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10-16-17

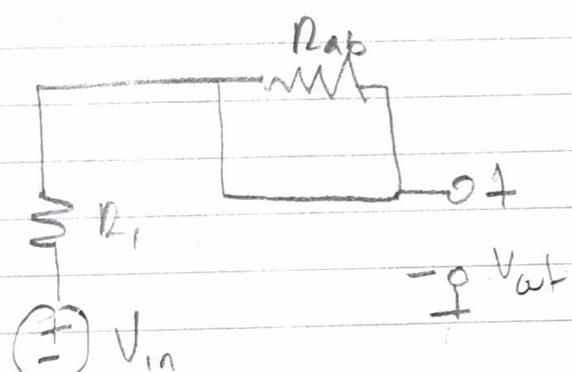
EE16A HW 7

1. $M_1 \rightarrow$ resistivity ρ
$M_2 \rightarrow$ resistivity ρ

A. R_{AB} = resistivity of M_1 + resistivity of M_2
The length of each bar is $L+kt$.

$$R_{AB} = R_1 + R_2 = \boxed{\frac{\rho(L+kt)}{A} \times 2}$$

B.



$$V_{out} = -\frac{R_{AB}}{R_1} V_i$$

Cell
Phone
Battery ① 2770 mAh at 3.8 V = 10526 mWhr

@ 4 W → 400 mW $\frac{10{,}526 \text{ mWhr}}{400 \text{ mW}} = 26.315$ Hrs.

② 1 Joule = 1 W second

$$\frac{10\,526 \text{ mW hr}}{1 \text{ W second}} \times \frac{1 \text{ W}}{1000 \text{ mW}} \cdot \frac{3600 \text{ sec}}{1 \text{ hr}} = 37.8936 \text{ kJ}$$

③ 1 Amp = 1 $\frac{\text{Coulomb}}{\text{sec}}$ $2770 \text{ mA hr} \times \frac{3600 \text{ sec}}{\text{hr}}$

= 9972000 mAseconds = 9972000 Coulombs

$9972{,}000 / 1.602 \times 10^{-19} = 6.224719 \times 10^{25}$ Electrons

④ From previous question 2770 mAH @ 3.8 V = 10526 mWhr

10,526 mWhr · 31 Days = 326,306 mWhr are 31 dy

≈ 0.326306 kWhr · $\frac{12¢}{\text{kWh}}$ = approximately 4 cents.

⑤ Energy = power · time

$P = I_r^2 R_{bat}$ 200 mΩ resist + R_{bat} in series

$V = Ir$ $I = \frac{V}{r}$ $I_r = \frac{5V}{200 \text{ m}\Omega + R_{bat}}$

$$P = \left(\frac{5}{.02 + R_{bat}}\right)^2 R_{bat}$$

$$\frac{dP}{dR_{bat}}\left[\frac{25 R_{bat}}{(R_{bat}+\frac{1}{5})^2}\right] = 25 \cdot \frac{d(x)\cdot(x+\frac{1}{5})^2 - x \cdot d(x+\frac{1}{5})^2}{(x+\frac{1}{5})^{2\cdot 2}}$$

Let $R_{bat} = x$

(4c) $= 25 \cdot \dfrac{\left(1 \cdot (x+\frac{1}{5})^2 - 2x \cdot (x+\frac{1}{5}) \cdot \frac{d}{dx}(x+\frac{1}{5})\right)}{(x+\frac{1}{5})^4}$

$$= 25\left((x+\tfrac{1}{5})^2 - 2(1+0)\,x\,(x+\tfrac{1}{5})\right)$$

$$= \frac{25\left((x+\frac{1}{5})^2 - 2x\,(x+\frac{1}{5})\right)}{(x+\frac{1}{5})^4}$$

$$= \frac{25}{(x+\frac{1}{5})^2} - \frac{50x}{(x+\frac{1}{5})^3} = \frac{25(x+\frac{1}{5}) - 50x}{(x+\frac{1}{5})^3}$$

$$= \frac{25x + 5 - 50x}{(x+\frac{1}{5})^3} = \frac{-25x + 5}{(x+\frac{1}{5})^3}$$

$\dfrac{-25(x - \frac{1}{5})}{(x+\frac{1}{5})^3}$ $\quad \dfrac{dP}{dR_{bat}} = 0$ when $x = \frac{1}{5} = R_{bat}$

$\frac{1}{5}\,\Omega = 200\ m\Omega$ $\quad R_{Total}$ in series $= 400\ m\Omega$

so the battery will be $\dfrac{5V}{0.4\Omega} = 12.5$ Amps

$P_{bat} = I_{bat}^2 \times R_{bat} = 12.5^2 \times 0.2 = 31.25$ watts

to get charge time $\dfrac{10.526\ \text{Whr}}{31.25\ \text{watts}} \approx 20$ minutes

Temperature 5
Sensor

A By observation, we can see that $R_{TH} = \dfrac{R_1 R_2}{R_1 + R_2}$

$$\boxed{V_{out} = \frac{R_1 R_2}{R_1 + R_2} \cdot V_S}$$

B By observation, $V_{out} = \dfrac{R_1 R_0}{R_1 + R_0} V_S$ $R_0(1+\alpha T)$

$$V_{out} = \frac{R_1 R_0 (1+\alpha T)}{R_1 + (R_0)(1+\alpha T)} \cdot V_S$$

$$(V_{out})(R_1) + (V_{out})(R_0)(1+\alpha T) = (R_1)(R_0)(1+\alpha t) V_S$$

$$(V_{out})(R_1) = (R_1)(R_0)(1+\alpha t)(V_S) - (V_{out})(R_0)(1+\alpha t)$$

$$\frac{(V_{out})(R_1)}{(R_1)(R_0)(V_S) - (V_{out})(R_0)} = (1+\alpha t)$$

$$\frac{\dfrac{(V_{out})(R_1)}{(R_0)(R_1 V_S - V_{out})} - 1}{\alpha} = T$$

5.

$$V_{out} = \frac{R_1 R_2}{R_1 + R_2} = \frac{R_1(1+\beta t)\, R_2(1+\alpha t)}{R_1(1+\beta t) + R_2(1+\alpha t)}$$

$$V_{out} R_1(1+\beta t) + V_{out}(R_2)(1+\alpha t) = R_1(1+\beta t) R_2(1+\alpha t)$$

$$(R_1 R_2)(1+\beta t + \alpha t + \beta\alpha t^2)$$

$$V_{out} \frac{(R_1 + \beta t + R_2 + \alpha t)}{R_1 R_2} = 1 + \beta t + \alpha t + \beta\alpha t^2$$

$$V_{out} \frac{(R_1 + R_1\beta t + R_2 + R_2\alpha T)}{R_1 R_2} - 1 = T(\beta + \alpha + \alpha\beta T)$$

$$\frac{V_{out}}{R_2} + \frac{V_{out}\beta t}{R_2} + \frac{V_{out}}{R_1} + \frac{V_{out}\alpha t}{R_1} - 1 = (1+\beta t)(1+\alpha t)$$

$$V_{out}\left(\frac{1}{R_2} + \frac{1}{R_1}\right) = (1+\beta t)(1+\alpha t) - \frac{V_{out}\beta t}{R_2} - \frac{V_{out}\alpha t}{R_1}$$

5. $$V_{out} = \frac{R_1 R_2}{R_1 + R_2} = \frac{R_1 R_2(1+\alpha T)}{R_1\cancel{(1+\alpha t)} + R_2(1+\cancel{\alpha t})} = \frac{R_1 R_2}{R_1 + R_2}(1+\alpha T)$$

$$\frac{V_{out}}{V_s} \cdot \frac{R_1 + R_2}{R_1 R_2} = 1 + \alpha T$$

$$\frac{\frac{V_{out}}{V_s} \cdot \frac{R_1 + R_2}{R_1 R_2} - 1}{\alpha} = T$$

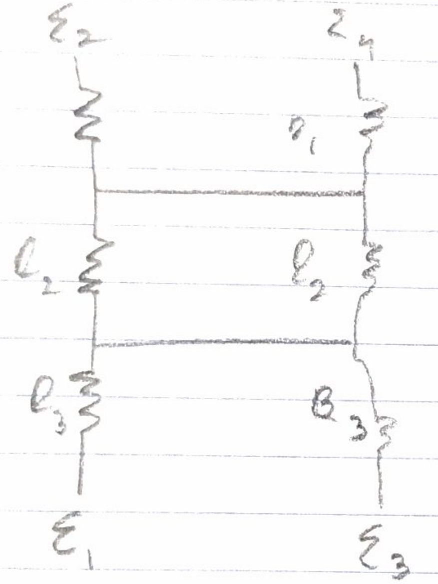
yes, this circuit can be used to measure temperature

6A $R = \rho \cdot \frac{L}{A} \Rightarrow R_{E_1-E_2} = \rho \left(\frac{H}{W \cdot t}\right)$

$R_{E_1-E_2} = 1\,\Omega m \left(\frac{12\times10^{-2}\,m}{3\times10^{-2} \cdot 0.5\times10^{-3}\,m}\right)$

$R_{E_1-E_2} = 8\,k\Omega$

6B



$R_2 = \frac{3\,cm}{12\,cm} \cdot R_{E_2-E_1} = 1.25\,k\Omega$

$R_2 = \frac{7-3\,cm}{12\,cm} \cdot R_{E_2-E_1} = 1.667\,k\Omega$

$R_1 = \frac{12-7\,cm}{12\,cm} \cdot R_{E_2-E_1} = 2.0833\,k\Omega$

6C Equivalent resistor between $E_4 - E_3$ is

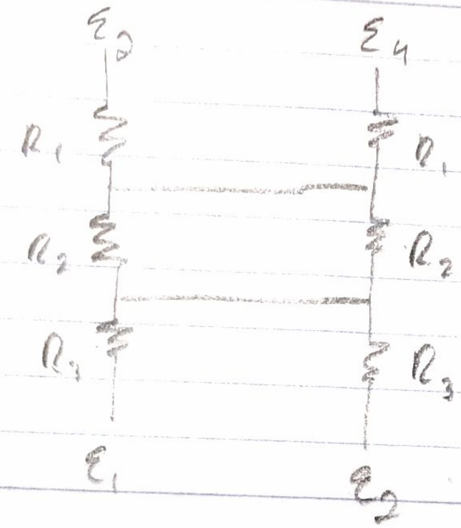
$R_{E_4-E_3} = R_1 + R_2 \parallel R_2 + R_3 = R_1 + \frac{R_2}{2} + R_3$

$= 1.25\,k\Omega + \frac{1.667\,k\Omega}{2} + 2.0833\,k\Omega$

$\approx 4.167\,k\Omega$

$V_{E_4-E_3} = 1\,mA \cdot R_{E_4-E_3} \Rightarrow V_{E_4-E_3} = 4.167\,V$

6D



$R_3 = \frac{y_1}{12cm} \cdot 5k\Omega$

$R_2 = \frac{y_2 - y_1}{12cm} \cdot 5k\Omega$

$R_1 = \frac{12cm - y_2}{12} \cdot 5k\Omega$

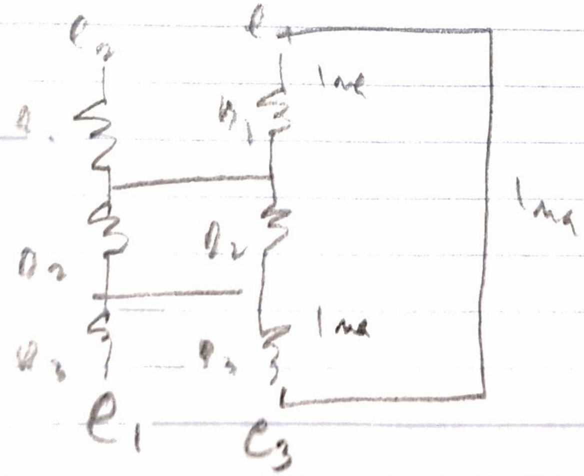
$$R_{E_4} - R_3 = R_1 + \frac{R_2}{2} + R_3 = \left(12\,cm - y_2 + \frac{y_2 - y_1}{2} + y_1\right) \cdot \frac{5k\Omega}{12cm}$$

$$= \left(12\,cm + \frac{y_1}{2} - \frac{y_2}{2}\right) \cdot \frac{5k\Omega}{12cm}$$

$$V_{\varepsilon_4 - \varepsilon_4} = \frac{12cm + (y_2 - y_1)/2}{12cm} \cdot 5V$$

We can [illegible] across the [illegible] between the two touch points

6E



$V_{R_4 - R_3} = IR_1 = \frac{12cm - y_2}{12cm} \cdot 5V$

$V_{\varepsilon_1 - \varepsilon_3} = IR_3 = \frac{y_1}{12cm} \cdot 5V$

7 Find the mWH of the Samsung Galaxy S8+ with 3500 mah battery @ 3.85 V

A $3500 \cdot 3.85 = 13475$ mWHr

B, Convert to joules. $13475 \times 3.6 \frac{sec}{hr} = 3\ 48.510$

C Convert to coulombs $3500 mah \times \frac{3600 sec}{hr} = 12600000$ Coulombs.

8 I worked on this assignment alone.