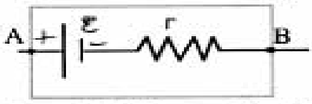
Battery Equivalent Circuit

We typically treat a battery as a source of constant voltage, constant potential difference, but battery terminals, in fact, have different potential differences depending on the circuit they are part of.

The diagram below shows a simple way to think about how a power supply / battery acts.



Start @ B & add/subtract V's to get to A

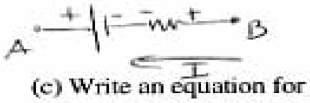
$\rightarrow V_B \pm Ir + \mathcal{E} = V_A$

(a) Write an equation for the terminal potential difference $V_A - V_B$ when there is **no current** flowing.

when $I = 0$, voltage across $r = Ir = 0$

so $V_A - V_B = +\mathcal{E}$

(b) Write an equation for the terminal potential difference $V_A - V_B$ when the current flows to the **left** in the diagram above.

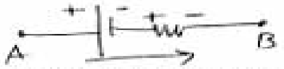


$V_B - Ir + \mathcal{E} = V_A$ $\quad$ $V_A - V_B = \mathcal{E} - Ir$

(c) Write an equation for the terminal potential difference $V_B - V_A$ when the current flows to the **left** in the diagram above.

$V_B - V_A = -(V_A - V_B) = -(\mathcal{E} - Ir)$

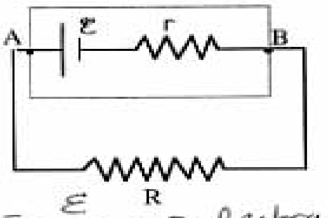
(d) Write an equation for the terminal potential difference $V_A - V_B$ when the current flows to the **right** in the diagram above.



$V_B + Ir + \mathcal{E} = V_A$

$V_A - V_B = \mathcal{E} + Ir$

(e) Now consider a circuit which consists of a variable resistor R connected across this battery. Let's define the terminal potential difference $V = V_A - V_B$.



(i) How is the terminal potential difference related to the voltage across R?

$V = V_A - V_B = IR$ = voltage across R

(ii) Write an equation for the current through R as a function of $\mathcal{E}$, r, and V.

$I = \frac{\mathcal{E}}{R_{tot}} = \frac{\mathcal{E}}{R+r}$ & $R = \frac{V}{I}$ so $I = \frac{\mathcal{E}}{\frac{V}{I}+r} \rightarrow$ algebra

(iii) Sketch a graph that you would expect to get if you plot I (current) as a function of V (voltage) as R is varied.

algebra

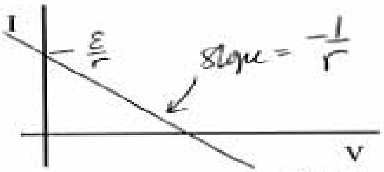
$I\left(\frac{V}{I}+r\right) = \mathcal{E}$

$V + Ir = \mathcal{E}$

$\underset{\text{"y"}}{I} = \frac{\mathcal{E}}{r} - \frac{V}{r} = \underset{\text{"m"}}{-\frac{1}{r}}\underset{\text{"x"}}{(V)} + \underset{\text{"b"}}{\frac{\mathcal{E}}{r}}$

negative slope

positive y-intercept



10/12/05