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Department of Engineering Sciences
Phy102 Physics II
Final Examination
June 07, 2024 10:20 – 11:50
Good Luck!

NAME-SURNAME:

SIGNATURE:

◇ **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.**
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.**

Question	Grade	Out of
1A		10
1B		15
2		20
3		15
4		20
5		20
TOTAL		100

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1. A) A 24.0 m length of 2.0 mm diameter cylindrical conducting wire carries a 140 A current when 28.0 V is applied to its ends.

   i Calculate the resistance R and resistivity ρ of the conducting wire.

   ii Find the current density J and electric field E inside the conducting wire.

   iii If the current is maintained in the conductor for 3 hours, calculate the dissipated energy in the conducting wire.

i) $R = \frac{V}{I}$ & $R = \rho \frac{L}{A} \rightsquigarrow \rho = \frac{A}{L} R$, $A = \pi r^2$

$R = \frac{28V}{140A} = \underline{\underline{0.2\,\Omega}}$ (1) (1)

$= \frac{\pi (2\times10^{-3} m/2)^2}{24m} 0.2\,\Omega$ (1)

$= \underline{\underline{2.6\times10^{-8}\,\Omega m}}$ (1)

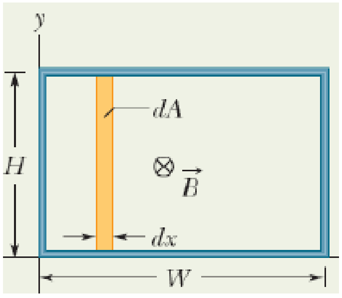
ii) $J = \frac{I}{A} = \frac{140A}{\pi (10^{-3} m)^2} = \underline{\underline{4.5\times10^{7}\,A/m^2}}$ (1) (1)

$E = \rho J = (2.6\times10^{-8}\,\Omega m)(4.5\times10^{7} A/m^2) = \underline{\underline{1.2\ V/m}}$ (1) (1)

iii) $\frac{\Delta U}{\Delta t} = P = i^2 R \rightsquigarrow \Delta U = i^2 R \Delta t$

$\rightsquigarrow \Delta U = (140A)^2 (0.2\,\Omega)(3\times60\times60s) = \underline{\underline{4.2\times10^{7}\ J}}$ (1) (1)

B) Figure shows a rectangular loop of wire immersed in a nonuniform and varying magnetic field $\vec{B}$ that is perpendicular to and directed into the page. The field's magnitude is given by $B = 4t^2x^2$, with B in teslas, t in seconds, and x in meters.



The loop has width $W = 3.0\ m$ and height $H = 2.0\ m$. What are the magnitude and direction of the induced emf ξ around the loop at $t = 0.10\ s$?

$\Phi_B = \int \vec{B} \cdot d\vec{A}$, $B // A$, $\Phi_B = \int B\,dA = \int 4t^2x^2 H\,dx$

$B(x,t) = 4t^2x^2$

$A = Hx$, $dA = H\,dx$

$W = 3\,m$ & $H = 2\,m$

$\Delta t = 0.10\,s$

(3)

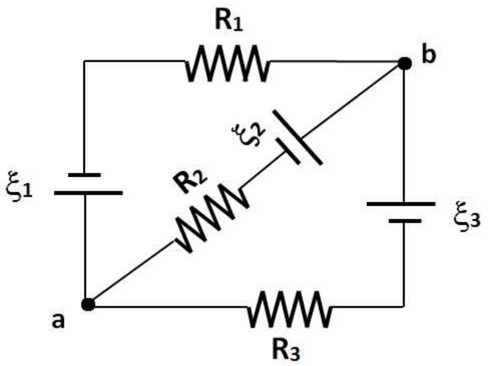
$= 4t^2 H \int_0^3 x^2\,dx = 4t^2 H \frac{x^3}{3}\Big|_0^3$

$= 72t^2 = \Phi_B$ (3)

$|\mathcal{E}| = + \frac{d\Phi_B}{dt}$ (3) $= +144t \Big|_{t=0.1s} = 14.4\,V$ (3) magnitude

Increasing B ⊗ → induced current should oppose (3) ⊙ ⇒ CCW

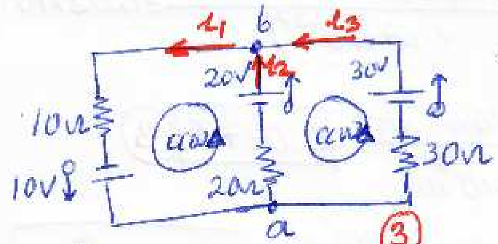
2. The circuit containing three ideal batteries and resistors is shown in figure. If $R_1 = 10\ \Omega$, $R_2 = 20\ \Omega$, $R_3 = 30\ \Omega$, $\xi_1 = 10\ V$, and $\xi_2 = 20\ V$, $\xi_3 = 30\ V$;



i Calculate the current through each battery.

ii Calculate $V_b - V_a$, the potential difference between the points b and a.

iii Find the total thermal energy dissipation rate in the circuit.



(3)

$\rightarrow 10I_1 + 20I_2 = 30$

$20I_2 - 30I_3 = -10$

$10(I_2 + I_3) + 20I_2 = 30$

$20I_2 - 30I_3 = -10$

3/ $30I_2 + 10I_3 = 30$

$20I_2 - 30I_3 = -10$

$110I_2 = 80 \rightsquigarrow$ $I_2 = 0.73A$ (2), $I_3 = 0.82A$ (2), $I_1 = 1.55A$ (2)

i) $I_1 = I_2 + I_3$ (1)

$-20\Omega I_2 + 20V - 10\Omega I_1 + 10V = 0$ (2)

$-30\Omega I_3 + 30V - 20V + 20\Omega I_2 = 0$ (2)

$-20I_2 + 30 - 10I_1 = 0$

$-30I_3 + 10 + 20I_2 = 0$

ii) $V_b - 20V + (20\Omega)(0.73A) = V_a$

$V_b - (1.55A)(10\Omega) + 10V = V_a$

$V_b - 30V + (30\Omega)(0.82A) = V_a$

$\Rightarrow V_b - V_a = 5.5V$ (3)

iii) $P_{tot} = I_1^2 R_1 + I_2^2 R_2 + I_3^2 R_3$

$= (1.55A)^2\, 10\Omega + (0.73A)^2\, 20\Omega + (0.82A)^2\, 30\Omega$

$= 54.9\ W$ (3)

3. **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; $F_c = m\frac{v^2}{R}$)

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

$R = 0.35\,m$

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

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

$B = ?$

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

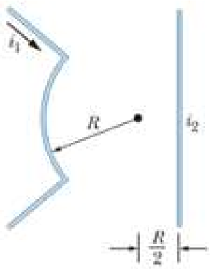
$|q| v B \sin 90° = m_e\, v^2/R$ (5)

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

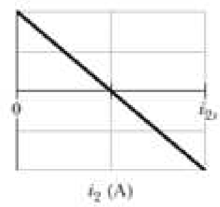
$= \frac{(9.109 \times 10^{-31}\,kg)(1.3 \times 10^6\,m/s)}{(1.602 \times 10^{-19}\,C)(0.35\,m)}$

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

4. 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 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 } net magnetic field at point P
i_2 : variable, $R/2$ }

$$B_p = \frac{\mu_0 i_1}{4\pi R}\phi - \frac{\mu_0 i_2}{2\pi R/2}$$

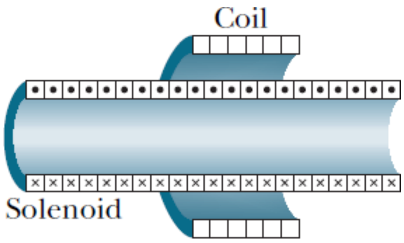
(5) circular arc (out of page) — (5) straight wire (into page)

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 $= 76.4^\circ$ (3) (2)

$(3.14\ rad \rightsquigarrow 180^\circ)$

5. In Figure below, a 120-turn coil of radius 1.8 cm and resistance 5.3 Ω is coaxial with a solenoid of 220 turns/cm and diameter 3.2 cm. The solenoid current drops from 1.5 A to zero in time interval $\Delta t = 25\ ms$.



What current is induced in the coil during Δt?

We need the induced emf, $\mathcal{E}$ on the coil by changing current in the solenoid.

Changing current → changing magnetic flux ⇒ induced emf

Lenz's law (3) $\mathcal{E} = -N\frac{d\Phi_B}{dt} = -NA\frac{dB}{dt}$ (3) { Magnetic Field of a solenoid $B = \mu_0 n i$

$\Rightarrow \mathcal{E} = -NA\frac{d}{dt}(\mu_0 i n) = -NA\mu_0 n \frac{di}{dt}$ (3), $\frac{di}{dt} \sim \frac{\Delta i}{\Delta t}$ (3) $\frac{\Delta i}{\Delta t} = \frac{0-1.5A}{25\times10^{-3}s - 0}$

(1) (1)

$\Rightarrow \mathcal{E} = -(120)(\pi\times(1.6\times10^{-2}m)^2)(4\pi\times10^{-7}Tm/A)(22000\ \frac{turns}{m})\left(\frac{-1.5A}{25\times10^{-3}s}\right)$ (1)

(1) $\boxed{= 0.16V}$ (1)

→ Then, Ohm's law $i = \frac{\mathcal{E}}{R}$ (1) $= \frac{0.16V}{5.3\Omega}$ $\boxed{= 0.030\ A}$

(1) (4)