# Current Electricity

3.1 Emf of the battery, $E = 12V$
Internal resistance of battery $= 0.4\Omega$
Maximum current drawn $= I$
According to ohm's law

$E = Ir$

$$I = \frac{E}{r}$$

$$= \frac{12}{0.4} = 30\,A$$

The maximum current drawn from the given battery is 30 A.

3.2 $E = 10V$
$r = 3\Omega$
$I = 0.5\,A$
Resistor $= R$

$$I = \frac{E}{R+r}$$

$$R + r = \frac{E}{I}$$

$$= \frac{10}{0.5} = 20\Omega$$

$\therefore R = 20 - 3 = 17\Omega$

Terminal voltage of the resistor $= V$
According to ohm's law

$V = IR$

$= 0.5 \times 17 = 8.5V$

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3.3 (a) ~~The~~ Three resistors of resistance $1\Omega, 2\Omega$ and $3\Omega$ are combined in series. Total resistance of the combination is given by the algebraic sum of individual resistances

Total resistance $= 1+2+3 = 6\Omega$

(b) Current flowing through the circuit $= I$

$E = 12V$

$R = 6\Omega$

$I = \frac{E}{R}$

$= \frac{12}{6} = 2A$

Potential drop across $1\Omega$ resistor $= V_1$

$V_1 = 2 \times 1 = 2V$ — (i)

potential drop across $2\Omega$ resistor $= V_2$

$V_2 = 2 \times 2 = 4V$ — (ii)

potential drop across $3\Omega$ resistor $= V_3$

$V_3 = 2 \times 3 = 6V$ — (iii)

3.4 (a) There are three resistors of resistances $R_1 = 2\Omega$, $R_2 = 4\Omega$ and $R_3 = 5\Omega$

They are ~~connected~~ Connected in parallel. Hence, total resistance (R) of the combination is given by,

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$= \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{19}{20}$

Total resistance of the combination is $\frac{20}{19}\Omega$

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(b) $V = 20V$

$I_1 = \frac{V}{R_1} = \frac{20}{2} = 10A$

Current ($I_2$) flowing through resistor $R_2$ is given by,

$I_2 = \frac{V}{R_2} = \frac{20}{4} = 5A$

Current ($I_3$) flowing through resistor $R_3$ is given by,

$I_3 = \frac{V}{R_3} = \frac{20}{5} = 4A$

Total current, $I = I_1 + I_2 + I_3 = 10+5+4 = 19A$

3.5 $T = 27°C$

$R = 100\Omega$

Let $T_1$ is the increased temperature of the filament

$R_1 = 117\Omega$

$\alpha = 1.70 \times 10^{-4} C^{-1}$

$\alpha = \frac{R_1 - R}{R(T_1 - T)}$

$T_1 - T = \frac{R_1 - R}{R\alpha}$

$T_1 - 27 = \frac{117 - 100}{100(1.7 \times 10^{-4})}$

$T_1 - 27 = 1000$

$T_1 = 1027°C$

(3.6) $l = 15\,m$

$a = 6.0 \times 10^{-7}\, m^2$

$R = 5.0\,\Omega$

Resistivity of the material of the wire $= \rho$

Resistance is related with the resistivity as

$$R = \rho \frac{l}{A}$$

$$\rho = \frac{RA}{l}$$

$$= \frac{5 \times 6 \times 10^{-7}}{15} = 2 \times 10^{-7}\,\Omega m$$

(3.7) $T_1 = 27.5°C$

$R_1 = 2.1\,\Omega$

$T_2 = 100°C$

$R_2 = 2.7\,\Omega$

Temperature ~~coffi~~ coefficient of Silver $= \alpha$

A/Q,

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

$$= \frac{2.7 - 2.1}{2.1(100 - 27.5)} = 0.0039\,°C^{-1}$$

(3.8) $V = 230V$

$I_1 = 3.2A$

A/Q

$$R_1 = \frac{V}{I}$$

$$= \frac{230}{3.2} = 71.87\,\Omega$$

$I_2 = 2.8A$

$$R_2 = \frac{230}{2.8} = 82.14\,\Omega$$

~~Temp Temperature~~

Temeperature co-efficient of nichrome, $\alpha = 1.70 \times 10^{-4}\,°C$

$T_1 = 27.0°C$

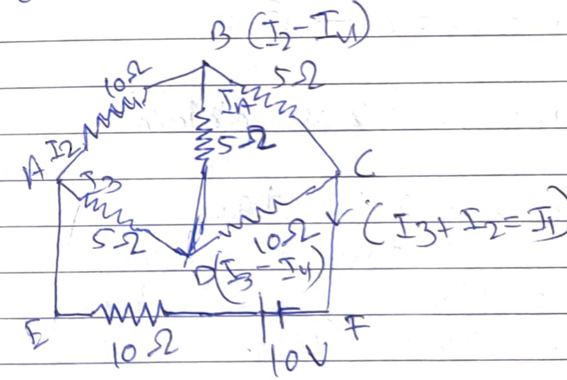
A/Q

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

$$T_2 - 27°C = \frac{82.14 - 71.87}{71.87 \times 1.7 \times 10^{-4}} = 840.5$$

$T_2 =$ ~~840~~ $840.5 + 27 =$ ~~868~~ $867.5°C$

(3.9)




$I_1$ = Current flowing through the outer ~~cc~~ circuit

$I_2$ = current flowing branch AB

$I_3$ = Current flowing through branch AD

$I_2 - I_4$ = Current flowing through branch BC

$I_3 + I_4$ = Current flowing through branch CD

$I_4$ = Current flowing through branch BD

For the closed circuit ABDA, potential is zero

$10I_2 + 5I_4 - 5I_3 = 0$
$2I_2 + I_4 - I_3 = 0$
$I_3 = 2I_2 + I_4$ — (1)

For the closed circuit BCDB potential is zero
$5(I_2 - I_4) - 10(I_3 + I_4) = 5I_4 = 0$
$5I_2 + 5I_4 - 10I_3 - 20I_4 = 0$
$I_2 = 2I_3 + 4I_4$ — (2)

For the closed circuit ABCFEA

$-10 + 10(I_1) + 10(I_2) + 5(I_2 - I_4) = 0$
$10 = 15I_2 + 10I_1 - 5I_4$
$3I_2 + 2I_1 - I_4 = 2$ — (3)

From eqn. 1 and 2 we obtain

$I_3 = 2(2I_3 + 4I_4) + I_4$
$I_3 = 4I_3 + 8I_4 + I_4$
$-3I_3 = 9I_4$
$-3I_4 = +I_3$ ... (4)

Current branch $AB = \frac{4}{17}$ A

branch $BC = \frac{6}{17}$ A

" $CD = \frac{-4}{17}$ A

" $AD = \frac{6}{17}$ A

branch $BD = \left(\frac{-2}{17}\right)$ A

Total current $= \frac{4}{17} + \frac{6}{17} + \frac{-4}{17} + \frac{6}{17} + \frac{-2}{17} = \frac{10}{17}$ A

3.11 (a) $E = 8.0V$
$r = 0.5\Omega$
$V = 120V$
$R = 15.5\Omega$
Effective voltage $= V'$

$V' = V - E$
$V' = 120 - 8 = 112V$

$I = \frac{V'}{R+r} = \frac{112}{15.5+.5} = \frac{112}{16} = 7A$

Voltage across resistor R given by the product
$IR = 7 \times 15.5 = 108.5V$
DC supply voltage = Terminal voltage of battery + Voltage drop across R
Terminal voltage of battery $= 120 - 108.5 = 11.5V$
A series resistor in a charging circuit limits the current drawn from the external source

3.12 $E_1 = 1.25V$
$l_1 = 35cm$
The cell is replaced by another cell of emf $E_2$
New balance point of the potentiometer, $l_2 = 63$ cm

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

$$E_2 = E_1 \times \frac{l_2}{l_1}$$

$$= 1.25 \times \frac{63}{35} = 2.25V$$

Therefore emf of the second cell is 2.25V.

3.13 Number density of free electrons in a copper conductor, $n = 8.5 \times 10^{28} m^{-3}$ length of the copper wire, $l = 3.0m$.
Area of cross-section of the wire $A = 2.0 \times 10^{-6} m^2$
Current carried by the wire, $I = 3.0A$

$e$ = Electric charge $= 1.6 \times 10^{-19} C$

$V_d$ = Drift velocity

$$I = nAe \frac{l}{t}$$

$$= \frac{3 \times 8.5 \times 10^{28} \times 2 \times 10^{-6} \times 1.6 \times 10^{-19}}{3.0}$$

$$= 8.27 \times 10^{4} s$$

3.14 $\sigma = 10^{-9} cm^{-2}$
$I = 1800A$
$r = 6.37 \times 10^{6} m$
Surface area of the earth,
$$A = 4\pi r^2$$
$$= 4\pi \times (6.37 \times 10^{6})^2$$
$$= 5.09 \times 10^{14} m^2$$
charge on the earth surface,
$$q = \sigma \times A$$
$$= 10^{-9} \times 5.09 \times 10^{14}$$
$$= 5.09 \times 10^{5} C$$
Time taken to neutralize the earth's surface $= t$

$$I = \frac{q}{t}$$

current,
$$t = \frac{q}{I}$$

$$= \frac{5.09 \times 10^{5}}{1800} = 282.77 s$$

3.15 (a) $n = 6$
$E = 2.0V$
$r = 0.015\Omega$
Resistance of the resistor, $R = 8.5\Omega$
Current drawn from the supply $= I$

$$I = \frac{nE}{R + nr}$$

$$= \frac{6 \times 2}{8.5 + 6 \times 0.015} = \frac{12}{8.59} = 1.39A$$

$V = IR = 1.39 \times 8.5 = 11.87A$

(b) After a long use, emf of the secondary cell, $E = 1.9V$
Internal resistance of the cell, $r = 380\Omega$

Maximum current $= \frac{E}{r} = \frac{1.9}{380} = 0.005A$

17 It can be inferred from the given table that the ratio of voltage with current is a constant, which is equal to 19.7. Hence, manganin is an ohmic conductor, the alloy obeys ohm's law. According to ohms law, the ratio of voltage with current is the resistance of the conductor. Hence the resistance of manganin is $19.7\Omega$.

18 (a) When a steady ~~current~~ current flows in a metallic conductor of non uniform cross section, the current flowing through the conductor is constant.

(b) No, ohm's law is not universally applicable for all conducting elements. Vacuum diode semi conductor is a non ohmic conductor. ohm's law is not valid for it.

(c) ~~According to ohm's law, the relation for all conducting elements.~~ vacuum

(c) According to ohm's law, the relation ~~for~~ for the potential is $V = IR$
Voltage (V) is directly proportional to current (I).
R is the internal resistance of the source.

$$I = \frac{V}{R}$$

(d) In order to prohibit the current from exceeding the safety limit, a high tension supply must have a very large internal resistance. If the internal resistance is not large, then the current drawn can exceed the safety limits in case of a short circuit.

3.19 (a) Alloys of metals usually have greater resistivity than that of ~~their~~ their constituent metals

(b) Alloys usually have a lower temp. coefficients of resistance than pure metals

(c) The resistivity of the ~~resistance than~~ alloy, manganin is nearly independent of increase of temperature.

(d) The resistivity of a typical ~~insulator~~ insulator is greater than that of a metal by a factor of the order of $10^{22}$.

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3.21 The resistance of each resistor connected in the given circuit, R = 1 Ω
Equivalent resistance of the given circuit = R

$\therefore R = 2 + \frac{R}{(R+1)}$

$R^2 - 2R - 2 = 0$

$R = \frac{2 \pm \sqrt{4+8}}{2}$

$= \frac{2 \pm \sqrt{12}}{2} = 1 \pm \sqrt{3}$

Negative value of R cannot be accepted.
$R = (1 + \sqrt{3}) = 1 + 1.73 = 2.73\ \Omega$

$r = 0.5\ \Omega$
Total resistance of the given circuit $= 2.73 + 0.5 = 3.23\ \Omega$

Supply voltage, V = 12V

3.22 (a) $E_1 = 1.02$ V
Balance point on the wire, $l_1 = 67.3$ cm

A cell of unkown emf, ε replaced the standard cell. Therefore new balance point on the wire, $l = 82.3$ cm.

$\frac{E_1}{l_1} = \frac{\varepsilon}{l}$

$\varepsilon = \frac{l}{l_1} \times E_1 = \frac{82.3}{67.3} \times 1.02 = 1.247$ V

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(b) The purpose of using the high resistance of 600 kΩ is to reduce the current through the galvanometer when the movable contact is far from the balance point.

(c) The balance point is not affected by the presence of high resistance

(d) The point is not affected by the internal resistance of the driver cell.

3.23 $R = 10.0\ \Omega$
Balance point for this resistance, $l_1 = 58.3$ cm
Current in the potentiometer wire = i
Hence, potential drop across R, $E_1 = iR$
Resistance of the unknown resistor = X
Balance point for this resistor, $l_2 = 68.5$ cm
$E_2 = iX$
A/Q

$\frac{E_1}{E_2} = \frac{l_1}{l_2}$

$\frac{iR}{iX} = \frac{l_1}{l_2}$

$X = \frac{l_1}{l_2} \times R$

$= \frac{68.5}{58.3} \times 10 = 11.749\ \Omega$

3.24 Intercell resistance of the cell = $r$
Balance point of the cell in open circuit,
$l_1 = 76.3$ cm
An external resistance (R) is connected to the circuit with $R = 9.5\Omega$
New balance point of the circuit, $l_2 = 64.8$ cm
Current ~~flowing~~ flowing through the circuit = I
The relation connecting resistance is

$$r = \left(\frac{l_1 - l_2}{l_2}\right) R$$

$$= \frac{76.3 - 64.8}{64.8} \times 9.5 = 1.69\ \Omega$$