Solutions for Topic 5 – Electricity and magnetism

1. a) (i) substitute for $r = a\sqrt{2}$

into $E = \dfrac{kQ}{r^2}$ to get

$$E = \frac{kQ}{2a^2}$$

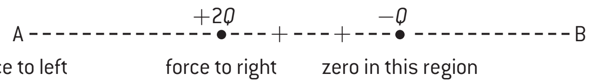
(ii) arrow pointing downwards

(iii) E for each component $= \dfrac{kQ}{a^2}$

add vectorially

to get $E_{tot} = \sqrt{2}\,\dfrac{kQ}{a^2}$

2.



3. a) the charges equalize when the spheres are touched together. So total charge becomes + 4.0 nC.

This is shared on separation so +2.0 nC on each.

b) The original force $F = \dfrac{6.0\text{ nC} \times -2.0\text{ nC}}{r^2} = -\dfrac{12\ nC}{r^2}$

after touching, force is $\dfrac{2.0\text{ nC} \times 2.0\text{ nC}}{r^2} = -\dfrac{F}{3}$

The force becomes repulsive and drops to one-third of the original magnitude.

4. The charges double, so E goes up by four times.
The weight of the top sphere remains constant, but the electrostatic force on this sphere goes up four times too.
Therefore the distance between the spheres must double to reduce E by four times so that the overall electrostatic force must remain the same.

5. a) (i) *at A*: constant;
at B: decreasing

(ii) field line gives the direction of the force (on mass or charge)
if lines touched (or crossed), particle would move in two directions at the same time and this is impossible

b) pattern is the same in all four quadrants *ie* symmetry; correct pattern in one quadrant; field directions correct

6. a) (i) power = p.d. × current = 12 × 0.5 = 6.0 W

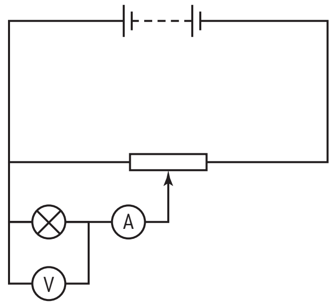
(ii) $V = \text{I} \times \text{R}$ to give $R = \dfrac{12}{0.5} = 24\Omega$

b) correct positioning of ammeter in series with lamp
correct positioning of voltmeter in parallel with lamp

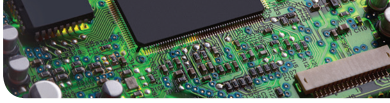
c) (i) there must be some resistance in the circuit some p.d. is used up so less than 12 V is available

(ii) low voltage requires low current and thus large resistance max resistance of variable resistor is not infinite

d) (i)



(ii) 12 V is shared by the two halves of the resistor if the left-hand half has zero resistance, then the p.d. will be zero



7. a) (i) Ohm's law states that V proportional to I provided physical conditions constant temperature is not constant as current varies

(ii) lamp B must have greater power dissipation since it has a greater current for the same p.d.

b) (i) current lamp A equals the current in lamp B

(ii) answer between 0.3 A and 0.5 A each lamp does not have the same pd find the current from the graph when the individual p.d.s *sum* to 12 V 0.4 A (±0.1)

(iii) lamp A will have greater power dissipation since current the same, but it takes greater share of pd

8. a) from the value of $\frac{V}{I}$ at any point on the curve

b) (i) 50 Ω

(ii) recognize that the voltage must divide in the ratio 3 : 1 150 Ω

9. a) (i) 4.0 A

(ii) use of $R = \frac{V}{I}$ (**not** gradient of graph)
resistance = 1.5 Ω

b) (i) straight-line through origin, quadrants 1 or 3 or both passes through $V = 4.0$ V, $I = 2.0$ A

(ii) p.d.s across X and across R will be 3.7 V (±0.1 V) and 6.0 V

total p.d. = 9.7 V

10. a) (i) resistance = 15 Ω

(ii) power = 0.6 W

b) (i) resistance of circuit too high identification of high resistance component/other appropriate and relevant comment

(ii) voltmeter reads 3 V because most of the pd is across the voltmeter

11. a) there are no positions the lamp is effectively in series with 100 kΩ no matter what the position of S this means that the pd across it will always be close to zero

b) $I = \frac{V}{R} = \frac{12}{15} = 0.80$ A

12. a) (i) $I = 0.40$ A

$R = \frac{V}{I} = \frac{10}{0.4} = 25\ \Omega$

(ii) the rate of increase of I decreases with increasing V because the conductor is heating up as the current increases and resistance increases with increasing temperature

b) (i) resistance of Y at 0.20 A = 12.5 Ω

(ii) total series resistance = 12.5 + 25 = 37.5 Ω

total p.d. across resistance = 0.2 × 37.5 = 7.5 V = e.m.f.

13. a) e.m.f. $= \frac{\text{energy}}{\text{charge}} = \frac{(8.1 \times 10^3)}{(5.8 \times 10^3)}$
=1.4 V

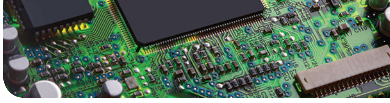
b) p.d. across internal resistance = 0.2 V

resistance $r = \left(\frac{0.2}{1.2}\right) \times 6.0$

= 1.0 Ω

c) energy transfer $= \frac{6}{7} \times 8.1 \times 10^3$ 6.900 J

d) charge carriers have kinetic energy
these carriers collide with the lattice ions
causing increased amplitude of vibrations
this increase is seen as a temperature rise
which is a transfer to thermal energy

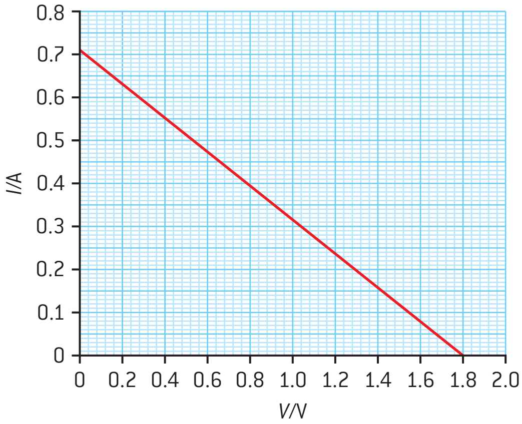


14. 1500 J of energy is used in the battery and 2500 J in the external circuit making 4000 J in total.

2000 C of charge moved through the circuit.

So the emf $= \frac{4000}{2000} = 2.0$ V

15. The I–V graph for the data is



emf = 1.8 V (x-intercept)

$r = 2.5\ \Omega$ (from $\frac{1}{\text{gradient}}$)

16. a) When the switch is closed energy must be used to drive charge through the internal resistance of the battery. The energy disappears as *lost* p.d. in the cell so terminal p.d. drops.

b) (i) 12 V

(ii) $I = \frac{11.6}{25} = 0.464$ A

$12 = 11.6 + 0.464\, r$

$r = 0.86\ \Omega$

c) 0.4 V is dropped across the battery and the current in it is 0.464 A.
The power dissipated is P = IV = 0.464 × 0.4 = 0.19 W

17. $F = q\, v\, B = q\, E$

$v = \frac{E}{B} = 1.5 \times 107 \text{ m s}^{-1}$

18. The question provides the force per unit length, not the total force, therefore

$F \times l = B \times I \times l \times \sin\theta$

Re-arranging the expression $B = \frac{F}{(I \sin\theta)}$

19. $F = BIl = 0.058 \times 35 \times 0.75 = 1.5$ N

20. The appropriate equation is $F = B\, Q\, v \sin\theta$, $\theta = 90°$ so $\sin\theta = 1$

$F = 4.6 \times 10^{-4} \times 3.2 \times 10^{-19} \times 4800 = 7.1 \times 10^{-19}$ N

Acceleration $= \frac{(7.1 \times 10^{-19})}{(2.7 \times 10^{-26})} = 2.6 \times 10^{7} \text{ m s}^{-2}$

The acceleration is directed towards the east.