Second mid term exam FFI
November 30th 2015
Year 2015/16

Applied Physics Dept.

On every exercises, effective communication will be taken in account up to a 10% of final mark

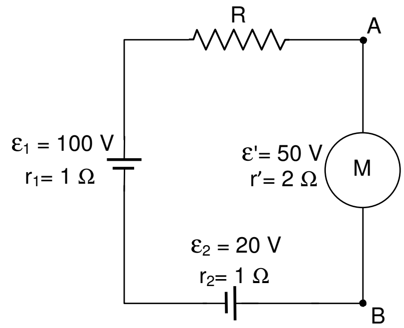
En todos los ejercicios, la comunicación efectiva será tenida en cuenta hasta en un 10% de la calificación final.

1. (3 points) On circuit on picture, difference of potential between points A and B is **56 V (V_A-V_B=56 V)**. Compute:

a) (0,6) Intensity of current flowing along circuit.
b) (0,6) The resistance R.
c) (1,2) Generated and consumed power on each device of circuit, clearly stating which of them are acting as generators and which as receptors.
d) (0,6) Efficiency of motor.

1. (3 puntos) En el circuito de la figura, la diferencia de potencial entre los puntos A y B es de **56 V**. **(V_A-V_B=56 V)**. Calcula:

a) (0,6) La intensidad de corriente en el circuito.
b) (0,6) La resistencia R.
c) (1,2) Potencia generada y consumida en cada uno de los elementos del circuito, indicando claramente qué elementos actúan como generadores y cuáles como receptores.
d) (0,6) El rendimiento del motor.



a) As V_A-V_B is positive, point A will have higher potential than point B. Therefore, difference of potential between terminals of motor is:

$$V_A - V_B = \varepsilon' + Ir' = 50 + I \cdot 2 = 56 \Rightarrow I = \frac{56-50}{2} = 3\ A$$ This intensity goes from A to B through the motor

b) By computing the same difference of potential along the longest path:

$$V_A - V_B = -3(R+1+1) - (-100+20) = 56 \Rightarrow R = 6\ \Omega$$

c) According the direction of intensity, generator 1 acts as generator, but generator 2 acts as a receptor. Powers on these elements are:

Generator 1: $P_g = \varepsilon_1 I = 100 * 3 = 300\ w$ $\quad P_{r_1} = I^2 r_1 = 3^2 \cdot 1 = 9\ w$ $\quad P_s = P_g - P_{r_1} = 300 - 9 = 291\ w$

Generator 2: $P_{t_2} = \varepsilon_2 I = 20 * 3 = 60\ w$ $\quad P_{r_2} = I^2 r_2 = 3^2 \cdot 1 = 9\ w$ $\quad P_{c_2} = P_{t_2} + P_{r_2} = 60 + 9 = 69\ w$

Motor: $P_t = \varepsilon' I = 50 * 3 = 150\ w$ $\quad P_{r'} = I^2 r' = 3^2 \cdot 2 = 18\ w$ $\quad P_c = P_t + P_{r'} = 150 + 18 = 168\ w$

Resistor: $P_R = I^2 R = 3^2 \cdot 6 = 54\ w$

Obviously, the power supplied to the circuit must be equal to the consumed power:

$$291 = 69 + 168 + 54 = 291$$

d) $\eta_m = \frac{P_t}{P_c} = \frac{150}{168} = 0{,}89 \approx 89\%$

2. (3 points) Given the circuit on picture, compute:

a) (1,5) Intensity of current flowing along each branch with the shown directions, I_1, I_2 and I_3.

b) (0,5) Difference of potential between points B and D.

c) (0,5) Tehevenin's equivalent generator between points B and D, clearly showing its polarity.

d) (0,5) If point C is connected to ground, ¿which would be the potential on point B?

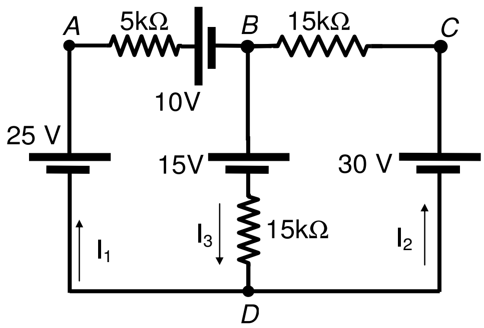
2. (3 puntos) Dado el circuito de la figura, calcula:

a) (1,5) La intensidad de corriente en cada rama con los sentidos mostrados, I_1, I_2 y I_3.

b) (0,5) Diferencia de potencial entre los puntos B y D.

c) (0,5) El generador equivalente de Thevenin entre los puntos B y D, indicando claramente su polaridad.

d) (0,5) Si el punto C se conecta a tierra, ¿cuál sería el potencial del punto B?

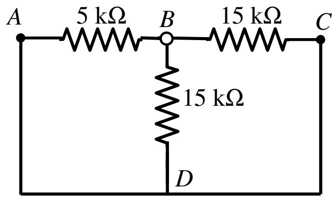


This is a network with 2 junctions and two loops, and so we'll need one equation for junctions and two equations for loops:

a) $$\left.\begin{array}{r} I_1 + I_2 = I_3 \\ V_{AD} = 25 = I_1 5 - (-10) + I_3 15 - (-15) \\ V_{CD} = 30 = I_2 15 + I_3 15 - (-15) \end{array}\right\} \Rightarrow I_1 = -\frac{3}{5} = -0{,}6\ mA \quad I_2 = \frac{4}{5} = 0{,}8\ mA \quad I_3 = \frac{1}{5} = 0{,}2\ mA$$

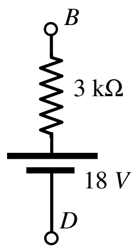
b) $V_B - V_D = 15 I_3 - (-15) = 15\frac{1}{5} + 15 = 18\ V$

c) Passive circuit and equivalent resistance between B and D (removing all the generators) is



$$\frac{1}{R_{eq}} = \frac{1}{5} + \frac{1}{15} + \frac{1}{15} \Rightarrow R_{eq} = 3\ k\Omega$$

So, Thevenin's equivalent generator between B and D is:



d) If point C is connected to ground, then V_C=0; as $V_B - V_C = -I_2 15 = -\frac{4}{5} 15 = -12\ V$, then V_B=-12 V

3. (2 points) The picture shows two parallel conductor plates perpendicular to the plane of paper, being 5 mm the distance between them. A magnetic field 2 T sized is acting inside the space between plates (as can be seen on picture). An electron is entering inside the space between plates with speed $2 \cdot 10^6$ m/s. Calculate:

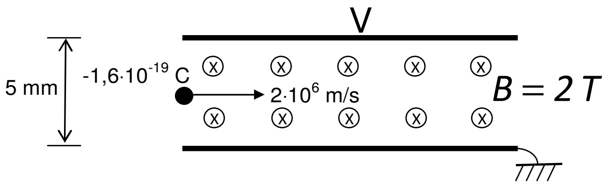
a) (1) The force due to the magnetic field acting on this electron when it's entering between the plates ($q^- = -1{,}6 \cdot 10^{-19}$ C); give its direction.

b) (1) If lower plate is connected to ground, ¿which potential V should be applied to upper plate in order the electron wouldn't deflect its rectilinear trajectory?

3. (2 puntos) La figura muestra dos placas conductoras paralelas y perpendiculares al plano del papel, siendo 5 mm la distancia entre ellas. Un campo magnético de 2 T actúa en el espacio entre ambas placas, tal y como puede verse en la figura. Un electrón entra en el espacio entre placas con velocidad $2 \cdot 10^6$ m/s. Calcula:

a) (1) La fuerza debida al campo magnético que actúa sobre el electrón cuando está entrando en el espacio entre placas ($q^- = -1{,}6 \cdot 10^{-19}$ C); indica su dirección.

b) (1) Si la placa inferior está conectada a tierra, ¿qué potencial hay que aplicar a la placa superior para que el electrón no se desvíe de su trayectoria rectilínea?



a) According the force acting on a moving charge inside a magnetic field:
$\vec{\mathbf{F}} = q(\vec{\mathbf{v}} \times \vec{\mathbf{B}})$ The direction of force is downwards (cross product upwards, but q is negative). As v and B are perpendicular vectors, the modulus of force is: $F_m = qvB = 1{,}6 \cdot 10^{-19} 2 \cdot 10^6 2 = 6{,}4 \cdot 10^{-13}\ N$

b) When a difference of potential is applied to both plates, an electric field (E) perpendicular to magnetic field appears: $E = \frac{V}{d}$ being d the distance between plates. If the electron musn't be deflected, then the force acting on electron due to the electric field must cancel the magnetic force:

$$F_E = qE = 1{,}6 \cdot 10^{-19} \frac{V}{5 \cdot 10^{-3}} = 6{,}4 \cdot 10^{-13} \Rightarrow V = 20000\,V$$

The electric force must act upwards, and so the electric field must go downwards; the upper plate must have positive potential (+20000 V).

4. (2 points) State Ampère's law (1) and apply it (1) to compute the magnetic field created by an infinite straight carrying current wire, flowed by an intensity of current **I**, at a point placed at a distance **x** from wire. Explain the computations done.

4. (2 puntos) Enuncia el teorema de Ampère (1) y aplícalo (1) para calcular el campo magnético creado por un conductor rectilíneo e indefinido, recorrido por una intensidad de corriente **I**, en un punto situado a una distancia **x** del conductor. Explica los cálculos realizados.

Ampére's law statement appears on point 7.5 of notes:
"The circulation of magnetic field vector along any enclosed curve equals the product of the constant μ0 by the addition of the intensities of current crossing any surface bordered by the curve. The sign of the intensity will be positive when it was in accordance with the screw or the right hand rule with the sense of the circulation, and negative in another case."

$$C = \oint \vec{B} d\vec{l} = \mu_0 \sum I$$

Related to the magnetic field created by a straight carrying current wire, on a point placed at a distance x, appears on next page:

In order to apply Ampère's law, we choose a circumference of radius *x*, perpendicular to conductor and centered on a point of such conductor. This circumference is a field line of magnetic field, being the magnetic field vector tangent to this line at any point. On the other hand, as distance to conductor is the same for all the points of line, modulus of magnetic field will also be the same. So, circulation of magnetic field along this circumference is $C = \oint \vec{B} d\vec{l} = B 2\pi x$

Considering the surface of a disk bordered by this circumference, the intensity crossing this disk is *I* (positive because its sense is in accordance with the sense of circulation chosen). Then, applying Ampère's law becomes

$$C = \oint \vec{B} d\vec{l} = B 2\pi x = \mu_0 I \Rightarrow B = \frac{\mu_0 I}{2\pi x}$$

FORM

Direct current $V_A - V_B = I\sum R - \sum \varepsilon$ $\quad I = \frac{\sum \varepsilon}{\sum R}$ $\quad P = V \cdot I$ $\quad \varepsilon = \frac{dW}{dq}$ $\quad P_R = R \cdot I^2$

$P_g = \varepsilon \cdot I$ $\quad P_t = \varepsilon' \cdot I$ $\quad P_g - P_r = P_s$ $\quad P_t + P_{r'} = P_c$ $\quad \eta_g = \frac{P_s}{P_g}$ $\quad \eta_r = \frac{P_t}{P_c}$

Magnetic Forces $\vec{F} = q(\vec{v} \times \vec{B})$ $\quad d\vec{F} = I d\vec{l} \times \vec{B}$ $\quad \vec{\mu} = N \cdot I \cdot \vec{S}$ $\quad \vec{\tau} = \vec{\mu} \times \vec{B}$ $\quad V_H = \frac{I \cdot B \cdot d}{n \cdot e \cdot S}$

Sources of magnetic field $d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{\ell} \times \vec{r}}{r^3}$ $\quad \mu_0 = 4\pi 10^{-7}$ (I.S.units) $\quad B = \frac{\mu_0 I}{2\pi x}$

$B = \frac{\mu_0 I}{2R}$ $\quad \oint_L \mathbf{B} \cdot \vec{\mathbf{dl}} = \mu_0 \sum I$ $\quad B = \frac{\mu_0 N I}{l}$