Chapter 26 Current and Resistance

01. (***a***) The charge that passes through any cross section is the product of the current and time. Since 4.0 min = 240 s, $q = it = (5.0\text{ A})(240\text{ s}) = 1.2\times10^3$ C. (***b***) The number of electrons N is given by $q = Ne$, where e is the magnitude of electron charge. Thus,

$$N = q/e = (1200\text{ C})/(1.60\times10^{-19}\text{ C}) = 7.5\times10^{21}.$$

03. Suppose the charge on the sphere increases by Δq in time Δt. Then, in that time its potential increases by $\Delta V = \Delta q/4\pi\varepsilon_0 r$, where r is the radius of the sphere. This means $\Delta q = 4\pi\varepsilon_0 r\Delta V$. Now, $\Delta q = (i_{in}-i_{out})\Delta t$, where i_{in} is the current entering the sphere and i_{out} is the current leaving. Thus, $\Delta t = \Delta q/(i_{in}-i_{out}) = 4\pi\varepsilon_0 r\Delta V/(i_{in}-i_{out}) = (8.99\times10^9)^{-1}(0.10)(1000)/(1.0000020-1.0) = 5.6\times10^{-3}$ (s).

07. The cross-sectional area of wire is given by $A = \pi r^2$, where r is its radius (half its thickness). The current density is $J = i/A = i/\pi r^2$, so $r = (i/\pi J)^{1/2} = [0.50/\pi(440\times10^4)]^{1/2} = 1.9\times10^{-4}$ (m). The diameter of the wire is therefore

$$d = 2r = 2(1.9\times10^{-4}\text{ m}) = 3.8\times10^{-4}\text{ m}.$$

09. We use $v_d = J/ne = i/Ane$. Thus, $t = L/v_d = L/(i/Ane) = LAne/i = (0.85\text{ m})(0.21\times10^{-14}\text{ m}^2)(8.47\times10^{28}/\text{m}^3)(1.60\times10^{-19}\text{ C})/300\text{ A} = 8.1\times10^2$ s = 13 min.

13. We find the conductivity of Nichrome (the reciprocal of its resistivity) as follows:

$$\sigma = \frac{1}{\rho} = \frac{L}{RA} = \frac{L}{(V/i)A} = \frac{Li}{VA}$$

$$= \frac{(1.0\text{ m})(4.0\text{ A})}{(2.0\text{ V})(1.0\times10^{-6}\text{ m}^2)} = 2.0\times10^6\ /\Omega\cdot\text{m}.$$

15. The resistance of the wire is given by $R = \rho L/A$, where ρ is the resistivity of the material, L is the length of the wire, and A is its cross-sectional area. In this case, $A = \pi r^2 = \pi(0.50\times10^{-3})^2 = 7.85\times10^{-7}$ (m^2). Thus, $\rho = RA/L = (50\times10^{-3})(7.85\times10^{-7})/2.0 = 2.0\times10^{-8}$ ($\Omega\cdot$m).

17. Since the potential difference V and current i are related by $V = iR$, where R is the resistance of the electrician, the fatal voltage is

$$V = (50\times10^{-3}\text{ A})(2000\ \Omega) = 100\text{ V}.$$

18. The thickness (diameter) of the wire is denoted by D. We use $R \propto L/A$ (Eq. 26-16) and note that $A = \pi(D/2)^2 \propto D^2$. The resistance of the second wire is given by

$$R_2 = R\left(\frac{A_1}{A_2}\right)\left(\frac{L_2}{L_1}\right) = R\left(\frac{D_1}{D_2}\right)^2\left(\frac{L_2}{L_1}\right) = R(2)^2\left(\frac{1}{2}\right) = 2R.$$

31. (***a***) The current in each strand is $i = 0.750\text{ A}/125 = 6.00\times10^{-3}$ A. (***b***) The potential difference is $V = iR = (6.00\times10^{-3})(2.65\times10^{-6}) = 1.59\times10^{-8}$ (V). (***c***) The resistance is

$$R_{total} = 2.65\times10^{-6}\ \Omega/125 = 2.12\times10^{-8}\ \Omega.$$

38. The resistance is

$$R = P/i^2 = (100\text{ W})/(3.00\text{ A})^2 = 11.1\ \Omega.$$

39. (***a***) The power dissipated, the current in the heater, and the potential difference across the heater are related by $P = iV$. Therefore, $i = P/V = 1250\text{ W}/115\text{ V} = 10.9$ A. (***b***) Ohm's law states $V = iR$, where R is the resistance of the heater. Thus, $R = V/i = 115\text{ V}/10.9\text{ A} = 10.6\ \Omega$. (***c***) The thermal energy E generated by the heater in time $\Delta t = 1.0\text{ h} = 3600$ s is $E = P\Delta t = (1250\text{ W})(3600\text{ s}) = 4.50\times10^6$ J.

43. (***a***)* The monthly cost is (100 W)(24 h/day)(31 day/month)(6 cents/kWh) = 446 cents = US$4.46, assuming a 31-day month. (***b***) $R = V^2/P = (120\text{ V})^2/100\text{ W} = 144\ \Omega$. (***c***) $i = P/V = 100\text{ W}/120\text{ V} = 0.833$ A.

56. (**a**) Since $P = i^2R = J^2A^2R$, the current density is

$$J = \frac{1}{A}\sqrt{\frac{P}{R}} = \frac{1}{A}\sqrt{\frac{P}{\rho L/A}} = \sqrt{\frac{P}{\rho LA}} = 1.3\times10^5\text{ A/m}^2$$

$$= \sqrt{\frac{1.0\text{ W}/(3.5\times10^{-5}\ \Omega\cdot\text{m})}{\pi(2.0\times10^{-2}\text{ m})(5.0\times10^{-3}\text{ m})^2}}.$$

(**b**) From $P = iV = JAV$ we obtain

$$V = \frac{P}{AJ} = \frac{P}{J\pi r^2} = 9.4\times10^{-2}\text{ V}$$

$$= \frac{1.0\text{ W}}{\pi(5.0\times10^{-3}\text{ m})^2(1.3\times10^5\text{ A/m}^2)}.$$

57. Let R_H (R_L) be the resistance at the higher (lower) temperature 800°C (200°C). Since the potential difference is the same for the two temperatures, the power dissipated at the lower temperature is $P_L = V^2/R_L$, and the power dissipated at the higher temperature is $P_H = V^2/R_H$, so $P_L = (R_H/R_L)P_H$. Now $R_L = R_H + \alpha R_H\Delta T$, where ΔT is the temperature difference $T_L - T_H = -600$ C° = –600 K. Thus,

$$P_L = \frac{R_H}{R_H + \alpha R_H\Delta T}P_H = \frac{P_H}{1+\alpha\Delta T}$$

$$= \frac{500}{1+(4.0\times10^{-4})(-600)} = 660(\text{W}).$$

68. We use Eq. 26-28:

$$R = V^2/P = 200^2/3000 = 13.3\ (\Omega).$$

79. (**a**) In Eq. 26-17, we let $\rho = 2\rho_0$ where ρ_0 is the resistivity at $T_0 = 20$°C:

$$\rho - \rho_0 = 2\rho_0 - \rho_0 = \rho_0\alpha(T - T_0),$$

and solve for the temperature T:

$$T = T_0 + \alpha^{-1} = 20°\text{C} + (4.3\times10^{-3}/\text{K})^{-1} \approx 250\ °\text{C}.$$

(**b**) Since a change in Celsius is equivalent to a change on the Kelvin temperature scale, the value of α used in this calculation is not inconsistent with the other units involved. It is worth noting that this agrees well with Fig. 26-10.

28.* We use $J = \sigma E = (n_+ + n_-)ev_d$, which combines Eqs. 26-13 and 7. (***a***) $J = \sigma E = (2.70\times10^{-14})(120) = 3.24\times10^{-12}$ (A/m^2). (***b***) The drift velocity is

$$v_d = \frac{\sigma E}{(n_+ + n_-)e} = \frac{(2.70\times10^{-14})(120)}{(620+550)(10^6)(1.60\times10^{-19})}$$
$= 1.73\times10^{-2}$ (m/s) = 1.73 (cm/s).

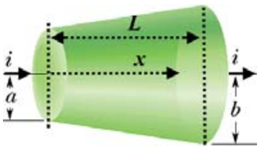
45. (**a**) Using Table 26-1 and Eq. 26-10 or 11), we have $|\boldsymbol{E}| = \rho|\boldsymbol{J}| = (1.69\times10^{-8})(2.00)/(2.00\times10^{-6}) = 1.69\times10^{-2}$ (V/m). (**b**) Using L = 4.0 m, the resistance is found from Eq.26-16: $R = \rho L/A = 0.0338\ \Omega$. The rate of thermal energy generation is found from Eq. 26-27:

$$P = i^2 R = (2.00\text{ A})^2(0.0338\ \Omega) = 0.135\text{ W}.$$

Assuming a steady rate, the thermal energy generated in 30 minutes is

$$(0.135\text{ J/s})(30\times60\text{ s}) = 2.43\times10^2\text{ J}.$$

33.* (**a**) The current i is shown below entering the truncated cone at the left end and leaving at the right. This is our choice of positive x direction. The assumption is that the current density J at each value of x may be found by taking the ratio i/A where $A = \pi r^2$ is the cone's cross-section area at that particular value of x. The direction of $\boldsymbol{J}$ is identical to that shown in the figure for i (+x direction). Using Eq. 26-11, we then find an expression for the electric field at each value of x, and next find the potential difference V by integrating the field along the x axis, in accordance with the ideas of Chapter 25. Finally, the resistance of the cone is given by $R = V/i$. Thus,



$$J = i/(\pi r^2) = E/\rho,$$

where we must deduce how r depends on x in order to proceed. Note that the radius increases linearly with x, so we may write $r = c_1 + c_2 x$. Choosing the origin at the left end of the truncated cone, the coefficient c_1 is chosen so that $r = a$ (when x = 0); therefore, $c_1 = a$. Also, the coefficient c_2 must be chosen so that (at the right end of the truncated cone) we have $r = b$ (when $x = L$); therefore, $c_2 = (b–a)/L$. Our expression, then, becomes

$$r = a + x\,(b–a)/L.$$

Substituting this into our previous statement and solving for the field, we find

$$E = \rho J = i\rho/(\pi r^2) = i\rho/[\pi(a+\frac{b-a}{L}x)^2].$$

Consequently, the potential difference between the faces of the cone is

$$V = -\frac{i\rho}{\pi}\int_0^L (a+\frac{b-a}{L}x)^{-2}dx = \frac{i\rho}{\pi}\frac{L}{b-a}(a+\frac{b-a}{L}x)^{-1}\Big|_0^L$$
$$= \frac{i\rho}{\pi}\frac{L}{b-a}(a+\frac{b-a}{L}x)^{-1} = \frac{i\rho}{\pi}\frac{L}{b-a}(\frac{1}{a}-\frac{1}{b}) = \frac{i\rho}{\pi}\frac{L}{ab}.$$

With ρ = 731 Ω·m, L = 1.94 cm, a = 2.00 mm, and b = 2.30 mm, the resistance is therefore

$$R = \frac{V}{i} = \frac{\rho L}{\pi ab} = 9.81\times10^5\ \Omega.$$

Note that if $b = a$, then $R = \rho L/(\pi a^2) = \rho L/A$, where $A = \pi a^2$ is the cross-sectional area of the cylinder.

(如發現錯誤煩請告知, jyang@mail.ntou.edu.tw, Thanks.)

你要怎麼做才能減低地面電流之危險？

重點整理－第 26 章 電流與電阻

電流：電荷之運動形成電流，電流大小為**單位時間流經某截面之淨電量**，$I \equiv \Delta q/\Delta t$，(**單位**：A = C/s)。電流為**純量**,但有方向,其方向只表正電荷運動方向♦**電荷守恆**：沿著導線電流到處皆相等。

電流密度： $J = i/A$ or $i = JA$;

流經單位截面積之電流(向量, **單位**：A/m^2)

漂移速率：電荷載子於電場方向移動之平均速率

$v_d = J/nq$ or $v_d = J/nq$, nq: 載子電荷濃度, (對大多數金屬, $q > 0$; 對半導體, $q < 0$)

電阻 $R \equiv V/i$ (定義), V: 元件兩端之電位差, i: 電流，單位：Ω ≡ ohm = V/A；**電阻器**：可提供特定電阻之元件, 電路符號-/\/\/-。♦**電阻率**(單位：Ω·m = V·m/A) 對均方向性物質 $\rho = E/J$ or $E = \rho J$；♦**導電率**(單位：$\Omega^{-1}\cdot m^{-1}$) $\sigma = 1/\rho$ (or $\sigma\rho = 1$), $\sigma = J/E$ or $J = \sigma E$。♦**電阻與電阻率之關係**：對於均勻截面積之導線，$R = \rho L/A$, L (A): 導線之長度(截面積)。

電阻率與溫度之關係：$\Delta\rho = \rho - \rho_0 = \rho_0\alpha\Delta T$，$\Delta T = T - T_0$: 溫度改變量，$T_0$: 參考溫度，$\rho_0$: 參考溫度之電阻率，$\alpha$: 電阻率之溫度係數(K^{-1})(對金屬, $\alpha > 0$; 對半導體, $\alpha < 0$)。

歐姆定律：對多數金屬，**流經元件之電流正比於施於該元件之電位差**，$i \propto V$，$V/i = R$ = 常數。

$$V = i\,R \text{ or } i = G\,V,\ G\text{: comductance.}$$

Note 電流方向為高電位區指向低電位區。線(歐姆)性材料：遵循歐姆定律的材料。

金屬之電阻率(自由電子氣體,傳導電子行為類似理想氣體)：m, τ, n: 電荷載子(電子)之質量, 平均自由時間,濃度，$\rho = m/ne^2\tau$; 平均自由路程: 連續兩次碰撞間之平均運動距離, $\lambda = v_{\text{eff}}\tau$, v_{eff}: (熱能造成的)等效速率; 平均自由時間τ: 連續兩次碰撞之平均時距。

電路之電功率 $P = iV$，V: 電位差, i: 電流。

電阻性耗損功率 $P = iV = i^2R = V^2/R$。

電力公司提供電能收費單位 kilowatt-hours

1 kWh (度) = (1 kWh)(10^3)×(3,600) = 3.60×10^6 J.

S1. 家用電器電阻越小,功率越大;溫度升高,電阻變大,而功率變小。***S2.*** 電器必標示額定功率 P 及電壓 V, 工作時電流 $i = P/V$. ***S3.*** 省電燈泡 23W 的發光亮度等於 100W 傳統鎢絲燈泡。

Ohm's law 歐姆定律; ohm (Ω)歐姆; resistance 電阻; resistor 電阻器; color-coding mark 色碼標記; color code system 色碼系統; steady state/current 穩定態/電流; ampere (A)安培; (electric) current 電流; current density 電流密度; resistivity 電阻率; conductivity 導電率; electric power 電功率; carry current 載電流; charge carrier 電荷載子; carrier charge density 載子電荷密度; drift speed 漂移速率; effective speed 等效速率; mean free time/path 平均自由時間/路程; free-electron model/gas 自由電子模型/氣體; Nichrome 鎳鉻; doping 摻雜; semiconductor 半導體; transistor 電晶體; ceramics 陶瓷; material 材料,物質; object 物體; power system 電力系統; lightning protection 避雷; lightning bug/firefly 螢火虫; ground current 地面電流; livestock 家畜; hoof/hooves 蹄; victim 受害者; electrostatics 靜電學; •**備忘錄**•

物理會考注意事項:

1. 會考時間為 **5** 月 **19** 日(星期**六**)上午 **10** 點至 **12** 點，共計 **120** 分鐘。
2. 可以使用簡易型計算機(當天統一由監試人員發放)。
3. 全部考題是選擇題。
4. 試卷有 4 種‧請在答案卡上填寫卷別、學號。
5. 請用 2B 鉛筆填寫答案。
6. **10 點半後不可進場考試**，11 點後始可出場。
7. 考試地點如下，考試位置當天公佈

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   資訊工程學系一 B, 海事大樓 410