Kuwait University **Department of Physics**

General Physics II for Biological Sciences (Phy 122)

Second Midterm Examination (Summer Semester 2024-2025)

July 24, 2025

Time: 4:00 PM to 5:30 PM

Instructor: Dr. S.S.A. Razee

Solution

Fundamental Constants

$k = \dfrac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \mathrm{N \cdot m^2/C^2}$	Coulomb's constant
$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/(N \cdot m^2)}$	Permitivity of free space
$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}$	Permeability of free space
$e = 1.6 \times 10^{-19}\ \mathrm{C}$	Elementary charge
$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$	Mass of an electron
$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$	Mass of a proton
$\mathrm{eV} = 1.6 \times 10^{-19}\ \mathrm{J}$	Conversion from eV to J
$N_A = 6.022 \times 10^{23}/\mathrm{mol}$	Avogadro's number

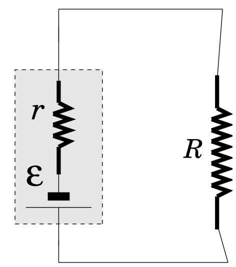
Prefixes of units

$\mathrm{m} = 10^{-3}$ $\mu = 10^{-6}$ $\mathrm{n} = 10^{-9}$ $\mathrm{p} = 10^{-12}$ $\mathrm{k} = 10^{3}$ $\mathrm{M} = 10^{6}$

Instructions to the Students:

- All communication devices must be switched off and placed in your bag. Anyone found using a communication device will be disqualified.
- Programmable calculators, which can store equations, are not allowed.

1. In the circuit shown, $R = 22.0\ \Omega$, the emf of the real battery $\mathcal{E} = 36.0$ V and the internal resistance of the battery is $r = 2.0\ \Omega$. Find the **terminal voltage** of the battery. **3 points**



Solution: The current in the circuit is

$$I = \frac{\mathcal{E}}{R + r} = 1.5\text{ A}$$

The terminal voltage is

$$V_T = \mathcal{E} - Ir = 33\text{ V}$$

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2. An electric heater is required to produce 3.6×10^5 J of heat energy in 5 minutes. It is to be connected to a 220 V source and the heating element is made of a material with resistivity $\rho = 6.0 \times 10^{-6}\ \Omega\cdot$m. If the radius of the wire is 1.2 mm, what must be the length of the wire? **3 points**

Solution: We have

$$P = \frac{\text{Energy}}{t} = 1200\text{ W}$$

The resistance of the wire: $\quad P = \frac{V^2}{R} \implies R = \frac{V^2}{P} = 40.3\ \Omega$

Then

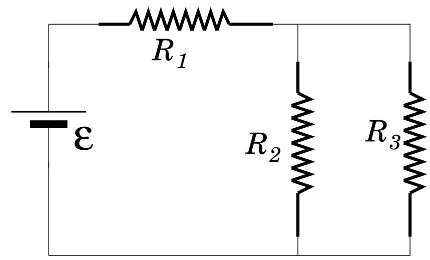
$$R = \rho\frac{L}{A} \implies L = \frac{RA}{\rho} = \frac{R\pi r^2}{\rho}$$

$$\implies L = 30.4\text{ m}$$

3. In the circuit shown, $R_1 = R_2 = 12.0\ \Omega$ and $\mathcal{E} = 21.0$ V, but R_3 is unknown. The power dissipated in R_2 is $P_2 = 3.0$ W.

   (a) Find the power P_1 dissipated in R_1. **3 points**

   (b) Find the power P_3 dissipated in R_3. **2 points**



Solution: We can calculate V_2 and/or I_2,

$$P_2 = \frac{V_2^2}{R_2} \implies V_2 = \sqrt{P_2 R_2} = 6.0 \text{ V}$$

Then

$$\left.\begin{array}{l} R_2 \text{ and } R_3 \text{ are parallel} \\ R_1 \text{ and } R_{23} \text{ are in series} \end{array}\right\} \implies \left\{\begin{array}{l} V_{23} = V_2 = 6.0 \text{ V} \\ V_1 = \mathcal{E} - V_{23} = 15.0 \text{ V} \end{array}\right.$$

So $$\boxed{P_1 = \frac{V_1^2}{R_1} = 18.75 \text{ W}} \quad \text{and} \quad I_1 = \frac{V_1}{R_1} = 1.25 \text{ A}$$

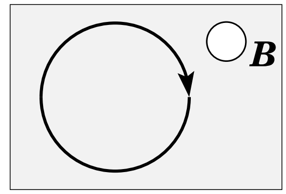
$$\left.\begin{array}{l} R_2 \text{ and } R_3 \text{ are parallel} \\ R_1 \text{ and } R_{23} \text{ are in series} \end{array}\right\} \implies I_{123} = I_1 = 1.25 \text{ A}$$

Total power in the circuit: $P = I_{123}\mathcal{E} = 26.25$ W

Power dissipated in R_3: $P_3 = P - P_1 - P_2 \implies \boxed{P_3 = 4.5 \text{ W}}$

4. An electron moves in a **clockwise** circular path of radius $R = 2.0$ mm in a region of uniform magnetic field of magnitude $B = 4.0 \times 10^{-3}$ T (shown in the figure).

   (a) What is the **direction** of the **magnetic field** $\vec{B}$? (Tick the correct answer) **1 point**



   into-the-plane $\otimes$ ✓ **out-of-the-plane** $\odot$

   (b) Find the magnitude of the **magnetic force** $\vec{F}_B$ on the electron. **2 points**

   First find the speed:

$$R = \frac{mv}{B|q|} \implies v = \frac{B|q|R}{m} = 1.4 \times 10^6 \text{ m/s}$$

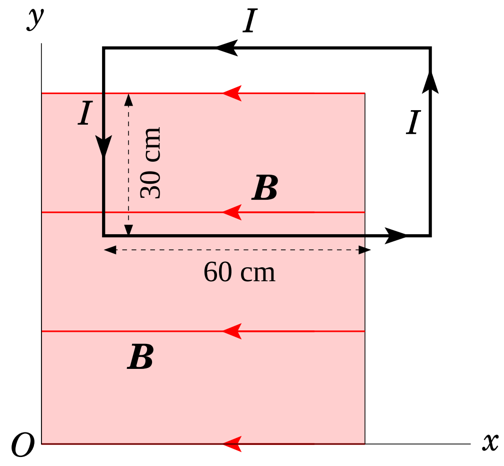
   For circular motion, the angle between $\vec{B}$ and $\vec{v}$ is $\theta = 90^o$. So

$$F_B = |q|vB = 9.0 \times 10^{-16} \text{ N}$$

   (c) Find the **kinetic energy** of the electron in **eV**. **1 point**

$$\text{KE} = \frac{1}{2}mv^2 = 8.93 \times 10^{-19} \text{ J} = 5.6 \text{ eV}$$

5. A uniform magnetic field of magnitude $B = 5.0 \times 10^{-3}$ T in the $-\boldsymbol{x}$**-direction** is established in the shaded area (see figure below). A rectangular (80 cm×40 cm) wire carrying a current $I = 7$ A is partly inside the region as shown.



(a) Find the **magnitude** of the **magnetic force** ($\vec{F}_B$) on the wire. **2 points**

For a **straight** wire, the magnetic force is

$$F_B = ILB\ \sin\theta$$

where, L = length of the wire **inside** the region of magnwetic field and θ = angle between L and $\vec{B}$.

Here, we have **two** pieces of straight wires inside the region of magnetic field:

$$L_1 = 30 \text{ cm}, \quad \theta = 90^o \qquad\qquad L_2 = 60 \text{ cm}, \quad \theta = 0^o$$

$$\Longrightarrow \quad F_{B1} = IL_1B\ \sin 90^o = 0.0105 \text{ N} \qquad\qquad F_{B2} = IL_2B\ \sin 0^o = 0$$

So, the **magnitude** of the **net magnetic force** is

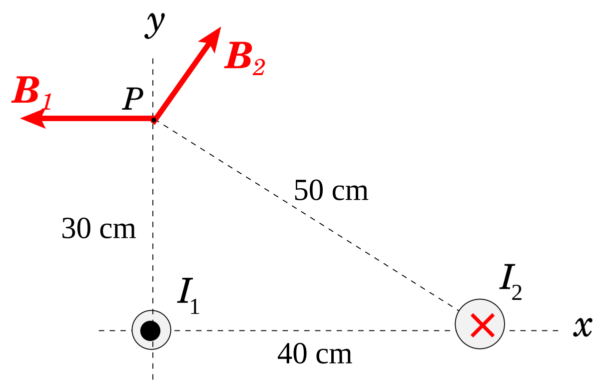
$$F_B = F_{B1} + F_{B2} = 0.0105 \text{ N}$$

(b) What is the **direction** of $\vec{F}_B$? (Tick the correct answer) **1 point**

upward ↑ | **downward** ↓ | **to-the-right** →

to-the-left ← | **into-the-plane** ⊗ ✓ | **out-of-the-plane** ⊙

6. Two long straight wires carrying currents perpendicular to the xy−plane are shown. The current $I_1 = 6$ A, **out-of-the-plane** (see the figure) and the x−**component of the net magnetic field** at the point P is $B_x = +3.0 \times 10^{-6}$ T. The current I_2 is unknown. We denote $\vec{\boldsymbol{B}}_1$ and $\vec{\boldsymbol{B}}_2$ as the magnetic fields at P due to currents I_1 and I_2 respectively.



(a) Draw the vector $\vec{\boldsymbol{B}}_1$ at P. **1 point**

Using the right-hand-rule, $\vec{\boldsymbol{B}}_1$ is in the negative x-direction

(b) Find $B_{1,x}$ and $B_{2,x}$. **2 points**

$$B_{1,x} = -B_1 = -\frac{\mu_0 I_1}{2\pi \times 0.3} = -4.0 \times 10^{-6} \text{ T}$$

$$B_x = B_{1,x} + B2, x \implies B_{2,x} = +7.0 \times 10^{-6} \text{ T}$$

(c) Use the value of $B_{2,x}$ to draw the vector $\vec{\boldsymbol{B}}_2$ at P. **1 point**

Since $B_{2,x} > 0$ and $\vec{\boldsymbol{B}}_2$ must be perpendicular to the 50 cm line, the only way to draw $\vec{\boldsymbol{B}}_2$ is as shown in the figure.

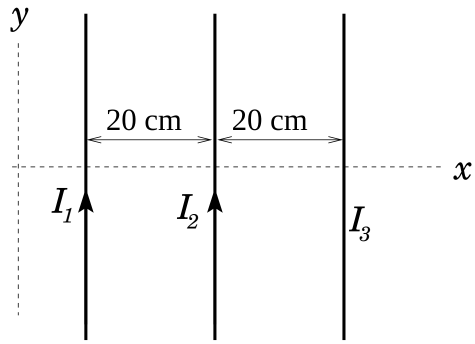
(d) Use the vector $\vec{\boldsymbol{B}}_2$ to find the **direction** of I_2 (Tick the correct answer). **1 point**

I_2 is **into-the-plane** $\otimes$ ✓	I_2 is **out-of-the-plane** $\odot$

(e) Find the value of I_2. **2 points**

$$B_{2,x} = +B_2 \times \frac{0.3}{0.5} \implies 7.0 \times 10^{-6} = \frac{\mu_0 I_2}{2\pi \times 0.5} \times \frac{0.3}{0.5} \implies I_2 = 29.2 \text{ A}$$

7. Three long straight current-carrying wires are parallel to the $y-$axis and in the $xy-$plane as shown. The current $I_1 = 3$ A, **upward** (↑) and the current $I_2 = 4$ A, **upward** (↑). The **net magnetic force** per m of the **wire 1**, *i.e.* $\frac{\vec{\boldsymbol{F}}_1}{L} = 0$.



(a) What is the **direction** of the current $\boldsymbol{I_3}$? (Tick the correct answer) **1 point**

$\frac{\vec{\boldsymbol{F}}_{12}}{L}$ is to the **right**. So $\frac{\vec{\boldsymbol{F}}_{13}}{L}$ must be to the **left** to make $\frac{\vec{\boldsymbol{F}}_1}{L} = 0$. So I_3 must be downward.

upward ↑   **downward ↓** ✓

(b) What is the **value** of $\boldsymbol{I_3}$? **2 points**

$$\frac{F_{12}}{L} = \frac{F_{13}}{L} \Longrightarrow \frac{\mu_0 I_1 I_2}{2\pi \times 0.2} = \frac{\mu_0 I_1 I_3}{2\pi \times 0.4} \Longrightarrow I_3 = 8 \text{ A}$$

(c) $\frac{\vec{\boldsymbol{F}}_2}{L}$ = **net magnetic force** per m of **wire 2**. Find its **magnitude**. **2 points**

$$\frac{F_{21}}{L} = \frac{\mu_0 I_1 I_2}{2\pi \times 0.2} = 1.2 \times 10^{-5} \text{ N/m}, \quad \textbf{to-the-left}$$

$$\frac{F_{23}}{L} = \frac{\mu_0 I_2 I_3}{2\pi \times 0.2} = 3.2 \times 10^{-5} \text{ N/m}, \quad \textbf{to-the-left}$$

So, the magnitude of $\frac{\vec{\boldsymbol{F}}_2}{L}$ is

$$\frac{F_2}{L} = \frac{F_{21}}{L} + \frac{F_{23}}{L} = 4.4 \times 10^{-5} \text{ N/m}, \quad \textbf{to-the-left}$$

(d) What is the **direction** of $\frac{\vec{\boldsymbol{F}}_2}{L}$? **1 point**

to-the-left ← ✓   **to-the-right →**