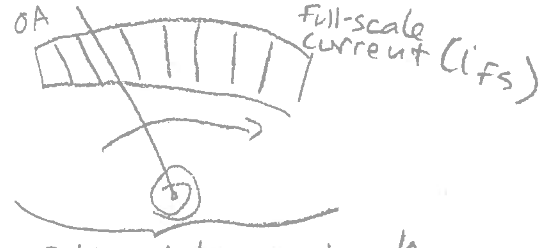
PS #4 PRACTICAL AMMETER PROBLEM

1) D'ARSONVAL GALVANOMETER
Full-scale current (i_{FS}) of 1mA
Internal resistance (R_M) of 50Ω
Measured current (i_m)

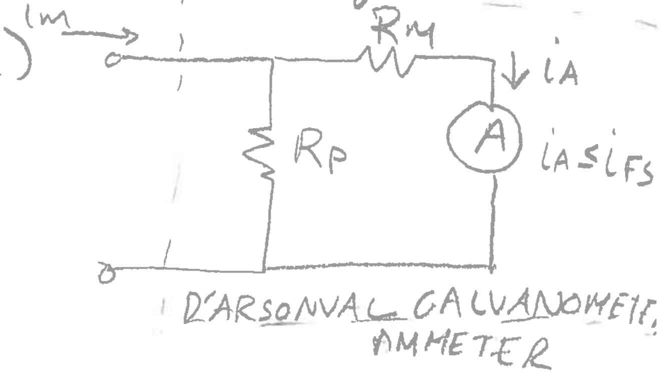


circuit equivalence

Ratio of measured current i_m to current i_A (using current division)

$$i_A = i_m \frac{R_P}{R_M + R_P}$$

$$i_m = i_A \left(\frac{R_M + R_P}{R_P}\right) = i_A \left(1 + \frac{R_M}{R_P}\right)$$



a) We want to measure up to 1mA. Since the full-scale is 1mA, we can measure the current directly without R_P. An open circuit is the same as $R_P \to \infty$

$$i_m = i_A\left(1 + \frac{R_M}{\infty}\right)$$

$$i_m = i_A.$$

$$\boxed{R_P = \infty}$$

b) We want to measure up to 10.0mA ($i_m = 10.0$mA).
At that i_m, we will reach full-scale $\rightarrow$ $i_A = i_{FS} = 1$mA

therefore $i_m = i_A\left(1 + \frac{R_M}{R_P}\right) \Rightarrow 10.0\text{mA} = 1\text{mA}\left(1 + \frac{50\Omega}{R_P}\right)$

$$\boxed{R_P = 5.556\,\Omega}$$

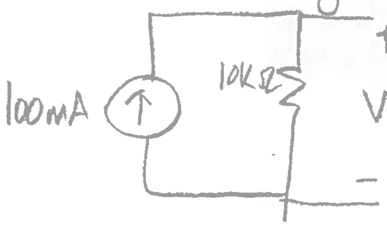
c) We want to measure up to 100.0mA ($i_m = 100$mA)
At that i_m, we will reach full-scale $\rightarrow i_A = i_{FS} = 1$mA

$$\therefore\ i_m = i_A\left(1 + \frac{R_M}{R_P}\right) \Rightarrow 100\text{mA} = 1\text{mA}\left(1 + \frac{50\Omega}{R_P}\right)$$

$$\boxed{R_P = 0.505\,\Omega}$$

In this problem:
Note that as more current need to be measured, R_P gets smaller to allow to "diverse" more current away

2) The practical voltmeter uses a d'Arsonval Galvanometer with a series resistance. A huge series resistance (R_s) allows to keep the current within the full-scale limit (i_{FS}). Recall that an ideal voltmeter doesn't draw any current. In practice, there is some current leading to some errors in the measurement.



$V_x = 10\,k\Omega \cdot 100\,mA = 1000\,V = 1\,kV$

Ideally, we would find that $V_x = 1\,kV$

In practice, we don't measure exactly that value. Let's see what we get depending on the voltmeter we use.

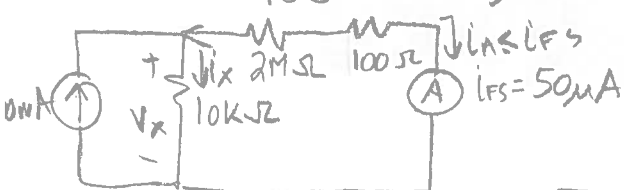
Practical voltmeter

The relationship between i_A and V_m

$V_m = i_A(R_s + R_M)$

a) $R_M = 100\,\Omega$ and $i_{FS} = 50\,\mu A$ $\quad i_A = i_{FS}$ when $V_M = 100\,V$

$100\,V = 50\,\mu A\,(R_s + 100\,\Omega) \rightarrow R_s = 2\,M\Omega - 100\,\Omega \approx 2\,M\Omega$ $\quad \boxed{R_s \approx 2\,M\Omega}$



when using that voltmeter

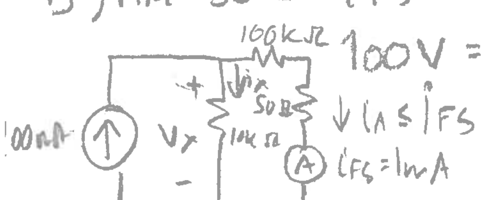
$V_x = i_x \cdot 10\,k\Omega \qquad i_x = 100\,mA \times \dfrac{2\,M\Omega}{2\,M\Omega + 10\,k\Omega}$ $\quad (2\,M\Omega + 100\,\Omega) \approx 2\,M\Omega$

$i_x = 99.5\,mA$

note: 5 V lower than actual value $\longrightarrow$ $\boxed{V_x = 995\,V}$

b) $R_M = 50\,\Omega \quad i_{FS} = 1\,mA \qquad i_A = i_{FS}$ when $V_m = 100\,V$

$100\,V = 1\,mA\,(R_s + 50\,\Omega) \rightarrow R_s = 100\,k\Omega - 50\,\Omega \approx \boxed{100\,K\Omega \approx R_s}$



$V_x = i_x \cdot 10\,k\Omega \qquad i_x = 100\,mA \times \dfrac{100\,k\Omega}{100\,k\Omega + 10\,k\Omega}$ $\quad 100\,k\Omega + 50\,\Omega \approx 100\,k\Omega$

$\boxed{V_x = 909\,V} \qquad i_x = 90.9\,mA$

91V below ideal value!