Current Electricity Homework

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3.1. Emf = 12V, $r = 0.4\Omega$, Maximum current = I

$E = Ir$

$I = \frac{E}{r} = \frac{12}{0.4} = 30A$

∴ Maximum current = 30A

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

Using Ohm's Law,

$I = \frac{E}{R+r}$, $\Rightarrow R + r = \frac{E}{I} = 20\Omega$

∴ $R = 20 - 3 = 17\Omega$

Terminal voltage = V

∴ $V = IR$, $V = 8.5V$

∴ Resistor = 17Ω and Voltage = 8.5V

3.3 Resistors are 1Ω, 2Ω, 3Ω

$R_{net} = 6\Omega$

Current = I, Emf = 12V ∴ $I = E/R = 2A$

Potential drop across resistors

$V_1 = 2 \times 1 = 2V$

$V_2 = 2 \times 2 = 4V$

$V_3 = 2 \times 3 = 6V$

3.4 2Ω, 4Ω and 5Ω are in parallel.

∴ $\frac{1}{R_{net}} = \frac{10+5+4}{20} = \frac{19}{20}$ $= \frac{20}{19}\Omega$

$V = 20V$. $I_1 = \frac{V}{R_1} = \frac{20}{2} = 10\Omega$, $I_2 = \frac{V}{R_2} = \frac{20}{4} = 5A$

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

Total current = 10 + 5 + 4 = 19A

3.5 Room temperature = 27°C, Resistance of heating element at T, R = 100Ω
Let T_1 be the increased temperature of the filament.
Resistance of the heating element at T_1, $R_1 = 117\,\Omega$
$\alpha = 1.70 \times 10^{-4}\,°C^{-1}$

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

$\therefore T_1 - 27 = \dfrac{117 - 100}{100(1.7 \times 10^{-4})}$, $T_1 = 1027°C$

3.6 length (l) = 15 m, area (a) = $6.0 \times 10^{-7}\,m^2$, $R = 5.0\,\Omega$, resistivity =

$R = \dfrac{\rho l}{A}$; $\rho = \dfrac{5 \times 6 \times 10^{-7}}{15} = 2 \times 10^{-7}\,\Omega\,m$.

3.7. $T_1 = 27.5°C$, $R_1 = 2.1\,\Omega$, $T_2 = 100°C$, $R_2 = 2.7\,\Omega$

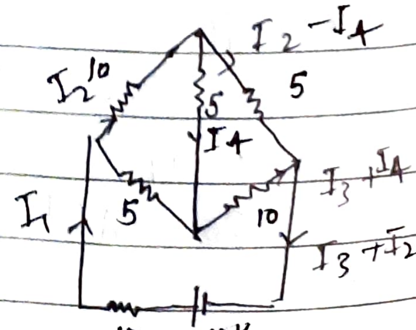
$\alpha = \dfrac{R_2 - R_1}{R_1(T_2 - T_1)} = \dfrac{2.7 - 2.1}{2.1(100 - 27.5)} = 0.0039\,°C^{-1}$

3.8 $V = 230\,V$, $I_1 = 3.2\,A$

$\therefore R_1 = \dfrac{V}{I} = \dfrac{230}{3.2} = 71.87\,\Omega$

$I_2 = 2.8\,A$, $R_2 = 230/2.8 = 82.14\,\Omega$
$\alpha = 1.70 \times 10^{-4}\,°C^{-1}$, $T_1 = 27.0°C$

$\alpha = \dfrac{R_2 - R_1}{R_1(T_2 - T_1)}$, $\Rightarrow T_2 = 840.5 + 27 = 867.5°C$



3.9 I_1 = Current flowing outer circuit
I_2 = Current through branch AB
I_3 = Current through AD
$I_2 - I_4$ = Current through BC
$I_3 + I_4$ = Current through CD

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I_4 = Current through BD
On solving through Kirchoff's law,
$I_1 = I_3 + I_2$
$I_2 = -2 I_4$
$I_3 = -3 I_4$
$I_4 = -2/17$ A

∴ Current through AB $= \frac{4}{17}$ A, BC $= \frac{6}{17}$ A, CD $= -\frac{4}{17}$ A, AD $= \frac{6}{17}$ A
BD $= -\frac{2}{17}$ A

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

3.10 Balance point from end A, $l_1 = 39.5$ cm
Resistance of the resistor $Y = 12.5\,\Omega$
$\Rightarrow \frac{X}{Y} = \frac{100 - l_1}{l_1}$

$\Rightarrow X = \frac{100 - 39.5}{39.5} \times 12.5 = 8.2\,\Omega$

∴ Resistance of $X = 8.2\,\Omega$
X & Y are interchanged, then l_1 and $100 - l_1$ get interchanged.
∴ $100 - l_1 = 100 - 39.5 = 60.5$ cm
∴ Balance point is 60.5 cm from A.

3.11 $E = 8.0$ V $\quad R = 15.5\,\Omega$
$r = 0.5\,\Omega \quad V = V'$
$V = 120$ V
$V' = V - E = 120 - 8 = 112$ V
$I = \frac{V'}{R + r} = \frac{112}{15.5 + 5} = \frac{112}{16} = 7$ A

Voltage across $R = IR = 108.5$ V
DC supply voltage = Terminal voltage + Voltage drop

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$\Rightarrow$ Terminal voltage of battery $= 120 - 108.5 = 11.5\,V$

3.12 $E_1 = 1.25\,V$
$l_1 = 35\,cm$
$l_2 = 63\,cm$
$\frac{E_1}{E_2} = \frac{l_1}{l_2}$, $\Rightarrow E_2 = \frac{E_1 \times l_2}{l_1} = 1.25 \times \frac{63}{35} = 2.25\,V$

3.13 $n = 8.5 \times 10^{28}\,m^{-3}$ $A = 2.0 \times 10^{-6}\,m^2$
$l = 3.0\,m$ $I = 3.0\,A$
$I = nAev_d$
$e = 1.6 \times 10^{-19}\,C$
$v_d = \frac{l}{t}$ $\therefore I = \frac{nAel}{t} = \frac{3 \times 8.5 \times 10^{28} \times 2 \times 10^{-6} \times 1.6 \times 10^{-19}}{3.0}$
$\therefore t = 2.7 \times 10^4$

3.14 $\sigma = 10^{-9}\,C\,m^{-2}$ $r = 6.37 \times 10^6$
$I = 1800\,A$ $A = 4\pi r^2 = 5.09 \times 10^{14}\,m^2$
$q = \sigma \times A = 10^{-9} \times 5.09 \times 10^{14} = 5.09 \times 10^5\,C$

$I = q/t$, $\Rightarrow t = q/I = \frac{5.09 \times 10^5}{1800} = 282.77\,s.$

3.15 $n = 6$ $R = 8.5\,\Omega$
$E = 2.0\,V$
$r = 0.015\,\Omega$
$I = \frac{nE}{R + nr} = \frac{6 \times 2}{8.5 + 6 \times 0.015} = 1.39\,A$
$V = IR = 1.39 \times 8.5 = 11.87\,A$
$r = 380\,\Omega$
$\therefore$ Maximum current $= \frac{E}{r} = \frac{1.9}{380} = 0.005\,A$

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3.16 $\rho_{Al} = 2.63\times10^{-8}\,\Omega m$ $\rho_{cu} = 1.72\times10^{-8}\,\Omega m$
$d_1 = 2.7$ $d_2 = 8.9$
l_1 - length, m_1 - mass R_2 - resistance, A_2 - area
R_1 - resistance, A_1 - Area l_2 - length, m_2 - mass

$$R_1 = \rho_1 \frac{l_1}{A_1},\quad R_2 = \rho_2 \frac{l_2}{A_2}$$

Since, $R_1 = R_2$
$\Rightarrow l_1 = l_2$ ~~and~~

$$\therefore \frac{\rho_1}{A_1} = \frac{\rho_2}{A_2},\ \Rightarrow \frac{A_1}{A_2} = \frac{2.63\times10^{-8}}{1.72\times10^{-8}} = \frac{2.63}{1.73}$$

m_1 = Volume × density
$= A_1 l_1 \times d_1 = A_1 l_1 d_1$
$m_2 = A_2 l_2 d_2$
Now,
$$\frac{m_1}{m_2} = 0.46$$

∴ Aluminium is lighter, it is preferred for overhead power cables over copper.

10^{-29}

3.17 It can be inferred from the given table that ratio of voltage with current which is equal to 19.7. Hence, manganin is ohmic conductor i.e. the alloy obeys Ohm's law. According to Ohm's law, the ratio of voltage with current is the resistance of the conductor, Hence, the resistance of manganin is 19.7 Ω.

3.18

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.

3.18 According to Ohm's law, $V = IR$

$V \propto I$

$I = V/R$

If V is low, R must be very low, so that high current can be drawn.

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

Alloys of metals have greater resistivity than their constituent metals. Alloys usually have lower temperature coefficients of resistance than pure metals.

The resistivity of alloy, manganin, is nearly independent of increase of temperature.

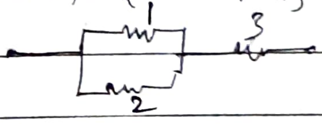
The resistivity of a typical insulator is greater than that of a metal by a factor of the order of 10^{22}.

3.20 No. of resistors = n, Resistance of each resistor = R

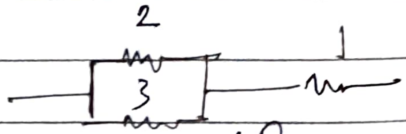
$R_1 = nR$, $R_2 = R/n$

$R_1 / R_2 = n^2$

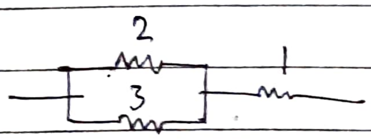
$R_1 = 1\Omega$, $R_2 = 2\Omega$, $R_3 = 3\Omega$



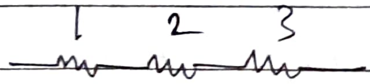
$R_{net} = \frac{11}{3}\Omega$



$R_{net} = 6\Omega$



$R_{net} = \frac{11}{5}$



$R_{net} = 6$

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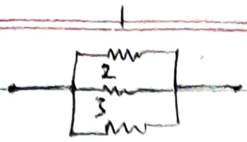
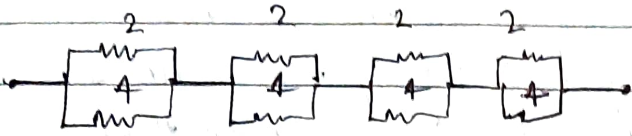


$R_{net} = 6/11\,\Omega$

(e) From observance



$R'_{net} = \frac{4}{3}\,\Omega$

$R_{net} = \frac{4}{3} \times 4 = \frac{16R}{3}$

Equivalent resistance $= R + R + R + R + R = 5R$

3.21 $R = 1\,\Omega$

$R_{net} = R'$

$R' = 2 + \frac{R'}{(R'+1)}$, $\Rightarrow R' = \frac{2 \pm \sqrt{12}}{2} = 1 \pm \sqrt{3}$

$\Rightarrow R' = 1 + \sqrt{3} = 2.73\,\Omega$

$r = 0.5$

$\therefore R_{net} = 2.73 + 0.5 = 3.23\,\Omega$

$\therefore I = V/R = 12/3.23 = 3.72\,A$

3.22 $E_1 = 1.02\,V$, $l_1 = 67.3$ cm, $l = 82.3$ cm

$\frac{E_1}{l_1} = \frac{\mathcal{E}}{l}$, $\Rightarrow \mathcal{E} = \frac{82.3 \times 1.02}{67.3} = 1.247\,V$

The purpose of using the high ~~voltag~~ resistance of 600 kΩ is to reduce the current through the galvanometer.

The balance point is not affected by presence of high resistance.

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The point is not affected by the internal resistance of the driver cell.
The method would not work.
The circuit would not work.
The given circuit can be modified if a series resistance is connected with the wire AB. The potential drop across AB is slightly greater than emf measured. The percentage error would be small.

3.23 $R = 10.0\Omega$ Resistance of unknown resistor $= X$
$l_1 = 58.3$ cm $l_2 = 68.5$ cm
Current $= i$ $E_2 = iX$
$E_1 = iR$

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}, \Rightarrow \frac{R}{X} = \frac{l_1}{l_2}, \therefore X = \frac{l_1}{l_2} \times R = 11.749\,\Omega$$

∴ Value of unknown resistance $= 11.75\,\Omega$

If we fail to find a balance point with the given cell of emf e, the potential drop across R and X must be reduced by
3.24 putting a resistance in series with it. Only if the potential drop across R or X is smaller than the potential drop across the potentiometer wire AB, a balance point is obtained.

3.24 $l_1 = 76.3$ cm, $R = 9.5\,\Omega$, $l_2 = 64.8$ cm, current $= I$
internal resistance $= r$

$$r = \left(\frac{l_1 - l_2}{l_2}\right) R = 1.68\,\Omega$$

∴ The internal resistance of the cell is $1.68\,\Omega$.