BPY 1101 BASIC ELECTRICITY AND OPTICS

CAT 1 [30 MARKS] **TIME: 1½ HOURS**

Instruction: *Attempt **ALL** questions in CAT I & II*

a) The charge in a certain body is determined to be $+0.6\mu\text{C}$. Determine the number of electrons needed to neutralize the body. **[3 marks]**

Solution:

$+1\text{C} = 10^6\mu\text{C}$ *of charge consists of* 6.25×10^{18} *protons.*

Let the number of protons be N_p

Therefore, for $+0.6\mu\text{C}$ *of charge*

$N_p = \frac{0.6}{10^6}\times 6.25\times10^{18} = 3.75\times10^{12}$ *protons* ***[2 marks]***

Number of electrons (N_e) *needed must be equal to the number of excess protons. Hence,*

$N_e = 3.75\times10^{12}$ *electrons.* ***[1 mark]***

b) State the four factors that affect the resistance of a conductor. **[4 marks]**

Solution:

The resistance R offered by a conductor depends on the following factors:

(i) The length of the conductor ***[1 mark]***

(ii) the cross-sectional area A of the conductor ***[1 mark]***

(iii) the nature of the material ***[1 mark]***

(iv) the temperature of the conductor ***[1 mark]***

c) Silicon atom has Z = 29. Give its electronic distribution indicating which orbits are full and which are not. **[2 marks]**

Solution:

Since atomic number represents protons, then the number of electrons is also 29. Thus the distribution is:-

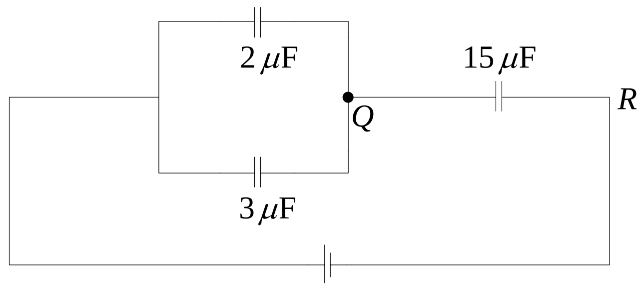
K-orbit	***2 electrons***	***full***
L-orbit	*8 electrons*	*full*
M-shell	*18 electrons*	*full*
N-shell	*1 electron*	*incomplete*
Total	*29 electrons*	

d) For the arrangement shown in the diagram, find

(i) The equivalent capacitance of the circuit

(ii) The voltage across QR

(iii) The charge on each capacitor **[12 marks]**



Solution:

(i) The equivalent capacitance of the circuit

$$\frac{1}{C_{eq}} = \frac{1}{2+3} + \frac{1}{15} = \frac{1}{5} + \frac{1}{15} = \frac{3+1}{15} = \frac{4}{15} \quad or$$ ***[2 marks]***

$$C_{eq} = \frac{15}{4}\,\mu F = 3.75\,\mu F$$

(ii) The voltage across QR

The charge flowing in the circuit is given by

$$Q = C_{eq}V = \left(3.75\times10^{-6}\right)(240) = 9\times10^{-4}\,C$$

Voltage across QR is given by

$$V_{QR} = \frac{Q}{15\times10^{-6}} = \frac{9\times10^{-4}}{15\times10^{-6}} = 60\,\text{V}$$ ***[2 marks]***

(iii)The charge on each capacitor

Voltage across the capacitor connected in parallel is

$$V_p = V - V_{QR} = 240 - 60 = 180\,\text{V}$$ ***[2 marks]***

Charge on $2\,\mu F$ *capacitor is*

$$Q_{2\mu F} = (2\,\mu F)(V_p) = \left(2\times10^{-6}\right)(180) = 3.6\times10^{-4}\,C$$ ***[2 marks]***

Charge on $3\,\mu F$ *capacitor is*

$$Q_{2\mu F} = (2\,\mu F)(V_p) = \left(3\times10^{-6}\right)(180) = 5.4\times10^{-4}\,C$$ ***[2 marks]***

The charge on $15\,\mu F$ *capacitor is*

$$Q = C_{eq}V = \left(3.75\times10^{-6}\right)(240) = 9\times10^{-4}\,C$$ ***[2 marks]***

e) A coil is would from a 10m length of copper wire having a cross-sectional area of $1mm^2$. Calculate the resistance of the coil. Take the specific resistance of copper as $1.73\times10^{-8}\ \Omega - m$. **[3 marks]**

Solution:

$$R = \rho\frac{l}{A} = \left(1.73\times10^{-8}\right)\frac{10}{1\times10^{-6}} = 0.173\,\Omega$$ ***[3 marks]***

f) A small sphere is given a charge of $+20\,\mu\text{C}$ and a second sphere of equal diameter is given a charge of $-5\mu\text{C}$. The two spheres are allowed to touch each other and are then spaced 10 cm apart. What force exists between them? What electric field is being radiated by the $+20\,\mu\text{C}$ sphere?. Assume air as the medium.

[6 marks]

Solution:

When the two spheres touch each other, the resultant charge is:

$= 20 + (-5) = 15\,\mu\text{C}$ ***[1 mark]***

When the spheres are separated, charge on each sphere is:

$Q_1 = Q_2 = \frac{15}{2}\,\mu\text{C} = 7.5\,\mu\text{C}$ ***[1 mark]***

Hence, force between is

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0\varepsilon_r r^2} = \frac{(9\times10^9)(7.5\times10^{-6})(7.5\times10^{-6})}{1\times(0.1)^2} = 50.56\,N \textit{ repulsive}$$ ***[2 marks]***

Electric Field $E = \frac{F}{Q} = \frac{50.56}{7.5\times10^{-6}} = 6.74\times10^6\; N/C$ ***[2 marks]***

CAT 2 [25 MARKS]

a) For the circuit shown in Fig. Q a), find

(i) the total circuit resistance

(ii) the supply current

(iii) the current through each resistor

(iv) the voltage across each resistor **[9 marks]**

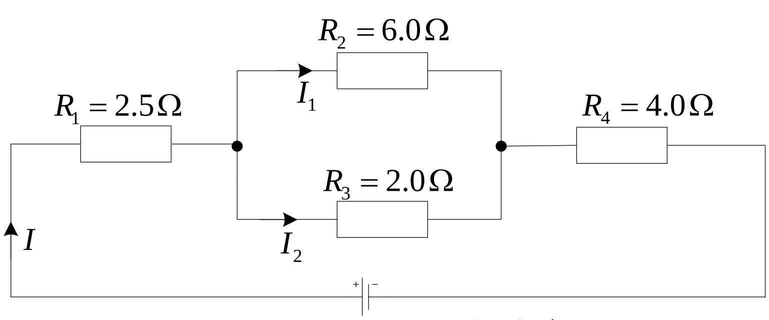
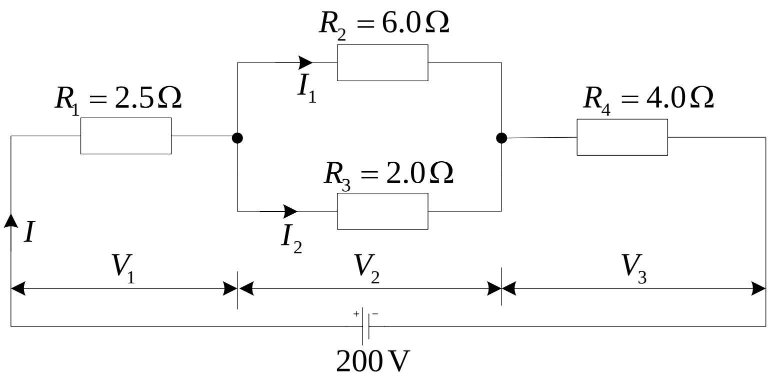


Fig.Q a)

Solution:

Let the voltages be in the circuit as shown below. Hence,



(i) the total circuit resistance

$$R_T = R_1 + \frac{R_2 R_3}{R_2 + R_3} + R_4$$ **[1 mark]**

$$= 2.5 + \frac{6 \times 2}{6+2} + 4$$

$$= 2.5 + 1.5 + 4$$

$$= 8\,\Omega$$ **[1 mark]**

(ii) the supply current

$$I = \frac{V}{R_T} = \frac{200}{8} = 25\,\mathrm{A}$$ **[1 mark]**

(iii) the current through each resistor

$$I_1 = \left(\frac{R_3}{R_2 + R_3}\right) I = \left(\frac{2}{6+2}\right) 25\,A = 6.25\,A$$ **[1 mark]**

$$I_2 = \left(\frac{R_2}{R_2 + R_3}\right) I = \left(\frac{6}{6+2}\right) 25\,A = 18.75\,A$$ **[1 mark]**

Current through R_1 *is* $I = 25\,\mathrm{A}$ **[½ mark]**

Current through R_4 *is* $I = 25\,\mathrm{A}$ **[½ mark]**

(iv) the voltage across each resistor

$$V_1 = R_1 I = (25)\,2.5 = 62.5V$$ **[1 mark]**

$$V_2 = (R_2)\,I_1 = (6.25)\,6 = 37.5V$$ **[1 mark]**

$$V_3 = (R_4)\,I = (25)\,4 = 100\,\mathrm{V}$$ **[1 mark]**

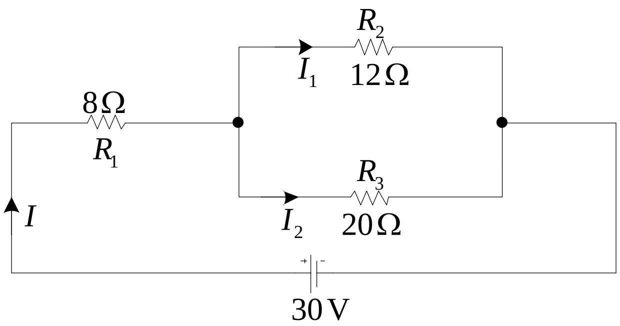
b) A coil of $12\,\Omega$ resistance is in parallel with a coil of $20\,\Omega$ resistance. This combination is connected in series with a third coil of $8\,\Omega$ resistance. If the whole circuit is connected across a battery having a e.m.f. of 30V, calculate

i) the terminal voltage of the battery and

ii) the power in the $12\,\Omega$ coil.

iii) currrent flowing in each resistor **[7 marks]**

Solution:



i) *The terminal voltage of battery is 30V since it does not have internal resistance* ***[1 mark]***

ii) *Total circuit resistance is* $R_T = R_1 + \dfrac{R_2 R_3}{R_2 + R_3}$ ***[1 mark]***

$$= 8 + \frac{12 \times 20}{12 + 20} = 15.5\,\Omega$$

[1 mark]

Circuit current is $I = \dfrac{V}{R_T} = \dfrac{30}{15.5} = 1.94\,A$

[1 mark]

Current through the $12\,\Omega$*,* $I_1 = \left(\dfrac{20}{12+20}\right) I = \left(\dfrac{20}{12+20}\right) \times 1.71 = 1.2125\,\text{A}$

[1 mark]

Current through the $20\,\Omega$*,* $I_2 = \left(\dfrac{12}{12+20}\right) I = \left(\dfrac{12}{12+20}\right) \times 1.94 = 0.7275\,\text{A}$

[1 mark]

iii) *Power in the* $12\,\Omega$*,* $P_{R_2} = R_2 I_1^2 = 12(1.2125)^2 = 17.64\,\text{W}$ ***[1 mark]***

c) State the Kirchhoff's laws. **[3 marks]**

(i) Kirchhoff's Current Law (KCL): It states that in any network of conductors, the algebraic sum of currents meeting at a point (or a junction) is zero i.e. the total current leaving a junction is equal to the total current entering that junction. ***[1½ marks]***

(ii) Kirchhoff's Voltage Law: It states that the algebraic sum of all IR drops and emfs in any closed loop (or mesh) of a network is zero i.e. ***[1½ marks]***

d) Use Kirchhoff's laws to obtain the values of I_1 and I_2 in Fig Q d). **[6 marks]**

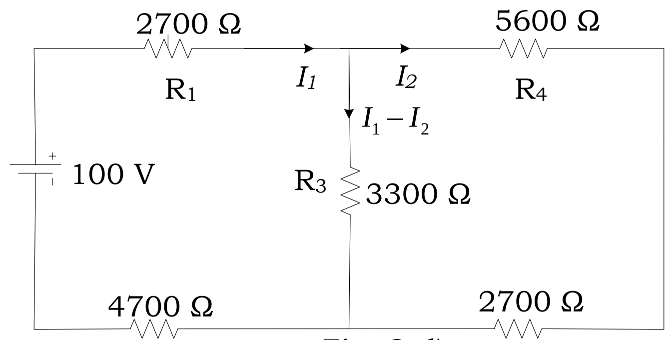


Fig. Q d)

Solution:

Applying KVL to the first loop of Fig. 2, we get

$$-2700I_1 - 3300(I_1 - I_2) - 4700I_1 + 20 = 0$$

$10700I_1 - 3300I_2 = 100$ ------------------[i] **[2 marks]**

Applying KVL to the second loop of Fig.2, we get

$$-5600I_2 - 2700I_2 + 3300(I_1 - I_2) = 0$$

$3300I_1 - 11600I_2 = 0$ -------------------[ii] **[2 marks]**

Solving equation [i] and [ii] for the currents, have

$I_2 = 2.91 \times 10^{-3}$ A **[1 mark]**

$I_1 = 0.0102$ A **[1 mark]**