Mississippi State University
Department of Physics and Astronomy
PH 2223 Lab

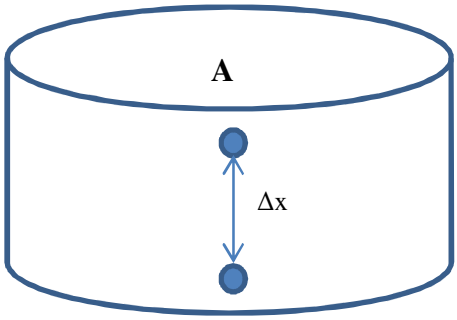
Ohm's Law, Resistance and Resistivity

What is the law that we are going to study? State its mathematical form.

In the lab you will see that not all materials behave according to the law. That is because there is a separate microscopic process that governs the quantities of current and consequently resistance. We will now derive the microscopic law. All the consequences will be evident (and trivial!) ones you have derived the expressions. Let us do something fun and consider only gravitational force (neglect the fact that electrons do interact through electric field!). You will do the actual expressions for electric field in class. Let's calculate current due to gravity (and not due to electric force)! Show me all your work.

The known values are {mass of the electron $\mathbf{m_e}$, acceleration due to gravity **g**, cross section area of the wire **A**, charge on electron **e**, and a term known as mean relation time which is the time that an electron spends moving freely before colliding with another electron $\boldsymbol{\tau}$, number of free electrons per unit volume of the material **n**}

Fig. 1



1. What is the force on the electron? Thereby calculate its acceleration.
2. For effective simplicity assume that the electrons always travel in the direction of acceleration and that when they collide their velocity goes to 0. If $\boldsymbol{\tau}$ is the time in which the electron accelerates, what is the maximum velocity? This maximum possible velocity is known as drift velocity $\mathbf{v_d}$.
   Now let us calculate the gravitational current!
3. Current is rate of flow of charge $\Delta q/\Delta t$, what is the charge in the distance **Δx**, given **n**, **A**, **Δx**, **e**? In other words **Δq**?
4. Divide **Δq by Δt** and substitute $\Delta x/\Delta t$ with velocity $\mathbf{v_d}$.
5. Now substitute for $\mathbf{v_d}$ from equation you obtained in step 2 to obtain expression for current **I**. ($I = neAg\tau$)
   Let us see what the relation between potential and gravitational current is actually?
6. Divide **I** by applied voltage **V**, is this term a constant? Given $\boldsymbol{\tau}$ stays constant for a particular temperature (Room temperature).
7. Plug in values $\mathbf{n} = 10^{29}\text{m}^{-3}$, $\mathbf{A} = 1\text{m}^2$, $\mathbf{g} = 10\text{ms}^{-2}$, $\mathbf{e} = 1.6 \times 10^{-19}\text{C}$, $\boldsymbol{\tau} = 10^{-15}\text{s}$ and calculate the value of **I.** If you did it right you will get a current that is lab measurable. But you cannot measure this. Can you tell me why?

Challenge

Give the expressions for the current density, resistance, resistivity, conductance and the conductivity of the material. How would the expressions change if no electrons ever collided and the wire was of length **l**?