STATE UNIVERSITY OF NEW YORK
New Paltz, New York.

General Physics 2
Second Exam

Instructor: Dr. T. Biswas
October 31, 2024.

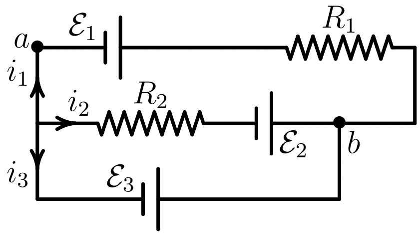
Solutions

Constants and Formulas

$$
\begin{aligned}
\mu_0 &= 4\pi \times 10^{-7}\ Tm/A. \\
V &= iR \\
q &= CV \\
C &= C_1 + C_2 \\
1/C &= 1/C_1 + 1/C_2 \\
\vec{\mathbf{F}} &= i\vec{\mathbf{L}} \times \vec{\mathbf{B}} \\
d\vec{\mathbf{B}} &= \frac{\mu_0 i}{4\pi r^2} d\vec{\mathbf{s}} \times \hat{\mathbf{r}} \\
&= \frac{\mu_0 i}{4\pi r^3} d\vec{\mathbf{s}} \times \vec{\mathbf{r}}
\end{aligned}
$$

Name______________________________

Problem I



The above circuit has components of the following values: $R_1 = 4.0\ \Omega$, $R_2 = 5.0\ \Omega$, $\mathcal{E}_1 = 60$ V, $\mathcal{E}_2 = 20$ V, and $\mathcal{E}_3 = 50$ V.

Solution

Question 1

The outer boundary loop gives

$$\mathcal{E}_1 - i_1 R_1 - \mathcal{E}_3 = 0.$$

Hence,

$$i_1 = \frac{\mathcal{E}_1 - \mathcal{E}_3}{R_1} = 2.5 \text{ A}$$

Question 2

The lower rectangular loop gives

$$-i_2 R_2 + \mathcal{E}_2 - \mathcal{E}_3 = 0.$$

Hence,

$$i_2 = \frac{\mathcal{E}_2 - \mathcal{E}_3}{R_2} = -6.0 \text{ A}$$

Question 3

The junction equation gives

$$i_1 + i_2 + i_3 = 0$$

Hence,

$$i_3 = -i_1 - i_2 = 3.5 \text{ A}$$

Question 4

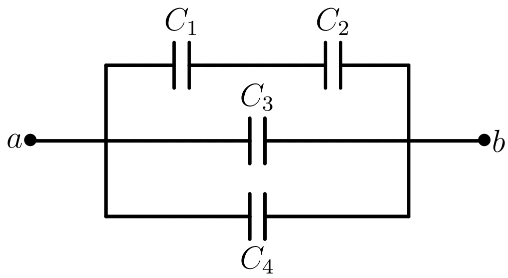
Starting at a, going down and then going right through $\mathcal{E}_3$ to b gives

$$V_a + \mathcal{E}_3 = V_b$$

Hence,

$$V_b - V_a = \mathcal{E}_3 = 50 \text{ V}$$

Problem II



Four capacitors are connected as shown above. Each capacitor has a capacitance of 4.0μF. A voltage of 10V is applied between the points a and b.

Solution

Question 5

C_1, and C_2 are in series. So their combination has capacitance C_s given by

$$1/C_s = 1/C_1 + 1/C_2 = 1/2$$

Hence,

$$C_s = 2.0\mu\text{F}$$

C_s, C_3 and C_4 are in parallel. Hence, the net capacitance C is given by

$$C = C_s + C_3 + C_4 = 10.0\mu\text{F}$$

Question 6

The full voltage of 10V is across the capacitance C_s. The charge in the series combination is the same as the charge in each member of the combination. Hence,

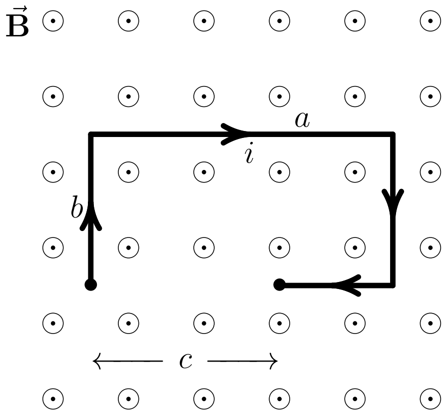
$$q_1 = q_s = C_s V = 2.0 \times 10 = 20\mu\text{C}$$

Question 7

The voltage across C_4 is 10V. Hence the charge in it is

$$q_4 = C_4 V = 4.0 \times 10 = 40\mu\text{C}.$$

Problem III



The figure above shows a magnetic field $\vec{\mathbf{B}}$ directed out of the page. Its magnitude is 3.0T. A piece of wire is placed in this magnetic field in the plane of the page as shown. The top segment has a length $a = 4.0$m and the left segment has a length $b = 2.0$m. The distance between the ends of the wire is $c = 2.5$m A current of $i = 5.0$A is flowing in the wire in the direction shown.

Solution

Question 8

The force is given by

$$\vec{\mathbf{F}} = i\vec{\mathbf{L}} \times \vec{\mathbf{B}}$$

The right hand rule gives the direction of $\vec{\mathbf{F}}$ to be towards the bottom of the page. The magnitude is

$$F = i|\vec{\mathbf{L}} \times \vec{\mathbf{B}}| = iaB \sin 90^\circ = 60 \text{ N}$$

Question 9

The right hand rule gives the direction of $\vec{\mathbf{F}}$ to be to the right. The magnitude is

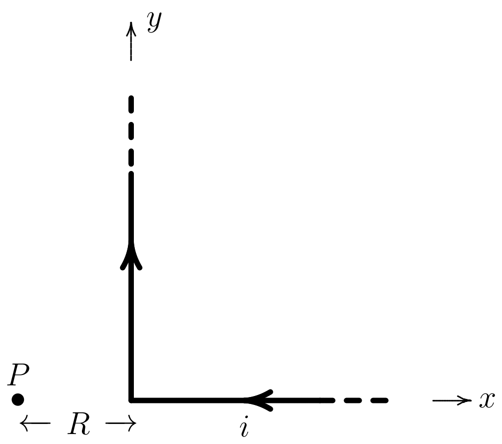
$$F = i|\vec{\mathbf{L}} \times \vec{\mathbf{B}}| = ibB \sin 90^\circ = 30 \text{ N}$$

Question 10

Here, the vector $\vec{\mathbf{L}}$ is the one joining the end-points in the direction of the current. So, the right hand rule gives the direction of $\vec{\mathbf{F}}$ to be towards the bottom of the page. The magnitude is

$$F = i|\vec{\mathbf{L}} \times \vec{\mathbf{B}}| = icB \sin 90^\circ = 37.5 \text{ N}$$

Problem IV



A long thin wire is bent in the shape shown above. Assume it extends to infinity in the positive y and positive x directions as shown. A current i flows in the wire as shown. The point marked P is at a distance R along the negative x axis as shown.

Solution

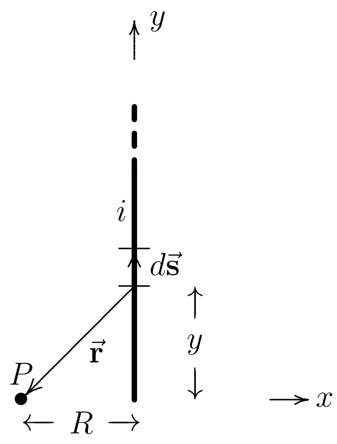
Biot-Savart law gives

$$d\vec{\mathbf{B}} = \frac{\mu_0 i}{4\pi r^2} d\vec{\mathbf{s}} \times \hat{\mathbf{r}}$$

Question 11

For this part, the angle between $d\vec{\mathbf{s}}$ and $\hat{\mathbf{r}}$ is zero. So, $d\vec{\mathbf{s}} \times \hat{\mathbf{r}} = 0$. Hence, the magnetic field due to this part is zero.

Question 12



Using the right-hand-rule, the magnetic field direction due to the element of wire $d\vec{\mathbf{s}}$ is found to be out of the page. As this direction is the same for all elements of wire, integrating the magnitude of the field will give the total field.

$$dB = \frac{\mu_0 i}{4\pi r^2} ds \ \sin\theta$$

where $\sin\theta = R/r$. Hence,

$$B = \int dB = \frac{\mu_0 i R}{4\pi} \int \frac{ds}{r^3}$$

Choosing the bottom end of the wire as the origin of the y axis and the distance of the line element from the origin to be y, it follows that $ds = dy$ and $r = (y^2 + R^2)^{1/2}$. Hence,

$$B = \frac{\mu_0 i R}{4\pi} \int_0^\infty \frac{dy}{(y^2 + R^2)^{3/2}}$$

Question 13

Direction is out of the page as seen in the solution of question 12.