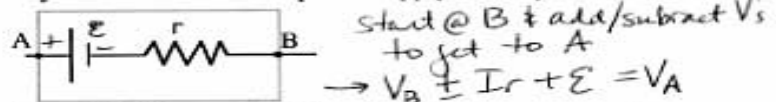


Battery Equivalent Circuit

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.

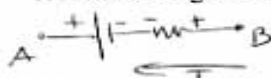
The diagram below shows a simple way to think about how a power supply / battery acts.



(a) Write an equation for the terminal potential difference $V_A - V_B$ when there is **no current** flowing. *when $I = 0$, voltage across $r = Ir = 0$*

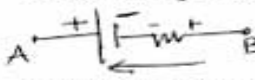
So $V_A - V_B = +\epsilon$

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



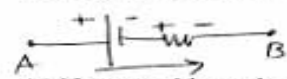
$V_B - Ir + \epsilon = V_A$ $V_A - V_B = \epsilon - Ir$

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



$V_B - V_A = -(V_A - V_B) = -(\epsilon - Ir)$

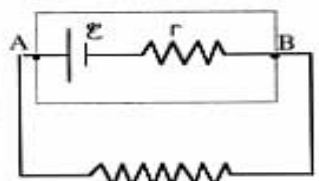
(d) Write an equation for the terminal potential difference $V_A - V_B$ when the current flows to the **right** in the diagram above.



$V_B + Ir + \epsilon = V_A$
 $V_A - V_B = \epsilon + Ir$

(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 ?
 $V = V_A - V_B = IR = \text{voltage across } R$



(ii) Write an equation for the current through R as a function of ϵ , r , and V .
 $I = \frac{\epsilon}{R+r} = \frac{\epsilon}{R+\frac{V}{I}}$ & $R = \frac{V}{I}$ so $I = \frac{\epsilon}{\frac{V}{I} + r}$ → 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
 $I \left(\frac{V}{I} + r \right) = \epsilon$
 $V + Ir = \epsilon$
 $I = \frac{\epsilon}{r} - \frac{V}{r} = -\frac{1}{r}(V) + \frac{\epsilon}{r}$
negative slope
positive y-intercept

