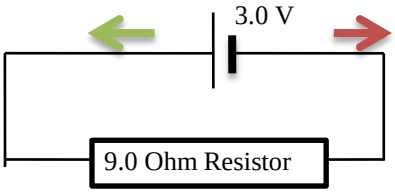
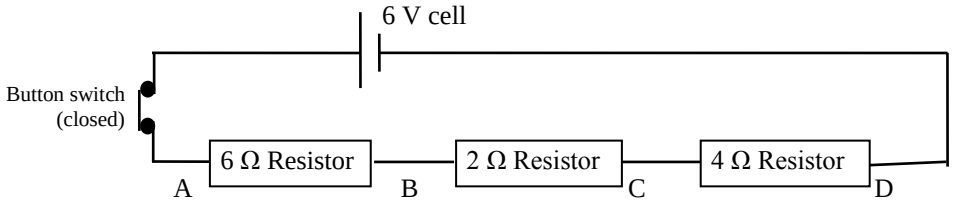
05 Electric currents review answers

1. Simple circuit.



(a) Draw arrows showing the direction of the **current flow** and the direction of the **electron flow**.
(b) State the value of the potential difference across the 9 Ohm load. **V = 3 Volts**
(c) Calculate the current flowing through the circuit. **I = V/R = 0.33A**
(d) Calculate the power dissipated in the resistor.
Power = p.d. x current = 3 x 0.33 = 1.0 W
(e) How long would it take before 60 Joules of energy had been transferred?
1 Watt = 1 Joule per second……60 seconds
(f) How many coulombs of charge will have flowed in this time?
Δq = IΔt = 0.33 x 60 = 20C
(g) How many electrons will have flowed through the resistor to transfer the 60 Joules of energy?
$20C \div 1.6 \times 10^{-19}C = 1.25 \times 10^{20}$

2. In line (series) circuit.



(a) Calculate the total resistance of the circuit. **12 Ω**
(b) Calculate the current flowing around the circuit. **I = V/R = 6/12 = 0.5A**
(c) Calculate the potential differences between:
(i) A and B **3V** (ii) B and C **1V** (iii) C and D **2V** (iv) A and C 4V (v) A and D **6V**
(d) Calculate the power being dissipated at each of the loads **A: 1.5W, B: 0.5W, C: 1W, D: 3W**

3. Parallel circuit

(a) Redraw the circuit as a parallel circuit with a button switch for each load. Explain what the advantages of parallel circuits are. Each component receives the supply voltage and can be switch on/off independently.
(b) Calculate the combined resistance of the three parallel loads and hence the total current.
1/R = 1/6 + ½ + ¼ = 2/12 + 6/12 + 3/12 = 11/12 so R = 12/11 = 1.09 Ω
I = 6/1.09 = 5.5 A
(c) Show that this total current is consistent with calculating the current though each of the three resistors independently and adding the result.
6 Ω : I = 6/6 = 1A, 2 Ω: I=6/2 = 3A, 4 Ω: I=6/4 = 1.5A These sum to 5.5A

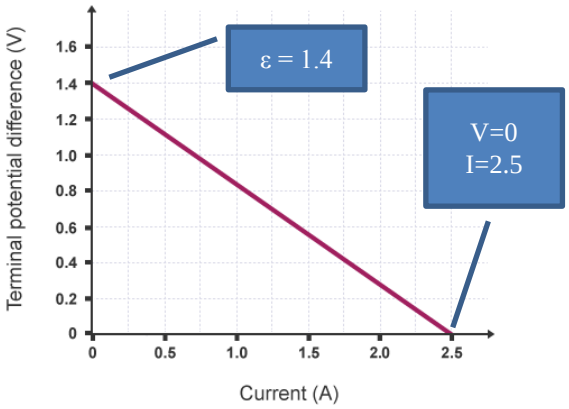
4. Additional observations.

(a) In questions 2 which resistor has the most power dissipated across it and in questions 3 which resistor has the most power dissipated across it. **Most power in series is the highest value resistor ($P=I^2R$, I is the same for all resistors, Most power in parallel is lowest value resistor ($P=V^2/R$)**
(b) The 6V cell will in reality has internal resistance. The internal resistance is 1 Ohm .
(i) What is the current flowing?
Resistance is now 13 Ω: I = V/R = 6/13 = 0.46A
(ii) What is the potential difference at the cell terminals?
Some voltage will be dissipated internally: Vlost = Ir = 0.46 x 1 = 0.46V
Terminal voltage = 6-0.46=5.54V

(c) Measuring the values of current and resistance will also affect the values. Explain this statement.

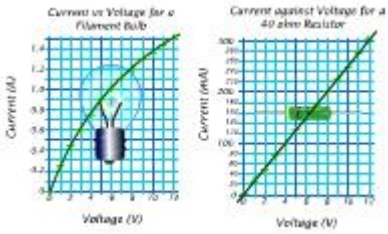
Voltmeters do not have infinite resistance and ammeters do not have zero resistance so they will affect the current flow.

(d) The graph shows measurements of potential difference at the terminal of a cell varying with current. Calculate the internal resistance of the cell.



ε = I(R+r)
ε = IR+Ir
Terminal potential difference = V = IR
ε = V+Ir
Ir = ε – V
r = (ε –V)/I
r = (1.4-0)/2.5 = 0.56 Ω

5. Resistivity and Ohms law



(a) A wire of diameter 0.5mm and length 0.8m has a resistance of 8 Ohms. Calculate the resistivity of the wire.

$R=\rho L/A$ so $\rho = RA/L = 8 \times 2\pi(0.5\times10^{-3}/2)^2/0.8 = 3.9\times10^{-6}\ \Omega m$

(b) Potential difference does not affect resistivity but if the temperature of the wire increases the resistivity of the wire increases. Explain whether or not the wire obeys Ohm's law. **The wire does obey Ohms law if resistivity does not change.**

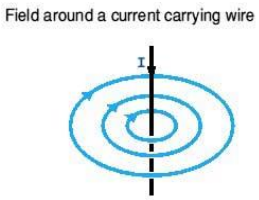
(c) Sketch a graph of Current against voltage for a perfect resistor, this wire and a filament lamp.

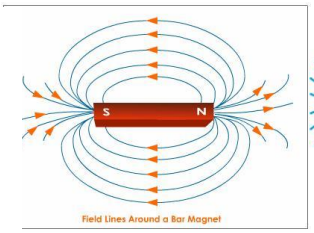
6. Drift speed

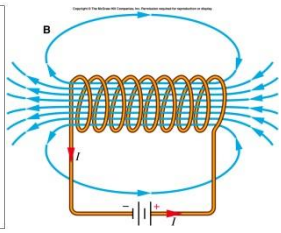
A copper wire of 1mm^2 cross-sectional area has 1A of current flowing through it. The density of copper is 8900 kgm^{-3} and atomic mass no. 63.5 g/mol. What is the average drift velocity of electrons assuming one free electron per copper atom?

Using I = nAvq ➔v = I/nAq
n = number of moving charged particles per m^3
n = NA = (8900/63.5x10^{-3} x 6.02x10^{23} = 8.44x10^{28} **[N = number of moles = mass/molar mass]**
A = 1mm^2 = 1x10^{-6}m^2
q (per electron) = (-)1.6x10^{-19}C
v = 1 / (8.44x10^{28}x1x10^{-6}x1.6x10^{-19}) = 7.4x10^{-5}ms^{-1}.

7. Magnetic effects

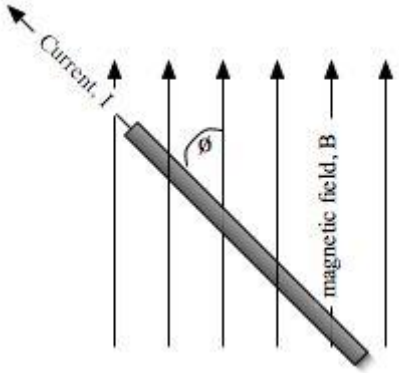






(a) draw the magnetic field pattern produced by:
i) a long, straight current carrying wire
ii) a bar magnet
iii) solenoid

(b) The 0.1m wire in the diagram opposite is carrying a current of 2.0A; the field strength is 0.024 Tesla, ϕ=45^o.

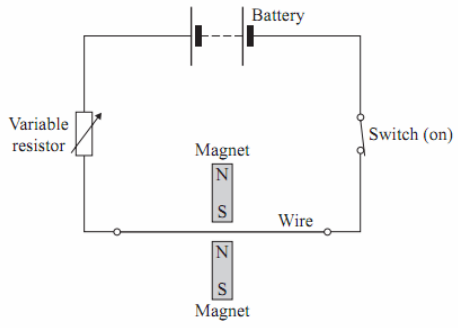


i) In what direction is the force on the wire?
Out of paper
ii)What is the magnitude of this force?
F = BILsinφ = 0.024x2.0x0.1sin45 = 0.034N
iii) If an alpha particle is travelling in the same direction as the current at 5% of the speed of light what is the force acting on it?
F = qvBsinφ = 1.6x10^{-19}x0.05x3x10^{8}x0.024sin45 = 4.08x10^{-14}N

(c) Look at the diagram opposite

i) Determine the direction of the force on the wire due to the interaction of its magnetic field and the magnets.
Using Fleming's left hand rule force will be out of the page

ii) If the field strength in between the magnets is 0.2T and approximately 0.1m of wire is affected by the field calculate the size of the force.
F = Blv = 0.2 x 0.1 x 2.5 = 0.05N



8. Coulombs law

(a) State Couloms law.
(b) Two paint droplets are charge with +0.5μC. If they are 1mm apart what force is acting between them (assuming the electric permittivity of air is 1.0)?
(c) If the droplets are between a positively charged plate and a negatively charged car door there is a force of 0.4N acting on the droplets. Calculate the field strength in between the plates.
(d) If the work done accelerating the droplet onto the car door is 5mJ what voltage has the droplet moved through?
(e) If the droplets in (b) are within a block of polyethylene which has a permittivity of 2.25 what will the force be?

(a) There will be a force between two charges proportional to the product of the charges and inversely proportional to their separation.
(b) $F = kqq/r^2 = 8.99x10^9\ Nm^2\ C^{-2}\ x\ 0.5x10^{-6}\ C\ x\ 0.5x10^{-6}\ C/(1x10^{-3}m)^2 = 2250\ N$
(c) $E = F/q = 0.4/0.5x10^{-6} = 8x10^5 NC^{-1}$.
(d) $V = W/q = 5x10^{-3}/0.5x10^{-6} = 10kV$
(e) 2250 N / 2.25 = 100N