1. (i) Total charge = Alne
   (ii) Time taken = L/v
   (iii) current I = Total charge/time
   = ALne/(L/v) = nAve
   (iv) v = I/nAe
   $= 1/(9x\ 10^{28})(1x\ 10^{-6})(1.6x10^{-19})$
   $= 6.9 \times 10^{-5}$ m/s

3. (a) E = Ir +IR
   I = E/(R+r)
   Because V = IR = R E/(R+r)
   Hence E/V = 1 + r(1/R)
   1/R = (E/r)(1/V) – (1/r)
   (b) r = 0.4 Ω, E = 1.5 V

4. (a) Terminal A should be "positive", because it is a charging process.
   (b) (2.4 – 12.6) = 5 (1+R+0.1)
   Therefore R = 1.18 Ω
   (c) When R = 0.9 Ω,
   I = (2.4-12.6)/(0.9+1+0.1)
   = 5.7 A
   $V_1 = \varepsilon_1 - I r_1 = 24 - 5.7(1) = 18.3$ V
   $V_2 = \varepsilon_2 - I r_2 = 12.6 + 5.7(0.1) = 13.17$

5. (a) (i) $\frac{R}{l} = \frac{4\rho}{\pi d^2}$
   (ii) Slope = $4\rho/\pi$
   $= (0.045 / 2x10^6)$
   Therefore, $\rho = 1.77x10^{-8}\ \Omega m$
   (b) (i) P = IV, I = 3000 / 240 = 12.5A
   (ii) From graph R/l = 0.005 at d = 1.78 mm
   R = 10 x 0.005 = 0.05 Ω
   (iii) $P = I^2R = (12.5)^2 \times 0.05 = 7.81$ W
   (iv) Thinner wire results in higher resistance.
   -It means a lower portion of voltage drops across the heating element. (heater works below its rated power).
   -Temperature of cable rises due to its high resistance.(joule heating)

5. Originally R = ρ(l)/A
   Now R' = $\rho(l_1)/4A = \rho(l/4)/4A$
   = 1/16 (ρ(l)/A = R/16
   Therefore current is increased to
   16 x 0.1 A = 1.6 A

6. Consider same length and resistance,
   Since R = ρ(l)/A , therefore R/l =ρ/A
   $\rho_{cu}/A_{cu} = \rho_{AL}/A_{Al}$
   Cross-sectional area for Al cable is 1.6 times greater
   However, mass = volume x density
   = A x l x σ
   Therefore, mass of copper is 3.2/1.6 = 2 times that of aluminium.
   Therefore, cost for Aluminium would bve half that of copper.
   Because the line is lighter, the pylons and insulators that support it can be built more cheaply. However, extra thickness leads to problems of larger forces on the line in high winds.

7. (a) Figure 1 is impossible, B is on open circuit, $V_{BC} = 0$
   Figure 2 is impossible, B is on open circuit, $V_{AB} = 0$
   Figure 3 is impossible, A and B is short-circuited. Therefore $V_{AB} = 0$
   Figure 5 is impossible, A and C is short-circuited. Therefore $V_{AC} = 0$
   The possible arrangement are Figure 4 and Figure 6.
   (b) (i) Figure 6 is impossible, C is on open circuit, $V_{BC} = 0$.
   (ii) X = 10Ω, Y = 20 Ω, Z = 30 Ω

8. When K_2 is closed, voltmeter reading should be 8 Volts.

12. (a) The resistance of the voltmeter R is given by 60/(40R/(40+R) + 60) x 4
= 2.5 , R = 360 Ω
(b) With voltmeter connection, equivalent resistance across Y'Z' is
(400)(360)/760 = 189.5 Ω
Hence voltmeter reading is
189.5/(189.5 + 600) X 4 V = 0.96 V
Voltmeter should not be used in measuring the p.d. across resistance comparable to voltmeter resistance.

13. (a) When S is open, voltmeter reading =
100/(100+100) x 12 V = 6 V
When S is closed, voltmeter reading =
50/(100 + 50) x 12 V = 4V

14. The e.m.f. ε of the source is given by
400/(400 +2000) x ε = 10
e.m.f ε = 60 V
When voltmeter is not used, p.d. across 2000 Ω is 2000/(500+2000) x 60V = 48 volts

15. Equivalent resistance across voltmeter is 5000 x 2000/7000 = $10^4/7$ Ω
Total resistance of the circuit is $10^4/7$ + 5000
45000/7 Ω
Therefore, voltmeter reading is
(10000/7) / 45000/7) x 10 V = 20/9 V

16. Use Σ ε = Σ IR
(6 – 4) = I_1 (2), I_1 = 1A
4 = I_2 (2), I_2 = 2A

17. (i) For parallel connection, power dissipated for L_1 is 12 W and L_2 is 24 W and total power is 36 W.
(ii) Resistance of L_1 is V^2/P = 12 Ω
Resistance of L_2 is V^2/P = 6 Ω
p.d. across L_1 is 12 x 12/18 = 8 V and so
p.d. across L_2 is 4 V
Therefore, power dissipated in L_1 is
V^2/R = 16/3 W
power dissipated in L_2 is V^2/R = 8/3 W
Hence total power is 8 W.

18. (a) $P_R = (2/(2+R))^2 R = 4R/(2+R)^2$
(plot graph)
(b) η= output power/input power =
R/(R+2)x 100% (plot graph)
(c) η = i^2R/i E = i R/ E = ...= R/(R+2)
p.d. = i R = (2/2+R)R = 2R/(2+R)
p.d.= 2 x η=1.5 V when η = 0.75