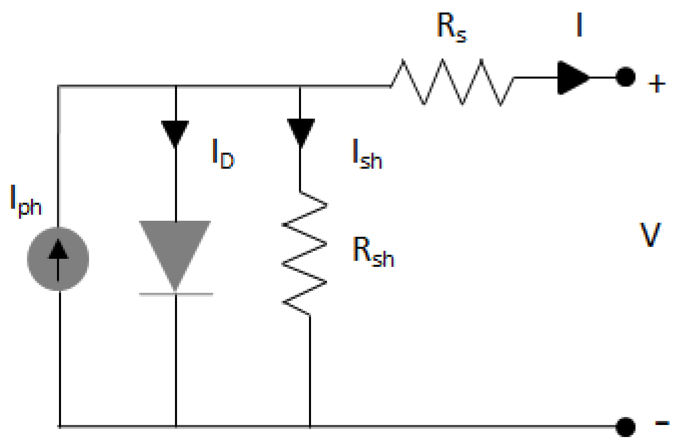
Parameter Estimation for Photovoltaic Diodes



The behavior of a photovoltaic diode is described by this equation

$$pv := I_f = I_{ph} - I_{SD} \cdot \left(\exp\left(\frac{(V_f + I_f \cdot R_s)}{n \cdot V_t} \right) - 1 \right) - \frac{(V_f + I_f \cdot R_s)}{R_{sh}}$$

where
- I_f and V_f are the experimental current and voltage
- I_{sh} and R_{sh} are the shunt current and resistance
- R_s is the series resistance
- I_{SD} is the diode saturation current (normal diode current)
- I_{ph} is the cell-generated photocurrent
- V_t = k T / q is the thermal voltage (where k is the Boltzman - constant, T is the ambient temperature and q is the electron charge)
- n is the ideality factor

This application will rearrange this equation to give I_f in terms of the LambertW equation, and find the best-fit parameters (I_{ph}, I_{SD}, n, R_s, R_{sh}) against experimental values of I_f and V_f

Rearrange photovoltaic diode equation for forward current

$I_r := \mathrm{solve}(pv, I_f)$

$$I_r = -\frac{-\left(-\mathrm{LambertW}\left(-\frac{I_{SD} \cdot R_s \cdot R_{sh} \cdot e^{\frac{R_{sh} \cdot (I_{SD} \cdot R_s + I_{ph} \cdot R_s + V_f)}{n \cdot V_t \cdot (R_s + R_{sh})}}}{-R_s \cdot V_t \cdot n - R_{sh} \cdot V_t \cdot n}\right) + \frac{R_{sh} \cdot (I_{SD} \cdot R_s + I_{ph} \cdot R_s + V_f)}{n \cdot V_t \cdot (R_s + R_{sh})}\right) \cdot n \cdot V_t + V_f}{R_s}$$

Import experimental data

```
data_file_path := FileTools:-JoinPath([kernelopts(mapledir), "toolbox", "MapleFlow", "data",
"examples", "diodeexperimentaldata.xlsx"])
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data := ImportMatrix(data_file_path)
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plot(data, style = point) =
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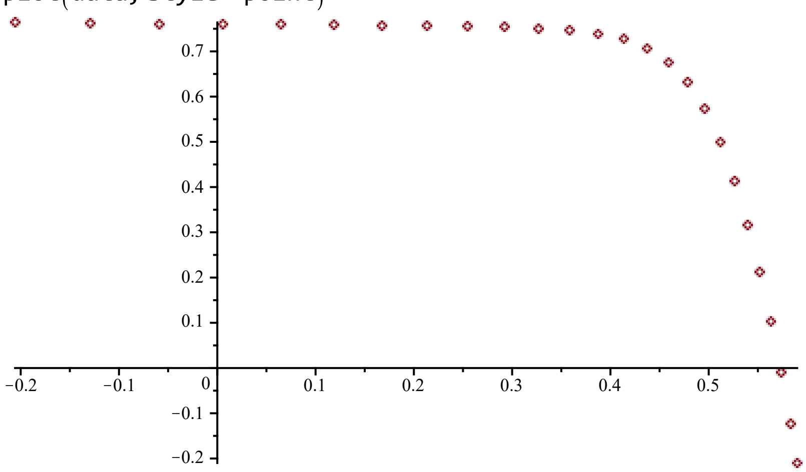

Define parameters

$T := 306$

$k := 1.380650 \times 10^{-23}$

$q := 1.602176 \times 10^{-19}$

$V_t := \frac{k \cdot T}{q} = 0.026$

Unknown values to be found

$\text{indets}(I_r, \text{name}) = \{I_{SD}, I_{ph}, R_s, R_{sh}, V_f, n\}$

Fit parameters to data

$\text{res} := \text{Statistics:-NonlinearFit}(I_r, \text{data}, V_f, \text{parameterranges} = [I_{ph} = 0.1..1, I_{SD} = 0..0.0001, n = 1..2, R_s = 0.01..0.1, R_{sh} = 1..100], \text{output} = \text{parametervalues}, \text{iterationlimit} = 50, \text{optimalitytolerance} = 0.01)$

$\text{res} = [I_{SD} = 9.325 \times 10^{-6}, I_{ph} = 0.766, R_s = 0.016, R_{sh} = 51.329, n = 1.924]$

Plot the experimental data against the calibrated model

$\text{p1} := \text{plot}(\text{data}, \text{style} = \text{point}, \text{legend} = \text{"Experimental Data"})$

$\text{p2} := \text{plot}(\text{eval}(I_r, \text{res}), V_f = \min(\text{data}[..,1])..\max(\text{data}[..,1]), \text{legend} = \text{"Model Curve"})$

$\text{plots:-display}(\text{p1}, \text{p2}) =$