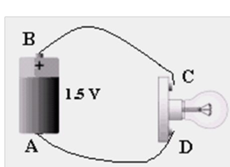
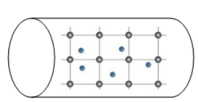
Electric Circuits

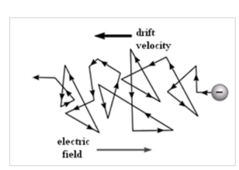
Quantity	Symbol	Units	Alternate Units	Formula
Charge	Q,q	coulomb (C)	$1 e.c. = 1.6 \times 10^{-19}$ C	
Electric Potential	V	volt (V)	1 V = 1 J/C	$V = E_p/q$ $V = W/q$
Work, energy	W, E_p	joule (J)	$1 eV = 1.6 \times 10^{-19}$ J	$W = qV$ $E_p = qV$
Current	I	ampere (A)	1 A = 1 C/s	$V = IR$ $I = \Delta q/\Delta t$
Drift speed	v	meters/sec (m/s)		$I = nAvq$
Charge density	n			(number of charge carriers per unit volume (m^3))
Resistance	R	ohm (Ω)	1 Ω = 1 V/A	$R = V/I$ $R = \rho L/A$
Resistivity	ρ	ohm·meter (Ω·m)		$R = \rho L/A$
Power	P	watt (W)	1 W = 1 J/s = 1 VA	$P = VI = I^2 R = V^2/R$
Energy, work	E, W, Q	joule (J)	1 kWh = 3.6 MJ $1000 \frac{J}{s} \cdot 3600 s$	$E = W = Q = Pt = VIt = I^2 Rt = V^2 t/R$

1. How does a battery cause a light bulb to light up?

Chemical processes inside a battery cause one terminal of the battery to be at a high electric potential (+) and the other to be at a low electric potential (-). The negative terminal is usually taken to be the base level for the electric potential (0 volts). This difference in electric potential sets up an electric field in both the wire and the bulb's filament causing free electrons everywhere in the circuit to start moving at once towards the positive terminal (electron current). This can be alternatively described as positive charge carriers moving towards the negative terminal (conventional current). As the charge carriers move, they collide with the stationary positive lattice ions making up the wire and filament thus transferring kinetic energy. The resulting increase in kinetic energy of the lattice ions in the filament is exhibited as thermal energy, that is, the filament gets hot enough to glow in the visible portion of the EM spectrum.







$A = \pi\left(\frac{d}{2}\right)^2$

2. A copper wire of diameter 0.65 mm carries a current of
I 0.25 A. There are 8.5 x 10^{28} charge carriers in each cubic meter of copper. n

Calculate the drift speed of the charge carriers.

$I = nqAv$

$$v = \frac{I}{nAq} = \frac{.25\ \cancel{c}/s}{8.5\times10^{28}\ \frac{\cancel{c}}{m^3}\cdot\pi\left(\frac{.00065\cancel{m}}{2}\right)^2\cdot\frac{1.6\times10^{-19}\ \cancel{c}}{\cancel{e}}}$$

$= .000055\ m/s$

3. What is the difference between a source of emf and a potential difference?

Electromotive force (EMF): conversion from some other form of energy into electrical energy voltage rise, potential increase

Potential difference (PD): conversion from electrical energy into some other form of energy voltage drop, potential decrease

Device					pd or emf?
Cell	*converts energy from*	chemical	*into*	electrical	emf
Resistor		electrical		internal	pd
Microphone		sound		electrical	emf
Loudspeaker		electrical		sound	pd
Lamp		electrical		light (and internal)	pd
Photovoltaic cell		light		electrical	emf
Dynamo		kinetic		electrical	emf
Electric motor		electrical		kinetic	pd

4. What is the difference between a cell and a battery?

Cell: a container in which a chemical reaction occurs to convert chemical potential energy to electrical energy – a source of EMF

Battery: two or more cells connected together

5. What is the difference between a primary cell and a secondary cell?

Primary cell: non-rechargeable

Secondary cell: rechargeable

6. A cell-phone battery is marked as "90 mA h 12 V 1.08 Wh".

$q \quad (I)\cdot(t) \qquad E$

a) What quantity is being measured as 90 mAh?

$I = \frac{q}{t}$

$$90\,mA \cdot hr = 90\times10^{-3}\,\frac{C}{s}\cdot 3600\,s = 324\,C$$

(Charge) Capacity: a quantity used to measure the ability of a cell to release charge

A battery whose capacity is 90 mA h means that before it "dies" and needs recharging you can run it:

at 90 mA for 1 hour or

$I = q/t$

at 45 mA for 2 hours or

at 9 mA for 10 hours, etc.

b) Determine how much energy is stored in the battery

$q = 324\,C$

$$E_p = qV = 324\,C \cdot 12\,J/C = 3888\,J$$

$90\,mA \cdot 12\,V$

$3888\,J \cdot \frac{1\,kWh}{3.6\,MJ}$

$= .00108\,kWh$

$1.08\,Wh$

7. A cell has a capacity of 1400 mA h. Calculate the number of hours for which it can supply 1.8 mA.

q I

$I = q/t$

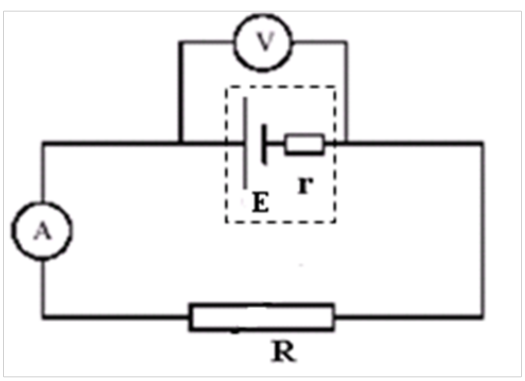
$t = q/I = \frac{1400 \cancel{m}A\,h}{1.8 \cancel{mA}} = 780\,hr$

8. How does a real cell differ from an ideal cell?

Ideal cell: no internal resistance, voltage across terminals (terminal pd) remains constant over time

Real cell: has small internal resistance that increases over time as chemicals are used up, voltage across terminals (terminal pd) decreases over time

Schematic of circuit with real cell



r = internal resistance

R = total external resistance

ε, E = emf (open circuit voltage)

V = terminal potential difference V_{term}

Internal Resistance of Batteries

9. What is the difference between emf and terminal potential difference?

Electromotive force (emf):

total energy per unit charge supplied around a circuit by the battery

- Energy that is used by both the exteriaor circuit and by the interior chemical processes of the cell
- Remains constant as battery discharges

Terminal Voltage (V_{term}):

potential difference across the terminals of the battery

- Energy that is available for use by the exterior circuit
- Decreases as battery discharges

In an ideal cell..$emf=V_{term}$

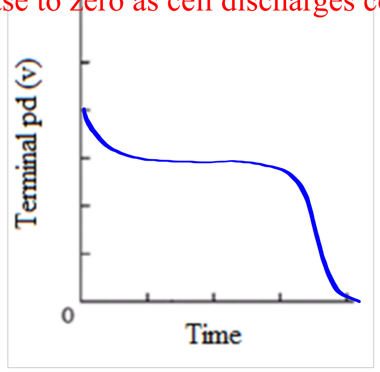
in a real cell... $emf>V_{term}$

10. What are the discharge characteristics of a cell, that is, how does the terminal potential difference vary with time?

a) loses its initial value quickly

b) has a stable and constant value for most of its lifetime

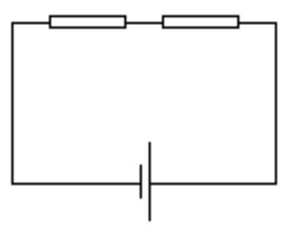
c) rapid decrease to zero as cell discharges completely



11. In which direction should current flow in order to recharge a secondary cell? Why?

Backwards through the cell – from positive to negative to reverse the chemical reaction within the cell

Series Circuits



Current		
Voltage		
Resistance		
Power		

Ratios: Control: