V_{AB} = 2 A × 2 Ω = 4 V

The voltage drop across BC is

V_{BC} = 2 A × 1 Ω = 2 V

Finally, the voltage drop across CD is

$$V_{CD} = 12\ \Omega \times I_3 = 12\ \Omega \times \left(\frac{2}{3}\right) \text{A} = 8\ \text{V}.$$

This can alternately be obtained by multiplying total current between C and D by the equivalent resistance between C and D, that is,

V_{CD} = 2 A × 4 Ω = 8 V

Note that the total voltage drop across AD is 4 V + 2 V + 8 V = 14 V. Thus, the terminal voltage of the battery is 14 V, while its emf is 16 V. The loss of the voltage (= 2 V) is accounted for by the internal resistance 1 Ω of the battery [2 A × 1 Ω = 2 V].

EXAMPLE 3.5

3.12 CELLS IN SERIES AND IN PARALLEL

Like resistors, cells can be combined together in an electric circuit. And like resistors, one can, for calculating currents and voltages in a circuit, replace a combination of cells by an equivalent cell.

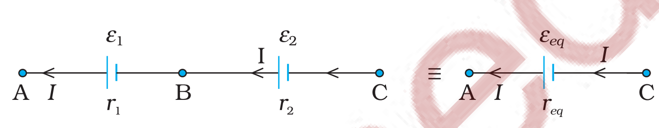

FIGURE 3.20 Two cells of emf's ε_1 and ε_2 in the series. r_1, r_2 are their internal resistances. For connections across A and C, the combination can be considered as one cell of emf ε_{eq} and an internal resistance r_{eq}.

Consider first two cells in series (Fig. 3.20), where one terminal of the two cells is joined together leaving the other terminal in either cell free. ε_1, ε_2 are the emf's of the two cells and r_1, r_2 their internal resistances, respectively.

Let V (A), V (B), V (C) be the potentials at points A, B and C shown in Fig. 3.20. Then V (A) – V (B) is the potential difference between the positive and negative terminals of the first cell. We have already calculated it in Eq. (3.57) and hence,

$$V_{AB} \equiv V(A) - V(B) = \varepsilon_1 - I r_1 \tag{3.60}$$

Similarly,

$$V_{BC} \equiv V(B) - V(C) = \varepsilon_2 - I r_2 \tag{3.61}$$

Hence, the potential difference between the terminals A and C of the combination is

$$V_{AC} \equiv V(A) - V(C) = \left[V(A) - V(B)\right] + \left[V(B) - V(C)\right]$$

$$= (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2) \tag{3.62}$$

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