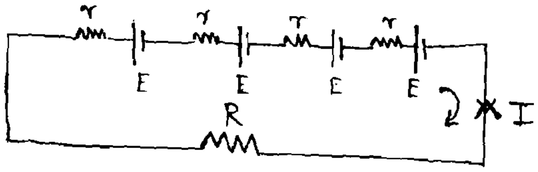
26. 2.



The four cells are shown in the diagram. We now consider the potential over the whole circuit.

$$(E - Ir) + (E - Ir) + (E - Ir) + (E - Ir) - IR = 0$$

$$4(E - Ir) = IR$$

$$4Ir = 4E - IR$$

$$\therefore r = \frac{4E}{4I} - \frac{\cancel{I}R}{4\cancel{I}} = \frac{1.5}{0.45} - \frac{12}{4} = 0.33\,\Omega$$

26.16. a) 680 Ω and 820 Ω are in parallel which is in series with 960 Ω.

$$\frac{1}{R_1} = \frac{1}{680} + \frac{1}{820} \qquad \therefore R_1 = \frac{820 \times 680}{820 + 680} = 372\,\Omega$$

$$R_{net} = R_1 + R_2 = 372 + 960 = 1332\,\Omega$$

b) We now find current in circuit.

$$V = I R_{net}$$

$$\therefore I = \frac{12}{1332} = 9.009 \times 10^{-3}\,A$$

To find voltage across 960 Ω, $V_{960} = I \times 960 = 8.649\,V$

Since the total voltage in circuit is 12 V, voltage drop across other two resistors will be same (since they are parallel) and equal to $(12 - 8.649)\,V = 3.4\,V$

26.17. We find the resistance in each bulb using-

$$P = \frac{V^2}{R}$$

$$\therefore R_1 = \frac{V_1^2}{P_1} = \frac{(110)^2}{75} \qquad R_2 = \frac{V_2^2}{P_2} = \frac{(110)^2}{25}$$

Since resistors are in parallel, the net resistance is -

$$R_{net} = \frac{R_1 R_2}{R_1 + R_2} = \frac{(110)^2}{75} \times \frac{(110)^2}{25} \times \frac{1}{\left(\frac{(110)^2}{25} + \frac{(110)^2}{75}\right)}$$

$$= \frac{(110)^2}{75 \times 25} \times \frac{25 \times 75}{(25+75)} = \cancel{\frac{HX14}{100}} = \frac{110 \times 110}{100}$$

$$= 121\,\Omega$$

26.25. a) On closing the switch we added an additional resistor in parallel to the circuit reducing the resistance across the parallel portion of the circuit. Thus net resistance is lowered as well. More current will be delivered by the same battery due to lower resistance. This would increase voltage across R_1. Net voltage in circuit is same. This implies that voltage across R_3 and R_4 decrease which are in parallel.

V_1 increases along with V_2 which was zero.

V_3, V_4 decrease.

b) Using Ohm's law $V = IR$. For fixed resistance, ~~volt~~ change in circuit will be same as change in voltage. Thus I_1, I_2 increase with decrease in I_3, I_4.

c) We know that $P = IV$. Since both I, V increase the power supplied by circuit increases.

d) Before switch is ~~closed~~ - open -

R_3, R_4 in parallel and then in series with R_1.

$$R_{net} = R_1 + \left(\frac{1}{R_3} + \frac{1}{R_4}\right)^{-1} = 125 + \left(\frac{2}{125}\right)^{-1} = 187.5\,\Omega$$

$$I = \frac{V_{bat.}}{R_{net}} = \frac{22}{187.5} = 0.1173\text{ A}$$

current through R_1 is 0.1173 A.

$$V_1 = IR_1 = (0.1173)(125) = 14.66\text{ V}$$

$$V_1 + V_3 = V \qquad V_3 = V_4 \;(\because \text{in parallel})$$

$$V_3 = 22 - 14.66 = 7.34\text{ V}$$

$$V_3 = I_3 R_3 \quad \therefore I_3 = \frac{7.34}{125} = \cancel{0.587\text{ A}} \quad 0.0587\text{ A}$$

Since $R_3 = R_4$. $I_4 = I_3 = 0.0587\,A$.

When switch is closed-

R_2, R_3, R_4 are in parallel and then in series with R_1.

$$R_{net} = R_1 + \left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)^{-1}$$

$$= 125 + \left(\frac{3}{125}\right)^{-1} = 166.7\,\Omega$$

$$I = \frac{V}{R_{net}} = \frac{22}{166.7} = 0.1320\,A$$

$V_1 = I_1 R_1 \quad \because I_1 = I$

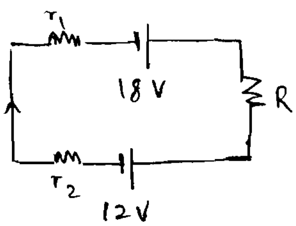
$\therefore V_1 = 0.132 \times 125 = 16.5\,V$

$V_1 + V_2 = V$ ($V_2 = V_3 = V_4$ all are in parallel connection)

$V_2 = 22 - 16.5 = 5.5\,V$

$I_2 = I_3 = I_4 = \frac{5.5}{125} = 0.044\,A$ ($\because R_2 = R_3 = R_4$, the current in them is same as well)

26.28.



Applying Kirchhoff's law to the circuit to find the current I,

$-I(2) + 18 - I(6.6) - 12 - I(1) = 0$ (note the orientation of the batteries are different along the loop)

$-3I - 6.6I = -6$

$\therefore I = \frac{6}{9.6} = 0.625\,A$

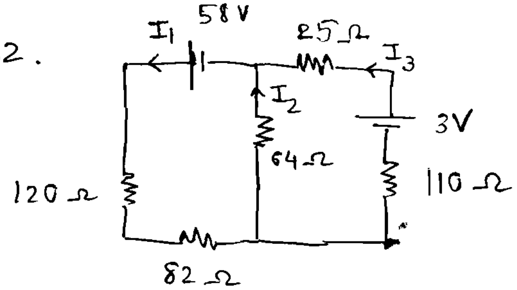
The terminal voltage is found by adding the voltage drop across internal resistance and the E.M.F. from left to right.

18V battery : $V = -I(2) + 18 = -(0.625A)(2\Omega) + 18\,V = 16.75\,V$

12V " : $V = I(1) + 12 = (0.625A)(1\Omega) + 12 = 12.625\,V$

The direction of current through the batteries is opposite for the two.

26.32.



We consider three currents I_1, I_2, I_3 flowing in the various loops but from conservation we see that.

$$I_1 = I_2 + I_3$$

Applying Kirchhoff's law to left loop we see-

$$58 - I_1(120) - I_1(82) - I_2(64) = 0$$

$$58 = 202\, I_1 + 64 I_2 \qquad -①$$

Applying Kirchhoff's law to right loop we see-

$$3 - I_3(25) + I_2(64) - I_3(110) = 0$$

$$3 = 135 I_3 - 64 I_2 \qquad -②$$

Using $I_1 = I_2 + I_3$.

$$3 = 135(I_1 - I_2) - 64 I_2 = 135 I_1 - 199 I_2 \qquad -③$$

$$\therefore 3 + 199 I_2 = 135 I_1 \qquad I_1 = \frac{(3+199 I_2)}{135}$$

Using ①,

$$58 = 202\, I_1 + 64 I_2$$

$$= 202 \frac{(3+199 I_2)}{135} + 64 I_2 = 4.88 + 324.29 I_2 + 64 I_2$$

$$\cancel{58 - 4.88 = 388.29 I_2 \quad \therefore I_2}$$

$$58 = 4.48 + (297.7 + 64) I_2$$

$$361.76 I_2 = 53.52 \qquad \therefore I_2 = 0.147\text{ A}$$

$$I_1 = \frac{3 + 199 I_2}{135} = 0.24\text{ A}$$

$$I_3 = I_1 - I_2 = 0.0919\text{ A}$$

The current in the resistors are -

120 Ω, 82 Ω } 0.24 A

64 Ω } 0.15 A

25 Ω, 110 Ω } 0.092 A

26.44. a) The time constant (τ) of a circuit is given as-

$\tau = RC$

$$C = \frac{\tau}{R} = \frac{24 \times 10^{-6}\, s}{15 \times 10^{3}\, \Omega} = 1.6 \times 10^{-9}\, F$$

b) The total EMF of the cell is 24 V and voltage across the resistor is 16 V.

Hence voltage across capacitor is $(24-16) = 8$ V.

The eq. showing the charging process of a capacitor is-

$$V = E\,(1 - e^{-t/\tau})$$

$$\frac{V}{E} = 1 - e^{-t/\tau}$$

$$e^{-t/\tau} = 1 - \frac{V}{E} = 1 - \frac{8}{24} = 1 - \frac{1}{3} = \frac{2}{3}$$

$$\therefore -\frac{t}{\tau} = \ln\left(\frac{2}{3}\right) \qquad \therefore t = -\tau \ln\left(\frac{2}{3}\right) = -24 \times 10^{-6} \ln\left(\frac{2}{3}\right) = 9.73 \times 10^{-6}\, S$$

26.46. Energy stored in a capacitor $= \frac{1}{2}\frac{Q^2}{C}$

The charge of the capacitor is $Q(t) = CE\,(1 - e^{-t/\tau})$

$$U_i = \frac{1}{2}\frac{Q^2(0)}{C}, \quad U_f = \frac{1}{2}\frac{Q^2(t)}{C} = 0.75\, U_i$$

$$\therefore \frac{U_f}{U_i} = \frac{Q^2(t)}{Q^2(0)} = 0.75$$

$$\frac{C^2E^2(1 - e^{-t/\tau})^2}{C^2E^2(1 - 0)^2} = (1 - e^{-t/\tau})^2 = 0.75$$

$$1 - e^{-t/\tau} = \sqrt{0.75} \qquad e^{-t/\tau} = (1 - \sqrt{0.75})$$

$$-\frac{t}{\tau} = \ln(1 - \sqrt{0.75}) \qquad \therefore t = -\tau \ln(1 - \sqrt{0.75}) = 2.01\tau$$

26.48. The voltage of a capacitor undergoing a discharging is given as-

$$V_c = V_0\, e^{-t/RC}$$

$$V_c = \frac{0.10}{100} V_0$$

$$\frac{0.10}{100} V_0 = V_0\, e^{-t/RC} \qquad e^{-t/RC} = 0.0010$$

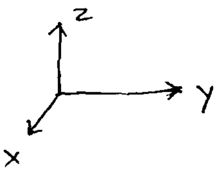
$$-\frac{t}{RC} = \ln(0.0010) \qquad \therefore t = -(8.7 \times 10^{3}\, \Omega)(3 \times 10^{-6}\, F) \ln(0.0010)$$

$$= 0.18\, s$$

27.2. The force on a wire placed in a magnetic field is –

$\vec{F} = I\vec{l}\times\vec{B} = I\,l\,B\sin\theta = (150\text{ A})(240\text{ m})(5\times10^{-5}\text{ T})\sin 68^\circ = 1.7\text{ N}$

27.16. Let us choose our coordinate system as below –



$\hat{i}\times\hat{j} = \hat{k}$
$\hat{j}\times\hat{k} = \hat{i}$
$\hat{k}\times\hat{i} = \hat{j}$

a) $\vec{V} = V\hat{i},\ \vec{B} = -B\hat{k}$

$\vec{F} = (-q)\,\vec{V}\times\vec{B} = qVB\,(\hat{i}\times\hat{k}) = -qVB\,\hat{j}$ (left)

b) $\vec{V} = -V\hat{k},\ \vec{B} = -B\hat{i}$

$\vec{F} = (-q)\,\vec{V}\times\vec{B} = -qVB\,(\hat{k}\times\hat{i}) = -qVB\,\hat{j}$ (left)

c) $\vec{V} = -V\hat{i},\ \vec{B} = B\hat{j}$

$\vec{F} = (-q)\,(\vec{V}\times\vec{B}) = qVB\,(\hat{i}\times\hat{j}) = qVB\,\hat{k}$ (upward)

d) $\vec{V} = V\hat{j},\ \vec{B} = B\hat{k}$

$\vec{F} = (-q)\,\vec{V}\times\vec{B} = -qVB\,(\hat{j}\times\hat{k}) = -qVB\,\hat{i}$ (inward into paper)

e) $\vec{V} = -V\hat{j},\ \vec{B} = +B\hat{j}$

$\vec{F} = (-q)\,\vec{V}\times\vec{B} = qVB\,(\hat{j}\times\hat{j}) = 0$

f) $\vec{V} = -V\hat{j},\ \vec{B} = B\hat{i}$

$\vec{F} = (-q)\,\vec{V}\times\vec{B} = qVB\,(\hat{j}\times\hat{i}) = -qVB\,\hat{k}$ (downward)

27.18. Since the electron goes undeflected, the electric force must compensate for the magnetic force acting on the ~~parti~~ electron.

$F_e = F_B$

$qE = qVB$

$\therefore V = \dfrac{E}{B} = \dfrac{8.8\times10^{3}\text{ V/m}}{7.5\times10^{-3}\text{ T}} = 1.173\times10^{6}\text{ m/s}$

If the electric field is turned off, the magnetic force will deflect the particle and make it move in a circle. The centripetal force will balance magnetic force now.

$F_B = qVB = \dfrac{mV^2}{r}$

$r = \dfrac{mV}{qB} = \dfrac{(9.11\times10^{-31}\text{ Kg})(1.173\times10^{6}\text{ m/s})}{(1.6\times10^{-19}\text{ c})(7.5\times10^{-3}\text{ T})} = 8.9\times10^{-4}\text{ m}$