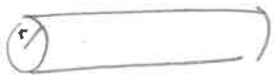
chapter 27

(1)



$r = 1.5$ mm , $A = \pi r^2$

$I = 3.6$ A

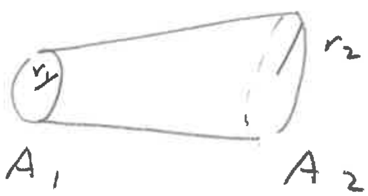
$n = 8.46 \times 10^{28}$ electrons $/m^3$ (copper)

a) $J = \frac{I}{A} = q n V_d$ where $q = 1.6 \times 10^{-19}$ Coulomb

$V_d = \frac{I}{qnA} = \boxed{3.76 \times 10^{-5} \text{ m/s}}$

b) If metal has larger n than copper, V_d decreases (all else being equal)

(2.)



$I = 5.60$ A

$r_1 = 0.260$ cm , $A_1 = \pi r_1^2$

a) $J_1 = \frac{I}{A_1} = \boxed{2.6 \times 10^5 \frac{A}{m^2}}$

b) current at A_2 is the <u>same</u> as at A_1

c) $J_2 = \frac{I}{A_2}$, since $A_2 > A_1$, J_2 is <u>smaller</u> than the current density at A_1

d) $A_2 = 3 A_1 \rightarrow \pi r_2^2 = 3 \pi r_1^2 \rightarrow r_2 = \sqrt{3}\, r_1$

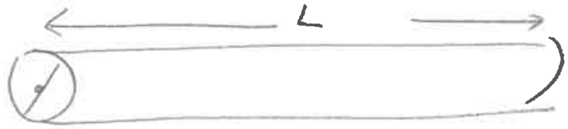
$= 0.45$ cm

$= \boxed{4.5 \text{ mm}}$

e) current at $A_2 = I = \boxed{5.60 \text{A}}$

f) $J_2 = \frac{I}{A_2} = \frac{I}{\pi r_2^2} = \boxed{8.8 \times 10^4 \frac{A}{m^2}}$

(3.)



$d = 2\ mm$, $A = \pi r^2$
$r = 1\ mm$

$L = 50\ m$
$\Delta V = 9.11\ V$
$I = 2.60\ A$
$Temp = 20\ °C$

$$R = \rho \frac{L}{A} \rightarrow \rho = \frac{R \cdot A}{L}$$

Now $R = \frac{\Delta V}{I} \rightarrow \rho = \frac{\Delta V \cdot A}{L \cdot I} = \boxed{2.2 \times 10^{-7}\ \Omega \cdot m}$

lead

(4.) Tungsten, gold wires have same length L

$\rho_{tungsten} = 5.25 \times 10^{-8}\ \Omega \cdot m$
$\rho_{gold} = 2.35 \times 10^{-8}\ \Omega \cdot m$

$R = \rho \frac{L}{A}$, R, L same $\rightarrow \frac{\rho_{tungsten}}{A_{tungsten}} = \frac{\rho_{gold}}{A_{gold}}$

$A = \pi r^2 \rightarrow$

$$A_{tungsten} = A_{gold} \frac{\rho_{tungsten}}{\rho_{gold}}$$

$$\pi r_{tungsten}^2 = \pi r_{gold}^2 \frac{\rho_{tungsten}}{\rho_{gold}}$$

$$\frac{r_{tungsten}}{r_{gold}} = \sqrt{\frac{\rho_{tunsten}}{\rho_{gold}}} = \boxed{1.5}$$

(5.) Tungsten filament: $\alpha = 4.5 \times 10^{-3}$ (temp coeff K^{-1})
$R_0 = 20.9\ \Omega$ at $20\ °C = T_0$
$R = 147\ \Omega$ at $T = ?$

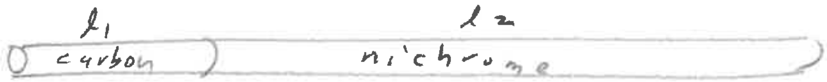
$R = \rho \frac{L}{A}$, $\rho = \rho_0 [1 + \alpha (T - T_0)]$

$$\frac{\rho}{\rho_0} = 1 + \alpha (T - T_0)$$

$$T - T_0 = \frac{\left(\frac{\rho}{\rho_0} - 1\right)}{\alpha} \rightarrow T = T_0 + \frac{\left(\frac{R}{R_0} - 1\right)}{\alpha}$$

$$= \boxed{1360\ °C}$$

(6)



$r = 1.10$ mm

$R = R_1 + R_2 = 14\,\Omega$
$T = 20°C$

carbon: $\rho_c = 3.5\times10^{-5}\ \Omega\cdot m$, $\alpha_c = -0.5\times10^{-3}\left(\frac{1}{C°}\right)$
nichrome: $\rho_N = 150\times10^{-8}\ \Omega\cdot m$, $\alpha_N = 0.4\times10^{-3}\left(\frac{1}{C°}\right)$

Now: $R = \frac{\rho L}{A}$, $L = l_1 + l_2$, $A = \pi r^2$

Assume L, A unaffected by temperature increase

$\rho = \rho_0\left[1 + \alpha(T - T_0)\right]$

$\rightarrow R = R_0\left[1 + \alpha(T - T_0)\right]$ if L, A unaffected by temperature

a) $R = R_1 + R_2$

$$= \rho_{oc}\left[1 + \alpha_c(T - T_0)\right]\frac{l_1}{\pi r^2} + \rho_{oN}\left[1 + \alpha_N(T - T_0)\right]\frac{l_2}{\pi r^2}$$

$$\frac{dR}{dT} = \rho_{oc}\,\alpha_c\frac{l_1}{\pi r^2} + \rho_{oN}\,\alpha_N\frac{l_2}{\pi r^2}$$

Want $\frac{dR}{dT} = 0 \rightarrow \rho_{oc}\alpha_c\frac{l_1}{\pi r^2} + \rho_{oN}\alpha_N\frac{l_2}{\pi r^2} = 0$

$\rightarrow \rho_{oc}\alpha_c l_1 = -\rho_{oN}\alpha_N l_2$

Since $\alpha_c < 0$ and $\alpha_N > 0$ can meet design goal. **Yes**

b) Lengths?

Now: $R = R_1 + R_2 = \left(\frac{\rho_{oc} l_1 + \rho_{oN} l_2}{\pi r^2}\right)$ at $T = T_0 = 20°C$

$\rightarrow \rho_{oc} l_1 + \rho_{oN} l_2 = R\cdot\pi r^2$

Also: $\rho_{oc} l_1 + \rho_{oN} l_2\left(\frac{\alpha_N}{\alpha_c}\right) = 0$

Subtract: $\rho_{oN} l_2\left(1 - \frac{\alpha_N}{\alpha_c}\right) = R\pi r^2 \rightarrow$ $l_2 = \frac{R\pi r^2}{\rho_{oN}\left(1 - \frac{\alpha_N}{\alpha_c}\right)}$ $= 19.7$ m

$$l_1 = \frac{-\rho_{oN} l_2\left(\frac{\alpha_N}{\alpha_c}\right)}{\rho_{oc}} = 0.67\text{ m}$$

(7.) Turbine: $P_{mech} = 1500\ hp$ $(1\ hp = 745.7\ watts)$

$P_{elec} = 0.80\ P_{mech}$, $\Delta V = 2020\ V$

$P_{elec} = \Delta V \cdot I \rightarrow I = \frac{P_{elec}}{\Delta V} = \frac{0.80\ P_{mech}}{\Delta V}$

$= \frac{0.80\ 1500\ hp\ \left(\frac{745.7\ watts}{hp}\right)}{2020\ V}$

$= \boxed{443\ Amps}$

(8.) $P = 1.04\ kW$, $\Delta V = 120\ V$

a) $I = \frac{P}{\Delta V} = \boxed{8.7\ Amps}$

b) $R = \frac{\Delta V}{I} = \boxed{13.8\ \Omega}$

(9.) $m = 131\ kg$ water

$\Delta T = (51°C - 20°C) = 31°C$

$\Delta t = 27\ min \times (60\ s/min) = 1620\ sec$

$\Delta V = 240\ volts$

$\Delta Q = mc\Delta T$, $c = \frac{4184\ J}{kg \cdot K}$ — or °C

$P = \frac{\Delta Q}{\Delta t} = \frac{mc\Delta T}{\Delta t} = \frac{(\Delta V)^2}{R} \longrightarrow R = \frac{(\Delta V)^2 \Delta t}{mc\Delta T} = \boxed{5.5\Omega}$

(10.) Fluorescent bulb: 11 W

Incandescent bulb: 40 W

$P_{diff} = (40 - 11)\ W = 29\ W = 29 \times 10^{-3}\ kW$

$cost = \frac{\$0.114}{kWh}$

$\Delta t = 130\ hr$

$\rightarrow E_{diff} = P_{diff}\ \Delta t$

savings $= cost \times E_{diff}$

$= \frac{\$0.114}{kWh} \cdot \left(\frac{29\ kW}{1000}\right) \cdot 130\ hr$

$= \boxed{\$0.43}$ (43 cents)