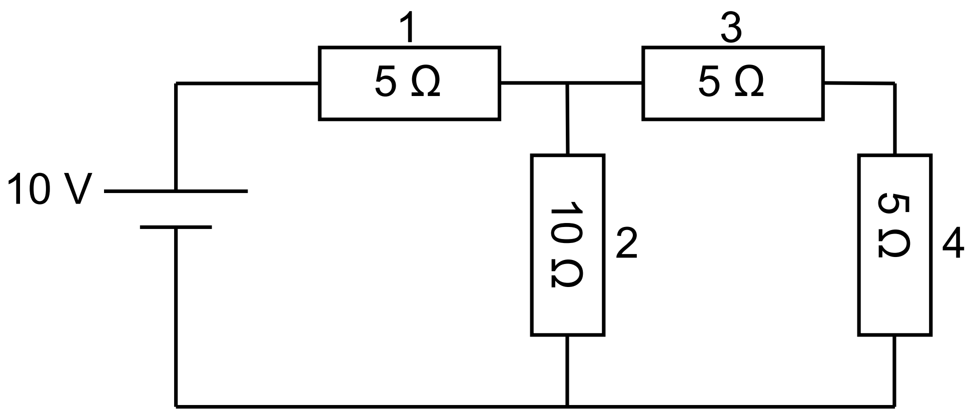
1032F Test 1a Solutions

Questions

1. (a) What is the potential difference between two points that are situated 10 cm and 20 cm from a 3.0 µC charge?
   (b) To what location should the point at 20 cm be moved to double that potential difference?
2. (a) Find the current through each of these four resistors.
   (b) Find the voltage across each of these four resistors.



3. An electron is accelerated from rest by a potential difference of 350 V. It then enters a uniform magnetic field of magnitude 200 mT with its velocity perpendicular to the field. Calculate
   (a) the speed of the electron.
   (b) the radius of its path in the magnetic field.

Answers

1. (a) The potential due to a point charge q at a distance r away from that point charge is given by $V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$. So

$$V_1 = 9 \times 10^9\,\mathrm{kg\cdot m^3s^{-4}A^{-2}}\frac{3 \times 10^{-6}\,\mathrm{C}}{0.01\,\mathrm{m}} = 2.7 \times 10^5\,\mathrm{V}$$
$$V_2 = 9 \times 10^9\,\mathrm{kg\cdot m^3s^{-4}A^{-2}}\frac{3 \times 10^{-6}\,\mathrm{C}}{0.02\,\mathrm{m}} = 1.35 \times 10^5\,\mathrm{V}$$

We can find the potential difference by subtracting one from the other. For convenience we subtract the smaller from the larger.

$$\Delta V = V_1 - V_2 = \underline{1.35 \times 10^5\,\mathrm{V}}$$

(b) In order to double the potential difference, we require

$$\Delta V = 2.7 \times 10^5\,\mathrm{V}$$
$$\implies 2.7 \times 10^5\,\mathrm{V} = 2.7 \times 10^5\,\mathrm{V} - V_2$$
$$\implies V_2 = 0$$

In order for the potential at a point to be zero, we must have that point be infinitely far from the charge. Thus the point must be moved to infinity in order to double the potential difference.

2. (a) To find the current through the whole circuit we first need to find the resistance of the whole circuit. R_3 and R_4 just add as they are in series, then that must be combined with R_2 according to the parallel rules, then finally we can add that to R_1 as it is in series.

$$\begin{aligned} R_{tot} &= R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3+R_4}} \\ &= 5\,\Omega + \frac{1}{\frac{1}{10\,\Omega} + \frac{1}{5\,\Omega+5\,\Omega}} \\ &= 10\,\Omega \end{aligned}$$

Then the total current is simply $I = \frac{V}{R_{tot}} = 1\,\mathrm{A}$.
The current through elements in series is all identical so $\underline{I_1 = 1\,\mathrm{A}}$. Then since $R_2 = R_3 + R_4$, the current splits equally between R_2 and the $R_{3,4}$. Thus $\underline{I_2 = 0.5\,\mathrm{A}}$ and $\underline{I_{3,4} = 0.5\,\mathrm{A}}$.

(b) Finding the voltage across each resistor is now simple as we know the current and the resistance, so we just use $V = IR$.

$$\underline{V_1 = 5\,\mathrm{V}, \quad V_2 = 5\,\mathrm{V}, \quad V_3 = 2.5\,\mathrm{V}, \quad V_1 = 2.5\,\mathrm{V}}$$

3. (a) From the definition of an electron volt, an electron gains 1 eV of energy when accelerated by one Volt of potential difference. So the electron gains 350 eV. Converting this to Joules we find 5.6×10^{-17} J. This is its kinetic energy, so we can find the velocity from $E_K = \frac{1}{2}mv^2$:

$$\begin{aligned} v &= \sqrt{\frac{2E_K}{m}} \\ &= \sqrt{\frac{2 \cdot 5.6 \times 10^{-17}\,\mathrm{J}}{9.1 \times 10^{-31}\,\mathrm{kg}}} \\ &= \underline{11.09 \times 10^6\,\mathrm{ms^{-2}}} \end{aligned}$$

(b) The radius of its path is simply found from $r = \frac{mv}{qB}$. We can simply plug the values in and find

$$r = \frac{9.1 \times 10^{-31}\,\mathrm{kg} \cdot 11.09 \times 10^6\,\mathrm{ms^{-2}}}{1.6 \times 10^{-19}\,\mathrm{C} \cdot 200 \times 10^{-3}\,\mathrm{T}} = \underline{3.155 \times 10^{-4}\,\mathrm{m}}. \tag{0.1}$$