1

(a) **(i)** $R = \dfrac{\rho l}{A}$

$= \dfrac{(5.5 \times 10^{-8})(2.0)}{\dfrac{\pi(0.020 \times 10^{-3})^2}{4}} = 350\ \Omega$

Power dissipated $= I^2R = (0.42)^2(350) = 62\ W$

(ii) 1. $nqAv$ for tungsten $= nqAv$ for copper

$v_{tungsten} = \dfrac{n_{copper}A_{copper}v_{copper}}{n_{tungsten}A_{tungsten}}$

$= \dfrac{(8.0)(1.4^2)(0.021 \times 10^{-3})}{(3.4)(0.02^2)}$

$= 0.24\ m\ s^{-1}$

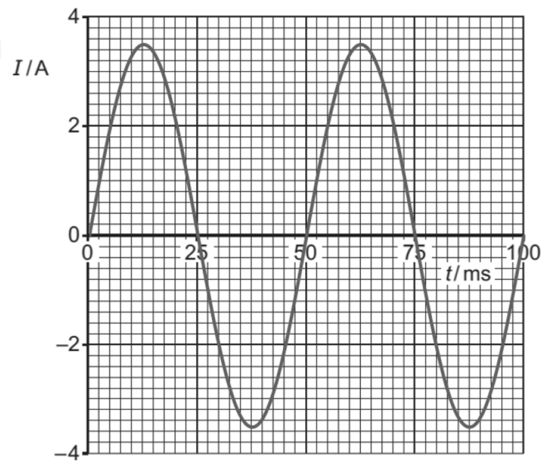
(ii) 2. The higher speed of the electrons in tungsten means that they have a much greater kinetic energy than those in copper. As the electrons collide with the fixed atoms, energy is lost to these atoms, resulting in a rise in temperature.

2

(a) Number of cycles per unit time.

(b) **(i)** $period = 2\pi / 40\pi = 0.050\ s = 50\ ms$

(ii)



(iii) $I_{r.m.s.} = \dfrac{3.5}{\sqrt{2}} = 2.5\ A$

(c) $P = I^2R$

$P_0 = 3.5^2 \times 680 = 8330$

$P_{avg} = I_{r.m.s.}^2R = \left(\dfrac{3.5}{\sqrt{2}}\right)^2 (680) = 4165$

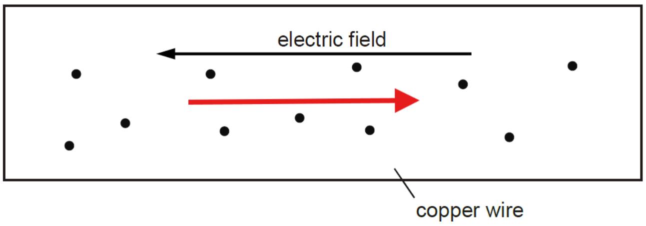
$\dfrac{P_{avg}}{P_0} = \dfrac{4165}{8330} = \dfrac{1}{2}$

$P_{avg} = \dfrac{1}{2}P_0$

3

(a) The motion of electrons is random, so there is no net flow of electrons in any direction.

(b)



(c) **(i)**

$$v = \frac{I}{nqA} = \frac{2.0}{(8.5 \times 10^{28})(1.60 \times 10^{-19})\pi(0.40 \times 10^{-3})^2} = 2.9 \times 10^{-4}\ m\ s^{-1}$$

$$t = \frac{L}{v} = \frac{0.50}{2.9 \times 10^{-4}} = 1700\ s$$

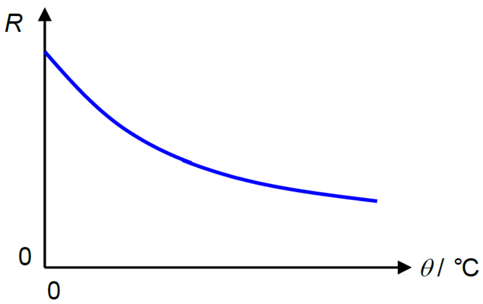
(ii) All mobile electrons in the circuit start drifting at the same time as the electric field is established in the wire almost instantaneously. The lamp lights up as soon as the mobile electrons already in the lamp filament begin to move which is much shorter than the time calculated in (c)(i).

(iii) As $I = nqAv$ and current (I), charge density (n) and charge (q) are the same in both wires, drift velocity v is inversely proportional to the cross-sectional area A of the wires. As the cross-sectional area for thicker wire is larger than that of the thinner wire, drift velocity of the electrons in the thicker wire is smaller than that in the thinner wire.

4

(a) p.d. refers to the electrical energy per unit charge converted to other forms of energy whereas e.m.f. refers to the electrical energy per unit charge converted from other forms of energy.

(b) **(i)**



(ii) 1.

$$E = \frac{W}{Q}$$

$$= \frac{2.4 \times 10^5}{2.2 \times 10^4} = 11\ V$$

(ii) 2.

$$Q = It = \left(\frac{E}{R}\right)t$$

$$t = \frac{QR}{E} = \frac{(2.2 \times 10^4)(2000 + 1800)}{11} = 7.6 \times 10^6\ s$$

(ii) 3.

$$\frac{P_{therm}}{P_{total}} = \frac{I^2 R_{therm}}{I^2(R_{therm} + R_{2000})}$$

$$= \frac{1800}{1800 + 2000}$$

$$= 0.47$$

(d) **(i)**
$$P = \frac{V^2}{R}$$
$$R = \frac{240^2}{1200}$$
$$= 48\ \Omega$$

(ii)
$$R = \frac{\rho L}{A}$$
$$L = \frac{(48)\pi(0.20 \times 10^{-3})^2}{1.0 \times 10^{-6}}$$
$$= 6.0\ m$$

(iii) Since $P = V^2/R$, a decrease in potential difference will result in a decrease in power, Hence, the time taken to dissipate the same amount of heat would increase.

5

(a) Resistivity is the proportionality constant between the dimensions of a specimen of a material and its resistance.

(b) **(i)**
$$V = 1.398 - 0.281 = 1.117\ V$$
$$I = 0.31 \times 10^{-3}\ A$$
$$R = \frac{V}{I} = 3600\ \Omega$$

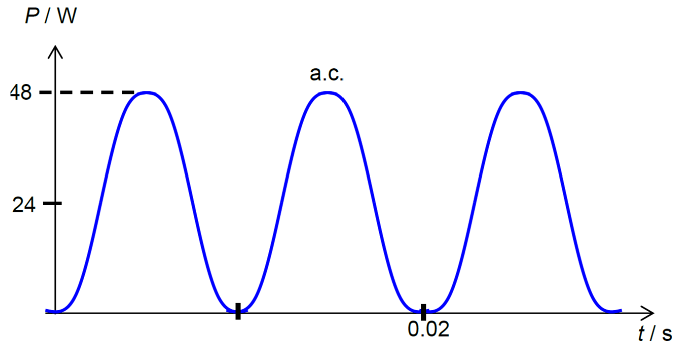
(ii)
$$R = \frac{\rho L}{A}$$
$$\rho = \frac{RA}{L} = \frac{3600 \times 0.800 \times 0.210}{0.900}$$

(iii) Among all the readings given, the least significant or most imprecise is the current reading (only 2 s.f.). The current reading will be subject to significant random errors.

Increase the area of the copper plates in the soil. This will decrease the resistance of the sample of soil to be measured and increase the current readings for the same voltage applied.

(c) **(i)**
$$P = \frac{V^2}{R} = \frac{12^2}{6.0} = 24\ W$$

(ii)



(iii) Power input = Power output

$$0.7V_1I_1 = V_2I_2$$
$$0.7(230)I_1 = 24$$
$$I_1 = 0.15\ A$$

(iv) Voltage can be easily stepped up using a transformer in order to reduce power loss in transmission wires ($P_{loss} = I^2 R$).

6

(a) **(i)** The volt is defined as the potential difference between two points in a circuit where 1 J of electrical energy is converted to other forms of energy when 1 C of charge passes from one point to the other.

(ii) e.m.f. is the amount of non-electrical energy converted into electrical energy per unit charge passing through the terminals of the cell (source).

p.d. is the amount of electrical energy converted to other forms of energy per unit charge passing from one point to the other.

(b) **(i)** When current in P is $0.15\ A$, the p.d. across P is $2.70\ V$.
The p.d. across Q is also $2.70\ V$.
From the I-V graph of Q, the current through Q is $0.0900\ A$.

Total current in battery = current in P + current in Q
$= 0.15 + 0.0900$
$= 0.24\ A$

(ii) P.d. across R $= 4.5 - 2.70 = 1.8\ V$
Resistance of R $= \frac{1.8}{0.24} = 7.5\ \Omega$

(iii) In the given circuit,

Resistance of P $= \frac{2.70}{0.15} = 18\ \Omega$
Resistance of Q $= \frac{2.70}{0.0900} = 30.0\ \Omega$
Since resistance $R = \frac{\rho L}{A}$ and $A \propto d^2$
$L \propto R d^2$

$$\frac{L_P}{L_Q} = \left(\frac{R_P}{R_Q}\right)\left(\frac{d_P}{d_Q}\right)^2$$
$$= \left(\frac{18}{30}\right)\left(\frac{2}{1}\right)^2$$
$$= 2.4$$

(iv) When Q stops conducting, effective resistance of the two lamps increases. By potential divider principle, the p.d. across lamp P increases.
The current through P also increases as no current passes through Q. From the graph, as p.d. across P (or current in P) increases, its resistance increases.

7

(a) **(i)**
$$\omega = \frac{2\pi}{T} = 628$$
$$T = 1.00 \times 10^{-2}\ s$$

(ii)
$$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{15}{\sqrt{2}} = 10.6\ V = 11\ V$$

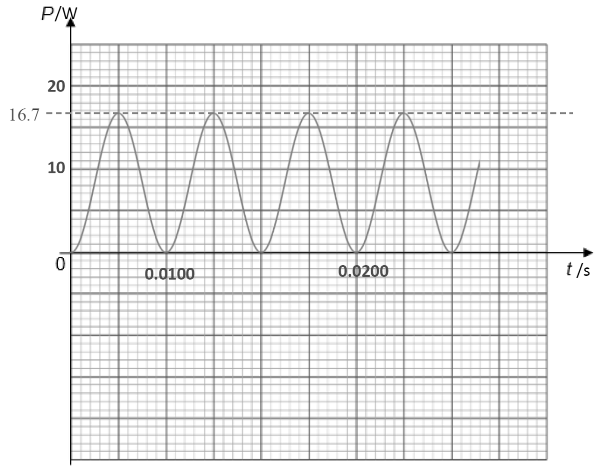
(iii)
$$\frac{1}{R_{eff}} = \frac{1}{12.0} + \frac{1}{3.0 + 6.0} = \frac{7}{36}$$
$$R_{eff} = 5.1429\ \Omega$$

$$I_0 = \frac{V_0}{R} = \frac{15}{5.1429} = 2.92\ A = 2.9\ A$$

(iv) V_{rms} across 6.0 Ω resistor $= \frac{V_0}{\sqrt{2}} = \frac{15\times\frac{6.0}{9.0}}{\sqrt{2}} = \frac{10.0}{\sqrt{2}} = 7.071\ V$

Mean power $= \frac{V^2}{R} = \frac{7.071^2}{6.0} = 8.33\ W = 8.3\ W$

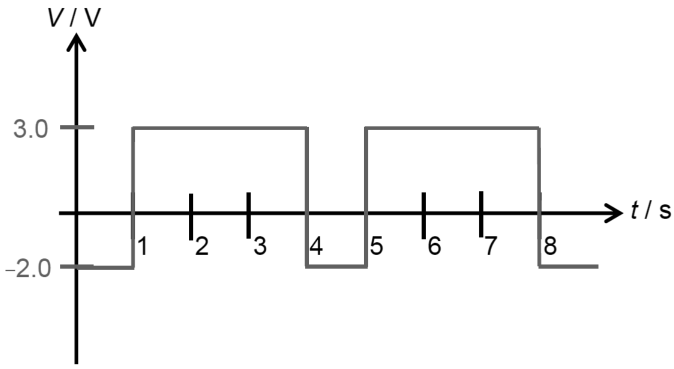
(b)



8

(a) **(i)**
$$< V^2 \geq \frac{3^3 \times 3 + 6^2 \times 1}{4}$$
$= 15.75$
$V_{rms} = \sqrt{15.75}$
$= 4.0\ V$

(ii)



(b) **(i)** Turns ratio $= 4.50 : 500 = 9 : 1000 = 0.009$

(ii) transmission line resistance $= 6.44 \times 10^5 \times 4.50 \times 10^{-4} = 289.8\ \Omega$

Given the voltage is stepped up to 500 kV at the output of the transformer,

Current $= \frac{5\times10^6}{500\times10^3} = 10\ A$

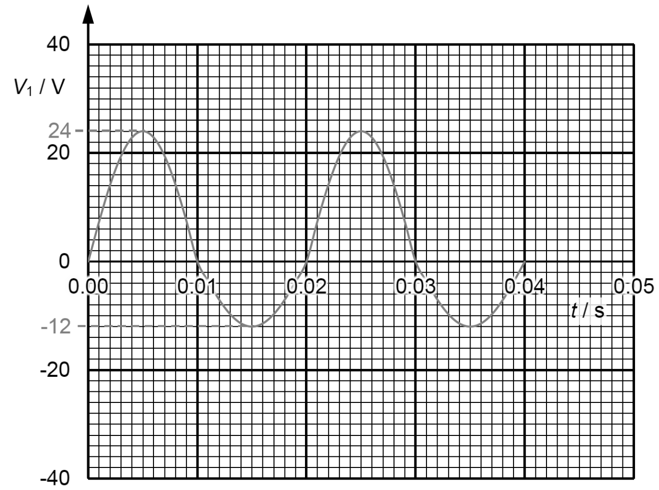
$P_{loss} = 10^2(289.8) = 2.9 \times 10^4\ W$

(iii) By stepping up the voltage, the current in the transmission line will be lowered and hence the amount of power loss in the transmission line will be lowered.

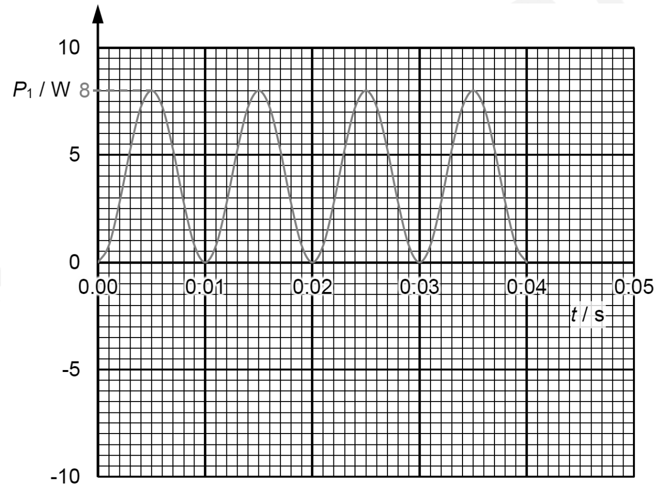
9

(a) The root-mean-square value of an alternating current is that value of the direct current that would produce thermal energy at the same rate in the same resistor.

(b) **(i)**



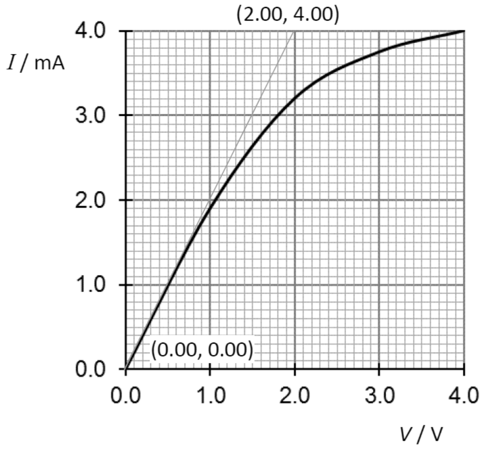
(ii)



10

(a) As V increases, I increases initially. Further increase of V will cause a less than proportionate increase in I. Since resistance is the ratio of potential difference to current, the resistance of the filament lamp increases.

(b)



The minimum resistance can be determined by drawing the tangent of the graph at the origin.
Gradient of tangent $= \frac{(4.00-0.00)\times 10^{-3}}{2.00-0.00} = 2.00 \times 10^{-3}$
Resistance $= \frac{1}{gradient} = \frac{1}{2.00\times 10^{-3}} = 500\ \Omega$

(c) From Fig. 6.1, when $V = 4.00\ V$, $I = 4.00\ mA$
Resistance $R = \frac{4.00}{4.00\times 10^{-3}} = 1000\ \Omega$

$$\rho = \frac{RA}{L}$$

$$= \frac{1000 \times \left(\frac{\pi}{4} \times (0.046 \times 10^{-3})^2\right)}{2.0}$$

$$= 8.3 \times 10^{-7}\ \Omega\, m$$

(d) From Fig. 6.1, when $I = 1.0\ mA$,
$V = 0.500\ V = terminal\ p.d.$ across cell

$$E - Ir = 0.500$$

$$E - \left(\frac{1}{1000}\right)(0.50) = 0.500$$

$$E = 0.5005\ V$$