\sqrt{\frac{2qV_1}{m_e}}\, B = \frac{V_2}{d}$ 2

$\Delta U = qV_1 - 0$ 2

$= (1.6\times10^{-19}\ C)\ 1\times10^{3}\ V$

$\Delta U = \Delta K = \frac{1}{2} m_e v_i^2$

2

$V_2 = Ed$

$\Rightarrow E = \frac{V_2}{d}$

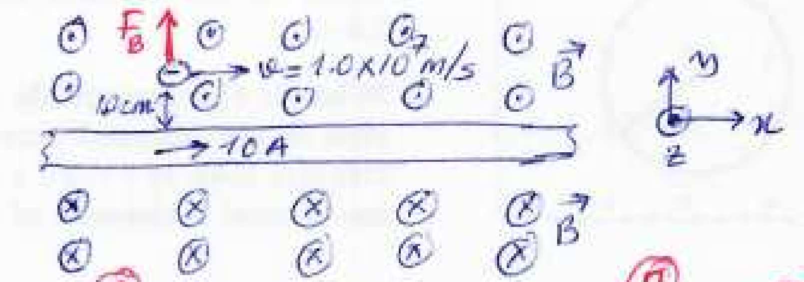
$\rightarrow B = \frac{50\ V}{10\times10^{-3}\ m}\sqrt{\frac{9.11\times10^{-31}\ kg}{2\times1.6\times10^{-19}\ C\ 1\times10^{3}\ V}}$

$B = 2.67\times10^{-4}\ T$

$\vec B = 2.67\times10^{-4}\ T(-\hat k)$

2 2

3. A long wire carries a 10 A current from left to right. An electron 1.0 cm above the wire is traveling to the right at a speed of 1.0×10^7 m/s. What are the magnitude and the direction of the magnetic force on the electrons?



$$B = \frac{\mu_0 I}{2\pi d} = \frac{(4\pi\times10^{-7}\,TM/A)\,10A}{2\pi\, 1.0\times10^{-2}\,m} = 2\times10^{-4}\,T$$

3 3 2

$$\vec{F}_B = q\,\vec{v}\times\vec{B} \Rightarrow |\vec{F}_B| = (1.602\times10^{-19}\,C)(1.0\times10^{7}\,m/s)(2\times10^{-4}\,T)$$

3

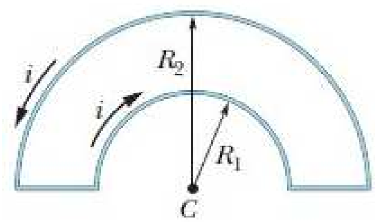
$$= 3.2\times10^{-16}\,N$$

3 2

$$\vec{F}_B = 3.2\times10^{-16}\,N\,\hat{j}$$

4

4. In Figure, two semicircular arcs have radii $R_2 = 3.9\ cm$ and $R_1 = 1.575\ cm$, carry current $i = 0.1405\ A$, and share the same center of curvature C.



What are the

i magnitude

ii direction (into or out of the page, why?)

of the net magnetic field at C?
Hint: Use Biot-Savart Law.

Biot-Savart law: $d\vec{B} = \frac{\mu_0}{4\pi} \frac{i\, d\vec{s} \times \hat{r}}{r^2}$ $\rightarrow$ R, $d\phi$, $d\vec{s}$, $\hat{r}$, $\hat{r} \perp d\vec{s}$

$dB = \frac{\mu_0}{4\pi} \frac{i\, ds \sin 90^\circ}{R^2} = \frac{\mu_0}{4\pi} \frac{i\, ds}{R^2}$ $\left\{ \begin{array}{l} \text{where} \\ ds = R\, d\phi \end{array} \right\}$ $\rightarrow B = \int dB$

$\rightarrow B = \frac{\mu_0}{4\pi} i \int_0^{\phi} \frac{R\, d\theta}{R^2} = \underline{\frac{\mu_0 i}{4\pi R} \phi}$ (4) $\left\{ \begin{array}{l} \text{where} \\ \phi \text{ is arc angle} \end{array} \right.$

$R_1 = 1.05 \times 10^{-2}\ m$
$R_2 = 2.6 \times 10^{-2}\ m$
$i = 0.0937\ A$
$\phi = 180^\circ \equiv \pi$

i) $B = B_1 + B_2 = \frac{\mu_0 i}{4\pi} \left(\frac{1}{R_1} - \frac{1}{R_2} \right) \pi$ (4)

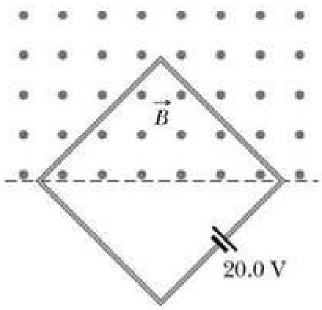
$\rightarrow B = \frac{(4\cancel{\pi} \times 10^{-7}\ Tm/A)\, 0.0937 A}{4\cancel{\pi}} \left(\frac{1}{1.05 \times 10^{-3}\ m} - \frac{1}{2.6 \times 10^{-3}\ m} \right) \cancel{\pi}$ (4)

$= \boxed{1.67 \times 10^{-6}\ T}$ (2) (2)

ii) into the page (4)

$\vec{B}_2$ (out of the page) $\leftarrow C \rightarrow \vec{B}_1$ (in to the page) & $|\vec{B}_1| > |\vec{B}_2|$

5. A square wire loop with 3.00 m sides and resistance 3 Ω is perpendicular to a uniform magnetic field, with half the area of the loop in the field as shown in figure. The loop contains an ideal battery with emf (ε) 20.0 V. The magnitude of the field varies with time according to $B = 0.0420 - 0.3870t$, with B in teslas and t in second.



i Find the value and direction of the induced ε.

ii What is the net emf in the circuit?

iii Find the magnitude and the direction of the net current around the loop?

Hint: Magnetic field is decreasing.

$l = 2.00\,m$
$R = 3\,\Omega$
$\mathcal{E}_B = 20.0\,V$
$B = 0.0420 - 0.870t$
$A = L^2/2$ 1

i) $\mathcal{E}_i = -\dfrac{d\Phi_B}{dt}$ 2 $= -\dfrac{d(BA)}{dt}$ 1 $= -\dfrac{L^2}{2}\dfrac{dB}{dt} = -\dfrac{L^2}{2}\dfrac{d(0.0420 - 0.3870t)}{dt}$ 2

$= -\dfrac{L^2}{2}(-0.3870\,T/s) = \dfrac{(3.00\,m)^2}{2}(0.3870\,T/s)$

$\mathcal{E}_i = 1.74\,V$ 2 ∴ B is out of page and DECREASING. 3
→ Induced emf should support the external magnetic field ⇒ ccc: direction of induced emf (current,
⇒ same direction with the battery →

ii) $\mathcal{E}_{total} = \mathcal{E}_B + \mathcal{E}_i = 20.0V + 1.74V$ 3
$= 21.74\,V$ 2

iii) Current is in the ccw. 2 $i = \dfrac{V}{R} = \dfrac{\mathcal{E}_{total}}{R} = \dfrac{21.74\,V}{3\,\Omega} = 7.23\,A$ 2

İzmir Kâtip Çelebi University
Department of Engineering Sciences
Phy102 Physics II
Final Examination
January 09, 2020 13:30 – 15:30
Good Luck!

NAME-SURNAME:

SIGNATURE:

ID:

DEPARTMENT:

INSTRUCTOR:

DURATION: 120 minutes

◇ **Answer all the questions.**
◇ **Write the solutions explicitly and clearly. Use the physical terminology.**
◇ **You are allowed to use Formulae Sheet.**
◇ **Calculator is allowed.**
◇ **You are not allowed to use any other electronic equipment in the exam.**
◇ **I declare hereby that I fulfilled the requirements for the attendance according to the University regulations and I accept that my examination will not be valid otherwise.**

Question	Grade	Out of
1A		15
1B		15
2		20
3		20
4		20
5		20
TOTAL		110

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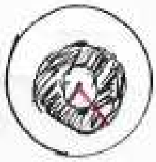
1. A) The magnitude J of the current density in a certain lab wire with a circular cross section of radius R=15.00 mm is given by $J = (6.00 \times 10^7)r^2$, with J in amperes per square meter and radial distance r in meters. What is the current through the outer section bounded by r=0.200R and r=0.600R?

$R = 15 \times 10^{-3}\,m$

$J(R) = 6 \times 10^7 r^2\ A/m^2$

$i = ?$ from $r = 0.2R$ to $r = 0.6R$



$$i = \int \vec{J} \cdot d\vec{A} = \int_{0.2R}^{0.6R} 6 \times 10^7 r^2\, 2\pi r\, dr$$

(2) (3) (2)

$$= 12\pi \times 10^7 \int_{0.2R}^{0.6R} r^3\, dr = 12\pi \times 10^7 \left. \frac{r^4}{4} \right|_{0.2R}^{0.6R}$$

(3)

$$= 3\pi \times 10^7 \left[(0.6R)^4 - (0.2R)^4 \right]$$

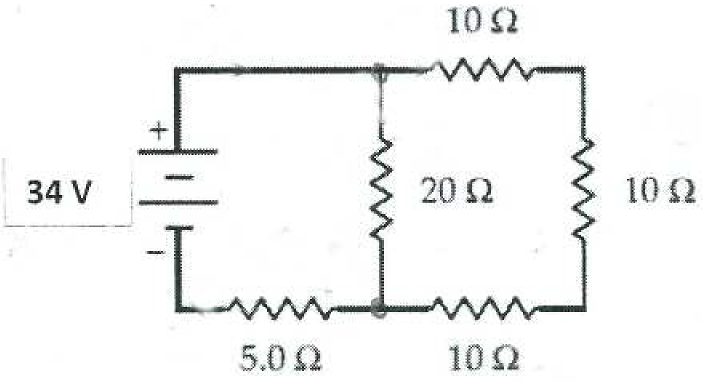
$$= 3\pi \times 10^7 \times 0.128 R^4 = \underline{\underline{0.61\,A}}$$

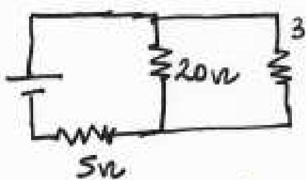
(3) (2)

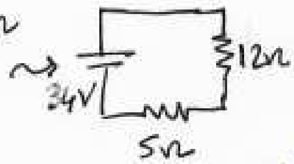
B) For the circuit shown find

i the current delivered by the battery,

ii the potential difference across the 20 Ω resistor.



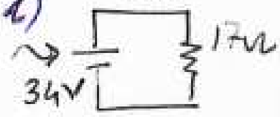




$$\frac{1}{R_{eq}} = \frac{1}{20\Omega} + \frac{1}{30\Omega}$$

$$R_{eq} = \frac{(30\Omega)(20\Omega)}{20\Omega + 30\Omega} = 12\Omega$$ 5

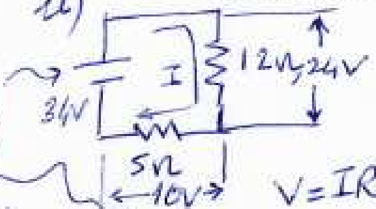
i)



$R = \frac{V}{I}$, $I = \frac{V}{R}$

$$I = \frac{34V}{17\Omega} = 2A$$ 5

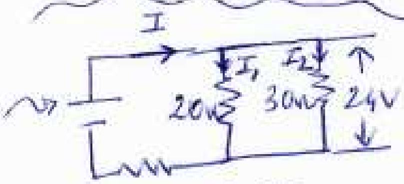
ii)



$V = IR$

$= 12\Omega * 2A$

$= 24\,V$ 5

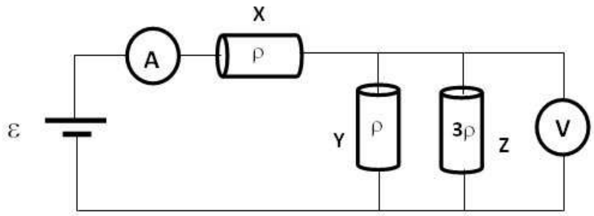


$$I_{20\Omega} = \frac{24V}{20\Omega} = 1.2A$$

$$I_{30\Omega} = \frac{24V}{30\Omega} = 0.8A$$

$I = I_1 + I_2$

2. The circuit containing three cylindrical resistors, namely X, Y and Z, which obey Ohm's Law is shown in the figure below. The resistors which have length of L and cross-sectional area of A are connected to an ideal battery of emf ε. As shown an ammeter is connected in series while voltmeter is connected to ends of resistor Z. The resistors X and Y have a resistivity ρ and the resistor Z has a resistivity 3ρ.



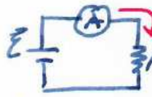
i Find the current i through the ammeter.

ii Find the reading of voltmeter. (Hint: Multi-loop circuit. Apply junction and loop rules.)

Express your result in terms of given quantities and constants $(\rho, \varepsilon, A, L)$.
(Hint: Resistance is related to resistivity.)

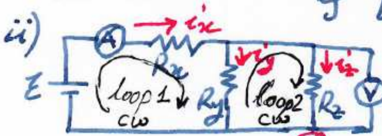
i) $\frac{1}{R_{yz}}=\frac{1}{R_y}+\frac{1}{R_z} \to R_{yz}=\frac{R_yR_z}{R_y+R_z}$ (2) $\Rightarrow R_{eq}=R_x+R_{yz}=R_x+\frac{R_yR_z}{R_y+R_z}$ (2)

where $R_x=R_y=\rho\frac{L}{A}$ & $R_z=3\rho\frac{L}{A} \Rightarrow R_{eq}=\rho\frac{L}{A}+\frac{\rho\frac{L}{A}\cdot 3\rho\frac{L}{A}}{\rho\frac{L}{A}+3\rho\frac{L}{A}}=\frac{7}{4}\rho\frac{L}{A}$ (2)



$\to i=\frac{\varepsilon}{R_{eq}}=\boxed{\frac{4}{7}\frac{\varepsilon A}{\rho L}}=i_x \to i_x=i_y+i_z$ (1)

ii)



(2)

Loop1: $\varepsilon-i_xR_x-i_yR_y=0 \to i_y=\frac{\varepsilon-i_xR_x}{R_y}$ (2)

loop2: $i_yR_y-i_zR_z=0 \to i_z=i_y\frac{R_y}{R_z}$ (2)

$\Rightarrow i_y=\frac{\varepsilon-i_xR_x}{R_y}$ & $i_z=\left(\frac{\varepsilon-i_xR_x}{R_y}\right)\frac{R_y}{R_z}=\frac{\varepsilon-i_xR_x}{R_z}$ (1)

$\Rightarrow V=i_zR_z=\left(\frac{\varepsilon-i_xR_x}{R_z}\right)R_z=\varepsilon-i_xR_x=\varepsilon-\left(\frac{4}{7}\frac{\varepsilon A}{\rho L}\right)\rho\frac{L}{A}=\varepsilon-\frac{4\varepsilon}{7}$

$\boxed{V=\frac{3\varepsilon}{7}}$ (1)

3. A proton of kinetic energy 2.10 keV circles in a plane perpendicular to a uniform magnetic field.The orbit radius is 25.0 cm. Find

   i the proton's speed,

   ii the magnetic field magnitude,

   iii the circling frequency,

   iv the period of the motion.

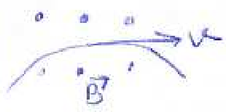
proton

$KE = 2.1 \times 10^{3}\ eV$

$R = 2.5 \times 10^{-2}\ m$

$$m\frac{v^2}{R} = qvB\sin 90$$

$$v = \frac{qRB}{m} \rightsquigarrow R = \frac{mv}{qB}$$



i) $\frac{1}{2} m_p v^2 = 2.1 \times 10^{3}\ eV \rightsquigarrow v^2 = \frac{2(2.1 \times 10^{3}\ eV)(1.6 \times 10^{-19}\ J/eV)}{1.67 \times 10^{-27}\ kg} = 4.02 \times 10^{11}\ m^2/s^2$ 4

$\rightsquigarrow v = \boxed{0.634 \times 10^{6}\ m/s}$ 3

ii) $B = \frac{m_p v}{qR} = \frac{(1.67 \times 10^{-27}\ kg)(0.634 \times 10^{6}\ m/s)}{(1.6 \times 10^{-19}\ C)(25 \times 10^{-2}\ m)} = \boxed{0.027\ T}$ 3

4

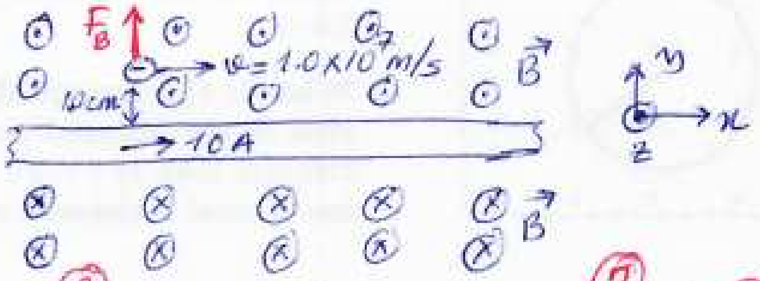
iii) $T = \frac{1}{f} = \frac{2\pi R}{v} \rightsquigarrow f = \frac{v}{2\pi R} = \frac{0.634 \times 10^{6}\ m/s}{2\pi(25 \times 10^{-2}\ m)} = \boxed{0.404 \times 10^{6}\ Hz}$

2 2

iv) $T = \frac{1}{f} = \boxed{2.48 \times 10^{-6}\ s}$

2

4. A long wire carries a 10 A current from left to right. An electron 1.0 cm above the wire is traveling to the right at a speed of 1.0×10^7 m/s. What are the magnitude and the direction of the magnetic force on the electrons?



(3)

$$B = \frac{\mu_0 I}{2\pi d} = \frac{(4\pi \times 10^{-7}\ TM/A)\ 10A}{2\pi\ 1.0\times 10^{-2}\,m} = \underline{\underline{2\times 10^{-4}\,T}}$$ (3) (2)

$$\vec{F}_B = q\,\vec{v}\times\vec{B} \Rightarrow |\vec{F}_B| = (1.602\times 10^{-19}\,C)(1.0\times 10^{7}\,m/s)(2\times 10^{-4}\,T)$$

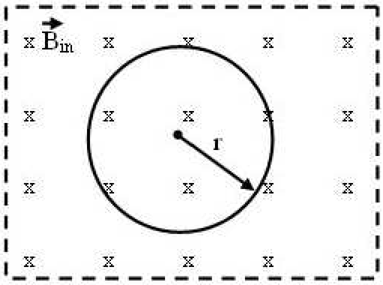
(3)

$$= \underline{\underline{3.2\times 10^{-16}\,N}}$$

(3) (2)

$$\underline{\underline{\vec{F}_B = 3.2\times 10^{-16}\,N\,\hat{j}}}$$ (4)

5. In figure below, the magnetic flux through the circular loop of radius $r = 2.0\ m$ increases according to the relation $\Phi_B = 6t^2 + 6t$, where Φ_B is in Webers and t is in seconds.



i Find the magnitude of the induced emf, ξ in the circular loop at $t = 2.0\ s$.

ii What is the magnitude and direction of the induced current in the circular loop at $t = 2.0\ s$ if the loop has a total resistance of $R = 60\ \Omega$?

i) $\phi_B(t) = 3t^2 + 3t$: increasing flux ⇒ induced $\mathcal{E}, i$ should oppose

$\mathcal{E} = -N \frac{d\phi_B}{dt}$ 5 $\rightarrow |\mathcal{E}| = \frac{d}{dt}(3t^2+3t)\Big|_{t=2s} = 6t+3\Big|_{t=2s} = \boxed{15\ V}$ 3 5

induced 1

ii) $i = \frac{\mathcal{E}}{R}$ 2 $= \frac{15\ V}{30\ \Omega} = \boxed{0.5A}$ 2

$\vec{B}_{applied}$ ⊗ ~ in to the page

$\vec{B}_{induced}$ ⊙ ← since it should oppose

by Right Hand Rule ~ direction of induced current is ccw 3

İzmir Kâtip Çelebi University
Department of Engineering Sciences
Phy102 Physics II
Final Examination
January 09, 2018 14:30 – 16:30
Good Luck!

NAME-SURNAME:

SIGNATURE:

ID:

DEPARTMENT:

DURATION: 120 minutes

◇ **Answer all the questions.**
◇ **Write the solutions explicitly and clearly. Use the physical terminology.**
◇ **You are allowed to use Formulae Sheet.**
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2		20
3		20
4		20
5		20
TOTAL		110

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1. A) A parallel-plate air-filled capacitor has a capacitance of 50 pF.

   i If each of its plates has an area of 0.35 m^2, what is the separation?

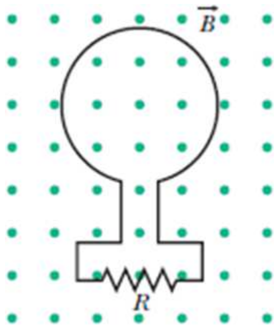
   ii If the region between the plates is now filled with material having k=5.6,what is the capacitance?

i) $C = \varepsilon_0 \frac{A}{d}$ (3) $\rightsquigarrow 50\times10^{-12} F = 8.85\times10^{-12} \frac{C^2}{Nm^2} \frac{0.35\,m^2}{d}$ (3)

$\rightsquigarrow d = \frac{(8.85\times10^{-12} C^2/Nm^2)(0.35 m^2)}{50\times10^{-12} F} = \underline{\underline{0.062\ m}}$ (1) (1)

ii) $C_1 = KC_0$ (2) $= (5.6)(50\times10^{-12} F) = \underline{\underline{280\ pF}}$ (3) (1) (1)

B) In Figure given below, the magnetic flux through the loop increases according to the relation $\Phi_B = 6.0t^2 + 7.0t$, where Φ_B is in miliwebers and t is in seconds.



i What is the magnitude of the emf (ε) induced in the loop when $t = 2.0\ s$?

ii Is the direction of the current through R to the right or left?

Increasing magnetic flux $\xrightarrow{1}$ induced emf in the loop

i) $|\mathcal{E}| = \left|\dfrac{d\Phi_B}{dt}\right|$ 3 $\rightarrow \mathcal{E}\Big|_{t=2s} = \dfrac{d}{dt}\left(6.0t^2+7.0t\right)\Big|_{t=2s}$ 2 $= 12t+7\Big|_{t=2s}$ 2

$\rightarrow \boxed{\mathcal{E} = 31\ mV}$ 2

ii) Increasing flux $\longleftrightarrow$ induced emf should create a magnetic flux to oppose (to decrease external field)

To have an inward (induced) B, we should have a clockwise current at the loop. 3

$\rightarrow$ $\boxed{\text{Left through } R}$ 2

2. The magnitude J of the current density in a certain lab wire with a circular cross section of radius R=5.00 mm is given by $J = (2.00 \times 10^7)r^2$, with J in amperes per square meter and radial distance r in meters. What is the current through the outer section bounded by r=0.800R and r=R?

$R = 15 \times 10^{-3}\,m$

$J(R) = 6 \times 10^7 r^2\ A/m^2$

$i = ?$ from $r = 0.2R$ to $r = 0.6R$

$$i = \int \vec{J} \cdot d\vec{A} = \int_{0.2R}^{0.6R} 6 \times 10^7 r^2\, 2\pi r\, dr$$

2 3 2

$$= 12\pi \times 10^7 \int_{0.2R}^{0.6R} r^3 dr = 12\pi \times 10^7 \frac{r^4}{4}\Big|_{0.2R}^{0.6R}$$

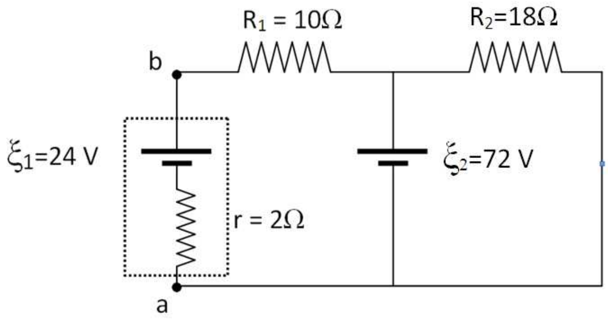
3

$$= 3\pi \times 10^7 [(0.6R)^4 - (0.2R)^4]$$

$$= 3\pi \times 10^7 \times 0.128 R^4 = \underline{\underline{0.61\,A}}$$

3 2

3. Consider circuit as shown in figure which consists of two batteries. One of the following batteries has an internal resistance r, while the other battery is an ideal battery. Calculate;

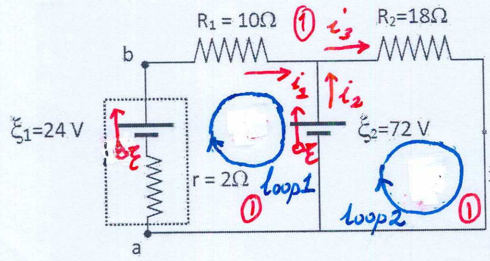


i Currents through each battery,

ii Potential difference between points a and b, V_{ab},

iii Total power supplied by batteries,

iv Total power dissipated by resistors.



i Currents through each battery,

ii Potential difference between points a and b, V_{ab},

iii Total power supplied by batteries,

iv Total power dissipated by resistors.

i) ① loop 1: $-i_1 r + \mathcal{E}_1 - i_1 R_1 - \mathcal{E}_2 = 0 \Rightarrow -2i_1 + 24 - 10i_1 - 72 = 0$ (2)

$-12 i_1 = 48$ $\boxed{i_1 = -4A}$ (1) opposite direction

② loop 2: $\mathcal{E}_2 - i_3 R_2 = 0 \Rightarrow 72 - 18 i_3 = 0$ (2) $\boxed{i_3 = 4A}$ (1)

③ $i_1 + i_2 = i_3$ (1) $\Rightarrow -4A + i_2 = 4A$ (1) $\rightarrow \boxed{i_2 = 8A}$

Three unknowns $(i_{1,2,3})$, three equations

$i_1 = -4A$: Through battery 1

$i_2 = 8\,A$: Through battery 2

$i_3 = 4A$: Through Resistor 3

ii) $V_{ab} = V_b - V_a$ (2)

b, $\mathcal{E}_1$, $i_1 = 4A$, a, loop 1

$V_a + i_1 r + \mathcal{E}_1 = V_b$

$V_b - V_a = 4A\,2\Omega + 24V \boxed{= 32V}$ (1)

iii) $P = i\mathcal{E}$

Battery 1: $P_1 = i_1 \mathcal{E}_1 = (4A)(24V) \boxed{= -96\,W}$ (1.5)

Battery 2: $P_2 = i_2 \mathcal{E}_2 = (8A)(72V) \boxed{= 576\,W}$ (1.5)

$P_1 + P_2 \boxed{= 480W}$

iv) $P = i^2 R$

Resistor 1: $P_1' = i_1^2 R_1 = (4A)^2 (10\Omega) \boxed{= 160\,W} \sim R_1$ (1)

Resistor 2: $P_2' = i_3^2 R_2 = (4A)^2 (18\Omega) \boxed{= 288\,W} \sim R_2$ (1)

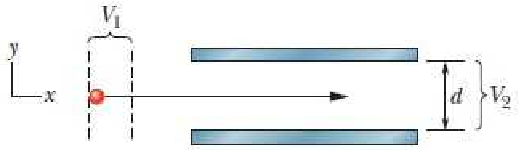
Internal Resistor r: $P_r' = i_1^2 r = (4A)^2 (2\Omega) \boxed{= 32\,W} \sim r$ (1)

$P_1 + P_2 = P_1' + P_2' + P_r'$

$480W = 480W$

3

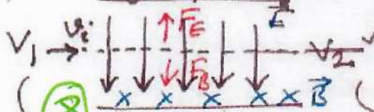
4. In Figure, an electron accelerated from rest through potential difference $V_1 = 1.00\ kV$ enters the gap between two parallel plates having separation $d = 20.0\ mm$ and potential difference $V_2 = 100\ V$. The lower plate is at the lower potential. Neglect fringing and assume that the electron's velocity vector is perpendicular to the electric field vector between the plates.



In unit-vector notation, what uniform magnetic field allows the electron to travel in a straight line in the gap?

$V_1 = 1\ kV$ & $d = 10\times10^{-3}\ m$, $V_2 = 50\ V$, $M_e = 9.11\times10^{-31}\ kg$

higher potential



(8)

lower potentail

(2)

$\Delta U = qV_1 - 0$ (2)

$= (1.6\times10^{-19}\ C)\ 1\times10^{3}\ V$

$\Delta U = \Delta K = \frac{1}{2} m_e v_i^2$

$V_2 = Ed$

$\Rightarrow E = \frac{V_2}{d}$

straight line $\Rightarrow |\vec{F}_B| = |\vec{F}_E|$

$|q| v_i B = |q| E$ (2)

$\sqrt{\frac{2qV_1}{m_e}}\, B = \frac{V_2}{d}$ (2)

$\rightarrow B = \frac{50 V}{10\times10^{-3} m} \sqrt{\frac{9.11\times10^{-31} kg}{2\times1.6\times10^{-19} C\ 1\times10^{3} V}}$

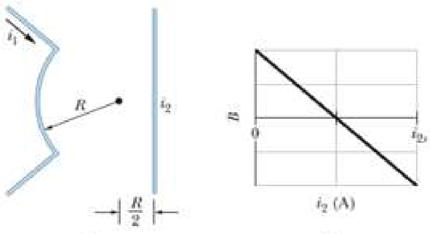
$B = 2.67\times10^{-4}\ T$

$\vec{B} = 2.67\times10^{-4}\ T(-\hat{k})$

(2) (2)

y x z

5. Figure(a) shows two wires, each carrying a current. Wire 1 consists of a circular arc of radius R and two radial lengths; it carries current $i_1 = 3.0\ A$ in the direction indicated. Wire 2 is long and straight; it carries a current i_2 that can be varied; and it is at distance R/2 from the center of the arc. The net magnetic field B due to the two currents is measured at the center of curvature of the arc.



(a) (b)

Figure(b) is a plot of the component of B in the direction perpendicular to the figure as a function of current i_2. The horizontal scale is set by $i_{2s} = 2.00\ A$. What is the angle subtended by the arc?

$i_1 = 3A$, R
i_2: variable, R/2

net magnetic field at point P

$$B_P = \underbrace{\frac{\mu_0 i_1}{4\pi R}}_{\substack{\text{circular arc} \\ \text{(out of page)}}} \phi - \underbrace{\frac{\mu_0 i_2}{2\pi R/2}}_{\substack{\text{straight wire} \\ \text{(into page)}}}$$

5 5

at $i_2 = 1A \rightsquigarrow B_P = 0 \rightsquigarrow \frac{\mu_0 3A}{4\pi R}\phi = \frac{\mu_0 1A}{\pi R}$ 5

$\rightsquigarrow \phi = \frac{4}{3}$ radians $= \underline{\underline{76.4^0}}$ 3 2

(3.14 rad $\rightsquigarrow$ 180°)